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A Multimedia Telemedicine System in Internet of Things

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Abstract—With the health requirement increasing, telemedicine is turning from the idea into the reality. However most current telemedicine systems are actually implemented by traditional video conference tools, which is very reluctant to support more complex medical activities. So this paper argues that new generation telemedicine should be composed of two necessary parts: one is traditional multimedia consultation and the other is physiology data collecting and transmitting in real time. From this view, an integrated reference implementation is introduced, through which several crucial technologies are discussed including the multimedia streaming, secure communication and interoperability between the gateway of internet of things and medical peripherals.

Keywords- multimedia; telemedicine; interoperability; internet of things

1. Introduction

Telemedicine is defined by the WHO as "the practice of medical care using interactive audiovisual and data communications. This includes the delivery of medical care, diagnosis, consultation and treatment, as well as health education and the transfer of medical data [1]." In 1906, Wilhelm Einthoven experimented the first telemedicine by transmitting ECG recordings through telephone [2]. Since then, telemedicine has become routine practice for specialists to review remote patients' radiology and neurosurgery image [3]. Currently most telemedicine are actually implemented by video conference tools like Polycom.

However, this situation is not welcomed by some clinicians who rely more on physical examination data than imaging [4]. They object to such new models of working, especially when real time physiology data from patient is seriously needed but lacking in common video consultation. Real time life data feeding and transmitting in telemedicine must be overcome if telemedicine is to reach its potential.

As a new generation information technology, Internet of Things (IOT) [5][6][7] brings telemedicine new chance, which applies sensors and network to traditional medical devices, therefore is able to assign the intelligence to them, implement deeper communication and interaction between patients and remote specialists. Besides patients' benefit, IOT even helps entire health industry, in which wide scope of medical devices are connected to existing health network, patient crucial life signal is captured by sensors and transmitted to remote medical centre, and doctor is able to remotely monitor patient condition, provide medical suggestion and aiding [8][9]. By Forrester Research, the global telehealth and telemedicine market will reach $5 billion in 2010 and even $34 billion in 2015 [10][11][12][13][14]. To catch this huge business opportunity, many companies, institutes, universities and governments are pouring into IOT health area. In 2009, GE and Intel Corporation formed an alliance to market and develop home-based telehealth technologies including Intel® Health Guide, that will help seniors live independently and patients with chronic conditions manage their care from the comfort of their home or wherever they choose. IMEC has developed next generation wireless smart ECG (electrocardiography) necklace and wearable EEG (electroencephalography) headset, which relies on a ultra-low-power ASIC for the acquisition of the life sensing data, a low-power microcontroller and radio providing local processing and wireless communication functionalities.

