An Architectural Framework for HMIS based on Internet of Things

Author

Amna Pir Muhammad

NUST201362526MCEME35413F

Supervisor

Dr. Muhammad Usman Akram

Co-Supervisor

Dr. Muazzam Ali Khan

DEPARTMENT OF COMPUTER ENGINEERING

COLLEGE OF ELECTRICAL & MECHANICAL ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

ISLAMABAD

July, 2015

An Architectural Framework for HMIS based on Internet of Things

Author

Amna Pir Muhamamd

NUST201362526MCEME35413F

A thesis submitted in partial fulfillment of the requirements for the degree of

MS Computer Software Engineering

Thesis Supervisor:

Dr. Muhammad Usman Akram

Thesis Supervisor's Signature:_____

DEPARTMENT OF COMPUTER ENGINEERING

COLLEGE OF ELECTRICAL & MECHANICAL ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY, ISLAMABAD

July, 2015

Declaration

I hereby certify that I have developed this thesis titled as *"*An Architectural Framework for HMIS based on Internet of Things*"* entirely on the basis of my personal efforts under the sincere guidance of my supervisor Dr. Muhammad Usman Akram. All of the sources used in this thesis have been cited and contents of this thesis have not been plagiarized. No portion of the work presented in this thesis has been submitted in support of any application for any other degree of qualification to this or any other university or institute of learning.

Signature of Student

Amna Pir Muhammad

NUST201362526MCEME35413F

Language Correctness Certificate

This thesis has been read by an English expert and is free of typing, syntax, semantic, grammatical and spelling mistakes. Thesis is also according to the format given by the university.

Signature of Student

Amna Pir Muhammad

NUST201362526MCEME35413F

Signature of Supervisor

Dr.Muhammad Usman Akram

Copyright Statement

Acknowledgements

"Those who do not thank people, they do not thank Allah." (Al-Tirmidhi)

It is with the grace of Almighty that I was led into the company of the following people, whose generosity, enthusiasm, and good shepherding sustained me in producing this work: Dr. Usman Akram, Dr. Muazzam Ali and all those people who generously shared their knowledge and expertise with me. I am beholden to my family for their love and continuing encouragement. My friends always backed me up very strongly. Therefore, I thank every single one of them for their support.

To my Parents, Advisors, colleagues and Friends

Abstract

Healthcare is very important factor in every body's life and Information technology is playing an important role in providing better health with number of advancements. Internet of things (IoT) is an emerging technology. Due to its popularity in technology and internet world, IoT is rising in every field of life and so in health sector. Health is something in which its focus is more concentrated due to its hypnotic features. Till now, not much work has been done in hospitals related to IoT especially in Pakistan. The main issues is the lack of a standardized design. So in order to deal with the problems of existing system of hospitals at large scale, in this thesis we have proposed an architectural framework for hospitals based on internet of things. Moreover we have discussed the main technologies of IoT and conceptual smart hospital constructed with the understanding of architecture of IoT based hospital. The architecture and application framework for hospitals are also defined in detail. The proposed system shows an optimistic and confident result for the treatment and diagnostic approach in hospitals. As IoT is aimed to connect everything to Internet, there are billions of sensors which are attached to things to access data and connect these things to internet. So the data provided by these sensors is growing very fast. We need to handle this big data on personals gadgets as well on central databases. To deal with this problem, in this research we have also presented IoT based architectural framework with context awareness for hospital management systems. We have introduced context awareness as a middleware on IoT's architecture above network layer to overcome the problem of data management. Patient's data would be placed on a cloud and only the required information would be available on their personal gadgets like smart phones and laptops etc.

We did a questionnaire based survey analysis of proposed framework to investigate the decision to adopt the IoT based system in Pakistani Hospitals. The accumulated results indicate that participants want to adopt this system and most of the population agreed that IoT based HMIS would provide better monitoring, communication and early diagnosis.

Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

Healthcare consistently has been an important thoughtful concern the all-time for humankind. In the last decade, with the fast development in web and internet technologies, smart hospitals have developed manifest in our lives. Advancement in the technology has changed the world due to the development of smart phones and other handheld gadgets. Good health is the basic necessity of good life. Several technologies and gadgets in last few years have been developed and have promoted to monitor the healthcare and other hospital's critical assets.

However in Pakistan such infrastructure rarely exists due to lack of resources, budget etc. There are some hospitals in which hospital management information system (HMIS) has implemented. But most of these systems are just maintaining database of patients for future reference. Few of the hospitals have telehealth or ehealth system, but these systems have just implemented telemedicine via the technologies of telecommunication, teleconferencing and videoconferencing etc. Literature has shown that these systems lack quality and are expensive and we need a better communication and monitoring system. If we talk about HMIS from all around the world, there are some countries, which have better mobile patient care systems. But still we lack at monitoring communication and tracking of assets and patients. And there is no common framework to manage the patients and others assets at one platform. Hence, so far all the development in field of health we lack a common communication environment or structural platform, therefore we are proposing an architectural framework that describes the components of hospital based IoT and their communication at one common platform in an organized way for the better quality of HMIS.

Imagine a world where everything could be connected to every other thing at anyplace and at any time over the network. This vision is stated as internet of things (IoT). IoT is an emerging technology, which we can find in every field of life. IoT's concept was given in 1999. But it got popularly in development lately with the advancement of sensor network technology, decreasing cost of hardware, cloud computing and wireless communication.

IoT is the fourth generation of technology revolution of information realm moreover to execute smart recognition, locating, tracking, following, checking and administration, by methods of GPS, infrared sensors, laser scanners, radio frequency identification (RFID) and some other data sensor devices, as indicated by traditional practice [1]. IoT can be defined as; a technology which allows connection of anything and anyone, anywhere, at any time possibly using any path, network or service [2]. Figure 1 [3], shows the new dimension of communication and information technology i.e. IoT. From the initiation of IoT in Auto-ID Center at MIT toward the start of 2000 numerous innovative developments have been fulfilled by technical scholars. As per Gartner [2] about 26 billion gadgets will be linked with Internet in 2020[4].

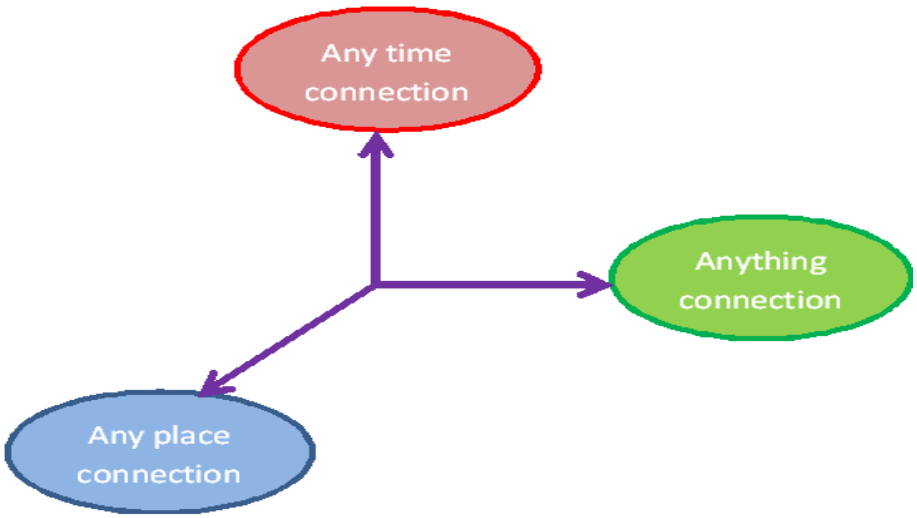


Figure 1.1: IoT as a new dimension

Because of the improvement of sensor innovations in all fields of life for instance industrial, bio, chemical and so on, microcontroller based systems and networking protocols improvement for embedded frameworks have been tranquil. The smart hospitals is new sort hospital, incorporated with the functionalities of decision making, management, treatment, administration and diagnosis based on IoT. The peculiarities from internet of things, for example, thorough recognition, solid transmission, smart processing et cetera gives strategy support framework for the development and execution of smart hospital [5].

In the propelling procedure of hospital management system, the implementation and the deployment of partial HMS (hospital management system) have made the hospitals to accomplish

certain level of digital information. However still HMS has some insufficiencies, for example, manual info record, settled networking data point, particular single propose, comparatively autonomous systems between every division [7] etcetera, which totally confine the development of hospital information system. Hence the rapidly growing new technology IoT, has given the new idea to overwhelm the problems mentioned above.

IoT possess intelligence while feeling things, thinking things, tracking things, identifying things, with embedded things and identification of things and tagging things [9]. And turning objects into smart objects and connecting this smart object in a network system [10]. IoT embodies 3 technological layers [8].

1. Sensing layer or perception layer: at this layer objects collects data and transmit s to upper layer.
2. Network layer: at this layer data is analyzed and processed for further processing for real time environment.
3. Application layer: this layer supports intelligence by providing useful data to users devices with the help of cloud computing and knowledge based technologies.

In hospitals technology made it possible to track a patient by browsing an internet address or by searching and linking it to data base with radio frequency identification (RFID) tagging technology. But now IoT has provided an opportunity to extend this idea. By connecting any medical apparatus, especially daily use devices, patients, medicines, labs, hospital equipment, ambulance etc. with anything or anyone at anytime, anyplace. These objects are connected to each other through devices like sensors and actuators.

Existing advancements in hospital management system sector are e-health and tele-health. The advancements provide online communication and easy access of patient records between doctors and patient. Whereas IoT based HMIS provides all these functionalities plus monitoring, identification and tracking of patients and doctors location, tracking of medical equipment and patient's record etc. IoT also provides intelligence for example in case of medicines, the pharmacy box can sent alerts of expiry date or it can automatically alarm to concerned doctor that patient's

condition is getting sever. For the better hospital management system we must need to provide effective system and IoT is a main technology which can provide effective and efficient hospital management system for enhanced patient protection.

Internet of things based framework for hospitals provide first and novel design for HMIS with the features of monitoring, communication, diagnosis, decision making etc. IoT supports measurement, analyses and visualization of data accumulated from different devices through biosensors. The data gathered from devices is forwarded to next level, where data is processed and stored on cloud and then transferred to user's laptops, tablets, desktops, android or IOS smart phones. At cloud data can be further analyzed.

Healthcare IoT framework is so designed that it could be implemented in and out door locations with help of number of communication protocols and microcontroller support. Healthcare IoT framework is envisaged to perform successful monitoring of health and providing a platform to provide remote prescriptions deploying less connectivity issues, cheaper cost, and plug n play support.

In purposed framework sensors are attached to patient and the things from which we want to get data. This data is then sent to doctors, nurses etc. through network layer and received on tablets, mobile, computer at application layer. Context awareness the middleware provides data timely, accurately and precisely to users for better health quality. In Pakistan we haven't implemented any IoT Based HMIS at any hospital. We have investigated through survey based study, if the users are ready to adopt the IoT based system.

1.1 Problem Statement

The main problem is that we lack a common platform to uniformly access and manage hospital information. We face a lot of problems in hospital management system such as absence of doctor, unavailability of ambulance a right time, delay in operation time, late diagnosis, problem in communication especially for e-health type of HMIS, data sharing issues, badly managed medical equipment, lack of tracking system for real time scenarios.

This thesis argues IoT based HMIS can offer a catalytic solution to overcome these problems. In existing system tracking and other data management is mostly done at centralized database and is closed loop. Even in most cases information is restricted to share between departments of same hospital. IoT based solution provides information storage at cloud.

As in IoT everything is going to connect with each other, so billions of sensors are connected to billions of devices and they continually accumulate data and forward it. So there comes another problem to handle and deal with this much data.

This study focuses to overcome the gaps in existing hospital management system by investigating IoT focused solutions towards health industry. Moreover big data problem raised by IoT driven solution, is handled through context awareness. This is used as a middle ware in IoT driven framework. This research particularly focuses on establishment of IoT empowered HMIS technologies.

1.2 The Vision

Our ultimate goal is to improve human health. IoT is an emerging technology which aims to provide better life. So to develop architecture based on IoT with practically usable technologies for hospital management system is the goal of this research.

As a latest computer-generated physical system, IoT provides and integrates all kind of sensing, intelligence, tracking , identification, monitoring, communication and networking of all types of objects, by connecting all the objects, at anyplace, at any time, and at anywhere using context awareness[12] which helps analyzing data and creates context and generate useful data for users.

The impact instigated by internet of things on individuals' life will be as huge as it was caused by internet to humans' life in past decades. Therefore IoT is predicted to be "the next generation of internet". Different researchers have mentioned IoT as the advancement of information technology and as next step in the evolution of ICT [6], [11]. The main technologies, which are part of IoT are,

sensors, actuators, radio frequency identification (RFID) ,micro electro mechanical system (MEMS), biosensors, gateways, wireless sensor networks, cloud computing, middle ware, service oriented architecture(SOA), data mining techniques, mobile communication and embedded systems.

1.3 Research objective

The study shows the lack of a methodology for hospital management information system, especially using the value generating features of internet of things. IoT is a new research area as it is a new technology and has not defined for the provision of hospital management information system. Only few studies are performed related to health care in patient perspective but we don't have one common platform to deal with complete hospital matters. Some serious diseases such as hemorrhagic tremor may cause death of patients if not treated on time; hence we have provided a framework based on IoT which provides early diagnosis and treatment.

The objective of this research is to reduce the limitations of existing HMIS by studying critical IoT technologies, and developing an architectural framework for hospital management information system based on IoT. Further it aims to address the problems of handling big data produced by sensor networks layer.

The objectives for the researchers and academia personals are:

1. To grab the attention of students and researchers towards the Internet of things because more research needs to be done on this topic.
2. To create awareness in academic persons such as students and researchers about the need of Hospital management information systems and technologies.
3. To create an environment for active research in HMIS applications in research & educational institutes of Pakistan for the betterment of health.

1.4 Motivation

Internet of things is an emerging technology, which is influencing our lives and hence becoming the popular topic for research. Health is very important factor in every body's life, but due to bad management of hospital's we face many chronic problems and there happens more causalities. These can be evaded by well management of hospitals information system. So we need to improve our existing HMIS.As IoT promises to provide better future. So he we have proposed IoT based HMIS.

1.5 Structure of Thesis

Rest of the thesis is organized as follows:

Chapter 2 explains the internet of things, its main technologies, architectural view and its applications. This chapter shows the importance internet of things, effects of IoT on our life and its impact on future.

Chapter 3 gives a detailed review of already presented methods and frameworks for hospital management system and patient care with IoT based technology and their gaps in existing systems.

In chapter 4, the proposed framework of HMIS and inclusion of context awareness in the IoT structure is discussed. It includes internet of things based architectural framework which shows the main structure of hospital and how it works. Contribution of each layer is discussed in detail. Further the perspective of context awareness is included to deal with the big data problem. Lastly working of proposed system is shown with an example.

Survey based analysis of IoT based HMIS is given in chapter 5. It contains all the questions and their results in textual as well in graphical view.

Chapter 6 contains the concluding remarks and future work of proposed system.

CHAPTER 2: Internet of things

2.1 Introduction to chapter

In this chapter, the brief introduction of IoT is presented. Our purpose is not to review the IoT but to discuss some information relevant to IoT. Such as what is IoT, how IoT has evolved, what are statistics of IoT, basic technology and characteristics. It will help to understand the evolvement of internet and innovative technology, towards which we are moving. The IoT has its own particular ideas and attributes. It is not only changing over living style and revolutionizing our lives but it is another step to the development of technology and internet evaluation. IoT shares ideas with other computing techniques. Explicitly IoT groups various technologies (for example sensors, middleware's, m2m, cloud computing, perception, reasoning, semantic, processing) to gather to formulate its vision. We use existing technologies with IoT in various manners keeping in view the qualities and requests of IoT.

IoT is an emerging technology. It is a fourth generation of the technology evaluation. IoT technology has started from improvements in data technology such as cloud computing big data and now internet of thing and web of things. Internet of things is development of information and communication technology connected with, pervasive computing, ubiquitous computing and intelligence. Ubiquitous and pervasive computing is a technology that has the ability to connect objects anywhere and anytime and communicate information. Intelligence is the ability of items to enlist changes in physical situations and effectively connect with procedures [13].

Hospital management information system(HMIS) is a medical system that keeps records and handles all the assets and actions of hospital. It can handle tasks like, billing, scheduling, appointments, maintains charts and notes, keeps lab results and x-rays, keep records of beds, drugs and so on. IoT is the main idea behind smart hospital. IoT infrastructures are rich in sensing and processing abilities and are intended to react wisely and support them in doing particular task. The IoT can be applied to open scenarios where new functionalities, capabilities and administrations can be set at run time, without seeing them or having them at design time. IoT solutions can be inalienably independent, i.e., showing the self-setup and self-association abilities expected to give this extra level of adaptability [14].

2.2 IoT definition and vision

In last decade IoT has got a major attention in education as well in business. In near future everything will be IoT based. The reason is the abilities that IoT proposes [22], [23]. It will not be only human who will be communicating to each other and to machines, but machines will communicate on behalf of humans and among themselves. Everything will be connected to the internet. The connected things, which are also known as smart objects, will be much more than the number of humans. Humans may become minority of things generated and received. We are entering in a new era of technology, we are entering in the era of internet of things, where there will be new sort of communication among people and machines, and machine themselves. There will be connectivity for everything, at every time, at every place connection. A definitive objective is to make 'a better world for people', where things around us act appropriately according to our needs, likes, without explicit commands. [26].

First time, the term “internet of things (IoT)” was used by Kevin Ashton in 1998. He has specified "The Internet of Things can possibly revolutionize the world, pretty much as the Internet did, perhaps more than so". Then in 2001 IoT vision was presented by MIT center [28]. Then there was an official introduction of IoT given the International Telecommunication Union (ITU) in 2005 [29].

The IoT encompasses a significant amount of technologies that drive its vision. In the document, *Vision and challenges for realizing the Internet of Things*, by CERP-IoT [16], a comprehensive set of technologies was listed. IoT is a very broad vision. The investigation into the IoT is still in its infancy. Therefore, there aren’t any standard definitions for IoT. The following definitions were provided by different researchers.

Figure 2.1: A vivid description of the vision of Internet-of-Things

The IoT incorporates a lot of technologies which propels its vision. "Vision and difficulties for understanding the Internet of Things", a document by CERP-IoT [16] has represented a wide ranging set of technologies used in IoT. Accordingly IoT has an extremely wide vision. The study of the IoT is still in its beginning stage. Hence, still there is not any standard interpretation to define IoT. But some of the definitions are given below which are represented by various researchers.

- *T.Lu and W. Neng defined IoT as*: *"things are smart and have identities and behaviors functioning in a smart world utilizing smart interface to communicate and link with people and environment."* [30]

- *"The semantic beginning of the term is created by two words and ideas i.e. Internet and Thing, where Thing is anything any object which is specifically recognizable while Internet can be characterized as the worldwide system of interconnected computer systems, where the network is based on a standard network protocol such as (TCP/IP). Thus, semantically, Internet of Things is defined as a large network of uniquely identifiable objects established on standard protocols." Definition by [20]*

- "*The Internet of Things permits individuals and things to be associated Anytime, Anyplace, with anything and anybody, preferably utilizing any network and any administration." by [21]*

Figure2.2: Internet of things: The Internet of Things permits individuals and things to be associated Anytime, Anyplace, with anything and anybody, preferably utilizing any network and any administration."

We acknowledge the definition given by [21] to our research. We accept this definition because this optimizes more extensive vision of internet of things (IoT). The more clear illustration of definition is shown in figure2.2.

2.3 Key technologies of IoT

IoT is progressively becoming the main technology of following era of data systems and networks. IoT is a combination of multiple integrated applications based on the internet. Next we have discussed some of the significant technologies involved in IoT.

1) Internet

Internet is in actual facts a network for next generation. So in order to communicate with anything, any individual and any object internet is an essential precondition for IoT.

2) RFID

RFID is a noncontact technology because it works with electromagnetic induction method, which reads and communicates data. RFID consists of three essential components i.e. tags, reader and backend system. RFID tags are attached with the objects, equipment's or other items. Tags might integrate sensors. Tags have the all the related information of items. Reader communicates information to tag and saves information to the backend database.

3) Sensor Network

Sensors are the essential technology of IoT, for better location tracking, actions, temperature, movement etc. specifically the status of objects, sensor network may collaborate with RFID structures. Sensor systems comprise of a specific number (which can be exceptionally high) of sensing hubs communicating in a remote multihop style. Mostly nodes send their sensing results to a little number (and usually just to one) of special nodes named sinks. With the constant advancement of science and innovation, the conventional sensors are in the technique of microminiaturization, digital information, intellectual systems, and being networked. Use of sensor technology networks has been anticipated in numerous application developments, for example, smart hospitals, tracking, monitoring, checking, smart transportation, military, and mechanical plant observing [17].

4) Wireless communication

Wireless communication knowledge is necessary to robotically communicate the data stored in RFID tag to central database system. , so in IoT wireless communication is fundamental technology. There are numerous wireless communication technologies available mostly take account of Zigbee, Bluetooth, IrDA (infrared data association) Wi-Fi, UWB (ultra wide band) etc.

