Remote Accessibility to Diabetes Management and Therapy in Operational Healthcare Networks

REACTION (FP7 248590)

D2-10 Final validation report of the REACTION platform

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Author(s)	F. Chiarugi (FORTH), A. Kouroubali (FORTH), V. Lagani (FORTH), H. Udsen (IN-JET), J. Thestrup (IN-JET), Fursse (CHC), M. Clarke (UBRUN), E. Kiss (ALL), S. Spat (MSG), K. Neubauer (MUG), T. Klotzbuecher (IMM), G. Vasilakis (FORTHNET), P. Rosengren (CNET), M. Enzmann (FHG-SIT), S. Schaller (BTS), J. Branebjerg (DELTA), I. Ramos (ATOS)
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1 Executive Summary

This deliverable completes the task T2.4 of WP2 which was carried out in the three subtasks of validation planning, organization of the application field trials and deployment preparation.

Validation has been concluded with the field trials defined in WP8, which aimed at demonstrating the benefits provided for individual users and healthcare organisations in terms of efficiency of closed loop healthcare provisioning in diabetes management. The field trials were used to evaluate the potential validity of the clinical applications, and the benefits for the healthcare domain, acceptance by patients and other users, and to assess the impact on the organizational level.

Validation activities were focused on impact on patients, their relatives, healthcare personnel and other individual users as well as on organizational processes (e.g., in primary and secondary care) mostly centred on organisational workflows and stakeholder interaction as observed during the field trials.

The main objective of the validation work was to assess the applied technologies from all stakeholders involved in order to evaluate the potential clinical value and appraise the impact of the REACTION solutions on clinical workflows.

This document briefly reports the validation methodology applied in the context of the project and provides a short description of the 22 components constituting the REACTION platform.

Then the targeted solutions for the 3 different environments addressed by the project are shown and the results of the internal verification activities are reported all the different environments.

The results of the user validation activity (in some case retrospective), including the user evaluation of significant components, have been reported. A summary of the results of the field trial activity has been provided, including the certifications issued for some components or solutions.

In the final iteration of the REACTION project the platform, composed of several potential “products” at different level of maturity, has been released. The components as well as the specific solutions for the three different environments considered in the REACTION project have been verified and validated.

Overall, the results of the field trials are positive. For the In-Hospital solution, 42 of the 57 advanced user acceptance and usability tests have been completely fulfilled, while in the Primary Care environment 51 of the 57 main usability tests have been totally fulfilled, showing that the integrated solutions for these two environments have already reached a good level of maturity.

Finally, the results of the validation in terms of the JIRA requirements identified for the REACTION project have been reported with some relevant statistical information.

2 Definitions and Abbreviations

3G	Third Generation
A2P	Application-to-Person
AC	Alternating Current
AGC	Automatic Glucose Control
AHD	Application Hosting Device
AIDL	Android Interface Definition Language
AMORS	ePatch for ambulatory monitoring
ANT+	An open access multicast wireless sensor network technology featuring a wireless communications protocol stack designed and marketed by ANT Wireless
API	Application Programming Interface
ARE	Absolute Relative Error
ASCII	American Standard Code for Information Interchange
BAN	Body Area Network
BG	Blood Glucose
BPM	Blood Pressure Monitor
C#	C Sharp Programming Language
CE	Conformité Européenne
CEG	Clarke Error-Grid
CEN	Comité Européen de Normalisation
CGM	Continuous Glucose Monitoring
CHF	Chronic Heart Failure
CI	Concordance Index
COPD	Chronic Obstructive Pulmonary Disease
DB	Database
DCCT	Diabetes Control and Complication Trial
DCK	Device Connectivity Kit
DHI	Danish Institute for Toxicology
DLL	Dynamic-Link Library
DSS	Decision Support System
ECG	Electrocardiogram
EMC	ElectroMagnetic Compatibility
EMN	Edge Monitoring Node
EPR	Electronic Patient Record
EU	European Union
F&F	Friends and Family
GIM	Glucose-Insulin Metabolism
GIP	Glucose-dependent Insulinotropic Polypeptide
GLP-1	Glucagon-Like Peptide-1

GP	General Practitioner
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GUI	General User Interface
HA	Home Automation
HbA1c	Glycated haemoglobin
HCP	Health Care Profile
HDP	Health Device Profile
HIS	Hospital Information System
HL7	Health Level 7
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IF	Interface
IHE	Integrating the Healthcare Enterprise
IoT	Internet of Things
IP	Internet Protocol
IR	Infrared
ISO	International Organization for Standardization
IV	Intra-venous
JIRA	Issue and Project Tracking Tool by Atlassian
KAGes	Krankenanstaltengesellschaft, Healthcare Company of Styria (Region of Graz)
LAN	Local Area Network
LED	Light-Emitting Diode
LNA	Low-Noise Amplifier
LTRA	Long-Term Risk Assessment
MAE	Mean Absolute Error
MARE	Mean Absolute Relative Error
MPC	Model Predictive Control
MPHG	Multi-Protocol Home Gateway
NA	Not Available
NFC	Near Field Communication
NHS	National Health Service
NLP	Natural Language Processing
NMS	Network Monitoring System
NYHA	New York Heart Association
OAD	Oral Anti-Diabetic

OS	Operating System
OTAU	Over The Air Update
PAN	Personal Area Network
PBPK/PD	Physiologically Based Pharmacokinetic/Pharmacodynamic
PC	Personal Computer
PCD	Patient Care Device Domain
PDF	Portable Document Format
PEMS	Predictive Emission Monitoring System
PG	Plasma Glucose
PID	Proportional-Integral-Derivative
PIN	Personal Identification Number
PK/PD	Pharmacokinetic/Pharmacodynamic
PoC	Point of Care
RCT	Randomised Controlled Trial
ROC	Receiver Operating Characteristic
RPM	Remote Patient Monitoring
RS-232	Series of standards for serial binary single-ended data and control signals
RX	Reception
SAE	Serious Adverse Event
SC	Subcutaneous
SD	Standard Deviation
SDK	Software Development Kit
SGC	Safe Glucose Control
SMS	Short Messaging Service
SNMP	Simple Network Management Protocol
SOAP	Simple Object Application Protocol
SQL	Standard Query Language
SSA	Security Service App
SUTAQ	Service User Technology Acceptability Questionnaire
T1DM	Type 1 Diabetes Mellitus
TX	Transmission
UC	Use Case
UI	User Interface
UK	United Kingdom
US	United States
USB	Universal Serial Bus
V&V	Verification and Validation
WAN	Wide Area Network
Wi-Fi	Wireless local area network products that are based on the Institute of Electrical and Electronics Engineers 802.11 standards

WP	Work Package
WS	Web Service
WSDL	Web Service Description Language
XML	Extensible Markup Language
XMLDSig	XML Signature
XMLEnc	XML Encoding
XSL-T	Extensible Stylesheet Language Transformations
ZHCP	ZigBee Health Care Profile
ZigBee	A specification for a suite of high level communication protocols used to create personal area networks

3 Introduction

3.1 Purpose, Context and Scope of This Deliverable

In this section we discuss the background and context of this deliverable. We also describe the target audience and the purpose and scope of this document.

3.1.1 Background and Context

This deliverable concludes the activities performed in the context of T2-4 “Validation of platform and services”.

The objective of the validation work has been to obtain feedback of the applied technologies from all stakeholders involved in order to evaluate the potential clinical value and validate the impact on clinical workflows from the REACTION applications with special focus on validating feedback and sensor performance as well as potential for interoperability and scalability.

A validation framework was identified and described in D2-7 “Validation framework”. This framework has been mainly used for the activities reported in this deliverable.

Validation activities have not been limited to the last iteration cycle. They have been applied in each iteration cycle in order to evaluate the intermediate prototypes and to decide the technical activities to be performed in the subsequent iteration cycle. However, these validation activities have been reported in previous internal deliverables issued at the end of each iteration cycle. For this reason, this deliverable is mainly focused on the “final” validation activities performed on each component or solution.

3.1.2 Target Audience

The target audience of this deliverable is mainly all REACTION partners, both technical and clinical since all verification and validation activities are summarized in this deliverable, but also the general public. The results reported will serve as documentation that may be used by the partners in their future exploitation efforts

3.1.3 Purpose

The purpose of this deliverable is to describe the overall architecture and the hardware and software components developed or used in the REACTION platform including the testing procedures performed, mainly in accordance with the validation framework described in D2-7. Furthermore, it describes the various solutions assembled for the different environments addressed by the REACTION project as well as the validation activities and results from the field trials where applicable.

3.1.4 Scope

The scope of this deliverable is to summarize the verification and validation (V&V) performed both on individual components and on the solutions assembling the various components in different targeted applications. This summary can be useful for each partner in order to plan the activities related to the integrated solutions or to the specific components after the end of the REACTION project (identification of strengths, weaknesses (to be covered in future releases, etc.)).

3.2 Outline

The remaining document is structured as follows.

Section 4 describes the validation methodology applied in the context of the project.

In Section 5, the various components are presented and the targeted solutions for the 3 different environments are described.

In Section 6 the results of the internal verification activities are reported for the 3 different environments addressed by the project.

In Section 7 the results of the user validation activity (in some case retrospective), including the evaluation of the REACTION SDK and the MPHG, have been reported.

In Section 8 the results of the field trial activity have been summarized, including the certifications issued for components or solutions.

Finally, in Section 9 the results of the validation in terms of the JIRA requirements identified for the REACTION project have been reported with some statistical information and in Section 10 some conclusions have been shown.

Appendix 1 contains the main certifications obtained about components/applications developed in the project.

Appendix 2 contains the details of the in-hospital internal test reports.

A separate Appendix (D2-10_Final-validation-report_Appendix_V2.0_FORTH.pdf) contains all the implemented requirements of the project, grouped by WP and by components.

4 Description of Validation Methodology

Verification and validation are part of the implementation of a user-centred development process. The main aim is to assure that the REACTION services developed adhere to the necessary quality standards for professional services, meet the needs and requirements of users and customers, and can be recommended for adoption. Validation and verification activities focused on obtaining feedback of the applied technologies from all stakeholders to establish the potential clinical value and validate the REACTION applications' impact on clinical workflows with special focus on validating feedback and sensor performance as well as potential for interoperability and scalability. Detailed descriptions of the validation framework and activities have been reported in deliverable D2-7 "Validation framework". A summary of the activities is presented in this chapter.

4.1 Internal Verification Activities

Internal verification activities aimed to prove that requirements are correct, complete, consistent, accurate and testable; to facilitate early detection and correction of software errors; to enhance management insight into process and product risk; and to support the software life cycle processes to ensure compliance with program performance, schedule, and cost requirements. An important part of the verification activities was the verification of adherence to mandatory standards, in particular the group of EU directives around medical devices. In the REACTION project, the internal verification procedures were performed at the technical partners' premises to check whether the products of a given development phase satisfied the conditions imposed at the start of that phase or that the starting specifications have been correctly implemented. The complete integrated platform of REACTION was not available in the verification phase. Auxiliary tools were used to allow a comprehensive verification of all the implemented workflows.

The lifecycle of the software followed the path composed of the software requirement definition, the architectural design, the detailed design and the coding. Once the code became available the testing phases aimed at verifying the correct behaviour in correspondence of each integration phase. The unit tests aimed at verifying the modules / components identified and built in the detailed design, the integration tests assembled the units in order to verify the architecture while the system tests aimed at putting together the subsystems and performed integration tests. The tests performed in the REACTION platform included, parameter testing to the Web Services (WS), unit tests to the backend components, integration tests, system tests, and adherence to standards tests.

All test procedures at unit level, subsystem level and prototype level have to be described and test cases have to be catalogued per unit, subsystem and prototype including also the requirement(s) they address.

Finally also hazard analysis, security analysis and risk analysis have to be reported, each one with any observed anomalies and suggestions for their solutions. In the hazard analysis it has to be verified that the implementation correctly implements the critical requirements and introduces no new hazards. In the security analysis it has to be verified that the implementation is completed in accordance with the system design, that it addresses the identified security risks and does not introduce new security risks. The verification is done against the requirements, thus using test cases addressing specifically the critical requirements and the security requirements. Furthermore, security has to be verified also at subsystem level. In the risk analysis any observed or anticipated technical risks have to be identified and recommendations provided in order to eliminate, reduce or mitigate the risks.

4.2 User Validation Activities

User validation aimed to assure that the implemented result is in agreement with the needs and requirements of users. The user validation activities focused on impact on patients, their relatives, healthcare personnel and other individual users as well as on organizational processes. The assessment of performance measurements was done with user partners and technical partners who had not contributed to the implementation, in order to evaluate the (stable) components and prototypes from different point of views.

The process included an initial preparation part, an internal verification activity and/or a validation activity with (expert) end users, the collection and analysis of the outcomes, and the feedback of the results into the loop for the next steps.

The JIRA tool and the Volere template were used as tools for managing the user requirements.

User validation reports throughout the project contained a description of the experience with the use of the platform at the clinical site, the results of the usability tests, the clinical workflow validations and the performance evaluations. Specific problems, inconsistencies or bugs were reported and addressed in subsequent releases and also new functionalities addressing specific user needs were clearly listed. User satisfaction was evaluated and reported and specific suggestions were retrofit to the technical team.

4.3 Field Trial Activities

Field Trial Usability Testing included usability tests of prototypes for assessment of the quality of the REACTION applications.

The field trials assessed the effectiveness of the REACTION platform (i) within a hospital environment, (ii) with primary care patients under therapeutic control and (iii) for patients who are self-managing their disease. They aimed to demonstrate the validity of the applications, the benefit for healthcare providers and provisioning authorities, to promote acceptance by patients and other users and to assess the impact at the organizational level.

Usability was tested in two field trials (in-hospital and primary care) with a small number of users to detect user problems and deficiencies of the prototypes and to feed these back to the development teams. Usability evaluation sessions targeted:

- Randomly selected users (Hallway testing).
- Real users, such as doctors and nurses.

The evaluation was based on specific usability metrics, in order to have objective and quantitative data for analysis of the usability test.

The objective of the in-hospital trial was to validate - in an inpatient environment - a suite of multi-parametric monitoring services designed to facilitate the close monitoring of diabetic patients by dedicated diabetes experts and so enable more widespread use of Safe Glucose Control (SGC).

For the primary care trial, the REACTION platform supported medication compliance, adherence to clinical pathways, education, and self-management health services for diabetes related conditions. Furthermore, clinical intervention for patients was targeted to those in higher need; well-controlled subjects had less need for routine check-up, while those above guidance levels received pro-active timely intervention.

5 The REACTION Solutions

5.1 A User Centred Design

There are three main phases of user centred design, which partly correspond to the project phases. In all phases the objective is to generate information by user analysis, which guides the design and development activities.

- Analysis of system requirements, user needs, and application context – involving all stakeholders.
- Evaluation of design concepts (UI specifications, design ideas, and early prototypes).
- Testing of working prototypes with real users (as early as possible) and feed back results to the development team.

The REACTION project has followed four iterative cycles with resulting prototypes and the stakeholders have been involved in each of these cycles.

During platform development, validation is carried out to detect possible deviations from the original objectives and to provide feedback to the development team and to the Project Board for early corrective action. To this end, project progress is assessed in yearly intervals corresponding to the four iterative cycles to allow tight, results-oriented monitoring of project status.

Annual user validation has been performed and, when applicable, concluded with usability testing, in some cases during field trials. This demonstrated the benefit provided for individual users and healthcare organisations in terms of efficiency of closed-loop healthcare provisioning in short-term and long-term diabetes management. The field trials have also been used to evaluate the acceptance by patients and other users, and to assess the impact on the organizational level.

It is essential that the results of user validation are addressed towards the individuals and groups who are able to use and implement them to improve design quality. In this respect, design refers to the entire software platform and other relevant features, which determine the user experiences when interacting with the applications developed, i.e., functionality, graphical and navigation design, and also quality factors such as performance and productivity, security, added value, etc.

The validation work has been carried out through verification and validation activities at the end of each iterative cycle and in application field trials with “friendly” users in the initial phases and real end-users in the final phases of the project. In addition, major releases entailed decisions about redesign, error correction, adjustments to existing functionalities and insertion of additional functionalities on the basis of the validation results.

The results of these activities were reported, discussed and analysed with the development team. Also the deployment activity was always performed through a preliminary in-lab pre-deployment phase in order to minimize potential errors or problems before the final deployment.

5.2 REACTION Components

Several components have been designed and developed in the context of this project, in many case from scratch and in other cases optimizing existing partner products or adapting them to the REACTION architecture.

The following sections contain brief descriptions of these components. More detailed information about the various components can be found in D10-5 “Final REACTION platform prototype including sensors, subsystems, security framework, services”.

5.2.1 REACTION GlucoTab

GlucoTab is a workflow and insulin dosing support system for the glycaemic management of patients with diabetes type 2 in hospitals. End users are nurses and doctors at the general ward. The GlucoTab system has been designed and developed and tested according to the strict guidelines of the Medical Device Directive for software within the REACTION project and has been CE marked in autumn 2013. Details about the system and the evaluation process are presented in section 6.1 “In-Hospital Internal Test Report”. Verification and validation (software testing) details are presented for the latest major release - GlucoTab R2.0.

5.2.2 REACTION Patient Portal

The REACTION patient portal is a secure multiplatform web application built on previous experiences of the Foundation for Research and Technology – Hellas (FORTH-ICS). The patient portal is developed as a web application and can be used on any type of desktop or mobile device with later versions of the most common web browsers.

Specifically focused on supporting patient empowerment and self-management, the Patient Portal is a key component, providing access for patients and their informal caregivers to their long-term diabetes management in the integrated environment of the primary care centre and their homes. It allows the capture of lifestyle data (e.g., activity, diet, compliance), the capture of medication data, the view of care plan, the view of own measurements, the view of material in support of education and motivation, the manual input of measurements, etc.

5.2.3 REACTION Clinical Portal

The REACTION clinical portal was developed for use by clinicians and care workers to manage patient data. The clinical portal was implemented first as a simple portal to add patient details and view the measurements then it was expanded to cover other requirements like care plan, questionnaires, notes, notification handling and long-term risk models. The main focus during development was to maintain user friendliness and scalability. The clinical portal is developed as a web application and can be used on any type of device with a web browser.

5.2.4 REACTION Multi-Protocol Home Monitoring Gateway

The REACTION Multi-Protocol Home Gateway is designed as an easy-to-use, easy-to-install gateway that can be deployed in large scale in patient homes. The intended use is for a two-weeks initial monitoring of patients. By using standard and off-the-shelf hardware and communication solutions we achieve true plug and play. This means that for instance Continua devices using Bluetooth can be replaced by Continua devices using USB, ANT+ devices without having to change the data format that is reported to the backend servers at the service provider (primary healthcare centre) premises.

The REACTION Multi-Protocol Home Gateway is normally delivered as a “black box” without a screen (see Figure 1). The gateway is connected to the Internet using wireless or wired standard connections.

Figure 1: REACTION Multi-Protocol Home Gateway ("black box")

In Figure 2 two different installations of the REACTION Multi-Protocol Home Gateway are shown. On the left the multi-protocol gateway is implemented in an existing PC, while on the right it is embedded in a “black box”.

Figure 2: Two different installations of the REACTION Multi-Protocol Home Gateway in the primary care trial

5.2.5 REACTION ZigBee Home Monitoring Platform

The ZigBee Home Monitoring platform deployed in the REACTION pilot is designed for maximum interoperability, and is a flexible, modular system based on IEEE 11073 communication standard and the ZigBee Healthcare profile (Figure 3). ZigBee is a low-cost, low-power, wireless mesh network standard providing the ideal solution to satisfy one of the main requirements of the project, that is a scalable, low cost solution.

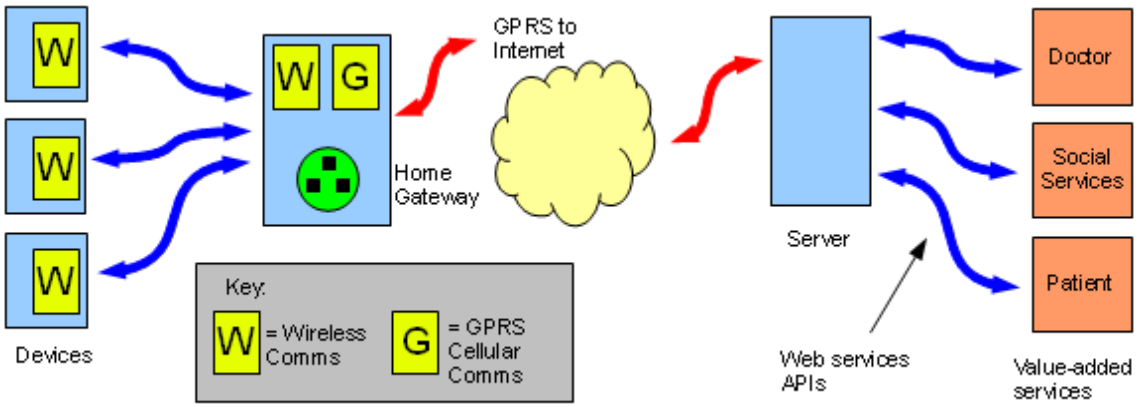


Figure 3: Communication path from health devices to healthcare professional

The home gateway (Figure 4) communicates with the health devices, and sends any readings to the backend servers at the primary healthcare centre to provide access to patient data for healthcare professionals. This gateway uses GPRS communication as used in mobile phones to provide connectivity to the internet. This means that additional connectivity such as Wi-Fi is not needed. The gateway is simply plugged into any AC mains socket, with no additional configuration required. HL7 messaging is used to communication from the gateway to the server.

Figure 4: The ZigBee home gateway

Using these standards has the additional advantage that the range of sensors can easily be extended to work with the existing platform. Inexpensive off-the-shelf blood glucose devices that do not incorporate any wireless communication and that are too small for integration in the internal device casing, can easily be extended with an external device that manages the ZigBee communication (Figure 5).

Figure 5: Blood glucose monitor extended for wireless communication

Note that though the blood glucose monitor is shown here as the principal device for diabetes management, many other devices from different manufacturers can be used that are supported through these communication standards and incorporated into the same system.

5.2.6 REACTION DCK

REACTION Device Connectivity Kit (DCK) is designed for developers who need to integrate and use medical devices in their applications. The diagram below shows how the REACTION DCK implements a device virtualization layer, so that all devices appear like IEEE 11073 devices to the outside and in communication with the REACTION backend (see Figure 6). The communication with the backend is done by the multi-protocol gateway sending IHE-PCD01 messages to the Observation WS.

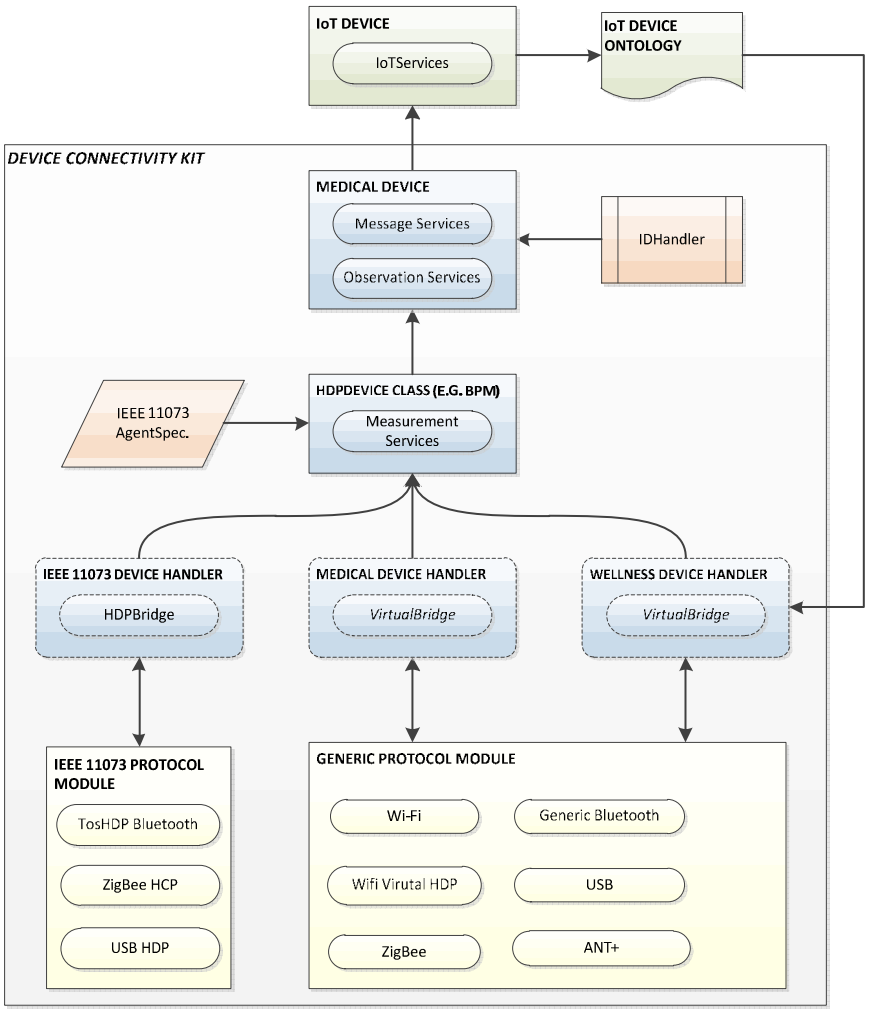


Figure 6: The REACTION DCK implements a device hierarchy so that devices are virtualised as IEEE 11073 devices

5.2.7 REACTION Platform Server Backend

The REACTION platform server backend is composed by the service orchestrator, the event manager, the rule engine and the service layer.

5.2.7.1 Service Orchestrator

The Orchestration Manager is responsible for managing and executing service orchestrations. A Service Orchestration is a high level description of how to execute a set of services in a specified sequence. The Service Orchestration is defined to support a specific workflow or task. The Service Orchestrations are defined by authorised stakeholders. The Orchestration Manager provides support for composite services and workflows.

The Service Orchestrator relies on and uses a combination of the Event Manager and Rule Engine. Actually the service orchestrations are expressed as execution rules and driven by events generated. It is possible to define service orchestrations for any given event, for instance which actions to take when a *new patient observation* arrives, what to do every *new day*, every *new week* etc.

5.2.7.2 Event Manager

The REACTION Event Manager provides publish/subscribe functionality, i.e., the ability for publishers to send a notification to multiple subscribers while being decoupled from them (in terms of, e.g., not holding direct references to subscribers).

The specific variant of publish/subscribe implemented is topic-based publish/subscribe where key/value pairs represent events.

Components generating events publish these events to the Event Manager. Components consuming events inform the Event Manager that they want to subscribe. With this approach, any subscriber or publisher defines a topic simply by executing the “publish” or “subscribe” actions.

A detailed explanation of the Event Manager is given in deliverable D5.5 “Implementation of Event Handling System”.

5.2.7.3 Rule Engine

The Rule Engine is implemented as an IoT-enabled device using the REACTION middleware. This means it is possible to have a number of “virtual devices” doing specific rule tasks. Such a Rule Engine device is configured using two configuration files. The first file defines the events which cover the scope of the rule device, i.e., these are the events that can trigger an action from this rule engine device.

The second file defines the rules and the actions to take if a rule triggers. The rules are expressed using XSL-T. The Rule Engine is flexible and allows expressions of very sophisticated rules.

5.2.7.4 Service Layer

A Service Layer has been defined and implemented on top of database. It provides an upper layer for the Service Orchestrator and other components and applications to access and use data. The following services have been defined so far:

- ClinicianWS
  Retrieve information about the clinician, patients for the clinician and weekly report.
- ContextWS
  Set or get contextual data for a patient.
- DeviceWS
  Retrieve information about the device, current device user, time period and log files.
- DietActivityWS
  Retrieve information about activity and diet plans.
- EducationWS
  Ease information gathering from pre-determined internet sources.
- MeasurementWS
  Can be used to do different calculation of the measurements for a given time period.
- OrchestrationWS
  Orchestrates information about available services, rule engines and handles Action Rules information.
- PatientListWS
  Retrieve information from a group of patients if value is higher/lower than certain value and gender. Get information regarding hourly, daily or weekly check-ups.
- PatientWS
  Retrieving patient information for a given patient, such as which health professional, latest measurement, monitoring rules, device, gateway and last triggered rule action.

5.2.8 REACTION Nutrition App

As maintenance of blood glucose level within the target range is a fundamental objective of diabetes care plans, nutrition management has a considerable influence on diabetes outcomes. Several available apps were evaluated and they had several deficiencies. Moreover, all of them were closed and so it was not possible to transfer the data into the REACTION system.

The nutrition app component considers, as a solution, a smartphone app to ease this major task to diabetes by exploiting the newest technology. The underlying philosophy of the component was to provide an integrated environment that enables the interaction of different users with conventional components as well as small and ubiquitous devices. Thus the objective persisted to develop a native platform that can integrate to the patient’s lifestyle and education plan as part of the care plan.

The Nutrition app is running on an Android platform which will be able to run on any mobile device that supports Android version 2.2 or later version. The nutrition app operates as an interactive personalized meal planner with a user-friendly graphical interface which performs a caloric graphical feedback based on personal goals concerning daily intake foods elements, to indicate the nutrient

balance. By using this feature the daily meal plan can be tailored to an individual's needs and it can be evaluated whether personal goals are achieved.

5.2.9 REACTION SMS Notification Component

The SMS component implements an instant communication service, based on the Short Messaging Service (SMS), and utilizes mobile networks for content delivery. While SMS is typically used in person-to-person messaging, the REACTION SMS service implementation realises a different communication model called application-to-person (A2P) messaging. A2P is a type of SMS sent from a user to an application or sent from an application to a user.

The component's role in the REACTION platform backend is to provide an emergency notification service to carers and patients to address alarm handling requirements in situations where the patient's condition needs to be immediately communicated, or in case there is an urgent need for the clinician to advise the patient on his/her treatment.

The SMS service is integrated in the REACTION platform through the Service Orchestrator and the Rule Engine components. The Rule Engine triggers events and consequently initiates the messaging to the SMS service. A second integration touch point is through the Clinical Portal. The SMS component is not tightly coupled with the REACTION backend, allowing it to be deployed on a dedicated server at partner FORTHNET's premises. As a result there were no significant issues during the integration with the Service Orchestrator component.

5.2.10 REACTION Network Monitoring Service for Mobile Devices

There was a clear need in the REACTION platform of a general network monitoring service for mobile devices, and it has been necessary to develop such component since commercial off-the-shelf services were not available.

The REACTION NMS monitors data traffic and assesses the transmission quality between the Patient's Sphere and the Clinician's Sphere, the REACTION backend and other cooperating systems such as HIS and primary care EPRs. Furthermore, it is able to analyze network traffic data and present them in graphical format; to generate email alerts to warn network or system administrators of abnormal network conditions or attacks; and to offer additional analysis about the behaviour of these attacks.

The architecture of the service is illustrated in Figure 7.

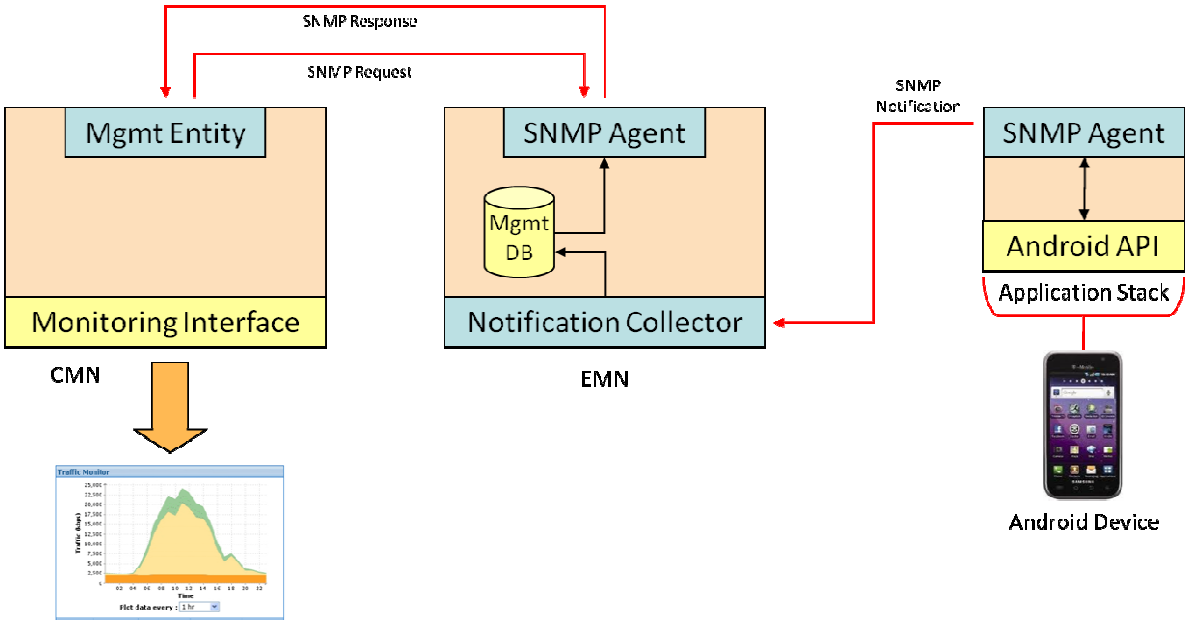


Figure 7: The architecture of the network monitoring service for mobile devices

5.2.11 REACTION Long-Term Risk Models

The Long-Term Risk Assessment (LTRA) component has been described in detail elsewhere (REACTION Deliverables D6.1 and D6.3). Here a synthetic description is reported.

The Long-Term Risk Assessment (LTRA) component is a module of the REACTION risk assessment engine that offers a set of functionalities for the mid-long term prognostic evaluation of diabetes type I patients. From a high level perspective, the LTRA component has the following functionalities:

- It accepts as input a **risk-assessment request**, containing information regarding the profile of a diabetes patient, and **provides an evaluation of the risk over time** of developing a user-specified diabetes complication. The set of relevant adverse outcomes that can be enquired is the following:
  - Adverse Cardiac Event
  - Hypoglycaemia
  - Ketoacidosis
  - Micro-albuminuria
  - Neuropathy
  - Proteinuria
  - Retinopathy
- It processes risk assessment requests even in case some of the clinical parameters required for performing the risk evaluation are not provided (**missing information**).

The LTRA component has been implemented as a Web Service (WS). The core of the component is constituted by a set of predictive models paired with a sub-module that manage the eventual presence of missing information. Particularly, the predictive models are a set of mathematical models that, on the basis of the patient profile, provide an evaluation of the risk over time of developing a given complication. The models were derived by applying state-of-the-art machine learning algorithms on a publicly available dataset (namely the Diabetes Control and Complication Trial, DCCT). The missing-information module applies a model-averaging procedure based on a Bayesian Network approach in order to provide meaningful risk evaluations even in presence of missing data.

5.2.12 REACTION Glucose-Insulin-Glucagon Model

In REACTION, models of the glucose insulin metabolism have been developed, both for people with diabetes and for people without, to gain a better understanding of processes involved in maintaining glucose homeostasis, and as a prediction kernel to create closed loop glucose control algorithms. The chosen modelling approach is a generic, whole-body physiology-based pharmacokinetic/ pharmacodynamic (PK/PD) model of the glucose-insulin-glucagon regulatory system (Figure 8) to encompass the complexity of the mechanisms involved in hormonal glycaemic control. In Figure 8, section A gives an overview of the pharmacodynamic interactions (what the injection of glucose/insulin does to the body) and section B shows the organ-level structure of the model (Schaller, 2013).

Although the model which has been developed within REACTION does account for healthy individuals and T1DM individuals, model development (or improvement) is a continuous process.

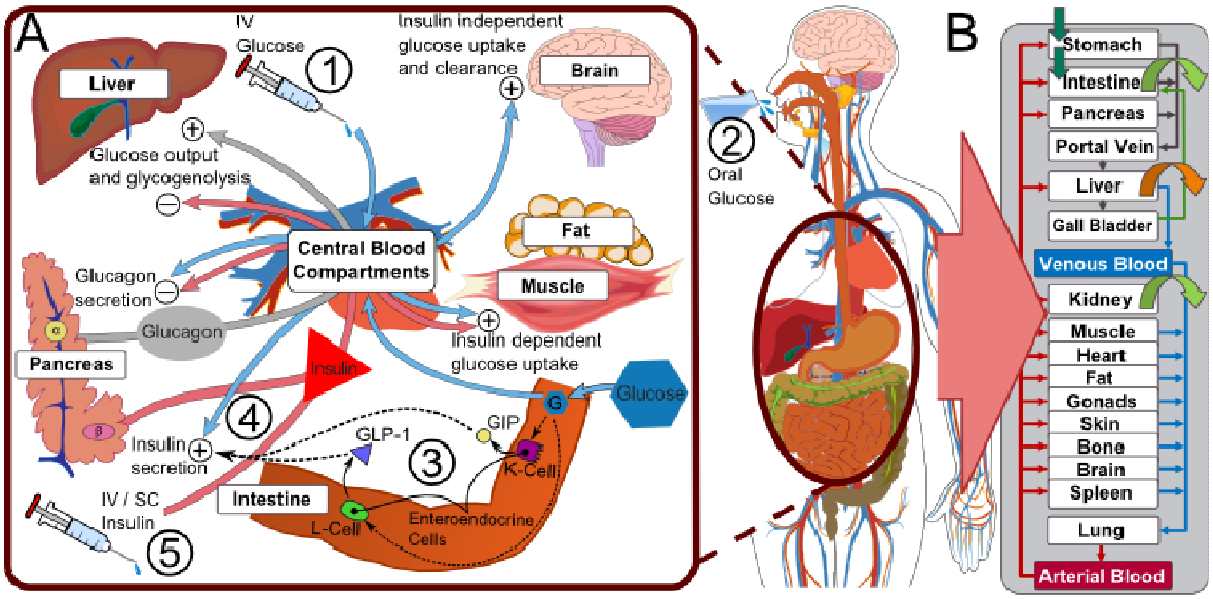


Figure 8: © Nature Publishing Group: The physiologically-based, whole-body model of the glucose-insulin-glucagon regulatory system couples three models for glucose, insulin, and glucagon

5.2.13 REACTION IR Continuous Glucose Monitoring Sensor

The IR CGM sensor (Figure 9) is based on IR difference absorption spectroscopy applied either with a perfusion solution generated via microdialysis (chips based type) or directly into a micro-needle acting as body interface (fibre based type). With the chip-based type, microdialysis was applied with medically approved dialysis catheters and combined with a disposable polymer chip (based on IMM patent US7894071B2), containing the optical flow through cells, connected to the microdialysis and a reference liquid. The chip based IR CGM sensor was used for clinical evaluation of the optical measuring technique to avoid time consuming, pre-clinical and biocompatibility testing within REACTION. The measurement principle of the IR CGM sensor is based on IR transmission spectroscopy on glucose containing perfusion solution in comparison to pure perfusion solution and correlation of the difference signal to the glucose concentration via a calibration process. The body interface is a medically approved microdialysis catheter (either subcutaneously or intravenously), representing the time-limiting element (degeneration of the selective membrane).

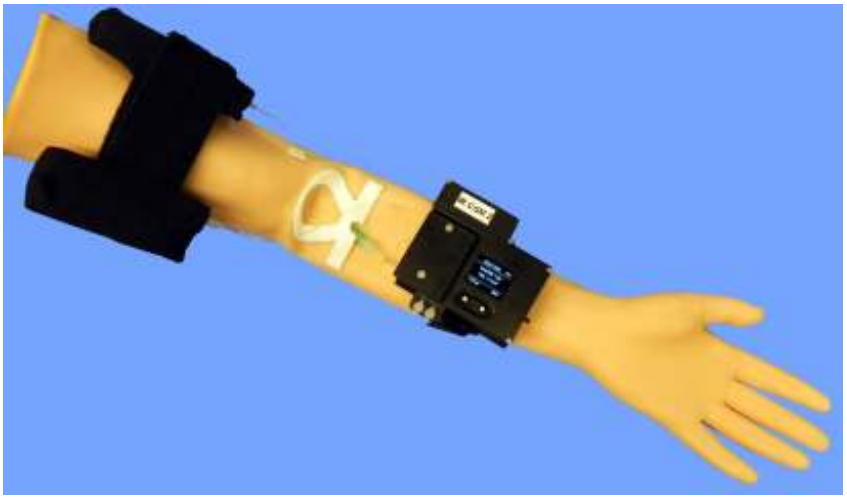


Figure 9: Latest version of the IMM IR CGM sensor, as applied during the second clinical trial REACTbySensors at the Medical University of Graz (MUG)

The fibre-based glucose sensor type is based on the same principle as the chip type sensor but is integrated into a micro-needle, acting as body interface. However, since for clinical trials CE-marked

sensors were requested by the partners for clinical trials, the fibre-based type of IR CGM sensor was only realized as a laboratory test setup to perform basic measurements for principle investigations.

The chip-based version of the IR CGM sensor was tested within 2 clinical trials at the Medical University of Graz (MUG), the results of which are presented in section 6.3.

5.2.14 REACTION I-Cath Sensor

The rationale I-Cath luminescence based continuous glucose monitoring device is explained on the basis of Figure 10.

