Smart Healthcare: A Review of Architectures

Varun M Tayur
Jain Global Campus, Jain University
Bangalore, India

Dr. Suchithra R
Jain Global Campus, Jain University
Bangalore, India

***Abstract* - The rapid evolution of IoT has touched many domains, healthcare is a prominent one. Modern healthcare systems influenced by the rapid developments in the IoT field are being redesigned with a promise of improved technological, economic and social prospects. The small tiny networked sensors' on the body or embedded in our surroundings enables capturing rich information indicating physical and mental health of the individual. This opens up numerous challenges with respect to capturing this information, analysis and importantly diagnosing the cause and ensuring right treatment at the right time for the patient. State-of-the-art platforms that cater to end to end patient monitoring and management and minimizing the security risk and privacy concerns are the need of the hour.**

Keywords: Internet of Things healthcare, architectures, networks, remote health-monitoring, IoT healthcare cloud

INTRODUCTION

The Internet of Things (IoT) is a concept reflecting a connected set of anyone, anything, anytime, anyplace, any service and any network [25]. The potential of IoT with respect to medical and health care is immense; it has applications in remote health monitoring, fitness programs, chronic diseases, elderly care, treatment and medication at home. The core constituent of such a smart healthcare setup is still the good old medical device, sensors, diagnostic and imaging devices. IoT enabled healthcare services are expected to build upon the core and add supplementary services that can increase the quality of life and enrich the user's experience and at the same time reduce the cost. Remote provisioning and monitoring of critical auxiliary services can be provided over it by reducing device downtimes and accurately identifying the time to replenishing supplies for various devices. IoT enables efficient scheduling of limited resources and ensures best use and servicing of more patients [7]. IoT-based health care needs a comprehensive architecture that enables interoperability between services and systems and at the same time be aware of the security of the systems as privacy is of utmost importance.

RELATED WORK

The study is organized under the following broad areas namely: Cloud Convergence – deals with architectures supplementing healthcare systems, Monitoring and Management – deals with end to end health management of individuals.

CLOUD CONVERGENCE

Internet of Things and Cloud Computing are two complementary technologies contributing to the enrichment of the experience and environment around us. Connected devices such as tablets, wearables and hand-held devices have led to a much richer user experience in delivering healthcare thereby increasing efficiency and making healthcare affordable [2].

The Smart Hospital System [6] collects environmental conditions and patients' physiological parameters via an ultra-low-power Hybrid Sensing Network (HSN) composed of 6LoWPAN nodes integrating UHF RFID functionalities which are delivered to a control center where an advanced monitoring application makes them easily accessible to both local and remote users via web services. Such services can be used in automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes.

An intelligent home-based solution called iHome Health-IoT [22] platform provides an end to end open-platform with intelligent medicine box called iMedBox and pharmacy supplies called iMedPack that are enabled by passive radio-frequency identification (RFID) and actuation capability and a flexible wearable bio-medical sensor device Bio-Patch with a system-on-chip. This platform provides IoT devices (e.g., wearable sensors and intelligent medicine packages) with in-home healthcare services (e.g., telemedicine) for improved user experience and service efficiency. IHHS [24] is built on the principles of reuse of 3C platform, certification of the Health Extension, interoperability and extendibility, convenient and trusted software distribution, standardized and secured electrical health care record handling, effective service composition and efficient data fusion.

Smart e-Health Gateway called UTGATE proposed in [1] is successful in extending the gateways by strategic positioning of them enabling them to provide several higher level services such as local storage, real-time local data processing etc. Ubiquitous healthcare systems require energy efficient, scalable, reliable and interoperable gateways that can aid in conversion from various native protocols like Bluetooth, LoWPAN etc. to IPv4. A service oriented healthcare platform based on the virtual medical sensors and REST APIs for unified management in IP addressable network has been proposed in [15]. Other protocol based networks require conversion gateways – however the different data models associated with different kinds of devices aren't addressed here.

A semantic data model to store and interpret IoT data and resource-based data accessing method (UDA-IoT)

is designed to acquire and process IoT data ubiquitously to improve the accessibility to IoT data resources [19]. Data acquisition and Transmission are crucial and most energy sapping operations, a low complex rule engine based health care data acquisition and smart transmission system architecture using the IEEE 802.15.4 standard is proposed in [21]. Static and adaptive rule engines decides transmission and extraction criteria based on nature of data, thereby achieving power saving.