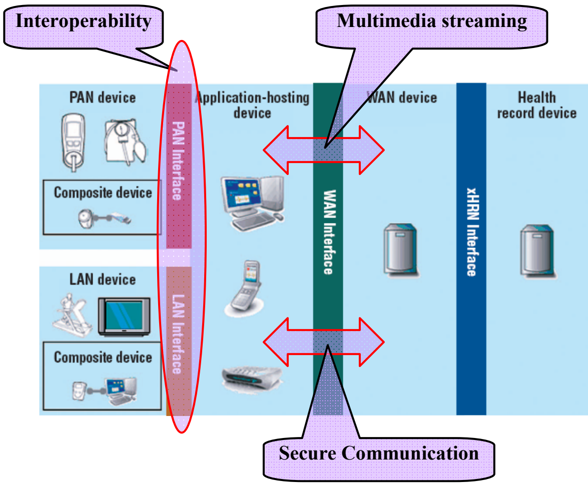

Figure 1. The crucial issues identified in CHA telemedicine architecture

This paper argues that new generation telemedicine should not only support multimedia consultation, but also integrate various medical peripherals through IOT gateway. So the paper introduces a simple integrated reference telemedicine system which helps in identifying and researching several crucial technological issues such as interoperability, multimedia streaming and secure communication. In Fig. 1, the discussed issues are identified in the architecture recommended by CHA (Continua Health Alliance) [15], an international authorized telemedicine and telehealth standard body. The interoperability issue majorly exists between PAN (Personal Area Network)/LAN (Local Area Network) health devices and IOT gateway which can be implemented on cell phone, PDA or set-top box and relays the data between peripheral medical devices and remote health service providers. The multimedia streaming issue stays between IOT gateway and remote backend WAN (Wide Area Network) devices which normally are specialists' own desktop PCs or laptops supporting multimedia distant communication. The last issue of secure communication is also located between IOT gateway and WAN devices which helps patients using IOT gateway and specialists using WAN devices in communicating more securely through either multimedia or command way.

The rest of the paper will discuss these technological issues and a telemedicine reference implementation.

2. Crucial Technologies

In this section, several crucial technologies of modern telemedicine are discussed including multimedia streaming, secure remote control and interoperability. To explain it better, a reference layered architecture of telemedicine is prompted in Fig. 2, in which multimedia streaming is supported by JAVA Multimedia Framework while secure remote control is powered by JAVA Remote Method Invoking model [16][17] and SSL security layer. For interoperability issue, ISO/IEEE 11073 health data standard [18], wireless communication health standard and wired communication health standard are discussed.

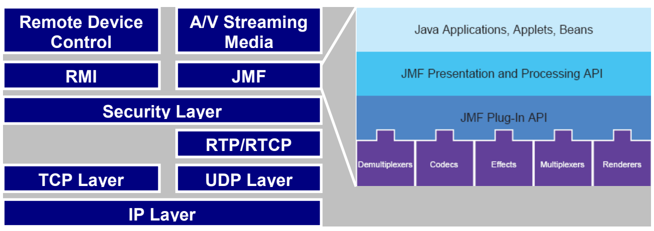

Figure 2. A telemedicine reference architecture

2.1 Multimedia streaming

As mentioned above, one of the basic roles in telemedicine system is multimedia consultation, so the streaming QoS (e.g. jitter and delay) between patient and remote specialist has great influence on distant medical service quality. However it is a tough job to maintain high quality real time streaming, some control mechanism has to be taken. Fig. 3 illustrates a streaming QoS control model based on RTP and RTCP protocols. In patient's part, the image and audio data is firstly captured and encoded by the DataSource object, and then pushed into a sending buffer which is under the control of SessionManager object. Later when network is available, the data in the buffer are sent to remote specialist's receiving buffer. Next, when the receiving buffer is full or waiting time is up, the data are pulled out and decoded by the DataSource object in the specialist part, and finally present or play to specialist. Like the counterpart of the patient, the specialist buffer is also completely controlled by SessionManager object which is the key to control the streaming QoS. For example, if SessionManager detects the jitter in current stream is too large through RTCP report, it is able to increase the size of buffer so as to smooth data flow, while it sometimes also reduces the buffer size to shorten the streaming delay.

