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PROPOSE AN ARCHITECTURE FOR E-HEALTH WITHIN SMART CITIES

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Master of Science

Supervisor

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Walid Ali ALGATUS

DEDICATION

To my beloved wife, Hajer, who encouraged me to urge myself to the limits. I am wholeheartedly grateful for everything she has done to me; her positive energy kept me focus on my goal whenever I felt desperate. Without her love, encouragement, and support I would not be walking on my path to accomplish my dream, to gain master degree.

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ABSTRACT

PROPOSE AN ARCHITECTURE FOR E-HEALTH WITHIN SMART CITIES

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According to the World Health Organization: eHealth is the cost-effective and secure use of information and communication technologies in support of health and health-related fields, including health-care services, health surveillance, health literature and health education. eHealth uses modern information technologies in order to improve medical services.

eHealth cloud is the implementation of cloud computing technologies in healthcare sector. It is the use of cloud technologies for the medical purposes. eHealth cloud can improve patient care, reduce operational cost and optimize IT resources utilization, it can be used to support researchers, national security and strategic planning; cloud allows to enhance security safeguards. In this thesis we proposed an e-health architecture within smart cities.

Keywords: Smart City, Service Systems, Information and Communication Technologies, Service Perspective

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LIST OF ABBREVIATIONS

AI	:	Artificial Intelligence
IoT	:	Internet of Things
PAN	:	Personal Area Network
FSK	:	Frequency Shift Keying
TDMA	:	Time Division Multiple Access
OFDM	:	Orthogonal Frequency Division Multiplexing

1. INTRODUCTION

The considerable increase of the urban population around the world has been a great challenging to the governments and the existing management of the cities with regards to the high demand of the public services, urban road network, more parking, health services, education, electricity, environment etc. The modern concept of the smart cities is strongly believed as one of the innovation strategies to solve these major issues in the most efficiency and cost-effective way by delivering the smart services faster, more reliable and safer to allow sustainable development and provide the smart living, smart economy and smart environment to the smart citizens.

According to the World Health Organization: “eHealth is the cost-effective and secure use of information and communication technologies in support of health and health-related fields, including health-care services, health surveillance, health literature and health education.” [3]. eHealth uses modern information technologies in order to improve medical services.

eHealth cloud is the implementation of cloud computing technologies in healthcare sector. It is the use of cloud technologies for the medical purposes. eHealth cloud can improve patient care, reduce operational cost and optimize IT resources utilization, it can be used to support researchers, national security and strategic planning; cloud allows to enhance security safeguards.

However, implementation of cloud computing technologies in the medical sector can be challenging. Generally, implementation of cloud computing technologies in any domain has its risks and healthcare domain is not an exception. Cloud computing challenges, such as data availability, data reliability, interoperability, etc. should be also considered in healthcare domain, with the emphasis, that mistakes in eHealth cloud will have a big impact on society in general. For this reason, the use of cloud computing technologies in healthcare sector stays apart from other cloud computing domains. Healthcare is still a new area for cloud computing technologies with many open questions, especially from the legal and standard point of view.

In order to implement cloud computing technologies in healthcare sector, it should be selected Cloud Management Software (CMS) to design cloud infrastructure and medical software which can be installed and used in a cloud environment.

Nowadays, there is a wide choice of Cloud Management Software on the IT market. CMS for the medical services should correspond to eHealth dynamic nature and provide wide functionality to manage cloud infrastructure. Selection of Cloud Management Software for eHealth services, based on comparison analysis, is one of the goals of this work.

1.1 RELATED WORKS FOR E-HEALTH

Amjad et al. propose a framework for protecting privacy to reduce the privacy leakage of smart city services. The source of this framework is generated through a series of data flowing between interconnected systems, and the function of the proposed framework.

-Analyzing the system by accessing technical leakage points that represent data leakage concerning the physical device and privacy leakage during transmission and storage operations.

-Defining privacy requirements, and here the system developer’s work with examination and processing procedures during the design process.

- Engineering requirements that are accomplished by integrating privacy processes with software engineering.