5) embedded Technology

Basically, IoT is an embedded technology focused around internet. Due to the fact that to a greater extent smart items have the necessities of network, it rush the generation of IoT idea [6], therefore IoT is the obvious result of embedded system development and it can't do broad utilization without support of embedded technology.

2.4 Architectural view of IoT

In this section we will discuss the IoT architecture at abstract level. The basic layers with key technologies and their functionalities are discussed here. By keeping in mind the definition and vision of IoT, infrastructure of IoT can be theorized at 3 layers i.e. i). sensing layer, ii).network layer and iii) application layer as explained in detail below. Figure 2.3 illustrates the IoT architecture at 3 levels.

1. **Sensing layer (component layer):**

   This layer shows the component level of IoT. This layer involves a range of smart objects, things and devices. Sensors are attached to the physical objects (such as car, home, fridge, and person) or installed to environment (such as forest, tree, and farm). And this layer can directly communicate to the real world using sensors for reading or accessing data and actuators for providing information. It is usually divided into 3 types.

   - **Smart Objects:** these objects are uniquely identified; possess communication abilities and have computational capabilities. These devices can sense the environment for example; they can sense the phenomena like change in light, temperature etc. and can process the data. They are able to immediately response to the change in real world, due to the ability of sensing the data, collection of data and then processing of complete data.

These objects communicate through the sensors network and they comprise the objects from wireless sensor networks [14].

- **Computing object:** these comprise objects like mobile phone, laptop, tablets and computers. Smart phones have abilities to communicate wirelessly such as with Wi-Fi or Bluetooth technologies alongside with the computational and sensing abilities that give users proximity information and network path planning. These devices provide a connection with smart objects. Moreover they have capabilities of providing user interface for personalized applications. Computers have many features such as they have smart little chips, low cost, fast computation, high performance, low power consumption and communicator Wi-Fi and have abilities to connect with smart phones and other smart devices. (Accenture, 2012).
- **High end objects:** these objects include devices like gateways. That gathers and precedes this information from smart and computing objects and deals with their operations. Gateways and other high end devices total focus is to carrying the other end objects and installed short range sensors online and supports communication among diverse remote technologies. (Wu et al., 20).

2. Network layer:

This layer shows the system level of IoT. This layer comprises of a very dynamic and fundamentally dispersed network structure, made up of smart objects that deliver and devour data. The dynamism is because of the proficiency of smart devices to make ad hoc associations with other devices, accordingly empowering self-administration and independent competencies. The network connection delivery among end devices is grouped into 3 categories and those are described below.

- **Low vitality network:** this network comprises many low cost, low energy protocols. Such as Zigbee, Bluetooth, IEEE 802.11, Zwave, IEEE 802.15 and electrical cable interconnection, by means of those objects at network layer can interconnect with each other.
- **Mobile network:** The expansion of mobile network gives universal integration to the client hence dispersing continuous real world data [13].

- **Wireless network**: Advanced remote networks give pervasive scope and provide broadband information services at a considerably lower expense. It is important for the IoT service platforms. These pervasive systems have some properties that provide service delivery for IoT. (Wu et al., 2011). With the advancement in technology there are some Wireless communication protocols have developed to communicate with diverse technologies in different situations from low energy, low transmission capacity, to more energy consuming high transfer speed, technologies (Compan, 2012).

3. Application Layer (Administration Level):

This layer shows the Application level of IoT. This layer provides interface to end user, where users can access to data and can customize applications according to them. At this level data is accessed from smart devices and computed. At this layer the functionalities and other data given by the smart objects (generally in type of information streams produced) are incorporated into value added services. At this layer data is huge in storage and processing power and mostly it is accessible through cloud computing. It provides such functionalities at large scale and at lower cost. The procurement of such cloud based objects administration and services involve processing at followings levels (at one or both levels):

1. Centralized device administration: at this level decision making, administration of devices and data processing can be done by establishment of centralized cloud computing.
2. Distributed device administration: at this level for this situation, items are empowered in a system to make distributed platform that allow the simple, easy usage of facilities on top.

Figure 2.3: An illustration of IoT layers.

2.5 Characteristics of IoT

Now in this section we have briefly described some characteristics of IoT from the research point of view. The Seven characteristics we have identified here are most important of attributes IoT. We have identified these characteristics on bases of previous research [16]: These attributes are *intelligence, everything as a service, space concerns, structure, architecture, time concerns and size concerns*. These qualities should be considered while developing the IoT based solution, through all phases of development including design, architecture, implementation and evaluation.

- **Intelligence:** This implies the utilization of information. First of all it is needed to b data generation by collection of data and the extracting knowledge by analyzing that data. The collected raw data can be transformed to useful knowledge (high level data) by collecting, analyzing, molding and reasoning the context data. Context information can be used with the sensors information to gather a new type of information. When we have some knowledge or information, it can be useful to more intellectual communication, interconnection and application.

- **Architecture:** IoT ought to be encouraged by a hybrid structure, which involves different types of structural design. Basically form research [51] we found there are two types of architectures. Those are event driven and time driven.

  i) Event driven sensors: these sensors generate data when an event takes place (for example gate sensor)

  ii) Time driven sensors: these type sensors continually generate data, based on indicated time period; for example temperature sensors

  For the most applications the sensors we are using now are event driven based, both in IoT and sensor networks (SN). Generally ECA (event condition action) rule is used in such systems.

- **Complex system:** IoT involves a large number of things including sensors and actuators, which communicate autonomously. New things will begin interconnection and present ones will vanish. In existing system, there are millions of sensors have implemented in world [53]. Interaction among object may rely upon their capabilities i.e. communication among objects can vary significantly according to their capabilities. Some of objects may have small information storage space and do a little or not at all processing. While some are with the huge data storage and processing capabilities and also have reasoning capabilities. That makes these types of objects more intelligent.

- **Size concerns (scalability):** the number of connected devices is increasing day by day. It is estimated that in 2020 almost 50-100 billion objects will be connected to internet [16]. The number of connected device will increase continually and will certainly not decrease. Like the number of objects, number of connection among them may also increase considerably in the same way. The IoT needs to encourage the collaboration amongst these items

- **Time contemplations:** For IoT real time processing is necessary. As millions of devices are connected to the internet, millions of events may occur concurrently and parallel, because of the huge number of collaborations and IoT can deal with these.

- **Space contemplations:** The exact location of objects is necessary [54], as location plays an important role in interaction of objects in context aware computing. When the quantity of items increase to a large number, keeping track of these items become difficult. So keeping track of these items becomes an important obligation. interconnection of objects highly reliant on their geographic location, their environments and occurrence of other things(for example person and car)

- **Everything as a Service:** Cloud computing is becoming very popular [55]. With its popularity everything is overwhelming its resources as a service [56]. For example, Infrastructure-as-a- Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS), has developed as a standard. Everything-as-an service model is profoundly scalable, productive, efficient and simple to utilize [57]. IoT needs an infrastructure where a large number of objects can be followed in a group based methodology, to mark its vision a reality. Thus sharing is important in IoT. So everything as a service would ensemble sensing as a service.

2.6 Applications of IoT in different domains

By assessing the application domain, we can identify the broad scope of IoT. So in this section IoT Applications is presented in different domains. IoT is an emerging technology and having its influence in every field of life. The interconnection of everything and there communication over internet has enabled many applications in many domains but only few of them has implemented in the world. There are a lot of fields and environments where IoT would have its influence to probably improve the quality of our daily life: at work, at gym, while traveling, while exercising, when sick and so on. Our environment is furnished with objects, to which sensors are attached, and have basic intelligence. If these objects start communication of data gathered from surroundings, a different environment can be created. The application of IoT is generally classified into following domains [23], [16]:

i) Industry
ii) Environment
iii) Society

The categorization is based on the focus of application. The statistics of the applications is presented in section 2.6.

Asin and Gascon [37] listed 54 application domains under twelve categories: smart cities, smart environment, smart water, smart metering, security and emergencies, retail, logistics, industrial control, smart agriculture, smart animal farming, domestic and home automation, and eHealth.

Some of the IoT applications which come under industry focused category are supply chain management [31], automotive, infotainment, telemetry, Nano power harvesting, aviation transportation and logistics [32]. Society focused IoT applications includes telecom, entertainment, brilliant building, media healthcare, smart grid, smart home[34] and office, mass media, medical technology[33], ticketing, the concept of smart city and so on. Farming and nurturing [35], [36], reusing, fiasco warnings, ecological observation, earth quick alerts, environmental context awareness and tsunami early warning system are some of the environmental dedicated applications of IoT.

Asin and Gascon [37] categorized IoT application in twelve groups and into 54 application areas. The classification groups are

- Intelligent agriculture
- Business
- Logistics
- Smart water
- Smart animal farming
- healthcare
- Smart energy
- Smart industry
- Smart environment
- Home and domestic automation
- Security and emergencies
- Smart security alerts

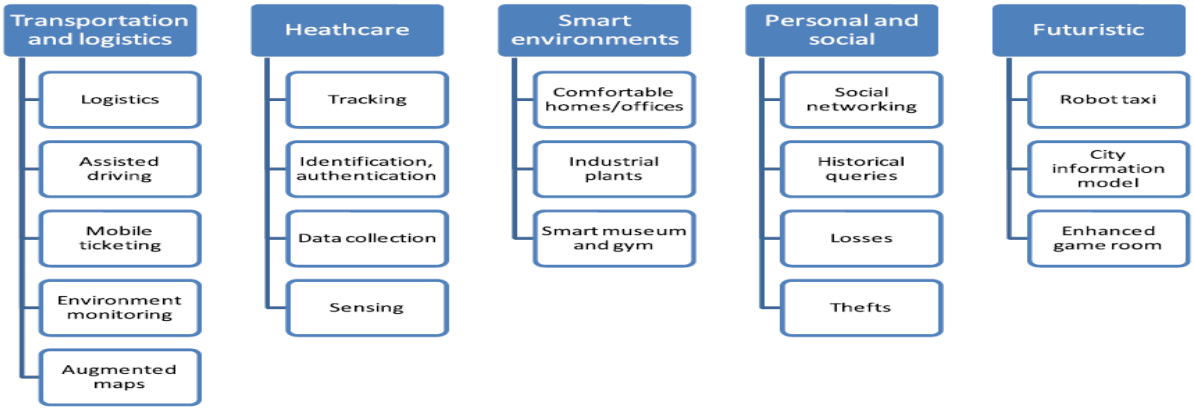


Figure 2.4: Applications domains and relevant major scenarios.

Figure 2.5 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. Amongst the many applications (Figure 2.5) which can be possibly implemented, we can separate them in two ways. That either they are directly relevant to our present living style or those which are advance and futuristic (those which we can just fancy of right now, as our cultures, peoples and technologies are not ready yet to implement them). In following subsection we have precisely discussed the short and medium level of applications and their scope for each category of IoT application.

Fig.2.5. Internet of Things schematic showing the end users and application areas based on data. [17]

2.6.1 Transports and logistics:

In modern age with advanced technology cars, bicycle, trains and buses in consort with roads and railings are turning out to be more equipped with sensors and actuator. And they also have processing power. Streets, trails and roads by themselves and transportation vehicles are also instrumented with sensors and tags, which communicate important information. They send data to the transported good and to the traffic control site to better control the route of vehicle movement, to better control and manage traffic load, to manage garages, guide the tourists with proper information of transportation and to monitor the overall transportation status. In following subsection core applications of Transportation and logistics domain are discussed.

Logistics: With the advancement of technology, currently data handling techniques based on NFC(near field communication)and RFID(radio frequency identification) can continually observe and identify every action of supply chain, covering a wide range from products design, crude material purchasing, manufacturing, supply, shipment, sell of items, process of returned items and provision of services after sale. Means we can realize real-time monitoring with

these technologies. Due to the these technologies, now it is feasible to get data associated to products instantly , timely and precisely so that business persons or even the entire organizations and supply chain can react to complicated and changeable businesses in the minimum time. The benefit of this application is that, generally enterprises takes 120 days from order of product to its shipment, while now the organizations that use this technology (e.g. metro and Wal-Mart) require a couple of days [39, 40].Furthermore, online access to the ERP project assists the shop collaborators to well inform clients about availability of items and give them more general information about products. [41]

2.6.2 Assisted driving:

Transportation vehicles such as cars, buses, cycles and trains in consort with roads and railings are equipped with sensors and actuator. So they have processing power. From the processing power drivers and passengers of vehicles may get data related to path navigation and road safety and give guidance about better route. The auto driver might find right way with the right data about road jams and accidents. This can be done with different techniques for example by continues monitoring of vehicles (especially with hazardous materials) and by collision avoidance systems. Other than individual and business persons it is also helpful for governments and traffic police. Government authorities may take benefit for planning purposes by taking exact information about road transportation load. The companies such as cargo organizations e.g. freight, who follows energy savings, would have the capacity to perform more efficiently with using effective rout optimization.

2.6.3 Health Domain:

IoT technology is also influencing health domain. Many applications have developed for the purpose of better healthcare. Most them are RFID based in which tags are used. The application of health care can be grouped in following groups:

- Tracking of objects and people (staff and patients),
- Identification and authentication of people
- Automatic data collection and sensing

CHAPTER 3: Literature review

3.1 Introduction to chapter

Literature has predicted that IoT is about to revolutionize the every domain of life including healthcare by significantly increasing quality and bringing down the cost. So management of hospital with IoT has become a very important research in the field of technology and health. What we are seeing now is that some of applications have already developed and implemented. RFID and sensor based network has deployed for the patient care, which collects patient data and transfers to gadgets (availability of data) used by medical officers for examining and delivery of patient care, which was not accessible before. In these manners IoT driven framework, making it possible to increase availability, improve the quality and reduce the cost of patient care. In this chapter we briefly explained the evolution of IoT some previously done work related to healthcare.

3.2 Evolution of internet of things

In this section we have briefly discussed the history of internet. In early 1960's, it was made possible to communicate between computers. The first complete package for the Communication between computers was developed by Department of defense and the called it ARPANET. Through this network they made possible to transfer of files without moving them physically. The stable communication between multiple computers started in 1969. In 1970's different communication packages were developed. In early 1980's TCP/IP protocols were developed and then in late 1980's commercial use of the internet were started. In early 1990'sthe internet evolved to World Wide Web (www) became accessible, which was another big step in the revolutionizing internet technology. In mid-1990's people started to use internet for the purposes of communication, business, etc. Sites like yahoo, eBay and amazon was developed. Later mobile internet was formed by connecting the mobile device to the internet [19] and somehow internet of things was based. Then people started to became linked over the internet, through the development of social networks. The next step in evaluation of internet is "internet of things (IoT)" where every object is connected to the internet and each other, where every object can communicate to other object [20].

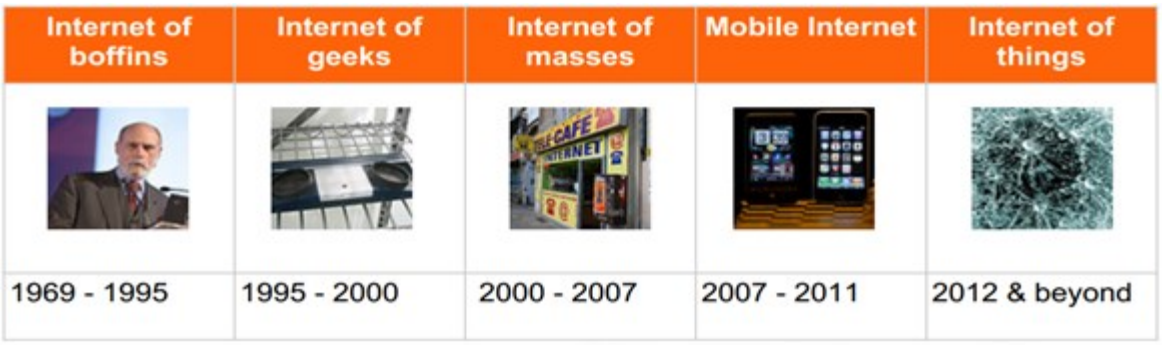


Figure 3.1: Evolution of internet of things

Figure 3.2 is illustrating the concept of internet of things evolution. In very start it was only 2 computers were connected, and then this concept moved towards World Wide Web, connecting large number of computers. This evolved to the mobile devices connection through internet. Then through social network's people identities joined the internet and now it is connecting every object to the Internet with the IoT technology.

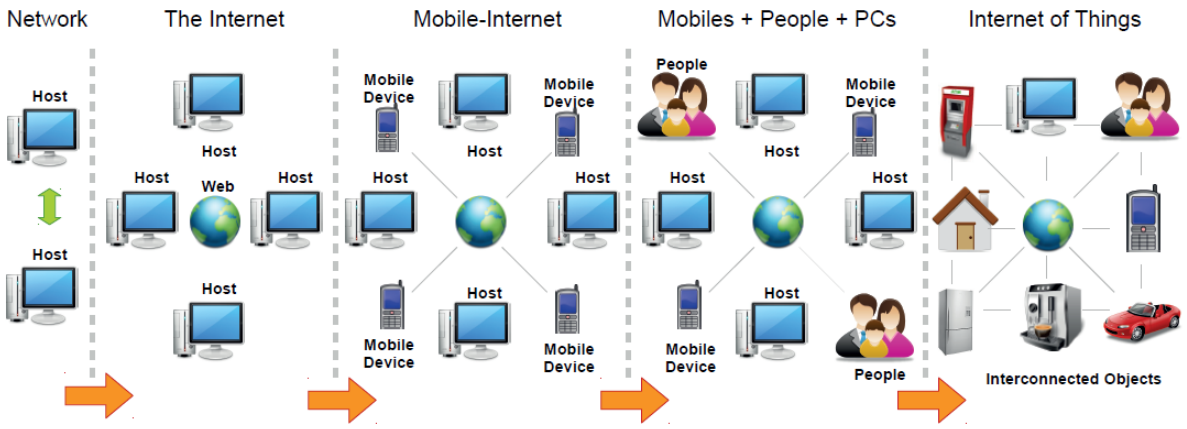


Figure 3.2: is illustrating the concept of internet evaluation.

3.3 IoT related statistics

As everything is connecting to the internet, the vision of IoT is typically increased by the estimations and statistics prediction. It is estimated that today there are almost 1.5 billion computers and 1 billion mobile devices are connected to internet. In future these computers and mobile will be connected to other internet enabled devices called the smart objects [24].

There are different statistics by different organizations of internet connected devices. According to cisco currently there over 10 billion things are connected to the internet out of 1.5 trillion. According to Gartner there are total 10 billion devices are connected to internet.

In near future the number of connected devices is increasing. According to Gartner in 2020, 12 billion mobile devices and total of 20 billion devices will be connected. According to Business insider we are currently connected to the 2.5 billion devices and in 2018 9 billion devices will be connected to the internet [25]. According to [4] 50 to 100 billion devices will be connected to the internet. Cisco says in 2020 about 50 billion devices will be connected to internet. According to Intel it will be 200 billion and according to IBC 212 billion objects will be connected [68].