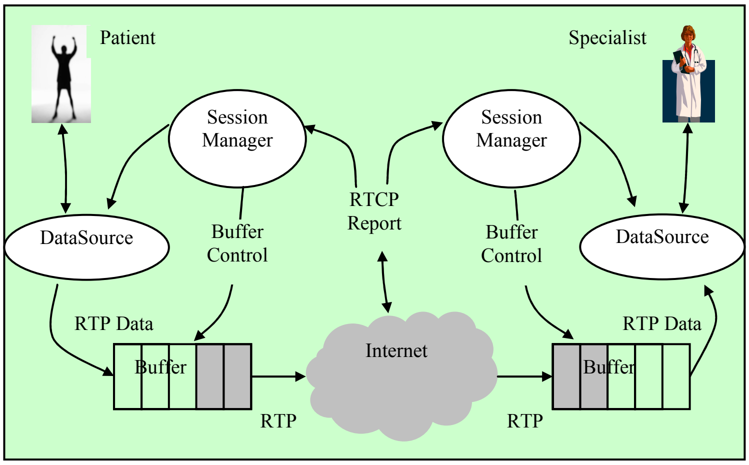

Figure 3. A streaming QoS control model

2.2 Secure communication

The communication between patient and specialist should be carefully secured because the data transmitted is very sensitive to privacy. The first type data needed to be secured is multimedia data like image and audio, however the encryption cost is expensive which consumes much CPU resource and always degrades the streaming quality. So in some situations, the special secure hardware has to be utilized to save the CPU computing. The other type of secured data is control command through which the specialist is capable of remotely and accurately operating the medical devices to access the patient situation. Unlike the multimedia data, these data is not CPU intensive, so more flexible communication methods can be utilized. One of the optimization communication solutions is the combination model of Remote Method Invoking (RMI) plus Secure Sockets Layer (SSL). RMI is based on distributed object model, in which the patient's medical device operations can be encapsulated in distributed object and published through IDL language on network. The specialist is able to easily access these distributed object through the stub generated automatically by IDL without requirement of considering underlying network marshalling and transmitting. While the SSL encryption and its related key exchange management can be seamlessly integrated with RMI, which is transparent to users and follows the same interface style as plain RMI.

2.3 Interoperability

Currently more and more people become accept the idea that real time data feeding should be greatly supported by telemedicine. However a more tough problem appears that is interoperability between IOT gateway and various medical peripheral devices [19]. Because of this, the integration of health data from different telemedicine and telehealth devices becomes complex and difficult, and hence discounts the benefit brought by IOT health application. For example, an ideal telemedicine system regularly needs to connect multiple medical devices, such as blood pressure meter, weighing scale, blood-glucose meter, pulse oximeter, ECG and pulmonary peak flow meter. While these medical devices are normally manufactured by different factories, the telemedicine system company has to contact and cooperate with multiple different device factories to develop as more devices services as possible. Moreover different factories could adopt different communication methods, such as Bluetooth, Infrared, USB, WiFi and serial port. While even they happen to take the same underlying transmission media, the upper data exchanging protocol is still perhaps different. So, it is really a headache issue for telemedicine system to deal with so much medical devices providers.

CHA suggests two layers structure for IOT health gateway interoperability: transplantation layer and data layer. On the transplantation layer, there are wireless communication health standard and wired communication health standard. In the rest of this section, the data layer and two types of transplantation layers are separately discussed.

1) Common Health Data standard

On the data layer of CHA architecture, ISO/IEEE 11073 Personal Health Data (PHD) standard is default adopted. IEEE 11073 PHD standard is composed of a set of protocols, designed to solve interoperability of personal health devices, including weighing scale, blood pressure meter and blood-glucose mete.

Firstly there is a common basic framework protocol, i.e. 11073-20601, which refers to application profile and optimized exchanging model. Some common data types, message types and communication models are defined here.

Then based on 11073-20601, other protocols are easily extended corresponding to specific medical devices, which means they only need to define the special data model corresponding to specific personal health device while sharing and keeping the common definition in the 11073-20601. This exhibits a modular design and makes better extensibility and more easily to add new medical devices support. Currently the supported specific medical devices include:

11073-10404 = Pulse Oximeter
11073-10406 = Pulse / Heart Rate
11073-10407 = Blood Pressure
11073-10408 = Thermometer
11073-10415 = Weighing Scale
11073-10417 = Glucose
11073-10441 = Cardiovascular Fitness Monitor
11073-10442 = Strength Fitness Equipment
11073-10471 = Independent Living Activity
11073-10472 = Medication Monitor

As to the architecture of IEEE 11073 PHD standard, there are several crucial features:

- Typical P2P structure: the medical device is called as "Agent", while IOT gateway acts as "Manager".
- Independence of underlying transplantation mechanism: it is convenient to transplant to a new underlying communication media.
- Object oriented model: it’s helpful in code reusing and new device support.
- Self description capability of Agent: it makes managers be able to understand agent property.
- Extensibility: it supports new agent type and existing defined agent customization.
- ASN.1 expression of data structure and message: it simplifies message analysis.

Under above architecture, IEEE 11073-20601 also defines three system model components:

- Domain Information Model (DIM)

It contains a group of objects expressing same agent; each object owns one or multiple properties; and the property is used to describe the measurement and state of Manager communication.