- Privacy assessment to ensure monitoring procedures and verify the discovery of the causes of leakage by verifying the integrity of the data.

The system developer should take into account the points of leakage, the flow of data, and the technologies used to examine potential attacks and find an appropriate solution to bypass the privacy barrier [55].

Jinglin et al. Use the Blockchain mechanism to provide health care security for smart cities on a large scale and facilitate secure storage of patient information through strong data encryption, Blockchain a potential technical mechanism that enhances data security and patient privacy in hospitals and abolishes the role of intermediaries to verify transactions for health care and allows only authorized persons to access system data without unwanted third party interference and infringes on the privacy of the health care system for smart cities[56].

Daojing et al. Instead, he used the method of integrating cloud computing and the Internet of things for health care and considered it is an integrated way to reach a higher level of privacy, the cloud contains a data center called the server whose function is to store data and the unit for obtaining health care data is called the client. This unit consists of care data sources Health and field control unit, secure links are used to send data from the client to the server. The process of transferring data from data sources to the field control unit is either wired using the Control Area Network (CAN) or the Highway Remote Power Adapter (HART) or wirelessly using a ZigBee network. Then the field control unit is connected to the internet, whether the connection method is wired or wireless, to send the data back to the cloud data center, and based on the output data that are analyzed online, health practitioners can make diagnostics on time [57].

The application of smart healthcare services depends on the quality of service QOS. So then Houriyeh et al. It is recommended to use the method of combining the cloud model and the Internet of things model. This integration is called in other articles a cloud of thing (COT). The overall quality of service assurance in health applications is determined by examining the quality of service parameters for the dimensions of the cloud (QOSC) and the quality of service parameters for the dimensions of the network (QOSN) The difference between the types of parameters in both the cloud and the network is one of the qualities of service challenges for the implementation of healthcare on time by carefully selecting the quality of service parameters, using decision-making algorithms such as the simple weighting method by simulating an ideal solution or the analytical hierarchy process (AHP), The (AHP) function is to divide the network and cloud parameters according to quality of service standards[58].

Vikas et al. use the Arduino Fio transmitter panel to create a proposed system that contains a different set of sensors, and The XBee module that is connected to the board. This system provides full support to the medical staff through the possibility of tracking and monitoring patients remotely in real-time since this system collects all the sensors, location sensors, temporary networks, electronic patient records, and web portal technology. Using the LabVIEW application on the home computer device connected to the Internet to read the perceived values after the values are sent wirelessly to the Arduino receiver connected to the Internet and creating a URL address that can be accessed through any other computing device and does not require special requirements [59].

Deepak et al. Extending this work by including a micro-control board called Arduino Uno that runs on the Microchip ATmega328P in addition to installing different sensors for each sensor with its own parameters, including an LM35 sensor to record body temperature, MEMS sensor and GYRO sensor to monitor the general condition of the body and Give an alert to the observer through a connected buzzer system, a pulse rate sensor that is connected to the micro-control board to measure the individual's pulse. Using IDE to program the micro-control unit either in C or C++ language because it contains a text editor capable of giving instructions to the mini control panel, it also contains a GSM module whose function is to send patient vital data collected from different sensors to the base station via the Internet, to display the items Vitality The control panel is connected to a screen 16 × 2 LCD. Using this system, the patient will be the direct supervisor of the monitoring process within a treatment cycle tailored to his physical needs, analysis of vital signs, the suggestion of observations, and freedom from reliance on a healthcare professional [60].

Parag et al. proposing a model based on the Internet of things for an intelligent and widespread electronic health system to reach a model system for clinical information capable of automated decision-making by making use of patient-related data available to the concerned health care personnel as an aid in the treatment stages. The proposed system was designed using a common platform with a wide range through which entities related to patient data is linked and add distributed database that enables data exchange for patient records within remote entities, The proposed system needs to Use an effective storage mechanism that provides regular access upon request by organizing health records by issuing a unique national identity UID and giving storage space only to the registered person, and Used tables to store each group in a separate table from the other by creating a separate identifier for the same table, in addition to a table containing all family information where the patient — the patient is linked to the unique identifier of the other patient belonging to family members by knowing medical information about the family. To appropriate treatment, and formation of preventive alerts to help in the advance detection of diseases. The system has a ubiquitous login feature for the patient to have a personal key storage space in UID.