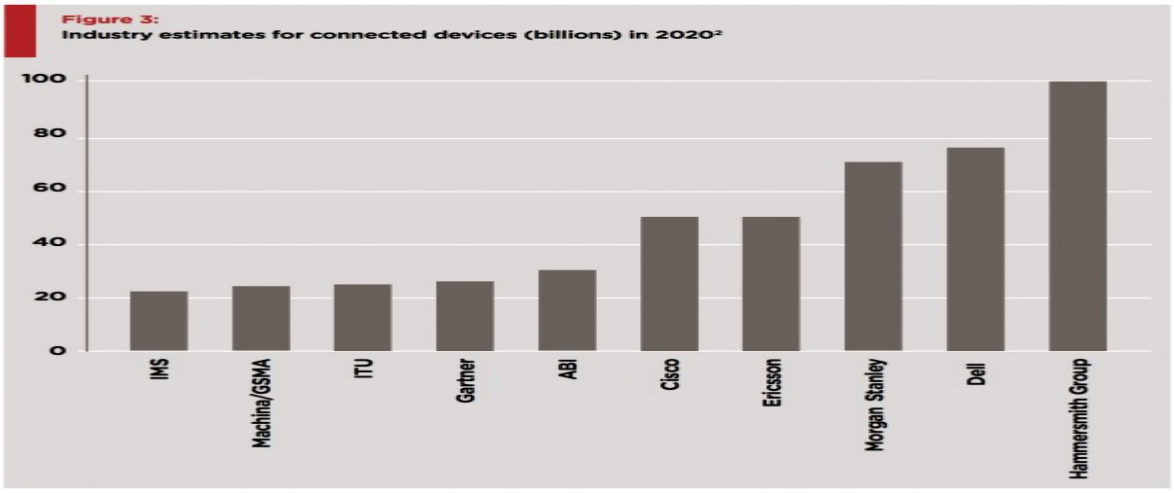


Figure 3.3: Illustrating the estimation of connected device by different researchers in 2020

By BCC research [38] in 2010 sensors' market was of almost $56.3 billion. In 2011 it increased to $62.8billion. It is estimated that by 2016 the worldwide market for sensors is $91.5 billion, at annual development rate of 7.8%

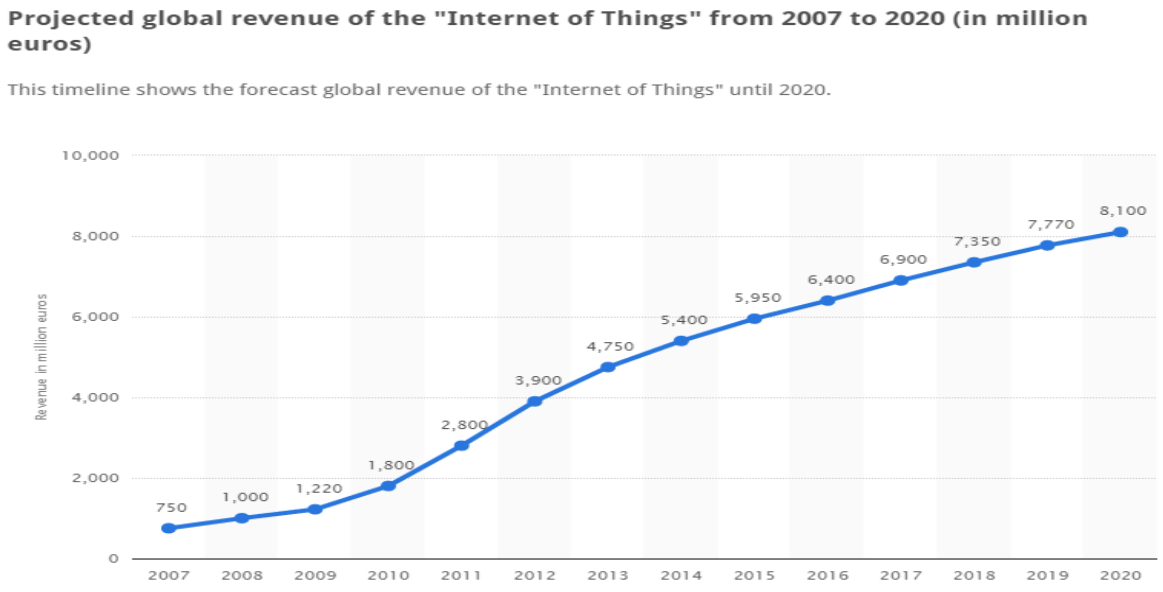


Figure 3.4: A graphical view of increasing revenue by sensors and connected devices in 2020

3.4 Previous research of IoT in HMIS

Now in this section we will explore in greater depth the role of IoT in hospital management system delivery, take a close look at the technological aspects that make it a reality and examine the opportunities and challenges the IoT poses for healthcare today. Very few researchers have pointed out the frameworks for health monitoring using IoT, and different studies have provided different strategies of hospital related management systems in the past few years. Some of the previous work is discussed in this section.

Partha P. Ray, 2014 [58], have proposed a framework for monitoring physical activity based on IoT. Author has catered the need of bridging the link between human and its physical in daily life based on IoT. PAMIoT (Internet of Things based Physical Activity Monitoring) advocates the helpful utilization of access to the applications made to analyze, visualize and measure the data accumulated from different biosensors while they(humans) are busy in their physical activities. The data gathered from biosensors are transferred to mobiles, computer gadgets or to cloud. PAMIoT is visualized to perform successful monitoring activities with less integrating issues and less cost. The utilization of this framework could be at games, gym home and hospital.

Security is very important to any personal and classified data and when we talk about information through internet, the first question arises of security. In security we say that information should be authentic and the person who is accessing should be trustworthy and authorized. For trust management of data, traditionally we use authentication by passwords, security questions, keywords and token etc. But these parameters can be hacked easily. So there should be some other authentic way. Then biometric authentication mechanism was introduced for security purposes. In biometric authentication includes physiological verification such as fingerprints, palm, Iris, voice, face, Deoxyribonucleic acid, signature and retinal recognition. Biometric authentication is more strong then passwords and token authentication, due to uniqueness, non- reducible and non-transferable characteristics. Radio fingerprinting has got stronger attention now days. This technique captures the signal from fingerprints and transmits this wirelessly. It is a method which makes it feasible to recognize a wireless device by irreplaceable radio transmission. In ehealth care, it is important to know if the data is sent from correct person and if the data sent is correct. Especially when we talk about remote patient monitoring, it is needed to ensure if data is authenticated and send from authorized person. Biometric and radio fingerprinting authentication is used for security purposes. But they are used separately. In hospitals we need to know if patient data is sent from the authenticated person and data is send using right device. They can be achieved by implementing both biometric and radio fingerprinting method together [65]. Kashif Habib et al, has proposed a 3 layered framework for security of patients data for e-health systems based in Internet of things. 1st layer ensures that data is being sent from correct person, 2nd layer ensures that data is being sent from right device, third layer is patient to remote server authentication. This formwork ensures that data belongs to right person.

M. Memon, et al., [2014] studied existing frameworks, platforms, quality attributes and technologies for ambient assisted living (AAL) [59]. Ambient assisted frameworks are proposed for elder people to help them to meet their health care and communicate important health related information. AAL platforms increasing day by day as different organizations and policy makers have drawn consideration of government and IT industry toward growing number of elder people. The literature shows that there are many limitations of existing frameworks, such as no security, lack of quality, interoperability and integration, design issues, limited feature and technology

issues. Besides these there are issues of complex system and so the complex deployment. Assisted living has been given priority to facilitate the elderly people.

Emergency care based on internet of things (IoT) for ST-elevation myocardial infarction (STEMI) patients is established by regional cooperative system [66]. As it is observed that quick reperfusion cure considerably decreases death and illness in patients with STEMI. So the proposed system is founded on this solution. To reduce the time of diagnoses and treatment of these patients' in in-hospital and pre hospital, process of emergency response is optimized by implementing internet of things. American health association suggested the ultimate time for patient rescue. Report said that patient can be saved if after attack reperfusion time is within 2 hrs. And door balloon time is less than 90minutes. This time is critical to patient. So many organizations and care centers tried to find solution of diagnosis and cure of STEMI within this time, but didn't find much satisfactory outcomes. By monitoring and remote mobile communication it was possible to reduce the time to take care of STMEI patients. For this purpose a network system based on IoT is proposed. The network for the treatment of STMEI is composed. This established the linkage between multiple departments (such as emergency department, cardiology, pre hospital emergency, imaging department), multiple hospitals and patients and family. The network is based on data collection, data transfer and information processing. By this system patient monitoring would help to reduce the time, as it will be diagnosed that in which department he need to send and what treatment has to be given, when he is in ambulance before reaching hospital. In this way the patient who would need to operate, their pre operation environment would be ready while they are in ambulance. The system was implemented in 2011, and the success ratio was 97.5%.

In [60] P. P. Ray [2014] has proposed an architectural framework for Monitoring Health of Elderly People. Home Health Hub Internet of Things (H3IoT) is developed for monitoring, ehealth, chronic disease supervision. The proposed framework consists of five layers including physiological layer, communication layer, data processing layer, layer and user application layer. Sensors are attached to persons and this happens on physiological layer. Physiological layers data is communicated to data processing layer through local communication layer. Data processing layer transfer data to internet and from there it is transferred to users' application layer, where users can access to data on their gadgets.

In [64] Boyi Xu et al, has address the problem of access heterogeneity data over IoT in medical emergency events. Data is increasing day by day so its access and storage is challenging. Author has proposed a ubiquitous data accessing method. First a semantic information model is projected to store and understand data. Then this data is ubiquitously attained and processed. By implementation of this model doctors and medical officers can access heterogeneous data online, quickly and easily through cloud and can help in making decision support systems fast and reducing the cost of process. To deal with the heterogeneity of data accessed from IoT in medical ubiquitous information reading (UDA-IoT) method is adopted with the RESTful web architecture. To facilitate doctors and medical staff with heterogeneous data, data is converted to semantic data model. Data is defined in xml so that it can be accessed form web. Here data is accessed in two ways, by time tags and by location tags. Time tags get real time data and location tags get data with physical positioning of medical equipment's. In this research instead of traditional data base distribution, cloud based multitenant data distribution architecture is used. Multitenant layer communicates with dynamic data. Multitenant based on clod handles two main constituents of databases, shared database and isolated database. Different organizations have different privacy policies. Companies which don't want to share their data they will keep this data in isolated database and data which they want to share with others will be put to share databases. Data from UDA-IoT architecture can be accessed in four steps, cloud send request to business layer to access data, business layer, business layer approves the request and send request to restful web, if request approves or not. Resource control mechanism assists request and send it to database. Database layer gets related data from isolated and shared databases. The focus in this paper is on semantic and unified data model in accessing and distribution of data. The proposed data model is suitable for industries with only short supply chain not for long supply chain.

Antonio J. Jara et al., [61] in their paper "Interconnection Framework for mHealth and Remote Monitoring Based on the Internet of Things" has purposed a framework for mobile health and presented a novel protocol for communication of personal data. For the personal health capability there was a limitation of available data, its communication for the better personal health. Because data is usually dynamic and incomplete, therefore it's difficult to analyze mine and trend. For that this study has presented an interconnection framework for personalized mobile health (mHealth)

based on internet of things. The internet capabilities makes continues and remote monitoring feasible and this has introduced the technology innovation for empowering health monitoring and patient devices. This also allows patient supervision and monitoring from central center and from personal gadgets such as tablets. The hardware used are 6LoWPAN for the wireless transmission and as middleware and RFID for patient identification in software it offers an effective, scalable and secure incorporation of the sensors used in the patient's personal environment through a novel protocol *YOAPY*. The proposed framework was evaluated in the framework of AIRE project, which is dedicated to patients breathing disease. It is concluded that dynamic continues checking is practical with proposed protocol and framework which is based on IoT.

In [67] P. P. Ray [2014] has proposed an architectural framework measuring and analyzing daily activities of people. Physical activity monitoring (PAMIoT) framework based on Internet of things intended to deliver continuous monitoring of physical activities of humans while they are doing their indoor or outdoor activities. Activities can be monitored to see if the person is doing well. That If he need fitness or he is fully fit. The proposed framework consists of five layers including physiological layer, communication layer, data processing layer, layer and user application layer. Sensors are attached to person's hip, elbow or wrist and this happens on physiological layer. Physiological layers data is communicated to data processing layer through local communication layer. Data processing layer transfer data to internet and from there it is transferred to users' application layer, where users can access to data on their gadgets.

An infrastructure for Healthcare system is purposed by [62]. In this paper author addressed the problem of lack of common platform to uniformly access data with the limitation of client devices and heterogeneous data from the emerging devices such RFID and context awareness. He proposed a solution with web2.0 and RFID context awareness. From that users can access data through web. There are two types of data access schemes. Push based scheme and pull based scheme. In push based scheme user will get the data for which he wants notification, which he wants to get automatically. The important data is send to user by push based scheme. In pull based user can access data by himself, what he would like to access. In this infrastructure data is gathered by RFID tags which are attached to patient and equipment. Data reader (SYRD245-1N) reads data such as identification of room from SYTAG245-HT1 tag, ambient and room temperature from

SYTAG245-TM tag, from SYTAG245-2K tag which is attached to patient for identification and sends to context aware technology by wavecom. Wavecom acts as a GSM like GSM in mobile to send sms where data is analyzed and generate useful information to user. The limitation of this system is maintenance of big data.

Context aware user interface framework based on internet of things was proposed by Jae Pill Yoo et al [69]. It makes available easy navigation and provides user interface for real time services. In the existing system IoT applications provide all combination of services. But with context aware, it can be made possible to compose only those combinations that user requires according to time, location and surroundings. Framework is composed of two parts. One is middleware that collects and analysis data and composes services according to situation. Second is to communicate with middleware and from this layer, user can monitor accessible services and control the services.

In [70] David Niewolny (2013), enumerated in his paper "How the Internet of Things Is Revolutionizing Healthcare" that in health domain internet of things is participating an important role by continues monitoring and clinical healthcare. He said that by IoT it is possible to collect, analyze and process data gathered by sensors. Some of systems are implemented such as Masimo Radical-7; this provides monitoring and graphical representation of patient status. Data is captured through sensors, analyzed through complex algorithms and communicated to doctors, nurses or other concern persons through wireless connectivity. This saves the regular visits of doctors to come and check patient.

In [63], Martyn Casserly has discussed the benefits of connected devices. AS IoT is an emerging technology and connecting everything to internet. It is influencing every fields of life along with health. Author said, currently there are very few examples of internet of things applications implemented in health domain. But the vision of IoT has shown us the bright future. In health it can make possible to remind patient to take medicine, we can monitor patient at distance, we will receive alerts if patients condition is getting sever. Cars navigation then can tell which rout to choose to reach hospital in shortest time and to which hospital has the most free beds and available doctors.

RFID based sensors and context aware systems are emerging technology in health. There is still lack of consistent access to manage heterogeneous methods, issues of healthcare context aware middleware, limitations of client devices and different healthcare context aware presentations in existing health care systems. So a common standard is required to homogeneously access the context aware healthcare systems and to permit interoperability amongst the numerous context aware healthcare systems [64]. Ching Hsu, has addressed these gaps and presented RFID based context aware health care system implemented in web 2.0 environment and is based on wireless communication system. The Web 2.0 sensor technologies deliver a catalytic resolution to this problem.

3.5 Methods, themes and research gaps

Table 3.1: Summarizes the methods used and research gaps revealed within each theme.

Table 3.1: Summary of existing works their theme and gaps.

Themes	Authors	Research Gap
Monitoring physical activities based on internet of things.	Partha P. Ray,[2014] [58]	— Limited to general physical activity monitoring — Not suitable for critical physiological activities.
Privacy /Security /authentication	Kashif Habib et al. [2014][65]	— Blocked transmission in case of one mismatch — No adoptive security — Fixed parameters.

Ambient Assisted Living Healthcare Frameworks	M. Memon, et al. [2014] [59]	many limitations of existing frameworks, some of them are; — no security — lack of quality — interoperability and integration — design issues — limited feature — and technology issues — privacy issues
Emergency care Establishment of STEMI patients monitoring on Internet of things Reduction of time to diagnose and response.	Hao Chen et al. [2014] [66]	
Patient Monitoring	P. P. Ray [2014] [60]	— Lack of provision in emergency situation for serious elder patients.

heterogeneity of data	Boyi Xu et al [2014] [64]	— The proposed data model is suitable for industries with only short supply chain not for long supply chain.
Mobile health Monitoring	Antonio J. Jara et al., [61] [2014]	— Latency — Security — Band width performance
Monitoring physical activities	P. P. Ray [67] [2014]	— Limited to general physical activity monitoring — Not suitable for critical physiological activities
Interoperability Uniform RFID-based Context-aware Healthcare System (RCHS) access of data	Ching Hsu[2014][62]	— limitation of this system is maintenance of big data
easy navigation user interface	Yoo et al [2013][69]	— lake of interoperability

Monitoring Health care	David Niewolny [2013], [70]	— lake of standard
Connected devices	Martyn Casserly [2013] [63]	— threat to privacy

CHAPTER 4: PROPOSED METHODOLGY

Healthcare consistently has been an all-time important thoughtful concern, for humankind. So for the betterment of healthcare heavy part of budget is invested by government (for making better health policies and improvement in technology). As information technology is playing an important role in every field of life so is doing in health sector. In the current system, our study shows these functionalities are expensive, fixed and a lot of information is needed to update manually. While gathering requirements, we observed that doctors are fed up using the existing system, especially due to manual entry of diagnosis, results and they don't have proper methodology for communication of data and monitoring of patients. So we have researched on frameworks used in HMIS and concluded that, with the advancement of technology we can change the environment for better result of hospital management system. Now technology has made our lives very comfortable, from Ac's, mobile phones to airplanes. It is influencing every field of life and so in health sector. But our research shows that currently there is not much use of advance technology in health, while we can take many advantages from technology. So we have proposed a new framework for HMIS with new technology (the technology towards which world is moving).
For better health care, better treatment results we need to focus on the management of hospital in whole rather than just focusing on patient. There have been made some developments such as eheath telemedicine and patient care systems. But we don't have any common platform to handle all the hospital assets and patients. So here we proposing a framework for Hospital management System based on IoT. IoT based smart hospital is beneficial for both the health industry and information & communication technology. We have proposed a layered architectural framework. IoT based smart hospital is ubiquitous and patient oriented, discussed in detail in the following sections. In this chapter we have discussed the key features of IoT based HMIS, proposed architectural framework. This chapter also explains the proposed technique for data management. In last the working of system has presented with an example.

4.1 Smart Hospital

When we talk about IoT technology in medical field, we see, many scholars have put their work based on IoT in medical, healthcare based IoT, IoT based patient care and other associated ideas, which have the same pith, just distinctive in perspective and scope of depiction. But in Pakistan

none of this is implemented. So we are proposing a smart hospital framework based on IoT. Smart hospital, with the perspective of the IoT technology and built with the course of different program service structures, is the determined impression of internet of things applied in the particular spots of hospital and it is another sort of hospital. This has the functionalities of identification of abnormal condition or determination of diseases, treatment, administration and decision making. Furthermore, coordinating the ideas of intelligent hospital [80], digital doctor's facility, informative hospital and computerized doctor's facility [81], it is the more particular, complete, dynamic, effective depiction regarding hospitals. By the deployment and usage of smart hospital based IoT, it can execute digital application system through which individuals can access related, significant, fast and accurate service information, consequently it can figure it out analysis, diagnosis, administration regularization, , and decision making. Overall concept of smart hospital is illustrated in figure 4.1. The detailed architectural framework is discussed in Section 4.3.

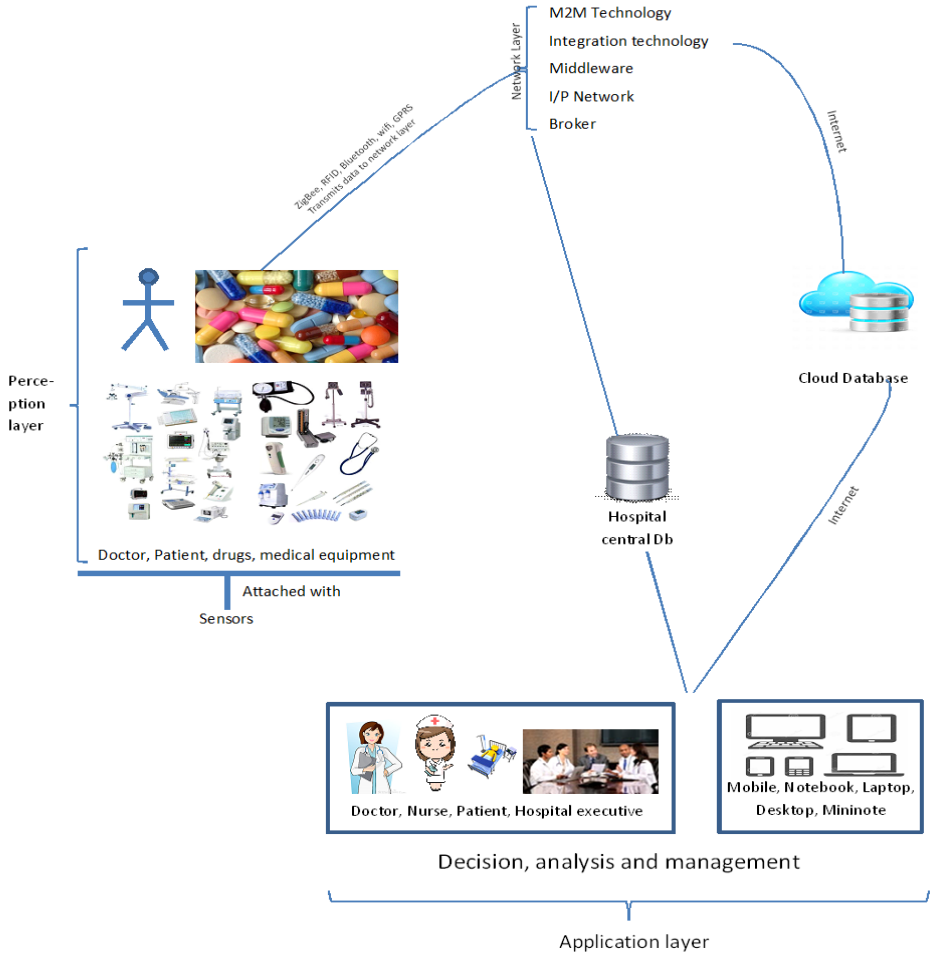


Figure 4.1: Conceptual smart hospitals

4.2 Main Features

There are many of advantages of using IoT. The typical applications by our proposed smart hospital based IoT framework are grouped in the following:

- Tracking
- Monitoring
- Remote services
- Communication
- Information management / Data Transfer
- Diagnosis
- Management
- Intelligent recognition

In the following section we have briefly discussed these features. It is discussed how we can realize these feature and using what technologies.