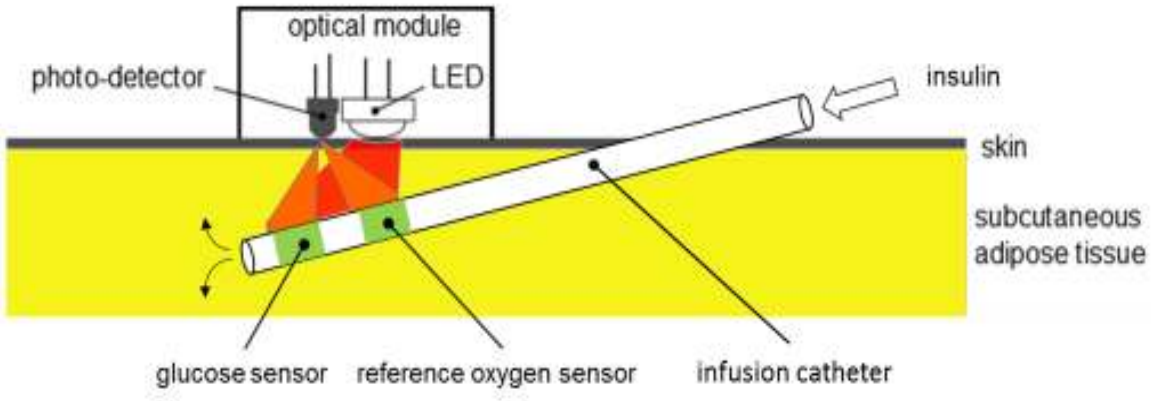


Figure 10: Schematic of the luminescence based continuous glucose monitoring device (displayed in red are the IR light beams passing through the tissue)

The system is divided into two major parts:

- Disposable glucose and reference oxygen sensors applied as thin coatings on the cannula of an insulin infusion set.
- A reusable optical module which carries the 2 LEDs for excitation of the sensor layers and 2 photodetectors to read the emitted luminescence light coming back from the sensor layers.

The measurement principle is based on the effect that oxygen quenches the luminescence of the applied luminescent agents which is measured as the luminescence phase shift in the frequency domain by the optical module.

A detailed description of the glucose monitoring system is given in deliverable D3-3-1 “I-Cath ready for clinical trial”.

5.2.15 Wireless Sensor (ePatch) for Heart Rate Monitoring

The ePatch® monitoring device is a miniaturised monitoring system formed as a patch and applied to the skin surface with a skin friendly adhesive. The developed version of the ePatch monitor is made for recording of ECG with 2 recording channels. It is intended to be placed on the sternum of the chest as shown in Figure 11. The ePatch monitor consists of two parts: a sensor with a weight of appr. 15 grams within all electronics and a re-chargeable battery is placed; and an electrode in which 3 skin contacts is integrated along with screened printed wires connecting the individual skin contact points and a special designed connector. Before applying the monitor on a patient, the sensor is inserted into the connector on the electrode. By this, electric contacts are made to the input terminals of the sensor and the sensor is as well mechanically fixed to the electrode. The two parts of the ePatch monitor are shown in Figure 11.

Figure 11: ePatch for ECG recording is applied on the sternum of a patient (photo on left). The ePatch monitoring system consists of a re-usable sensor that is placed into a connector on the ePatch electrode which is designed for single used (photo on right)

The clinical performance of the ePatch system when used to record ECG of a patient is validated in several clinical studies (some of them conducted in the context of REACTION). Basically it was found that the ePatch records ECG data, that has the expected clinical content, and was very easy to use, and the patients do nearly not feel the ePatch.

5.2.16 REACTION Short Term Risk Management Component

The Short Term Risk Management component is a system, which contains several beneficial functions, including: data visualization with intelligent, adaptive graphical display options; showing daily profile with therapeutic data and providing statistical methods for data processing. In the Short Term Risk Management model the pattern management approach was applied with pattern recognition and definition functions. Having a pattern detected, it is important to review the possible causes and take appropriate action. The component also has the ability to support healthcare professionals and patients with suggestions for decision support purposes. A generated report summarizes all of the results from monitoring data processing.

The Short Term Risk Management component can display physiological and lifestyle data together from the REACTION database. For advanced information extraction all of the physiological and lifestyle data can be analyzed by performing pattern search. In diabetes management self-monitoring of blood glucose can provide large amounts of data which might be hard to interpret both for patients and health professionals. Risk-factors are specified as undesirable patterns which reflect undesired combinations of blood glucose values. Pattern extraction, in our view, is the key methodology to assess short term risk, as patterns can reveal predefined combinations of blood glucose values (or other physiological parameters), which appear repeatedly over time within the monitoring period. While single out-of-target measurements occur every now and then, patterns existing over several days may indicate that the patient's treatment is not ideal or it is not properly aligned to his/her lifestyle.

Pattern Management is a systematic approach to help patients and healthcare providers to identify patterns in blood glucose readings to determine whether changes are needed to optimize their glucose control. It's a review of blood glucose readings in relationship to the factors that affect blood glucose control, and making treatment changes accordingly to achieve target blood glucose values and avoid hypo- and hyperglycaemia.

The component may contain predefined patterns. These could reveal the following symptoms: hypoglycaemic and hyperglycaemic state, oscillating state, Dawn phenomenon, Somogyi rebound, morning hyperglycaemia, excessive postprandial excursion and excessive excursions between meals.

5.2.17 REACTION Semantic Search Component

The Semantic Search technology helps information extraction, data mining from databases, non-structured and structured text. Knowledge discovery aimed at analysing the collected data (e.g., qualitative and quantitative data such as data from real-time observations, direct patient inputs and health history). The formalisation of pre-existing clinical knowledge and the discovery (e.g., with semantic data mining techniques) of new elicited knowledge represent one of the main innovations in REACTION project on diabetes management. Methods provided for the semantic analysis of natural language texts as well as methods for discovering new pieces of knowledge on the basis of qualitative

and quantitative data, textual and numerical elements can be searched together. The process of search is illustrated on the following Figure 12.

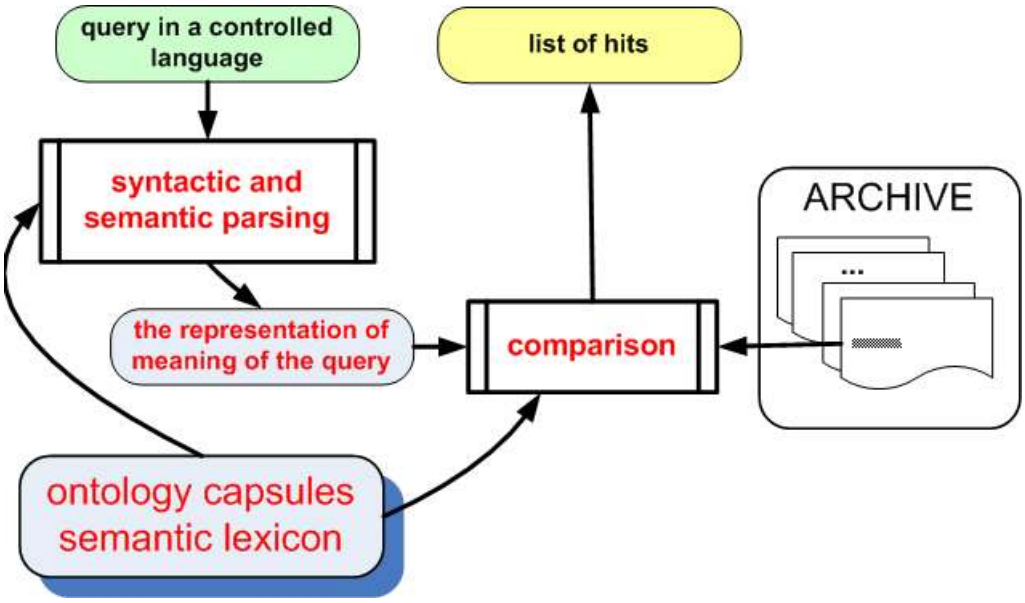


Figure 12: The semantic search process

The semantic search tool built into the REACTION platform retrieves information from the recommendations of guidelines and selected scientific papers. This version was tested in ALL on the recommendations of selected guidelines.

5.2.18 REACTION Closed-loop Algorithm Using Physiological Model

We have developed a novel control approach, which, for the first time, combines a detailed a-priori individualizable generic whole-body PBPK/PD model of the glucose-insulin metabolism (GIM) (also developed within REACTION), with a robust model predictive control (MPC) algorithm for automatic glucose control. This robust MPC AGC scheme allows handling of system lag times and patient variability, as well as sensor inaccuracy. Using the PBPK/PD model kernel for accurate predictions of an individual's core dynamics of blood glucose levels, the MPC computes an optimal control input. The model kernel is adapted over time using continuously gathered patient data to improve its predictions of the individuals cor dynamics. The high level of mechanistic detail represented by the model fully exploits the potential of MPC and enables long-term predictions by capturing relevant process variability. To increase closed-loop stability and robustness against disturbances and model uncertainties a proportional-integral-derivative (PID) based feedback controller is used for compensation of prediction errors (offset).

The developed glucose control framework (Figure 13) allows both, in silico evaluation of controller concepts and control of blood glucose in type 1 diabetes patients in a clinical setting. In Figure 13, the model kernel is initialised with general patient data (weight, height, gender). Blood glucose measurements are taken frequently, stored and the most recent measurements are delivered to the Controller. The process works within two timeframes: the online calculation of the optimal insulin dose (control input for closed-loop glucose control) based on recent glucose measurements and the offline "model adaptation" based on the full measurement data history in an extended timeframe.

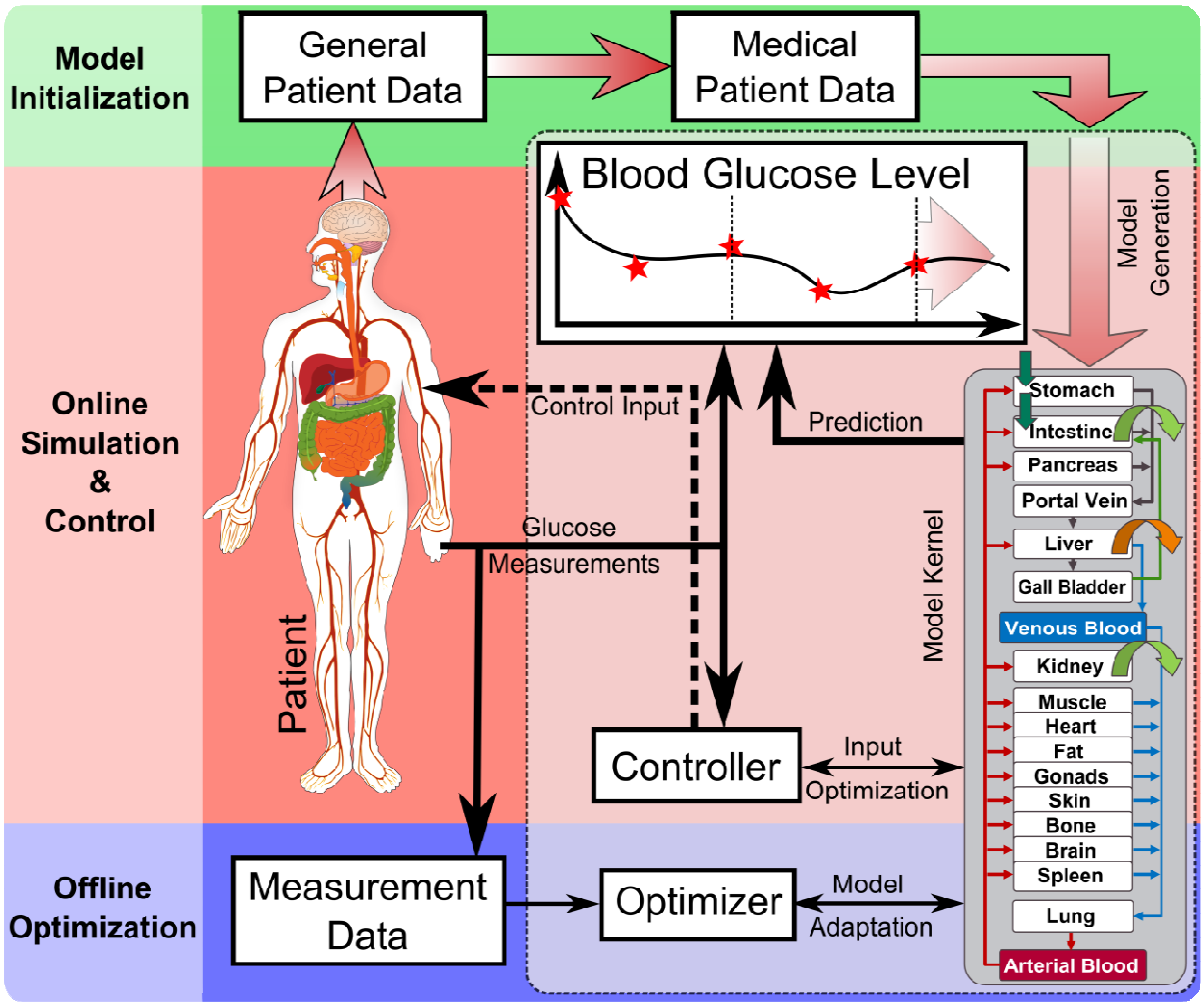


Figure 13: © Bayer Technology Services: the workflow and information flow of an integrated system in a clinical environment during continuous closed-loop glucose control

The interaction of the components of the integrated system is based on a modular approach. Here, interacting layers work on different timescales, where the outer layer (offline optimization) with the larger timescale adjusts the parameters of the inner, i.e., fast layer (online simulation & control). For the system described here, the outer layer is represented by the model adaptation, i.e., individualization routine, using glucose measurement data for the adjustment of the model kernel of the control algorithm (middle layer), which calculates insulin delivery based on latest CGM data, and meal information. The middle layer is further restricted by the innermost layer, the robustness layer, which comprises the offset-controller with algorithms for pump shutoff and insulin-on-board constraints.

The algorithm for the integrated closed-loop control system was first validated in computer simulated clinical trials followed by two feasibility studies involving 24-hour clinical trials on 10 patients each with diabetes type 1 at the Medical University of Graz in January and February 2013 (with intravenous measurements) and 2014 (with subcutaneous measurements). The results show that glycaemic control in patients with type 1 diabetes can be achieved with the developed control approach using individualised PBPK/PD model kernels within a robust MPC framework and that large-scale computer simulated models of the glucose metabolism can provide a framework to improve diabetes research, the development of automatic control strategies for diabetes and ultimately everyday diabetes management.

5.2.19 REACTION Primary Care Patient Monitoring Protocols

In order to carry out the field trial a monitoring protocol was developed that would support the usual clinical management of patients (**Error! Reference source not found.**). All patients are invited to take part at the time of their usual diabetes review which takes place twice per year at 6 monthly intervals.

The REACTION platform including remote monitoring of blood glucose, blood pressure, diet and activity levels is used to support the usual diabetes review guidelines and to identify at risk patients and, using clinical intervention, initiate appropriate changes to management. The integrated REACTION solution for primary care was realized in order to be able to implement the primary care patient monitoring protocols.

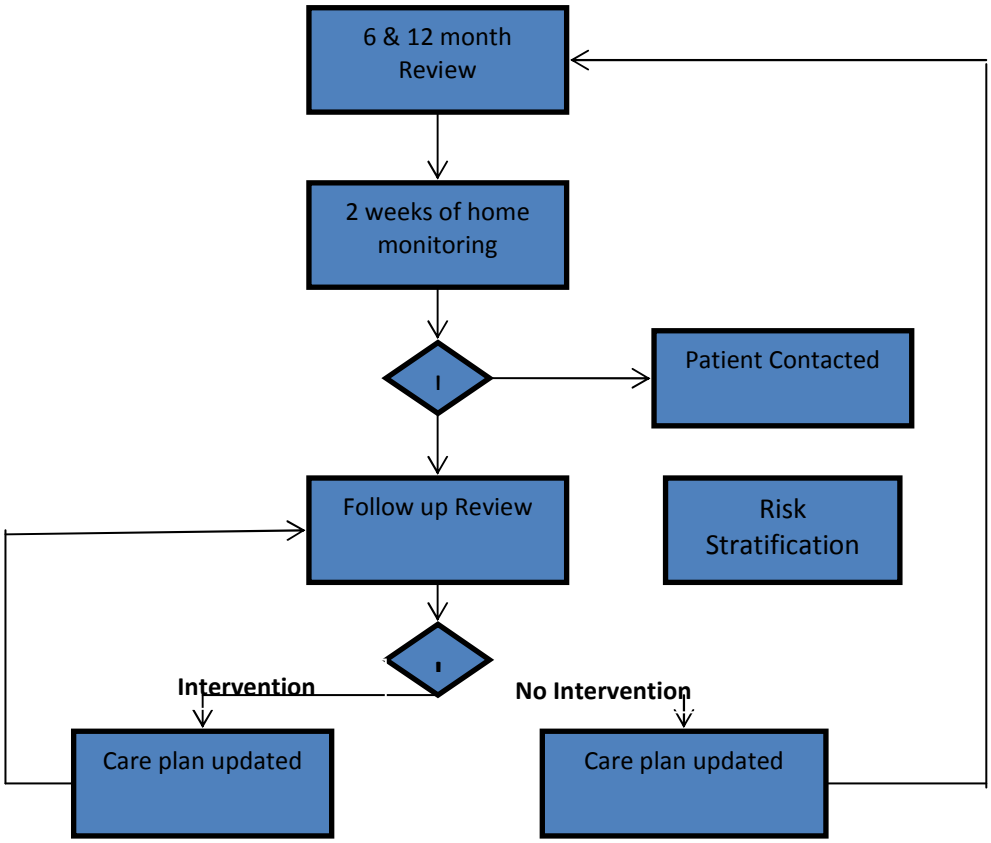


Figure 14: Monitoring protocol flow diagram

5.2.20 REACTION Security Environment

The REACTION Security Environment is a framework for securing communication between Android devices and Web services, controlling access to Web services based on roles and security tokens (e.g., identity certificates), validating security tokens, and managing user information. In REACTION, the framework is employed in the in-hospital ward to control access to web services of the GlucoTab system. Furthermore, it provides authentic and confidential communication between a mobile device running the GlucoTab app and the server hosting the GlucoTab services. An overview of the REACTION Security Environment is shown in Figure 15.

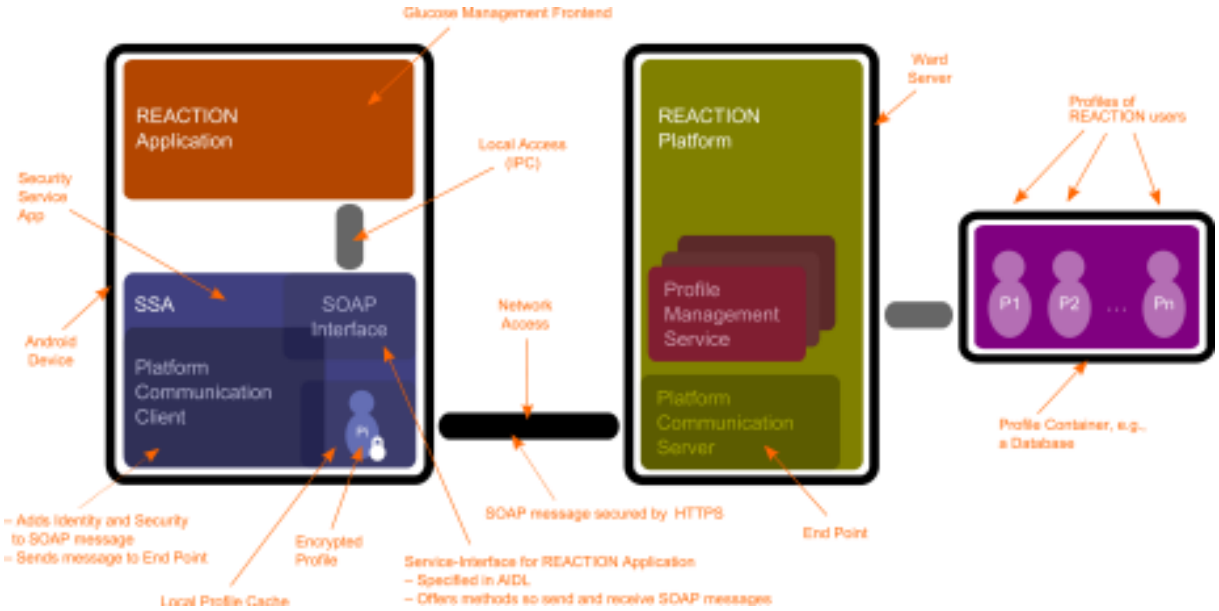


Figure 15: Architectural overview of the REACTION security environment

5.2.21 REACTION Database

The REACTION database was designed in order to allow the storage and the retrieval of the information related to the diabetes management in the integrated environment of primary and home care. It is a relational database and contains tables for the storage of the users, their roles (administrator, clinician, patient), observations (blood glucose, blood pressure, etc.), information about lifestyle (nutrition and activity), compliance and treatment, the care plan, etc. The structure of the database (data model) represents considerable knowledge about how to model primary care integrated solutions.

In the design phase tools like Sybase Power Designer and Microsoft Visio were used. Specific script functions have been produced for generating the database schema, for updating it from a version to another without losing the already inserted data, etc. The generation of the database has been done trying to use strictly SQL in order to allow the use of different relational database engines and satisfy different user needs. In the specific case of CHC the database engine used is Microsoft SQL Server.

5.2.22 REACTION Notification Handler

The *Notifications Handler* system is based on the research and development behind the rule-based service orchestration engine (i.e., Rule Engine and Service Orchestrator) that allows for the static or dynamic assembly of services and their execution on the REACTION platform. The *Notifications Handler* GUI (General User Interface) represented as part of the Clinical Portal forms the basis for application-oriented workflows, including underlying layers of event handling and crisis management interface. It allows healthcare professionals to pre-define notifications and activities to be performed according to a set of pre-defined rules based on individual changes in patients' health status and/or their environment. It is based on a closed cycle that involves patients, healthcare professionals and the informal carers that combine the orchestration of services with an essential efficient networked-based event management solution. The system is composed by the *Global Settings*, *Alarm Handling*, *Alarm Tray Details*, *Personalized Settings* and *Reports*.

The *Global Settings* contains the *Rule editor* and the *Notification editor*. The main functionality of the *Rule editor* is to set global thresholds in order to identify patients' adverse events based on the analysis of the received information. By default, a new rule is defined to be applied to all the patients with the identical pathological condition. It is possible to Add/Remove global rules and combine different parameters such as age, weight, blood glucose, etc. The *Notification editor* allows to select the communication channels that will be used (email, short message service or other), the level of the notification (advice, warning, critical) that is associated to different colours (green, yellow and red) according with the severity of the event.

The *Personalize Settings* module (which is divided in *Patient Selection*, *Alerts* and *Rule Editor*) contains the global settings applied by default that can be adapted to the individualized patient's features; it is possible to filter data by status, name or NHS ID (National Health Service Identification). The thresholds can be modified if needed and different ways of communication can be configured for the same patient.

The *Reports* allow clinicians to personalize the information required and add extra information and generate it in .pdf files summarizing the alarm status and actions taken. It allows adding the parameters snapshots, annotations, tables, etc.

5.3 The REACTION Platform

The REACTION platform is composed by the set of services and applications described above. They have been assembled and integrated in different ways in order to address the different needs of the 3 different application environments addressed by the REACTION project: in-hospital ward for the short-term management of people with diabetes, primary and home care for the long-term management of people with diabetes and automatic glucose control.

5.3.1 In-Hospital Application

In the hospital ward, the diabetic patient is managed in the short term through the platform and the services provided by hospital department, fully integrated with the hospital information system. The GlucoTab frontend (Android-based) is fully integrated with its backend (using web services and SOAP messages) in order to support the workflow and provide insulin dosing support system for the glycaemic management of patients with diabetes type 2. The REACTION Security Environment is fully applied.

5.3.1.1 In-Hospital General Testing Concept

Software testing was performed in three stages: (1) testing of software units, (2) testing of software components, and (3) testing the system against the user requirements. Moreover, usability validation of the GlucoTab system during the clinical trial was performed. The goal of the verification and validation was to check whether the GlucoTab system confirms to the requirements of the users and to ensure a minimal number of errors in the software.

Testing of the GlucoTab system was performed in three different test environments (see also Figure 16):

- **Test environment 1 (TE01):**

  Laboratory tests were done firstly at the development department in a non-productive system environment. The tests include unit, integration and system tests.

- **Test environment 2 (TE02):**

  After these tests have been successful, testing with testing data was performed at the ward. In this environment, the system was integrated into the Wi-Fi infrastructure of the ward including running the backend application on the KAGes (Krankenanstaltengesellschaft, Healthcare Company of Styria, Region of Graz) server. HL7 interface tests (integration) to the hospital information system were done. The main aim of these tests was to prove a successful integration and to show that all functions are working correctly.

- **Test environment 3 (TE03):**

  Finally, testing of the system was performed in the real world setting at the ward including the productive hospital information system. In this setting usability and user acceptance tests was done. In addition, installation and configuration of each GlucoTab system was tested at each ward.

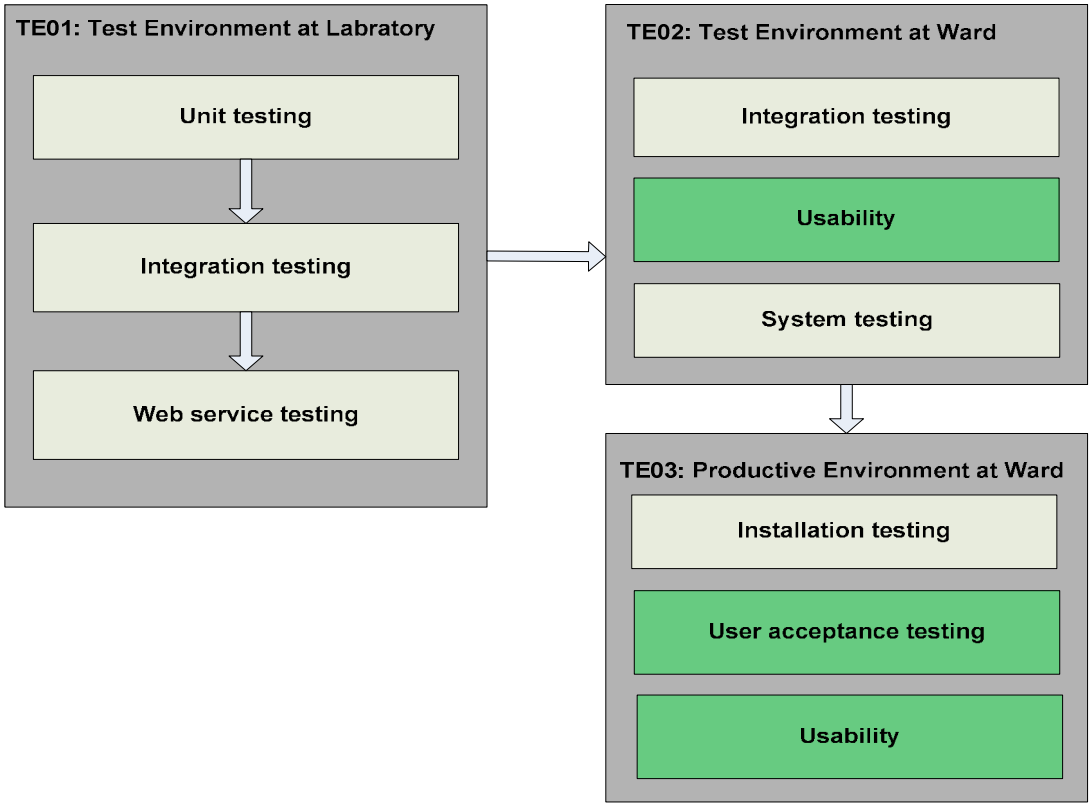


Figure 16: General testing procedure for the GlucoTab system

5.3.1.2 In-Hospital Verification and Validation Methods

This chapter describes the verification and validation methods used to test the GlucoTab system. Based on the granularity of the testing unit, different tests have to be performed.

The application was split into the smallest identifiable software units. Figure 17 illustrates the separation of the overall system to the smallest identifiable units based on the system architecture.

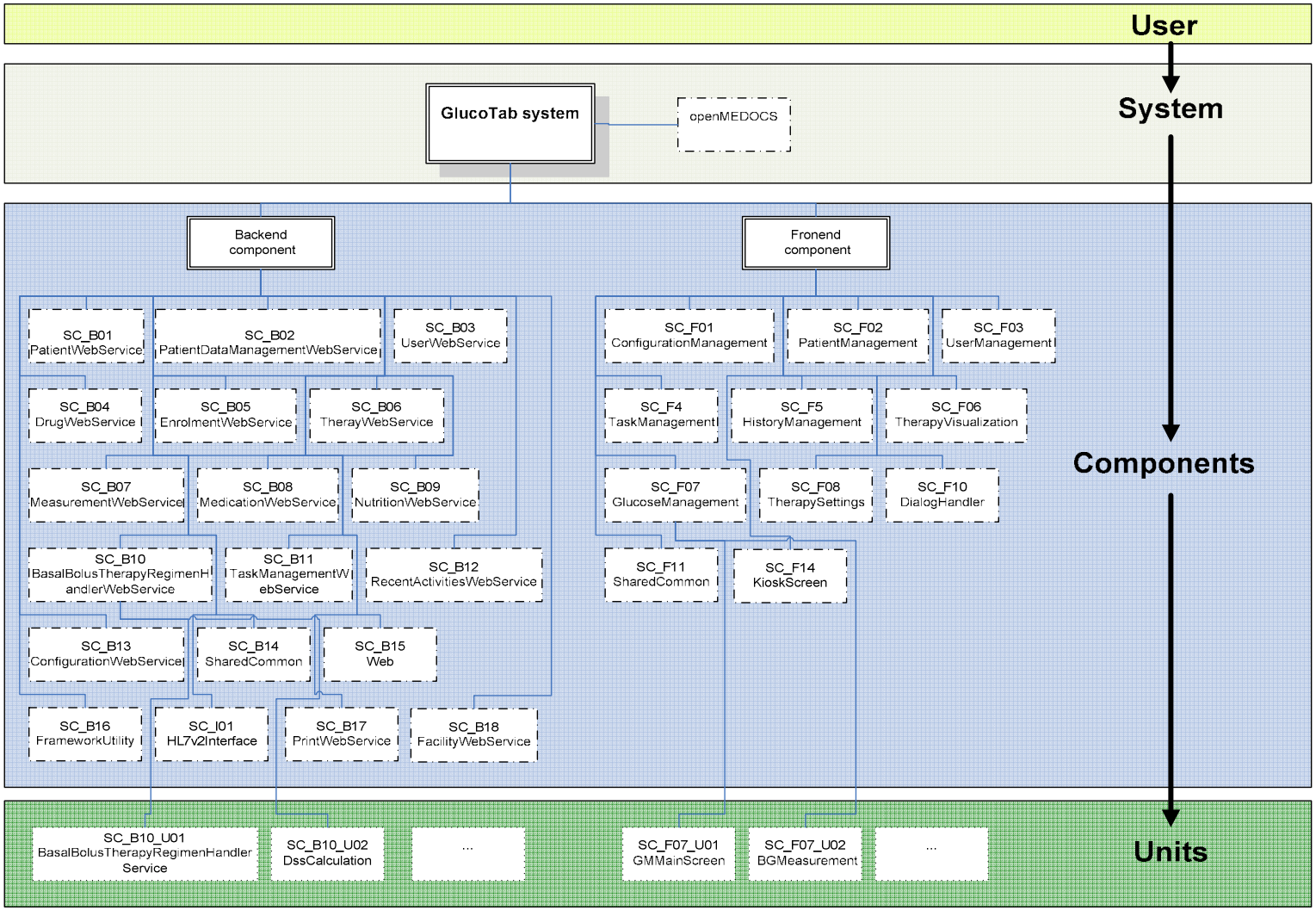


Figure 17: Splitting GlucoTab into units

The testing is conducted into the opposite direction, indicated in Figure 18.

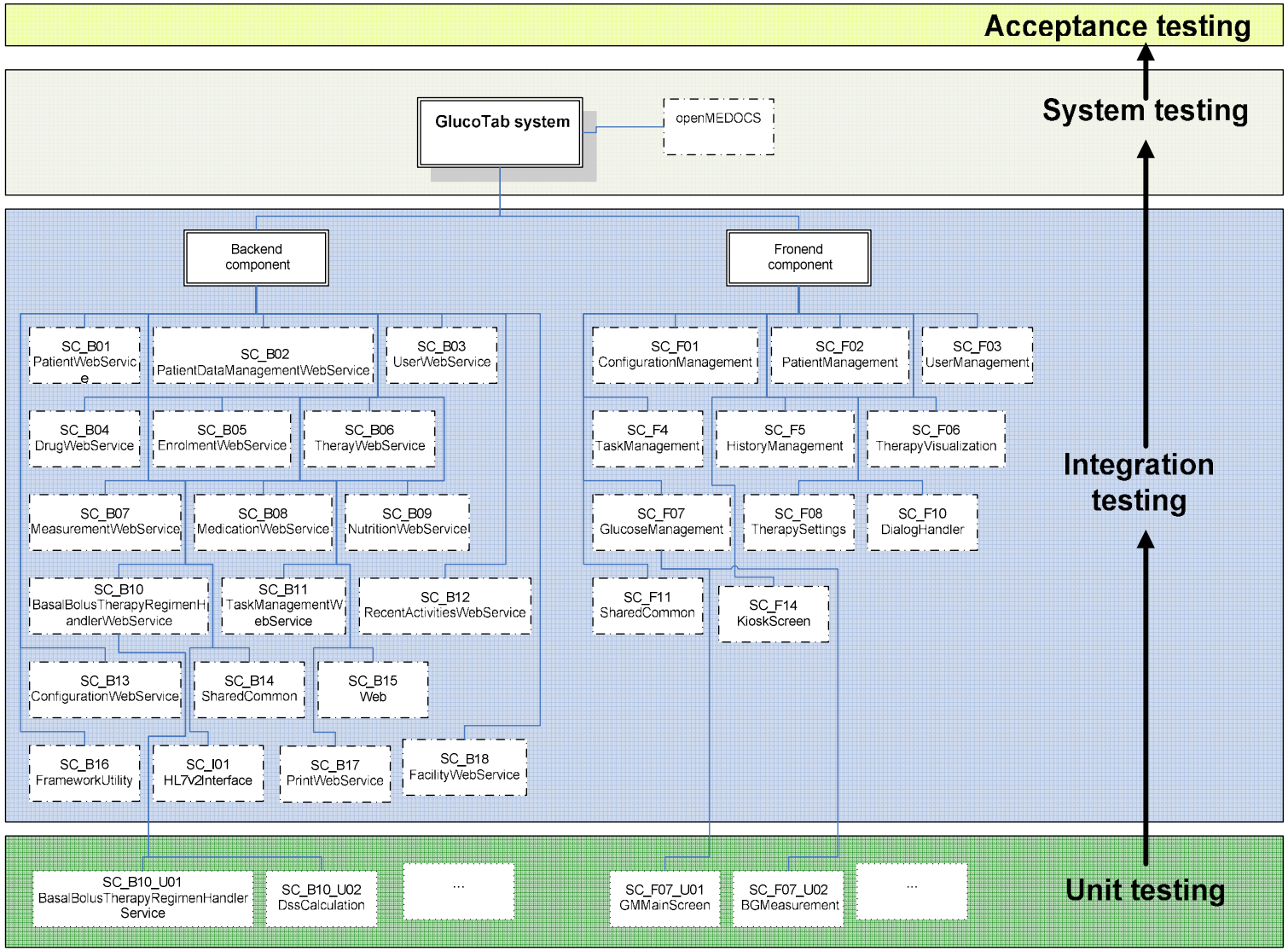


Figure 18: Test of GlucoTab

Unit tests verify the encapsulated functionality of one unit independently of any other unit. In contrast, testing components means to test the functionality of in several components encapsulated units. System tests should test all of the system's components. Finally, acceptance tests ensure that the system implements the requirements correctly.

Following tests were performed to verify and validate the GlucoTab system:

- **Unit tests**

  These tests ensure the verification of identified software units (e.g., unit tests).

- **Integration tests**

  These tests ensure the correct interaction of the identified units in components or between components (e.g., web service tests)

- **System tests**

  These tests ensure the correct functionality of the overall system in the productive environment. Some system tests are performed for each installation (installation tests) in each participating ward.

- **Installation Tests**
  These tests ensure that the installation of the GlucoTab system works correctly at each ward.

- **User acceptance and usability tests**

  Usability tests ensure the usability of the GlucoTab system. The results of these tests are outcomes of the clinical trial. These tests verify the user requirements against the system (e.g., evaluation). The results of these tests are secondary endpoints of the clinical trial.

5.3.2 Primary Care Application

When at home, the diabetic patient is managed in the long term through the platform and the services provided by the primary healthcare centre. The basic components of the system from the stakeholders' point of view are: a) the home or mobile platform composed of medical and environmental devices and a home or mobile gateway for the secure connection with the backend servers; b) the health professional (clinical) portal; c) the patient portal. All components have also the capability to interoperate with each other and at least weakly with the electronic health record of the primary care centre. A REACTION database accessible through web services focused on guaranteeing interoperability is used by all components. A REACTION platform server backend is used for hosting the web applications, the web services, the REACTION database and the primary care patient monitoring protocols. Finally, the REACTION security environment is fully applied, through the use of transport security (secure HTTP) as well as message security (XMLEnc and XMLDSig).

All components of the overall solution have been developed in order to be simple, easily usable by elderly people (hiding technology as much as possible), with low cost and with easy procedures for installation and removal.

Optional components of the REACTION platform that can be used in the Primary Care are: a) the REACTION nutrition app; b) the REACTION network monitoring service.

The architecture of the primary care solution is illustrated in Figure 19.

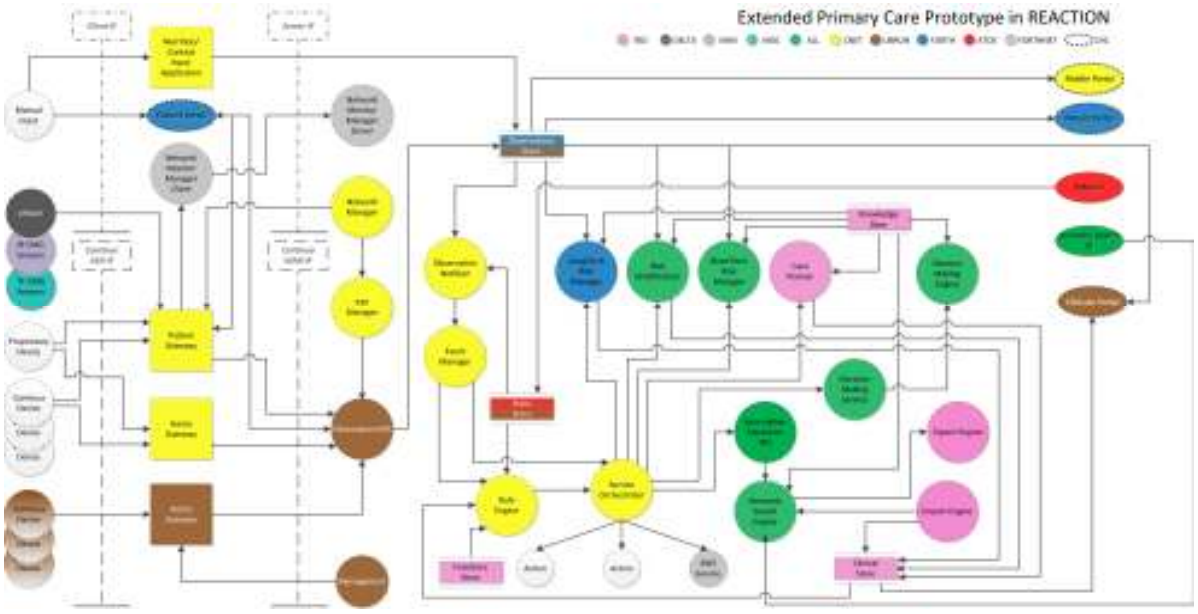


Figure 19: The architecture of the primary care solution

5.3.2.1 Primary Care Basic Components

5.3.2.1.1 Clinical Portal

The health professional portal supports the clinicians with the following main functionalities: a) system administration; b) user management; c) patient management; d) education and care plan (lifestyle and medication) management; e) remote monitoring scheme plan; f) daily measurement management; g) view of additional data and questionnaire responses; h) risk management; i) notification management.

It integrates several components of the REACTION platform like the REACTION long-term risk models, the REACTION short term risk management, the REACTION semantic search and the REACTION notification handler. A proper interface for the REACTION SMS notification is also built-in the clinical portal.

5.3.2.1.2 Devices and Home Gateways

The home or mobile platform is dedicated to the automatic collection of vital sign, environmental and context measurements with a focus on user friendliness, low costs, use of standards and use of wireless medical and other devices.

Different solutions in terms of gateways have been implemented in order to address the different needs of different end users: a) ZigBee home monitoring platform (where the devices use the ZigBee protocol and the gateway is implemented as SmartMeter); b) REACTION Multi-Protocol Home Monitoring Gateway (where the devices use the Bluetooth protocol and the gateway is a PC-based black-box).

In both cases interoperability standards recommended by Continua Health Alliance are promoted and the IHE-PCD01 for the communication with the backend is used.

The REACTION SDK has been used for the development and the test of the software running on the gateways.

The REACTION Multi-Protocol Home Gateway supports commercial off-the-shelf devices with different communication protocol. The complete list of devices is showed in Table 1.

Device	Manufacturer	Model	Communication Protocol
Blood pressure	A&D	UA-767PBT-C	IEEE 11073 Bluetooth
Weighing scale	A&D	UC-321PBT-C	IEEE 11073 Bluetooth
Medication monitor	Pivotell Carousel	Automatic Pill Dispenser GSM enabled	GSM
Pulse oximeter	Nonin	Onyx II 9560	IEEE 11073 Bluetooth or serial communication
Glucose meter	Bayer	Contour USB Contour Next USB Contour XT	USB
Glucose meter	Accu-Chek	Accu-Chek Aviva Nano v3 Accu-Chek Aviva Accu-Chek Mobile v3 Accu-Chek Compact Accu-Chek Compact Plus Accu-Chek Combo v3 Accu-Chek Spirit Accu-Chek D-TRONplus Accu-Chek Comfort Accu-Chek Sensor Accu-Chek Pocket Compass 3.0	Smart Pix USB device reader supporting (IR)
Pedometer	Charder	CH110	USB
Activity monitor	A&D	UW-101NFC	NFC
Activity monitor	FitBit	The ONE	Cloud based web server
Activity monitor	GARMIN	Forerunner 305, 405	USB and ANT+
Heart rate monitor	GARMIN	GARMIN Heart Rate Monitor	ANT+
Heart rate monitor	Wahoo Fitness	Fitness soft Heart Rate Strap	ANT+
Motion sensor	Netvox	ZB01C	ZigBee (HA profile)
Contact closure	Netvox	Z302A	ZigBee (HA profile)
Temperature and humidity sensor	Netvox	Z711	ZigBee (HA profile)
Power outlet	Netvox	Z800F	ZigBee (HA profile)

Table 1: List of devices used at patients' homes

5.3.2.1.3 Patient Portal

The patient portal supports the patients and informal carers with the following main functionalities: a) capture of lifestyle data (activity, diet, emotional status); b) capture of medication data (insulin, OADs); c) support of lifestyle and compliance questionnaires; d) view of care plan (lifestyle and medication); e) view of own measurements; f) view of feedbacks; g) view of notifications, alerts and reminders; h) view of material in support of education and motivation; i) manual input of measurements (as back-up solution).