The data related to the patient's medical history is collected where the system can absorb past and current data and the authorized person has access to this data. These data are the inputs through which knowledge and system logic are obtained and then health problems are identified and addressed. Efficiently, the system solves the problems of medical errors by conducting a search for drugs and issuing an alert if the drug carries collateral damage or medical risks, and also medical cases can be exchanged for research all over the world to reach appropriate solutions and address all obstacles, as the medical services will be Which depends in its system on the Internet of things services with a wide future [61].

Ahmed et al. Use the platform SM-IoT to allocate personal smart healthcare to patients and caregivers in smart cities. The platform is based on the Internet, the proposed structure of the platform SM-IoT consists of four functional layers: 1) data layer,2) network layer,3)data processing layer, 4) application layer. The function of the platform SM-IoT is to collect data from different and non-identical sources and merge it using a flexible network that is stored in the cloud, analyze this data using graphic interfaces and share it according to the safety data to ensure privacy, as the platform provides the connected user with several services such as the patient communication service And the doctor, the smart emergency detection service, the medical text simplification service by replacing complex medical terms into simplified vocabulary, and the health promotion service by exchanging medical experiences and benefits with patients and doctors [62].

1.2 ELECTRONIC HEALTH RECORDS SOFTWARE

Nowadays, there is a wide choice of EHR software, however, the deep comparison analysis of medical software is not the main purpose of this work. Therefore, in this work I defined the following requirements for the EHR application: it should be open source software that provides all basic functionality of EHR with strong community support and many users. In other words, it should be “standard” Electronic Health Records software that can be used to simulate a medical environment. Based on comparison analysis of medical software [43, 44, 45] for this work were selected several available and active cloud based open source EHR applications: ClearHealth, VistA, FreeMED, and OpenEMR. Nowadays exist many EHR available applications, but here I would like to focus on the most popular of them represented in the literature and in open source repositories. In this section will be briefly described and selected EHR software for the private eHealth cloud.

1.3 EHR FUNCTIONALITY

Institute of Medicine defined eight core functions of Electronic Health Records [46, 47]:

Health information and data, to keep all medical information and provide friendly interface;

i. Result management provides access to the medical tests results from labs;

ii. Order management supports electronic prescriptions.

iii. Decision support helps medical providers to make the best decisions for the patients' treatment

iv. Electronic communication and connectivity supports communication with multiple providers, such as hospitals, labs, in a secure way;

v. Patient support allows providing educational information to patients and entering data about home monitoring devices to the system by themselves;

vi. Administrative processes and reporting support practice management functions, such as scheduling appointments;

vii. Reporting and population health provide the possibility to create reports on the local and state level;

1.4 CLEARHEALTH

ClearHealth is one of the most popular open source EHR software, it is implemented on hundreds of sites around the world. It supports features, such as Demographics, Scheduling, Full Medical Billing, Disease Management, Decision Support, EPrescribing. ClearHealth uses HL7, HIPAA, CCR, DICOM and XML standards [50]. It is capable to run on most platforms, such as Linux, Windows, MAC OS X and other platforms. ClearHealth supports cloud distribution and is available under the GNU General Public License.

More information about ClearHealth can be found at the following resources [48, 49].

1.5 VISTA (VETERAN HEALTH INFORMATION SYSTEMS AND TECHNOLOGY ARCHITECTURE)

VISTA is an open source EHR application that was developed in the USA to support health system for veterans. Currently, VistA is used by hundreds of hospitals, clinics, and nursing homes [50]. The application is written in a specifically designed for medical systems MUMPS language. It supports clinical functions (care management, patient assessment documentation package), financial-administrative functions (veterans Identification Cards, clinical monitoring system Integrated billing), infrastructure functions (capacity management tool, survey generator). VISTA is available under the GNU General Public License [44].

