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m-Health System for Life-style Enhancement: WiFIT

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***Abstract*— In this paper we present a novel m-health system which provides personalized real-time recommendations for life-style enhancement. The system, termed WiFIT, is capable of monitoring a wide range of the *a priori* defined biometric parameters and generates recommendations for achieving or maintaining the desired health and life-style goals. WiFIT is designed as an open platform which could be as complex or as simple as required for a particular application. Its key components include secure wireless broadband links, personal area body area sensory network, and an interactive data base with built-in prediction algorithms. The paper describes the WiFIT architecture and outlines system performance for certain case studies.**

Keywords- Life Style Ehnacement, Wi-FIT, m-health, healthcare.

I. INTRODUCTION

The benefits of a healthy lifestyle are well known, including longer life as well as better physical and psychological well-being. It is now established and proven that 'being healthy' is not simply about exercise and low-fat foods, but it is a complex of a series of factors comprising of a combination of an active life-style, good nutrition and awareness and limits to 'bad' habits such as alcohol intake and smoking. These factors reduce the risks associated with cardiovascular disease amongst others, and have been shown to help us live well for longer. In this paper we introduce a novel system, named "Wi-FIT" which considers individual users in terms of their baseline health and current physical state in combination with nutrition, physical and psychological well-being.

The rest of this article is organized as follows: section II presents general overview of the proposed system (Wi-FIT) and explains system functionality through a number of user case scenarios. Section III describes the overall system architecture while Section IV outlines the generic communications network architecture where simulation results for a particular case of WiMAX networks are present. Finally, in conclusion, we summarize the results and discuss the open problems.

II. WI-FIT SYSTEM OVERVIEW

Wi-FIT [1] is a complex express-diagnostics system which utilizes secure and robust wireless links [2] to collect and analyses the individual's personal data based upon health factors such as nutrition, current physical activity and physical state as well as sleep patterns and psychological health. It is then able to produce a series of visual, easy to understand life-style recommendations to suit the individual's goals. These recommendations are generated as nutritional advice, exercise videos and generic psychological recommendations. The recommendations are based upon results of real-time monitoring and analysis of the required biometric parameters, for example heart rate, blood pressure and blood glucose readings. Wi-FIT can also be used by the individual's medical practitioner who can have access to the produced data via Bluetooth for e.g. and thus provide further input towards the improvement of the overall health-state of the user. The individual profiles of the users are constantly updated and new recommendations are generated in accordance with the changes in user's conditions or on the achievement of the pre-defined targets (for example weight loss, physical fitness).

The system architecture is flexible by design and can be tuned for various groups of users - starting from healthy people and spanning to cover elderly people and patients with various dysfunctions and diseases.

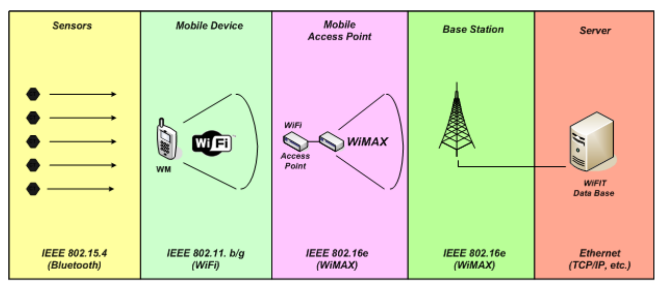

Figure 1. Wi-FIT General Diagram

Figure 1 illustrates the most typical example when individual sensors are connected to a personal body area Bluetooth network, which in turn provides connectivity to a personal handset device (smart phone), while both the local area network (WiFi) and metropolitan area network (MAN) are used for communications between the user, the data base and the expert system.

III. WI-FIT: PRINCIPLE OF OPERATION.

The WiFIT protocol consists of the following three steps:

1. *Diagnostics* of vital signs based on personal data;
2. *Recommendations* of an individual program based on diagnostics results, personal goals, and requirements;
3. *Control* and assessment of the progress and continuous adjustment of the individual programme according to achieved results and outcome of embedded predictions algorithms.

The interrelation between the main components of Wi-FIT is presented in Figure 2 and explained bellow.

A. Diagnostics - Personal data

The first step for every new user starts with personal data input, including age, height, weight, background medical history and 'bad habits' such as smoking status and alcohol intake.

Data is entered via a dedicated secure interface which can be downloaded to a smart phone as a WiFIT application.