5.3.2.2 Primary Care General Testing Concept

The primary care platform has adopted an extended waterfall design methodology as in Figure 20. In this approach each step is frozen before proceeding to the next step in the process. The extended waterfall method allows to iterate back one step at a time to correct design and implementation. This approach supports the REACTION project well, in which separate partners are responsible for

implementing the various components. The design and specification were completed and agreed and a formal change methodology was agreed and adopted to minimise design changes and to ensure coordinated migration to common versions.

An iterative design methodology was adopted, with evaluation and user feedback used to inform new requirements and design. A pro-active approach was adopted to collect fault reports and respond.

Extensive testing stages were incorporated in the methodology to ensure that devices and the platform were reliable and robust for deployment to the patients and for the health professionals.

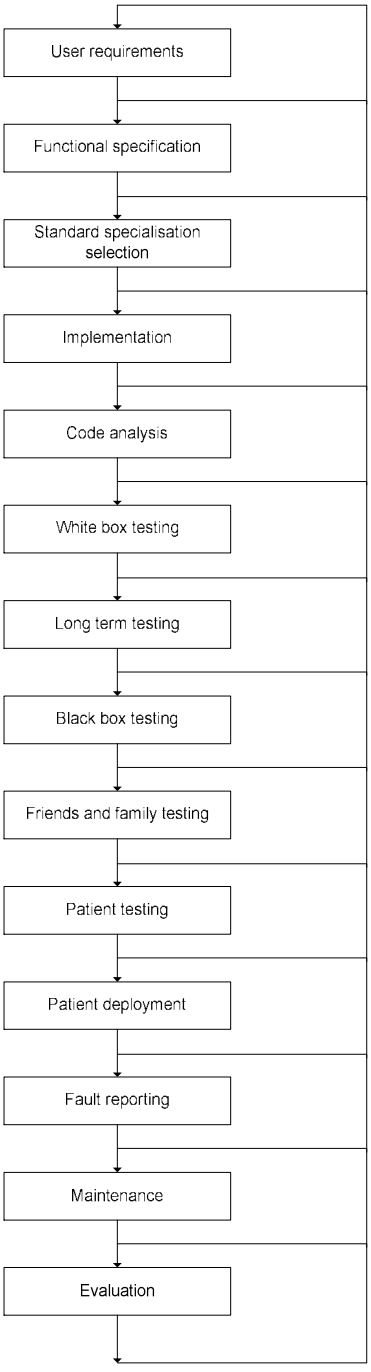


Figure 20: Primary care design methodology

Code analysis, white box testing, long-term testing and black box testing of Figure 20 are related to the internal verifications and are reported in Section 6 for the major components (even if they have been used for most of components and applications without being explicitly reported in most cases)

while the subsequent ones are related to the user validation activities and are reported in the Section 7.

Similar approach was also adopted for the testing of the components and their integration even if, in some cases, at a lesser extent.

5.3.2.2.1 User Requirements

User requirements for the primary care platform were collected through JIRA, however they were largely driven by the experience gained by the teams at UBRUN and CHC from prior projects in undertaking and evaluating remote patient monitoring, and informed by focus group meetings with patients and health professionals. It was also informed by the experience of the team being members of the medical device standards committees (ISO, IEEE 11073, CEN and HL7); these standards having been designed and developed specifically to support these applications. The standards were therefore adopted for the primary care platform. Adopting the standards simplified design and development as these were already available and so expedite the development and implementation stages.

Primary requirements to support the primary care pilot were identified for the platform:

- To be deployed to all patients irrespective of age and condition.
- To be simple to use.
- To be deployed without need for installation and with minimum training.
- To be independent of facilities available to patient (no prior requirements for internet or technology).
- To be flexible and extensible to support multiple types of device to monitor comorbidities and independent living.
- To be appropriate for use in primary care.

These requirements are evaluated in the final phase of the methodology and reported separately.

5.3.2.2.2 Functional Specification

The user requirements have been interpreted against experiences and from an understanding of the standards to define the platform that was to be deployed in the primary care pilot. The functional specification included aspects elicited from knowledge of other platforms in order to incorporate best features. The functional specification was verified with the users.

5.3.2.2.3 Standard Specialisation Selection

The platform was based on the Continua Reference Architecture and adopted the defined standards for each of the interfaces; IEEE 11073 for the LAN/PAN interface and IHE-PCD01 for the WAN interface.

For each device in the platform, the “standard” IEEE 11073 device specialisation was adopted where possible. The standard glucose meter and standard blood pressure meter are used for REACTION. The devices were conformance tested against these standards.

5.3.2.2.4 Implementation

Implementation followed best practices. Industrial compilers (IAR Workbench and Visual Studio) were used to produce all software for devices, server and web applications. C has been used for all devices due to memory and resource constraints. C# is used for the server and the applications. Components have been developed as web service (using WSDL for their interfaces) in order to exploit in the best way each partner’s expertize and to allow him to use the tools with which he was mostly confident without any need for anybody to purchase any new development environment and/or to build new expertize.

5.3.3 Automatic Glucose Control

The REACTION consortium and Roche agreed on a collaboration in the field of insulin pumps for AGC purposes. For that, in September 2013 IMM received a number of AccuCheck Combo insulin pumps, together with dynamic-link library (DLL) files and a C# computer code (for Windows operating systems) for pump control.

In this way it has been possible to integrate a PC-based concept demonstrator of the automatic glucose control which integrates the IMM sensor, the glucose-insulin physiological model and drives the Roche insulin pump.

6 Results of Internal Verification Activities

6.1 In-Hospital Internal Test Reports

All internal tests have been performed as automated tests at unit, integration and systems level.

6.1.1 Unit Tests

Unit tests were performed for backend and frontend of the GlucoTab system separately. All backend unit tests were successful. Individual results for the backend tests are shown in Table 27 in Appendix 2.

All unit tests for the GlucoTab frontend were done with an automatic test runner for Android Apps. The test result was positive with no testing errors. Individual results for the frontend tests are shown in Table 28 in Appendix 2.

The tests for the Security Environment cover components used within the Security Service App (SSA) on the client as well as security components used on the server side. All Security Environment unit tests were successful. Individual results for the security environment tests are shown in Table 29 in Appendix 2.

6.1.2 Integration Tests

Integration testing was done for the backend, the frontend and for the security environment.

No integration testing errors were detected for the backend. Individual results for the backend tests are shown in Table 30 in Appendix 2.

Likewise, in the integration tests for the frontend of R2.0 of the GlucoTab system, no testing errors were detected. Individual results for the frontend tests are shown in Table 31 in Appendix 2.

Integration tests were performed for the Security Environment components, covering components used for the frontend and components used for the backend. All Security Environment integration tests were successful. Individual results for the security environment tests are shown in Table 32 in Appendix 2.

6.1.3 System Tests

System tests were performed in the real world environment at the hospital with a test HIS system. All tests were positive with no relevant testing errors. System tests also included the installation tests at the hospital wards for the clinical trials. Individual results for the system tests are shown in Table 33 in Appendix 2.

6.2 Primary Care Internal Test Reports

6.2.1 Results of Devices, ZigBee Gateway and Clinical Portal Verification

6.2.1.1 Code Analysis

Misra-C has been applied where possible to the code for the devices. Misra-C is a set of rules that have been evolved from analysis of many lines of code to identify sources of common code errors and to define approaches to writing code that can prevent their introduction. The IAR Workbench compiler may be used to apply Misra-C.

Code for the devices has been checked using static code analysis. Static code analysis checks code for violations that might occur during run-time, such as out of bounds for arrays, missing logic checks, so that code may be made inherently safe. CodeSonar has been used as the analysis tool.

6.2.1.2 White Box Testing

The code for the devices has a console menu with options to test numerous aspects of device performance including generating test measurements and introducing specific faults (disconnect, no acknowledgement) to test robustness of code. The console also has diagnostic messages to assist fault and performance analysis.

The device code is heavily based on state models, and the verbose mode of diagnostic messages includes printing of all state-event changes. The code also incorporates several logs of system state.

White box testing was performed on specific sections of code as they were developed.

A series of test tools was produced for the PC to check integrity of messages and to perform testing. This included analysis of IEEE 11073 and HL7 messages.

The test options were used to undertake systematic integrity checking of all messages of all devices. Numerous scenarios were tested such as making measurements with no gateway turned on, out of ZigBee range, no GSM signal, multiple devices, maximum stored observations, etc.

6.2.1.3 Long Term Testing

Each stable build was installed in a test set up and left for long term testing with verbose logging of all diagnostic messages for device and gateway. Location of the gateway was varied to introduce events of poor GSM/GPRS performance to ensure reliability of performance (connect/disconnect/reconnect) was tested and that no observations were lost.

6.2.1.4 Black Box Testing

The ZigBee devices were tested at several Continua Alliance plugfest events against other reference ZigBee devices. The ZigBee devices were also tested using the Continua Alliance test tool for check on conformance. All devices were submitted for conformance testing at independent laboratories and certified.

6.2.2 Results of Multi-Protocol Home Gateway Verification

The Multi-Protocol Home Gateway (MPHG) has been used during the Primary Care trials by CHC and in adaptations by IN-JET with devices for MPHG listed in 5.3.2.1.2. It's developed with the help of the REACTION DCK and supports multiple communication protocols. In order to fully support multiple protocols each communication protocols have been tested separately during development. Some of the communication protocols have been implemented through 3rd Party APIs following the acquired documentation supporting the API.

By implementing the Continua Alliance profiled version IHE-PCD01 and HL7 WAN-IF communication to the REACTION Platform Server backend have been successfully. Communication to the REACTION Platform server uses Ethernet or Wi-Fi connectivity and requires internet access to function. If connectivity has been lost during the test period the measurements have been stored in a local storage, until communication can be established again and the data be transmitted.

To ensure the code quality The REACTION DCK and developed software has been covered with Visual Studio 2010 Unit Test Framework, applied where it has been possible. Unit test has been used by setting up tests covering functionality of developed libraries, modules and components.

Further testing has been conducted to other HL7 WAN-IF supported server backends outside the REACTION platform. By keeping the core part intact using the REACTION DCK and change required configuration the communication has been successfully. The adaptations have been using the same devices as the REACTION implementation and additional devices such as A&D UW-101NFC Activity Monitor, which use Near Field Communication protocol.

Details of the related main JIRA requirements are shown in Table 2, with main hints related to the implementation performed in order to match the requirements.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-3	Support for IEEE medical device standards	To support a wide variety of medical devices, the selected subsets of the IEEE medical device standards should be supported.	Show that REACTION device proxies can be developed for at least 2 different devices from different manufacturers .	Through the support IEEE11073 in REACTION DCK a wide range of device proxies have been developed – GlucoMeter, WeightScale, BPM, PulseOxymeter and several more
REACTION-6	Any REACTION device should have an associated semantic model (description)	To facilitate device discovery and application development, a device ontology should be part of the architecture.	New devices can be matched against descriptions in the device ontology.	The LinkSmart Device ontology has been extended to handle IEEE11073
REACTION-14	Persistent local/global data storage	Configurable storage architecture allowing both local (in PAN) and global storage (in WAN).	At least global storage is supported.	Global storage is supported through the REACTION DB and temporary local storage is supported to handle situations when there is no communication link available
REACTION-32	The architecture should support the Continua WAN interface (WAN-IF)	Need to support Continua	The REACTION system implements at minimum the IHE PCD01 format	IHE PCD01 is supported and is used for the communication from MPHG to backend systems. It has been verified with several different backend system – REACTION DB, IBM SensorEvents, KMD CareLink.
REACTION-79	Off-the-Shelf Devices	Non standard communication protocols imply a significant development effort. Such development effort can be very huge and very often also not feasible if non standard protocol is non disclosed.	The commercial devices not developed by the consortium have to be compliant with relevant communicatio n standard or, only in special cases, have a full-disclosed protocol	Implemented with common communication standards when available. Otherwise using available third party APIs and documentations to enable communication to the devices and integrating them into the MPHG.
REACTION-124	Portable device should collect all the relevant vital signs measured on	A portable with adequate features/performances should collect all the relevant vital signs	A commercial portable device will be selected in order to	The Multi-Protocol Home Gateway was ported to both an Android tablet and Smart Phone. It was validated as part of the

	the patient	measured on the patient realizing the BAN	perform the internal tests and the field trials	Demonstration Activities in WP11.
REACTION-207	ePatch communication	The reusable sensor in the ePatch communicates wirelessly at 2.4 GHz using the Continua Alliance ZigBee standard and/or Bluetooth.	The ePatch sensor can wirelessly transfer data to other parts of the REACTION platform (BAN integration node or portable device of the "black box").	The Multi-Protocol Home Gateway implements support for ePatch communication and data transfers.
REACTION-401	Device specialization - A list of devices to be provided	Based on the necessary information to be monitored from the patient, a complete list of IEEE 11073 device specialization has to be completed. Measurements which cannot be collected using IEEE 11073 device specialization are also to be mentioned in this list. The complexity of the IEEE 20601 manager also depends on the number of device specializations to be managed.	For each device the supported standard has to be specified (or the company documentation).	The Multi-Protocol Home Gateway supports commercially available IEEE 11073 and a number of proprietary device protocols.
REACTION-461	Sensor devices (PAN/LAN devices) and receiving devices (AHDs) MUST be paired to ensure entity authentication.	Without any authentication, sensors may send data to unintended receivers, which might become a privacy problem, or AHDs may receive measurements from devices which are not the patient's, which might become a security problem and eventually a health problem if the patient receives the wrong treatment due to 'false' measurements.	Some kind of 'pairing mechanism' or entity authentication MUST be used before any sensor data is transmitted or received.	All devices are paired with the MPHG using their native protocol (Bluetooth, USB, NFC).

Table 2: The main JIRA requirements for the home gateway

6.2.3 Results of REACTION DCK Verification

REACTION Device Connectivity Kit is designed for developers who needs to integrate and use medical devices in their applications. The REACTION DCK implements a device virtualization layer, so that all devices appear like IEEE11073 devices to the outside and in communication with the REACTION backend. The communication with the backend is done by the multi-protocol gateway sending IHE-PCD01 messages to the Observation WS.

The REACTION DCK was verified by building and adopting the REACTION platform for several different scenarios as part of both WP10 work with the primary care application as well as several different demonstration activities in WP11 including export of observations to third-party backends. All needs for integration of different devices and sensors could be met in a cost effective way.

6.2.4 Results of SMS Notification Component Verification

During the initial deployment procedure of the REACTION platform backend in the actual context that will be used to carry out the primary care validation trials (at UBRUN's premises), communication between the Service Orchestrator and the SMS service was not possible due to firewall issues. This was the only actual integration issue, which made necessary the requirement that the SMS service should be accessible through a Web Services (WS) interface, through a secure connection. Therefore, besides the XML-based primary communication interface (which was initially used), a WS API was also implemented and accessible through an encrypted connection.

The integration of the SMS component involved no installation procedure, since it was already installed on a dedicated external server. The integration involved several configuration steps in order to establish successful communication with the Service Orchestrator and verify that the firewall issues initially encountered were resolved. More details regarding the installation and configuration procedure for the SMS component can be found in deliverable D10.3.2 "*Second prototype of backend infrastructure*".

Table 3 summarizes the tests that have been carried out during the integration of the SMS component with the REACTION platform backend.

Test description	Status
Send SMS through the Service Orchestrator	Success
Check SMS credits for specific account	Success
Verify that communication with SMS service is done through a secure connection	Success
Test integration with the Rule Engine by verifying that SMS is being sent when a rule is being fired	Success

Table 3: SMS component integration tests

6.2.5 Results of Network Monitoring Service for Mobile Devices Verification

The NMS validation has not taken place in the medical trials since it is not a feature that can be validated by patients or medical personnel. It provides a service for the network administrator managing the REACTION platform. The NMS validation has been carried out by another consortium partner that was not directly involved in its implementation in order to check its functionality and verify its optimal networking performance.

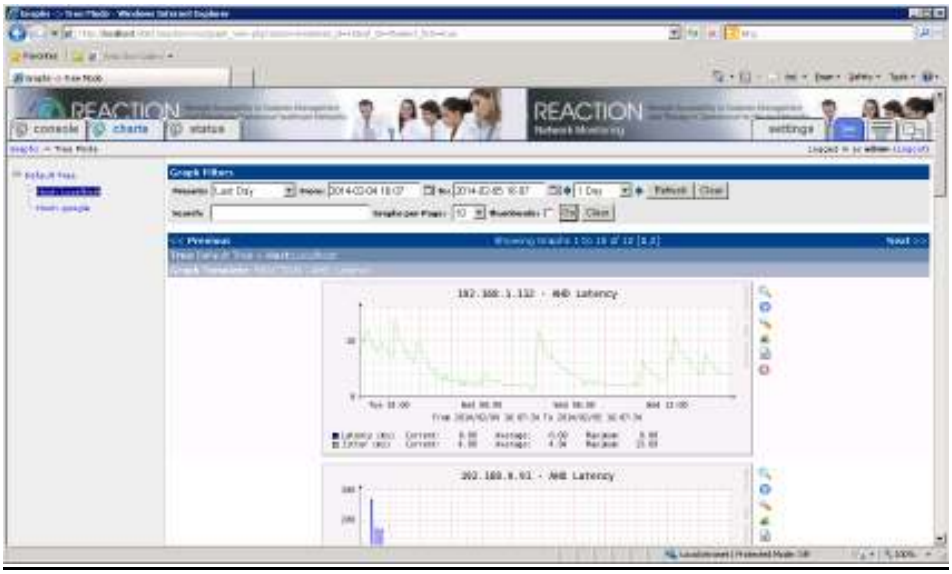


Figure 21: REACTION NMS – AHD latency during the tests

The REACTION NMS has been installed on 4 different machines, 2 PC-clients with Multi-Protocol Home Gateway and 2 Android clients with Multi-Protocol Home Gateway. The PC-clients was located in an office environment while the 2 Android clients where in two different “patient” homes.

Data was recorded for one week and was analyzed after the test period. See below for some examples of Application Hosting Device latency and traffic graphs (Figure 21 and Figure 22). The REACTION NMS tool was verified using the test protocols of D10.3.1 “Prototype of backend infrastructure & integration and test plan for backend infrastructure”.

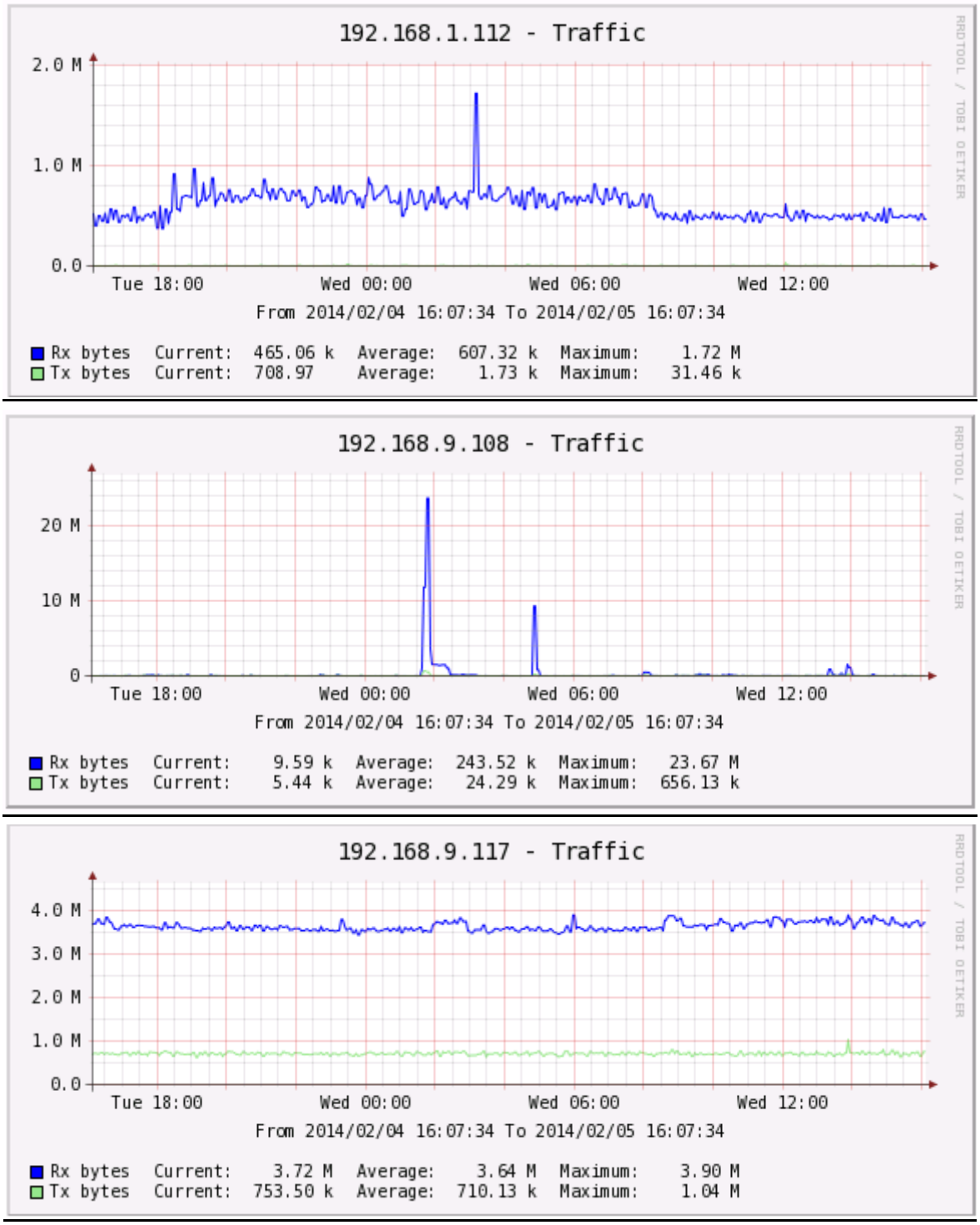


Figure 22: REACTION NMS – Traffic in the nodes during the tests

6.2.6 Results of REACTION Platform Server Backend Verification

The backend server includes Rule Engine, Service Orchestrator, Event Manager and Service Layer.

During development of the subsystem for the management of alarms / alerts and notifications a set of use cases were provided by CHC. The use cases were analyzed and structured into set of tasks used as requirements for the implementation. The requirements were sorted into alarm/alert types (Table 4), notification types (Table 5) and scope of rules (Table 6).

Once the development was finished, tests were done for each alarm / alert type individually using each of the notification type later set in the action rule. These use cases were used to verify the functionality of the components Rule Engine, Service Orchestrator, Event Manager and Service Layer.

Alarm / Alert type	Comment	Realization
Simple threshold notifications	Comparing measurement to be within or outside threshold range.	Tested with Rule Engine and notification stored in REACTION database
Average threshold notifications	Calculating the average value of measurements over time and comparing with received measurement.	Tested with Rule Engine and notification stored in REACTION database
Range of days thresholds		Tested with Rule Engine and notification stored in REACTION database
Missing data	Controlling the devices for each patient if data have been received.	Tested with Rule Engine and notification stored in REACTION database
Nestled rules	Handling multiple types of measurements thresholds in a single rule.	Tested with Rule Engine and notification stored in REACTION database
Alerts, priority on screen	Flagging of measurements depending on level of critical grade.	Implemented but not tested (time constraints)
Trends, increase/decrease	Controlling increasing/decreasing trends in measurements received over time.	Tested with Rule Engine and notification stored in REACTION database
Standard deviation	Controlling if measurement is within the standard deviation of historical data.	Implemented but not tested against verified measurements (time constraints)
Measurement notification	Notification that the measurement has been received by the server.	Tested with Rule Engine, sent with Email or SMS

Table 4: Use cases (alarm/alert type)

Notifications type	Comment
AlertNotification (advice, warning or critical)	Tested to store in REACTION database at CNET
SMS	Tested through FORTHNET SMS web service
Email	Tested through CNET Email web service

Table 5: Use cases (notification type)

Scope of rules	Comment
Global	Is triggered for all patient
Personalized	Individual set of rules trigged for each patient

Table 6: Use cases (scope of rules)

Details of the related main JIRA requirements are shown in Table 7 with details about how these main JIRA requirements are realized.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-161	Active alarm system- reminder to perform measurements	The system should remind caregivers to perform measurements	Active alarm system- reminder to perform measurements is available within the inpatient platform	Event is raised with the REACTION event manager each day controlling each patient through the REACTION Rule Engine. Notification can then be transmitted with SMS or Email to the caregiver.
REACTION-193	Alarm & alert generation	The alerts and alarms should not be generated too often in such a way the system will be considered too intrusive for the patient himself. However serious and especially life-threatening situations have to be promptly signalled. ROC analysis might be used in order to tune the alarm and alert system.	Some serious or life-threatening situations can be simulated in the integration environment and the production of adequate alarms can be verified.	Threshold rules set in REACTION Clinician Portal and each measurement is evaluated with REACTION Rule Engine once they are transmitted to the REACTION Server Backend. If a rule is trigger a notification is stored in the REACTION database.
REACTION-217	Acquired values in the alarm range	When the acquired values are in the alarm range, an alarm has to be sent to the clinicians in charge (call centre). If the alarm is confirmed by them, then either the patient has to be sent to the hospital in case of serious episode or the treatment and the RPM schema have to be adequately changed	Check the overall procedure in case of acquired measurements in the alarm range.	Threshold rules set in REACTION Clinician Portal and each measurement is evaluated with REACTION Rule Engine once they are transmitted to the REACTION Server Backend. If a rule is trigger a notification is stored in the REACTION database.

Table 7: The main JIRA requirements for the REACTION platform server backend

6.2.7 Results of Long Term Risk Assessment Component Verification

The internal tests of the LTRA component have been performed through simulations. Particularly, for each model a set of simulated “patient profiles” have been generated, and the risk evaluations provided by the models have been compared against the known, expected risk profiles. The risk evaluations matched the expected risk profiles in all tests, demonstrating that the models have been implemented correctly.

6.2.8 ePatch Product Verification

Verification tests of the ePatch system were performed and all tests were passed. This, together with a successful validation, resulted in granting a CE-mark for the ePatch as a 2 channel ECG monitor.

The specific tests performed to verify the developed ePatch for ambulatory monitoring (AMORS) are listed in the following sections.

6.2.8.1 Biocompatibility

AMORS has been evaluated for biocompatibility by an independent toxicologist from DHI (Danish Institute for Toxicology) in accordance with the ISO 10993 family of standards.

6.2.8.2 Biological Safety

AMORS neither contains animal derivatives, nor materials of animal origin.

6.2.8.3 Physical Safety

AMORS is compliant with the IEC 60601-1 family of standards and all the physical safety aspects that are covered by this standard family.

6.2.8.4 Electrical Safety

AMORS is compliant with the IEC 60601-1 family of standards and all the electrical safety aspects that are covered by this standard family. This includes EMC which is according to the IEC 60601-1-2:2007 and modified according to the IEC 60601-1-11:2010 standard.

6.2.8.5 Software Verification and Validation

AMORS is compliant with clause 14 of the IEC 60601-1:2012 for PEMS as well as the IEC 62304:2006 standard for software life cycle processes.

6.2.8.6 Usability

AMORS is compliant with the standard IEC 62366:2008 (Application of usability engineering to medical devices).

6.2.9 Results of Short Term Risk Management Component Verification

The Short Term Risk Management component was internally tested on data sets which are coming from an experiment with diabetic patients under close observation. This database contains maximum 4 daily blood glucose measurements, covering several weeks' to months' worth of outpatient care on 70 patients, which is suitable for demonstrate the pattern management function of the Short Term Risk Management system, as it can present the main features of the component comprehensively. The Pattern Editor enables the user to create a pattern (considering the number of available measurements) with the query editor, which can be an answer to a concrete question related to the actual diabetic patient.

Integration process for the Short Term Risk Management System component has been conducted by UBRUN. The component has been integrated with the REACTION Clinical Portal. The Short Term Risk Management component (including the Pattern Editor with the test data set) was given to the primary care partner Chorleywood Health Centre participating in the REACTION project. Usability test has been performed by CHC.

Details of the related main JIRA requirements are shown in Table 8 below with details about how these main JIRA requirements are realized.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-73	Short-term risk management (primary care)	Identification of short-term risks would help to optimize the patient's management and to prevent the development or deterioration of complications.	A module is available for the identification of short-term risks (based on pattern management).	A Short Term Risk Management component was developed with the following functions: intelligent visualization, daily profile with therapeutic data, statistical analysis, report generation, pattern search and definition, and decision support by suggestions for healthcare professionals and patients.
REACTION-409	Risk assessment models and rules	Models and rules must be defined to determine personal risks.	Models and rules for risk assessment are present.	Risk models and rules can be defined with the Pattern Editor part of the Short Term Risk Management component.
REACTION-399	Ongoing management	Ongoing management follows	Specific fields have to be present in	A special pattern management technology and tool was developed. The tool takes lifestyle data into consideration together

		investigative stage. This stage is used to: support patients with difficulties in managing their diabetes, check effectiveness of lifestyle and medications, support changes in patient lifestyle, identify better diabetes management for patients.	ontologies and data management.	with blood glucose data. This may prompt for adjustments in the care plan such as modification of therapy (e.g. insulin dose), changes in diet or exercise, just more frequent monitoring, or making pre-emptive or responsive actions, as appropriate.

Table 8: Main JIRA requirements related to the short-term risk management

6.2.10 Results of Semantic Search Component Verification

The Semantic Search Component was internally tested for searching in natural language texts. The tool retrieves information from the recommendations of guidelines and selected scientific papers. A collection of diabetes guidelines was selected by REACTION partner Chorleywood Health Centre (CHC) for this test.

The Semantic Search component has been integrated with the REACTION Clinical Portal. The component and the guidelines were given to the primary care partner Chorleywood Health Centre for further testing. Usability test has been performed by CHC.

Details of the related main JIRA requirements are shown in Table 9 below with details about how these main JIRA requirements are realized.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-346	Knowledge Discovery from unstructured clinical text information	In order to use unstructured text information for decision support or diabetes management the information has be pre-processed. NLP-technologies to find relevant information for REACTION applications from these textual bases can be a useful tool.	REACTION provides a knowledge discovery module to process unstructured information and store this information in the data storage for further processing.	Diabetes guidelines has been pre-processed for search in unstructured text information. Methods are provided for the semantic analysis of natural language texts as well as methods for discovering new pieces of knowledge on the basis of qualitative and quantitative data.
REACTION-386	Medical knowledge base	Contains the relevant medical knowledge or is able to connect to external sources, e.g. evidences, diabetes guidelines etc.	A medical knowledge base is built.	A document repository has been created as a medical knowledge base. The repository contains diabetes guidelines selected by Chorleywood Health Centre

REACTION-355	Computer interpretable guidelines	Evidence based guidelines as important constituents of the knowledge base must be encoded in a computer-interpretable way for decision support.	Guidelines are encoded.	Guidelines are represented in a form suitable for semantic search. The information generated as search result supports the decision.

Table 9: Main JIRA requirements related to the semantic search

6.2.11 Results of Nutrition App Verification

The nutrition app has been verified internally in a “living lab” environment by project users that have used it as part of their daily life. Usability tests with diabetes patients conducted during January-February 2014 have been reported in D11-1.

Based on the user id the nutrition app will be able to send carb history data to the patient portal to support decision making. The Nutrition app uses compiled nutrition data information from different National food agencies. The data is released under free commercial use and as is basis. The data has not been changed or manipulated in any way and is in its original format.

These National Food Agencies are:

- SE, slv.se
- EU, tna.europarchive.org
- US, ars.usda.gov
- DK, foodcomp.dk
- AU, foodstandards.gov.au
- NO, matportalen.no
- FR, afssa.fr

The application will not change the base values referencing 100 g of food item measured by the different Food Agencies. All measurements and unit conversions are made by separate measurement table and in code and are just a different way of representing and presenting 100 g food item in a more comprehensive way.

By default only mass measurements are available due to the Nutrition database base reference of 100 g per nutrition item. When a user saves a meal, every nutrition item has a measurement size, type and reference size to 100 g nutrition item. Because of the fact that mass is not equal volume the user must define a separate volume measurement for each nutrition item referencing any of the supported mass measurements that are already based on the Nutrition database base reference of 100 g per item.

This unit conversion is made by using predefined values to convert both mass and volume to a specific base measurement. In the case of unit conversion of mass values the input value is converted to milligram and then to the requested output mass measurement. Conversion of volume values is made by the same principle by converting the input value to a base value, in this case milliliter, and then to the requested output volume measurement. The result value is then multiplied by the differential value between the different measurements.

This method will make all the supported volume attributes available if the user defines one of them in relation to the mass of the measured volume. All other user defined measurements are marked as UNKNOWN and are referenced by the user defined string, for example portion/slice and so on (example of volume/mass relation: 1 dl rice = 90 g).

Details of the related main JIRA requirements are shown in Table 10 with details about how these main JIRA requirements are realized.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-8	User interface for manual entry of lifestyle data	To supply and support feedback on effectiveness of lifestyle behaviour and therapies to clinicians and patients.	User interface exists.	To support and effectiveness of lifestyle, were developed Nutrition App on Android platform. The system can integrates to the patient portal within the REACTION platform which in addition the data could be shared with care professionals. Integration test is done by CNET. The app provides feedback based on statistical analysis and simplify the complex process of nutrition components calculating on interface level.
REACTION-330	Patient access to a library of diseases with questionnaires which help the patient to better manage his lifestyle and disease	An educational library with helpful content about patient's lifestyle shall be created. This library shall contain information about diet, activity, medication and advice to the patient in response to patient's lifestyle, etc.	It should be evaluated by focus group and the test plan.	A plugin database is implemented in the application. Further Through integrating the application to the most standard European nutrition databases provides all needed informations in 7 European languages.
REACTION-334	Devices should be able to operate anywhere in the home	To make a system that is ubiquitous and fits patient lifestyle	Device specification	It has developed unit conversion. Through dynamic calculation the nutrition components can be converted based on personal preferences setting that is implemented to the application. The dynamic computing and access to the nutrition informations is possible in offline mood. So the application can operate and compute in offline mood or at the air plan.
REACTION-383	Self-management and lifestyle support	Support of the patients' self-management by lifestyle (diet, exercise etc.) advices, therapy advices, health status assessment.	Self-management is supported.	A caloric feedback implemented through developing algorithm to support the lifestyle plan changes based on personal desire or an agreement whit nutritionist. Thus the app integration to patient portal is tested which further could be shared with care team. In addition the application can send other format of data to the care team as well as SMS.
REACTION-399	Ongoing management	Ongoing management follows investigative stage. This stage is used to: support patients with difficulties in managing their diabetes, check effectiveness of lifestyle and medications, support changes in patient lifestyle,	Specific fields have to be present in ontologies and data management	It is developed other module contain guidelines for diabetes nutrition such as exchange list and GI-Low. These modules are based on educational nutrition relates to maintaining of glucose level in the blood and improvement of

		identify better diabetes management for patients.		lifestyles
REACTION-449	Personalized care plan	A copy of the patient's diabetes care plan will be entered onto the clinical portal (manually). This can be viewed by the patient on the patient portal. The care plan is based on a validated care plan used within primary care to aid the management of patients with Diabetes and is part of the current workflow to be incorporated into REACTION as per the clinical requirements	The care plan can be updated by the clinician within the clinical portal.	As Personalised care plan ID to person is implemented by Nutrition App and not devices ID. Nutrition App counts as corn of lifestyle as well as part of the care plan. By implementing own diet module can person change and choose and follow the plan that is adjusted by the person or care professional team. The Patient Portal is sharing lifestyle data with clinical portal after all.

Table 10: Main JIRA requirements for the nutrition app

6.3 Automatic Glucose Control Internal Test Reports

6.3.1 Unit Test Report

6.3.1.1 Results on IR-CGM Sensor Verification

For the performance of clinical trials the chip based IMM IR CGM sensor has been combined with microdialysis (Figure 23). The reason for application of microdialysis was that corresponding catheters were available on the market already, as medically approved devices, allowing for easy ethical approval of clinical trials at MUG, without the need of any intensive biocompatibility tests.

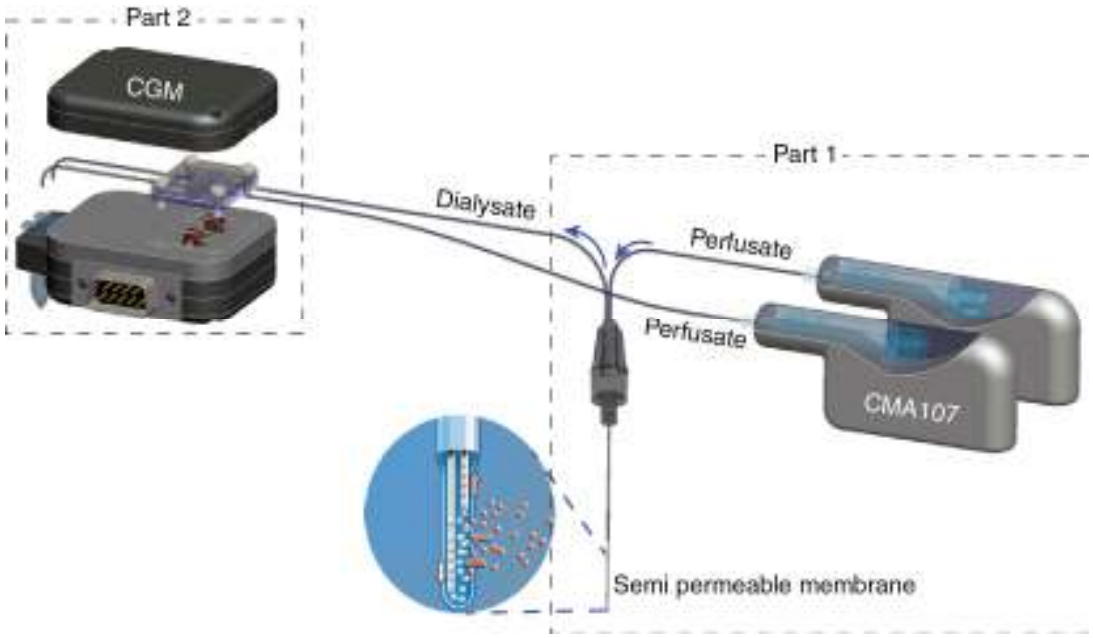


Figure 23: Schematic of the IR continuous glucose monitoring sensor, containing two main parts: the perfusion pumps and microdialysis catheter (part 1) and the electronic board with disposable fluidic chip and wastes (part 2)

The system is divided into two major parts, first a medically approved microdialysis catheter, combined with a medically approved perfusion pump (CMA107) and second a disposable polymer chip with microfluidic channels and optically functionalized surfaces which is connected to an electronics driving the light sources (light-emitting diodes (LED´s)) and using InGaAs-photodetectors for optical transmission spectroscopy, performed within a disposable polymer chip.

The microdialysis catheter represents the body interface, being applied either subcutaneously or intravenously. It consists of a biocompatible polymer needle which at its front tip is equipped with a semi-permeable membrane that allows passing through molecules with < 20,000 Dalton (CMA64 catheter) and <10,000 Dalton (PMEO11 catheter), respectively. The polymer needle consists of an inner and an outer tube, both connected to a separate tube via a Luer-connector or similar connector. The inner tube is connected to the perfusion pump, delivering the perfusion solution and is ending in the region of the membrane. The perfusion solution (perfusate) is interacting with the extracellular body fluid under application via diffusion processes through the membrane and then directed back between the inner and the outer tube of the catheter into the outlet tube (dialysate).

The dialysate is guided through the measuring channel on the disposable polymer chip. The reference channel on the disposable polymer chip is either filled with a reference liquid (usually the perfusion solution) or operated in flow-through via an additional tube connected to a second perfusion pump. After passing the polymer chip, each liquid (dialysate and reference perfusate) is guided into a separate waste. The polymer chip is realized as a disposable for one-time usage (on only one patient for a time period of several days), to avoid the risk of infection.

The non-disposable unit carrying the disposable chip is wearable on the forearm of a patient or at other parts of the body and has dimensions of about 40x80x30 mm (width x length x height). It is operated via a RS-232 cable (via medical insulating transformer), connected to a PC.

The sensor housing can be connected to the patients forearm or hand via a flexible rubber band (Figure 24). The vials for collecting the dialysate as control measurement are attached to clamps at the outer side of the housing. The microdialysis pumps used for driving the perfusate in the measuring and reference channel are also connected to the patients forearm by flexible rubber bands.

