Healthcare applications of the Internet of Things: A Review

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Abstract— **The fields of computer science and electronics have merged to result into one of the most notable technological advances in the form of realization of the Internet of Things (IoT). The impact of IoT in healthcare, although still in its initial stages of development has been significant. This paper attempts to review and understand the applications of IoT in personalised healthcare to achieve excellent healthcare at affordable costs. We have explained in brief how IoT functions and how it is used in conjunction with wireless and sensing techniques to implement the desired healthcare applications.**

Keywords— **Internet of things, personalised healthcare, Ubiquitous computing, wireless sensor networks.**

I. INTRODUCTION

The Internet and the web has evolved through the ages to reach its present day form. The evolution can be broadly classified into 4 stages.

Stage 1: The ARPANET.

The ARPANET stands for Advanced Research Project Agency Network. This project was funded by the US military and the Department of Defence and was primarily used for research and academic purposes by Universities and research institutes.

Stage 2: The Gold Rush for domain names.

By this time, HTML had been developed, and companies were rushing to their domain names registered. The main aim was to create a platform to share information pertaining to products and services. It has been termed as brochureware.

Stage 3: The boom and bust of the dot com bubble.

The internet migrated from the static phase to the transactional exchange phase. Companies like Ebay and Amazon became household names by enabling the purchasing and selling of goods and services over the internet.

Stage 4: The social and experience web.

The internet has now become a medium of social interaction. Companies like Facebook, Twitter and Groupon have enabled people to share their day to day activities and experiences.

Stage 5: The Internet of Things. (IoT)

This is an immensely important development which has the ability to change and impact the way people work, learn and live. [1] The Internet of Things (IoTs) can be described as connecting everyday objects like smart-phones, Internet TVs, sensors and actuators to the Internet where the devices are intelligently linked together enabling new forms of communication between things and people, and between things themselves .[2] .

II. ABOUT INTERNET OF THINGS.

The term internet of things was first coined by Kevin Ashton in 1999. The RFID group defines Internet of things as the worldwide network of interconnected objects uniquely addressable based on standard communication protocols. It incorporates traditional fields like Embedded Systems, Control Systems and Automation, Wireless Sensor Networks to facilitate Device to Device (D2D) communication through the internet. The concept was first used at the Auto-Id centre at MIT. RFID (Radio Frequency Identification) was seen as a pre-requisite for implementing systems which were classified as IoTs. Today, it has applications for both private as well as business users. From the perspective of private users, healthcare, e-learning, domotics are the major fields while from business users' perspective, automation, logistics and industrial manufacturing are the important domains.

A. *Ubiquitous Computing*

The advancements and convergence of micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics have led to the development of miniature devices. These devices have the ability to sense, compute, and communicate wirelessly. These miniature devices called nodes interconnect to form a wireless sensor networks (WSN). [3]

B. *Applications.*

In the Internet of Things (IoT), it is possible to collect, record and analyze new data streams faster and more accurately by making devices gather and share information directly with each other and the cloud .The Internet of Things will impact several application domains. The applications can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact. [4]

These applications can be categorized into four domains: Personal and healthcare, enterprise, utilities and mobile. This is depicted in Fig. 1, which represents Personal and healthcare IoT at the scale of an individual or home, enterprise IoT at the scale of a community, utility IoT at a national or regional scale and mobile IoT which is usually spread across other domains mainly due to the nature of connectivity and scale.

Fig.1. Internet of Things schematic showing the end users and application areas based on data. [5].

III. INTERNET OF THINGS AND HEALTHCARE

The reliance of healthcare on IoT is increasing by the day to improve access to care, increase the quality of care and most importantly reduce the cost of care. [6]

Based on an individual's unique biological, behavioural, social and cultural characteristics, the integrated practice of well-being, healthcare and patient support is termed as personalised healthcare. This empowers each and every individual by following the basic healthcare principle of "the right care for the right person at the right time", which leads to better outcomes and improvement in satisfaction thus making healthcare cost-effective. A sustainable service focuses on the prevention, early pathology detection, and homecare instead of the expensive clinical one, and checks the overall well-being to anticipate needs and ensure compliance to healthcare plans. Internet of Things promises to manage the personalization of care services and can maintain a digital identity for every person. Different equipment is used in healthcare, to communicate and to make the ubiquitous system-of-system. The classifications of IoT based personalised healthcare systems are Clinical care and remote monitoring .[7]

A. Clinical Care

IoT-driven, noninvasive monitoring systems are used for hospitalized patients whose physiological status requires constant close attention. These monitoring systems employ sensors to collect physiological information which is analyzed and stored using gateways and the cloud. This information is then sent wirelessly to caregivers for further analysis and review hence, rendering a health professional having to check the patients' vital signs after regular intervals unnecessary. Instead, it provides a continuous automated flow of information. Thus, the quality of care is improved through constant attention which in turn lowers the cost of care and eliminates the need for a caregiver to actively engage in data collection and analysis. [6]