- **Tracking and Monitoring:** tracking is intended at the identification of objects, patients etc. in motion. It keeps track of both the real time position tracking of patient and assets such as tracking of patients flow in hospital and monitoring of choke points. We can keep tracks of assets by keeping continuous track of inventory location, whether they are in store, available or busy, and where it is being used and materials tracking to stop left-ins during operation. We can accomplish tracking and monitoring by identification tags, sensors, and communication. That can be achieved by wearable wireless sensor networks [71].
- **Remote service:** Many services such as emergency detection and emergency treatment, nutritional and medicine management, stroke tenancy and exercise, telemedicine, ehealth and health social networking are provided by remote services, through internet and wireless devices [72].
- **Hospital management:** with the property of global connectivity of IoT, it is possible to collect analyze and manage and use the hospital's data including finance, assets, logistics, treatment, rescuing, medicines prescriptions, management and even daily activities throughout the value chain.[73]

- **Diagnosis:** in relation to patient it includes the diagnosis of disease (when the system shows abnormal behavior in readings), infant diagnosis in hospital to prevent mismatch of child and family and in same way in Hospital mortuaries it is used to identify and enhance the verification of dead bodies. With respect to staff identification and verification it is usually used for permission and to develop employee assurance for the protection of patient. Diagnosis of assets is used to avoid theft, security purposes and to avoid loss of essential tools and products.
- **Data Management:** it is now easy to transfer data. Automated data collection and transfer usually meant to reduce the processing time (includes data entry), increase automated patient care, process auditing, and hospital inventory management. Data entries such as heart beat rate, BP, diabetes readings and so on can be collected and recorded automatically, so there will be less data errors as we are preventing entries by human. This function also used for integrating HMIS with other hospital management information systems and medical applications, within hospital and across the hospital.
- **Intelligent Recognition:** As in IoT everything is on internet. So to provide security to data intelligent recognition application is used. With respect to person it is identified if the information is coming from the right person and information provided is from authenticated person. When we talk about devices, it is checked that if data is sent from the identified devices or its deceit.

4.3 Architectural framework

Numerous scholars have carried related research on IoT and networking structures, and there are 3 types of architectures found.

i) the EPCGlobal based architecture, based on the RFID

ii) the application architecture focused around sensor networks [82] mostly mentioning to wireless sensor network (WSN),and

iii) The application architecture focused on machine to machine (M2M). M2M contains partial components of WSN and EPCGlobal and have the most broad application range.

In medical scope although there is no literature work that specifically refer the smart hospital architecture based on IoT in medical field, certain interrelated articles have showed up, for

instance applications of RFID technology to realize boundary less sensing hospital is projected by[83], a prototype of advanced encompass smart hospital anticipated by[84].

With perspective of the flow of existing study of establishment and the real natural attributes of hospitals, we have proposed smart hospitals framework based on third IoT architecture stated earlier(i.e. M2M). our architecture also consists of three layers, which are i) perception layer, ii) network layer and iii) application layer as demonstrated in figure 4.4 and have discussed in detail in following section. But in our Architectural framework we have shown the functionalities of each layer with respect to hospital management system and also represented the technologies used. For complete infrastructure as discussed in detail in following sections, we have used some of technologies that are have already introduced for IoT, but some are novel such as context awareness for the control of massive data.

4.3.1 Perception layer

Perception layer is composed of two sub layers, and that is correspondingly

i) Data acquisition layer and

ii) Data access layer.

Data Collection Layer: Data collection layer recognizes hospital networking hubs, observes and collects relevant information, for example, personality data of nurse, specialist, doctor and attendant, characteristic personality information and medical data of patient, essential basic data and location data about medications, medical apparatus and waste, Biological data of inpatient, hospital's environmental data etc.

Data access layer: Access layer communicates data that have collected by data acquisition (sub layer) layer to the main network system named as worldwide object-conjunction system. Data can be accessed by several means such as, mobile networks, digital TV system, fixed network, wireless networks, remote networks etc. While to access smart hospital, smart phones i.e. mobile network will become foremost accessing mean, because of its worthy characteristics for example its broad coverage scope, low development cost, easy deployment and distribution, flexibility and mobility attributes.

Actually in real world we have to decide by observing real time situations, e.g. for outpatient management systems and technical management systems fixed location networks are more appropriate, and to use hospitalization management approach by mobile network or wireless networks are more appropriate.

4.3.1.1 Wireless Sensor Network overview

Basically wireless sensor network is an important part in IoT. It associates sensors and actuators through wireless linkage. It collects data and communicates to the upper layer through gateways, routers etc. Means it also integrates this layer to the higher layer of system. [74] At this layer sensors are attached to the body, patient and other equipment or things. Sensors are mostly light weight, consuming less power, inexpensive and easy to implement and maintain. But the challenges come when competencies and functionalities are constrained by resources (processing, memory, power resources). In [75] Yick *et al.* have studied in detail the challenges, applications and protocols. He concluded many challenges; from them we have addressed energy efficiency, communication reliability and system mobility in our sensor network system for smart hospital.

The main components or layers of wireless sensor network are:

1. Sensor networks: includes sensors, actuators, processor, memory, power resource and communication interface. The sensors are used to collect data and communicate data with related to their environment. This layer with the advancement of technology also includes many other standardized technologies such as WIA-PA, 6LoWPAN, ZigBee, ISA100, Bluetooth, IEE802.1 and Wireless HART. Some other technologies for example Z-wave, with no standard but still have been utilized in industry. Certain trademarked technologies are also proposed. In spite of variety of technical specifications, all these technologies exhibit common properties such as light weight protocol, low consumption, short distance communication capabilities and flexible networking and these are main characteristics required by Wireless sensor networks (WSN).
2. Wide area network: also known as network access. This component comprises of gateways or routers or sink nodes, it collects data from sensors and transmits to the central unit to other concerned entities.
3. Middleware: is for the gathering and further processing of large amount of data.

4. Application framework: provides interaction for the effective use of WSN, to a particular application or industry.

As in hospital, patients and other apparatuses are habitually moving, portable and broadly distributed, so the wireless network system should provide mobile and widespread deployment. We need a reliable communication to even work with poor radio signals and when we need to communicate with the water rich body part. Moreover, for the high rate data transfer sensors we need data compression to manage traffic load and energy consumption. The network system should be deployed with low-cost chips and should have long life cycle.

4.3.1.2 Wide Area Deployable WSN

The one other important value feature in smart hospital is real time monitoring and tracking of patients and goods. The things that system needs keep track are movable and scattered. Hence the WSN nodes also need to be mobile and distributed to gather these values.

And lastly the devices and system should be integrated, to provide services. All the functionalities of the system must be modeled as a group of services. There are many open platforms to integrate in smart hospital, so for proper integration we need to know the proper interoperability and security[76]. In figure 4.2 we have shown the integration of many diverse services from different groups related to smart hospital solution. For business environment we need the Service oriented architecture (SOA). So here we have shown the integration from SOA perspective.

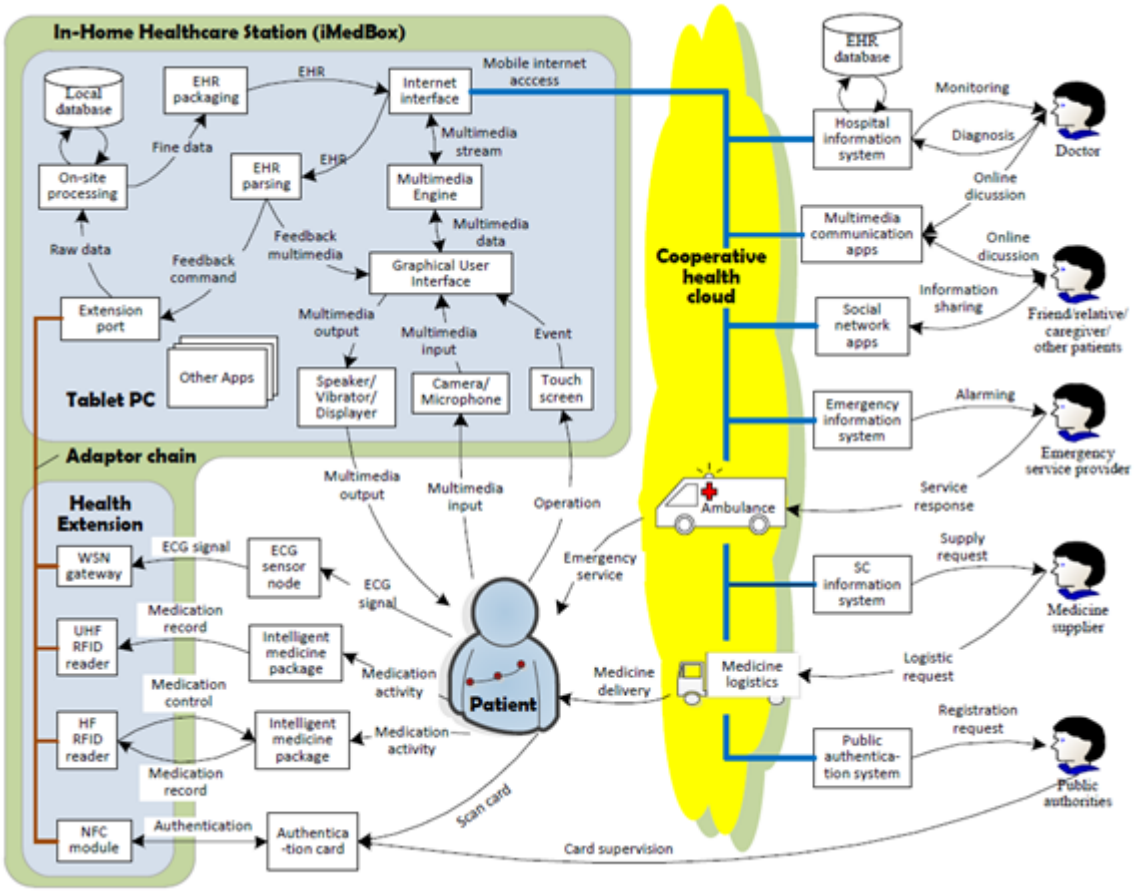


Figure 4.2: Smart hospital based IoT view from the perspective of service oriented architecture

4.3.2 Network layer

Network layer is a main layer of hospital network. Network layer is composed of two sub layers. These are correspondingly

i) network transmission layer and

ii) Application platform layer.

Transmission layer: is the foundation of medical system having real world, interruption free, consistent, trustworthy and highly reliable communication of data received by the 1st layer (that is perception layer) utilizing different transmission technologies such as Ethernet, wireless, mobile, remote communication, M2M etc.

Application platform: deploys integration of different data, having representation of unified data, information middleware, and warehouse unified data and on this premise to establish an administration platform and makes available an open interface for the different services of application layer [85]. An open platform is made available so that third party developers can easily develop medical and other hospital related applications.

4.3.2.1 Middleware Support for IoT

We need to support IoT with middleware solution. Middleware supports an important role in layered systems. Middleware is a solution to distinguished problems such as heterogeneity, dependability, interoperability, decision making, and security [86]. It is a layer between network and application, but generally in IoT it resides on network layer. Different IoT middleware have been developed. In [29] middleware solutions and their required functionalities for IoT have been discussed in detail. Moreover in [87] challenges for developing middleware solution have been discussed. Bandyopadhyay et al. [79] did survey on middleware solutions for IoT in 2014, they selected most commonly used middleware solutions and analyzed them based on different characteristics such as device management, interoperability, portability and privacy. Charith Perera et al [88] also did survey and concluded that GSN and ASPIRE middleware were progressing in extending the processing towards EU FP7 project Open IoT (2012- 2014) [89].

According to the results of survey it is concluded that most of the middles wares used in IoT are device oriented which are focused towards connecting sensors to the IoT middleware solution, and majority of the middleware do not offer context awareness. In start (before last decade) context awareness was only used in pervasive and ubiquitous computing. Some of the middleware was supporting context awareness but did not satisfying the functionalities that IoT requires.

4.3.2.2 Context awareness

So here we have used Context aware middleware, especially to address the problem of management of big data. As in IoT there are a lot of sensors attached to a lot of things, there are billions of sensors from which we will get data in real time, which means it's not feasible to process all of the data gathered from these devices. Hence we will use context awareness as

middle ware of IoT on network layer to decide which data we need to process. It provides more functionality towards managing data. Context awareness has played an important role in pervasive and ubiquitous computing to in analyzing, interpreting and understanding the meaning values of collected data. So we believe it would be successful in IoT paradigm as well. Context awareness stores the information in context to interpret it easily and make it more meaningful. Moreover there are a lot of other benefits to use context awareness, such as to merge and exploit the heterogeneous data provided by sensors, to define ontology of medical terms and so on.

Context aware definition: different definitions have been presented by different researchers. In this thesis we have used definition given be Abowd et al. [90], any information that is used to depict the circumstances of an object is context. Context is with respect to objects and applications.an object is a place, a person or anything which is relevant to the user and application.

Context awareness usually supports acquisition of data, its processing, representation and delivery of information. The key features supported by context awareness are presentation, processing and tagging.

- The **presentation** feature decides which data need to present to user, for example [91] when a person enters to the shopping mall, he takes out his mobile to see the list of things he needs to buy, context awareness retrieves information from home e.g., it connects to smart fridge[90] and presents a list to user. This fulfills the idea of IoT to provide services at any time, any place and anywhere. And most importantly it presents the only data user needs at that time.
- The **execution** of a task at time is very important in IoT. The execution feature automatically executes tasks with the context, For example when a person leaves office and head towards home the IoT implemented system should switch on air conditioning system and coffee machine automatically , so that person can find the things ready to use by the time he steps into house.
- **Tagging:** this feature fuses the information gathered from different sensors [92], [93]. Data generated by single sensor is usually not sufficient to understand the complete scenario. We need to fuse data gathered from numerous sensors to make it fully useful

and understand the state. So we tag the context with sensor data to make it fully understood later.

4.3.2.2.1 Context life cycle

Context awareness completes its life cycle in four steps, as shown in figure 4.3.

a) Context acquisition:

Firstly context is acquired from different sensors data.in context acquisition data is acquired with different techniques depending upon the scenario. Some of the context acquisition techniques are frequency based, responsibility based, based on data acquisition process.[94]

b) Context Modeling:

Second step is context modeling. In this context data acquired is modeled with different modeling techniques. [95], [96] There are different modeling techniques available such as ontology based context modeling [97], [98], [99], object oriented modeling, graphical modeling[100] and some others [101], [102], [103]. Basically context modeling is defined in 2 steps. First is to model the process, in this step attributes, parameters, characteristics and queries of context are defined. Second step is to organize context. In this step the data from first step is validated and new information is added and merged to the repository. Finally it is made available to be used to application layer.

c) Context reasoning:

Context reasoning is third step. In this step new knowledge is extracted based on existing context data. The two main requirements for reasoning were to remove uncertainty and imperfection (ambiguity, erroneous). Reasoning can be done in three steps [104]. 1st is preprocessing of existing context. Due to hardware or network insufficiencies data may not be collected accurately or it may be missing. So we need to clean data accessed from sensors. Data is cleaned by adding missing values, removing outliers and validating context. These activities are broadly done in data mining artificial intelligence and network communications. In 2nd step data fusion is performed to make data complete, interoperable and more accurate, Data acquired from multiple sensors is merged to extract new knowledge that cannot be extracted from single sensor. 3rd step is data intervention. In this step data is high level context data is produced from low level context data.

There are multiple data reasoning techniques are available such as hidden markov model decision tree, rule-based support vector machines, naive Bayes, K-nearest neighbor (KNN), artificial neural networks, fuzzy reasoning, ontology-based and many more [105], [106], [107].

d) Context Distribution:

In this step data is delivered to the users at application layer. Data can be accessed by users in two ways by querying data or by subscription. In query user makes requests with queries, in result context management system produces desired results. In subscription user subscribes for particular requirements and they get data periodically or when an event occurs.

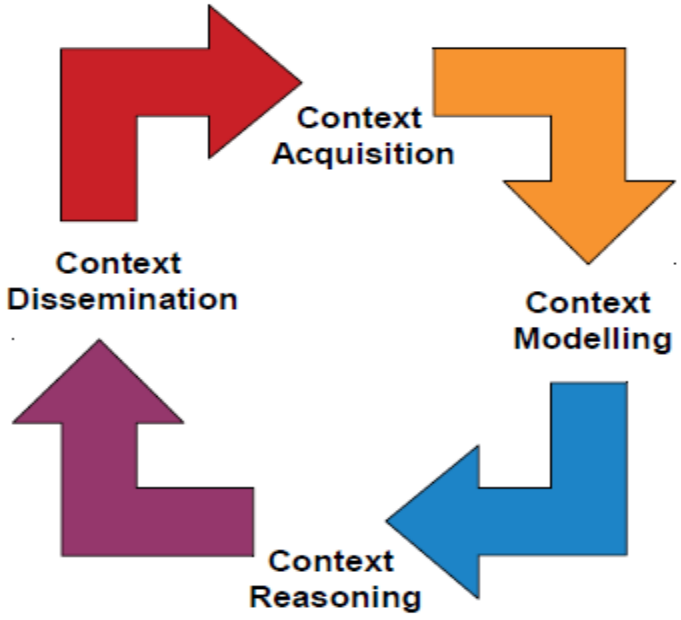


Figure 4.3: Context life cycle

4.3.3 Application layer

Application layer incorporates two layers and these are

i) hospital digital information application and

ii) Hospital decision making application layer.

Hospital digital information application layer:

Hospital information part incorporates digital information of hospital , patients doctors, outpatient , technical medical including physiotherapy, radiology, diagnosis, patient examination data etc.), medication administration , apparatus and other hospital material management, health and economic management etcetera.

Decision making application layer:

is a high ranking application, for example disease diagnosis(start time, remote communication, geographical distribution and treatment expense of different illness), disease analysis (location distribution, age dissemination, percentage of free medical and patient visitor time), health center exploration (outpatient appointments , inpatient appointments, physician's visit) medicine examination (quantity, amount of consumption and economic benefits different medications) different department inquiry(expense of analysis and treatment of each department in distinctive times) etc.