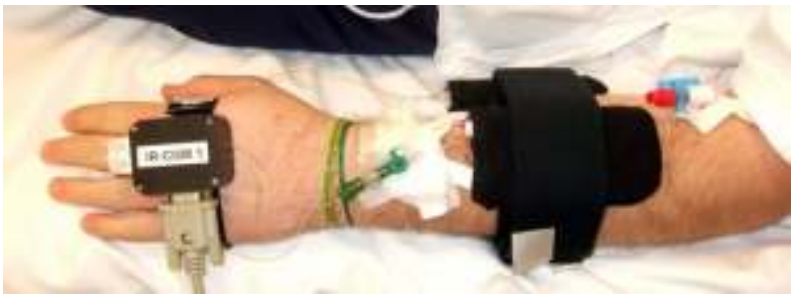


Figure 24: IMM IR CGM sensor prototype, together with microdialysis pumps, on the forearm of a patient, as applied during the clinical trials at MUG

In-vivo trials on type 1 diabetic patients have been performed during the clinical study REACTbyALGO-1 (open, single-centre, non-controlled feasibility study). Within the study also the glucose control algorithm of BTS was tested in parallel. For a detailed description of the study it is referred to the corresponding study protocol. Here only the basic information is given to the reader.

During the study 10 type 1 diabetic patients were investigated. Each patient was investigated over a period of 30 hours (see Figure 25 for the different phases of a study day). The sensor was connected to the patients at the beginning of the clamping phase in which the patient was stabilised on a glucose level of 100-120 mg/dl. Measurements were taken till the next day, while the algorithm was operated only from 19:30 first day till 19:30 second day (see also Figure 26).

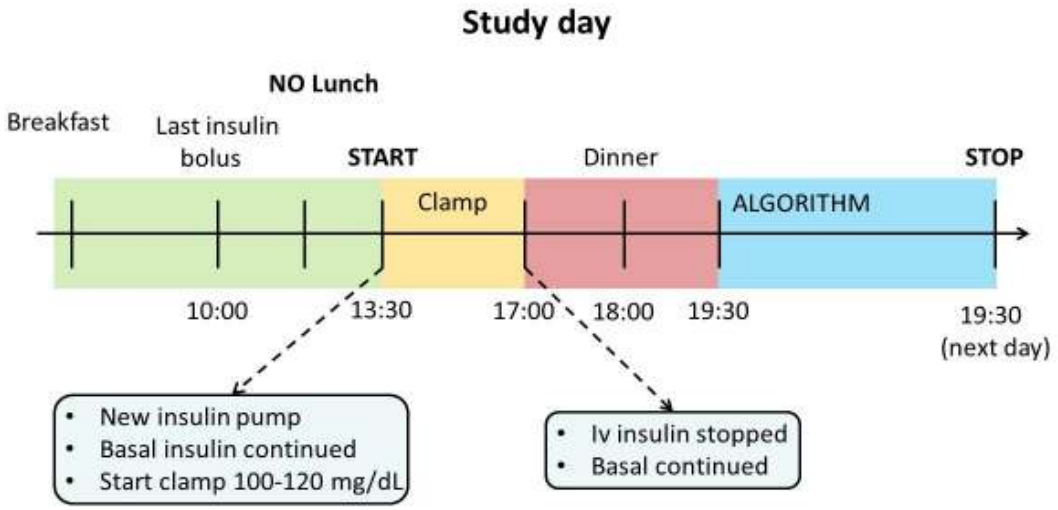


Figure 25: Schematic of the time line and different phases of a typical study day within REACTbyALGO.

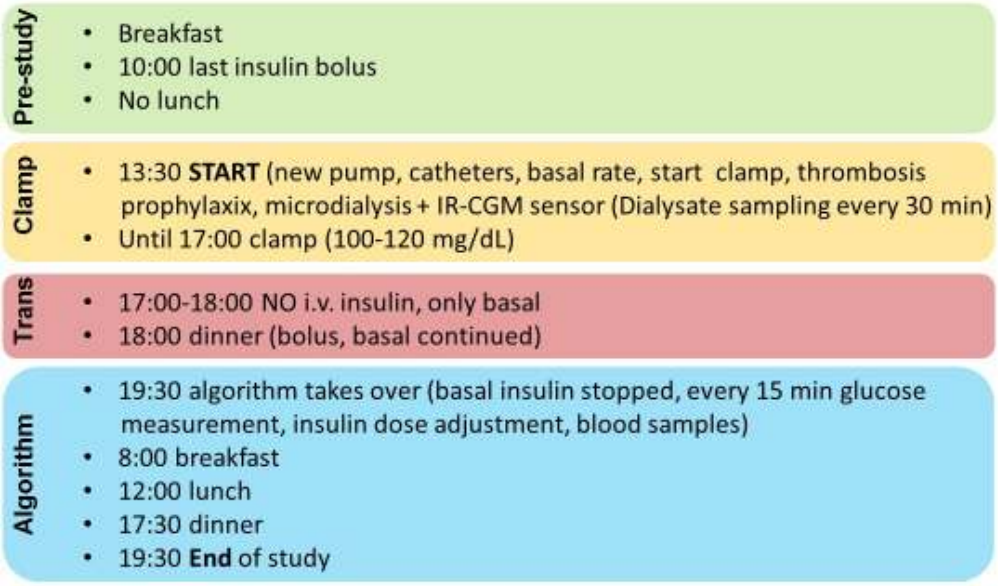


Figure 26: Actions taken during the different phases of a study day within REACTbyALGO

For each patient a patient number was assigned (01…10) and demography (date of birth, gender, ethnicity), admission diagnosis, medical history, diabetes history as well as diabetes therapy was assessed. Body measurements were taken (body weight, height and body mass index), vital signs were determined (diastolic and systolic blood pressure, pulse rate, body temperature) and routine laboratory parameters (HbA1c, haematology, biochemistry, human insulin antibodies) were recorded and everything documented.

For **microdialysis** catheters CM64 from Microdialysis and PME011 from Microeye have been used, for intravenous application. As perfusion solution 4.5 ml EloMel in 5 ml syringe with 0.4 ml Arixtra (5mg/0.4ml) was used, where the volume was split on two CMA106 syringes (one for the perfusate and one for the reference solution). The patients were connected to the microdialysis during the clamp phase and measured till the end of study. The applied flow rate for all patients was 0.5 µl/min. The dialysate was collected every 30 minutes for control measurements of the blood glucose levels (change of collecting vials).

For **reference data** blood glucose levels were measured with a *Dr. Müller SuperGL2* glucometer every 15 minutes during the study (mean value of two measurements of the same sample). As **control data** the collected dialysate glucose level was measured with a *Dr. Müller SuperGLcompact* glucometer every 30 minutes during the study (mean value of two measurements of the same

sample). The accuracy of both laboratory glucometers is given by the manufacturer as +/-4 mg/dl at a reference glucose concentration of 216 mg/dl (determined from 20 samples). Additionally the lactate values were measured in the dialysate with the *Dr. Müller SuperGLcompact* glucometer every 30 minutes during the study (mean value of two measurements of the same sample).

The **data acquisition and analysis** of the IMM IR CGM sensor was performed as follows:

1) Recording of difference voltage during trial (data of 1 minute interval is averaged, one value every minute)
2) Time shift correction (adaptation of dialysate and sensor data to reference data)
3) Retrospective baseline correction (usually two-point at identical reference concentrations)
4) Retrospective calibration (usually two-point at two clearly different reference concentrations)
5) Additional offset correction (only in regions where obviously a disturbing event happened)
6) Removal of spike data points (obvious single point outliers)
7) Plotting concentration curves with dialysate and reference data & correlation plots
8) Calculation of MARE values

The **mean absolute relative error (MARE)** value is defined by:

$$MARE = \sum \left| \frac{bg_i - cm_i}{bg_i} \right| \cdot \frac{100}{n}$$

where bg_i is the i^{th} reference blood glucose value, cm_i is the corresponding sensor measured value and n is the total number of reference measurements.

In the following for all patients the sensor measured, reference and dialysate control glucose levels are given as a function of time, together with the corresponding glucose correlation plots and comments.

A summary of the 10 patients investigated during the clinical study REACTbyALGO is given in Table 11.

Patient #	Sensor #	Calibration factor [mg/dl/mV]	MARE [%]
01	1	8576	12.8
02	1	9979	16.3
03	1	3702	12.3
04	2	5367	12.7
05	1	3419	11.9
06	2	6660	25.8
07	2	9449	4.9
08	1	2801	14.5
09	1	NA	NA
10	2	9773	13.1
mean		6636	13.8

Table 11: Summary of results on patients investigated with two different IMM IR CGM sensors during clinical study REACTbyALGO

The IMM IR CGM sensor, combined with microdialysis, was tested during the clinical study REACTbyALGO on 10 patients with 2 different sensors. The sensor data was retrospectively baseline corrected and calibrated on the reference blood glucose values, taken every 15 minutes. The baseline correction was required for drift compensation of the sensor signal which is most likely attributed to non-identical flow conditions in the measuring and reference cells, causing a temperature difference between both cells. The dialysate glucose level was measured for control purposes. The calibration

factors, recalculating the measured difference voltage into a glucose level change, clearly vary from patient to patient which was to be expected, since the difference spectroscopy method is not specific to glucose. The mean absolute relative error (MARE) values achieved with this technology varied between about 5% and 25%, with a mean MARE over all sensors and patients of about 14%. The dialysate control glucose values are systematically higher than the reference blood glucose levels although the curves as function of time are congruent. This effect seems to be related to microdialysis with low flow rates, as in our case with 0.5 µl/min. Since the calibration of the sensor is made relative to the reference blood glucose rather than to the dialysate glucose, it has no influence on the accuracy of the sensor. The lactate concentration changes of typically <25 mg/dl do not seem to have a major influence on the accuracy of the sensor.

For the performance of the second clinical trial the third generation chip based IMM IR CGM sensor has been combined with subcutaneous microdialysis (catheter CMA63). During the study 6 type 1 diabetic patients were investigated. Each patient was investigated over a period of 12 hours (Figure 27).

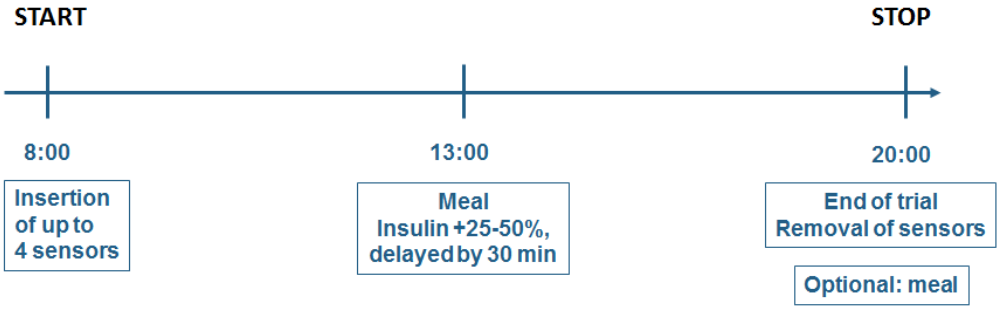


Figure 27: Time line of a typical day within the study REACTbySENSOR

Both sensors (I-Cath sensor and the IR CGM) perform continuous monitoring of interstitial glucose profiles for the entire duration of their application. Similar to the previous study, arterialised venous blood glucose has been measured as reference every 15 minutes and glucose in the collected dialysate every 45 min. The time interval 45 min was necessary to collect sufficient (20 Microliter) dialysate for the laboratory glucose meter (Super GL compact). Additionally both concentrations of lactate in blood and dialysate were recorded in the same time intervals. To control the flow rate of the subcutaneous microdialysis catheter, both vials of reference and measurement channel were weighed every 45 min.

It should be noted that the overall patient compliance was positive and that during the trial's measurements the patients ate and injected insulin according to their usual regimen. At 13:00 a lunch (with fast glucose absorption characteristics) has been served. Up to 30 minutes after the usual insulin dosing time, the subjects took his/her lunch dose of insulin adjusted to the chosen lunch plus additional approximately 25% (in the range of 0-50% according to the discretion of the Investigator) of insulin – in order to provoke moderate postprandial hypoglycaemia with glucose values < 70 mg/dl.

The data acquisition and analysis of the IMM IR CGM sensor was performed retrospectively as follows:

1. Recording of difference voltage during trial (data of 1 minute interval is averaged, one value every minute)
2. Time shift correction (adaptation of dialysate and sensor data to reference data)
3. Retrospective calibration (usually two-point at two clearly different reference concentrations)
4. Additional offset correction (only in regions where obviously a disturbing event like bubbles happened)
5. Removal of spike data points (obvious single point outliers)
6. Average of the sensor data over 15 min time interval
7. Plotting concentration curves with dialysate and reference data & correlation plots
8. Calculation of MARE values
9. CEG plot

A summary of the results achieved during the REACTbySensor study is shown in Table 12. For each patient the mean absolute error (MAE) and mean absolute relative error (MARE) with standard deviation are given.

Patient Nr.	Sensor Nr.	MAE ± SD [mg/dL]	MARE ± SD [%]
02	2	16 ± 15	6 ± 4.6
03	1	NA	NA
04	1	8.7 ± 8	5.4 ± 4.8
06	1	9 ± 7.7	9 ± 8
07	1	12.6 ± 10	10 ± 12.7
07	2	11 ± 9	9.4 ± 8
08	2	13.6 ± 15.5	11.5 ± 12.6
mean		12	8.5

Table 12: Summary of results on patients investigated with two different IR CGM sensors during the clinical study (data for patient 03 could not be evaluated due to severe problems with the microdialysis)

The Clarke error grid analysis was used to quantify the clinical accuracy of the IR CGM sensor in reference to the arterialized venous data (Figure 28).

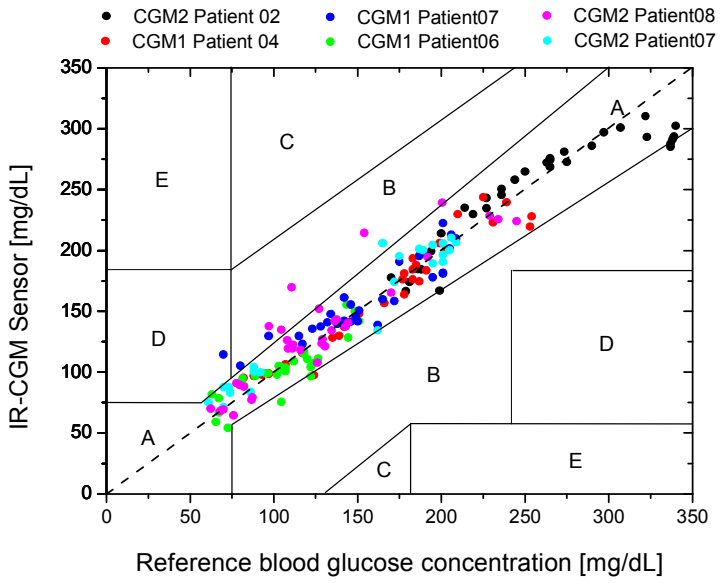


Figure 28: Clarke error-grid plot

From the CEG, it appears that the IR CGM consistency is clinically acceptable (Zone A and B). Most sensor values fall in zone A and only few in zone B. The mean MARE taken over all patients is about 8.5 % and the mean MAE is about 12 mg/dL. In conclusion, the pilot study indicates a highly acceptable accuracy of the IR CGM sensor if a proper calibration is made. Future work will focus on performing a real time calibration and reducing the lag time as well as improving the ease of use of the IR CGM sensor.

Details of the related main JIRA requirements are shown in Table 13 with, in most cases, details about how these main JIRA requirements are realized.

Key	Summary	Rationale	Fit criterion	Realization
REACTION-053	*The portable touch device must have at least the following connectivity options: WiFi (802.11g or 802.11n), Bluetooth, USB; *Also it must have built in at least the following sensors: GPS, accelerometer; *If mobile phone it must support 3G networks.	The device must support the latest and most widespread communication protocols. The presence of specialized sensors like the accelerometer, and the GPS will improve the usability of the device, and will allow the collection of additionally useful information.	All devices, those used in the field of testing and those that will eventually be selected, must comply with this mandatory requirement.	Bluetooth communication with ModbusASCII protocol has been implemented for the IR CGM sensor.
REACTION-128	Portable device should allow the display of feedback to patient	In mobile situation the only available device is the portable device and patient should be able to use it for uploading or downloading data. The possibility of using the "black box" also as output device for displaying data related to feedback to patient would help in simplifying cost and complexity of the solution.	The portable user interface should be used also for displaying the clinician feedback to patients, graphical representation of the data acquired in the last week/day/etc.	
REACTION-236	Blood glucose measurements in In-hospital environment	PoC devices are currently used and will be used in In-hospital environment. The procedure is reliable and has been used since several years. Substitution of the used PoC devices with other devices (consortium sensors) in the daily practice can be done only after passing through a very severe procedure. This might not be foreseen (for the daily practice) in this project.	There should be in the platform an alternative way for acquiring blood glucose measurements from other commercially available glucose sensors using a procedure which should be quite simple and user friendly.	The general practice with commercial sensors in the REACTION project was to read out their data and enter it manually into the REACTION platform (e.g. blood glucose measurements with AccuCheck Systems from Roche). To implement commercial sensors into the REACTION platform automatically it would require the access to the corresponding protocols, which is not feasible or sensors following a certain standard, like a Continua based which, however, is not available yet for continuous monitoring. For the REACTION sensors (IMM IR-CGM and MSG I-Cath sensor) it is of no importance, since

				these sensors are tested in clinical trials only, where no automatic data communication is required for qualification of the sensors.
REACTION-253	Data entry shall be facilitated as much as possible	Data entry in any information system is an additional task for formal carers. This additional workload has not to be burdensome in order to facilitate the adoption of the platform in the clinical sites.	Specific evaluation (e.g. using questionnaire) shall be made on this issue asking end-users how much additional work they have to do and how much this additional work (if any) is useful.	
REACTION-267	Accuracy/precision of sensors should be specified	For all types of sensors the accuracy/precision has to be known. In some sensors a high accuracy can be required, as, for example, for online monitoring of glucose where a high precision is required, especially in the hypoglycaemic regime.	The accuracy/precision should be specified by the sensor manufacturers.	Based on clinical trials for the IR CGM sensor mean absolute relative errors (MARE) between 5% and 25% have been achieved over a measuring range of 50-300 mg/dl, with the prerequisite that drift is compensated and outliers are withdrawn. The mean MARE taken over all patients is 13.8%. For the I-Cath sensor, based on animal trials, a median absolute relative error (median ARE), taken over all sensors and animals, of 25.6% has been achieved over a measuring range of 40-250 mg/dl. This slightly varies, depending on whether additional infusion over the catheter is applied or not. However, both sensors at time of specification (month 36 in the project) are expected to be further improved during the project.
REACTION-272	The body interface of the sensors should be specified	The body interface of the sensors determines whether it is invasive or non-invasive, it probably influences the accuracy and operating time of the sensors.	The body interface should be specified by the sensor manufacturers.	For the IMM IR CGM sensor the body interface will be a CMA 64 IView catheter from Microdialysis AB (Sweden) for intravascular application or a CMA 60 IView catheter from the same company for subcutaneous application, both

				connected to the chip-based IR sensor of IMM. Alternatively for intravascular application also a catheter Microeye PME 11 from Probe Scientific (England) can be used. The body interfaces are medically approved. For the JOA fluorescence spectroscopy sensor the body interface is a medically approved insulin cannulae made of PTFE (Polytetrafluorethylene) of 0.5-0.9 mm tubing diameter which will be applied subcutaneously under an angle of 20-45°.

Table 13: Main JIRA requirements for the continuous glucose monitoring sensor

6.3.1.2 Results on I-Cath Sensor Verification

Test results from the REACTbySensor study are reported in D3-4 “I-Cath prototype for AGC”.

6.3.1.3 Results on BTS-Algorithm Verification

Evaluation, i.e., verification and validation (but also documentation of development) of the closed-loop glucose control algorithm (AGC) developed by BTS is documented in detail in the deliverables D3-11 (documentation of first prototype algorithms) and D3-12 (documentation of final (best algorithm) version including validation report).

Evaluation of the AGC has been conducted is successive steps. The first (iteration) prototypes have been evaluated *in-silico* (D3-11) before tests were conducted in a clinical feasibility study in Graz in Jan/Feb 2013 (reported in D3-12) using, for safety reasons, accurate glucose measurements from blood measurements.

In the second iteration, the AGC has been further improved and tailored towards blood-glucose control using subcutaneous CGM data for the calculation of insulin dosing, which corresponds to the state of the art in (other) AGC systems currently in development (i.e., AP@Home). Performance of the control system using CGM data has first been evaluated *in-silico* (documented within the “Contingency Plan” as well as within D3-12). The final system was then evaluated within the last clinical trial for AGC in Jan 2014. Results of both trials, also in comparison to state-of-the-art systems w.r.t. key performance indicators, are shown in Figure 29 and Figure 30.

In Figure 29 the mean (+-SD) of venous plasma glucose (PG) levels with 15-min sampling is shown from all (N= 10) 30-h experiments in ten subjects for each trial, respectively. In **REACTbyALGO1** during control (t > 330 min) the maximum in mean PG was 225 mg/dL at 10:00 A.M. after the first breakfast, and the mean nadir was 105 mg/dL at 4:45 P.M. before dinner on day 2. The overall mean of all 30-h PG results (N = 119 measurements per experiment) was 156 mg/dL. The overall mean PG during night-time (10 P.M.–8 A.M.) was 149 mg/dL (N = 66 measurements per experiment). In **REACTbyALGO2** during control (t > 330 min) the maximum in mean PG was 205 mg/dL at 7:15 P.M. after the second lunch, and the mean nadir was 85 mg/dL at 12:00 P.M. before lunch on day 2. The overall mean of all 30-h PG results (N = 119 measurements per experiment) was 127 mg/dL. The overall mean PG during night-time (10 P.M.–8 A.M.) was 110 mg/dL (N = 66 measurements per experiment). The four meals are indicated by the black bar at the bottom of the plot. The mean of subcutaneous insulin infusion rates administered by the controller are plotted at lower end of plot (right axis).

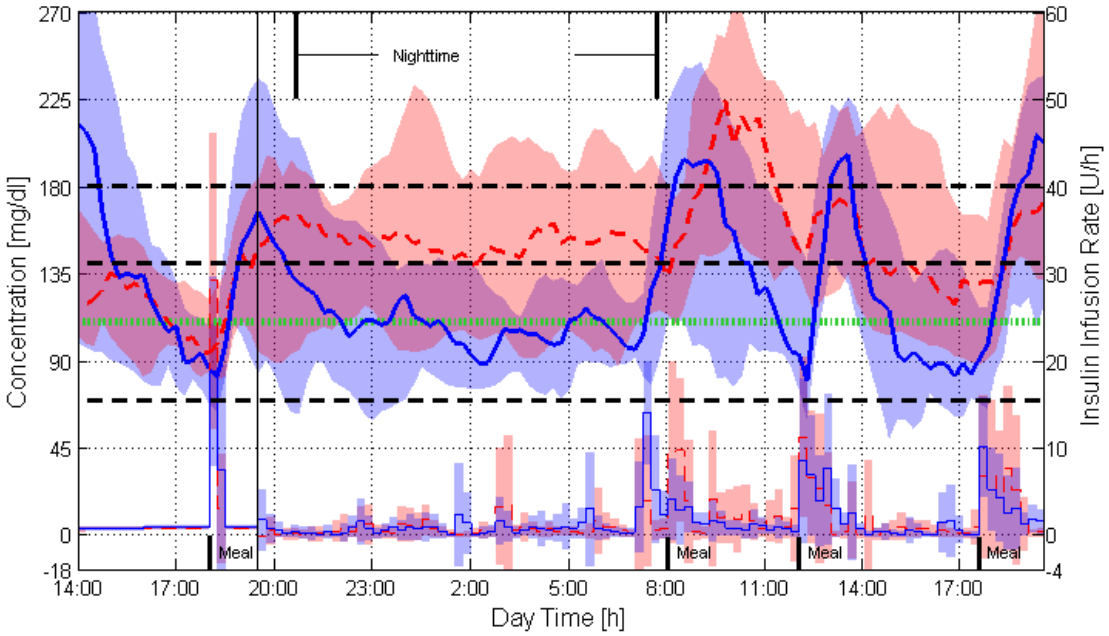


Figure 29: Mean (±SD) of venous peripheral glucose levels and insulin doses for REACTbyALGO1 (n=10, red trajectories and shaded areas) as well as REACTbyALGO2 (n=10, blue trajectories and shaded areas)

The first trial for the BTS GCA (REACTbyALGO1) does not achieve the best scores for “Time in Target Range”, but the least individuals with episodes below 70 mg/dL. As an outcome of the first trial, to improve Time in Target, controller aggressiveness was increased an also adapted to cope with subcutaneous CGM measurements. During the second trial (REACTbyALGO2), time in target was increased significantly despite the challenge of less accurate and delayed subcutaneous measurements. Increased uncertainty in glucose measurements, as well as the increase in controller aggressiveness, however, led to an increase in hypoglycaemic events.

In Figure 30 the g**raphical representation of the key performance indicators of published control trials** (**El-Khatib-1**: El-Khatib et al., Sci Transl Med (2010); **El-Khatib-2**: Russell et al., Diabetes Care (2012)) **and unpublished Data** (**CSII**: standard clinical (non automated) basal-bolus therapy; **Cambridge**: Hovorka et al. (ADICOL04) (2004)) **and the REACTION control trials** (**REACTbyALGO1/2**: the two control-trials using the BTS algorithm developed within REACTION) is shown. Time in Target (left) is defined as Time of measured blood glucose levels within: 70 mg/dl < BG < 140 mg/dl (in fasted state) and 70 mg/dl < BG < 180 mg/dl (for 3h postprandial). Time below 70 mg/dl (right) is defined as Time of measured blood glucose levels BG < 70 mg/dl. Displayed are percentages of measured glucose values in the respective range for overall control performance (top axis) and daytime control (bottom axis).

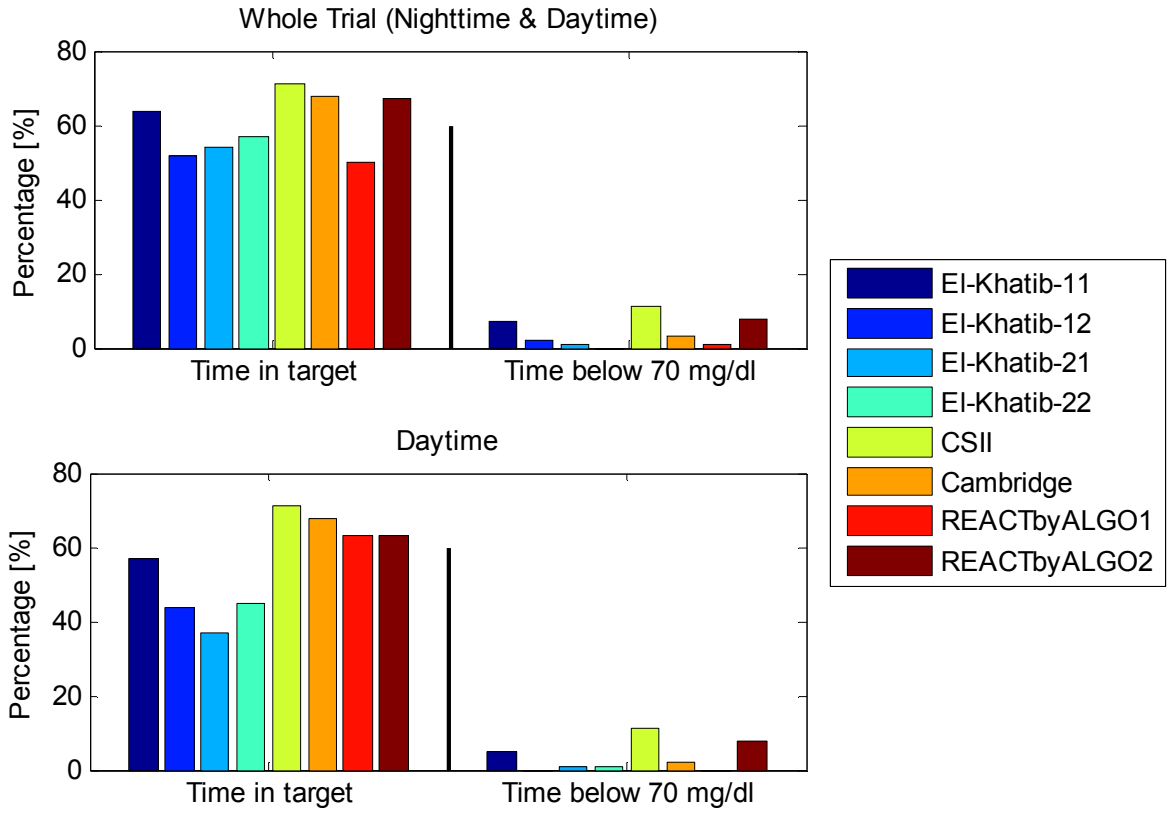


Figure 30: Graphical representation of the key performance indicators of published control trials, unpublished data and the REACTION control trials

A detailed description of the validation results can be found in deliverable “D3-12 Evaluation of integrated systems with best out of prospective evaluation of 2 top-ranked algorithms”.

6.3.1.4 Results on Roche Insulin Pumps Verification

For the AGC purposes, in September 2013 IMM received a number of AccuCheck Combo insulin pumps (Figure 31) together with the necessary software for driving them.

Figure 31: Roche AccuCheck Spirit Combo insulin pump, together with the AccuCheck Aviva glucometer.

IMM implemented a LabView based code (NI Labview 2012), allowing for control of the AccuCheck Spirit insulin pumps via the dynamic libraries provided by Roche.

In this way PC-based control of the major pump data and automatic delivery of boluses was achieved, a picture of the test setup is given in Figure 32. The procedure for pump connection and control is as follows:

- Insertion of batteries into pumpe
- In menu of pump under Bluetooth-settings selection of parameter ”Gerät hinzufügen Verb. Starten”
- Press button “pair” in Control-Programme (Figure 33, left)
- Wait till devices (pump and PC) have connected
- Enter PIN code (Figure 33, middle)
- After successful connection wait, till display of pump switches off
- By setting the bolus amount and subsequent pressing of the button “Deliver Bolus”, a bolus can be delivered to the pump

The bolus can also be set and delivered via a separate software connected to the IMM sensor (also via Bluetooth) and additionally the actual date and time of the pump can be read via the “get date/time” command.

Figure 32: IMM test setup for automatic insulin pump control via PC and Bluetooth communication

Figure 33: Screen surface shots of the IMM insulin pump control software

For the AGC demonstrator the software was modified, so that a file (bolus.txt) generated by the BTS algorithm software could be read automatically and the latest value in the file could be delivered to the insulin pump automatically (Figure 34).

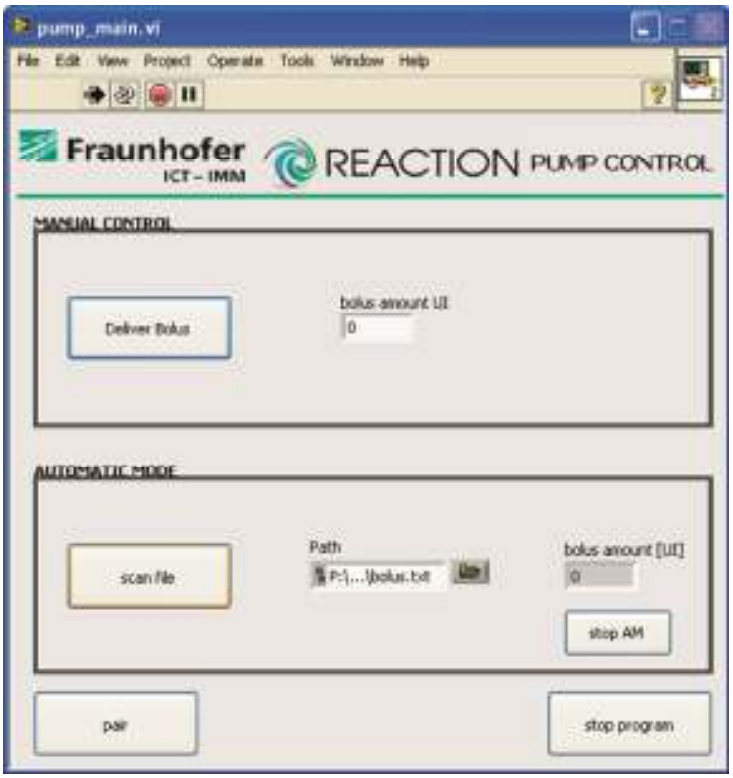


Figure 34: Graphical user interface of the automatic pump control via data, as delivered by the BTS algorithm

6.3.2 System Test Report

Since the AGC algorithm from BTS is built within a graphical user interface which was developed within Matlab® and the AGC is accessing model kernels which have been developed with the Computational Systems Biology Software Suite from BTS through Matlab interfaces, which are provided with the software suite and both requiring adequate computational power, it was not possible to operate the BTS algorithm on a mobile device. It was therefore decided to demonstrate an automatic glucose control platform on a PC based setup, the schematic of which is shown in Figure 35.

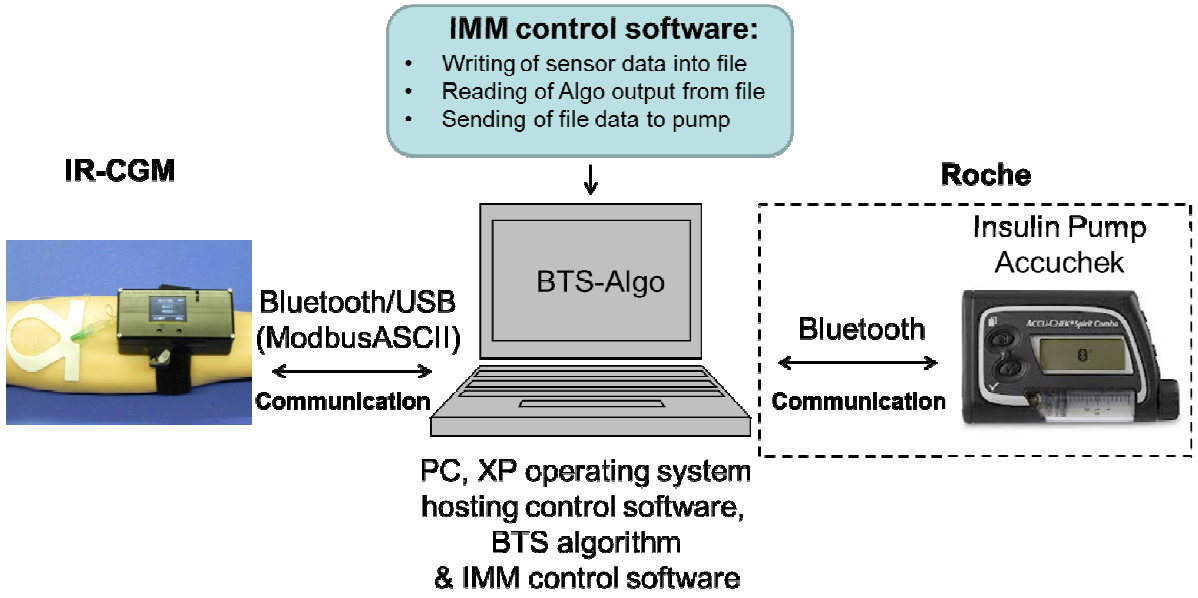


Figure 35: Schematic of the REACTION AGC setup.

As a basis for the AGC demonstrator a PC with a Windows XP operating system (OS) was used. The Windows XP operating system was required for external pump control of the Roche AccuCheck Spirit pumps, since the Roche source code was referred to this system. On the PC the Matlab-based BTS algorithm together with the BTS software tools PK-Sim® and MoBi® were operated. The BTS algorithm was modified in a way that sensor data from a file could be read and bolus shot data could be written to another file every 15 minutes (same time intervals, as used during the clinical trial REACTbyALGO2). The IMM control software reads out the IMM IR CGM sensor data and writes a glucose concentration value into a file every 15 minutes. The BTS algorithm reads out that file every 15 minutes to calculate an insulin bolus value which is written in another file that is read out by the IMM control software every 15 minutes. The calculated bolus value can then be delivered to the insulin pump automatically.

For control of an external CGM sensor (IMM IR CGM sensor for demonstration purposes), an external insulin pump (Roche AccuCheck Spirit) and the data generated by the BTS glucose control algorithm, a LabView-based software has been written, to be operated on a PC with Windows XP operating system (Figure 36). The Windows XP operating system was mandatory for operation of the Roche insulin pump, since the DLL files delivered by Roche were programmed for Windows XP.

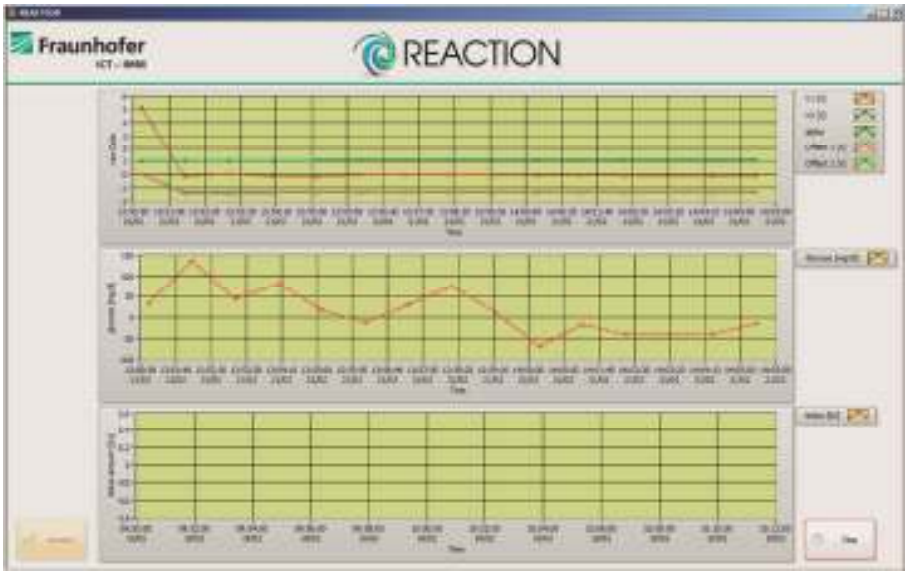


Figure 36: Graphical user interface of the IMM AGC control software, displaying the raw data of the IMM IR CGM sensor (top), the glucose concentration in mg/dl as calculated from the raw data (middle) and the bolus shots delivered to the pump (bottom), each as a function of time

The IMM IR CGM sensor which communicates wirelessly with a PC via Bluetooth, was not been able to be operated with a Windows XP operating system, since the Bluetooth module integrated within the IMM sensor did not work properly with the Windows XP operating system. Therefore a two-PC-system with connection to a central server has been realized for communication between the BTS algorithm and the IMM control software. The BTS algorithm in combination with the Computational Systems Biology Software Suite and the pump control software was operated on the XP-based PC. The IMM control software, reading the IMM sensor data was operated on a Windows7-based PC. The sensor data is written into a text file (CGMdata.txt) every 15 minutes and the file is stored on the central server drive for read out by the BTS algorithm software. The typical processing time of the BTS algorithm is much smaller than 15 minutes, allowing for non-time critical generation of a bolus value by the BTS algorithm which is in turn is written into a text file (bolus.txt), stored on the central server drive again. The bolus.txt file is addressed by the insulin pump control software which delivers the latest bolus value in the bolus.txt file to the insulin pump. The pump control software is connected to the closed loop control software, delivering the bolus value and time stamp for graphical representation on the graphical user interface of the closed loop control software. All values generated, the sensor raw data, the calculated glucose concentration as well as the bolus shots are stored in a separate file as a function of time.

For AGC demonstration and test purposes, a laboratory setup was made, consisting of two PC´s, the IMM IR CGM sensor and the Roche AccuCheck Spirit insulin pump (Figure 37). The first PC was operated with a Windows XP operating system, hosting the BTS Computational Systems Biology Software Suite and the IMM pump control software. The AccuCheck Spirit insulin pump was connected via Bluetooth to the Windows XP-based PC. The second PC was operated with a Windows7 operating system, hosting the IMM sensor and closed loop control software. The IMM IR CGM sensor was connected via Bluetooth to the Windows7-based PC. Both PC´s were connected to a central server disk, hosting the CGMdata.txt and the bolus.txt files.

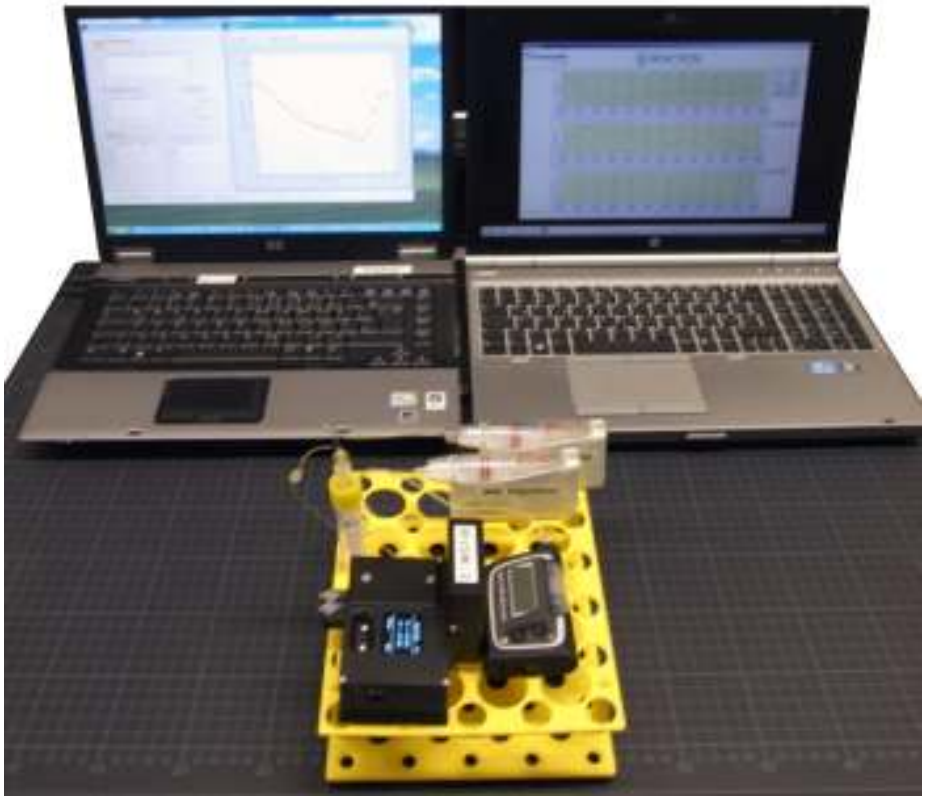


Figure 37: Laboratory test setup of the AGC demonstrator at IMM

Before operating the complete system with the BTS algorithm, the basic functions were tested with a dummy-algorithm, creating a bolus value every 15 minutes into the bolus.txt file, and, sensor dummy

data written every 15 minutes into the CGMdata.txt file. By this it was verified that the closed loop control software operates adequately and file management via the central server was correct.