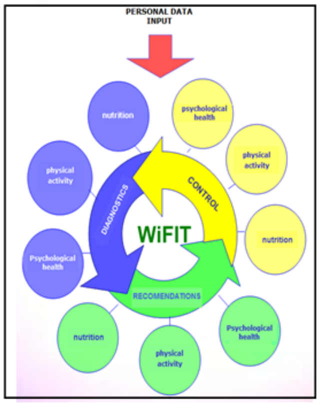

Figure 2. Wi-FIT Principle of Operation

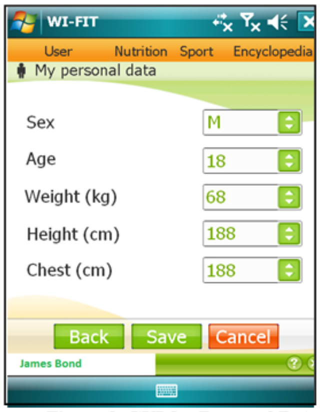

Figure 3. GUI for Personal Data Entry Stage

Data can be entered manually by typing or through voice recognition system. A typical graphic user interface (GUI) for Personal Data entry stage, implemented on a Smartphone, is shown in Figure 3. The initial diagnostics is performed by the dedicated proprietary software operating on Windows Mobile platform and includes personal data processing, nutrition diagnostics, physical state diagnostics, and psychological state diagnostics.

1) Diagnostics – Nutrition

Figure 4. GUI for Nutrition Diagnostic Stage

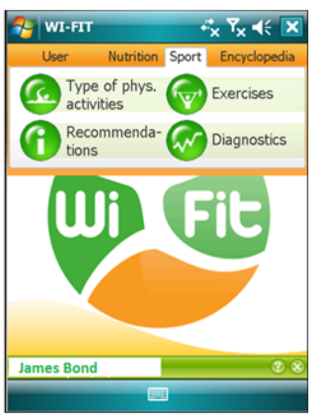

Figure 5. GUI for Physical Diagnostic Stage

The nutrition section of WiFIT involves analysis of a series of nutritional data which is entered by the user including all consumed products over a series of set days (chosen by the user). The product is able to produce an individual nutritional programme based upon the various aspects of the individual's nutrition including, calorie content of each product, nutritional advice of each product as well as suggested recipes which can be tried by the individual. Typical GUI for nutrition diagnostics stage is shown in Figure 4.

2) Diagnostics - Physical State

To fulfill the physical state of diagnostics the user should pass through the series of tests which will assess person's physical condition and abilities. During the tests the program provides the user with visual and sound assistance. A number of short video clips with different recommended exercises will be made available for download. Typical GUI for Physical state diagnostics is shown in Figure 5. If required, WiFIT will support data reading directly from the biometric sensors (example, wireless pulse oximeter), ensuring real time and accurate monitoring of the required biometric parameters. WiFIT's modular architecture provides complete flexibility and allows rapid adaptation to different groups of users: people with various diseases (hypertension, diabetes etc.) or people with special requirements (aged, frequent travelers, etc.).

The following wireless sensors are supported by the current release of the system: Blood pressure monitor, Electronic body scale, Peak-flow meter, Pulse-oximeter, Heart rate monitor, Blood glucose monitor, ECG monitor.

These are incorporated into a generalized wireless biometric sensor as mentioned in Figure 1. Such integration allows more efficient use of bandwidth resources, reduces interference between the various sensors, reduces measurement latency and improves overall system robustness, usability, and security.

There are embedded tests which are supported by the system such as Gurevich test (heart rate after exercise stress); Test "Steps" (heart rate adjustment after exercise stress); Serkin test (breath holding time before and after exercise stress); Flexibility and power tests; Physical state diagnostics for people with various dysfunctions and diseases, which should be done under medical supervision.

In addition, system architecture allows inclusion of any other desired tests, which could be incorporated as an individual application or as a built-in function.

3) Diagnostics - Emotional state

Emotional health has been shown to be a vital part of an overall healthy lifestyle. This is measured by various parameters which are entered by the user, including sleep pattern, the Luscher colour test [3] as well as various concentration tests to build an overall picture of the user's current psychological state which can then be integrated along with the physical and nutritional data:

B. Individual Recommendations

The second stage of the algorithm involves the analysis of the received sensory data and data entered by the user in order to produce a personalized life-style programme to suit each individual. This is performed by utilizing obtained information describing nutrition, physical health, and current fitness level as well as emotional well-being. The programme starts by showing the user his/her current health state in comparison with people of similar gender, age, height and weight. WiFIT recommendations are based on extended data base which is self-content and includes products and dishes, divided into nutrients (currently over

6000 items and constantly increasing); «Exercise series" (video films with voice assistance); Recommendations on vitamins and minerals; Recipe-books; Relaxation multi-media content (films, music, electronic books).

In addition, system supports an option for interaction with external data bases from other similar programs [4].