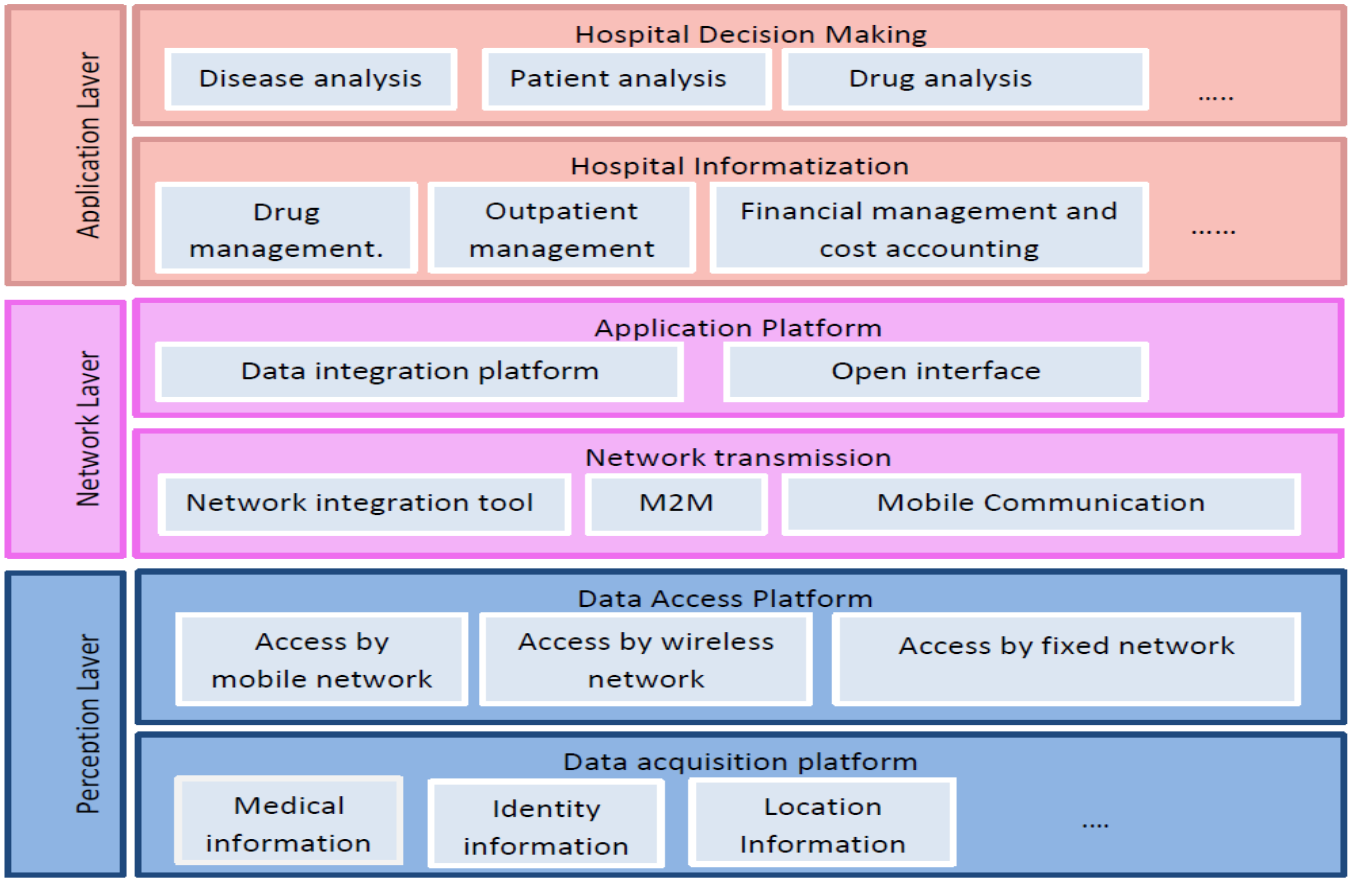
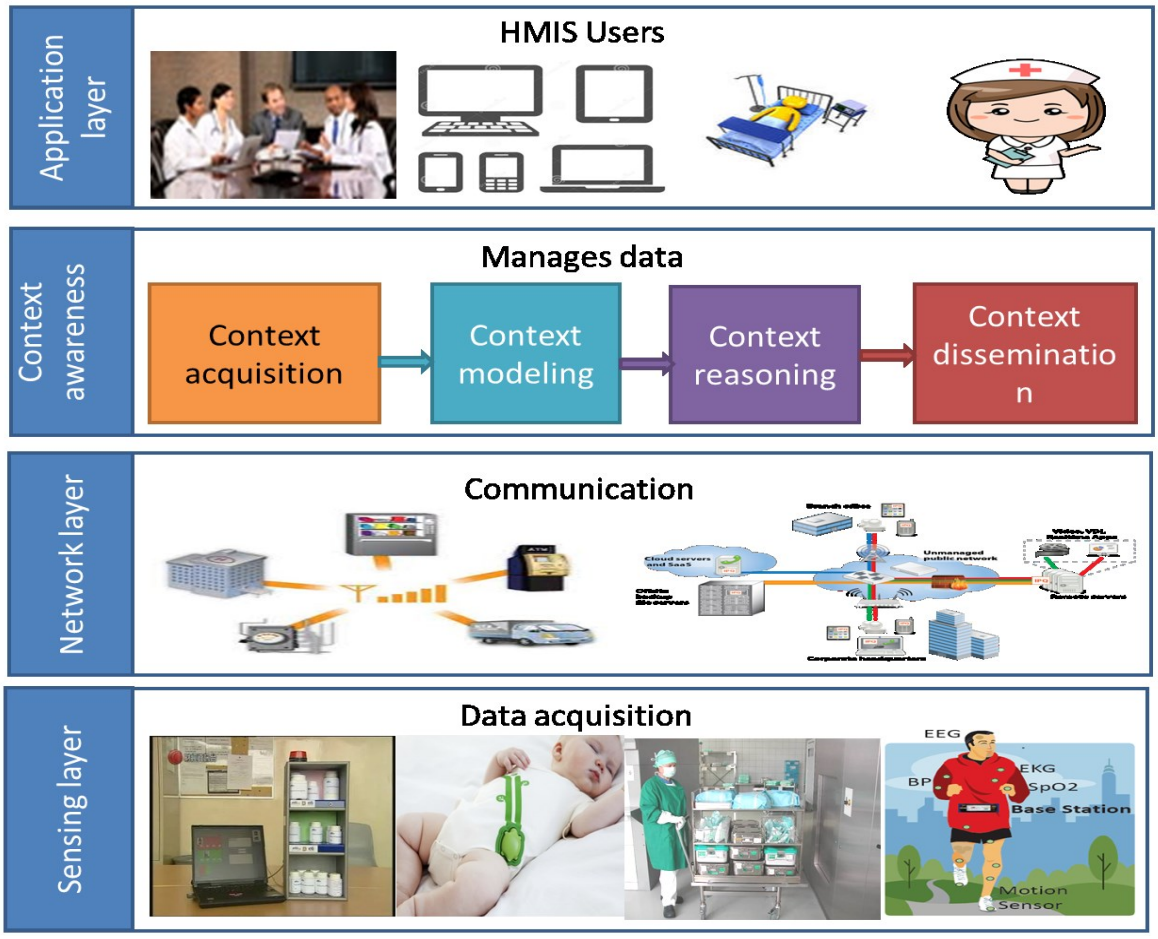


Figure 4.4: Architecture of smart hospital

4.4 Proposed architectural framework for data management

Figure 4.5 shows architectural framework for data management. The basic structure is based on above mentioned IoT based framework. In this framework the difference is that we have added context awareness as a middle ware to control data. Context awareness transmits only required data.



4.5: An illustration of IoT based architecture with support of context aware middleware

4.5 Application scheme of smart hospital

After full examination above on smart hospital's implication, building design, key innovation and fundamental substance of development, consolidated with the execution of smart hospital, this paper gives a particular application plan. Initially it is planned to implement this new architecture of smart hospital in PIMS or AFIO. At start, the smart hospital architecture implements fundamental development of wireless network supporting environment, and takes in account a few

departments for experiment and in some definite range attains remote and mobile medicinal treatment for hospital staff. The implementation of new smart hospital's architecture changes the current existing hospital system and attains better, satisfied and more efficient result.

Next, this research objective is to construct an incorporated data service platform having the qualities of openness, cooperation, innovation and smartness. At that platform the majority of medical staff, administrative people, logistics work force, patients and their relatives can use system according to their roles and can connect and access the assets of hospital and get shared, connected and supportive environment of medical and other relevant stuff.

Application framework of smart hospital is the exemplification of architecture. In general, it follows the smart hospital's 3 basic layers i.e., application layer, network layer and perception layer. But here in figure 4.6 we have shown more detailed and specific according to hospital actual scenario. This application framework comprising of 7 layers, from below in sequence of objects on first layer, communication of objects and perception of data on second layer , network integration on third layer, information integration on fourth layer, service integration on fifth layer, information service portal platform sixth layer , client on seventh layer. We have shown its application on Smart hospital based on IoT.

Figure 4.6: Application framework of smart hospital

4.6 Working of framework with respect to patient

In our proposed solution data related to patient and hospital can be accessed on mobile, computers, tablets and other such gadgets. There are small sized sensors available which are attached to medicines, beds, patients and hospital apparatus and so on. From which data is transmitted to the upper layer. These devices are wirelessly interconnected to each other. The sensors from which we acquire data are called data provider and the gadgets on which doctors, nurses, patients and other concerned persons access data are called service provider. Here in this section we have discussed the full scenario how it works in real time. Our proposed architectural framework has broad vision and it manages the whole hospital, here we have discussed the scenario related to patient care.

Different types of wearable biomedical sensors are available. Some are too small in size that patient won't get distracted by them while doing their daily activities. Small biomedical sensors are available which are attached to the patient. These biomedical sensors are also called motes. These sensors are capable continuous monitoring and transmitting, blood pressure (BP), heartbeat rate, temperature, oxygen saturation and carbon dioxide concentration, electrocardiogram (ECG) etc. Acquired data is transmitted to upper layer where data is preprocessed. In data preprocessing outliers are removed, consistency checked, noise removal is performed. Contextual information (such as environmental conditions, physical activities) is gathered by processing of data from these kinematic sensors (e.g. GPS, humidity).

These sensors are attached to the patient, which gathers data such as temperature, BP, ECG, EMG HBR and transmits this data to service providers using wireless technology such as zigbee, blue tooth, Wi-Fi. The data collected at local grid is uploaded to the cloud and used to produce and send emergency alerts to service providers (figure 4.7). The proposed framework supports communication between data providers (sensor layer) and service providers (application layer) via network layer. The communication between data providers and service providers is through messages these messages are in the form JSon string to make the data communication interoperable. Over the network layer intra body network protocol is used ensure the connectivity of devices and data providers, that also address's the challenges of quality of service. Packet

scheduling protocols are used to prioritize and schedule data according to the severity of patient's condition. That avoids congestion and increased reliability by minimizing response time and reducing the load of doctors. It reduces the load of doctors, ambulance and other equipment by equal distribution of work, which also represents fairness characteristic. This also saves time of doctors as well patients. IPV6 protocol is used to communicate to provide a large domain for large connectivity of things and VPN and WPA2 protocols are used for security.

Here we have discussed an example to support real time working and effectiveness of our proposed framework using IoT based on context awareness. Wounds that causes hemorrhagic tremor (especially when we talk about internal bleeding) if not detected and treated in first 2 hours, critical to the patient health (these hours also called golden hour [77]) may lead to death of patient. So a reliable and quick cure is needed. To reduce the time of diagnoses and treatment of these patients' in in-hospital and pre hospital, process of emergency response is optimized by implementing internet of things. By monitoring and remote mobile communication it was possible to reduce the time to take care of these patients. So IoT based solution, which process and analyze important signal data (such as BP) gathered from multiple sensors attached to the patient provides accurate reliable and useful way out. A model to forecast the blood pressure waveform of large arteries has been developed by Department of Biomedical Engineering, Rutgers University for early detection of hemorrhagic.[88] Sensors attached to patient body works as data provider and laptops, mobile etc. works as service providers as shown in figure 4.6. Data is sent to the network layer where context awareness middleware analyzes data and send only relevant and with high priority data to doctors and nurses. Data on the laptops and mobiles is arranged with the priority and with complete reliable values, which helps doctors to decide which patient they need to treat first. At the backend this work is done by decision making algorithms and continuous monitoring helps early diagnosis of disease with the help of derived parameters under context awareness.

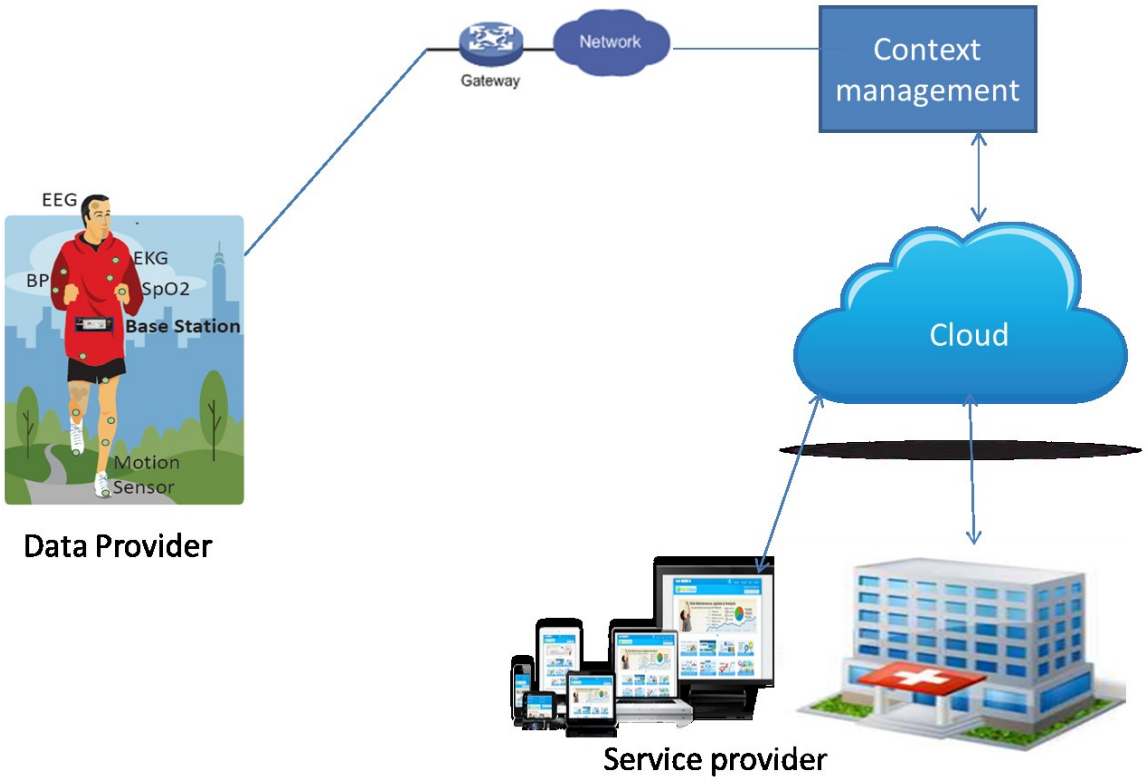


Figure 4.7: A scenario illustrating how the data is communicated

4.7 Advantages

- improvement in response time
- quality
- robustness
- reliable transmission
- fairness
- data interoperability
- minimize computational load
- minimum communicating cost

CHAPTER 5: RESULTS

5.1 Implementation methodology

The ultimate goal of proposed architectural framework is to provide better communication, monitoring of patients, tracking, early diagnosis and treatment, interoperability of data and so on. These features are directly related to better patient health care and easy and efficient management of overall hospital.

5.1.1 Intended survey particpants

The primary participants here are the doctors, nurses and management administrator and hospital servants who will use system. They are capable to ensure that survey is valid from their perspective, and also that it is performed in accordance with the standards considered. IT related personals are also considered, who implements and deploys system such systems.

5.1.2 Designing form for survey

The survey form is designed in accordance with IEEE Standard.
Major respondents were from large hospitals of Islamabad and Rawalpindi including combined military hospital (CMH) and Pakistan institute of medical sciences (PIMS) hospital. Survey was conducted during the months of May 2015 and June 2015.

5.2 Conducting survey

The survey was taken out through questionnaire. Potential members were given hard copy of questionnaire and requested to fill up the questionnaire. Before asking them to fill-up the questionnaire we gave them a good understanding about currently used HMIS, our proposed architectural framework that how it works, how the implementation is carried out of such system and some well-known features and characteristics which have significant importance in patient care and HMIS via presentation and video. The survey is done to ensure frameworks feasibility, its implementation and after effects and their tradeoffs, while using HMIS based IoT.
Survey participants are required to answer around 45 questions. Six sections are mentioned to classify questions. In first 2 sections we have asked about the basic computer knowledge of

individuals and availability of computers at their workplaces. In next two sections we have asked about the current HMIS and satisfaction with it if they are using any. Then there are questions about role of HMIS for different outcomes and then there is a section containing questions related to our proposed architectural framework i.e. HMIS based on IoT. For this section we have prepared 22 questions, to analyze how doctors are supporting this system, what they think about usage of system. All survey participants were needed to fill up the form according to their skills and experience. Sample survey questionnaire is given in Appendix A.

5.3 Survey Results

Twenty participants from public and private hospitals took part in the survey. The given answers from professionals are then represented in Table I, Table II, Table III, Table IV, Table V and Table VI. Tables are prepared for each section with respect to questionnaire. It is revealed while conducting survey that some questions asked in survey might not be interpreted as the author intended; otherwise results could have been more accurate.

5.4 Aggregated results

5.4.1 Respondents score for computer usage

The complete analysis of combined and aggregated data from section one is shown in table 5.1. And the graphical representation of data is shown in figure 5.1. Table 1 is representing the data related to respondent's computer usage we have noticed that around 65% respondents use computer daily for their personal use but only 17% percent of them use computers for medical purposes.

Table 5.1: Survey Aggregated Results for respondents experience with computers

Experience with computers	Rarely %	Monthly %	Weekly %	Daily %
1. How frequently, do you use computer?	11.76	5.88	17.65	64.71

2. How often do you use the Internet for professional use, including e-mail from home, work, or another location?	23.53	47.06	5.88	5.88
3. How would you rate your computer skills?	Lowest	Average	Highest	
	5.88	76.47	17.67	

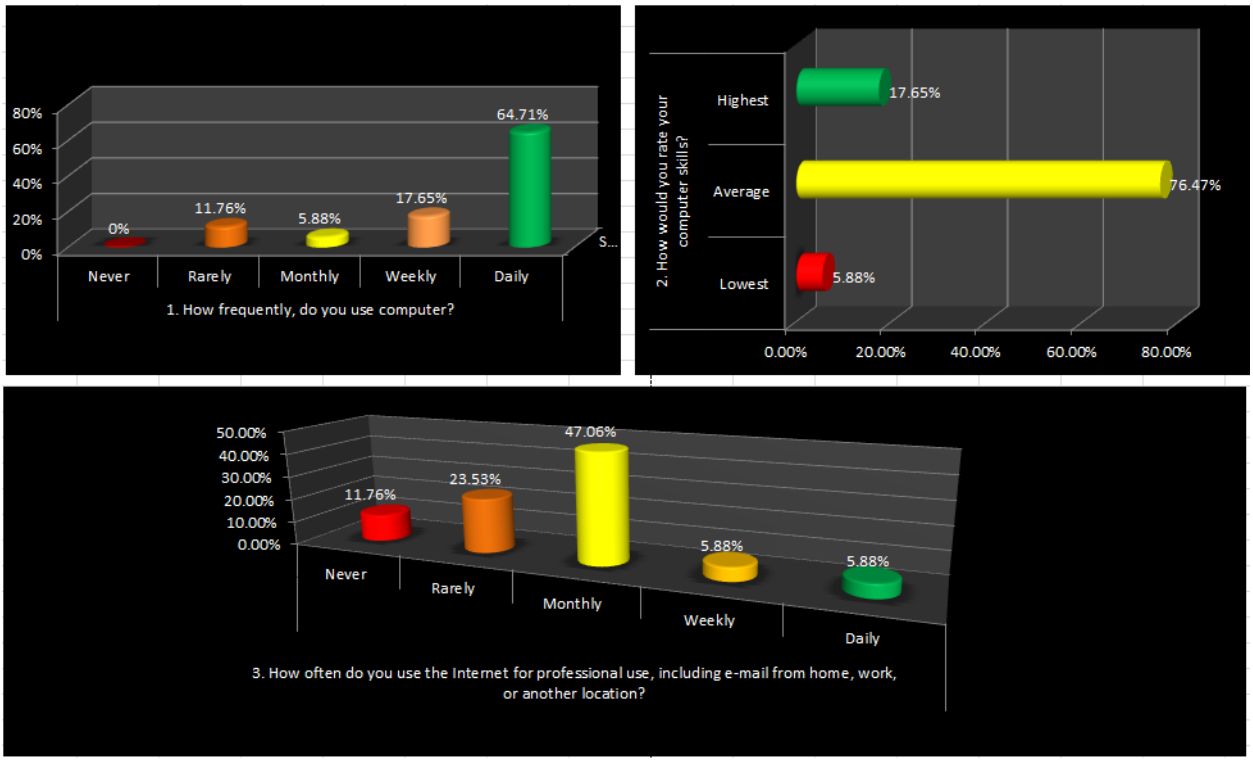


Figure 5.1: Experience of respondents with computer

a.b. c.

5.4.2 Respondents score for computer availability at their workplace

Most of the respondents (82.35%) don't have computers at their workplaces and those who have computers are most of the time prevented to use computers due to system's technical fault or its

unavailability because others were using it. Respondent's complete results are shown in table 5.2 and its graphical representation is in Figure 5.2.

Table 5.2: Survey Aggregated Results for availability of computers at their work places

Availability of computers			Yes %	No %
1. Do you have a computer in your office?			17.65	82.35
2. Concerning other rooms, you use for clinical work (e.g. ward, outpatient clinic offices, and investigation rooms)				
a) Are there computers available for you?			5.88	94.12
b) If yes do you use these computers?			5.88	94.12
Availability of computers	Never %	Monthly %	Weekly %	Daily %
3. About the computers installed in the ward, at the outpatient clinic offices, investigation rooms, etc.				
a) How often are you prevented from using them because others are using them?	0.0	5.88	0.0	94.12
b) How often are you prevented from using them due to computer errors, forgotten passwords or other machine-related problems?	5.88	5.88	0.0	88.24

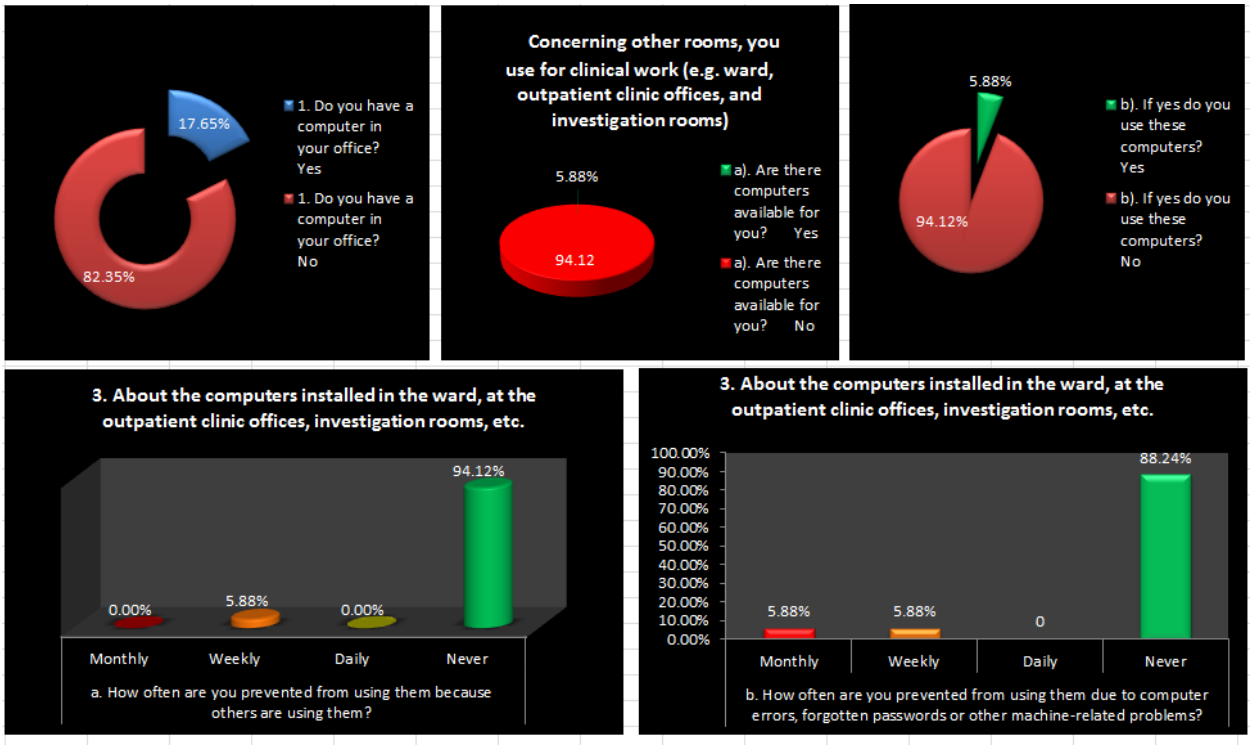


Figure 5.2: Availability of computers

5.4.3 Respondents result for the use of current HMIS

Our result is showing that most of the respondents (88.24%) are not using any hospital management information system. Respondent's complete score for each question is shown in table 5.3 and figure 5.3 is showing its graphical representation.