In U-healthcare interaction end-user experience is enhanced by the edge Cloud to Fog (C2F) computing [9]. Fog in conjunction with the cloud in healthcare can address issues with the scalability, latency, mobility and security with more precision as there is much more fine grained control.

HEALTH MONITORING AND MANAGEMENT

Wireless body area network (WBAN) is a highly suitable communication tool for the medical IoT devices as it is fitted to the patient. The design of such a system requires a connected topology, mobility support and transmission efficiency [3]. Smart hospital system (SHS) [5] relying on different technologies like RFID, WSN, Smart mobile, interoperating with each other through a Constrained Application Protocol (CoAP)/IPv6 over low-power wireless personal area network (6LoWPAN) provides automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes. Another system developed in [8] for chronic diseases management is enabled by a body sensor network and a wireless body area network using the ZigBee and Bluetooth technology whose analysis is possible on a smartphone. An energy-efficient mechanism to automatically send an emergency alerts also have been developed

A service model developed in [4] allows user recognition and transmits data to healthcare service platform; this model can also be used with patients with chronic illness to perform self-diagnosis with convenience. Another proposal for home care/tele-monitoring for patients with chronic illnesses is presented in [18] it becomes possible to continuously manage and monitor personal healthcare information with the use of smart phone or wearable devices.

RF identification (RFID) technology has been extensively used in the IoT physical layer for the personal healthcare in smart environments through low-cost, energy-autonomous, and disposable sensors for application to body centric systems and for gathering information (temperature, humidity, and other gases) about the user's living environment [13] [14]. RFID with sensing capability can enable better health monitoring and control of rural and poor. Management of chronic diseases is important to self-management, so, an application network protocol with intelligent servicing that gives an effective feedback through collaboration and intellectualized service application [16].

The ubiquitous network consisting of interconnected objects based on sensor tags communication architecture for healthcare service systems has been proposed in [10]. A secure single sign-on authentication scheme and binding protocol proposed in [12] enables streaming data transmission in real-time enabling interwork between mobile phones, medical devices and monitoring services thereby enabling users to share the public medical devices as if they are their own medical devices. The m-health Things (m-IoT) enables intelligent identification and management in a heterogeneous environment targeting major chronic diseases like diabetes for non-invasive glucose level sensing with advanced opto-physiological assessment technique [20]. An energy efficient generic model for routing in IoT network is developed in [11] based on an analytical model of a naive flooding using Markov chains. Steady state transition probabilities of transmit and receive states is used in predicting power consumption.

A Business Process Model Notation [17] has been used to model the communication interactions in a WBAN based on the 6LoWPAN network and its interaction with the internet. Healthcare networks typically have to bear with the massive amount of network traffic together with being able to handle the mobility of patients and devices – A resilient high performance network with low latency is promised by a Software Defined Network which could enable high performance, low latency and agile network, SDNFx [26].

CHALLENGES

Standardization

Huge diversity in the range of products and devices in the healthcare systems and most of them have not followed standard rules and regulations for compatibility. Standardization should consider the entire communications stack, device interfaces, data aggregation interfaces, and gateway interfaces. The management of auxiliary services such as electronic health records, access management also needs to be looked into.

Healthcare Platforms

A healthcare platform would need to support end to end workflows for health monitoring and management, offering a unified interoperable environment in the near real time. Such platforms would require libraries and frameworks that take into consideration use of domain specific documents, codes, classes, message templates, and other useful data. Library or a catalogue of at-least chronic diseases symptoms, diagnosis and other details in a semantic query-able format would be desirable.

QoS

Ensuring high system availability and robustness is critical to healthcare services. Real time decision making and support is a key QoS requirement. Other QoS parameters that are important are reliability, maintainability. On a broader perspective it is important for critical systems to be fully aware about the backup plans and be able to switch to it as required.

Data Protection

The crucial health data is aggregated from multiple sources, strict policies and technical security measures have to be enforced to share health data with authorized users, organizations, and applications. Physical security of the devices is also important as the device could be captured by an attacker and it could be replaced with a modified device.

DISCUSSION

Figure 1 illustrates the typical components of a smart healthcare system, the bottom layer is constituted by the medical devices, sensors and actuators and WBAN. They are the core constituent of the healthcare setup as they are attached to the patient and hence generate the critical health data. The data feed from multiple such devices and essentially in different formats may have to be processed and analyzed for taking up effective diagnosis. So, these devices are connected via gateways or via 6To4 tunneling if devices are on 6LoWPAN. The middleware is essentially composed of the Cloud which has abundant processing and storage capabilities and can suitably complement the device layer and also provide a unified northbound interface for applications to be hosted on the upper layer. The applications on the upper layer can present the analysis of the data in an appropriate way based on the user-type.

