35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Improving Quality of Experience in M-health Monitoring System

Da Xu, Chenguang He, and Ye Li*, *Member, IEEE*

Abstract—**Quality of Experience (QoE) is proposed to evaluate user's overall satisfaction with the network system and services. For m-health systems, improving QoE means starting from user's view to make patients and doctors (the main users of m-health system who are especially captious to services related to health) to achieve best satisfaction. In this paper, we proposed an improved model for QoE of m-health systems based on energy consumption and information integrity received by the users, and then explore on how the users' satisfaction with m-health systems' energy consumption and received information integrity by exponential formula, which is influenced by the quantity of the transmitted information. Finally, from the results of simulation, we concluded that the appropriate compression of information quantity is the best way to improve QoE performance of the m-health system.**

I. Introduction

M-health is healthcare technique that uses mobile equipment. Using m-health monitoring technology, people can observe their physiological signals anywhere at any time, such as photoplethysmograph (PPG) signals, electrocardiogram (ECG) signals and body temperature etc. This is very important for the health of people. In recent years, more and more m-health applications appear around us. However, until now, m-health systems have not been prevalent as supposed. The main constraint is the experiences of existing m-health monitoring services do not match users' expectation. For a long time, the main promoters of m-health, telecommunication equipment manufactures and operators, are using Quality of Service (QoS) to estimate the quality of m-health monitoring system [1]. QoS indexes are delay, jitter and loss tolerance. QoS cannot evaluate users' feeling with services, so an m-health monitoring system driven by QoS often cannot satisfy users' specific experience requirements.

Quality of Experience (QoE) is proposed to measure user's synthetic feeling about the device, network, system and applications. The best way to popularize the m-health applications is to raise users' satisfaction with them during operation. For m-health system, QoE is a standard, reflecting the gap between existent service and users' expectation. People are always harsh and prudent for health-related services, so if they feel uncomfortable, they'll give up the idea of keeping on and distrust the data given by m-health monitoring system. If we want to design m-health monitoring system that users are willing to use, increasing QoE degree is crucial that we have to take QoE into account before we start designing m-health monitoring systems.

Recently, some studies on QoE have been presented. Gong et al. proposed a pentagram model for measuring QoE degree [2]. They proposed 5 factors contributed to the QoE degree of a service. But they don't link these factors with objective measurable parameters. An adaptation scheme that is QoE-driven for optimizing content provisioning and network resource utilization for video applications over wireless networks has been proposed [3]. Unfortunately, this design is not for m-health applications.

Among m-health applications, energy consumption [4] affects QoE seriously. The battery capacity of mobile devices is usually limited, so if m-health devices' energy consumption is too heavy, it will lead to interruptions of service and reduce QoE greatly as a result. Information integrity [5] received by users is also crucial because if users only receive part of the medical information, their experience for this monitoring service will be damaged.

In our research, the management of original medical information will influence energy consumption of m-health systems as well as the information integrity. We proposed some models to describe the correlations among the sensor's management of original information, energy consumption, information integrity and QoE. Through theoretical derivations and simulations, we propose an optimal transmitting compress mechanism in wireless m-health system considering health information integrality and energy consumption issues to achieve the optimum QoE performance.

II. System Model And Problem Formulation

A. Mobile Health Scenario

At present, plenty of m-health systems are proposed [6] [7]. A generic m-health monitoring system's architecture is illustrated in Figure 1 for example. The user wears several information acquisition sensors on the body and the sink node receives information collected by physiological sensors. After preprocessing of original information, the managed information is transmitted to display device directly (e.g. a

*This work is supported by the Improvement and Development of Key Lab in Shenzhen under Grant CXB201104220026A, National Natural Science Foundation of Youth Science Foundation under Grant 81101127, and in part by the Comprehensive Strategic Cooperation Projects for Guangdong Province and Chinese Academy of Sciences under Grant 2011A090100025.

D. Xu and C. He are all with the Key Laboratory for Health Informatics of Chinese Academy of Sciences, and with Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China. They are also with the University of Chinese Academy of Sciences, Beijing 100049, China.(e-mail:{da.xu, cg.he}@siat.ac.cn).

Y. Li is with the Key Lab for Health Informatics of Chinese Academy of Sciences, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China (Corresponding author, +86-755-86392201, e-mail: ye.li@siat.ac.cn).

mobile phone or a pad), or to the back servers via telecommunication networks or Internet for further processing. Anyway, the user can get the information of his body whichever the path they adopted.