Table 5.3: Survey Aggregated Results for the use of current HMIS

About Current HMIS:	Yes	No
1. Do you currently use any Hospital management information system (HMIS) system in your practice?	11.76	88.24

2. Do you attempt to measure the effectiveness of this HMIS system?	5.88	94.12
3. Are there currently any plans to change/improve this HMIS?	5.88	94.12
4. Problems often occur in the exchange of information across hospital units.	5.88	94.12
5. The total computerized hospitals are not fully implemented in Pakistan?	5.88	94.12

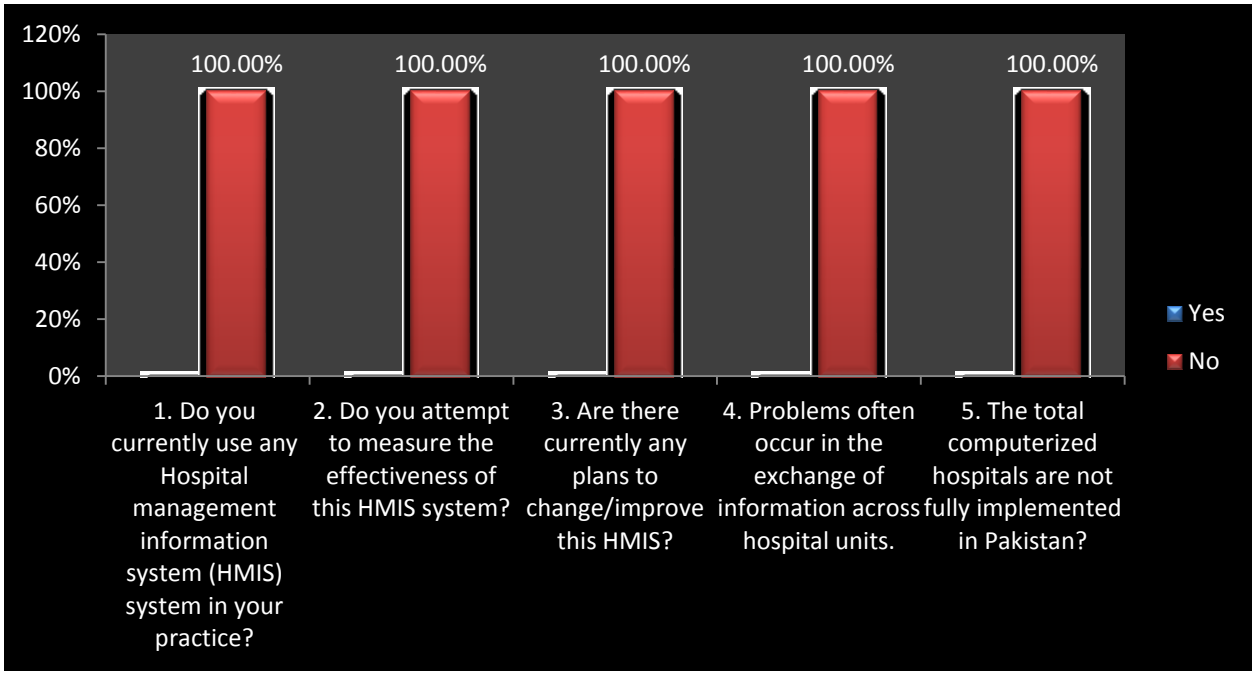


Figure 5.3: Data about current HMIS

5.4.4 Respondents response for satisfaction with current HMIS

We included this part of questionnaire to ask about the satisfaction of users from current HMIS, most of the answers were in dissatisfaction as most of the respondents are not using any hospital management system. Figure 5.4 and table 5.4 are the evident that respondents are dissatisfied with the current HMIS.

Table 5.4: Survey Results for satisfaction of current system

satisfaction with the current HMIS installed in your department	**Never**	**Seldom**	**half of time**	**most of time**	**Always**
1. Content a) How often does the system provide the precise information you need? b) How often does the information content meet your needs?	88.24	0.0	0.0	11.76	0.0
	94.12	0.0	0.0	5.88	0.0
1. Accuracy a) How often is the system accurate? b) How often are you satisfied with the accuracy of the system?	88.24	0.0	0.0	0.0	11.76
	94.12	0.0	0.0	5.88	0.0
2. Format a) How often do you think the output is presented in a useful format? b) How often is the information clear?	100	0.0	0.0	0.0	0.0
	100	0.0	0.0	0.0	0.0
3. Ease of use a) How often is the system user-friendly? b) How often is the system easy to use?	100	0.0	0.0	0.0	0.0
	100	0.0	0.0	0.0	0.0
4. Timeliness a) How often do you get the information you need in time?	100	0.0	0.0	0.0	0.0
	100	0.0	0.0	0.0	0.0

b) How often does the system provide up-to-date information					
5. How often you are satisfied with HMIS installed in your department?	100	0.0	0.0	0.0	0.0

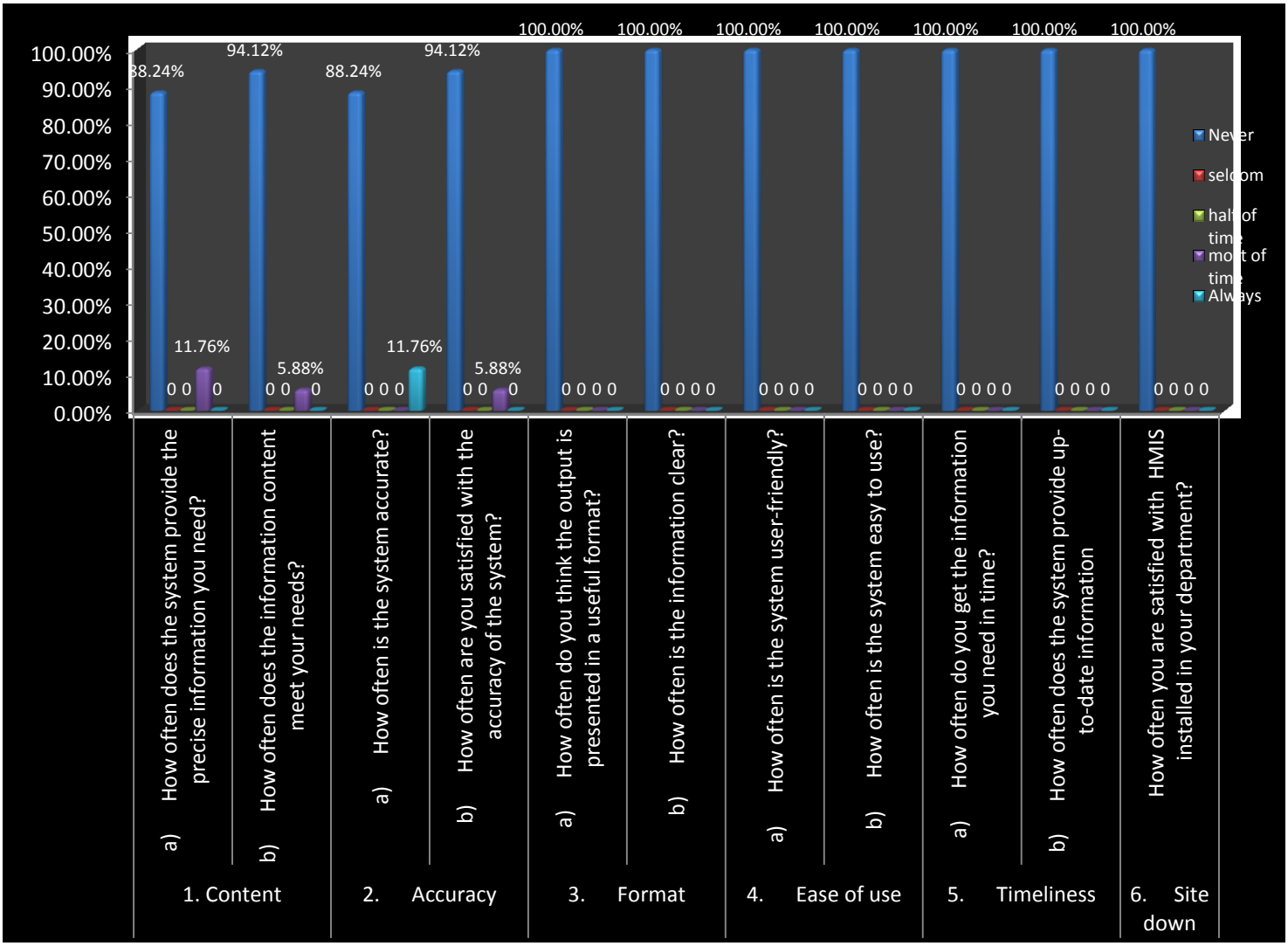


Figure 5.4: satisfaction with the current HMIS installed in department

5.4.5 Score for effect of HMIS on different activities

From Table 5.5 and Figure 5.5, it is evident that Survey results shows that the usage of HMIS have positive effects in all of the major activities in the hospital. Most of the individuals participated in the survey have shown their maximum positive interest in the "very positive effect" and "positive effect" for the effect of HMIS on these given activities.

Table 5.5: Survey Aggregated Results for effect of HMIS on different activities

For each outcome listed below, indicate whether you think the effect of computers is, or would be, very positive, somewhat positive, no effect, somewhat negative, or very negative:	Very positive	Somewhat positive	No effect	somewhat negative	negative
1. Controlling costs of health care	29.41	41.18	17.65	17.65	0.0
2. Quality of health care	41.18	47.06	5.88	0.0	0.0
3. Patient-physician communication	41.18	47.06	0.0	11.76	0.0
4. Patient privacy	23.53	23.53	11.76	23.53	17.75
5. Clinicians' access to up-to-date knowledge	47.06	52.94	0.0	0.0	0.0
6. Efficiency of providing care	35.29	64.71	0.0	0.0	0.0
7. Interactions within the health care team	29.41	64.71	0.0	5.88	0.0
8. Medication errors	0.0	35.29	52.94	5.88	5.88

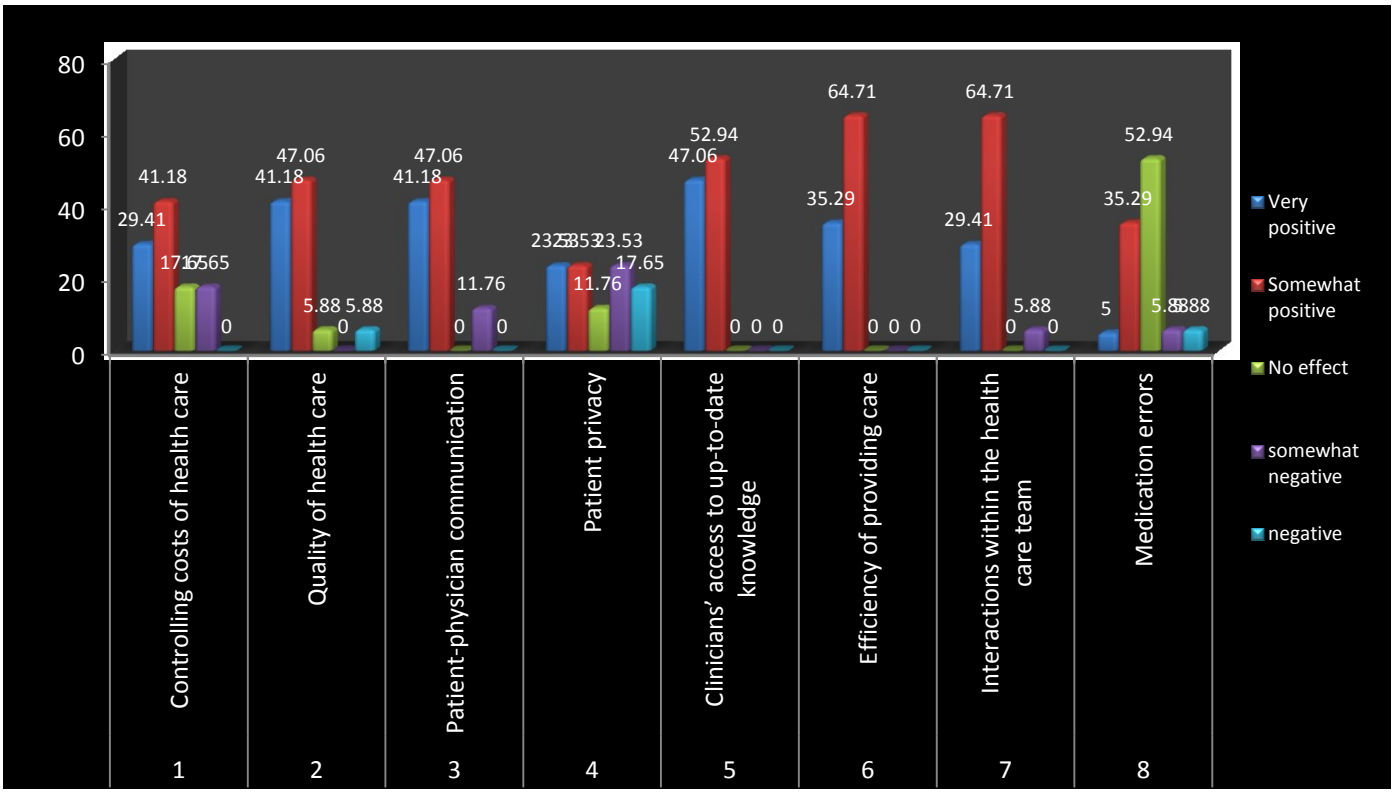


Figure 5.5: effect of HMIS on patient care, cost, privacy, errors

5.4.6 Respondents support for IoT based HMIS

Most of the respondents were happy to adopt IoT based HMIS and agreed that most of the functionalities are beneficial for them as well for patients, especially for the time saving, monitoring and communication purposes.

From Table 5.6 and Figure 5.6 is evident that Survey results have about 88 % of respondents are agreed to adopt use the IoT based HMIS while 6% are uncertain and 6 % disagreed to accept the system. For the mean values of all the features most of the individuals participated in the survey have shown their maximum positive interest in the "Strongly Agreed" and "Agreed".

Table 5.6: Survey accumulated Results for IoT based HMIS

		strongly agree	agree	uncertain/ not applicable	Disagree	strongly disagree
1.	Will the system be accepted and used?	11.76	76.47	5.88	5.88	0.0
2.	Patient care is more reliable and perceptive than to the existing system?	11.76	58.82	23.53	5.88	0.0
3.	This system would help me to see more patients per day and also save time (or go home earlier) than you could with the existing system.	23.53	64.71	5.88	5.88	0.0
4.	Do you believe that IoT will bring a disruptive change?	0.0	5.88	52.94	41.18	0.0
5.	This system would be more effective for the situation to monitor and instruct far from patient	23.53	64.71	5.88	5.88	0.0
6.	This system wouldn't just enable us to manage the assets and data of hospital but it would actually help to provide better patient care	11.76	76.47	5.88	5.88	0.0
7.	Would it be beneficial?	17.65	64.71	11.76	5.88	0.0
8.	The e-health and telemedicine is easy, fast and error free with the IoT.	5.88	52.94	41.18	0.0	0.0
9.	The way, in which architecture is proposed is suited to the task you want to perform with the software	11.76	47.06	35.29	5.88	0.0
10.	There are some features of this systems, that are not related to actual work	0.0	35.29	52.94	11.76	0.0

11.	Will system implementation have an impact on control in the organization	17.65	47.06	35.29	0.0	0.0
12.	You would be able to track the stuff (including equipment and patient data) easily and efficiently with IoT based hospital	23.53	76.47	0.0	0.0	0.0
13.	Intra-office communication and tasking would be fast, easy, and effective with IoT based hospital	29.41	41.18	5.88	5.88	0.0
14.	The data, you would be able to handle easily (thorough IoT) with the new HMIS that you could not do before?	23.53	76.47	0.0	0.0	0.0
15.	This would provide useful tools for disease management (for instance, diagnosis-specific prompts, alerts, and patient education materials).	17.67	58.82	17.67	5.88	0.0
16	Is the system cost-effective?	5.88	29.41	35.29	29.41	0.0
17	IoT based HMIS promotes patient safety?	5.88	47.06	29.41	17.67	0.0

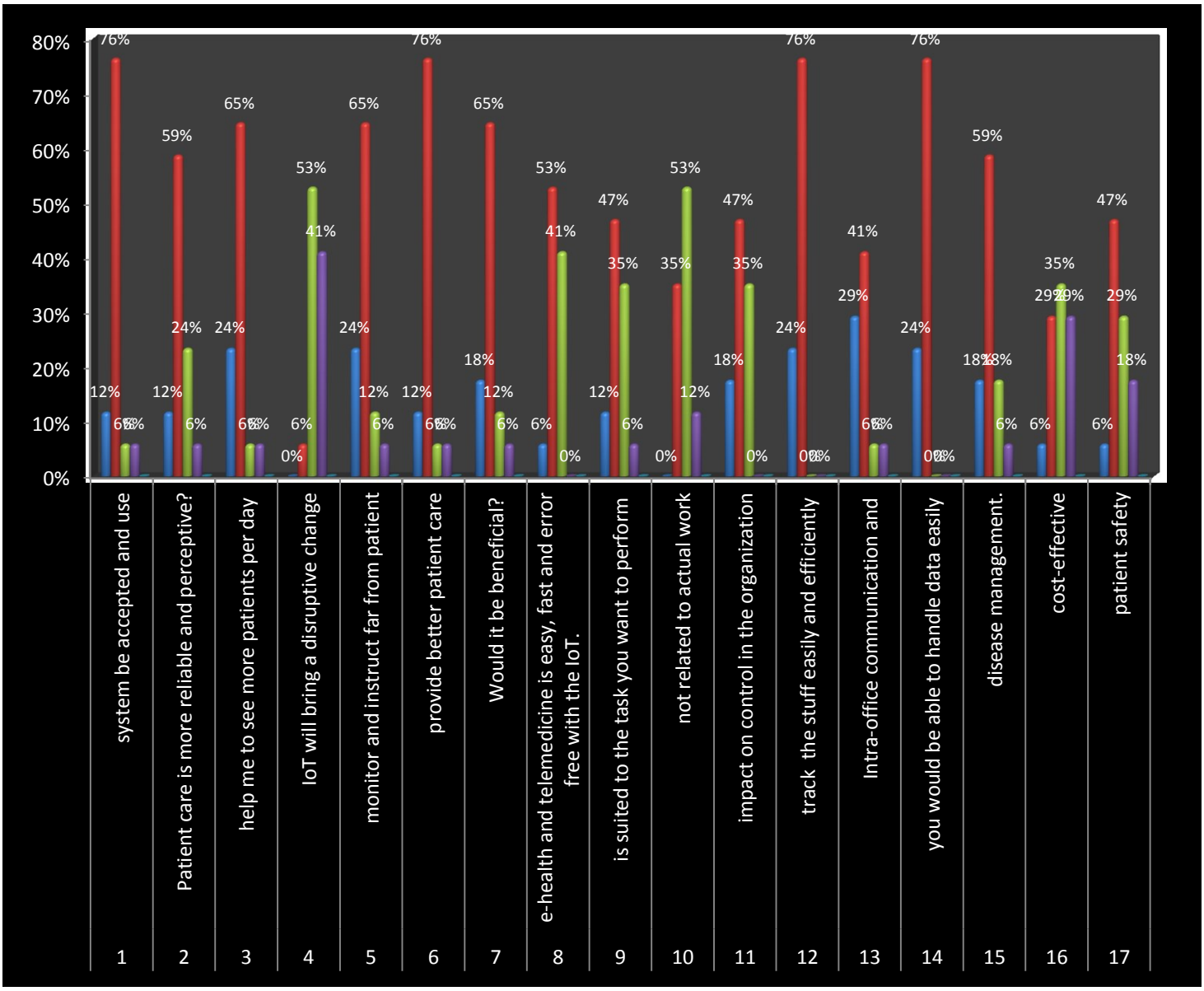


Figure 5.6: Respondent's response for the IoT based HMIS

5.4.7 Need of IoT based HMIS

We surveyed and asked the respondents about "which department need this IoT based HMIS now"? Individuals selected options from given list, some of the respondents selected more than one option. The accumulated results are shown in table 5.7 and figure 5.7. As we can see most of the respondents wanted it in OPD and then in ICU.