- Service Model

It provides several commands, such as Get, Set, Action and Event Report, which are transmitted between Agent and Manager, and exchange data with DIM.

- Communication Model.

It establishes state machine for Agent and Manger including connected, associated and operation. It can translate abstract data model in DIM into binary message format transmitted in Communication model.

2) Wireless Telehealth standard

In wireless communication telehealth standard, there are currently two sets of protocols, i.e. Bluetooth Health Device Profile (HDP) [20] and ZigBee Health Care^{TM} Profile [21].

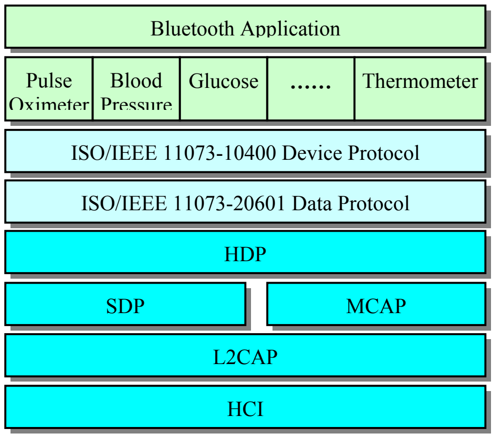

Figure 4. The federated Bluetooth health framework

Bluetooth HDP is a big contribution to the wireless health interoperability. While aforementioned IEEE 11073 specification has the feature of independence of underlying communication media, there is the possibility to integrate it with Bluetooth HDP (Fig. 4).

In this federated framework, MCAP means Multichannel Adaptation Protocol, HDP refers to Health Device Protocol, L2CAP presents Logical Link Control and Adaptation Protocol, HCI is Host Controller Interface, SDP stands for Service Discovery Protocol, they all belong to Bluetooth medical/health device standard. Among them, MCAP and L2CAP guarantee robust connection, support retransmit model, streaming model and interoperability requirement definition, while HDP provides Bluetooth application framework, specifies data exchange between source devices (like blood pressure meter, weighing scale and blood-glucose meter) and sink devices (e.g. cell phone, notebook and other embedded health equipment).

Several crucial technological issues have been identified in Bluetooth federated health framework:

- The standard and structure method to link and coordinate data channel through control channel;
- Timer synchronous mechanism with support of timestamp direct comparing;
- Energy effective reconnection method;
- Integration model between Bluetooth health protocol and ISO/IEEE 11073-20601 personal health data exchange protocol;
- The mechanism of SDP wireless discovering device type and application data type;
- More reliable behavior oriented to connection, which allows devices identify the problems and take actions when source devices move beyond communication scope;
- Multiple concurrent data communication channels mechanism.

Besides Bluetooth health standard, ZigBee also provides wireless health standard through its Health Care^{TM} Profile, although it is not listed in the CHA recommendation architecture. Like the Bluetooth standard, ZigBee health standard integrates with ISO/IEEE 11073 PHD standard, and also support some extra excellent features like strong security mechanism which can better meet medical and health requirement.

3) Wired communication health standard

For wired telehealth communication between gateway and peripheral medical devices, USB Personal Healthcare Device Class (PHDC) [22] is CHA's default recommending standard. It defines seamless interoperability between personal health device and USB host, which standardizes necessary functionalities of transmitting standard data and message from personal health devices to host through USB. Like the Bluetooth health standard, ISO/IEEE 11073-20601 protocol is also considered as data fundamental in USB PHDC framework.

To guarantee the Quality of Service (QoS) for different types of medical/health devices application under the USB PHDC framework, a special QoS describing and negotiating mechanism is also defined.

Additionally three basic data transmission models have been supported by USB PHDC, including episodic fashion, stored and forwarded fashion and continuous fashion. They are applied to different health situations: for example, a USB weight scale prefers to send sample data in episodic way, a USB pulse oximeter more often continuously monitors and sends patient's oxygen saturation level data, and a USB fitness watch would like to collect and store data throughout the exercise, and upload them to personal computer later when convenient.