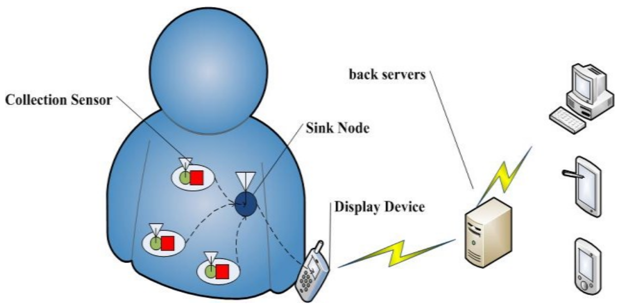

Figure 1. Architecture for m-health monitoring [8]

B. QoE Model

In [2], Gong et al. proposed a pentagram model for measuring QoE degree, which can be computed as:

$$QoE = \frac{1}{2}\sin(\lambda)(a \cdot b + b \cdot c + c \cdot d + d \cdot e + e \cdot a), \tag{1}$$

where λ represents the 72-degree angle between the two sides in the QoE pentagram model, and *a, b, c, d* and *e* denote service availability, service usability, service integrality, service retainability, and service instantaneousness, respectively.

The five parameters *a, b, c, d* and *e* reflect users' experience of different aspects of the service. For m-health services, integrality (*c*) is used to measure how much information users get from m-health monitoring service [9]. For example, a doctor hope to get patients' daylong body temperature data, but m-health monitoring cluster node only transmit 18-hours data to him, which transmits 75% information of user's expectation, so user's experience for information integrality of this service would not be 100%. Here, we take user experience for m-health monitoring service's information integrality as QoE for Information Integrity (QoE_Inf); retainability (*d*) describe user experience for how long the monitoring can last, so it can be regarded as QoE for Energy Consumption (QoE_Eng). So that

$$QoE = \frac{1}{2}\sin(\lambda)(a \cdot b + b \cdot QoE\_Inf + QoE\_Inf \cdot QoE\_Eng + QoE\_Eng \cdot e + e \cdot a), \tag{2}$$

C. System Model

Information Integrity Received By User: Users receive medical information from sink sensor node (cluster sensor) in monitoring system. The information integrity of one monitoring service is decided by the information quantity users receive from cluster sensor [10]. Cluster sensor manages original information collected by acquisition sensors and then transmits managed information to users.

In [11], the authors point out that user experience of a service follows the logarithmic laws, and QoE function can be modeled in the logarithmic form. However, the QoE in [10] only focuses on the aspect of information integrity, apart from the synthetic user experience for the whole system. So we adopt the QoE for Information Integrity as the logarithmic function between r_i and r in m-health system, which is specified as

$$QoE\_Inf(r_i, r) = a_1 \ln\frac{a_2 r_i}{r}, \tag{3}$$

where the constant parameters a_1 and a_2 are both positive and vary according to the information type the system transmits. r_i is the actual transmit information quantity and r is the excepted information quantity.

Energy consumption influence on QoE Model: In m-health monitoring system, the energy consumption is a key factor influences user experience that can not be ignored [11]. QoE varies with energy consumption, and the trend map is given as Figure 2 [12].

We normalized QoE for Energy Consumption as 0~1, when $QoE\_Eng = 1$, it means users feel completely satisfied while $QoE\_Eng = 0$ means the user are completely unsatisfied. The bigger the value of QoE_Eng is, the more satisfied the user will be about the energy consumption performance of the system.

When the energy consumption is less than threshold *A* (means the whole monitoring time of the system is lasting long enough), *QoE* for Energy Consumption always stay at high level; on the contrary, if the energy consumption is more

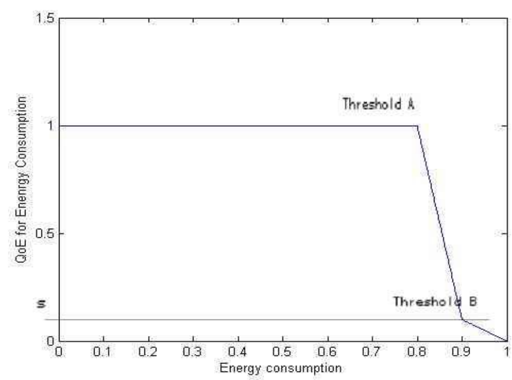

Figure 2. Linear approximation for Relationship between the *QoE* and remained energy

than threshold *A*, QoE_Eng will drop acutely. In addition, when the energy consumption is more than threshold *B* (means the monitoring service cannot last for a very short time), the user has accepted the fact that the system would power off soon. So, QoE for Energy Consumption will drop slowly but in a very low level. In summary, the relationship between the QoE for energy of the system and the remained energy is shown in Figure 2. Here *s* is the value of QoE for Energy Consumption when the energy consumption of the system is *B*.