B. Remote Monitoring

Lack of ready access to effective health monitoring systems may lead to many health risks go undetected, which is a problem being faced all over the world. But small, powerful wireless solutions connected via the IoT make it possible for monitoring to come to patients instead of vice-versa. Patient health data can be securely captured using these solutions. A variety of sensors and complex algorithms are used to analyze the data and then share it through wireless connectivity. The medical professionals can then make appropriate health recommendations remotely.
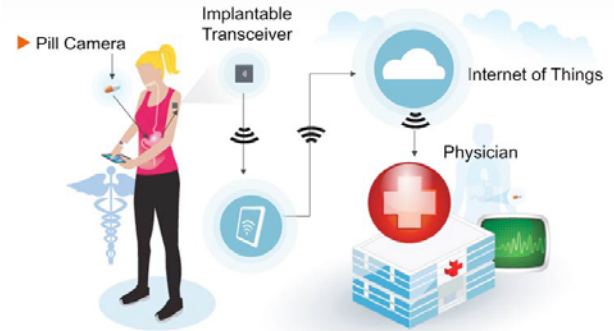

Fig 2: Remote patient monitoring. [6]

IV. TECHNOLOGICAL FRAMEWORK

Diverse architectures constitute the mutually non-interoperable application specific solutions that shape the market requirements for health monitoring devices.

The links between the many applications in health monitoring are:

• The process of gathering data from sensors. (WSNs-Wireless sensor networks)

• Support for standard user interfaces and displays.

• Network connectivity for access to infrastructural services.

• In-use requirements such as low power, robustness, durability, accuracy and reliability. [8]

A. Wireless Sensor Networks(WSNs)

Wireless Sensor Network (WSN) is an important enabling technology of IoT. It connects a number of sensor and actuator nodes into a network through wireless communication. This integrates the network into a higher level system through a network gateway. [9]

Ubiquitous Sensor Network (USN) is an extension of the WSN integrated with an application system of the IoT. Gateways are information hubs which collect sensor data, analyse it and then communicate it to the cloud through wide area network (WAN) technologies. Gateways can be designed for clinical or home settings. In home settings, they may be part of larger connectivity resource that also manages energy, entertainment and other systems.

Sensors measure physical data of the parameter to be monitored. The sensor nodes are normally lightweight, inexpensive, easy to deploy and maintain. A drawback

though is that, the capability and functionality are limited by resources like sensor accuracy, processors, memories, energy sources, etc. As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source of less than 0.5-2 ampere-hour and 1.2-3.7 volts.

Connecting WSNs to the Internet is possible in three main approaches. The first proposed approach (Fig. 3) consists of connecting both independent WSN and the Internet through a single gateway. This approach is currently adopted by most of the WSNs accessing the Internet, and presents the highest abstraction between networks.
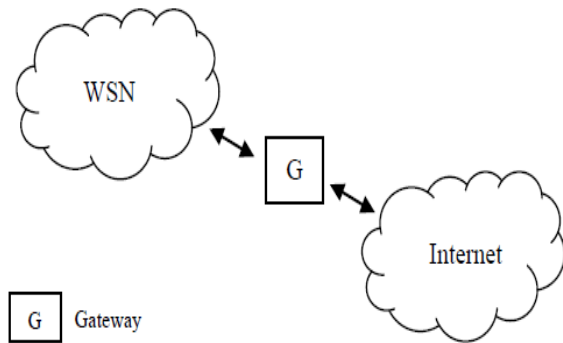

Fig 3: Independent Network. [10]

The second approach forms a hybrid network which shows an increasing integration degree. It is composed of both, a considered network structure which remains independent and a few dual sensor nodes who can access the internet.
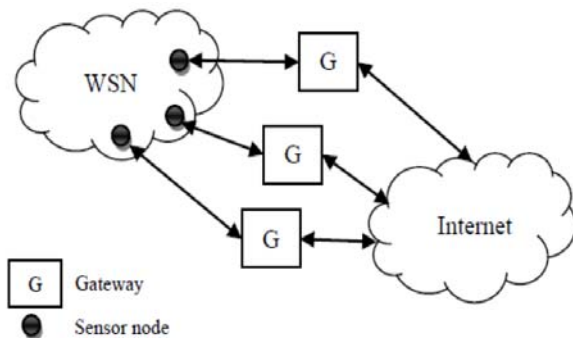

Fig 4: Hybrid Network. [10]

In the last approach, multiple sensor nodes can join the Internet in one hop.[10]
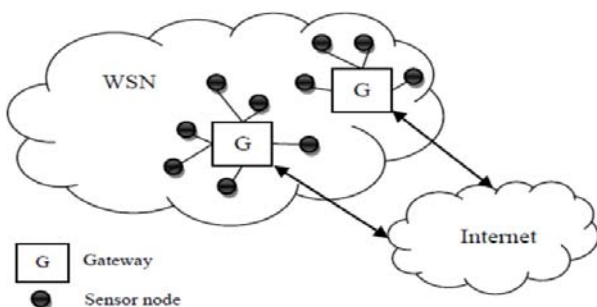

Fig 5: Access Point Network. [10]

B. Standard user interfaces , displays and in use-requirements

Usability is improved by enabling display devices to deliver a great deal of information with the help of graphics user interfaces(GUIs) This information can be easily accessed due to the vivid detailing done by the GUIs. Processors with high graphics-processing performance support advanced GUI development.