4) Interoperability analysis

From above discussion, large progress has been achived in IOT gateway interoperability, however, there are still several crucial interoperability problems as followings:

- Security problem. Health and medical data is heavy security sensitive, in US there is strict HIPPA law to regulate their manipulation. However in previously discussed short distance health related standard, only ZigBee wireless health standard specifies security features, which is lack in the Bluetooth and USB.
- IPv6 support. In the near future, it can be predicted that IPv6 will be widely adopted even in health field. 6LoWPan [23][24][25] currently has become a more and more popular IPv6 solution for low power devices and personal area network. However, there are still no written health specifies in 6LoWPan.
- WiFi support. WiFi should be the most widely used wireless solution, many medical and health devices actually are equipped with WiFi module, so just like 6LoWPan there is no existing health standard to regulate its communication.
- Medical imaging. During telemedicine, multimedia image is very helpful and required. Some medical imaging standards have been established such as DICOM, but how to integrate it with other health standards introduced in this paper is a real problem.
- Integration with health/medical management standards. As a bridge between peripheral medical devices and backend health/medical management system, IOT health gateway still need to communicate with varies backend system complying with other standards like HL7 and EHR (Electronic Health Record). So the interaction between gateway and backend standard body of HL7 and EHR should also be standardized.

3. REFERENCE IMPLEMENTATION

Following the discussion in this paper, a telemedicine system is implemented, in which the IOT gateway takes USB as wired connection way to interact with surrounding medical devices [26][27]. The connected medical peripherals contain blood pressure meter, blood-glucose meter and heart rate meter. The IOT health gateway is currently implemented on a desktop PC with Windows XP and JMF/RMI/SSL employed to support multimedia consultation and secure communication. Fig. 5 demonstrates the interface of video/audio communication between patient and remote specialist, and interface of remote control on medical high definition camera.

Figure 5. Reference implementation

As a gateway implementation, desktop PC is obvious too large and not user friendly, although it is acceptable in the early experiments. So in the next plan, an embedded handheld SmartPad will be adopted as IOT gateway platform which is composed of 1 GHz CPU, 10 inches multiple touch points screen and Android mobile operating system [28][29]. And current JMF multimedia framework will be replaced by a smaller PV's Open Core multimedia framework [31] in Android environment.

4. Conclusion

This paper researches the crucial technological issues in current telemedicine which covers multimedia streaming, secure communication and interoperability of IOT health gateway. Especially in IOT gateway, there are several mainstream health standards discussed including ISO/IEEE 11073 PHD specifies and health communication protocols of Bluetooth, USB and ZigBee. Finally the reference implementation issue is discussed.

5. Acknowledgment

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6. References

[1] WHO website, http://www.who.int/eht/eHealthHCD/en/.

[2] D. Hailay, R. Roine, A. Ohinmaa, "Systematic review of evidence for the benefits of telemedicine," J Telemed Telecare, vol. 8. 2002, pp. 1–7.

[3] S. Stowe, S. Harding, "Telecare, telehealth and telemedicine," European Geriatric Medicine, vol. 1, 2010 , pp. 193–197.

[4] E. Rinde, L. Balteskard, "Is there a future for telemedicine?" Lancet, vol. 359, 2002, pp. 1957–8.

[5] L. Atzori, A. Iera and G. Morabito, "The Internet of Things: A survey," Computer Networks, vol. 54, 2010, pp. 2787–2805.

[6] International Telecommunication Union (ITU), "ITU Internet Reports 2005: The Internet of Things," Geneva, Nov. 2005.

[7] COMMISSION OF THE EUROPEAN COMMUNITIES, "Internet of Things — An action plan for Europe", Brussels, Jun. 18, 2009.

[8] S. C. Wu, et al., "The development of a tele-monitoring system for physiological parameters based on the B/S model," Computer in Biology and Medicine, 2010, doi:10.1016/j.compbiomed.2010.09.009.