In a second step the system was tested in-vitro together with the BTS algorithm and Computational Systems Biology Software Suite, by connecting the IMM IR CGM sensor to an aqueous glucose solution vial of constant concentration via a microdialysis catheter CMA63 and additionally connecting the pump catheter. After a defined time interval the concentration in the vial was changed by a considerable amount to force the algorithm to calculate a bolus shot. This bolus value was successfully stored in the bolus.txt file and submitted to the pump, demonstrating that the system is working properly.

For time constraint reasons, caused by late availability of the Roche pumps as well as availability of accurate sensors from the REACTION project, it was not possible to test the closed loop system within clinical trials within REACTION. Therefore the BTS algorithm was tested with commercial Dexcom G4 platinum sensors as well as Roche AccuCheck Spirit pumps, both used with manual entry of the sensor data into the algorithm and bolus shot data into the pump.

7 Results of User Validation Activities

7.1 Summary of User Needs and Preferences

User needs and preferences were collected in specific workshops and focus groups in the initial phase of the project and then re-assessed at each iteration based on the feedback from the validation of the intermediate prototypes. All stakeholders were considered in the analysis, including technical people that had to run and maintain the REACTION platform services.

The needs of users were summarized as requirements represented according to the Volere template and managed using the JIRA issue manager. The complete list of the effective REACTION requirements is reported in Appendix 3.

Of course user needs are not fixed in the sense that precise requirements, constraints, and preferences are maintained under all conditions, but there is a certain amount of "elasticity" such that one attribute may be traded for another attribute.

At each iteration it was ensured that the people who lead the evaluation had sufficient skills and experience in the methods used. When necessary some outside expertise was brought or the scope of the validation enlarged.

Users who have some experience with a service are quite capable to answer questions, which allow the analysis of the user preferences in terms of trade-offs. A meaningful (quantitative) analysis demanded that a substantial amount of data was systematically available, and was outside the scope of the project. But interview and rating techniques allowed the collection of data, which gave an indication of the trade-offs which users consider when selecting services or products for use and purchase.

The results may allow estimates of the value of adding specific quality features to the services, and may indicate which main quality features users would like to see integrated into application packages.

The user validation report contains a description of the experience with the use of the platform at the clinical site, report the results of the usability test, the clinical workflow validation and the performance evaluation. Specific problems, inconsistencies or bugs at any level have been reported in order to be properly addressed in next releases and also new functionalities addressing specific user needs not yet included in the current requirement specifications may be reported.

7.2 Validation Reports

7.2.1 In-Hospital User Validation Report – Results

For user validation of the in-hospital application (GlucoTab) please refer to section 8.1.5.

7.2.2 Primary Care User Validation Report – Results

There are a number of components that were specifically validated with real users in the primary care clinical site. These are described below.

7.2.2.1 Results of Long Term Risk Assessment Component User Validation

In the period February – August 2013 Chorleywood personnel has extracted clinical information from the Electronic Health Record of the Chorleywood Medical Centre. The final dataset is composed of the clinical, anonymized profiles of 24 type I diabetes and 25 type II diabetes patients. For each subject clinical data from a randomly chosen past visit were extracted, as well as the information regarding whether each subject experienced any of the complications/adverse events modelled by the LTRA component.

The patients' profiles were then submitted to the LTRA models in order to be evaluated, and the provided evaluations were compared against the time of the known event. The concordance between the predictions and the actual events was assessed through the Concordance Index, i.e., a statistical metric that measures the probability for two randomly chosen subjects of being correctly ranked according to their respective risks.

The validation results now follow:

1) On the 24 type I diabetes patients, 5 predictive models out of seven (Adverse Cardiac Event, Hypoglycaemia, Ketoacidosis, Neuropathy and Retinopathy) reached predictive performances similar to the ones obtained on the original DCCT data. The other two models did not have enough cases in order to provide meaningful results.
2) For the 25 type II diabetes patients, 3 predictive models out of seven (Adverse Cardiac Event, Microalbuminuria and Neuropathy) performed well on the new data. The Ketoacidosis model was not applicable on Type II patients, while for the models related to Hypoglycaemia and Proteinuria we did not have enough cases for the evaluation of the performances. The Retinopathy model provided results close to random guessing.

The validation results have been summarized in Table 14 below. From left to right, the results are reported for the DCCT data (nested cross validated expected results), the Type I validation cohort (test set with 24 patients) and the Type II validation cohort (test set with 25 patients). The Concordance Index (CI) measures the probability of correctly ranking two randomly chosen subjects according to their respective risks of developing/experiencing a given complication or adverse event. For each value of CI, a p-value referring to the null-hypothesis: "the CI is statistically indistinguishable from random predictions" is presented as well. For all the models with a sufficiently low p-value (i.e., under 0.1) it is possible to reject the hypothesis that the model provides a random rank of the patients in terms of risks.

	DCCT sample	Type I validation cohort		Type II validation cohort	
Model	**Concordance Index**	**Concordance Index**	**p-value**	**Concordance Index**	**p-value**
Adverse Cardiac Event	0.7257	0.7759	0.0469	0.863	0.0076
Hypoglycemia	0.6694	0.6078	0.2471	-	-
Ketoacidosis	0.6745	0.8824	0.024	-	-
Microalbuminuria	0.7421	-	-	0.7288	0.0941
Proteinuria	0.833	-	-	-	-
Neuropathy	0.6661	0.8	0.0588	0.7442	0.0585
Retinopathy	0.6573	0.6635	0.0648	0.4911	0.5413

Table 14: Performances of the long term risk assessment models

Two important concepts should be underlined here:

1. The statistical models are equally predictive when transferred from a US populations (DCCT data, collected in the 90's) to a nowadays UK population.
2. The models adequately predict occurrence of Adverse Cardiac Events, Microalbuminuria and Neuropathy complications in Type II diabetes patients, despite the fact that the training sample (the DCCT data) was composed by Type I diabetes subjects.

Both point 1 and point 2 suggest that the models seem to be applicable in the context of the clinical practice of a UK medical centre, for both type I and II diabetes patients.

7.2.2.2 Results of ePatch Product Validation

The validation of the ePatch product was made in two steps. First was made the formal validation plan to fulfil the regulatory requirements to achieve the CE-mark of the ePatch for ambulatory monitoring (AMORS). Below is listed the tests performed with successful results:

- ***Clinical Evaluation***

  AMORS has a clinical evaluation report in accordance to the requirements of Annex X of the Medical Devices Directive 93/42/EEC as amended and the guidance provided by the document MEEDEV.2.7.1 Rev .3.

- ***Critical Evaluation of Scientific Literature***

  AMORS has a literature review report that is part of the clinical evaluation report.

- ***Post Market Surveillance Activities***

  The Post Market Surveillance Procedure that is part of the quality management system describes the Post Market Surveillance activities.

In the second step of the validation a clinical pilot study was made to further validate the performance of the ePatch. The clinical usefulness was investigated at two levels in this pilot study: The first level uses a procedure that mimics the well-known Holter analysis, and the second level is a high level comparison of clinically relevant information from simultaneously well-known telemetry and ePatch monitoring on patients in a cardiac ward.

For the first part, an experienced nurse extracted 200 noise-free ECG segments from 25 patients. These ECG segments were evaluated according to their usefulness for heart rhythm analysis by two medical doctors. They found 98.5 % and 99.5 % of the segments useful, respectively.

For the second part, 11 24-hours ePatch recordings were compared to available information from the regular telemetry system. This comparison was conducted by a cardiologist. No clinically relevant differences were found in any of the recordings.

These results clearly indicate the clinical usefulness of ECG recorded on the sternum with an ePatch as input to diagnosis of cardiovascular diseases. A preliminary version of this paper was presented at CARDIOTECHNIX 2013.

7.2.2.3 Results of Devices, Gateway and Clinical Portal User Validation

The phases of Figure 20 related to the validation with users are reported here below.

7.2.2.3.1 Friends and Family (F&F) Testing

Release candidate versions of software were installed on devices and kits were given to selected members of the team at Chorleywood for systematic testing at home. These members should not be involved in development and have no detailed technical skills. The criterion for successful F&F testing was no error for 7 days of use. Any error would require restarting the F&F test period. Several cycles of F&F testing were required before having satisfactory results and thus producing the final release of the software.

This phase also allowed staff at Chorleywood Health Centre to become familiar with use of the platform.

7.2.2.3.2 Patient Testing

The previous final release version of the software was given to a small number of patients for testing for a short period to test for software errors and ergonomic design of the devices. Useful retrofits were collected that helped in the production of the release deployed for the field trials. For example, the A&D blood pressure meter was modified to include an LED to give positive indication that data had been sent to the gateway.

7.2.2.3.3 Patient Deployment

Practical issues with deploying to patients were noted and changes made to software and devices as appropriate. Main problems related to pairing devices with gateway. To simplify procedures, all initialisation and replacement of kit was performed by the team at UBRUN.

7.2.2.3.4 Fault Reporting

All faults were reported to the team at UBRUN using email. Most reported faults were resolved by returning kit to UBRUN.

7.2.2.3.5 Maintenance

Software for the devices and gateways was maintained by UBRUN. Devices and gateway were deployed with V1.8 of the software in December 2011 for the primary care pilot.

7.2.2.3.6 Evaluation

User evaluation is reported separately. Evaluation was used to help define requirements and specification for the second iteration of the devices and gateway for the primary care pilot.

7.2.2.4 Platform Monitoring

Several monitoring tools were deployed to monitor performance and to assist in fault diagnosis. This included PingAssist. This tool can be configured to send periodic ping requests to configured devices. The tool was set to send a ping to each REACTION gateway every 10 minutes. An example of the status of all devices is shown in the summary page (Figure 38).

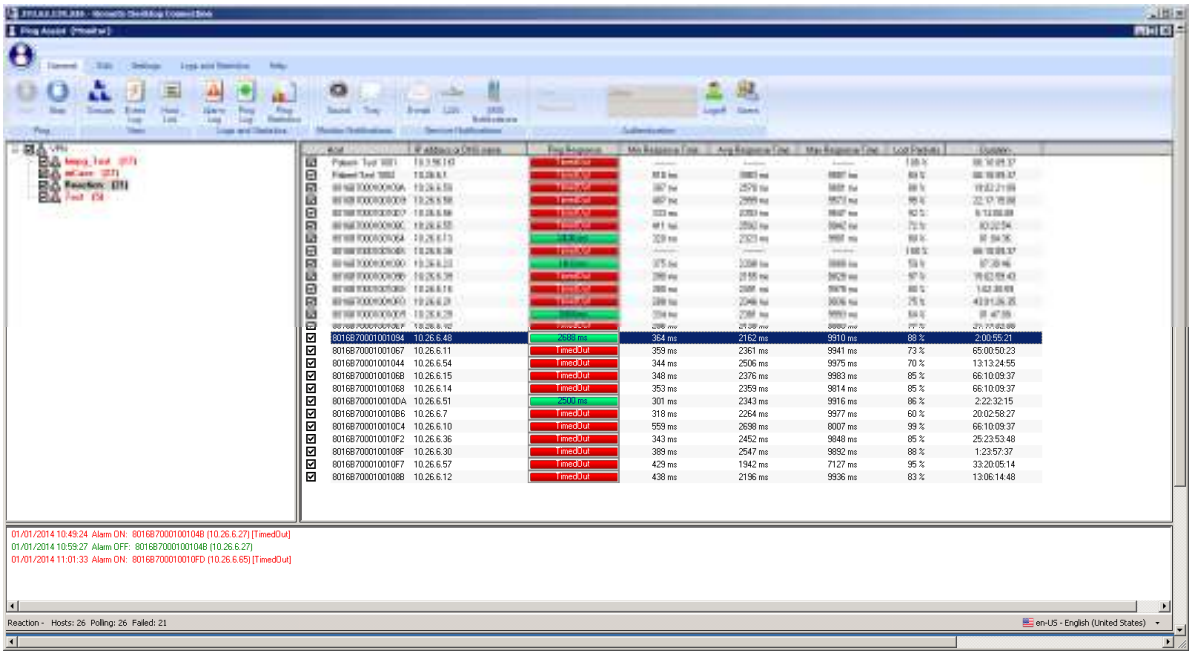


Figure 38: PingAssist status summary

Status of a device over a 24 hour period may be viewed as in Figure 39. Here a device is seen to lose connectivity abruptly, which is not restored for several days over the holiday period.

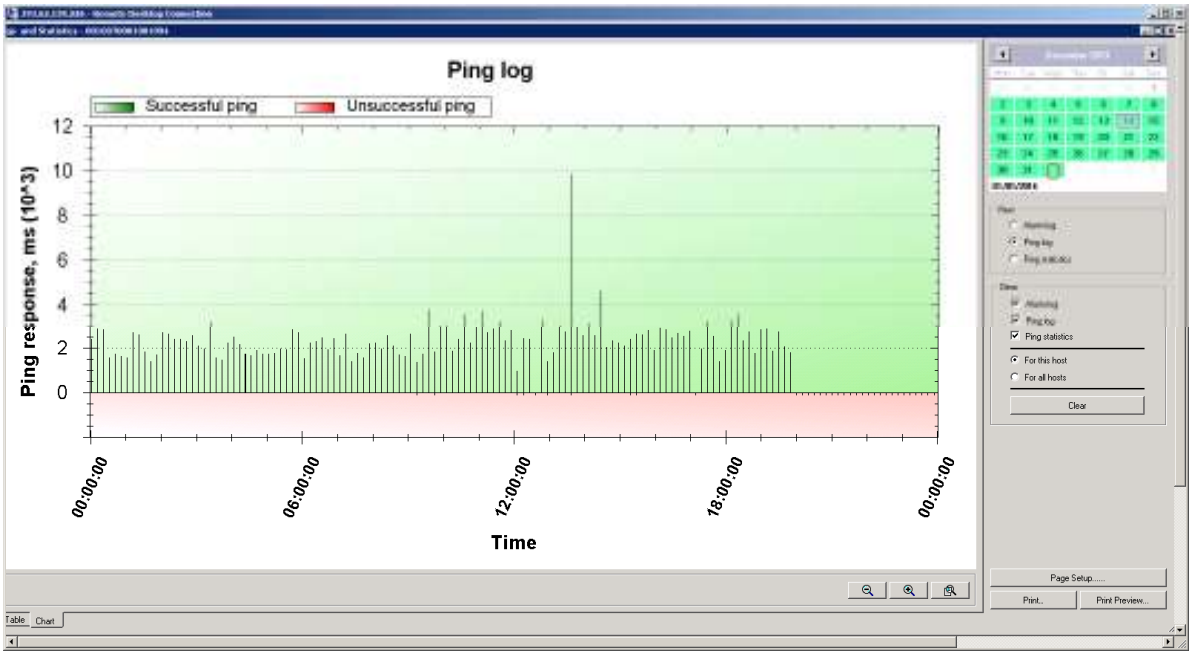


Figure 39: PingAssist device status

7.2.2.5 Devices External Test Report

All devices have been independently tested for conformance with respective the IEEE 11073-104xx specialisation and the ZigBee Health Care Profile.

The seven ZigBee devices were submitted to AT4Wireless (Malaga, Spain) testing laboratories in December 2011. All tests were completed according to the submitted electronic conformance statements and published testing procedures for Continua Alliance certified LAN/PAN products.

The seven ZigBee devices were submitted to TRAC (Hull, UK) testing laboratories in January 2012. All tests were completed according to the submitted conformance statements and published testing procedures for ZigBee Alliance certified ZigBee Health Care Profile (ZHCP) products.

Conformance certificates from independent testing laboratories are attached in Appendix 2.

7.2.2.6 Platform Issues

Several issues were identified and resolved.

A critical error has been identified in Atmel BitCloud, used in the ZigBee gateway that cause software to freeze through missing events. However this fault occurred rarely in patient use and it has been decided that devices would not be upgraded.

Several glucose docking stations were returned due to cable wires being broken inside the case. The docking station has since been completely redesigned as a cradle.

An issue occurs when observations are sent by the gateway and received by the server but the acknowledgement sent by the server is not received by the gateway. This occurs in low signal conditions. The observation will be resent until an acknowledgement is received however this results in duplicate observations being received in the server. The server was modified to filter out such duplicate observations.

The glucose docking station stored the date of the last sent reading, thereby preventing all readings stored in the glucose meter from being sent every time the glucose meter was docked. However, if the glucose docking station was reset, all stored readings would again be sent. A simple cable and PC program was developed to delete all readings from a meter each time it was sent to a new patient.

7.2.2.7 Platform Evolution and Iteration

The platform was deployed to patients in December 2011 and devices and gateway have remained unchanged. Development of server and applications continues as these require no deployment. We recognise that functionality was limited in order to allow us to freeze software and undertake rigorous testing. Since that time we have taken feedback, undertaken evaluation and defined new functionality to assist management and monitoring status.

New functionality for V1.9 includes:

- ARM core processor.
- Increased memory to accept more concurrent devices.
- LNA to increase TX power and improve RX performance.
- Over the Air Update (OTAU).
- ZigBee commissioning cluster to allow reset at base.
- Implement commissioning extended PAN to allow reset of devices at base.
- Gateway back channel based on object models.
- Purpose designed boards for devices.
- Glucose docking station.

7.3 Performance Evaluation

This section provides a quantitative analysis and evaluation of the usability and technical performance of the REACTION Multi-Protocol Home Gateway developed with the REACTION SDK (Software Development Kit). The data was collected by IN-JET in a trial outside the REACTION project, but has been analysed and reported in the project, because the data provide valuable, quantified evaluation results related to the usability and performance of important REACTION components, which could not be obtained from the project's own field trials.

7.3.1 Background of the Evaluation

As part of its business strategy, IN-JET derives innovative results from research projects and applies them to develop successful commercial products. Since 2012 IN-JET has marketed a telemedicine platform frontend called LinkWatch. The frontend provides a patient communication interface and capabilities for data collection from medical devices. The frontend is marketed for healthcare management in cooperation with major players like IBM. Scandinavia is in a very advanced stage of eHealth with many services in place. IN-JET and CNET have thus entered into a strategic cooperation with the aim to develop and market a common telemedicine platform in the Danish and Swedish markets. The two partners have also cooperated to provide the frontend for the clinical trial that has provided data for the present evaluation.

The frontend in LinkWatch is based on the REACTION Multi-Protocol Gateway and a frontend application developed with the REACTION SDK.

7.3.2 The Clinical Trial

In 2012, IN-JET was invited to participate with a LinkWatch patient frontend in a 3-year randomised controlled trial (RCT) under the Capital Region of Denmark, the regional healthcare provider for Copenhagen and North Zealand. The project finished in December 2013 and a massive amount of usage data has been collected from this project, allowing for a comprehensive analysis of usage and performance of the REACTION components over a period of two and a half years.

Three Chronic Heart Failure (CHF) Outpatient Clinics in the region cooperated with private commercial partners to establish and evaluate the use of telemedicine. The project focused on the clinical and organisational effects including cooperation with general practitioners and local government for outpatient treatment.

The clinical trial project aimed to verify the clinical use of telemedicine in the up-titration of patients with newly diagnosed CHF. Because of the side effects of CHF drugs, patients are called in for medical checks in the Outpatient Clinic every few weeks over several months with the aim of fine-tuning their medication. This process is very time consuming; both for patients and the clinical staff. With a telemonitoring platform, the patients were able to make simple measurements, such as weight, pulse and blood pressure, in the home and exchange data and communicate with the staff at the Outpatient Clinic

A total of 60 CHF patients were selected to participate in the trial with the following conditions:

- Inclusion criteria: 1) Newly diagnosed CHF, 2) basic ICT skills, 3) accept
- Exclusion criteria: 1) Atrium fibrillation, 2) NYHA class IV[1], 3) Frailty
- Opting-out criteria: 1) at wish, 2) anxiety with the technology, 3) negative effects on the communication between patient and clinical staff.

All patients were newly diagnosed with CHF, and many had diabetes, COPD and other chronic conditions. The randomisation allocation was 1:1.

The REACTION Multi-Protocol Home Gateway and SDK components were deployed on All-In-One Touch Screen PCs, both in the Outpatient Clinics and at home with the patients (Figure 40). The patients were asked to measure pulse, blood pressure and weight every day. The patient verified and approved the measurements before they were transmitted to a backend hospital system using a user-friendly

Figure 40: User interface for the home monitoring application

[1] New York Heart Association Classification IV: Severe patients

patient application with audio feedback and video conferencing capability.

7.3.3 Project Statistics

The REACTION SDK components on the patient frontend perform comprehensive logging of user activity and performance of the software (human activity at the screen, reception of data from devices, transmission of data to the backend server) as well as comprehensive software logging of exeptions and errors. No patient identifiable health data are logged.

The data foundation consists of data from 31 patients using the frontend telemonitoring platform between 26 June 2012 and 2 January 2014 – a total of 2 years and 6 months.

The total number of sessions (periods where the patient is using the monitoring equipment) was 3.318 resulting in 5.361 measurements being transmitted to the clinic (Figure 41).

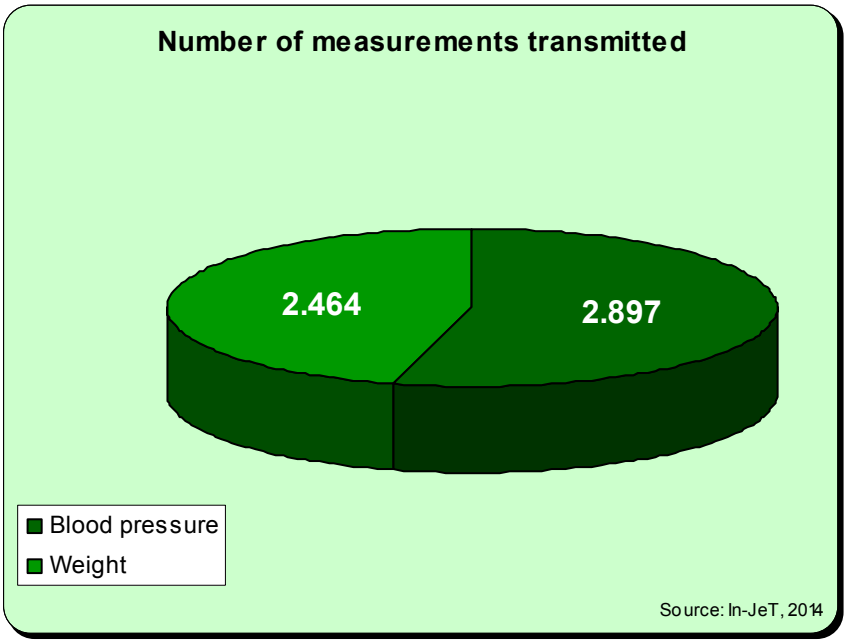


Figure 41: Total number of measurements transmitted to the backend server

7.3.4 Usability Results

A detailed usability and patient acceptance study presently being conducted by the Capital Region of Copenhagen is outside the scope of the REACTION project. However, the quantitative usage pattern reveals significant information about the use of the telemonitoring platform and how the patients have adopted the technology in their daily management of their disease.

The patient performs a measurement by clicking through a series of steps (screens). The first step is to decide which measurement to perform. After the physical measurement has been performed, the next step is to display the measurement on the screen followed by either a rejection or an acceptance of the values. If the measurement is accepted, the software sends the data to the backend server and displays the result to the patient. If the measurement is rejected, the patient reverts to the first screen. The entire procedure, i.e., from first to last click, is logged under one session.

Each patient performed a varying number of sessions during the time they were enrolled in the project. Some patients only made very few (1-5) sessions, because they left the project. Other patients stayed in the project for the entire length. These patients carried out up to 350 sessions. The number of sessions in total per patient is shown in Figure 42.

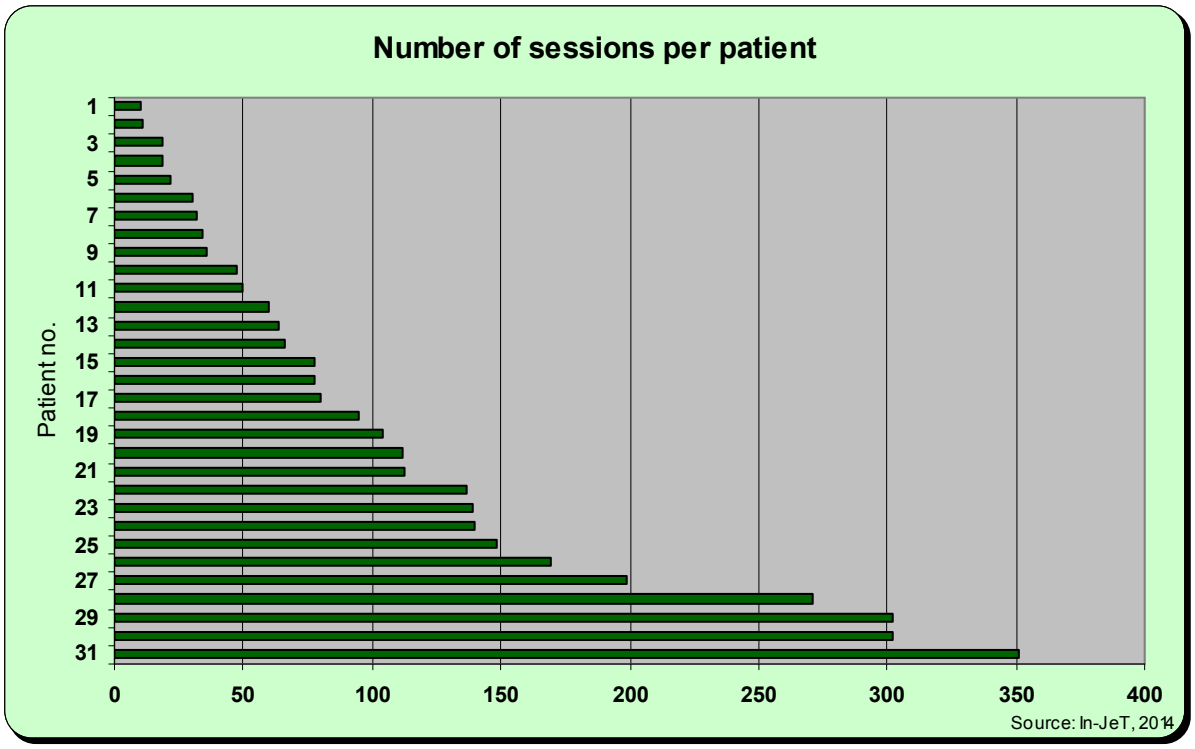


Figure 42: Total number of sessions per patient

The number of sessions is of course related to the length of the monitoring period. A better measure for the workload is thus the number of sessions carried out per week. The data shows that the patients typically made between 2 and 8 sessions per week with the median being 5. It indicates that most of the patients used the monitoring as part of their daily routine.

The enrolment time varied from a few weeks up to typically 16 weeks (Figure 43), at which time the up-titration was completed. Some patients stayed in the project for the entire length, either because their up-titration was slower, because they were reluctant to give back the equipment, or because they were used as reference patients.

The length of the session can be measured as shown in Figure 44. The length of the session indicates how complex the measurement is for the patient; the longer the time it takes, the more pressure it puts on the patient.

As can be seen, the vast majority of the sessions have been completed within 6 minutes, i.e., it took only 6 minutes to measure blood pressure and weight once every day.

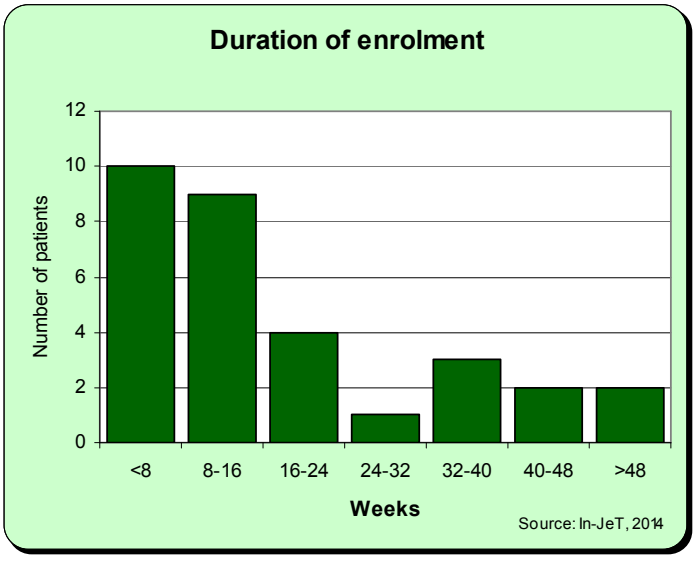


Figure 43: Length of enrolment in project

This is perhaps one reason why the patients consistently carried out their measurements daily.

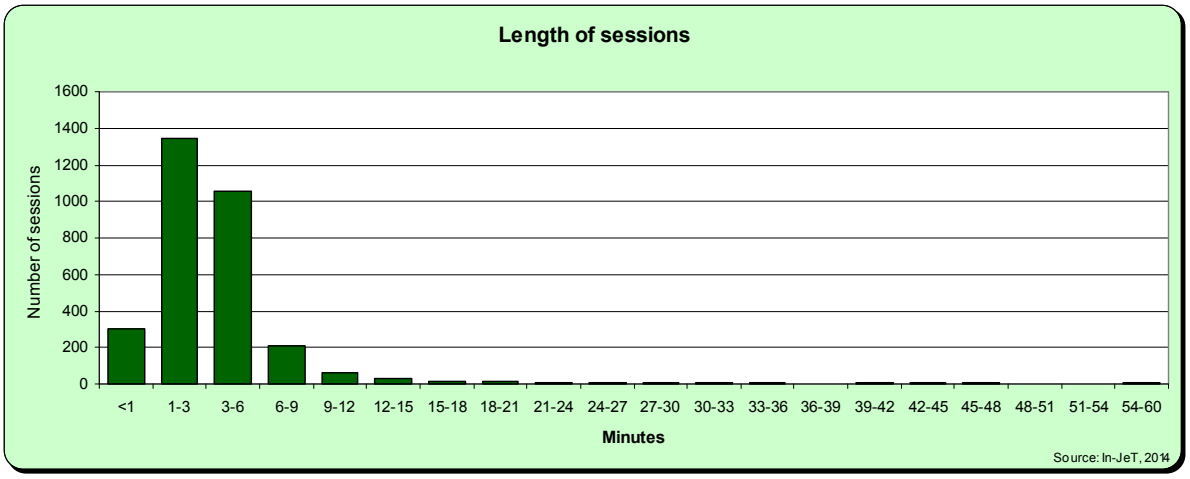


Figure 44: Length of sessions

In the entire trial the total number of steps performed was a stunning 6.568 in a total of 3.318 sessions. The number of steps needed to complete a session indicates how complex the operation has been to carry out.

The minimum number of steps needed to send *two* measurements successfully to the server is 9 including starting and stopping the application. As patients get more used to operating the equipment, they also perform the task more effectively. This is reflected in the total number of steps required in each session over the course of the enrolment as seen in Figure 45.

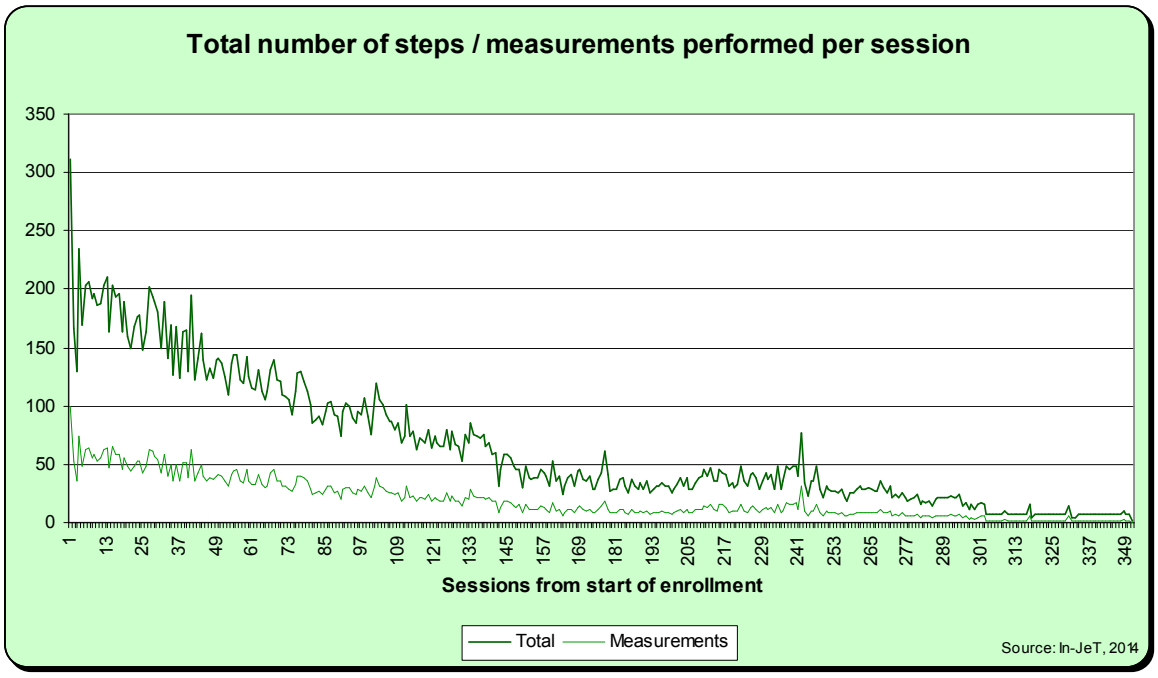


Figure 45: Number of steps per session across the entire enrolment

The initial phase is dominated by the patients' exploration of the system and its features. In the first week or so, most of the patients have navigated heavily around the user applications, partly because they were unfamiliar with the system, and partly because they were curious about what it could do. As time passed, the patients became more and more familiar with the equipment, and the number of steps per session decreased. Also the number of measurements decreased, reflecting that the patients are beginning to see the equipment as a daily tool rather than a new gadget.

A comparison of the number of steps logged in each session with the number of measurements transmitted, shows a remarkably consistent efficiency of 3-4 steps for each measurement on average, which is close to the optimum (Figure 46).

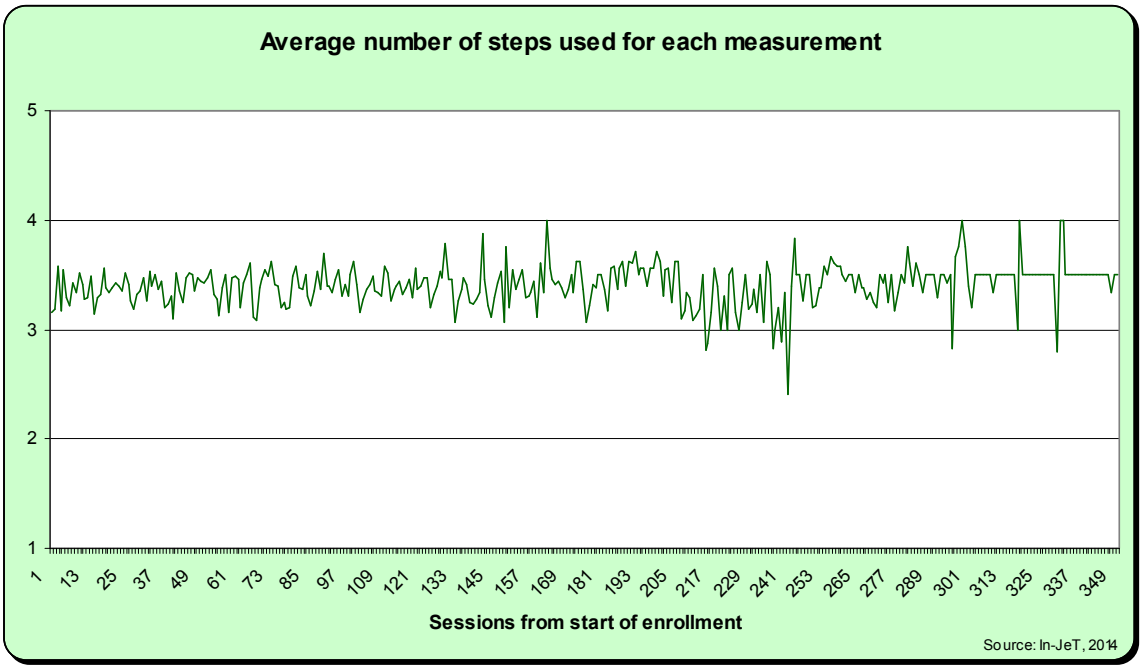


Figure 46: Average number of steps used for each measurement

In conclusion, the data shows that the patients have very easily adopted the new technology and that they relatively quickly could get into the habit of performing daily measurements of both blood pressure and weight. When the initial training period was over, each measurement session lasted for only 5 - 6 minutes: The patients managed to send more than 5,300 measurements to the clinic in the course of the 2½ year period.

7.3.5 Performance Results

The most important quantitative technical performance parameters are reliability and speed. Both parameters can be analysed from the available data.

Logging of abnormal events, transmission failures, software failures, etc. allows for the evaluation the robustness and efficiency of the REACTION SDK run-time environment and the concept of the REACTION Multi-Protocol Home Gateway.

Technically, each transaction was logged, not only transactions initiated by the patient (such as screen navigation) but also transactions internally in the frontend application as well as technical transactions logged in the REACTION SDK run-time environment.

The patient transactions are logged as:

- Perform measure blood pressure activity
- Perform measure weight activity
- Send blood pressure
- Send weight
- Return to previous screen
- Try to send measurement again
- End session

The application transactions are logged as:

- Timeout (error)
- Data sent to server

- Data not sent to the server (error)

The transmission transactions are logged as:

- Acknowledgement received from server
- Error codes for availability of internet connection
- Error codes for configuration of patient data (refused by server)
- Software exceptions

The performance in the process of measuring with the health devices is shown in Figure 47.

Efficiency of measurements performed				
Measurement sequence	Blood Pres.	Weight	Total	%
Initatied by patient	3.710	3.083	6.793	100%
Performed with device	3.067	2.578	5.645	83%
Sendt to server	2.897	2.464	5.361	79%

Figure 47: Number of process to complete and send measurements throughout the enrolment

Patients have started the measurement process 6.793 times in total. But only 83% of the times they continued to perform the physical measurement. The process was thus not completed 1.148 times, the main reason being that patients arrived at the initiation screen by accident or interrupted the process before taking the measurement.

Of the 5.361 measurements that the patients decided to send to the server, only 4.137 measurements were received and acknowledged, corresponding to 77% (Figure 48).

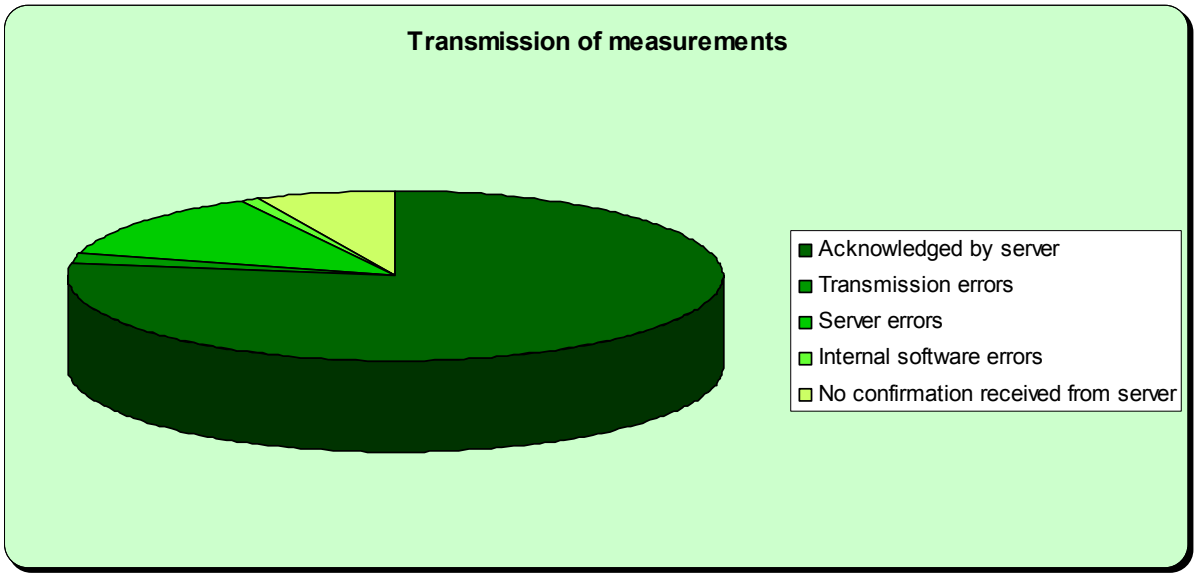


Figure 48: Transmission of measurements results

The remaining 1.124 measurements (23%) were lost due to abortion and various errors in the transmission path. A total of 22% were lost due to errors outside the REACTION SDK environment but only 1% (46 cases) was due to internal software errors. Especially the server solution experienced a great deal of problems during the project.

The gathered data can be used to further analyse the sources of errors in the transmission path.

The most important source of error arises in the transmission between devices and the patient's frontend terminal. This path accounts for 57% of all transmission errors (Figure 49). However, it must

be noted that a significant part of them comes from various malfunctions in the device itself or by the user.