More information about ClearHealth can be found at the following resource [50].

1.6 FREEMED

FreeMed is an open source electronic medical record system with the web-based interface. It can run on different platforms and it is also available under GNU General Public License. It supports features, such as health information and data, electronic communication and connectivity (e.g. email), administration processes (e.g. scheduling and billing), reporting and population health management (quality indicators) [51].

More information about ClearHealth can be found at the following resources [52, 53].

1.7 OPENEMR

Nowadays OpenEMR is one of the most popular open source electronic medical records, supported by the strong community. It is free and open-source software is available under GNU General Public License (GPL). OpenEMR can run on Windows, Linux, MAC OS X and other platforms. It has features, such as patient demographics, patient scheduling, EMR, prescriptions, and reports. Moreover, it is ONC Complete Ambulatory EHR certified by ICSA Labs. OpenEMR has more than 3 700 downloads per month [54]. More information about OpenEMR can be found in the following resource, [54].

1.8 CONCLUSION OF EHR COMPARISON ANALYSIS

The described medical software has several common characteristics, such as availability under GNU General Public Licence, possibility to run on most platforms. All considered EHR software support basic functionality that is expected by hospitals from EHR and EMR software.

OpenEMR has the strongest community support compare to other medical applications. OpenEMR is able to react fast to any changes in medical sphere and continuously fulfill customer requirements. OpenEMR supports all basic functionality of EHR, it is one of the most popular open source software for hospitals and has the support of cloud structure, encryption and web browser access [43]. Based on literature review and overview of open source medical software functionality OpenEMR is selected as EHR software to run on eHealth cloud.

2. SMART CITES ACROSS THE WORLD

In this chapter, we will discuss smart city development around the world by regions [6]. We will mention interesting projects in Europe, North America, South America and Asia.

2.1 SMART CITIES IN BELGIUM

Based on the practical study and research of the different case studies of smart cities, we provide an overview of some smart city researches in Belgium.

Anthony Simonofski, Estefanía Serral Asensio, Johannes De Smedt and Monique Snoeck at the faculty of Economics and Business, KU Leuven, Belgium proposed a framework as enablers of the citizen participation in the smart cities [9]. The framework consists of three fundamental categories of the citizen participation specifically citizens as democratic participants, citizens as co-creators and citizen as ICT users. Citizens as democratic participants, the citizens are involved basically with the democratic process of making decision of the smart city's strategy. Citizens as co-creators, the citizens become the providers of experiences, competences, innovation ideas in order to propose the smart city's strategy for the existing challenges or needs in the smart cities. Citizen as ICT users, the citizens can help to collect data by using mobile devices or other technologies in order to make them feel as an integral part of the smart city. The framework is applied to the ongoing smart city design of Namur, Belgium to discovery and improve the degree of the citizen participations. This framework mainly provides three core benefits for the city planners as well as the decision makers in the smart cities. Frist, it is widely used as an evaluation tool to assess a smart city's strategy. Second, it can be used as either a government tool or guideline for the governments officials or the city planners to implement the citizen-oriented smart city strategy. Finally, it can be used as a creativity tool by enabling comparative analysis of best practices for one criterion or category of criteria across different smart cities by providing new means for designing and implementing the citizen participations in the smart cities.

The three different enablers of the citizen participations from the proposed framework in transforming the traditional city to the smart city context are one of the best practice paradigm by carefully structuring the smart citizens into three different essential roles and involving them into the democratic process of identifying social needs, priorities, strategies, goals etc. within the smart governance which is one of the three dimensions that we have proposed in this research in order to classify weather the city considered as the smart city or not.