[9] Y. F. Ding, et al., "A biomedical sensor system for real-time monitoring of astronauts' physiological parameters during extra-vehicular activities," Computer in Biology and Medicine, vol. 40, 2010, pp. 635-642.

[10] X. M. Zhang, "A Semantic Grid Oriented to E-Tourism," IEEE Proc. The First International Conference on Cloud Computing (CloudCom 2009), Beijing, LNCS 5931, Dec. 2009, pp. 485-496.

[11] X. M. Zhang, C. Xu, "A Semantic E-Tourism Framework Based on Cloud-computing," IEEE Proc. The 2010 International Conference on Management Science and Information Engineering, Zhengzhou, Dec. 2010, in press.

[12] Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, "National Health Care Expenditures Data", Jan. 2008. http://www.cms.hhs.gov/nationalhealthexpenddata/

[13] Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, "Costs of Chronic Disease". http://www.cdc.gov/nccdphp/overview.htm

[14] S. Wild, "Global Prevalence of Diabetes, Estimates for the year 2000 and projections for 2030," Diabetes Care, vol. 27, 2004, pp. 1047–1053.

[15] R. Carroll, R. Cnossen, M. Schnell and D. Simons, "Continua: An Interoperable Personal Healthcare Ecosystem," IEEE Pervasive Computing, vol. 6, no. 4, Oct-Dec, 2007, pp. 90-94.

[16] X. M. Zhang, H. M. Wang and Q. Y. Wu, "High performance virtual distributed object," Journal of Computer Research and Development (Supplement), 2000, pp. 102-107.

[17] X. M. Zhang, Q. Y. Wu, H. M. Wang and Y. Jia, "A Dynamic Scalable Asynchronous Message Model Based on Distributed Objects," Computer Engineering and Science, vol. 3, 2002, pp. 48-50.

[18] L. Schmitt, T. Falck, F. Wartena and D. Simons, "Novel ISO/IEEE 11073 Standards for Personal Telehealth Systems Interoperability," 2007, pp. 146-148.

[19] The Continua Health Alliance, http://www.continuaalliance.org/

[20] Bluetooth Medical Working Group press release, http://www.bluetooth.com/Bluetooth/Press/SIG/BLUETOOTH_SIG_AIMS_TO_IMPROVE_HEALTHCARE_EXPERIENCE_THROUGH_INTEROPERABILITY.htm

[21] ZigBee Health Care Working Group, “ZigBee Health CareTM Profile 1.0,” Mar. 2010.

[22] USB Personal Healthcare Device Profile, http://www.usb.org

[23] A. Dunkels and JP. Vasseur, “IP for Smart Objects,” IPSO Alliance White Paper, Sep. 2008.

[24] IPv6 over Low power WPAN (6lowpan) Working Group, IETF. http://www.ietf.org/html.charters/6lowpan-charter.html.

[25] J. Hui, D. Culler and S. Chakrabarti, “6LoWPAN: Incorporating IEEE 802.15.4 into the IP architecture,” Internet Protocol for Smart Objects (IPSO) Alliance White paper, Jan. 2009.

[26] X. M. Zhang and J. Li, “Research on Interoperability of Internet of Things’ Gateway Oriented to Telehealth and Telemedicine”, in IEEE Proc. 2010 International Conference on Future Information Technology, December 14-15, 2010, Changsha, China. In press.

[27] X. M. Zhang and N. Zhang, “Research on Interoperability of Telehealth Gateway Based on Internet of Things,” in IEEE Proc. 2010 International Conference on Computer and Computational Intelligence, December 25-26, 2010, Nanning, China. In press.

[28] P. Ballon and A. Henten, “Introduction: Mobile service architecture and middleware,” Telematics and Informatics, vol. 28, 2011, pp. 1-4.

[29] R. Rogers, J. Lombardo, Z. Mednieks and B. Meike, “Android Application Development: Programming with the Google SDK (1st ed.),” O'Reilly Media, May, 2009, ISBN: 0596521472.

[30] PacketVideo Corp. white paper, “OpenCORE Multimedia Framework Capabilities, OHA 2.07, rev 2,” Dec. 2009.