Table 5.7- Survey Aggregated Results for need of HMIS

Which department needs this system now??	
Radiology	5.88%
ICU	41.18%
Cardiology	17.65%
OPD	52.94%
Others	17.65%

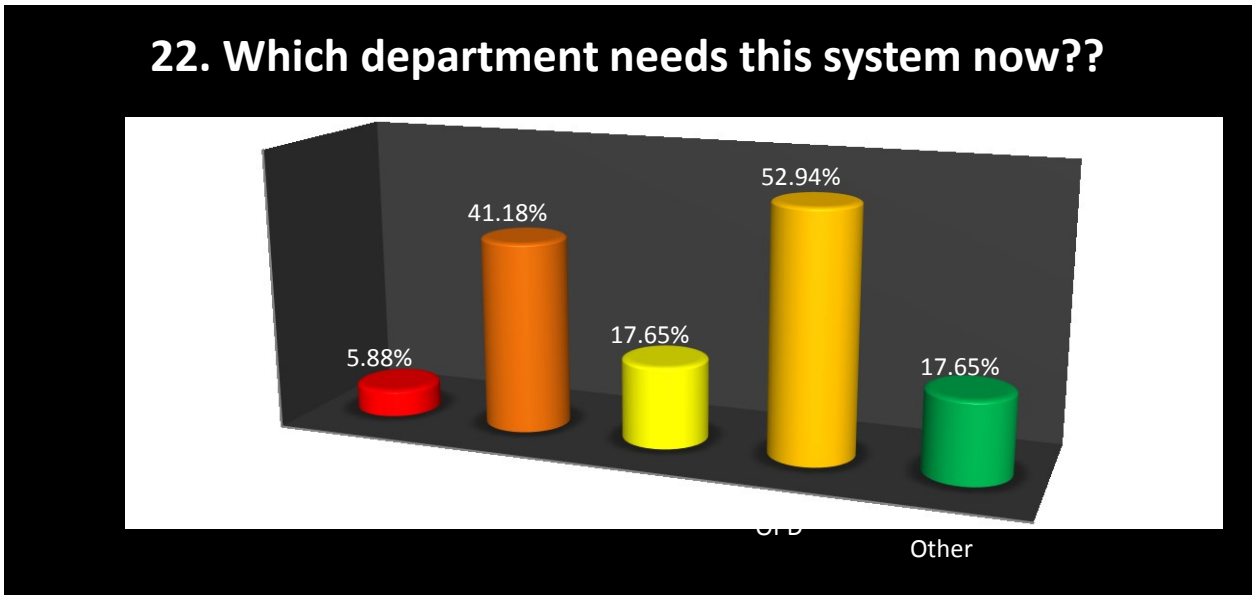


Figure 5.7: Need of IoT based HMIS in Department.

Bn n

5.5 Discussion

Despite the widespread use of information technology, hospitals in Pakistan still lack in IT advancement. Currently used many large hospitals still don't use computer systems, but many are using simple HMIS systems, such as CMH. Some of hospitals also have implemented basic level of e-health and working on tele-health and making progress. Our survey is showing that people are

willing to accept and use HMIS with advanced technology as technology is always there to ease humans and give comfort in our daily life. So does our proposed framework. And around 80% of respondent's agreed that IoT based system would provide better communication, better health care, reduce cost, better monitoring, and early diagnosis, better data management and so on.

Most of the questions in questionnaire were understood and correctly interpreted by most of the respondents. But for some questions respondents were confused and scored questionnaire with wrong interpretation. For example some of doctors were thinking that with on distance monitoring as we are already doing in ehealth and telemedicine, communication with patients would be less and difficult.

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 Conclusions

IoT (Internet of Things) has turned into a real life changer. In last decade this technology through its excellence of pertinence is emerging in every zone of life from logistics to environment observing and trades to farming. Healthcare is one of those fields which request a motivational provision which may only be fulfilled by IoT in conservative and helpful way. In this paper we have proposed a framework for smart hospitals based on IoT, implementation of this framework will change the existing hospital architecture and will give satisfied result and this methodology is for sure fit to tackle the issues of hospital. We have discussed the basic connotation of smart hospital, the architecture of smart hospital with the innovation of context awareness on the network layer of data management, key technologies of IoT and development.

We have presentenced architectural framework on basic structure of IoT. It consists of three layers i.e. application layer, network layer and perception layer. With the presentation of this framework for hospital we have added a middleware on Network layer to cater the problem of big data management. The architectural framework provides better communication, better monitoring, better diagnosis, tracking, treatment and management. We can diagnose the patient while on their way to hospital and when he will arrive to hospital, according to patients condition environment for him will be already prepared. For example if patient needs operation, operation theater will be ready before he will arrive to hospital, in this way we are saving time. As IoT is aimed to connect everything to Internet, there are billions of sensors are attached to things to access data and connect these things to internet. So the data provided by these sensors is growing very fast. In near future it would be difficult to handle this too much data on personals gadgets as well on central databases. The biggest challenge about IoT based framework that we addressed is data management. To deal with this problem we have introduced context awareness as a middleware on IoT's architecture. Context awareness stores the information in context to interpret it easily and make it more meaningful. When context is defined then only relevant data is further processed and forwarded.

Moreover we did survey based analysis of this architectural framework. To investigate the how users have perceived this system, how they differentiate this system from existing (this one is better or the existing), decision about adoption of IoT based hospital management system in Pakistan and in which department we need this system now. Most of the respondents supported this framework, and agreed that this system is more reliable and beneficial than they have used previously. They agreed to use HMIS based on IoT framework and wanted its implementation at their corresponding workplaces to reduce the work load and provide better health care and management. For the question 'which department needs this system now?' the high priority was given to ICU and OPD department.

Discussing the advantages, the smart hospital based on IoT has low energy consumption communication technology; the system is more cheap and easy to maintenance, less connectivity issues, efficient performance in less restricted environment.

6.2 Contributions

The main contributions of this thesis are

- It proposed an architectural framework for IoT based automated hospital management information system.
- The proposed system addressed the problem of big data management in IoT by introducing context awareness.
- The IoT based proposed HMIS would provide tracking, identification, monitoring, early diagnosis, help in decision making and other management facilities with less cost and minimizing response time.
- A complete survey has been done to check the need of IoT based HMIS in Pakistan. The survey showed that around 90% respondents' wants to use IoT based HMIS.
- A survey for department level inclusion of proposed system has also been done and the highest priority is given to OPD and ICU.

6.3 Future work suggestions

As IoT is a new paradigm in technology. Hence still a lot of work is need to do for the wide adoption of IoT. Despite the benefits of Internet of things with context awareness there are some issues of security as well privacy. Although the aim is to provide comfort and convenience to users while minimizing the interactions between users and devices, we should keep in mind to give control to user for sharing to keep their mind set at ease. Currently users don't have access to control their privacy in internet of things, and when they will feel they are in control they will hesitate to adopt the system. In future we will work to provide privacy controls to individuals. At system level, we will develop algorithm to set the priority of patients with the severity of their condition to reduce latency delay with medical perspective.

Evidently our work is near to beginning than the end. It is our hope that this framework will eventually be fully adopted in future. We believe that our proposed architecture is a good 1st step towards HMIS using IoT with context awareness, and it could be successfully applied to other senor networks.

References

[1] Vermesan, O., Harrison, M., Vogt, H., Kalaboukas, K., Tomasella, M., Wouters, K., Gusmeroli, S., and Haller, S. (2010). *Vision and Challenges for Realising the Internet of Things*. European Commission - Information Society and Media DG.

[2] P. Guillemin and P. Friess, "Internet of things strategic research roadmap," http://www.internet-of-thingsresearch.eu/pdf/IoT

[3] Koop, C.E.; Mosher, R.; Kun, L.; Geiling, J.; Grigg, E.; Long, S.; Macedonia, C.; Merrell, R.; Satava, R.; Rosen, J. (2008). Future delivery of health care: Cybercare. *IEEE Engineering in Medicine and Biology Magazine,* 27(6), 29-38.

[4] "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020". Gartner. 2013-12-12. Retrieved 2014-01-02. Wen Hao, "RFID, EPC and Things of Internet", *RFID Technology and Application*, No. 5, 2009, pp. 17-20

[5] Lei Yu, hospital based on IoT, journal of Networks, Vol 7, No 10 (2012), 1654-1661, Oct 2012

[6] Atzori, L., Antonio, I., and Giacomo, M. (2010). The internet of things: A survey. *Computer Networks*. [14]Koop, C.E.; Mosher, R.; Kun, L.; Geiling, J.; Grigg, E.; Long, S.; Macedonia, C.; Merrell, R.; Satava, R.; Rosen, J. (2008). Future delivery of health care: Cybercare. *IEEE Engineering in Medicine and Biology Magazine,* 27(6), 29-38.

[7] P. Guillemin and P. Friess, "Internet of things strategic research roadmap," Cluster Strategic Research Agenda 2009.pdf

[8] Sun, Y., Yan, H., Lu, C., Bie, R., and Thomas, P. (2012). A holistic approach to visualizing business models for the internet of things. *Communications in Mobile Computing*.

[9] P. Guillemin and P. Friess, "Internet of things strategic research roadmap," Cluster Strategic Research Agenda 2009.pdf

[10] Perera, C., Zaslavsky, A., Christen, P., and Georgakopoulos, D. (2013). Sensing as a service model for smart cities supported by internet of things. *Transaction on emerging telecommunication* technologies.

[11] Dohr, A., Modre-Osprian, R., Drobics, M., Hayn, D., and G.Schreier (2010). The internet of things for ambient assisted living. *Seventh International Conference on Information* Technology

[12] Sheng, Q., Zeadally, S., Luo, Z., Chung, J., Maamar, Z. (2010). Ubiquitous RFID: Where are we? *Information Systems Frontiers,* 12(5), 485-490.

[13] Dohr, A., Modre-Osprian, R., Drobics, M., Hayn, D., and G.Schreier (2010). The internet of things for ambient assisted living. *Seventh International Conference on Information Technology*.

[14] Miorandi, D., Sicari, S., and Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *AdHoc Networks*.

[15] Teng, X.; Zhang, Y.-T.; Poon, C.C.Y.; Bonato, P. (2008) Wearable Medical Systems for p-Health. *IEEE Reviews in Biomedical Engineering.* Vol 1, 62-74.

[16] H. Sundmaeker, P. Guillemin, P. Friess, and S. Woelffle, "Vision and challenges for realising the internet of things," European Commission Information Society and Media, Tech. Rep., March 2010, http://www.internet-of-things-research.eu/pdf/IoT Clusterbook March 2010.pdf

[17] Jayavardhana Gubbi, Rajkumar Buyyab, Slaven Marusic, Marimuthu Palaniswami. 24 February 2013. Internet of Things (IoT): A vision, architectural elements, and future directions, Future Generation Computer Systems 29 (2013) 1645–1660.

[18] D. Guinard, "Towards the web of things: Web mashups for embedded devices," in *In MEM 2009 in Proc. WWW 2009. ACM*, 2009.

[19] Casaleggio Associati, "The evolution of internet of things," Casaleggio Associati, Tech. Rep., February 2011, http://www.casaleggio. it/pubblicazioni/Focus internet of things v1.81%20-%20eng.pdf

[20] European Commission, "Internet of things in 2020 road map for the future," Working Group RFID of the ETP EPOSS, Tech. Rep., May 2008, http://ec.europa.eu/information society/policy/rfid/ documents/iotprague2009.pdf

[21] P. Guillemin and P. Friess, "Internet of things strategic research roadmap," The Cluster of European Research Projects, Tech. Rep., September 2009, http://www.internet-of-things-research.eu/pdf/IoT Cluster Strategic Research Agenda 2009.pdf

[22] Carnot Institutes, "Smart networked objects and internet of things," Carnot Institutes' Information Communication Technologies and Micro Nano Technologies alliance, White Paper, January 2011, http://www.internet-of-things-research.eu/pdf/IoT Clusterbook March 2010.pdf

[23] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Comput. Netw.*, vol. 54, no. 15, pp. 2787–2805, Oct. 2010. [Online]. Available: http://dx.doi.org/10.1016/j.comnet.2010.05.010

[24] G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, "Smart objects as building blocks for the internet of things," *IEEE Internet Computing*, vol. 14, no. 1, pp. 44 –51, jan.-feb. 2010. [Online]. Available: http://dx.doi.org/10.1109/MIC.2009.143

[25] http://www.businessinsider.com/the-internet-of-everything-2014-slide-deck-sai-2014-2#-16

[26] A. Dohr, R. Modre-Opsrian, M. Drobics, D. Hayn, and G. Schreier, "The internet of things for ambient assisted living," in *Information Technology: New Generations (ITNG), 2010 Seventh International Conference on*, 2010, pp. 804–809. [Online]. Available: http: //dx.doi.org/10.1109/ITNG.2010.104

[27] K. Ashton, "That 'internet of things' thing in the real world, things matter more than ideas," *RFID Journal*, June 2009, http://www.rfidjournal. com/article/print/4986.

[28] D. L. Brock, "The electronic product code (epc) a naming scheme for physical objects," Auto-ID Center, White Paper, January 2001, http://www.autoidlabs.org/uploads/media/MIT-AUTOID-WH-002.pdf

[29] International Telecommunication Union, "Itu internet reports 2005: The internet of things," International Telecommunication Union, Workshop Report, November 2005, http://www.itu.int/dms_pub/itu-s/opb/pol/SPOL-IR.IT-2005-SUM-PDF-E.pdf

[30] T. Lu and W. Neng, "Future internet: The internet of things," in *3rd International Conference on Advanced Computer Theory and Engineering(ICACTE)*, vol. 5, August 2010, pp. V5–376–V5–380. [Online]. Available: http://dx.doi.org/10.1109/ICACTE.2010.5579543

[31] L. W. F. Chaves and C. Decker, "A survey on organic smart labels for the internet-of-things," in *Networked Sensing Systems (INSS), 2010 Seventh International Conference on*, 2010, pp. 161–164. [Online]. Available: http://dx.doi.org/10.1109/INSS.2010.5573467

[32] Y. Chen, J. Guo, and X. Hu, "The research of internet of things' supporting technologies which face the logistics industry," in *Computational Intelligence and Security (CIS), 2010 International Conference on*, 2010, pp. 659–663. [Online]. Available: http: //dx.doi.org/10.1109/CIS.2010.148

[33] Y.-W. Wang, H.-L. Yu, and Y. Li, "Internet of things technology applied in medical information," in *Consumer Electronics, Communications and Networks (CECNet), 2011 International Conference on*, april 2011, pp. 430 – 433. [Online]. Available: http://dx.doi.org/10.1109/ CECNET.2011.5768647

[34] G. Chong, L. Zhihao, and Y. Yifeng, "The research and implement of smart home system based on internet of things," in *Electronics, Communications and Control (ICECC), 2011 International Conference on*, sept. 2011, pp. 2944 –2947. [Online]. Available: http://dx.doi.org/10.1109/ICECC.2011.6066672

[35] J. Burrell, T. Brooke, and R. Beckwith, "Vineyard computing: sensor networks in agricultural production," *IEEE Pervasive Computing*, vol. 3, no. 1, pp. 38 – 45, jan.-march 2004. [Online]. Available: http://dx.doi.org/10.1109/MPRV.2004.1269130

[36] L. Lin, "Application of the internet of thing in green agricultural products supply chain management," in *Intelligent Computation Technology and Automation (ICICTA), 2011 International Conference on*, vol. 1, 2011, pp. 1022–1025. [Online]. Available: http://dx.doi.org/10.1109/ICICTA.2011.256

[37] A. Asin and D. Gascon, "50 sensor applications for a smarter world," Libelium Comunicaciones Distribuidas, Tech. Rep., 2012, http: //www.libelium.com/top 50 iot sensor applications ranking/pdf

[38] BCC Research, "Sensors: Technologies and global markets," BCC Research, Market Forecasting, March 2011, http://www.bccresearch. com/report/sensors-technologies-markets-ias006d.html

[39] I. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," *IEEE Commun. Mag.*, vol. 40, no. 8, pp. 102 – 114, aug 2002. [Online]. Available: http: //dx.doi.org/10.1109/MCOM.2002.1024422

[40] A. Mainwaring, D. Culler, J. Polastre, R. Szewczyk, and J. Anderson, "Wireless sensor networks for habitat monitoring," in *Proc. 1st ACM international workshop on Wireless sensor networks and applications*, ser. WSNA '02. New York, NY, USA: ACM, 2002, pp. 88–97. [Online]. Available: http://doi.acm.org/10.1145/570738.570751

[41] D. Malan, T. Fulford-jones, M. Welsh, and S. Moulton, "Codeblue: An ad hoc sensor network infrastructure for emergency medical care," in *In International Workshop on Wearable and Implantable Body Sensor Networks*, 2004. [Online]. Available: http://www.eecs.harvard. edu/ ~mdw/papers/codeblue-bsn04.pdf

[42] S. Rooney, D. Bauer, and P. Scotton, "Techniques for integrating sensors into the enterprise network," *IEEE Trans. Network and Service Management*, vol. 3, no. 1, pp. 43 –52, jan. 2006. [Online]. Available: http://dx.doi.org/10.1109/TNSM.2006.4798306

[43] A. R. Da Rocha, F. C. Delicato, J. N. de Souza, D. G. Gomes, and L. Pirmez, "A semantic middleware for autonomic wireless sensor networks," in *Proc. 2009 Workshop on Middleware for Ubiquitous and Pervasive Systems*, ser. WMUPS '09. New York, NY, USA: ACM, 2009, pp. 19–25. [Online]. Available: http://doi.acm.org/10.1145/1551693.1551697

[44] A. Gluhak and W. Schott, "A wsn system architecture to capture context information for beyond 3g communication systems," in *Intelligent Sensors, Sensor Networks and Information, 2007. ISSNIP 2007. 3rd International Conference on*, dec. 2007, pp. 49 –54. [Online]. Available: http://dx.doi.org/10.1109/ISSNIP.2007.4496818

[45] F. Neto and C. Ribeiro, "Dynamic change of services in wireless sensor network middleware based on semantic technologies," in *Autonomic and Autonomous Systems (ICAS), 2010 Sixth International Conference on*, march 2010, pp. 58 –63. [Online]. Available: http://dx.doi.org/10.1109/ICAS.2010.17

[46] K. Al Nuaimi, M. Al Nuaimi, N. Mohamed, I. Jawhar, and K. Shuaib, "Web-based wireless sensor networks: a survey of architectures and applications," in *Proc. 6th International Conference on Ubiquitous Information Management and Communication*, ser. ICUIMC '12. New York, NY, USA: ACM, 2012, pp. 113:1–113:9. [Online]. Available: http://doi.acm.org/10.1145/2184751.2184881

[47] S.-H. Sho, K.-S. Kim, W.-r. Jun, J.-S. Kim, S.-H. Kim, and J.-D. Lee, "Ttcg: three-tier context gathering technique for mobile devices," in *Proc. 5th international conference on Pervasive services*, ser. ICPS '08. New York, NY, USA: ACM, 2008, pp. 157–162. [Online]. Available: http://doi.acm.org/10.1145/1387269.1387296

[48] C. Alcaraz, P. Najera, J. Lopez, and R. Roman, "Wireless sensor networks and the internet of things: Do we need a complete integration?" in *1st International Workshop on the Security of the Internet of Things (SecIoT'10)*, 2010.