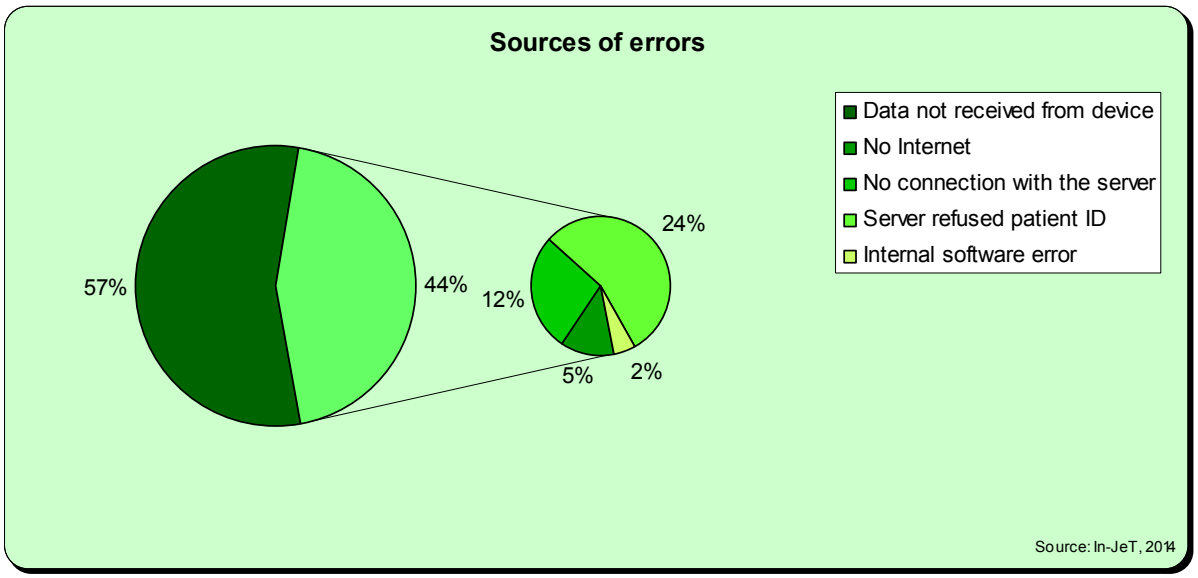


Figure 49: Sources of errors

A further analysis of the remaining errors reveals that unavailability of server services and wrong patient ID setup accounts for 36% while the frontend only accounts for 7%, mainly due to unavailability of internet and a few internal software errors.

Technical performance in terms of speed is related to the time between the patient sending the data to the backend server until the acknowledgement is received and displayed on the screen.

The demand for fast response time for web applications changes over time. In the late 1990'ies, response times of around 10 seconds were perceived by the Internet observer Jakob Nielsen to be a very reasonable requirement[2]. The 10 seconds is generally accepted as being the mental wall for web service response time, since it is the limit of peoples' ability to keep their attention focused while waiting.

In a 2010 update of the same article, Jakob Nielsen assessed that with the present broadband internet access, a 1 second response time is advisable, since it *"keeps the user's flow of thought seamless. Users can sense a delay, and thus know the computer is generating the outcome, but they still feel in control of the overall experience and that they're moving freely rather than waiting on the computer. This degree of responsiveness is needed for good navigation"*.[3]

The response time in the REACTION frontend application is slightly more complex than a website, so longer response times can be expected. The data needs to be transmitted through the REACTION SDK environment, via the Internet to the server and back. The transmission speed of the internet connection is irrelevant due to the low volume transmitted. Instead, the response time is heavily depending on the processing speed of the Gateway and the response time of the web service receiving the data on the server.

Analysis of the data shows that the frontend platform has a low response time with an average of just 7 seconds based on 3,884 transmissions. 73% of all response times were below 9 seconds (Figure 50).

[2] http://www.nngroup.com/articles/the-need-for-speed/
[3] http://www.nngroup.com/articles/website-response-times/

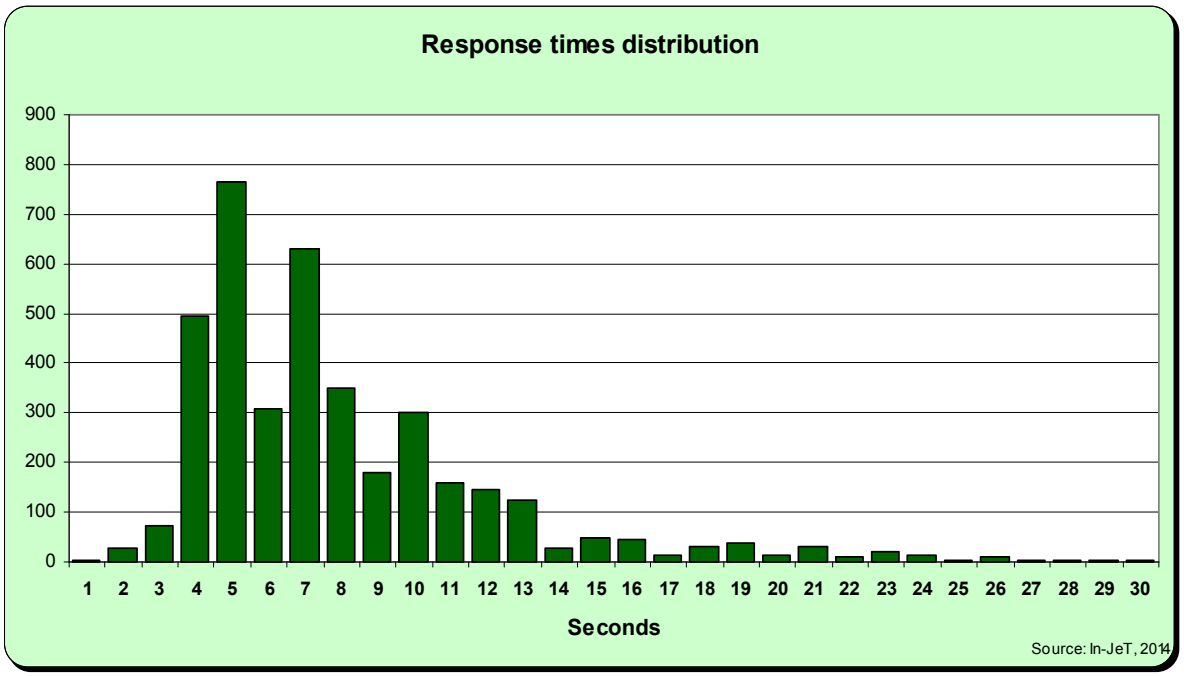


Figure 50: Response times

7.3.6 Overall Results

The external project has provided a unique possibility to evaluate the performance of the REACTION Multi-Protocol Gateway and the REACTION SDK in a real setting. The 2½ year clinical trial has provided data from more than 3.300 patient sessions collecting more than 5.400 health data in their homes and making more than 60.500 transactions on the user interface. The data foundation for a quantitative evaluation is thus much wider than could ever be expected in the REACTION project.

As a whole, the frontend platform has proven to be extraordinarily user friendly and easy to use by the patients. After a very short learning phase the patients quickly got used to making measurements. The analysis shows that patients on average measured their blood pressure and weight more than 5 times per week and that each session could be done in 4-5 steps and took less than 6 minutes.

The patients rapidly reached a high level of proficiency with the equipment which also meant that most of the patients enrolled in the project decided to continue with the measurements for at least the foreseen up-titration period.

In terms of technical performance, the quantitative evaluation shows a high degree of reliability in terms of capture and transmission of data, but the total number of transmitted measurements actually received at the server was only 77% due to a relative large number of aborted measurements and unavailability of the server to receive the data. More qualitative work is needed to investigate why measured data were not sent to the server.

When the data were transmitted through to the server, the patients enjoyed low response times of average 7 seconds from the patient clicked to transmit the date until the acknowledgement was shown in the screen 7 seconds from the patient clicked to transmit the date until the receipt was shown in the screen.

Overall, the quantitative evaluations thus show a high degree of reliability and speed of the technical solution.

8 Results of Field Trial Activities

8.1 Results of In-Hospital Field Trial

After a first phase of analysis of glycaemic management, a total of three clinical trials have been performed in line with the different phases of the GlucoTab development (Figure 51). The first clinical trial (ClinDiab02; Phase II) proofed the safety and effectiveness of the basal/bolus insulin dosing protocol which is an integral part of the GlucoTab system. The ClinDiab02 trial was performed on paper without electronic system. The second (ClinDiab03; Phase III) and the third (ClinDiab04; Phase IV) clinical trial were performed with the GlucoTab system.

Clinical studies for evaluating GlucoTab have been conducted at the clinical partner MUG participating in the REACTION project. User requirements defined by the clinical partners were already implemented into the overall system and safety concept of GlucoTab.

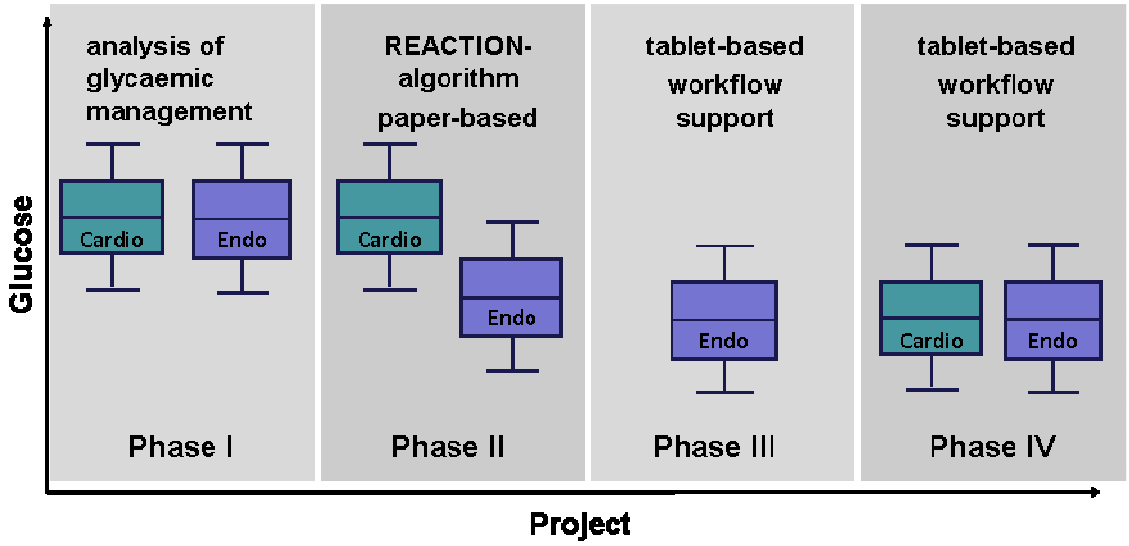


Figure 51: The different phases of the GlucoTab development

8.1.1 Parameters and Results of the In-Hospital Trial

Phase I (ClinDiab-01 study):
Analysis of glycaemic management at two different wards of the University Hospital of Graz (approval by Ethics Committee Graz 21-485 ex 09/10). The survey has shown that hospitalised patients with type 2 diabetes mellitus have a mean blood glucose level above the recommended target range. The analysis of 50 consecutive patients, who were treated with insulin at the general wards of endocrinology and cardiology, revealed a mean blood glucose level of 181 mg/dl. No difference between admission and discharge blood glucose values was observed, indicating an insufficient insulin titration process throughout the hospital stay.

Results: Journal paper (Neubauer et al. 2013)

Phase II (ClinDiab-02 study): Test of the paper based REACTION algorithm in an open, single-centre, controlled trial to investigate the efficacy and usability to control glycaemia in hospitalised patients with type 2 diabetes (approval by Ethics Committee Graz 23-351 ex 10/11). 37 patients at the endocrinology ward (intervention group) and 37 patients at the cardiology ward (control group) of the University Hospital of Graz were included in this trial. It could be shown that the REACTION algorithm titrates the patients safely to the recommended target range.

Results: Journal paper (Mader et al., 2013)

Phase III (ClinDiab-03 study):
The feasibility study of the performance of the electronic tablet-based support system with the implemented REACTION algorithm is subject of Phase III. In this investigation the performance but also the safety and usability of the GlucoTab system was tested.

Results: In this study, a satisfactory blood glucose control could be achieved (mean value of 161 mg/dl in part 1 and 148 mg/dl in part 2; n=15+15). The number of hypoglycaemic events in this study was lower than in clinical practice (1.7% of all measured values) and lower than in a comparable and well performed clinical trial (Umpierrez et al., 2011). A very high adherence to the suggestions of decision support system of over 95% can be noted.

In summary, it can be stated that phase 3 (ClinDiab-03 study) showed that the GlucoTab system was efficient, provided good usability, and was safe for patients. Publication of the results is in preparation and will be submitted to the Journal of the American Medical Informatics Association (http://jamia.bmj.com/).

Phase IV (ClinDiab-04 study):
In this phase the tablet-based workflow and decision support system was transferred to 3 other wards (endocrinology, cardiology, nephrology, plastic surgery) .

Results: The aim of phase IV (ClinDiab-04 study) was to investigate efficacy, safety and usability of the GlucoTab system in more than one clinical ward, involving also surgical departments in addition to departments of internal medicine. The relevance of the study results therefore lies in general information about generalizability and applicability of the GlucoTab system in clinical practice.

The GlucoTab system was able to demonstrate a very high level of adherence with a recommended treatment regimen (again above 95%). The GlucoTab was constantly in use in the clinical routine, blood glucose measurements were entered and insulin injections were performed and confirmed in the GlucoTab. Dose recommendations by the algorithm were well accepted, correction values by the user were small.

Blood glucose control was improved (patient-day weighted mean blood glucose was 151 mg/dl) and the rate of hypoglycaemic events (again 1.7%) was not increased compared to standard care.

There was no increased risk of hypoglycaemia in this study compared to state of the art clinical trials using basal bolus therapy in hospitalised patients with type 2 diabetes. This low risk of hypoglycaemia was achieved, although patients in this trial had a longer duration of diabetes and a higher proportion of patients treated with insulin before hospital admission.

In contrast to the studies by Umpierrez et al., the treatment protocol using the GlucoTab has to be followed very strictly, any deviations from the protocol are recorded. Therefore these GlucoTab results are especially valuable because they give very precise and reliable information on the applicability of the clinical protocol in clinical practice (and its implementation in software). Publication of the results is in preparation.

8.1.2 Stakeholders in the In-Hospital Trial

The main stakeholders of the in-hospital trial are:

- nurses and doctors as end users of the GlucoTab system;
- patients who are treated with the system;
- hospital IT-provider who are responsible for installation and operation of the GlucoTab system within the hospital IT-infrastructure;
- medical department heads who need to identify the benefit of the GlucoTab system;
- board of medical directors who are responsible for acquisition of the GlucoTab solution and
- finally the development partners of the GlucoTab who are interested in the safety, efficacy and feasibility of the system.

8.1.3 In-Hospital Metrics for User Satisfaction

Please refer to section 8.1.5 for details.

8.1.4 Safety and Performance Tests

Please refer to section 8.1.1 and 8.1.5 for details.

8.1.5 User Acceptance and Usability Tests

Table 15 presents the results of the user acceptance and usability testing. The tests have been performed in the clinical trial ClinDiab04 with 11 end users (doctors and nurses) who actively participated in the clinical trial. Results show that not all tests were performed successfully. Therefore a separate risk assessment for the failed test cases has been performed. The results of this assessment are presented in Table 16. Overall, the tests are satisfying but also room of improvement can be stated for the next development steps and clinical testing.

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC1_01	UC1	Starting the GlucoTab application	Button for starting the application must be clearly presented	100% of users know to how to start the GlucoTab application	Usability test	45% 5/11 passed	NO
TC_UC2_02	UC2	Login into application	Login button must be clearly presented and large enough for correct clicking	100% of users know how to login into the application	Usability test	100% 11/11 passed	YES
TC_UC3_03	UC3	Logout from application	Logout button must be clearly presented and large enough for correct clicking	100% of users know how to logout from the system	Usability test	100% 11/11 passed	YES
TC_UC4_04	UC4	View open tasks	Symbol for BG measurement should be clearly presented in the open task list	90% of users know where to find the BG measurement symbol in the task list	Usability test	100% 11/11 passed	YES
TC_UC4_05	UC4	View open tasks	Scrollable toolbar should be indicated for users	90% of users are able to scroll the task list	Usability test	100% 11/11 passed	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC4_06	UC4	View open tasks	Symbol for insulin administration should be clearly presented in the open task list	10/10 users know where to find the insulin administration symbol in the task list	Usability test	91% 10/11 passed	NO
TC_UC4_07	UC4	View open tasks	Symbol for daily dose adjustment should be clearly presented in the open task list	100% users (only physicians) know where to find the insulin administration symbol in the task list	Usability test	100% 3/3 passed (only physicians) (acceptance criteria should point to daily dose adjustment task symbol)	YES
TC_UC5_08	UC5	View patient list	Patients should be clearly presented in the patient list	100% of users know where to find patients of the ward on the user interface	Usability test	100% 11/11 passed	YES
TC_UC5_09	UC5	View patient list	Patient details should be unambiguously in the patient list	interchanged patients in relation to all treated patients should be < 5%	Clinical Trial	2,5% 2/80 interchanged Deviation documented in: FB13_053	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC5_10	UC5	View patient list	Patient should be identified unambiguously even if room and bed number is wrong	interchanged patients in relation to all treated patients should be < 5%	Clinical Trial	2,5% 2/80 interchanged Deviation documented in: FB13_053	YES
TC_UC6_11	UC6	View list of enrolled patients	Patients who are enrolled for glucose management must be identifiable	100% of the users must know where to find enrolled patients in the user interface	Usability test	100% 11/11 passed	YES
TC_UC7_12	UC7	View patient details (course of therapy)	Patient details in the course of therapy tab should be clearly presented	interchanged patients in relation to all treated patients should be < 5%	Clinical Trial	2,5% 2/80 interchanged Deviation documented in: FB13_053	YES
TC_UC7_13	UC7	View patient details (course of therapy)	The amount of insulin dosage in the insulin profile has to be clearly and unambiguously presented to the user	100% of the users recognize the insulin dosage correctly in the glucose profile	Usability test	91% 10/11 passed	NO

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC7_14	UC7	View patient details (course of therapy)	BG profile should be clearly presented to the user	90% of the users can correctly explain the BG profile	Usability test	100% 11/11 passed	YES
TC_UC7_15	UC7	View patient details (course of therapy)	Actions presented in the therapy table should be clear for users	90% of the users can correctly explain the table with the therapy profile	Usability test	91% 10/11 passed	YES
TC_UC8_16	UC8	Add open BG-measurement task	The sequence of actions for adding a new BG measurement should be clear. It should be also clear for which patient the task will be created. Execution time should be set intuitively.	80% of the users should be able to correctly add a BG task	Usability test	9% 1/11 passed	NO
TC_UC9_17	UC9	Enrol patient (start Glucose Management)	The sequence of actions to enrol a new patient should be clear. System feedback for correct but also for wrong actions should be available.	The rate of unsuccessful patient enrolment should be < 5 %	Clinical Trial	0% Nu such documented event	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC10_18	UC10	Update enrolment	The update enrolment function should be found and executed easily by the users	80% of users should be able to find the update enrolment function. They should correctly explain the parameters to be updated.	Usability test	27% 3/11 passed	NO
TC_UC11_19	UC11	Stop enrolment (patient withdrawal)	The stop enrolment function should be found and executed easily by the user	The rate of unsuccessful patient enrolment should be < 5 %	Clinical Trial	0% Nu such documented event	YES
TC_UC12_20	UC12	Adjust therapy settings	The insulin type has to be clearly presented in the therapy settings.	90 % of the users should be able to correctly identify the currently approved insulin types	Usability test	100% 11/11 passed	YES
TC_UC12_21	UC12	Adjust therapy settings	The date of last daily dose adjustment has to be clearly presented	80 % of the users should be able to correctly identify the currently approved insulin types	Usability test	67% 2/3 passed (only physicians)	NO

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC13_22	UC13	Adjust Hypo-/Hyperglycaemia borders	Users know where Hyper/Hyper borders are presented (adjustment can only be performed by an administrator)	80 % of the users should be able to correctly identify the Hyper/Hypo borders	Usability test	100% 11/11 passed	YES
TC_UC14_23	UC14	Adjust target ranges in Basal/Bolus regimen	Users know where target ranges are presented (adjustment can only be performed in the free therapy)	80 % of the users should be able to correctly identify the target ranges	Usability test	100% 11/11 passed	YES
TC_UC15_24	UC15	Initialize Basal/Bolus Therapy	Entering of clinical parameters should be clearly presented. Impossible values should be checked and messages should be presented. Missing mandatory values must be avoided.	Rate of wrong parameters entered for therapy initialization should be < 2 %	Clinical Trial	1,3% At 1/80 patients wrong creatinine deviation documented in FB13_081	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC15_25	UC15	Initialize Basal/Bolus Therapy	The current support-“mode” of the GlucoTab system has to be clearly presented to the user. Changes of the support-“mode” have to be presented to the user.	90% of the users can explain which mode is currently activated in the GlucoTab system	Usability test	67% 2/3 passed (only physicians)	NO
TC_UC15_26	UC15	Initialize Basal/Bolus Therapy	The sequence of actions to initialize the basal/bolus therapy has to be clearly presented to the user.	No serious patient hazards (harms to patient = SAE)) related to the device have occurred during the clinical trial	Clinical trial	0% Nu such documented event	YES
TC_UC16_27	UC16	Perform “BG Measurement”	GlucoTab 1.4/1.4.1 is only intended for mg/dl. This has to be clearly presented in the user interface	90% of the users clearly know which unit has to be entered into the system.	Interview	Open (not asked during interview, but no such event documented in clinical trial)	N.A.
TC_UC17_28	UC17	Edit “BG Measurement”	The editing functionality of BG measurements must be known to the user	90% of the users know how to edit BG measurements	Usability test	91% 10/11 passed	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC18_29	UC18	Delete “BG Measurement”	The deleting functionality of BG measurements must be known to the user	90% of the user know how to delete BG measurements	Usability test	100% 11/11 passed	YES
TC_UC19_30	UC19	Perform “Insulin Administration”	The sequence of actions to perform the insulin administration has to be clear. Errors have to be avoided.	95% of the intended insulin administrations during the clinical trial have been performed with the GlucoTab system	Clinical Trial	More than 95 % 2 events are documented were administrations were wrongly not in the system (not clear if usability or technical problem) Deviations documented in FB13_038, FB13_066	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC19_31	UC19	Perform “Insulin Administration”	The sequence of actions to perform the insulin administration has to be clear. Errors have to be avoided.	95% of the intended insulin administrations during the clinical trial have been performed with the GlucoTab system	Clinical Trial	More than 95% 2 events are documented were administrations were wrongly not in the system (not clear if usability or technical problem) Deviations documented in FB13_038, FB13_066	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC19_32	UC19	Perform “Insulin Administration”	Insulin administration actions have to be possible with the GlucoTab system	95% of the intended insulin administrations during the clinical trial have been performed with the GlucoTab system	Clinical Trial	More than 95 % 2 events are documented were administrations were wrongly not in the system (not clear if usability or technical problem) Deviations documented in FB13_038, FB13_066	YES
TC_UC19_33	UC19	Perform “Insulin Administration”	The insulin type/name has to be presented clearly together with the insulin dosage to be administered	No serious patient hazards (harms to patient = SAE)) related to the device have occurred during the clinical trial	Clinical Trial	0% Nu such documented event	YES
TC_UC19_34	UC19	Perform “Insulin Administration”	The insulin type has to be clearly presented during the insulin administration.	90% of users understand the message of insulin dosage and insulin type shown before insulin administration	Usability test	100% 11/11 passed	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC19_35	UC19	Perform “Insulin Administration”	It has to clear in the user interface that meal only should be noted if it is intended.	90% of the users know where to note the meal in the user interface	Usability test	100% 11/11 passed	YES
TC_UC19_36	UC19	Perform “Insulin Administration”	It has to be clearly presented that an insulin dosage is a daily or a partial dosage (basal/bolus)	90% of the user can differ between daily and partial daily dose and can show where in the system they are presented	Usability test	67% 2/3 passed (only physicians)	NO
TC_UC20_37	UC20	Edit “Insulin Administration”	The editing functionality for insulin administrations must be known by the user	90% of the users can show where to edit an insulin administration	Usability test	100% 11/11 passed	YES
TC_UC21_38	UC21	Delete “Insulin Administration”	The deleting functionality for insulin administrations must be known by the user	90% of the users can show where to delete an insulin administration	Usability test	100% 11/11 passed	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC22_39	UC22	Perform “Daily Dose Adjustment”	The sequence of actions to perform a daily dose adjustment has to be clear. User input errors should be avoided.	95% of intended insulin dose adjustment have been performed by the users	Clinical Trial	More than 95 % 1 event (relates to 2 adjustments) are documented were adjustments were wrongly not in the system (not clear if usability or technical problem) Deviation documented in FB13_067	YES
TC_UC22_40	UC22	Perform “Daily Dose Adjustment”	It has to be clearly presented that an insulin dosage is a daily or a partial dosage (basal/bolus)	90% of the user can differ between daily and partial daily dose and can show where in the system they are presented	Usability test	67% 2/3 passed (only physicians)	NO

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC22_41	UC22	Perform “Daily Dose Adjustment”	The aim of the daily dose adjustment should be clear in the mental model of the user (incl. user training and user manual)	100% can explain why to set the daily insulin dose and how to do this in the GlucoTab system	Usability test	100% 3/3 passed (only physicians)	YES
TC_UC23_42	UC23	View History of activities	The view history tab must be known by the users	80% of users know where to find the history of activities	Usability test	100% 11/11 passed	YES
TC_UC24_43	UC24	Power on device	Users know how to turn on the tablet	90% of users know how to turn on the tablet	Usability test	100% 11/11 passed	YES
TC_UC25_44	UC25	Power off device	Users know how to turn off the tablet	90% of users know how to turn off the tablet	Usability test	100% 11/11 passed	YES
TC_UC26_45	UC26	Lock screen of device	Users know how to lock the screen of the tablet in order to clean the screen	80% of users know how to lock the screen off the tablet	Usability test	82% 9/11 passed	YES
TC_UC27_46	UC27	Cleaning the device	The cleaning process and utilities for the device must to clear to the users	90% of users know how to clean the tablet	Interview	55% 6/11 know how to clean device	NO
TC_UC28_47	UC28	Charging of the device	Users know how to charge the device (on the docking station)	100% of users know how to charge the tablet with the docking station	Interview	100% 11/11 know how to charge device	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
TC_UC29_48	UC29	Handling of the device	Users know how to handle the device and where to find a replacement device	80% of users know how and where to ask for technical support	Interview	100% 11/11 know what to do if device is defect	YES
TC_UC30_49	UC30	Storage of the device	Users know where to store device if it is not used	100% of users know how where store the tablet if is not used	Interview	100% 11/11 know where to store the tablet	YES
TC_UC31_50	UC31	Transportation of device	Users know how to pack the device before transportation	Administrative users know how where to store the tablet if is not used	Interview	100% 11/11 know where to store the tablet	YES
TC_UC32_51	UC32	Measurement of hypoglycaemic BG value	Users understand the process when a hypoglycaemic BG value has been measured	100% of users how to handle a hypoglycaemic event	Usability test	100% 11/11 passed	YES
TC_UC12_52	UC12	Adjust therapy settings	Users are always able to show the current therapy regimen	100% of users know the current therapy regimen	Usability test	100% 11/11 passed	YES
TC_UC19_53	UC19	Insulin on Board	User can interpret “insulin on board” function of the GlucoTab system	100% of the users are able to explain the meaning of “insulin on board” (shows the insulin dose which is in the body of the	Usability test	18% 2/11 passed	NO

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
				patient; “insulin on board” is subtracted from the bolus for meal and supplement insulin)			
TC_UC19_54	UC19	Basal Reduction	Users know why the basal insulin is reduced after midday core time.	90% of the users can explain why the amount of basal insulin decreases after midday core time (> 13:00).	Usability test	27% 3/11 passed	NO
TC_UC20_55	UC20	View remaining time to execute a task	Users are able to show the remaining time to execute a task	80% can show the remaining time for an execution of a task	Usability test	73% 8/11 passed	NO
TC_UC33_56	UC33	Refresh Wi-Fi connection	Users know how to refresh the Wi-Fi connection	100% of users know how to refresh the Wi-Fi connection	Usability test	73% 8/11 passed	NO
TC_UC35_57	UC35	Reactivate DSS	Physicians are able to reactivate the DSS by: Using the task symbol in the task list and using the related button in the main screen and using the	100% of users (physicians) are able to reactivate the DSS	Usability test	100% 11/11 passed	YES

Usability test ID	Use case ID	UC description	Usability requirement(s)	Usability acceptance criteria	Test method	Results	Passed
			therapy setting list				
TC_UC35_58	UC35	Reactivate DSS	Nurses are able to explain what to do if the pending mode is activated	100% of users (nurses) are able to explain what to do after pending mode is activated	Usability test	73% 8/11 passed	NO

Table 15: User acceptance and usability test results

Usability test ID	Test method	Remark	Risks	Measure
TC_UC1_01	Usability test	Most of the users have never powered on device because device was always powered on in docking station, consequently they never had to enter password for unlocking credential storage and training was too long ago to remember password. However, no user manual was used for usability tests (which contains complete instructions how to start application) and 100% of asked users know where they can get support if such a problem appears.	No	None
TC_UC4_06	Usability test	User thought that symbol means that insulin administration was already performed. Furthermore she argued that she never uses the task list for insulin administrations because she knows anyway at what time she has to administer insulin.	No	none
TC_UC7_13	Usability test	User did not found requested insulin administration in therapy profile, however she found requested insulin administrations in therapy table. She also mentioned that she primarily uses therapy table for viewing course of therapy.	No No correlating risk	none
TC_UC8_16	Usability test	Nobody of the tested users has ever manually created a new task from task list because it was not necessary. Furthermore no user manual for usability tests was used (which contains complete instructions how to manually add task). However, manually adding a task seems to be too less intuitive and usability should be improved for next releases.	Yes RA0294	Risk entry
TC_UC10_18	Usability test	Only one of the users has ever updated an enrolment parameter before. The user mentioned that he needed some time to find the functionality but he was able to do that without any help. Furthermore no user manual for usability tests was used (which contains complete instructions how to update enrolment parameter). However, updating an enrolment parameter seems to be too less intuitive and usability should be improved for next releases.	No Updated probability of RA0027	Risk entry
TC_UC12_21	Usability test	All asked users correctly knew the currently ordered types of insulin. Consequently this test case is PASSED. However test case is grouped in task with TC_UC19_36 and TC_UC22_40, therefore test case has status FAIL.	No No correlating risk	none

Usability test ID	Test method	Remark	Risks	Measure
TC_UC15_25	Usability test	One user did not know how to start Basal/Bolus initialization of patient who is in non-supported therapy. After a tipp, the user completed task without any problems. No user manual (which contains complete instructions how to initialize Basal/Bolus therapy) was used.	No No correlating risk	none
TC_UC19_36, TC_UC22_40	Usability test	One users correctly opened therapy settings of patient, however the user overlooked the second line of the list entry which presented the does and date/time of the last daily dose adjustment.	no	none
TC_UC27_46	Interview	Some wards has a cleaning supervisor, how is corresponding for cleaning all used devices at ward. At these wards other users do not know how to clean the device because only the cleaning supervisors do that. Furthermore it is not the task of a physician to clean the device, consequently it is comprehensible that physicians do not know how to clean the device. The user manual contains complete instructions how to clean the device.	No No correlating risk	none
TC_UC19_53	Usability test	Users did not know what the meaning of Bolus on Board is, however all users knew what is the Bolus dose to administer. It is not safety critical that the user exactly know how the suggested dose is composed. However at future trainings the details about the calculation should be more focused	No No correlating risk	Risk entry
TC_UC19_54	Usability test	Users did not know why on afternoon there is less Basal dose suggested than on midday (some correctly guessed it), however all users knew what is the Basal dose to administer. It is not safety critical that the user exactly know how the suggested dose is composed. However at future trainings the details about the calculation should be more focused	No No correlating risk	Risk entry
TC_UC20_55	Usability test	Usability acceptance criteria was barely missed (is: 73%, target: 80%). Task times are also stated in user manual and users approximately know at what time which task should be done.	No No correlating risk	none
TC_UC33_56	Usability test	73% were able to refresh wifi connection without the use of the user manual (which conations complete instructuions how to refresh the Wifi connection) However, refreshing the connection is not a safety critical task and therefore the target acceptance criteria of 100% seems to be too high.	No No correlating risk	Risk entry

Usability test ID	Test method	Remark	Risks	Measure
		However manually refreshing the wifi connection is not the optimal solution, an automatic reconnection should be targeted in future releases		
TC_UC35_58	Usability test	73% immediately could immediately show the symbol for the DSS deactivation. Other users, who fail mentioned that they know that the DSS is deactivated if they start an insulin administration.	No No correlating risk	none

Table 16: Risk assessment of failed user acceptance and usability tests

8.2 Results of Primary Care Field Trial

The aim of the primary care trial was to investigate the feasibility of using the REACTION platform including remote monitoring, patient education and Risk Stratification to improve clinical outcomes and patient self-management for a diabetes population in primary care.

The clinical field trial commenced in January 2013. A stepped approach was used in order to manage the start-up of the pilot. An initial 10 patients were recruited followed by another 20 up to March 2013. A review was held in March 2013 to evaluate protocols and pathways and based on the results the pilot ramped up to full capacity in July 2013. The data collection for the pilot was completed in January 2014.

107 (64%) of all diabetics registered at Chorleywood Health Centre took part in the primary care field trial between January 2013 and January 2014. In total there were 137 episodes of monitoring (Table 17).

Hub	No of Patients	Installation Method	Time to Install	Reason for Selection
Multi-Protocol Home Monitoring Gateway	9	9 X Clinicians and non-clinical staff	1 hour	Access to broadband or poor mobile signal
ZigBee home monitoring gateway	128	120 X patient self installs 8 X Clinicians and non-clinical staff	10 min training 45 min	Selected as main option unless patient had poor mobile signal

Table 17: Monitoring equipment assignment

Results from the paper based risk stratification model identified patients as being High (10%), Medium (69%) and low (21%).

37% of those who were monitored were identified as requiring an intervention. The mean Systolic for those patients who had in intervention reduced from 149mmHG prior to intervention to 140mmHG post intervention. The mean Diastolic increased slightly from 76mmmHG to 66mmHG but was within the prescribed target levels. The mean HbA1c for those patients who had an intervention reduced from 66 mmol/mol prior to the intervention to 61 mmol/mol post intervention.

Patient acceptance of the REACTION platform was high. 88% of patients felt that the experience had been worthwhile. 77% of patients felt that it had helped when discussing their diabetes with their clinician. 51% felt that the monitoring had given them a better understanding of their condition.

8.2.1 Stakeholders in the Primary Care Trial

The main stakeholders of the primary care trial are:

- nurses and doctors as end users of the clinical portal devices;
- non clinical support as end users of the clinical portal and devices;

- patients as users of the devices and patient portal;
- non-clinical carers who may support the patient in using the devices and patient portal.

8.2.2 Primary Care Metrics for User Satisfaction

Refer to 8.2.4.

8.2.3 Safety and Performance Test

Refer to 7.2.2.3.

8.2.4 Usability Tests

A number of different components were tested during the primary care pilot. These included the clinical portal and patient portal. In addition to these core components we also performed usability tests on the long term risk, pattern management and semantic search components.

8.2.4.1 Clinical Portal

The primary purpose of the clinical portal is to manage incoming data from the home monitoring equipment as well as data that is collected via the patient portal. The portal is used to record information on the care plan and share this with the patient.

The clinicians and those that monitor need to be able to access the data quickly and be able to interpret the results in a way that is meaningful and useful. The average duration of a consultation between a clinician and a patient is 10 minutes. Finding and interpreting information must be done as quickly as possible in order not to impact on that time.

Usability feedback was collected during the course of the field trial and fed back regularly to the developers in order to improve or change functionality. Clinical and non-clinical support accessed the portal and provided feedback. The user feedback per requirement is described in Table 18. Overall the clinical portal was found to be usable and met the primary purpose of being able to manage incoming data, share data with the patient and record relevant information.

The main criticism of the clinical portal was the duplication of data which is already stored in the EPR. With no direct links between the EPR and the clinical portal, data is manually transposed from one database to the other. This is time consuming and was seen as not being practical in “usual practice”.

ID	Requirement	Acceptance description	Results	Comment
C1.1	Access to clinical portal	Be able to sign in to the clinical portal via an internet connection.	Achieved	
C1.2	Registration of patient	Ability to manually register patients onto the system	Achieved	
C1.3	Automatic Registration of patient	Automatic registration of patient from EPR	Not Achieved	Out of Scope
C1.4	Search and Edit patient Data	Easily search for a patient and edit patient information	Achieved	
C1.5	Access to demographic data	Easily viewable demographic information	Achieved	
C1.6	Data entry	Easy data entry and missing data highlighted	Achieved	
C1.7	Be able to search for a patient	Be able to find a patient on the database	Achieved	
C1.8	Search for monitoring status	Find out if a patient is active	Achieved	

C1.9	View patient record	Be able to access the patient monitoring data	Achieved	
C1.10	View Physiological Data	To be able to view data in a graph and tabular form	Achieved	Cannot view graph data in Internet Explorer from desktops at the health centre
C1.11	View Activity Data	To be able to view patient activity data against recommended levels	Achieved	
C1.12	View Diet Data	To be able to view patient diet data against recommended activity levels	Achieved	
C1.13	View Medication compliance data	Indication of oral and insulin compliance data	Achieved	
C1.14	View Therapy History recorded on EPR	To be able to view combined EPR and RPM data	Partially achieved	RPM data could be attached manually into EPR and EPR data could manually be recorded in EPR
C1.15	View Notes History recorded on EPR	To be able to view combined EPR and RPM data	Partially achieved	RPM data could be attached manually into EPR and EPR data could manually be recorded in EPR
C1.16	View Comorbidity History	To be able to view combined EPR and RPM data	Partially achieved	RPM data could be attached manually into EPR and EPR data could manually be recorded in EPR
C1.17	Record and view Notes	To be able to record details of Intervention	Achieved	Recorded free text in patient notes. Would be better to be tick box
C1.18	Enter and or edit a care plan for a patient	To be able to enter a new care plan for a patient and publish or edit an existing plan	Achieved	
C1.19	Reset patient questionnaires	Able to reset patient questionnaires	Achieved	
C1.20	Review of data	Know if a patients data has been reviewed	Achieved	
C1.21	Set monitoring status	Able to mark the patient as active or inactive	Achieved	
C1.22	Mark patient data as reviewed	Know if a patients data is outside of given thresholds	Not Achieved	
C1.23	Identify prioritised patient data	Be able to view prioritised patient data	Not Achieved	
C1.24	Record outcome of	Be able to record outcome	Achieved	Outcome is recorded in patient notes.

	data review	of data review		Would prefer a tick box
C1.25	Set personalised thresholds	Able to set thresholds around a patients data	Not Achieved	
C1.26	Edit personalised thresholds	Able to edit personalised thresholds around a patients data	Not Achieved	
C1.27	Equipment Management	Able to add, edit or delete new equipment to the clinical portal	Achieved	
C1.28	Search for Equipment	Able to see if equipment is assigned to a patient	Achieved	
C1.29	Equipment assignment	Able to assign equipment to a patient	Achieved	
C1.30	Un-assign Equipment	Able to un-assign equipment from a patient	Achieved	
C1.31	Patient Portal sign in and Password	Set up a new patient portal username and password	Achieved	

Table 18: Clinical portal usability tests

8.2.4.2 Home Monitoring Equipment

The home monitoring provided to patients consists of a communication hub, blood glucometer and blood pressure. A number of other peripherals including weight scale and Pulse Oximeter were available if required.

There were two options of communication hub. The patient gateway which is a plug and play GSM mobile hub which plugged into a mains socket within the patients home and used mobile connectivity to transmit data, or the home gateway which is a PC box (without monitor) which could be set up to a patients broadband with via WIFI or through an Ethernet cable.

Due to the volume of patients within the study and where possible, patients were given the plug and play equipment to take home with them at the time of their 1st review. Where there was known limited mobile signal in the patients home the black box kit was deployed and installed by clinical and non-clinical staff. A total of 137 sets of monitoring equipment were assigned to patients for a minimum of two weeks. Table 17 describes patient's equipment assignment.

Usability feedback was collected during the course of the field trial and fed back regularly to the developers in order to improve or change functionality. The user feedback per requirement is described in Table 19.

Usability and acceptance of the plug and play kit was very high. It was felt to be easy to set up, clean and easy to demonstrate to patients. While most of the equipment stood up to the challenges of being rotated repeatedly to different patients, the blood glucometers proved to be subject to greater wear and tear.

Usability and acceptance of the black box kit was lower. This was mostly due to the need in home installation which was time consuming as opposed to being able to give equipment to the patient to take home with them. The installation also required more technical knowledge and complexity as there was a need to bring a keyboard, mouse and monitor in order to connect to the patient local Wi-Fi. Connecting the black box using an Ethernet cable restricted the location of the box and in some cases required purchasing additional routers.

Reliable communication was also an issue on several occasions for both sets of equipment. Some patients lived in areas where there was not a reliable mobile signal. In these occasions, patients were able to manually enter their readings on the patient portal. Other patients recorded data on paper and the data was entered in manually by the clinician. All of the Wi-Fi antennas on the black box equipment fell off and were no longer functional after the third rotation. This was seen to be an issue when trying to rotate devices across many patients.