WiFIT data base is also used for predicting user conditions in a *priory* defined time intervals. Based on the collected data and prediction results, an advice on nutritional factors as well as a tailored exercise programme (available as a set of short video clips on WiFIT website) will be generated. This includes recommendations on the duration and intensity of the exercises, using videos and voice assistance. To expedite and simplify nutrition data entry, WiFIT supports 2D reading and barcode scanning, allowing accurate measurements of consumed food. This is achieved with the help of customized OCR Mobile software, which extracts chemical product composition from the 2D code, as shown in Figure 7.

The individual programme is continuously updated and will change in accordance with the data entered by the user. As physical fitness improves and nutritional information changes this will be analysed in the programme to change the advice and information available to the user as well as to show their progress.

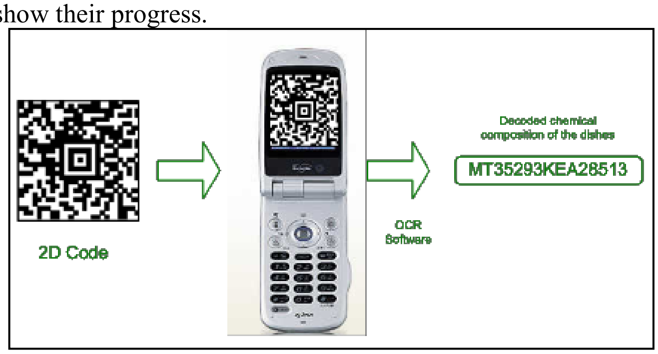

Figure 7. Wi-FIT Nutrition Database Entry

C. *Control of individual program*

The final stage is the continuous real-time control and update based on new biometric measurements, entered data and prediction results generated by the system. WiFIT data base incorporates Bayesian network protocols developed and implemented in aviation for monitoring and predicting the "health" of an aircraft [7]. Therefore, any non-desirable effects (for example, rapid deterioration of health) could be predicted and prevented by the system.

IV. WIFIT WIRELESS NETWORK ARCHITECTURE

As mentioned above, there are numerous products on the market, providing recommendations for a healthy lifestyle and well-being. However, the majority of these products operates off-line or does not support real-time interactive feedback recommendations. Partially, this is due to a lack of reliability, robustness, and security of wireless communication capabilities embedded within the system. The WiFIT system architecture allows incorporation of various wireless communication platforms, from wired to wireless, enabling real-time monitoring, user mobility and immediate access to the required data.

One of the key features of WiFIT's network architecture is support of seamless integration of different communication protocols, as shown in Figure 1. It is apparent that running WiFIT service on the existing MAN will require significant throughputs and potentially could affect the performance of the other network services as it can potentially data fusion process from multiple sensors. At the same time, as WiFIT relies on the transmission of multimedia information with various degrees of priority and importance (for example, video clips demonstrating exercises, real time biometric data, or nutrition recommendations), the overall throughput requirements can be reduced by assigned various levels of QoS to different types of data. As shown in [5,6], up to 30% of throughput requirements could be saved by splitting the data into 3 separate elementary traffic streams and assigning different priorities and QoS to different streams. The same concept is implemented in WiFIT, minimizing bandwidth requirements and operation cost.

In order to evaluate WiFIT performance, we developed and tested the model with the direct functional correlation between the data streams and QoS scheduling categories offered in WiMAX. We assumed that every Elementary Sreat (ES) with its QoS set can refer to a certain IEEE 802.16 Meadium Access Connection (MAC) identified for the related service class UGS, rtPS, nrtPS, etc. which is associated with the specific healthcare application. Thus, this approach means that the stream required for delivery of a data flow generated from a defined object with specific behavior would get appropriate scheduling service with the specific QoS-based application requirements.

In the first scenario, which represents the conventional approach [5], we establish three connections with different service classes, as indicated in Table 1. Figure 9 shows the simulation results for the scenario and is presented in Table 1.

Figure 9 illustrates simulation results for WiMAX based network architecture. Table 2 shows the simulation parameters for the second scenario, where the developed technique of stream splitting is applied. The aim of this simulation is not only to test the technique but also to compare its performance over the conventional transmission scenario 1 and demonstrate the advantages of the developed technique.

As shown in Table 2 both UGS and rtPS streams were split according to the developed video distribution technique. For example, in scenario 2.1 of Table 2, the total UGS load of 2Mbps is divided into two UGS streams of 1Mbps each.

Furthermore, the original 1Mbps connection served by rtPS service is separated into two streams. These streams are ertPS and BE with data rates 0.6Mbps and 0.4 Mbps respectively. In scenarios 2.2 and 2.3 (Table 2) the original UGS traffic rate is unchanged and the BE rate is constant throughout the whole simulation set.