[49] E. Elnahrawy and B. Nath, "Context-aware sensors," in *Wireless Sensor Networks*, ser. Lecture Notes in Computer Science, H. Karl, A.Wolisz, and A. Willig, Eds. Springer Berlin / Heidelberg, 2004, vol. 2920, pp. 77–93. [Online]. Available: http://dx.doi.org/10.1007/978-3-540-24606-0 6

[50] B. Firner, R. S. Moore, R. Howard, R. P. Martin, and Y. Zhang, "Poster: Smart buildings, sensor networks, and the internet of things," in *Proc. 9th ACM Conference on Embedded Networked Sensor Systems*, ser. SenSys '11. New York, NY, USA: ACM, 2011, pp. 337–338. [Online]. Available: http://doi.acm.org/10.1145/2070942.2070978

[51] S. Alam, M. M. R. Chowdhury, and J. Noll, "Senaas: An event-driven sensor virtualization approach for internet of things cloud," in *Networked Embedded Systems for Enterprise Applications (NESEA), 2010 IEEE International Conference on*, November 2010, pp. 1–6. [Online]. Available: http://dx.doi.org/10.1109/NESEA.2010.5678060

[52] P. Patel, S. Jardosh, S. Chaudhary, and P. Ranjan, "Context aware middleware architecture for wireless sensor network," in *Services Computing, 2009. SCC '09. IEEE International Conference on*, sept. 2009, pp. 532 –535. [Online]. Available: http://dx.doi.org/10.1109/SCC.2009.49

[53] D. Le-Phuoc, J. X. Parreira, M. Hausenblas, Y. Han, and M. Hauswirth, "Live linked open sensor database," in *Proc. 6th International Conference on Semantic Systems*, ser. I-SEMANTICS '10. New York, NY, USA: ACM, 2010, pp. 46:1–46:4. [Online]. Available: http://doi.acm.org/10.1145/1839707.1839763

[54] M. Botts, G. Percivall, C. Reed, and J. Davidson, "Ogc sensor web enablement: Overview and high level architecture," in *Geosensor Networks Lecture Notes In Computer Science*, S. Nittel, A. Labrinidis, and A. Stefanidis, Eds. Berlin, Heidelberg: Springer-Verlag, 2008, ch. OGC Sensor Web Enablement: Overview and High Level Architecture, pp. 175–190. [Online]. Available: http://dx.doi.org/10.1007/978-3-540-79996-2 10

[55] S. Patidar, D. Rane, and P. Jain, "A survey paper on cloud computing," in *Advanced Computing Communication Technologies (ACCT), 2012 Second International Conference on*, jan. 2012, pp. 394 –398. [Online]. Available: http://dx.doi.org/10.1109/ACCT.2012.15

[56] M. Zhou, R. Zhang, D. Zeng, and W. Qian, "Services in the cloud computing era: A survey," in *Universal Communication Symposium (IUCS), 2010 4th International*, oct. 2010, pp. 40 –46. [Online]. Available: http://dx.doi.org/10.1109/IUCS.2010.5666772

[57] P. Banerjee, R. Friedrich, C. Bash, P. Goldsack, B. Huberman, J. Manley, C. Patel, P. Ranganathan, and A. Veitch, "Everything as a service: Powering the new information economy," *Computer*, vol. 44, no. 3, pp. 36 –43, march 2011. [Online]. Available: http://dx.doi.org/10.1109/MC.2011.67

[58] Partha P. Ray, Internet of Things based Physical Activity Monitoring (PAMIoT): An Architectural Framework to Monitor Human Physical Activity,http://www.academia.edu/9173528/Internet_of_Things_based_Physical_Activity_Monitoring_PAMIoT_An_Architectural_Framework_to_Monitor_Human_Physical_Activity,[2014]

[59] M. Memon, S. R. Wagner, C. F. Pedersen, F.H. A. Beevi, F. O. Hansen, Ambient Assisted Living Healthcare Frameworks, Platforms, Standards, and Quality Attributes, Sensors, 14, pp-4312-4341, 2014.

[60] P. P. Ray, Home Health Hub Internet of Things (H3IoT): An Architectural Framework for Monitoring Health of Elderly People, CALCON, 2014

[61] Interconnection Framework for mHealth and Remote Monitoring Based on the Internet of Things Antonio J. Jara, Miguel A. Zamora-Izquierdo, and Antonio F. Skarmeta, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6585881 ,2013.

[62] Ching Hsu "Wireless Context-Aware Healthcare System Based on Sensor Web 2.0" http://www.ijimt.org/papers/432-D0142.pdf

[63] Martyn Casserly, "What Is 'The Internet of Things'? How Connected Devices Are Set to Change Our Lives, www.pcadvisor.co.uk, May 29, 2013

[64] Boyi Xu, Li Da Xu, Senior Member, IEEE, Hongming Cai, Cheng Xie, Jingyuan Hu, and Fenglin Bu "Ubiquitous Data Accessing Method in IoT-Based Information System for Emergency Medical Services" http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6742577

[65] Kashif habib http://www.thinkmind.org/download.php?articleid=smart_2014_2_30_40072 [2014]

[66] Hao Chen, Dingcheng Xiang, Weiyi Qin, Minwei Zhou, Ji-Jiang Yang, Qiang Gao, and Jian Liu "Optimal ST-Elevation Myocardial Infarction System by Regional Cooperative Emergency Care Based on the Internet of Things" http://link.springer.com/chapter/10.1007%2F978-3-319-08416-9_24

[67] Partha Pratim Ra "Internet of Things based Physical Activity Monitoring (PAMIoT): An Architectural Framework to Monitor Human Physical Activity" http://www.researchgate.net/publication/267924864_Internet_of_Things_based_Physical_Activity_Monitoring_%28PAMIoT%29_An_Architectural_Framework_to_Monitor_Human_Physical_Activity

[68] GE, *The Future of Big Data: Beyond the Internet of Things*, http://www.gereports.com/post/107450962595/the-future-of-big-data-beyond-the-internet-of-things

[69] Jae Pil Yoo, Jae" Il Lee, Cheonshik Kim, Jonghyuk Park "Life Navigator, Smart Internet of Things Based Context-Aware End-User Framework

[70] David Niewolny "How the Internet of Things Is Revolutionizing Healthcare" http://cache.freescale.com/files/corporate/doc/white_paper/IOTREVHEALCARWP.pdf

[71] Ludwig, W.; Wolf, K.; Duwenkamp, C.; Gusew, N.; Hellrung, N.; Marschollek, M.; Wagner, M.; Haux, R., (2012). Health-enabling technologies for the elderly–An overview of services based on a literature review. *Computer Methods and Programs in Biomedicine,* 106(2), 70-78.

[72] Klasnja, P., Pratt, W. (2012). Healthcare in the pocket: Mapping the space of mobilephone health interventions, *Journal of Biomedical Informatics,* 45(1), 184-198.

[73] Domingo, M. C. (2012). An overview of the Internet of Things for people with disabilities. *Journal of Network and Computer Applications,* 35(2), 584-596.

[74] Li, S., Xu, L., Wang, X. (2013). Compressed Sensing Signal and Data Acquisition in Wireless Sensor Networks and Internet of Things. *IEEE Transactions on Industrial Informatics*, in press DOI: 10.1109/TII.2012.2189222

[75] Yick, Jennifer; Mukherjee, Biswanath; Ghosal, Dipak, (2008). Wireless sensor network survey. *Computer Networks*, 52 (2008) 2292–2330.

[76] **Zhibo Pang,** Lirong Zheng, Junzhe Tian, Sharon Kao-Walter, Elena Dubrova , Qiang Chen. *Enterprise Information Systems*, DOI:10.1080/17517575.2013.776118, April 2013. IF 3.684.

[77] E. B. Lerner and R. M. Moscati, "The Golden Hour: Scientific Fact or Medical Urban Legend?," *Academic Emergency Medicine*, vol. 8, no. 7, July 2001, pp. 758–60.

[78] J. K.-J. Li, *Dynamics of the Vascular System*, World Scientific Publishing, Singapore, 2004.

[79] S. Bandyopadhyay, M. Sengupta, S. Maiti, and S. Dutta, "Role of middleware for internet of things," *International Journal of Computer Science and Engineering Survey*, vol. 2, pp. 94–105, 2011. [Online]. Available: http://airccse.org/journal/ijcses/papers/0811cses07.pdf

[80] Ma JinJun, A brief talk on the problem in integration of hospital intelligence and information and developing directionof intelligence [J], *Intelligent Building & City Information*, 2010, (158) , pp. 94-96

[81] Fu Zheng, Liang MingHuI, Conspectus of digital medicine [M].

[82] Framling K, nym an J. Information architecture for intelligent products in the internet of things [EB/OL]. [2010-05-22].

[83] Cheng ZhiHong, JiaoYahui, Liu Li, et al., Prospects for applications of RFID technology to realize boundaryless sensing hospitals [J], *Chinese Hospitals*, 2010, 14 (8) , pp. 8-9

[84] LI Jing, Zhang Hong; Wang ZhiQi, et al., Research of digital ambient intelligence hospital by RFID technology [J], *China Medical Devices*, 2009, 24 (7) , pp. 44-46

[85] Zhang Shen, Ding EnJie, Xu Zhao, Hua Gang, characteristics and key technologies of sensor mine internet of things [J], *Industry and Mine Automation*, 2010,(12) , pp. 117-121

[86] V. Issarny, M. Caporuscio, and N. Georgantas, "A perspective on the future of middleware-based software engineering," in *2007 Future of Software Engineering*, ser. FOSE '07. Washington, DC, USA: IEEE Computer Society, 2007, pp. 244–258. [Online]. Available:http://dx.doi.org/10.1109/FOSE.2007.2

[87] M. Nagy, A. Katasonov, O. Khriyenko, S. Nikitin, M. Szydlowski, and V. Terziyan, "Challenges of middleware for the internet of things," University of Jyvaskyla, Tech. Rep., 2009, http://cdn.intechopen.com/pdfs/8786/InTech-Challenges of middleware for the internet of things.pdf [Accessed on: 2011- 12-20].

[88] Charith Perera, Arkady Zaslavsky, , Peter Christen, and Dimitrios Georgakopoulos, "Context Aware Computing for The Internet of Things: A Survey" IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 16, NO. 1, FIRST QUARTER 2014

[89] OpenIoT Consortium, "Open source solution for the internet of things into the cloud," January 2012, http://www.openiot.eu

[90] G. D. Abowd, A. K. Dey, P. J. Brown, N. Davies, M. Smith, and P. Steggles, "Towards a better understanding of context and context-awareness," in *Proc. 1st international symposium on Handheld and Ubiquitous Computing*, ser. HUC '99. London, UK: Springer-Verlag, 1999, pp. 304–307. [Online]. Available: http://dl.acm.org/citation.cfm?id=647985.743843

[91] A. Moses, "Lg smart fridge tells you what to buy, cook and eat," The Sydney Morning Herald, January 2012, http://www.smh.com.au/digital-life/hometech/lg-smart-fridge-tellsyou- what-to-buy-cook-and-eat-20120110-1ps9z.html [Accessed on: 2012-04-04].

[92] M. Raskino, J. Fenn, and A. Linden, "Extracting value from the massively connected world of 2015," Gartner Research, Tech. Rep., April 2005, http://www.gartner.com/resources/125900/125949/ extracting valu.pdf [Accessed on: 2011-08-20].

[93] H. Chen, T. Finin, A. Joshi, L. Kagal, F. Perich, and D. Chakraborty, "Intelligent agents meet the semantic web in smart spaces," *IEE Internet Computing*, vol. 8, no. 6, pp. 69 – 79, nov.-dec. 2004. [Online]. Available: http://dx.doi.org/10.1109/MIC.2004.66

[94] J. Indulska and P. Sutton, "Location management in pervasive systems," in *Proc. Australasian information security workshop conference on ACSW frontiers 2003 - Volume 21*, ser. ACSW Frontiers '03. Darlinghurst, Australia, Australia: Australian Computer Society, Inc., 2003, pp. 143–151.

[95] M. Baldauf, S. Dustdar, and F. Rosenberg, "A survey on context aware systems," *Int. J. Ad Hoc Ubiquitous Comput.*, vol. 2, no. 4, pp. 263–277, Jun. 2007. [Online]. Available: http://dx.doi.org/10.1504/IJAHUC.2007.014070

[96] K. Balavalad, S. Manvi, and A. Sutagundar, "Context aware computing in wireless sensor networks," in *Advances in Recent Technologies in Communication and Computing, 2009. ARTCom '09. International Conference on*, oct. 2009, pp. 514 –516. [Online]. Available: http://dx.doi.org/10.1109/ARTCom.2009.85

[97] uml.org, "Unified modeling language (uml)," 2012, http://www.uml. org/ [Addressed on: 2012-05-29].

[98] D. Allemang and J. Hendler, *Semantic Web for the Working Ontologist, Second Edition: Effective Modeling in RDFS and OWL*, 2nd ed. Morgan Kaufmann, 2011. [Online]. Available: http://mkp.com/news/semantic-web-for-the-working-ontologist-2ndedition- effective-modeling-in-rdfs-and-owl-by-dean-allemang-jameshendler

[99] L. Yu, *A Developer's Guide to the Semantic Web*, 1st ed. Springer, 2011. [Online]. Available: http://www.springer.com/computer/database+management+%26+ information+retrieval/book/978-3-642-15969-5

[100] P. Hitzler, M. Krtzsch, and S. Rudolph, *Foundations of Semantic Web Technologies*. Chapman & Hall/CRC, 2009. [Online]. Available: http://www.semantic-web-book.org/page/Foundations of Semantic Web Technologies

[101] W3C Ubiquitos Web Domain, "Composite capabilities/preference profiles: Structure and vocabularies 2.0," June 2007, http://www.w3.org/ Mobile/CCPP/ [Accessed on: 2012-05-26].

[102] G. Chen and D. Kotz, "A survey of context-aware mobile computing research," Department of Computer Science, Dartmouth College, Hanover, NH, USA, Tech. Rep., 2000, http://www.cs.dartmouth.edu/ reports/TR2000-381.pdf [Accessed on: 2011-12-05].

[103] T. Strang and C. Linnhoff-Popien, "A context modeling survey," in *In: Workshop on Advanced Context Modelling, Reasoning and Management, UbiComp 2004 - The Sixth International Conference on Ubiquitous Computing, Nottingham/ England*, 2004. [Online]. Available: http://elib.dlr.de/7444/1/ Ubicomp2004ContextWSCameraReadyVersion.pdf

[104] P. Nurmi and P. Floree. (2004) Reasoning in context-aware systems. Position Paper. Department of Computer Science, University of Helsinki.

[105] A. Bikakis, T. Patkos, G. Antoniou, , and D. Plexousaki, "A survey of semantics-based approaches for context reasoning in ambient intelligence," in *Ambient Intelligence 2007 Workshops*,M.M, F. A, and A. E, Eds., vol. 11.

SPRINGER-VERLAG BERLIN, 2008. [Online]. Available: http://www.csd.uoc.gr/ ~bikakis/pubs/survey-ami07.pdf

[106] M. Perttunen, J. Riekki, and O. Lassila, "Context representation and reasoning in pervasive computing: a review," *International Journal of Multimedia and Ubiquitous Engineering*, vol. 4, no. 4, pp. 1–28, 2009. [Online]. Available: http://www.sersc.org/journals/IJMUE/vol4 no4 2009/1.pdf

[107] C. Bettini, O. Brdiczka, K. Henricksen, J. Indulska, D. Nicklas, A. Ranganathan, and D. Riboni, "A survey of context modelling and reasoning techniques," *Pervasive Mob. Comput.*, vol. 6, pp. 161–180,April 2010. [Online]. Available: http://dx.doi.org/10.1016/j.pmcj.2009.06.002

Annex

In this questionnaire, we would like to know about your current hospital management information system (HMIS) and use of & perception of the internet of things (IoT) Based smart hospital in your hospital.

A. Personal Information:

Age	Gender	Work Position	Designation	Experience
☐ 21-25 ☐ 26-30 ☐ 31-35 ☐ 36-40 ☐ 41 or above	☐ Male ☐ Female	☐ Intern ☐ Resident ☐ Consulting physician		☐ 1 Year ☐ 1-2 Year ☐ 3-5 Year ☐ Above 5 Year

B. Experience with computers

1. How frequently, do you use computer?
   Never _____ Rarely_____ Monthly_____ Weekly_____ Daily_____

2. How would you rate your computer skills?
   Lowest_____ Average_____ Highest_____

3. How often do you use the Internet for professional use, including e-mail from home, work, or another location?
   Never _____ Monthly_____ Weekly_____ Daily_____ Several times a day_____

C. Availability of computers

1. Do you have a computer in your office?
   yes____ no_____
2. Concerning other rooms, you use for clinical work (e.g. ward, outpatient clinic offices, and investigation rooms)
   a). Are there computers available for you? yes____ no_____
   b). If yes do you use these computers? yes____ no_____

3. About the computers installed in the ward, at the outpatient clinic offices, investigation rooms, etc.
   a. How often are you prevented from using them because others are using them?
      Monthly _____ Weekly _____ Daily____ Never_____

   b. How often are you prevented from using them due to computer errors, forgotten passwords or other machine-related problems?

Monthly _____ Weekly _____ Daily____ Never_____

D. About Current HMIS:

1. Do you currently use any Hospital management information system (HMIS) system in your practice?
   Yes__ No_____ part paper, part electronic_____ No, but in process_____

2. How long have you been using this HMIS? _____
3. Do you attempt to measure the effectiveness of this HMIS system?

   Yes ____ No ____
4. Are there currently any plans to change/improve this HMIS?

   Yes ____ No ____
5. Problems often occur in the exchange of information across hospital units.
   Yes _____ No _____ Oftenly_____

6. The total computerized hospitals are not fully implemented in Pakistan?
   Yes _____ No_____

E. satisfaction with the current HMIS installed in your department

	Never	seldom	half of time	most of time	Always
1. Content c) How often does the system provide the precise information you need?					
d) How often does the information content meet your needs?					
6. Accuracy c) How often is the system accurate?					
d) How often are you satisfied with the accuracy of the system?					
7. Format c) How often do you think the output is presented in a useful format?					
d) How often is the information clear?					
8. Ease of use c) How often is the system user-friendly?					
d) How often is the system easy to use?					
9. Timeliness c) How often do you get the information you					

need in time? d) How often does the system provide up-to-date information					
10. How often you are satisfied with HMIS installed in your department?					

F. Role/ Effects of HMIS on

For each outcome listed below, indicate whether you think the effect of computers is, or would be, very positive, somewhat positive, no effect, somewhat negative, or very negative:	Very positive	Somewhat positive	No effect	somewhat negative	negative
1. Controlling costs of health care					
2. Quality of health care					
3. Patient-physician communication					
4. Patient privacy					
5. Clinicians' access to up-to-date knowledge					
6. Efficiency of providing care					
7. Interactions within the health care team					
8. Medication errors					

G. The new Smart hospital based IoT:

	strongly agree	agree	uncertain/ not applicable	Disagree	strongly disagree
1. Will the system be accepted and used?					
2. Patient care is more reliable and perceptive than to the existing system?					
3. This system would help me to see more patients per day and also save time (or go home earlier)					

	than you could with the existing system.					
4.	Do you believe that IoT will bring a disruptive change?					
5.	This system would be more effective for the situation to monitor and instruct far from patient					
6.	This system wouldn't just enable us to manage the assets and data of hospital but it would actually help to provide better patient care					
7.	Would it be beneficial?					
8.	The e-health and telemedicine is easy, fast and error free with the IoT.					
9.	The way, in which architecture is proposed is suited to the task you want to perform with the software					
10.	There are some features of this systems, that are not related to actual work					
11.	Will system implementation have an impact on control in the organization					
12.	You would be able to track the stuff (including equipment and patient data) easily and efficiently with IoT based hospital					
13.	Intra-office communication and tasking would be fast, easy, and effective with IoT based hospital					
14.	The data, you would be able to handle easily (thorough IoT) with the new HMIS that you could not do before?					
15.	This would provide useful tools for disease management (for instance, diagnosis-specific prompts, alerts, and patient education materials).					
16	Is the system cost-effective?					
17	IoT based HMIS promotes patient safety?					

18. How much do you know about IoT based HMIS?
    - ☐ Almost nothing
    - ☐ Somewhat

- ☐ A few things
- ☐ A great deal

19. How many hours of training are you willing to devote to learn the new system?
    - ☐ 1 or less
    - ☐ 4
    - ☐ 8
    - ☐ 12 or more
20. What should be the staff's role in ensuring successful IoT based smart hospital?
    - ☐ The practice's physicians have a major role in successful implementation.
    - ☐ The nurses and staff will drive usage and successful implementation.
    - ☐ Physicians can use paper charts, and the staff will transfer the patient information to the new system.
    - ☐ other clinical staff
    - ☐ non clinical staff
21. Would you be interested in participating in an IoT based smart hospital awareness and adoption seminar?
    - ☐ Yes
    - ☐ No
    - ☐ Maybe
22. Which department needs this system now??
    - ☐ Radiology
    - ☐ ICU
    - ☐ Cardiology
    - ☐ OPD
    - ☐ Other

H. Comments if any:

_____

_____

_____

Thank you for completing this important questionnaire.

In this questionnaire, we would like to know about your current hospital management information system (HMIS) and use of & perception of the internet of things (IoT) Based smart hospital in your hospital.

A. Personal Information:

Age	Gender	Work Position	Designation	Experience
☐ 21-25 ☐ 26-30 ☐ 31-35 ☐ 36-40 ☐ 41 or above	☐ Male ☐ Female	☐ Intern ☐ Resident ☐ Consulting physician		☐ 1 Year ☐ 1-2 Year ☐ 3-5 Year ☐ Above 5 Year

B. Experience with computers

1. How frequently, do you use computer?
   Never _____ Rarely_____ Monthly_____ Weekly_____ Daily_____

2. How would you rate your computer skills?
   Lowest_____ Average_____ Highest_____

3. How often do you use the Internet for professional use, including e-mail from home, work, or another location?
   Never _____ Rarely_____ Monthly_____ Weekly_____ Daily_____

C. Availability of computers

1. Do you have a computer in your office?
   yes____ no_____
2. Concerning other rooms, you use for clinical work (e.g. ward, outpatient clinic offices, and investigation rooms)
   a). Are there computers available for you? yes____ no_____
   b). If yes do you use these computers? yes____ no_____

3. About the computers installed in the ward, at the outpatient clinic offices, investigation rooms, etc.
   a. How often are you prevented from using them because others are using them?
      Monthly _____ Weekly _____ Daily____ Never_____

   b. How often are you prevented from using them due to computer errors, forgotten passwords or other machine-related problems?
      Monthly _____ Weekly _____ Daily____ Never_____