Mathematically, the relationship shown in Figure 2 is as follows:

$$QoE\_Eng = \begin{cases} 1 & (NEC < A) \\ \frac{1-s}{A-B}(NEC - A) + 1 & (A < NEC < B) \\ \frac{s}{B-1}(NEC - 1) & (B < NEC < 1), \end{cases} \quad (4)$$

where *NEC* means Normalized Energy Consumed in one monitoring service [13].

Problem Formulation: The QoE of one m-health monitoring service are influenced by the energy consumption and information integrity. Information integrity and energy consumption are both determined by the information quantity the users receiving during the service. To achieve the highest *QoE*, the problem can be formulated mathematically as the following constrained optimization problem：

$$Max: QoE = \frac{1}{2}\sin(\lambda)(a \cdot b + b \cdot QoE\_Inf(r_i, r) + QoE\_Inf(r_i, r) \cdot QoE\_Eng + QoE\_Eng \cdot e + e \cdot a),$$
$$s.t: \quad r_{\min} < r_i < r_{\max},$$

where r_{min} and r_{max} stand for the minimum and maximum of information quantity transmitted to users in a system, respectively. It is limited by the hardware configuration and software scheme of the m-health monitoring system.

III. Optimal Transmission Driven By QoE

In this section, we will set some values to formulae to investigate the influence of transmitting medical information quantity on the QoE in a m-health monitoring system.

The research problem is to calculate the appropriate information quantity transmitted to users in one monitoring service. First, we suppose *r* as 1, if the information quantity user received in line with his expectation, i.e. r_i= 1; if exceeds expectation, then r_i> 1; if it is below expectation, then r_i< 1. For ease of calculation, we take a_1 equals 1 and a_2 equals 10, so that when information quantity reaches user's expectation, the QoE for the information integrity equals 1 which represents users are completely satisfied with the information integrity of this service. So,

$$QoE\_Inf(r_i) = \ln 10 r_i. \quad (5)$$

The energy consumption for a completed service is positively related to the information quantity transmitted during the service. We propose

$$NEC = kr_i, \quad (6)$$

where *k* is the energy it consumes to transmit unit quantity of information. So QoE for Energy Consumption can be written as

$$QoE\_Eng = \begin{cases} 1 & (r_i < \frac{A}{k}) \\ \frac{1-s}{A-B}(kr_i - A) + 1 & (\frac{A}{k} < r_i < \frac{B}{k}) \\ \frac{s}{B-1}(kr_i - 1) & (\frac{B}{k} < r_i < \frac{1}{k}). \end{cases} \quad (7)$$

According to Figure 2, we take *A*=0.8, *B*=0.9, and *s*=0.1. Therefore, QoE for Energy Consumption can be written as

$$QoE\_Eng = \begin{cases} 1 & (r_i < 0.8) \\ -9r_i + 8.2 & (0.8 < r_i < 0.9) \\ -r_i + 1 & (0.9 < r_i < 1). \end{cases} \quad (8)$$

Substituting equation (5) and equation (8) into equation (2), the *QoE* of an m-health system is given by

$$QoE = \begin{cases} \frac{1}{2}\sin(\lambda)(\ln 10 r_i + a \ln 10 r_i \\ +b + ad + bd) & (r_i < 0.8) \\ \frac{1}{2}\sin(\lambda)((8.2 - 9r_i)\ln 10 r_i + a \ln 10 r_i \\ +(8.2 - 9r_i)b + ad + bd) & (0.8 < r_i < 0.9) \\ \frac{1}{2}\sin(\lambda)((1 - r_i)\ln 10 r_i + a \ln 10 r_i \\ +(1 - r_i)b + ad + bd) & (0.9 < r_i < 1). \end{cases} \quad (9)$$

We suppose *a=b=d=1*, which means the availability, usability and instantaneousness of the system have reached users' expectation.

So the overall *QoE* function is given by

$$QoE = \begin{cases} 0.4755(\ln r_i + \ln r_i + 3) & (r_i < 0.8) \\ 0.4755((8.2 - 9r_i)\ln r_i + \ln r_i \\ +(8.2 - 9r_i) + 2) & (0.8 < r_i < 0.9) \\ 0.4755((1 - r_i)\ln r_i + \ln r_i + (1 - r_i) \\ +2) & (0.9 < r_i < 1). \end{cases} \quad (10)$$

Thorough calculation, we find that *QoE* reaches the peak when $r_i = 0.8$. It means that we only need to offer 80% information quantity of user's expectation to make the total QoE of m-health system the maximum. When cluster node receives the information collected by collection sensors, it should do some data process. Through our model and derivations, the optimal size of the processed information has been given. It can be concluded that the QoE in m-health monitoring services is promoted definitely by opting for the optimal information transmission mechanism of the system.