Figure 10 shows comparative results in terms of summary throughput gain (system capacity gain), achieved for the second scenario in agreement with the parameters presented in Table 2. The percentage gain is calculated based on the comparison of the average summary throughputs of conventional scenario with summary throughput results, obtained for the presented segmentation set scenarios:

$$T = T_{initial}/T_{segmented},\ (\%) \qquad (1)$$

where $T_{initial}$ - is the summarized throughput for the initial video stream; $T_{segmented}$ – is the summarized throughput for segmented scenarios.

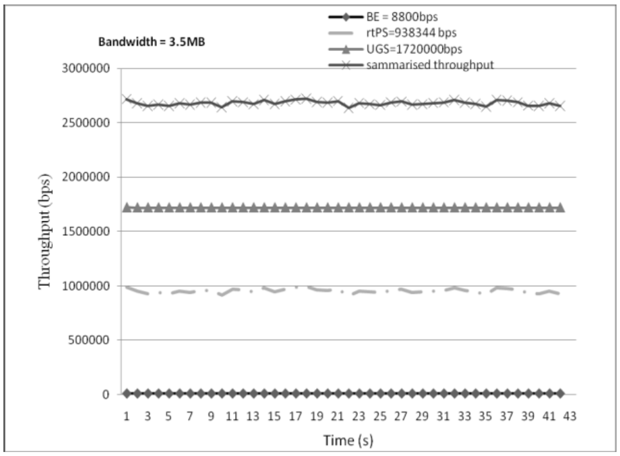

Figure 9. Throughput comparison for the first (conventional) Scenario

As it can be seen from Figure 10 the proposed stream splitting algorithm when applied to WiFIT for WiMAX-based network architecture can provide up to 13% throughput gain in comparison with the conventional transmission scheme. This traffic capacity gain can be translated into the provision of additional services on the existing network or increase of number of users.

TABLE I. TEST PARAMETERS FOR THE FIRST SCENARIO

Service Class	Type M-Health Data to be Transmitted	Packet size, Byte	Data rate, Mbps
UGS	Live Teleconference (video)	200	2
rtPS	Medical Video Transmission (surgery, tutorial, presentation, video consultation)	150	1
BE	Request to the Database	40	0.02

TABLE II. SIMULATION PARAMETERS

Parameters / Scenario	UGS 1, load, Mbps	UGS2 load, Mbps	ertPS load, Mbps	rtPS load, Mbps	BE1 load, Mbps	BE2 load, Mbps	load Mbps	Total BDW, Mb
№2.1	1	1	0.6	0	0.4	0.02	3.02	4
№2.2	2	0	0.4	0.5	0.1	0.02	3.02	4
№2.3	2	0	0.3	0.5	0.2	0.02	3.02	4

$$T_{initial} = \sum_{i=1}^{n} T_i = T_{UGS} + T_{rtPS} + T_{BE} \qquad (2)$$

where T_{UGS}, T_{rtPS}, T_{BE} – throughput results for UGS, rtPS and BE connections respectively.

$$T_{segmented} = \sum_{i=1}^{n}\sum_{k=1}^{m} T_{ik} \qquad (3)$$

where *i* – number of service groups, *k* – number of segmented streams within each service group.

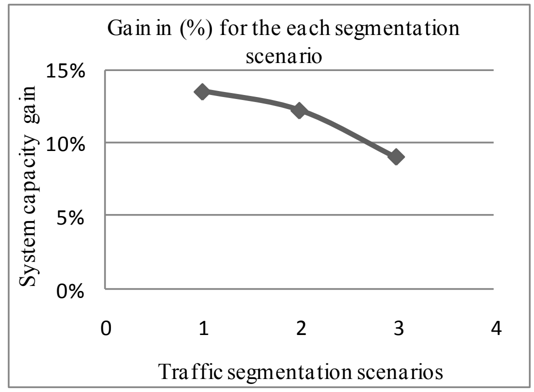

Figure 10. System bandwidth gain for the Scenario Presented in Table I

V. CONCLUSIONS

In this paper we described a novel m-health system (termed WiFIT) which provides personalized real-time recommendations for life style enhancement. The system is capable of monitoring a wide range of the *a priori* defined parameters and generating recommendations for achieving or maintaining the desired goals. WiFIT is designed as an open platform architecture which includes secure wireless broadband links, personal area body area sensory network, and interactive data base with build-in prediction algorithms. In order to minimize throughput requirements, WiFIT incorporates traffic splitting and QoS mapping, providing up to 13% savings in the overall throughput requirements without performance degradation.

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