The application layers would require a unified view of the topology for device management and control and rich end user applications with context sensitive data with inputs from the healthcare domain. The middleware would require devices to be exposed as services and at the same time require models that can abstract communication with heterogeneous devices. The devices itself can adapt to popular 6LoWPAN standards instead of the custom protocols as it enables quick adoption and manageability.

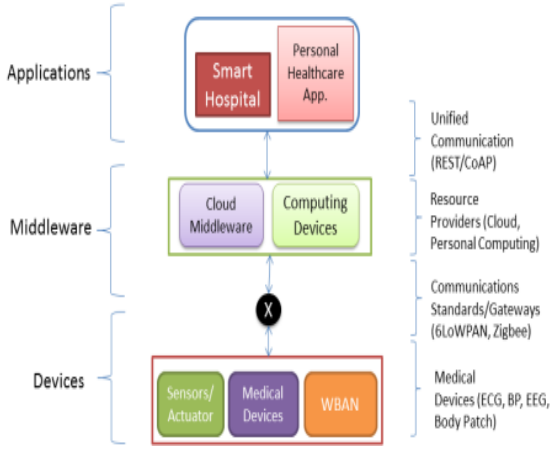

Figure 1: Components of a typical Smart Healthcare System

IoT's lifeline can be thought of as a 'network' - lot of its working is attributed to the communication aspects be it the 6LoWPAN or ZigBee or the programmatic network access enabled by SDN. The healthcare middleware is actively supplemented with the compute, storage and analytics which are abundant on the cloud. The 'smart' applications developed on the top can aid the medical and patient fraternity in making judicious decisions in near real-time. All these are riddled with numerous challenges in interoperability, poor implementation of standards, privacy and security concerns.

REFERENCES

[1] A. M. Rahmani *et al*., "Smart e-Health Gateway: Bringing intelligence to Internet-of-Things based ubiquitous healthcare systems," *Consumer Communications and Networking Conference (CCNC), 2015 12th Annual IEEE*, Las Vegas, NV, 2015, pp. 826-834.
doi: 10.1109/CCNC.2015.7158084n

[2] K. Babu, K. Jayashree, "A Survey on the Role of IoT and Cloud in Health Care", International journal of scientific engineering and technology research, ISSN 2319-885, Vol 4, Issue 12, May 2015, Pages 2217-2219

[3] T. Y. Kim, S. Youm, J. J. Jung and E. J. Kim, "Multi-Hop WBAN Construction for Healthcare IoT Systems," *Platform Technology and Service (PlatCon), 2015 International Conference on*, Jeju, 2015, pp. 27-28.
doi: 10.1109/PlatCon.2015.20

[4] Byung Mun Lee, "Personalized Service Model for Sharing Medical Devices in IoT Health-Platform", Advanced Science and Technology Letters Vol.99 (ITCS 2015), pp.180-182 http://dx.doi.org/10.14257/astl.2015.99.44

[5] Byung Mun Lee, "Registration Protocol for Health IoT Platform to Share the Use of Medical Devices", International Journal of Bio-Science and Bio-Technology Vol.7, No.4 (2015), pp.1-10

[6] L. Catarinucci *et al*., "An IoT-Aware Architecture for Smart Healthcare Systems," in *IEEE Internet of Things Journal*, vol. 2, no. 6, pp. 515-526, Dec. 2015.
doi: 10.1109/JIOT.2015.2417684

[7] M. Hassanalieragh *et al*., "Health Monitoring and Management Using Internet-of-Things (IoT) Sensing with Cloud-Based Processing: Opportunities and Challenges," *Services Computing (SCC), 2015 IEEE International Conference on*, New York, NY, 2015, pp. 285-292.
doi: 10.1109/SCC.2015.47

[8] Mir Sajjad Hussain Talpur, Md Zakirul Alam Bhuiyan and Guojun Wang, "Energy-efficient healthcare monitoring with smartphones and IoT technologies", Int. J. High Performance Computing and Networking, Vol. 8, No. 2, 2015

[9] Chandra Sukanya Nandyala, Haeng-Kon Kim, "From Cloud to Fog and IoT-Based Real-Time U-Healthcare Monitoring for Smart Homes and Hospitals", International Journal of Smart Home Vol. 10, No. 2, (2016), pp. 187-196