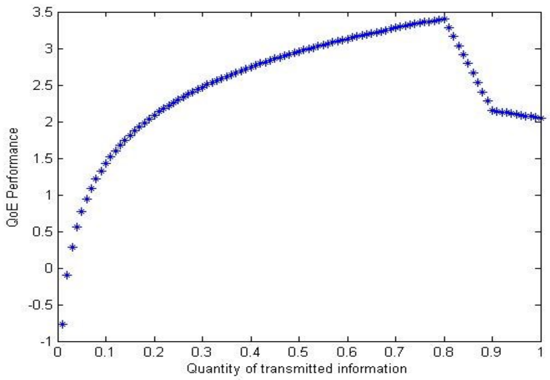

Figure 3. Variation of QoE degree along with the information quantity

From Figure 3, we conclude that for an m-health monitoring service, when the information quality transmitted to users is low, energy consumed in transmission keeps low and the service can run for a long time with the information integrity increases quickly. So the whole QoE increase in the end. When the transmitted information quantity reaches a threshold A, energy consumption reaches the level that makes m-health monitoring system to offer only limited service time, so user's experience for service retainability reduces more drastically than increase speed of QoE for information integrity, which leads to the reduction of synthetic QoE performance. The last curve after information quantity reaches threshold B indicates user's experience for service retainability is very low and even though the QoE for information integrity is very high, the synthetic QoE still keeps low. And this is coincident with our common sense.

IV. DISUSSION&CONCLUSION

In this paper, we investigated the problem of how to adapt the information collected by body sensors and transmit it to users for the highest QoE performance in m-health system. We propose new model, and figured out the optimal information quantity transmitted to users by the cluster sensor. In the future work, we will concentrate on how to find the practical parameters of these functions and the characteristics of different types of m-health monitoring services. Thus, we will establish the traffic model of m-health service and optimize the transmission mechanism according to the model.

REFERENCES

[1] D. Chen, and P. K. Varshney, "QoS support in wireless sensor networks: A survey," in International Conference on Wireless Networks (ICWN2004), Las Vegas, Nevada, USA, June 2004.

[2] Y. Gong, F. Yang, andL. S. S. Huang, "Model-based approach to measuring quality of experience," in First International Conference on Emerging Network Intelligence, pp. 29–32, 2009.

[3] A. Khan, L. Sun, E. Jammeh, and E. Ifeachor, "Quality of experience-driven adaptation scheme for video applications over wireless networks," *Communications* (IET),Volume 4, Issue 11, pp. 1337 – 1347, July 23 2010.

[4] A. Ksentini, and Y. Hadjadj-Aoul, "QoE-based energy conservation for VoIP over WLAN," in IEEE Wireless Communications and Networking Conference, pp. 1692-1697, 2012.

[5] L. Liu, W. Zhou, and J. Song, "Quantitative customer perception evaluation for telecommunication service," in Third International Conference of Pervasive Computing and Applications (CPCA), pp. 912-915, 2008.

[6] V. Jones, V. Gay, and P. Leijdekkers, "Body sensor networks for mobile health monitoring: experience in Europe and Australia," presented at Fourth International Conference on Digital Society, pp. 204-209, 2010.

[7] P. L. Benny L. S. Thiemjarus, R. King, and G.Z. Yang, "Body sensor network – a wireless sensor platform for pervasive healthcare monitoring," in Adjunct Proceedings of the 3rd International conference on Pervasive Computing, pp.77-80, May 2005.

[8] C He, X Fan, and Y Li, "Toward ubiquitous healthcare services with a novel efficient cloud platform," IEEE Transactions on Biomedical Engineering, Volume 60, Issue 1, pp.230-234.

[9] Y. W. Lee, D. M. Strong, B. K. Kahn, and R. Y. Wang, "AIMQ: a methodology for information Quality assessment," Information & Management, Volume 40, Issue 2, pp. 133–146, December 2002.

[10] P. Reichl, B. Tuffin, and R. Schatz, "Logarithmic laws in service quality perception: where microeconomics meets psychophysics and quality of experience," Telecommunication Systems, pp. 1–14, 2011.

[11] W. Eberle, B. Bougard, S. Pollin, and F. Catthoor, "From myth to methodology: cross-layer design for energy-efficient wireless communication," in 42nd Design Automation Conference, pp. 305-308, 2005.

[12] Y Li, B Bakkaloglu, and C Chakrabarti, "A system level energy model and energy-quality evaluation for integrated transceiver front-ends," IEEE Transactions on Very Large Scale Integration (VLSI) Systems, 15 (1), pp. 90-103.

[13] Y Li, M Reisslein, and C Chakrabarti, "Energy-efficient video transmission over a wireless link ," IEEE Transactions on Vehicular Technology 58 (3), 1229-1244.