ID	Requirement	Acceptance description	Results	Comment
CD1.1	Device Set Up	Able to set up devices for patient	Achieved	
CD1.2	Clear data from devices	Clear data from devices before issuing to patents	Achieved	
CD1.3	Cleaning of devices	Able to clean device ready to be issued to patients	Achieved	
CD1.4	Patient Training	Able to demonstrate equipment to patient	Achieved	
CD1.5	Installation / issue of devices	Installation of devices should be quick	Not Achieved	The black box kit required home installation which took time and had added complexity
CD1.6	Reliability	Data is received in a reliable and timely manner	Partly Achieved	Mobile signal and issues with strength updates on the black box caused reliability issues
CD1.7	Data accuracy	Data is received accurately	Partly Achieved	Issues with time stamps and erroneous data values were observed on a few occasions

Table 19: Usability of devices – professional

8.2.4.3 Patient Validation

A total of 107 patients were monitored for a minimum of two weeks over a 12 month period. 30 patients were monitored twice. Patient perception and overall experience was measured using two questionnaires. The first Service User Technology Acceptability Questionnaire (SUTAQ) questionnaire measured the patients' perception of the diabetes review process and the tools that they used to monitor their diabetes. The questionnaire was given to each patient at the time of their two week review and patients were asked to return it at the end of their monitoring period. The second questionnaire was a postal questionnaire which patients were asked to complete and return at the end of the field trial.

51% of patients completed a questionnaire about their experience of monitoring their diabetes at home. Patients were asked to complete the questionnaire at the end of the pilot. Questionnaires were self-administered.

The questionnaire was organised into three sections covering patient experience, patient management, and patient portal and then finally patients were asked about their overall experience with the study and equipment. Patients were also encouraged to add additional comments.

In addition the questionnaires, a focus group was held in order to again additional feedback about the patient experience. The focus group was held on the 20th February 2014 and was attended by 14 patients and carers. Table 20 and Table 21 provide user feedback per requirement.

ID	Requirement	Acceptance description	Results	Comment
PP1.2	Access patient portal	Access the patient portal via an internet browser	Achieved	The patient portal does not work on certain versions of browser
PP1.3	Navigation	Able to navigate around patient portal easily	Achieved	
PP1.4	Touch screen	Ability to use touch screen	Achieved	
PP1.5	Blood Sugar Levels	Be able to view data in both a graphical and table format	Achieved	
PP1.6	Blood Pressure Levels	Be able to view data in both a graphical and table format	Achieved	
PP1.7	Manual Entry of physiological data	Able to manually enter in physiological data	Achieved	Would like to be able to edit data and add comments
PP1.8	Manual entry of diet data	Able to manually record data about diet	Achieved	
PP1.9	Manual entry of Insulin Dose	Able to manually enter insulin dosage	Achieved	
PP1.10	Medication compliance	Able to answer questionnaire and receive feedback	Achieved	
PP1.11	Diet Advice	Able to answer questionnaires and receive automated feedback	Achieved	
PP1.12	Activity Advice	Able to answer questionnaires and receive automated feedback	Achieved	
PP1.13	Access to Educational content	Educational feedback to help understand condition	Achieved	
PP1.14	Accessible and unobtrusive Device	Devices to be east to use unobtrusive and accessible	Achieved	
PP1.15	Order repeat prescriptions	Ability to order repeat prescriptions via the patient portal	Achieved	
PP1.16	Make an appointment	Ability to order repeat prescriptions via the patient portal	Achieved	

Table 20: Patient portal usability tests

ID	Requirement	Acceptance description	Results	Comment
PD1.1	Transmission of Blood Glucose measurements	Able to transmit blood glucose measurements remotely	Achieved	Some patients reported difficulty with taking won blood glucose measurements
PD1.2	Transmission of Blood Pressure	Able to transmit blood pressure measurements	Achieved	

	measurements	remotely		
PD1.3	Able to use communication gateway in the home	Able to transmit data	Achieved	Difficulties with mobile phone signal strength reported
PD1.4	Ease of use	Home monitoring equipment was easy to use	Achieved	

Table 21: Usability of devices – patient

8.2.4.3.1 Patient Experience

Patients were asked if they understood why they were being asked to monitor their blood sugar and blood pressure at home. 95% answered positively and 91% of these felt that it would be a useful exercise indicating that they understood the importance of these measures in the self-management of their diabetes.

83% of patients felt that they had been supported by the staff at the health centre during the time that they were monitoring. 6% of patients responded that they felt unsupported; these patients indicated that they would have liked to have had phone contact during the time that they were being monitored.

When asked if patients felt that monitoring their blood sugar and blood pressure at home had been a worthwhile experience, 88% responded that they had, 10% remained undecided with only one patient felt that it had not been. Some patients responded that they already monitored their blood sugars at home and as such this study was not new to them in respect to self-monitoring.

Patients were asked if the monitoring at home had helped when discussing their condition with the GP and clinical staff. 77% felt that it had helped, 12 % felt that it had not and 10% remained undecided (Figure 52).

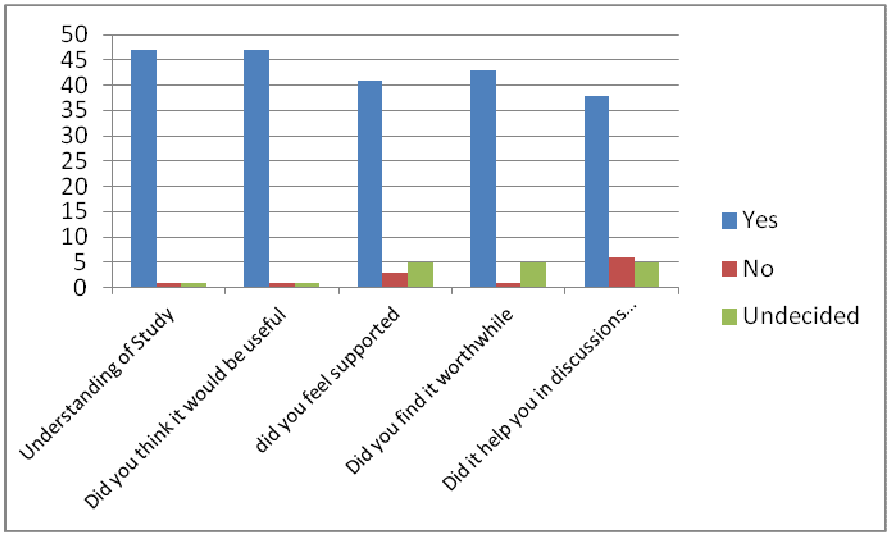


Figure 52: Patient experience (55 participating patients)

8.2.4.4 Patient Management

The results about the perception from patients of self-management are shown in Figure 53.

73% of patients reported that they understood the results from the home monitoring. Over half (51%) of patients felt that the experience of home monitoring had given them a better understanding of their diabetes, 22% remained undecided. However 63% reported that the experience had helped them to be more confident in managing their diabetes.

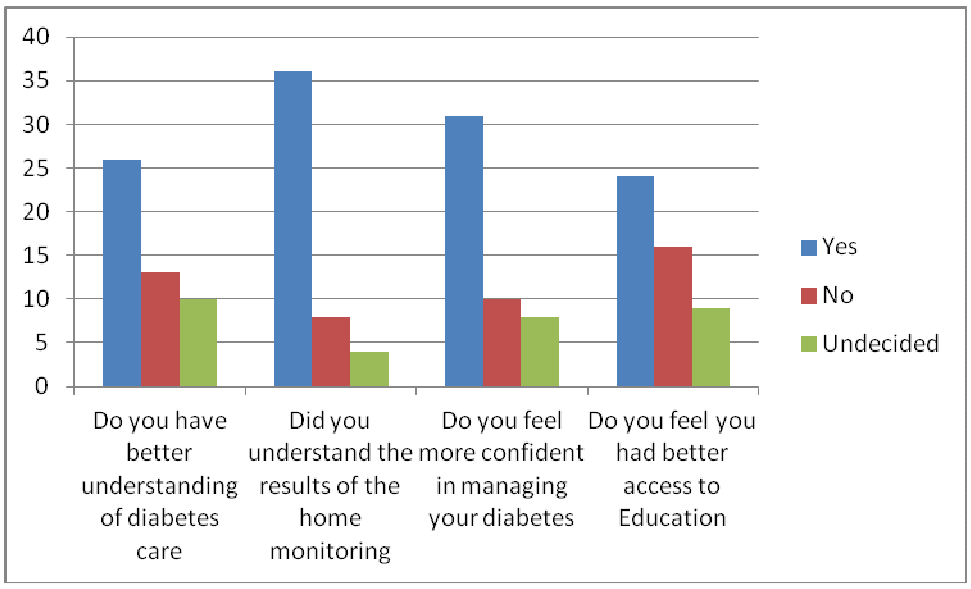


Figure 53: Patient self-management (55 participating patients)

Only 48% felt they had better access to education and information about their diabetes. However, this may in part correlate to the numbers who accessed the patient portal where the educational content was held.

73% of those that responded said that they had been given information about the patient portal (Figure 54). Patients were informed of and given username and password access to the patient portal at the training sessions. However, patients were also being trained on the devices and as such were taking in a lot of information in a short space of time. Of those patients that said they had been given information about the portal 60% said that they had used it. 5 patients responded that they had been unable to access the patient portal. On investigation we found that there had been a number of issues with the browser that was being used. Specifically the portal did not support older browsers. We also had issues when Internet Explorer had been updated.

Comments from the questionnaires:

"Easier to send results when equipment did not always work"

"I saw readings every day, portal was unnecessary for me"

"Could not access portal"

"Did not use as I keep my own diary"

"I had a good understanding already but I did purchase my own BPM machine after finishing"

"I already download blood test results to my PC"

"Did not feel it necessary to use the portal at this time but might wish to use in different circumstances"

"Did not use portal as was not worried and kept my own record"

"Interested in the portal but did not think to use it during the period. An excellent facility thank you for getting me involved"

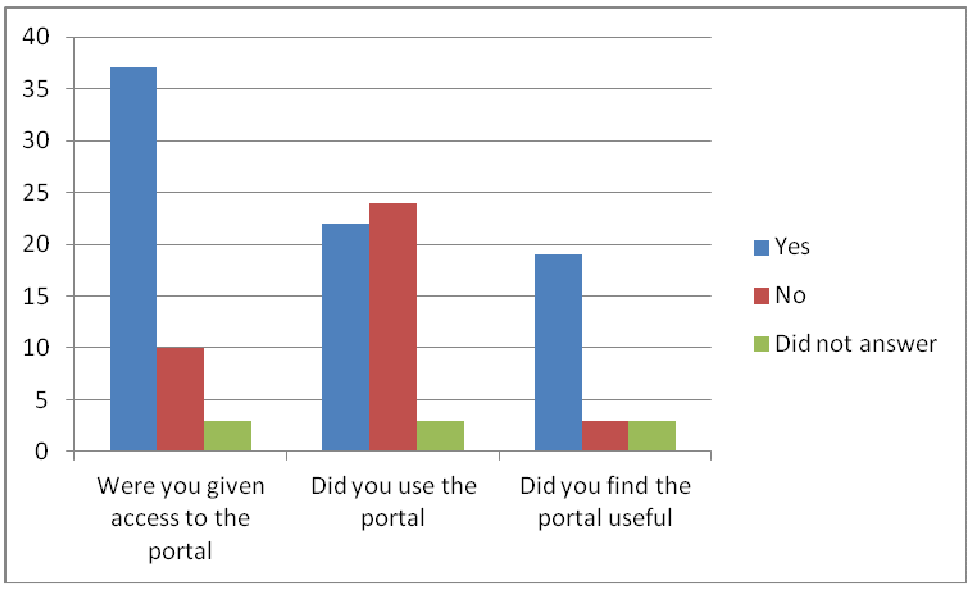


Figure 54: Patient experience of patient portal (55 participating patients)

The most common reason cited for using the portal was to review data as well as entering in data. This was felt to be particularly useful when there were problems with the devices. 10% said that they had used it to enter data about their diet, activity and medication usage. Only 2% had said that they had used or accessed the educational content on the portal. 82% had said that they found the portal to be useful. Of the patients who accessed it:

- All said they used it to view results
- 48% to enter in manual data
- 10% to complete diet and activity data
- 2% to access educational content

The SUTAQ is a Likert scale where 5 is very positive except for the privacy domain where the question is introverted. The SUTAQ patient perception results are shown in Figure 55.

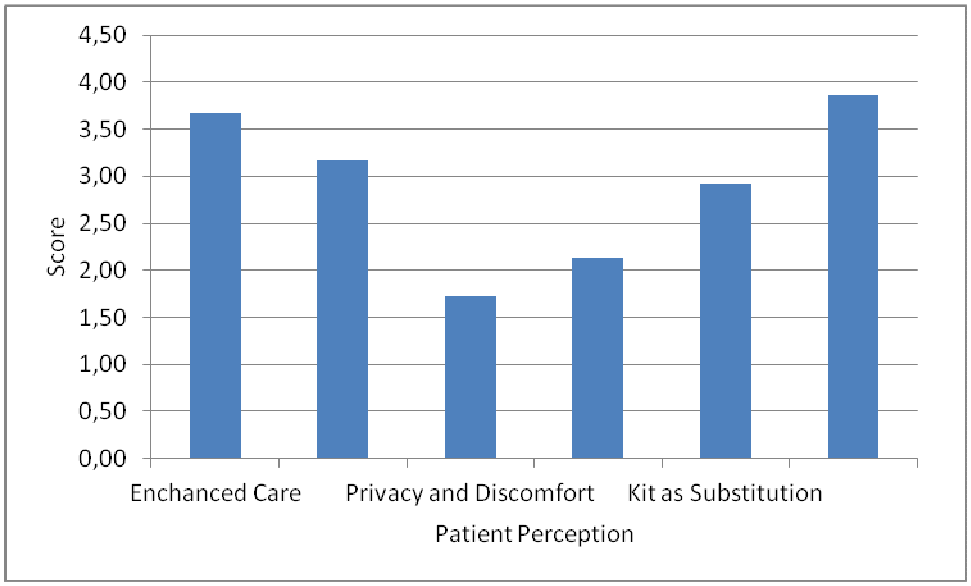


Figure 55: Distribution of the SUTAQ patient perception scores

8.2.4.5 Enhanced Care

The majority of patients felt that the service and technology provided enhanced care that was over and above what they consider to be their normal care. Patients reported that they were more actively involved in their own care and that the technology provided a good method for their clinicians to have better access to their information. Most reported that the technology was a good addition to their normal health and would recommend it to other patients with similar conditions.

8.2.4.6 Access to Services

Patients marginally felt that there taking part in the study had marginally improved their access to access to health services.

8.2.4.7 Privacy and discomfort

None of the patients felt that the technology had affected their privacy or made them concerned about the confidentiality of the information being exchanged through it.

8.2.4.8 Personnel care concerns

Almost all patients had no concerns over the level of expertise of those looking at their data collected via the technology or that their continuity of care was being affected.

8.2.4.9 Technology as replacement for usual care

None of the patients felt the technology could replace their regular healthcare. Although some patients felt that the technology was as suitable as a regular face to face consultation, there was no strong feeling that the technology had enabled the patients to feel less concerned about their health.

8.2.4.10 Satisfaction

Overall patients reported being satisfied with the technology. However some patients reported technical difficulties resulting from either mobile signal problems or access to the patient portal. In addition, others reported having difficulty using the blood glucose monitor in particular.

Comments from the questionnaires:

> “The equipment should prove to be consistent, reliable to ensure total confidence”
>
> “Poor Battery Connection or quality of equipment”
>
> “Could not always transmit data”

8.2.4.11 Patient Challenges

A number of challenges were faced by patients especially concerning the self-monitoring of blood glucose in the home. Many of the type 2 patients had not previously used a blood glucometer and found it very difficult. This often resulted in missing data or patients using many strips to take their measurement. Patients that were identified as having difficulty were often visited in their home to provide additional support.

Other patients were unable to transmit data due to poor mobile signal strength in their area. For these patients, we offered to swap the equipment for the black box broadband monitoring kit. Where this was not possible or not desired, patients either manually entered data on the patient portal or kept a paper record and this was manually entered into the REACTION database by the administrative support.

A small proportion of patients reported that they were unable to access the patient portal. On investigation it was often found that the internet browser that they were using was not supported either because it was out of date or because of recent updates.

8.2.5 Long Term Risk Model

The long term risk model is integrated into the clinical portal. It is accessed from the individual patient page. The clinician is able to select the model that they would like to run. Data that is already stored in the clinical portal is auto-filled into the model to reduce data duplication. Where data is missing or there is unknown the clinician can leave blank. A usability test was performed with two members of the clinical team. Each was asked to select a patient and run the models. The user feedback per requirement is

described in Table 22. Feedback was positive although the clinical team would like to be able to run the model on all patients in order to stratify all patients according to their long term risk.

ID	Requirement	Acceptance description	Results	Comment
LTR1.1	Access to Long Term Risk Models	Easily to locate models on clinical portal	Achieved	
LTR1.2	Data Entry	Avoid duplication of data and data errors	Partly Achieved	Auto fill of data reduces data entry. Some confusion over values to be entered and what to do if the data is unknown.
LTR1.3	Output of Results	Easily understood result in a text and graphical format	Partly Achieved	Would prefer to see results as a percentage and graph to be labelled

Table 22: Usability of long term risk model

8.2.6 Semantic Search

Usability tests were performed on the Semantic Search Component. Two clinicians were asked to take part, one general practitioner and one practice nurse. Clinicians were asked to enter in a search and locate the results.

Both users felt that the graphical user interface was not intuitive or easy to use. Both had to refer to the test guide in order to complete the test. One user commented that it was time consuming and that it would be difficult to undertake within a 10 minute consultation.

Recommendations were to provide a simple text data entry box, which hides all of the other elements. These were seen to be confusing to the clinicians.

The user feedback per requirement is described in Table 23.

ID	Requirement	Acceptance description	Results	Comment
SS1.1	Log into Semantic Search	Able to access the semantic search	Achieved	
SS1.2	Enter a query	Ease of entering a query	Partly Achieved	Controlled language is not intuitive and errors were made by all users in data entry.
SS1.3	Output of Results	Able to locate the required answer	Partly Achieved	Output was displayed

Table 23: Usability of semantic search component

8.2.7 Pattern Management

Usability tests were performed on the Short Term Risk and Pattern Management Component. Two clinicians were asked to take part, one general practitioner and one practice nurse. Users were given a test script to follow in order to navigate the component.

Both felt that the component was very useful and provided a great deal of information. The graphical user interface was felt to be complicated and they felt there were too many steps in order to generate the output. The report function was felt to be particularly helpful.

While the models within the pattern recognition part were not felt to be applicable to the diabetes cohort at the health centre, the clinicians felt it was very useful to be able to define their own models.

The user feedback per requirement is described in Table 24.

ID	Requirement	Acceptance description	Results	Comment
SS1.1	Log into Pattern Management	Able to access the Component	Achieved	
SS1.2	Find a patient	Able to search for a patient and enter date range	Achieved	
SS1.3	Output of Results	Visualisation of data	Achieved	
SS1.4	Start data statistical analysis	Able to locate statistical analysis tool kit	Achieved	
SS1.5	Review statistical options	Navigate the different options	Achieved	
SS1.6	Adjust meal types	Make adjustment to settings	Achieved	
SS1.7	Generate a report	Generate a summary report of data	Achieved	
SS1.8	Output of report	Check reports of BG data and statistical analysis	Achieved	

Table 24: Usability of short term risk and pattern management component

8.2.8 ePatch® Demonstration

14 patients who are registered at Chorleywood Health Centre were invited to take part in the demonstration of the ePatch®. 5 patients were selected from the warfarin Clinic who had previously had a Holter. 9 patients were selected as they had been identified at High Risk as part of the diabetes review process.

Each patient was asked to come to Chorleywood Health Centre at an agreed time where the ePatch® was demonstrated and where patients had an opportunity to ask any questions they had. Patients were asked to complete a consent form after they had agreed to take part.

Excess hair around the area of where the patch was to be fitted was removed and the area wiped clean. The ePatch® was then fitted to a patient who was asked to wear the sensor for 24 hours. The patient was instructed not to shower or get the sensor wet while they were wearing it. Patients were also asked to complete a short questionnaire containing 5 questions about their experience using the ePatch®.

2 Nurses and 1 healthcare assistant were involved in fitting the ePatch® to the patient. Each appointment lasted less than 10 minutes including the project explanation and consent taking.

8.2.8.1 Results

14 patients participated in the ePatch® demonstration. Mean age was 78 (SD8). 12 men and 2 women took part.

The first 10 patients were asked to return to the health centre the next day to have the sensor removed. The final 4 were asked to remove the sensor themselves and return it to the Health centre. One of the patients who was unable to return to the health centre and was visited in the evening at home to have the ePatch® removed. Patches were removed by a nurse, healthcare assistant and researcher. 1 of the patients reported redness around the area of the ePatch® when it was first removed but this may have been due to the chest hair being shaved off and no further issues were reported after the patient went home. Removal of the ePatch® took less than a minute.

The results from the sensors were uploaded to a software analysis software which could be accessed via the internet via a secure username and password. The software could then be used to analyse the data and generate a report which could be printed. Data was reviewed by a GP and notes were attached to the patient electronic patient record.

8.2.8.1.1 Patient Feedback

Patients were asked 5 questions about their experience wearing the ePatch®. 4 of the questions were designed to find out how they felt about the ePatch® and the 5th was used to capture information about any health events that took place while they were wearing it in order to look for these in the ECG results. Table 25 describes the usability requirements and results.

ID	Requirement	Acceptance Description	Results	Comment
EP1.1	Comfortable to wear	Patients should find the sensor comfortable to wear	Achieved	“Don’t know I've got it on, especially in bed. I have had boxes and in bed they are very uncomfortable" “Unaware of wearing it”
EP1.2	Discrete	The sensor should be discrete	Partially Achieved	“The ePatch would be very obvious if worn with an open top neckline” “Unnoticeable”
EP1.3	Errors	No patient reported difficulties with the devices	Achieved	
EP1.4	Physical Effects	No adverse physical affects during or after wearing the sensor	Partially Achieved	One patient reported short term redness around the area of the sensor once it had been removed.

Table 25: Usability of ePatch® - Patients

8.2.8.1.2 Professional Feedback

Table 26 describes the usability feedback from the professionals with regard to usability of the sensors and analysis software.

ID	Requirement	Acceptance Description	Results	Comment
EP1.5	Quick and Easy to use	The sensor should be easy to use and give to the patient	Achieved	Very quick and did not need a health professional experience to attach or remove from a patient.
EP1.6	Reliable	Data was captured reliably from the sensor	Partially Achieved	One of the sensors did not successfully capture the data. This may have been user error when setting up
EP1.7	Upload of sensor data	Data should be easily transferred to analysis software	Partially Achieved	Due to bandwidth restrictions, data was slow to upload to the software via the internet connection
	Reviewing of information	The results of the sensor should be accessible	Achieved	Could be accessed via the internet
EP1.4	Analysis of information	Results should be quickly and reliably analysed	Partially Achieved	Analysis software required a number of steps in order to analyse the data. Default language was not English Felt to be over sensitive in identifying atrial fibrillation.

Table 26: Usability of ePatch® - Professionals

8.3 Certifications

Certifications have been performed for some components or solutions. They are reported here below.

8.3.1 Primary Care Certifications

The REACTION platform for the primary care pilot is designed to follow standards for the devices, gateways and observations receiver in the enterprise. This includes IEEE 11073 as data protocol for the devices and home gateway and IHE-PCD01 (HL7) for the gateway to enterprise. It further includes ZigBee as the home wireless implemented as the ZigBee Health Care Profile for the patient gateway and devices. These devices were developed in the project, and it was decided that they should be validated independently for conformance to the standards. This would improve interoperability between existing

devices and the gateway, and ensure interoperability with future devices developed to the standards. The seven devices were thus subjected to independent testing by TRAC for conformance with the ZigBee Health Care Profile and testing by AT4Wireless for conformance with Continua Alliance requirements for the respective IEEE 11073-104xx specialisation.

Continua Alliance provides a test tool to allow self-test of devices before submission to the testing house. All devices were exhaustively tested using this tool to ensure conformance to the standards.

The patient gateway was not in a form that could be tested formally, however tests were conducted using the validated devices.

All seven devices have received certification for both ZigBee and Continua and the certificates are included in Appendix 1.

8.3.2 In-Hospital Certifications

The In-Hospital application has been CE marked in autumn 2013 as a medical device.

9 Results of Requirement Validation

9.1 Requirement Statistics and Progress

Nearing the end of the fourth cycle, the statistics obtained from the JIRA Requirement Repository can be summarised as seen in Figure 56.

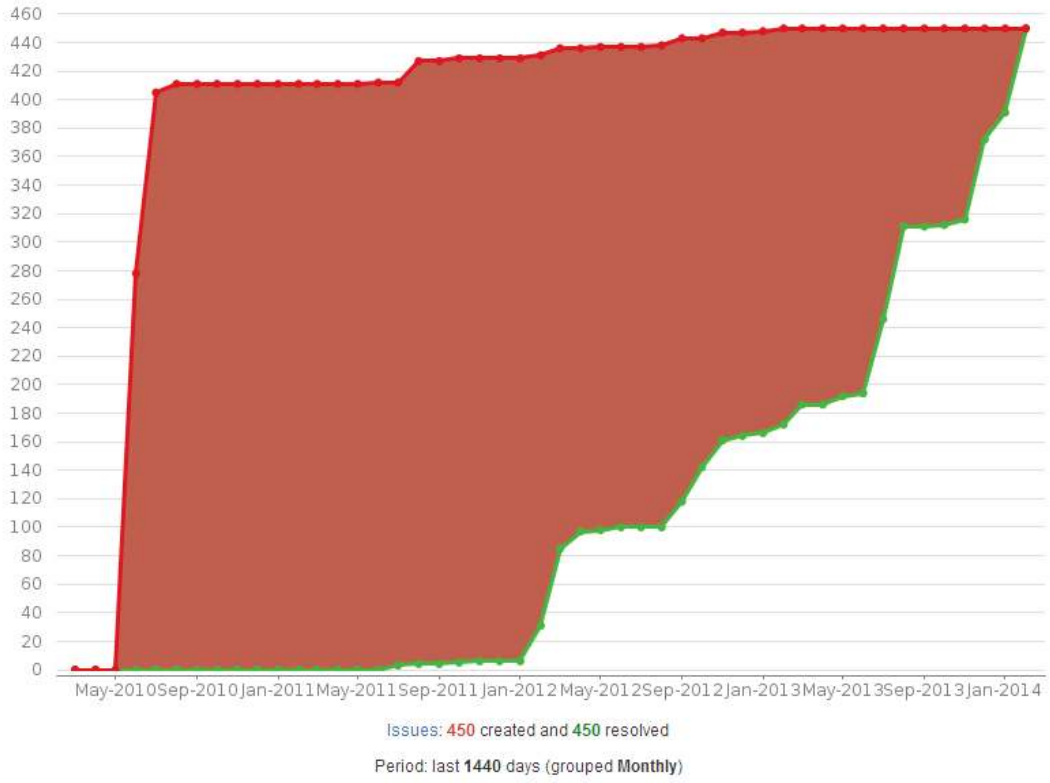


Figure 56: All Volere requirements – created versus resolved

Figure 56 shows that all the original 450 Volere requirements have been resolved. A number of these requirements were excluded from the final specifications, because they were Duplicates, Out of Scope, Conflicting, etc., as shown in Figure 57.

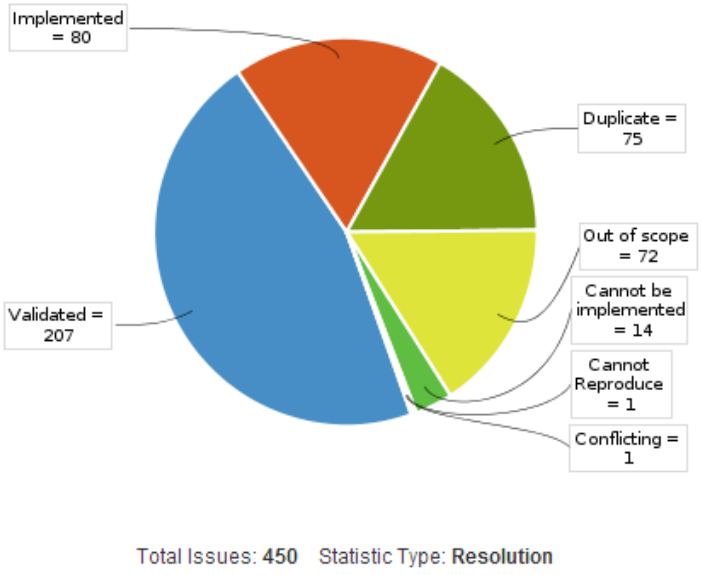


Figure 57: All requirements – resolution

In the remainder of these charts, only those 287 requirements that are Part of Specification are considered. Figure 58 shows that almost all requirements have been closed. Only 3 requirements have status Resolved, while none remain In Progress.

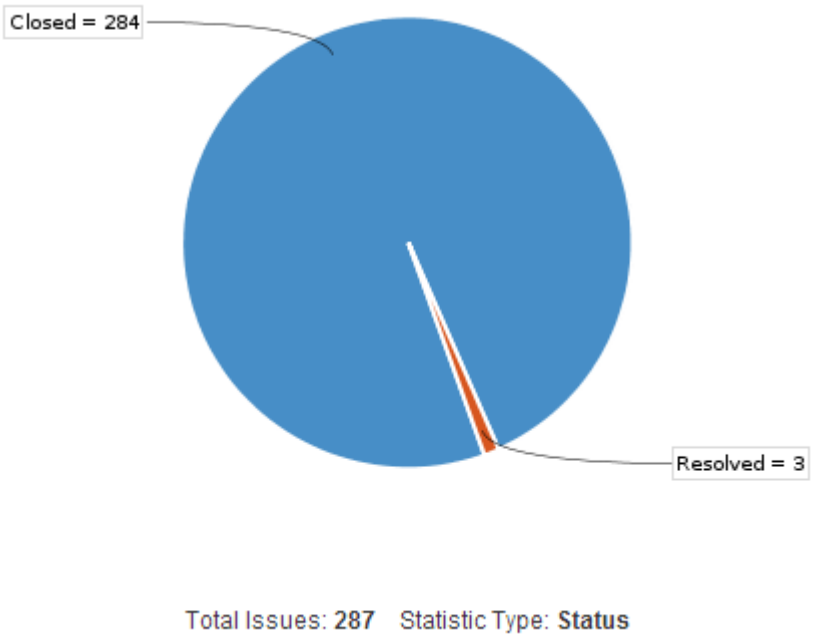


Figure 58: Status for requirements in specification

Resolutions for the same requirements are shown in Figure 59: 207 requirements have been validated and 80 have been implemented.

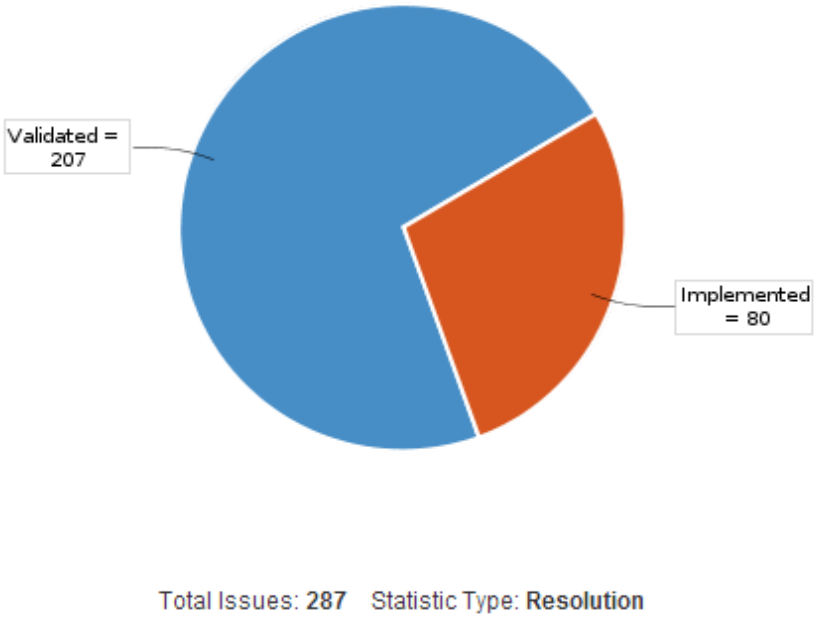


Figure 59: Resolutions for requirements in specification

A more informative overview is obtained when these requirements are referenced to the resulting applications.

9.1.1 Primary Care Prototype

The Primary Care prototype comprises 89 requirements, the resolutions of which are shown in Figure 60. About 85% of the requirements have been validated by the end users.

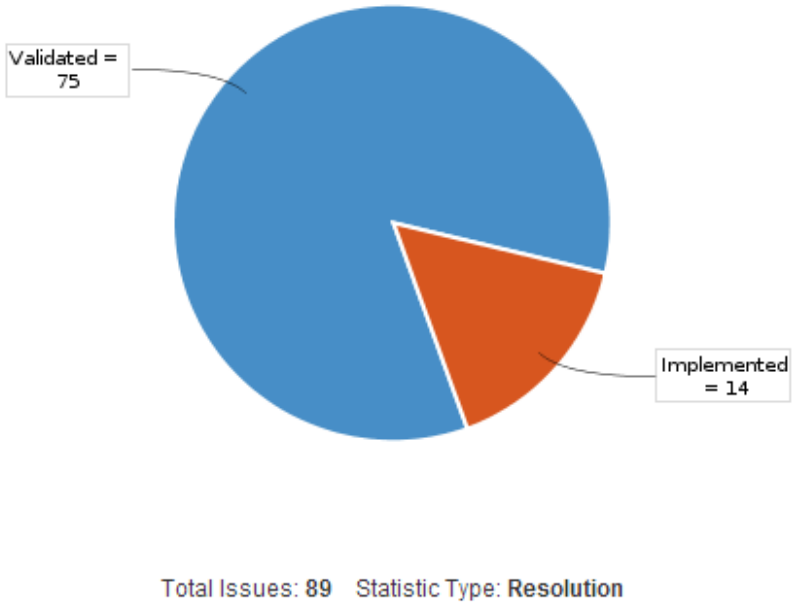


Figure 60: Resolutions for primary care prototype

9.1.2 In-Hospital Prototype

The In-Hospital prototype consists of 92 requirements, with more than 92% being validated by the end users as shown in Figure 61.

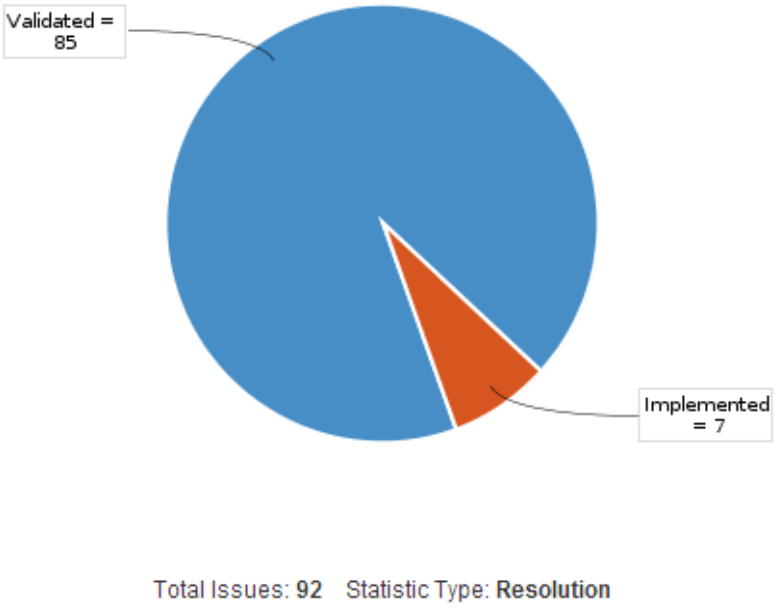


Figure 61: Resolutions for in-hospital prototype

9.1.3 Automatic Glucose Control

As shown in Figure 62, the Automatic Glucose Control prototype involves 23 requirements, about 2/3 of which have been validated.

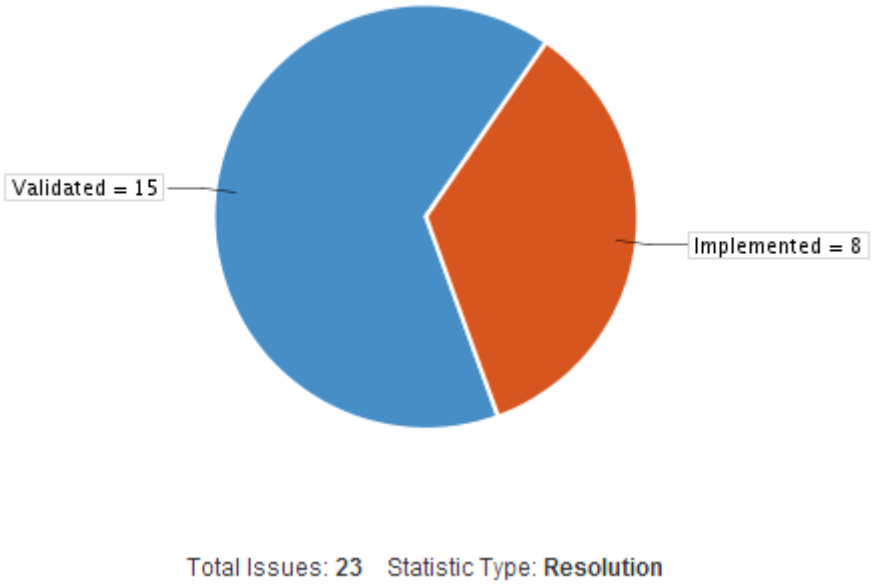


Figure 62: Resolutions for automatic glucose control

9.1.4 REACTION Platform

The platform includes 75 requirements, resolutions shown in Figure 63. The platform is engaging less transparently with the end users, hence just under 50% of the requirements have been validated.

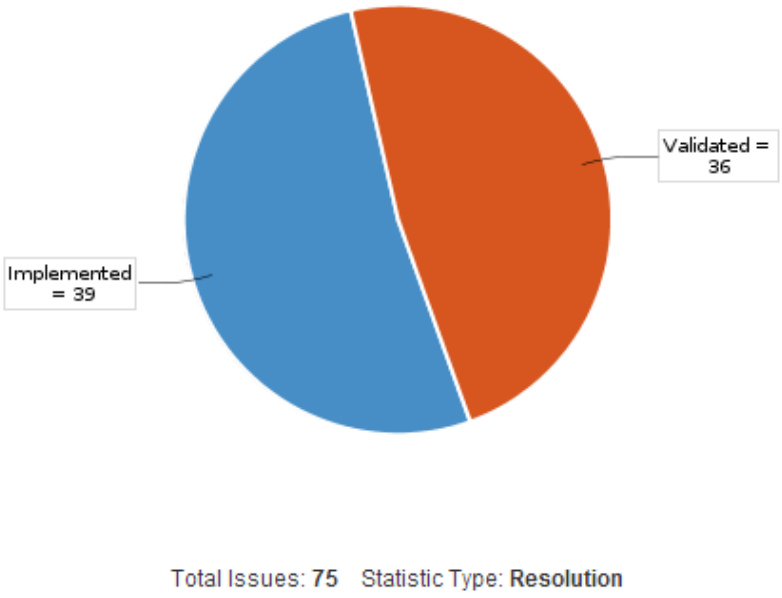


Figure 63: Resolutions for REACTION platform requirements

9.1.5 Peripherals

Peripherals are various devices, first and foremost the ePatch. Nine requirements are involved, all of them implemented and closed.

9.2 Implemented Requirements of the REACTION Project

In a separate Appendix (D2-10_Final-validation-report_Appendix_V2.0_FORTH.pdf) the requirements of the REACTION platform at the end of the project are reported per WP and per component showing only the major fields like priority, summary, rationale and fit criterion. Requirements in the “Resolved” or

“Closed” statuses with resolution “Duplicate”, “Out of scope”, “Nonsense”, “Conflicting”, “Cannot be implemented” or “Cannot reproduce” have not been listed. The focus is only on all requirements that at the end of the project are still “Unresolved” or “Implemented” or “Validated”.

It should be noted that, in the default workflow initially used, each requirement had an impact on more than a single WP and on more than a single component. Ideally each requirement should be assigned only to one component and to one WP, but the complexity of the project did not make that possible during the first iteration cycle. With the introduction of the new workflow and components in the second iteration cycle, each requirement was assigned only to one component, and for each requirement a WP of major impact was identified. For each requirement it was a task of its Assignee to coordinate the work during the life cycle of the REACTION project among different WPs in order to assure the requirement would be properly resolved.

In order to give an effective view of the requirements and to avoid an excessive length for this deliverable, each requirement has been listed only in the WP on which it has major impact.

10 Conclusions

The REACTION project has adopted since its beginning a requirement management approach supported by the use of JIRA issue management tool where the Volere template was implemented.

The specification and design methodology was based on an evolutionary requirements engineering procedure underpinned by a strong user-centric development process. The methodology calls for comprehensive iterative requirements and stakeholder analysis based on initial requirements gathered from medical and clinical scenario thinking. Requirements were initially collected either jointly or by each partner through focus groups or the involvement of the relevant stakeholders.

Towards the end of each iterative cycle (corresponding to one calendar year), but sometimes also in between, a prototype of the REACTION platform was assembled with a view to integrating as many of the existing components as are available at the time and in accordance with the detailed work plan. The components of the REACTION platform underwent technical verification of their functionality. Then, system integration and verification took place in each of the four iterative validation cycles in the research and development phase according to the validation framework described in D2-7.

After the successful completion of a prototype cycle, each work package analysed and reported its development results and experiences in the development, integration, verification and validation work through Lessons Learned. In addition, Lessons Learned resulted from the continuous monitoring of developments in the clinical, technology, market and regulatory standards fields, as reported in three M24 Watch reports. Lessons Learned constitute both individual and organisational knowledge gained by experience; either negative or positive. Based on the lessons learned and the continuous contact with the stakeholders each time the requirements were reviewed and the technical plan for the next prototype newly issued.

In the final iteration of the REACTION project the platform composed by several potential “products”, at different level of maturity, has been released. The components as well as the specific solutions for the three different environments faced by the REACTION project have been verified and validated. The verification and validation results have been reported in details in this deliverable for the various components as well as for the integrated solutions showing the strengths and weaknesses of each component/solution and paving the way for future releases or for more extensive trials or for exploitation in the real market.