[10] Jia-Li Hou and Kuo-Hui Yeh, "Novel Authentication Schemes for IoT Based Healthcare Systems", International Journal of Distributed Sensor NetworksVolume 2015, Article ID 183659, 9 pages

[11] S. Sankaran and R. Sridhar, "Modeling and analysis of routing in IoT networks," *2015 International Conference on Computing and Network Communications (CoCoNet)*, Trivandrum, 2015, pp. 649-655.
doi: 10.1109/CoCoNet.2015.7411258

[12] Byung Mun Lee, "Dynamic Data Binding Protocol between IoT Medical Device and IoT Medical Service for Mobile Healthcare", International Journal of Smart Home Vol. 9, No. 6 (2015), pp. 141-150

[13] S. Amendola, R. Lodato, S. Manzari, C. Occhiuzzi and G. Marrocco, "RFID Technology for IoT-Based Personal Healthcare in Smart Spaces," in *IEEE Internet of Things Journal*, vol. 1, no. 2, pp. 144-152, April 2014.
doi: 10.1109/JIOT.2014.2313981

[14] V. M. Rohokale, N. R. Prasad and R. Prasad, "A cooperative Internet of Things (IoT) for rural healthcare monitoring and control," *Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE), 2011 2nd International Conference on*, Chennai, 2011, pp. 1-6.
doi: 10.1109/WIRELESSVITAE.2011.5940920

[15] Byung Mun Lee, "Design Requirements for IoT Healthcare Model using an Open IoT Platform",

[16] Advanced Science and Technology Letters Vol.66 (Networking and Communication 2014), pp.69-72

[17] Byung Mun Lee* and Jinsong Ouyang, "Intelligent Healthcare Service by using Collaborations between IoT Personal Health Devices", International Journal of Bio-Science and Bio-Technology Vol.6, No.1 (2014), pp.155-164
[18] Nicola Bui and Michele Zorzi, Health Care Applications: A Solution Based on The Internet of Things, ISABEL '11, October 26-29, Barcelona, Spain 2011 ACM ISBN 978-1-4503-0913-4/11/10
[19] L. M. R. Tarouco *et al.*, "Internet of Things in healthcare: Interoperatibility and security issues," *Communications (ICC), 2012 IEEE International Conference on*, Ottawa, ON, 2012, pp. 6121-6125. doi: 10.1109/ICC.2012.6364830
[20] B. Xu, L. D. Xu, H. Cai, C. Xie, J. Hu and F. Bu, "Ubiquitous Data Accessing Method in IoT-Based Information System for Emergency Medical Services," in *IEEE Transactions on Industrial Informatics*, vol. 10, no. 2, pp. 1578-1586, May 2014. doi: 10.1109/TII.2014.2306382
[21] R. S. H. Istepanian, S. Hu, N. Y. Philip and A. Sungoor, "The potential of Internet of m-health Things "m-IoT" for non-invasive glucose level sensing," *Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE*, Boston, MA, 2011, pp. 5264-5266. doi: 10.1109/IEMBS.2011.6091302
[22] M. P. R. S. Kiran, P. Rajalakshmi, K. Bharadwaj and A. Acharyya, "Adaptive rule engine based IoT enabled remote health care data acquisition and smart transmission system," *Internet of Things (WF-IoT), 2014 IEEE World Forum on*, Seoul, 2014, pp. 253-258. doi: 10.1109/WF-IoT.2014.6803168
[23] G. Yang *et al.*, "A Health-IoT Platform Based on the Integration of Intelligent Packaging, Unobtrusive Bio-Sensor, and Intelligent Medicine Box," in *IEEE Transactions on Industrial Informatics*, vol. 10, no. 4, pp. 2180-2191, Nov. 2014. doi: 10.1109/TII.2014.2307795
[24] M. Maksimović, V. Vujović and B. Perišić, "A custom Internet of Things healthcare system," *Information Systems and Technologies (CISTI), 2015 10th Iberian Conference on*, Aveiro, 2015, pp. 1-6. doi: 10.1109/CISTI.2015.7170415
[25] Zhibo Pang et el., "Design of a terminal solution for integration of in-home health care devices and services towards the Internet-of-Things", Enterprise Information Systems, 2015, Vol. 9, No. 1, 86–116,
[26] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain and K. S. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey," in *IEEE Access*, vol. 3, no. , pp. 678-708, 2015. doi: 10.1109/ACCESS.2015.2437951
[27] http://www.avaya.com/usa/documents/networking_for_enhanced_agility_dn7836.pdf, Accessed: April 2016