The in-use requirements for a healthcare system based on IoT are:

Interoperability:

Interoperability is crucial for healthcare products based on IoTs to facilitate seamless integration of products designed by different manufacturers. This is achieved by the device manufacturers following set standards or by making sure that gateways are available to translate the identification of one device into another.

Reliability:

Together with interoperability, reliability is another crucial requirement for the adoption of the Internet of Things. If available IoT based healthcare systems are not reliable, or do not always provide the right information, people will move away from the technology and still rely on more trusted ways of healthcare.

Flexibility and Extensibility:

In order to allow for changes in the mapping of devices to location, to individuals, etc flexibility is necessary, whereas for the addition of healthcare devices to the "pool" owned by someone (say a hospital) extensibility is required.

Support for mobility.

With people moving constantly between different spaces, such as home and work, gym, etc mobility plays a crucial role. In this regard, personalised healthcare devices will have to support mobility by allowing the association with the user even if the underlying network addressing scheme changes.

V. APPLICATIONS OF INTERNET OF THINGS IN HEALTHCARE

In the last approach, multiple sensor nodes can join the Internet in oneFrom in-home monitoring devices to large hospital-based imaging systems and thin-client solutions, healthcare industry devices that are part of an intelligent system offer better care, by automating processes, facilitating collaboration and securely managing information. Intelligent systems provide clinicians with easier access to health information, streamline costs, and create operational efficiencies that help to improve the patient experience. Some examples are cited below.

A. Monitor an aging family member

Ultrasound-based technology already used in hospitals can be deployed as a personalized home healthcare solution to locate and track a senior resident's activity and detect falls. Emergency calls are managed by a battery operated cost effective system which is easy to install and requires only a wide area communication interface.

A system that works well for senior home monitoring can be a small waterproof sensor system, worn like a wristwatch. At regular intervals of 15 to 20 seconds, the system is programmed to send a positioning signal to the ultrasound receiver. This receiver, on receiving the signal communicates over standard wireless WLAN connections to the homecare gateway. Continuous analysis of the data is done by the gateway. Relevant data is broadcast, and the built-in wireless wide area network connection is used to send out a notification for help as soon as any critical event is detected. [11]

B. *Scalable, continuous, heart rate monitoring*

Each patient's biometrics are monitored individually by setting patient-specific threshold settings. Such a system can monitor a patient's: ECG Heart rate (including HR variability and HR reliability), respiration rate, activity level, body position. In order to remotely monitor vital signs like: Blood pressure and weight additional devices can be used in conjunction. of such a system are rhythm monitoring to understand the cardiac role of unexplained symptoms can be understood better using a rhythm monitoring system. Other clinical applications of such a system include arrhythmia medication therapy to monitor treatment effectiveness, post ablation procedure to monitor cardiac rhythm, vitals monitoring i.e. to monitor cardiac rhythm respiration and activity remotely in the hospital or at home and discharge for heart failure to monitor rhythm and respiration.[12]

VI. FUTURE OUTLOOK

The Internet of Things will change our society, and will bring seamless 'anytime, anywhere' personalized healthcare and monitoring over fast reliable and secure networks. This implies that we are approaching the end of the divide present between digital, virtual and physical worlds.

Today, the most widely adapted technology for the Internet is the standard web services. Wireless identifiable embedded healthcare systems at the edge of the network need to have and utilise similar functionalities and this will prove to be a challenge in the future for the internet. [13]

Wireless sensor networks and ubiquitous networks, where the sensors will be connected to and controlled by embedded systems, where services encapsulate the functionality and provide unified access to the functionality of the system. These billions of components produce consume and process information in different healthcare environments such as hospitals, households and nursing homes as well as in the work and everyday lives of people.

VII. CONCLUSION

As the examples in this paper make clear, the long-predicted IoT revolution in healthcare is already underway. And, as new use cases are emerging, they continue to address the urgent need for affordable, accessible care.

Meanwhile, the IoT building blocks of automation and machine-to-machine communication continue to be established. The addition of the service layer forms the complete IoT infrastructure. This revolution is characterised by providing end-to-end processing and connectivity solutions for IoT-driven healthcare.

ACKNOWLEDGMENT

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