Overall the results of the field trials have to be considered positively since the in-hospital 42/57 of the advanced usability acceptance and usability tests have been completely fulfilled while in the primary care environment 51/57 of the main usability tests, conducted on the core solution (portals and devices), have been totally fulfilled showing that the integrated solutions for these two environment have already reached an good level of maturity.

In terms of requirement management a total of 287 effective requirements have been managed with the help of JIRA and all of them have been implemented and most of them validated (207). It is worth noting that verification has been successfully performed on all implemented requirements when the requirement was not addressing patient or clinical end-users but rather developers or integrators.

11 Lists of Figures and Tables

11.1 List of Figures

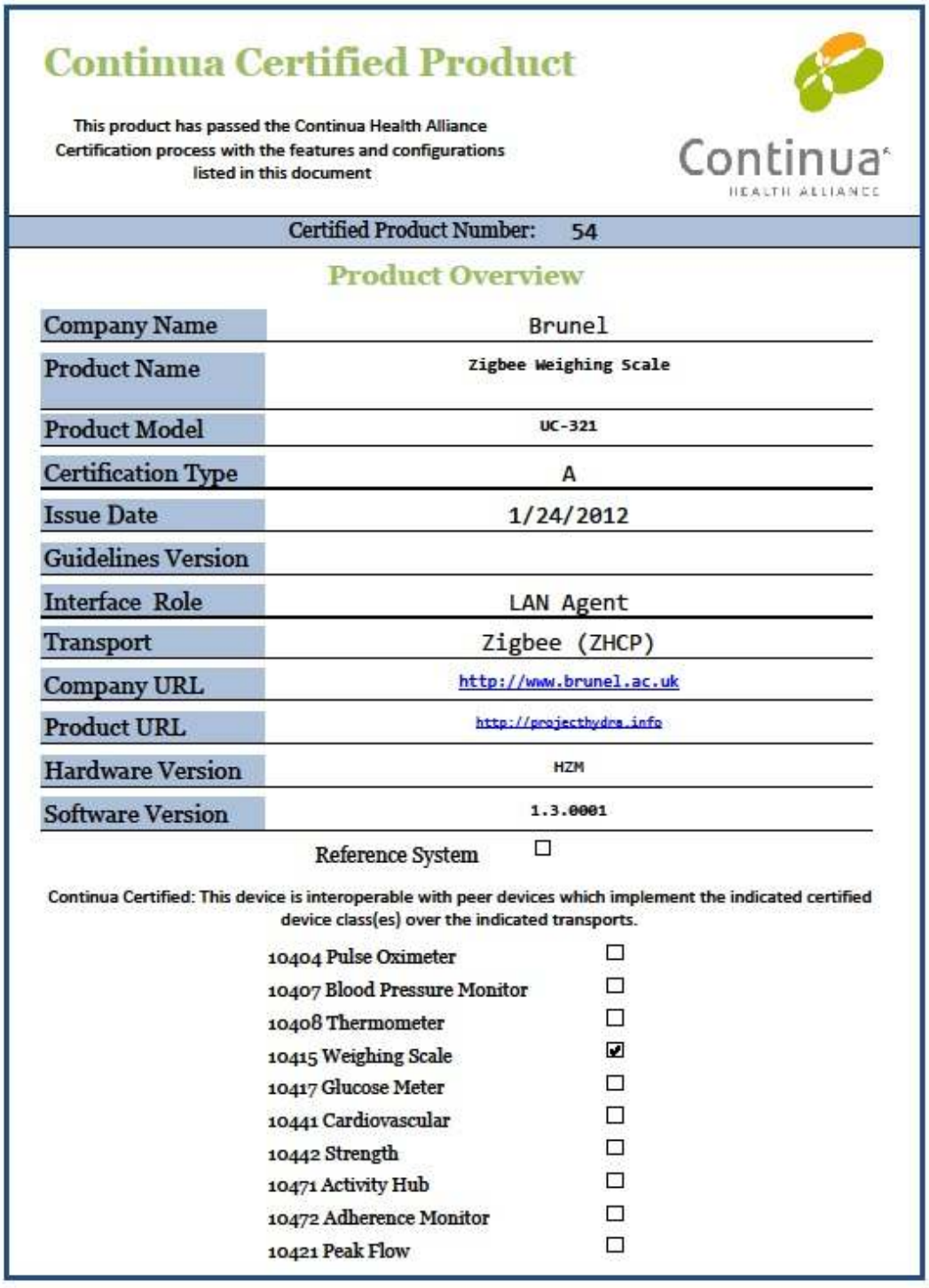
11.2 List of Tables

12 References

(Schaller, 2013) Schaller et al., CPT Pharmacometrics & Syst. Pharmacol. (2013) 2, e65; doi:10.1038/psp.2013.40

13 Appendix 1 – Certificates of Conformance

13.1 Continua Conformance – Weighing Scale



Continua Certified Product

This product has passed the Continua Health Alliance Certification process with the features and configurations listed in this document

Continua HEALTH ALLIANCE

Certified Product Number: 54

Product Overview

Company Name	Brunel
Product Name	Zigbee Weighing Scale
Product Model	UC-321
Certification Type	A
Issue Date	1/24/2012
Guidelines Version	
Interface Role	LAN Agent
Transport	Zigbee (ZHCP)
Company URL	http://www.brunel.ac.uk
Product URL	http://projecthydra.info
Hardware Version	HZM
Software Version	1.3.0001

Reference System ☐

Continua Certified: This device is interoperable with peer devices which implement the indicated certified device class(es) over the indicated transports.

10404 Pulse Oximeter	☐
10407 Blood Pressure Monitor	☐
10408 Thermometer	☐
10415 Weighing Scale	☑
10417 Glucose Meter	☐
10441 Cardiovascular	☐
10442 Strength	☐
10471 Activity Hub	☐
10472 Adherence Monitor	☐
10421 Peak Flow	☐

13.2 Continua Conformance – PIR (Motion Sensor)

Continua Health Alliance Authorized Test Lab

AT4 wireless, S.A.
Parque Tecnológico de Andalucía,
c/ Severo Ochoa nº 2
29590 Campanillas/ Málaga/ España
Tel. 952 61 91 00 - Fax 952 61 91 13
MÁLAGA, C.I.F. A29 507 456
Registro Mercantil de Málaga, Tomo 1169,
Libro 82, Folio 133, Hoja MA3729

TEST REPORT
REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.002**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-01-31
Identification of item tested :	PIR (Motion Sensor)
Trademark :	Optex
Model and/or type reference :	Optex Ex-35R
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-142
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10471™ – Independent Living Activity Hub
Description :	PIR (Motion Sensor)

13.3 Continua Conformance – Simple Medication Dispenser

Continua Health Alliance Authorized Test Lab

AT4 wireless, S.A.
Parque Tecnológico de Andalucía,
c/ Severo Ochoa nº 2
29590 Campanillas/ Málaga/ España
Tel. 952 61 91 00 - Fax 952 61 91 13
MÁLAGA, C.I.F. A29 507 456
Registro Mercantil de Málaga, Tomo 1169,
Libro 82, Folio 133, Hoja MA3729

TEST REPORT
REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.001**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-01-31
Identification of item tested :	Simple Medication Dispenser (ILAH)
Trademark :	Pivotell
Model and/or type reference :	Carousel Mk3
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-53
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10471™ – Independent Living Activity Hub
Description :	Simple medication dispenser

Report N°: (NIE) 35174RBT.001 **Page 1 of 22** **2012-01-31**

13.4 Continua Conformance – Blood Pressure Monitor

Continua Health Alliance Authorized Test Lab	AT4 wireless, S.A. Parque Tecnológico de Andalucía, c/ Severo Ochoa nº 2 29590 Campanillas/ Málaga/ España Tel. 952 61 91 00 - Fax 952 61 91 13 MÁLAGA, C.I.F. A29 507 456 Registro Mercantil de Málaga, Tomo 1169, Libro 82, Folio 133, Hoja MA3729

TEST REPORT

REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.003**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-01-31
Identification of item tested :	Blood Pressure Monitor
Trademark :	A&D Co., LTD.
Model and/or type reference :	UA-767PBT
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-270
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10407™ – Blood Pressure Monitor
Description :	Blood Pressure Monitor

Report N°: (NIE) 35174RBT.003 Page 1 of 21 2012-01-31

13.5 Continua Conformance – Usage Sensor (Bed/Chair)

Continua Health Alliance Authorized Test Lab	AT4 wireless, S.A. Parque Tecnológico de Andalucía, c/ Severo Ochoa nº 2 29590 Campanillas/ Málaga/ España Tel. 952 61 91 00 - Fax 952 61 91 13 MÁLAGA, C.I.F. A29 507 456 Registro Mercantil de Málaga, Tomo 1169, Libro 82, Folio 133, Hoja MA3729

TEST REPORT

REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.004**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-03-14
Identification of item tested :	Usage sensor (bed) (ILAH)
Trademark :	Tynetec Ltd.
Model and/or type reference :	ZXT450
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-169
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10471™ – Independent Living Activity Hub
Description :	Usage Sensor (bed) (ILAH)

Report N°: (NIE) 35174RBT.004 **Page 1 of 23** **2012-03-14**

13.6 Continua Conformance – Blood Glucose Meter

Continua Health Alliance Authorized Test Lab

AT4 wireless, S.A.
Parque Tecnológico de Andalucía,
c/ Severo Ochoa nº 2
29590 Campanillas/ Málaga/ España
Tel. 952 61 91 00 - Fax 952 61 91 13
MÁLAGA, C.I.F. A29 507 456
Registro Mercantil de Málaga, Tomo 1169,
Libro 82, Folio 133, Hoja MA3729

TEST REPORT
REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.006**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-03-14
Identification of item tested :	Blood Glucose Meter
Trademark :	Lifescan (J&J)
Model and/or type reference :	One Touch Ultra 2
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-6 & 10163-135
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10417™ – Glucose Meter
Description :	Blood Glucose Meter

Report N°: (NIE) 35174RBT.006 **Page 1 of 24** **2012-03-14**

13.7 Continua Conformance – Standard Spot Pulse Oximeter

Continua Health Alliance Authorized Test Lab

AT4 wireless, S.A.
Parque Tecnológico de Andalucía,
c/ Severo Ochoa nº 2
29590 Campanillas/ Málaga/ España
Tel. 952 61 91 00 - Fax 952 61 91 13
MÁLAGA, C.I.F. A29 507 456
Registro Mercantil de Málaga, Tomo 1169,
Libro 82, Folio 133, Hoja MA3729

TEST REPORT
REFERENCE STANDARDS:

ISO/IEEE 11073-20601A™ -2010: Standard for Health Informatics – Personal Health Device Communication – Application Profile – Optimized exchange protocol

Continua Design Guidelines 2010

NIE :	**35174RBT.005**
Approved by (name / position & signature) :	N. Pérez Wireless Lab. Coordinator
Elaboration date :	2012-03-14
Identification of item tested :	Standard Spot Pulse Oximeter
Trademark :	Nonin
Model and/or type reference :	IPOD
Final Hardware Version :	HZM
Final Software Version :	1.3.0001
Serial number :	10163-131 & 10163-63
Features :	Device Role: Agent Supported Transports: ZigBee Device specializations supported: IEEE 11073-10404™ – Pulse Oximeter
Description :	Standard Spot Pulse Oximeter

13.8 ZigBee Conformance – Weighing Scale

Declaration of Conformity

For ZigBee Certified Programs

ZigBee® Control your world

Manufacturer

Company: BRUNEL UNIVERSITY
Address: KINGSTON LANE
City: UXBRIDGE
State:
Zip Code: UB8 3PH
Country: UK

Contact Name: MALCOLM CLARKE
Phone: +44 1895 265053
Fax:
Email: malcolm.clarke@brunel.ac.uk

Testing Type (select one)

☑ End Product - Public Application Profile Product
(Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
☐ End Product - Manufacturer Specific Profile

☐ Compliant Platform
(Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)

Product Name: UC-321
Product type: WEIGHING SCALE
Firmware version: 1.3.0001
Hardware version: M2M
Radio Chipset: RF231 (ATMEL)
Tested PHY/MAC version: BITCLOUD V1.12

End Product Information (required for end products)

Manufacturer SKU or unique part #: ARD UC-321
ZigBee Compliant Platform used: ATMEL
Feature Set used: ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

☐ NTS Corporation
☑ TRaC Global
☐ TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

M Clarke — By (Signature)
22/12/2011 — Date
M CLARKE — Print name

For the Test Service Provider

Serial number of test sample: 10163-73
By (Signature)
23-12-11 — Date
Richard Cooper — Print name

Document # 074895

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13.9 ZigBee Conformance – PIR (Motion Sensor)

Declaration of Conformity

For ZigBee Certified Programs

ZigBee
Control your world

Manufacturer

Company: BRUNEL UNIVERSITY
Address: KINGSTON LANE
City: UXBRIDGE
State:
Zip Code: UB8 3PH
Country: UK

Contact Name: MALCOLM CLARKE
Phone: +44 1895 265053
Fax:
Email: malcolm.clarke@brunel.ac.uk

Testing Type (select one)

- [x] End Product - Public Application Profile Product
  (Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
- [ ] End Product - Manufacturer Specific Profile
- [ ] Compliant Platform
  (Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)

Product Name: OPTEX-35R
Product type: PIR (MOTION SENSOR)
Firmware version: 1.3.0001
Hardware version: M2M
Radio Chipset: RF 231 (ATMEL)
Tested PHY/MAC version: BITCLOUD V1.12

End Product Information (required for end products)

Manufacturer SKU or unique part #: OPTEX-35R
ZigBee Compliant Platform used: ATMEL
Feature Set used: ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

- [ ] NTS Corporation
- [x] TRaC Global
- [ ] TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

M Clarke — By (Signature)
22/12/2011 — Date
M CLARKE — Print name

For the Test Service Provider

Serial number of test sample: 10163-142

R Cooper — By (Signature)
23-12-11 — Date
RICHARD COOPER — Print name

Document # 074895

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13.10 ZigBee Conformance – Simple Medication Dispenser

Declaration of Conformity

For ZigBee Certified Programs

ZigBee® Control your world

Manufacturer

Company: BRUNEL UNIVERSITY
Address: KINGSTON LANE
City: UXBRIDGE
State:
Zip Code: UB8 3PH
Country: UK

Contact Name: MALCOLM CLARKE
Phone: +44 1895 265053
Fax:
Email: malcolm.clarke@brunel.ac.uk

Testing Type (select one)

- [x] End Product - Public Application Profile Product
  (Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
- [ ] End Product - Manufacturer Specific Profile
- [ ] Compliant Platform
  (Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)

Product Name: CAROUSEL MK3
Product type: SIMPLE MEDICATION DISPENSER
Firmware version: 1.3.0001
Hardware version: H2M
Radio Chipset: RF231 (ATMEL)
Tested PHY/MAC version: BITCLOUD V1.12

End Product Information (required for end products)

Manufacturer SKU or unique part #: CAROUSEL MK3
ZigBee Compliant Platform used: ATMEL
Feature Set used: ZIGBEE PRO, ZIGBEE HEALTH CARE PROFILE

Test Service Provider

- [ ] NTS Corporation
- [x] TRaC Global
- [ ] TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

By (Signature) — Date: 20/12/2011

M CLARKE
Print name

For the Test Service Provider

Serial number of test sample: 10163-53

By (Signature) — Date: 23-12-11

RICHARD COOPER
Print name

Document # 074885

ZigBee Alliance • 2400 Camino Ramon, Suite 375 • San Ramon, CA 94583 • USA • Phone +1.925.275.6607 • www.zigbee.org

13.11 ZigBee Conformance – Blood Pressure Monitor

Declaration of Conformity

For ZigBee Certified Programs

ZigBee
Control your world

Manufacturer	Company: BRUNEL UNIVERSITY	Contact Name:	MALCOLM CLARKE
	Address: KINGSTON LANE	Phone:	+44 1895 265053
	City: UXBRIDGE	Fax:	
	State:	Email:	malcolm.clarke@brunel.ac.uk
	Zip Code: UB8 3PH		
	Country: UK		

Testing Type (select one)

- [x] End Product - Public Application Profile Product (Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.) HEALTH CARE 1.0
- [ ] End Product - Manufacturer Specific Profile
- [x] Compliant Platform (Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)	
Product Name:	A&D BLOOD PRESSURE MONITOR
Product type:	BLOOD PRESSURE MONITOR
Firmware version:	1.3.0001
Hardware version:	HZM
Radio Chipset:	RF231 (ATMEL)
Tested PHY/MAC version:	BITCLOUD V1.12
End Product Information (required for end products)	
Manufacturer SKU or unique part #:	UA767
ZigBee Compliant Platform used:	ATMEL
Feature Set used:	2.1 ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

- [ ] NTS Corporation
- [x] TRaC Global
- [ ] TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer		*For the Test Service Provider*	
		Serial number of test sample: 10163-270	
By (Signature)	Date 20/12/2011	By (Signature)	Date 23-12-11
Print name: M C CLARKE		Print name: RICHARD COOPER	

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13.12 ZigBee Conformance – Usage Sensor (Bed/Chair)

Declaration of Conformity

For ZigBee Certified Programs

ZigBee
Control your world

Manufacturer	Company:	BRUNEL UNIVERSITY	Contact Name:	M ALCOLM CLARKE
	Address:	KINGSTON LANE	Phone:	+44 1895 265055
	City:	UXBRIDGE	Fax:	
	State:		Email:	malcolm.clarke@brunel.ac.uk
	Zip Code:	UB8 3PH		
	Country:	UK		

Testing Type (select one)

- ☑ End Product - Public Application Profile Product
  (Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
- ☐ End Product - Manufacturer Specific Profile
- ☐ Compliant Platform
  (Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)	Product Name:	BED SENSOR
	Product type:	USAGE SENSOR
	Firmware version:	1.3.0001
	Hardware version:	M2M
	Radio Chipset:	RF231 (ATMEL)
	Tested PHY/MAC version:	BITCLOUD V1.12
End Product Information (required for end products)	Manufacturer SKU or unique part #:	2XT450
	ZigBee Compliant Platform used:	ATMEL
	Feature Set used:	ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

- ☐ NTS Corporation
- ☑ TRaC Global
- ☐ TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

M Clarke — By (Signature)
23/12/2011 — Date
M CLARKE — Print name

For the Test Service Provider

Serial number of test sample: 10163-15

[signature] — By (Signature)
23-12-11 — Date
RICHARD COOPER — Print name

Document # 074895

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13.13 ZigBee Conformance – Blood Glucose Meter

Declaration of Conformity

For ZigBee Certified Programs

ZigBee
Control your world

Manufacturer

Company: BRUNEL UNIVERSITY
Address: KINGSTON LANE
City: UXBRIDGE
State:
Zip Code: UB8 3PH
Country: UK

Contact Name: MALCOLM CLARKE
Phone: +44 1895 265053
Fax:
Email: malcolm.clarke@brunel.ac.uk

Testing Type (select one)

☑ End Product - Public Application Profile Product
(Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
☐ End Product - Manufacturer Specific Profile

☐ Compliant Platform
(Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)

Product Name: ONE TOUCH ULTRA 2 BLOOD GLUCOSE METER DOCKING STATION
Product type: BLOOD GLUCOSE METER
Firmware version: 1.3-0001
Hardware version: H2m
Radio Chipset: RF231 (ATMEL)
Tested PHY/MAC version: BITCLOUD V1.12

End Product Information (required for end products)

Manufacturer SKU or unique part #: ONE TOUCH ULTRA 2
ZigBee Compliant Platform used: ATMEL
Feature Set used: ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

☐ NTS Corporation
☑ TRaC Global
☐ TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

By (Signature) — Date: 20/12/2011

M CLARKE
Print name

For the Test Service Provider

Serial number of test sample: 10163-6

By (Signature) — Date: 23-12-11

RICHARD COOPER
Print name

Document # 074895

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13.14 ZigBee Conformance – Standard Spot Pulse Oximeter

Declaration of Conformity

For ZigBee Certified Programs

ZigBee
Control your world

Manufacturer

Company: BRUNEL UNIVERSITY
Address: KINGSTON LANE
City: UXBRIDGE
State:
Zip Code: UB8 3PH
Country: UK

Contact Name: MALCOLM CLARKE
Phone: +44 1895 265053
Fax:
Email: malcolm.clarke@brunel.ac.uk

Testing Type (select one)

- [x] End Product - Public Application Profile Product
  (Specify the profile here: e.g. ZigBee Smart Energy, ZigBee Remote Control, etc.)
- [ ] End Product - Manufacturer Specific Profile
- [ ] Compliant Platform
  (Feature Set - e.g. ZigBee Pro, ZigBee RF4CE, etc.))

Product Information (required for all products)

Product Name: STANDARD SPOT PULSE OXIMETER (NONIN 1POD)
Product type: PULSE OXIMETER
Firmware version: 1.3.0001
Hardware version: M2.1M
Radio Chipset: RF231 (ATMEL)
Tested PHY/MAC version: BITCLOUD V1.12

End Product Information (required for end products)

Manufacturer SKU or unique part #: NONIN 1POD
ZigBee Compliant Platform used: ATMEL
Feature Set used: ZIGBEE PRO, ZIGBEE HEALTHCARE PROFILE

Test Service Provider

- [ ] NTS Corporation
- [x] TRaC Global
- [ ] TUV Rheinland Group

The manufacturer herewith declares that the above product has been assessed and found compliant to the test program selected below. The tests have been performed by a ZigBee Alliance authorized test service provider. The tested specimen is identical to the marketed product (excluding test modes used for the compliance testing). The manufacturer will notify the ZigBee Alliance in the event that the product is being modified. Retesting might apply.

For the Manufacturer

By (Signature) — Date: 20/12/2011

M CLARKE
Print name

For the Test Service Provider

Serial number of test sample: 10163-131

By (Signature) — Date: 23-12-11

RICHARD COOPER
Print name

Document # 074895

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14 Appendix 2 – In-Hospital Internal Test Reports

14.1 Unit Test Reports

ID	Name	Number PASSED	Number SKIPPED	Number FAILED
SC_B01	PatientWebService	17	0	0
SC_B02	PatientDataManagementWebService	68	0	0
SC_B03	UserWebService	12	0	0
SC_B04	DrugWebService	8	0	0
SC_B05	EnrolmentWebService	29	0	0
SC_B06	TherapyWebService	89	0	0
SC_B07	MeasurementWebService	64	0	0
SC_B08	MedicationWebService	38	0	0
SC_B09	NutritionWebService	30	0	0
SC_B10	BasalBolusTherapyRegimenHandlerWebService	127	0	0
SC_B11	TaskManagementWebService	66	0	0
SC_B12	RecentActivitiesWebService	5	0	0
SC_B13	ConfigurationWebService	89	0	0
SC_B14	SharedCommon	113	0	0
SC_B16	FrameworkUtility	7	0	0
SC_B17	PrintWebService	61	0	0
SC_I01	HL7v2Interface	103	0	0

Table 27: Unit test results – backend

Unit Tests	
Test Case ID	**Test Case Name**
TC_PatientManagementTests_0	testCheckActivityActionBar
TC_PatientManagementTests_1	testCheckPatientListDefaultPresentation
TC_PatientManagementTests_2	testCheckPatientListWithoutPatients
TC_PatientManagementTests_3	testPatientListOnClickListener
TC_PatientManagementTests_4	testSortAndFilteringPatientLists
TC_PatientEnrolmentTests_0	testCheckPatientEnrolmentActivityActionBar
TC_PatientEnrolmentTests_1	testCheckPatientEnrolmentActivityInUpdateMode
TC_PatientEnrolmentTests_2	testCheckPatientEnrolmentActivityWithAlreadyEnrolledPatient
TC_PatientEnrolmentTests_3	testCheckPatientEnrolmentActivityWithNeverEnrolledPatient
TC_TaskManagementTests_0	testCheckCorrectPresentationOfTasks
TC_TaskManagementTests_1	testCheckTaskListWithoutPatients
TC_TaskManagementTests_2	testCheckTaskListWithoutTasks
TC_TaskManagementTests_3	testCheckTaskManagementActivityActionBar
TC_TaskManagementTests_4	testTaskListOnClickListener
TC_StartScreenTests_0	testCheckStartScreenActivityActionBar
TC_GMMainScreenTests_0	testCheckGMMainScreentActivityActionBar
TC_GMMainScreenTests_1	testCheckPatientDetailsInBasalBolusRegimen
TC_GMMainScreenTests_2	testCheckPatientDetailsInBasalBolusRegimenWithDeactivatedDSS
TC_GMMainScreenTests_3	testCheckPatientDetailsInNonSupportedRegimen
TC_GMMainScreenTests_4	testCheckPermissionsInBasalBolusRegimen
TC_GMMainScreenTests_5	testCheckPermissionsInNonSupportedRegimen
TC_GlucoseTableTests_0	testCheckGlucoseTable
TC_GlucoseProfileTests_0	testCheckGlucoseProfile
TC_FullScreenTests_0	testCheckPatientDetailsInFullScreen
TC_FullScreenTests_1	testCheckTherapyProfileContainsAllExpectedPoints
TC_FullScreenTests_2	testCheckTherapyProfileScaling
TC_BGMeasurementTests_0	testCheckBGMeasurement

TC_BasalBolusInsulinAdministrationTests_0	testCheckInsulinAdministrationInBasalBolus
TC_NonSupportedInsulinAdministrationTests_0	testCheckInsulinAdministrationInNonSupported
TC_TherapyAdjustmentTests_0	testCheckDailyDoseAdjustment
TC_BasalBolusTherapySettingsTests_0	testCheckBasalBolusTherapySettings
TC_BasalBolusTherapySettingsTests_1	testCheckBasalBolusTherapySettingsWithDeactivatedDSS
TC_NonSupportedRegimenTherapySettingsTests_0	testCheckNonSupportedTherapySettings
TC_TaskUpdaterServiceTests_0	testIsTaskUpdaterServiceIsStartable
TC_TaskUpdaterServiceTests_1	testServiceTestCaseSetUpProperly
TC_TaskUpdaterServiceTests_2	testAndroidTestCaseSetupProperly
TC_BroadcastServiceTests_0	testIsBroadcastServiceIsStartable
TC_BroadcastServiceTests_1	testServiceTestCaseSetUpProperly
TC_BroadcastServiceTests_2	testAndroidTestCaseSetupProperly
TC_AndroidIndependentUtilsTests_0	testDateFormatUtilMethods
TC_AndroidIndependentUtilsTests_1	testFilterActivitiesByLastVersion
TC_AndroidIndependentUtilsTests_2	testGetInformationAboutLastBGMeasurement
TC_AndroidIndependentUtilsTests_3	testGetLastTherapyDate
TC_AndroidIndependentUtilsTests_4	testGetMillisecondsForHours
TC_AndroidIndependentUtilsTests_5	testGetProductCodeOfOrderedInsulin
TC_AndroidIndependentUtilsTests_6	testIsActualBGAvailable
TC_AndroidIndependentUtilsTests_7	testParseDateUtilMethods
TC_YesNoDialogTests_0	testYesNoDialogFunctionality
TC_AddTaskDialogTests_0	testCheckAddTaskDialogFunctionality
TC_CalcDailyInsulinDoseDialogTests_0	testCalcDailyInsulinDoseDialogFunctionality
TC_ChartPointInfoDialogTests_0	testChartPointInfoDialogFunctionalityWithBG
TC_ChartPointInfoDialogTests_1	testChartPointInfoDialogFunctionalityWithBGInHistoryMode
TC_ChartPointInfoDialogTests_2	testChartPointInfoDialogFunctionalityWithBolusInsulin
TC_ChartPointInfoDialogTests_3	testChartPointInfoDialogFunctionalityWithNutrition
TC_DailyInsulinDoseDialogTests_0	testDailyInsulinDoseDialogFunctionality
TC_DateTimeDialogTests_0	testDateTimeDialogFunctionality
TC_ListOperatorDialogTests_0	testListOperatorDialogFunctionality
TC_ListSelectorDialogTests_0	testListOperatorDialogFunctionality
TC_MessageDialogTests_0	testMessageDialogFunctionality
TC_RangeDialogTests_0	testRangeDialogFunctionality
TC_RootDialogTests_0	testRootDialogWithFunctionality
TC_SelectBasalBolusInsulinDialogTests_0	testSelectBasalBolusInsulinDialogFunctionality

TC_SelectFreeInsulinDialogTests_0	testSelectFreeInsulinDialogFunctionality
TC_SelectTabletsDialogTests_0	testSelectTabletsDialogFunctionality
TC_TaskDetailsDialogTests_0	testTaskDetailsDialogFunctionalityWithBG
TC_TaskDetailsDialogTests_1	testTaskDetailsDialogFunctionalityWithDocRA
TC_TaskDetailsDialogTests_2	testTaskDetailsDialogFunctionalityWithMedication
TC_TaskDetailsDialogTests_3	testTaskDetailsDialogFunctionalityWithTA
TC_TextInputDialogTests_0	testTextInputDialogFunctionality
TC_WheelPickerDialogTests_0	testWheelPickerDialogFunctionality
TC_DateDialogTests_0	testDateDialogFunctionality

Table 28: Unit tests – frontend

Unit Tests	
Test Case ID	**Test Case Name**
PROFILE_PERSISTENCE_01	**ProfilePersistence_GMSUser**
PROFILE_PERSISTENCE_02	**ProfilePersistence_Identity**
PROFILE_PERSISTENCE_03	**ProfilePersistence_KeyStore**
PROFILE_PERSISTENCE_04	**ProfilePersistence_Profile**
PROFILE_PERSISTENCE_05	**ProfilePersistence_RoleAssignment**
PROFILE_PERSISTENCE_06	**ProfilePersistence_Role**
PROFILE_PERSISTENCE_07	**ProfilePersistence_Settings**
PDP_01	**PDP_configuration_01**
PDP_02	**PDP_configuration_02**
PDP_03	**PDP_configuration_03**
PDP_04	**PDP_configuration_04**
PDP_05	**PDP_user_01**
PDP_06	**PDP_user_02**
PDP_07	**PDP_user_03**
PDP_08	**PDP_user_04**
PDP_09	**PDP_user_05**
PDP_10	**PDP_user_06**
PDP_11	**PDP_user_07**
PDP_12	**PDP_user_08**
PDP_13	**PDP_user_09**
PDP_14	**PDP_user_10**
PDP_15	**PDP_webservice_01**
PDP_16	**PDP_webservice_02**
PDP_17	**PDP_webservice_03**
PDP_18	**PDP_operation_01**
PDP_19	**PDP_operation_02**
PDP_20	**PDP_operation_03**
PDP_21	**PDP_operation_04**
PDP_22	**PDP_operation_05**
ANDROID_01	**ANDROID_voidScanner**
TS_PMS_GET_PROFILE_01	**PMS_GET_PROFILE_loginBackend**
SSA_01	**SSA_endpointMatchingAndTransformation**

SSA_02	**SSA_configurationFileEndpointTransformation**
SSA_03	**SSA_trustAnchorExclusion**
SSA_04	**SSA_syntaxCheckAndVariableSubstition**
SSA_05	**SSA_trustAnchorMatching**
SSA_06	**SSA_certPathValidation**
SOAP_01	**SOAP_messageProcessing**
UTILITY_01	**UTILITY_PBKDF**
UTILITY_02	**UTILITY_streamEncryption**
UTILITY_03	**UTILITY_X509CertificateDigest**
XML_01	**XML_XMLEncodingCheck**
XML_02	**XML_SOAPEncodingCheck**
CXF_MESSAGE_EXCHANGE_01	**CXF_messageExchangeCheck**
BOOTSTRAPPING_TOOL_01	**Check admin section of Bootstrap tool - clean**
BOOTSTRAPPING_TOOL_02	**Check admin section of Bootstrap tool - import of roles**
BOOTSTRAPPING_TOOL_03	**Check admin section of Bootstrap tool - import of default settings**
BOOTSTRAPPING_TOOL_04-13	**Check admin section of Bootstrap tool - missing or invalid parameters**
BOOTSTRAPPING_TOOL_14	**Check device section of Bootstrap tool - clean**
BOOTSTRAPPING_TOOL_15-16	**Check device section of Bootstrap tool - import of device identity and role**
BOOTSTRAPPING_TOOL_17-27	**Check device section of Bootstrap tool - missing or invalid parameters**
BOOTSTRAPPING_TOOL_28-29	**Check user section of Bootstrap tool - import user profile and role**
BOOTSTRAPPING_TOOL_30	**Check user section of Bootstrap tool - replace user profile and role**
BOOTSTRAPPING_TOOL_31	**Check user section of Bootstrap tool - delete user profile and role assignment**
BOOTSTRAPPING_TOOL_32	**Check user section of Bootstrap tool - delete user profile and role assignment**
BOOTSTRAPPING_TOOL_33-46	**Check user section of Bootstrap tool - missing or invalid parameters**
TS_PASSWORD_CHANGE_01	**Password reset by an administrator**
TS_PASSWORD_CHANGE_02	**Successful password change by a user**
TS_PASSWORD_CHANGE_03	**Failed password change by a user**

Table 29: Unit tests – security environment

14.2 Integration Test Reports

ID	Name	Number PASSED	Number SKIPPED	Number FAILED
SC_B01	PatientWebService	17	0	0
SC_B02	PatientDataManagementWebService	56	0	0
SC_B03	UserWebService	12	0	0
SC_B04	DrugWebService	6	0	0
SC_B05	EnrolmentWebService	29	0	0
SC_B06	TherapyWebService	69	0	0
SC_B07	MeasurementWebService	54	0	0
SC_B08	MedicationWebService	38	0	0
SC_B09	NutritionWebService	30	0	0
SC_B10	BasalBolusTherapyRegimenHandlerWebService	127	0	0
SC_B11	TaskManagementWebService	55	0	0
SC_B12	RecentActivitiesWebService	5	0	0
SC_B13	ConfigurationWebService	89	0	0
SC_B14	SharedCommon	113	0	0
SC_B16	FrameworkUtility	7	0	0
SC_B17	PrintWebService	51	0	0
SC_I01	HL7v2Interface	103	0	0

Table 30: Integration test results – backend

Component Tests	
Test Case ID	**Test Case Name**
TC_IntegrationTests_0	test01UserManagement
TC_IntegrationTests_1	test02ConfigurationManagement
TC_IntegrationTests_2	test03HistoryManagement
TC_IntegrationTests_3	test04GlucoseManagement
TC_IntegrationTests_4	test05PatientManagement
TC_IntegrationTests_5	test06TaskManagement
TC_IntegrationTests_6	test07TherapySettings
TC_IntegrationTests_7	test08TherapyVisualization
TC_IntegrationTests_8	test09DSSNewDailyDoseCalculation
TC_IntegrationTests_9	test10DSSPartialDoseCalculation

Table 31: Integration test results – frontend

Component Tests	
Test Case ID	**Test Case Name**
PROFILE_PERSISTENCE_INT_01	**ProfilePersistence_addKeyStore**
PROFILE_PERSISTENCE_INT_02	**ProfilePersistence_deleteKeyStore**
PROFILE_PERSISTENCE_INT_03	**ProfilePersistence_getAccessControlUser**
TS_PKI_01	**InvalidClientCertificate**
TS_PKI_02	**InvalidServerCertificate**
TS_ACC_MISCONFIGURATION_01	**ACC_Misconfiguration_PolicyFileNotFound**
TS_ACC_MISCONFIGURATION_02	**ACC_Misconfiguration_SchemaFileNotFound**
TS_ACC_MISCONFIGURATION_03	**ACC_Misconfiguration_InvalidPolicyFile**
TS_ACC_MISCONFIGURATION_04	**ACC_Misconfiguration_PersistenceManagerDatabase**
TS_ACC_MISCONFIGURATION_05	**ACC_Misconfiguration_PEPInterceptorBean**
TS_ACC_PROFILE_PERSISTENCE_01	**ACC_ProfilePersistence_CertificateNotFound**
TS_ACC_PROFILE_PERSISTENCE_02	**ACC_ProfilePersistence_NoRolesAssigned**
TS_ACC_PROFILE_PERSISTENCE_03	**ACC_ProfilePersistence_RoleDefinitionInconsistency**
TS_ACC_PDP_01	**ACC_PDP_GrantedPermissionTest**
TS_ACC_PDP_02	**ACC_PDP_RoleHierarchyTest**
TS_ACC_PDP_03	**ACC_PDP_DeniedPermissionTest**
TS_ACC_NO_SSL_01	**ACC_NoSSL_PositiveEmptyRoleTest**
TS_ACC_NO_SSL_02	**ACC_NoSSL_NegativeEmptyRoleTest**
TS_PMS_MISCONFIGURATION_01	**PMS_Misconfiguration_MissingLibraryFile**
TS_PMS_MISCONFIGURATION_02	**PMS_Misconfiguration_MissingApplicationContext**
TS_PMS_GET_USER_INFO_01	**PMS_getUserInfo_NoUserNameAssigned**
TS_PMS_GET_USER_INFO_02	**PMS_getUserInfo_InvalidUserNameAssigned**
TS_PMS_GET_USER_INFO_03	**PMS_getUserInfo_HTTPTest**
TS_PMS_GET_USER_INFO_04	**PMS_getUserInfo_PositiveTest**
TS_SSA_01	**SSA_BootStrapping**
TS_SSA_02	**SSA_DeviceProfileAvailability**
TS_SSA_03	**SSA_MissingDeviceIdentity**
TS_SSA_04	**SSA_OpenTasksTest**
TS_PMS_GET_PROFILE_01	**PMS_getProfile_AccessDenied**
TS_PMS_GET_PROFILE_02	**PMS_getProfile_PositiveTest**

Table 32: Integration test results – security environment

14.3 System Test Reports

System Test Case ID		Description	Test case successful (Yes/No)
	ST_TS01: testGeneralFunctionality		
ST_TS01-01		WIFI signal strength stats	Yes
ST_TS01-02		Device Battery Status Stats	Yes
ST_TS01-03		Device Time Stats	Yes
ST_TS01-04		Implausible checks	Yes
ST_TS01-05		Close application	Yes
ST_TS01-06		Refresh Wi-Fi connection	Yes
	ST_TS02: testUserManagement		
ST_TS02-01		Automatic Logout	Yes

ST_TS02-02		No multiple dialogs during user login	Yes
	ST_TS03: testTaskManagement		
ST_TS03-01		Auto-generation Open Tasks	Yes
ST_TS03-02		Add task blood glucose measurement	Yes
ST_TS03-04		Control of hypoglycaemic measurement	Yes
ST_TS03-05		Resolve task	Yes
ST_TS03-06		Continuous Task Update	Yes
ST_TS03-07		Critical Task Expired	Yes
ST_TS03-08		No multiple items in task preview	Yes
ST_TS03-09		No new tasks shortly before end time of measurement or medication task period	Yes
ST_TS03-10		Generation of daily dose adjustment-tasks	Yes
	ST_TS04: testPatientManagement		
ST_TS04-01		Viewing patients lists	Yes
ST_TS04-02		Patient Enrolment	Yes
ST_TS04-03		Update of Enrolment	Yes
ST_TS04-04		Patient withdrawal	Yes
ST_TS04-05		Sort and filter patient list	Yes
	ST_TS05: testHistoryManagement		
ST_TS05-01		View history of performed activities	Yes
ST_TS05-02		Extend recent activities list	Yes
ST_TS05-03		Filter recent activities list	Yes
ST_TS05-04		View details of performed activities in history	Yes
ST_TS05-05		Edit/Delete recent activities in history	Yes
ST_TS05-06		Edit recent activity – only comment	Yes
	ST_TS06: testTherapyVisualization		
ST_TS06-01		Patient Details in Basal/Bolus regimen	Yes
ST_TS06-02		Patient Details in non-supported regimen	Yes
ST_TS06-03		View last therapy activities in chart visualization	Yes
ST_TS06-04		View last therapy activities in tabular form	Yes
ST_TS06-05		View details of performed activities in therapy profile	Yes
ST_TS06-06		View activity details in therapy profile, which are located next to each other	Yes
	ST_TS07: testTherapySettings		
ST_TS07-01		Initialize Basal/Bolus regimen	Yes

ST_TS07-02		Initialize non-supported therapy	Yes
ST_TS07-03		Manually change to non-supported therapy	Yes
ST_TS07-04		Adjust therapy in Basal/Bolus regimen	Yes
ST_TS07-05		Adjust therapy settings in non-supported therapy	Yes
ST_TS07-06		Therapy Settings in Basal/Bolus regimen with deactivated DSS	Yes
	ST_TS08: testGlucoseManagement		
ST_TS08-01		Add blood glucose measurement	Yes
ST_TS08-02		Back-dated blood glucose measurement	Yes
ST_TS08-03		Add Basal/Bolus insulin administration	Yes
ST_TS08-04		Add non-supported insulin/OAD medication	Yes
ST_TS08-05		Adjust daily dose	Yes
ST_TS08-06		Perform DSS Reactivation	Yes
ST_TS08-07		Remind current state in main screen	Yes
ST_TS08-08		Overrule Suggested Basal dose	Yes
	ST_TS09: testChangeManagement		
ST_TS09-01		Edit/Delete blood glucose measurement in therapy profile	Yes
ST_TS09-02		Edit/delete insulin/OAD administration details in therapy profile	Yes
ST_TS09-03		Second user realizes changeover to non-supported therapy	Yes
ST_TS09-04		Second user realizes deactivation of DSS	Yes
	ST_TS10: testDecisionSupport		
ST_TS10-01		DSS Daily Dose adjustment	Yes
ST_TS10-02		DSS Initial Daily Dose	Yes
ST_TS10-03		DSS Basal/Bolus Inulin Dose	Yes
	ST_TS11: testPrintService		
ST_TS11-01		Print service	Yes
	ST_TS12: testConfigurationService		
ST_TS12-01		Configuration service	Yes
	ST_TS13: testHL7AndHIS		
ST_TS03-01		Admit and enrol patient	Yes
ST_TS03-02		transfer patient	Yes
ST_TS03-03		discharge patient	Yes

Table 33: System test results