S. Latre, P. Leroux, T. Coenen, B. Braem, P. Ballon and P. Demeester proposed "City of things: an integrated and multi-technology testbed for IoT smart city experiments" presenting the City of Things testbed, which is the smart city testbed located in the city of Antwerp, Belgium [10]. The City of Things consists of the highly realistic integrated approach, allowing the setup and validation of new smart city experiments both at a technology and user application level on three different layers namely the networks, data and users.

a- Network level: Internet of Things infrastructure consists of three different types of infrastructures. Frist, a series of multi-technology gateways is connected to the city' network, which acts as a control network to provide experiment management. Second, a dedicated private LoRa-Based Low Power WAN network mainly intends to ensure a continuous real-time stream of the sensor data and the citywide coverage. Finally, a variety of sensors such as mobile air quality sensors, traffic monitoring sensors, smart parking signs etc. is installed throughout the city to physically collect, analyst and interact with real-time environment.

b- Data level: Big data analysis, the City of Things data platform provides three main tools, which were previously developed within iMinds. First, DYAMAND (DYnamic, Adaptive Management of Networks and Devices) is running in a private Virtual Machine used for sensor data collection and discovery. Second, Tengu is an experimentation plaform instantiated on GENI (US federation of test beds) and Fed4FIRE (EU federation of test beds) used for sensor data processing and storage. Finally, LimeDS (Lightweight modular environment for Data-oriented Services) is used for data access, service composition and demo prototyping

c- User level: a large-scale living lab, the Living Lab services are offered in the City of Things classified into two main types of system: IOT-based and not IOT-based. The not- IoT based refers to digital systems, that should be tested in real-life environment to obtain a realistic insight, but not fallen under the IoT moniker such as the Google-maps like application. The IOT-based refers to systems gathering data with the user response in real- world environments such as city games etc. The three layers proposed in the City of Things testbed look reasonably practical at the first sight especially in the network as well as the data layer; however, it doesn't reveal the further detail of other layers such as the smart services and features (smart energy, smart mobility, smart healthcare etc.) identified as the core value that the smart participants will get. In this paper, we will introduce the holistic smart city architecture from the physical infrastructure to the smart participants, which will provide the complexed structure to implement the smart city projects.

2.2 SMART CITIES IN INDIA

We have conducted an overview study of a few practical researches in India, which can be used to represent the smart city concepts in Asia.

S. Madakam and R. Ramaswamy proposed "100 New smart cities (India's smart vision)" by mainly focusing on the six dimensions of the smart cities, the smart city enablers comprising of Internet of Things and the prerequisite consideration "How to set up 100 New Smart Cities in India" [11]. The characteristics of the smart cities are identified into six main dimensions based on traditional regional and neoclassical theories of urban growth and development: smart economy,

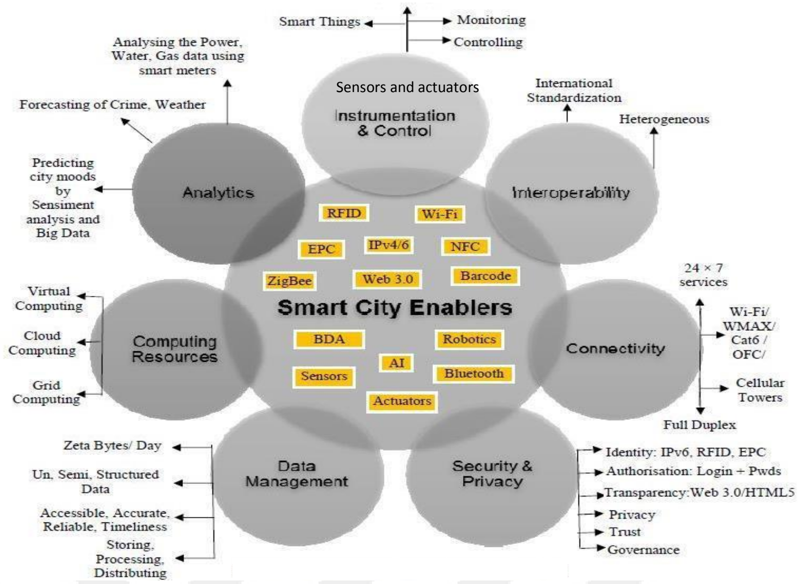

Figure 2.1: Model Diagram:IoT technologies in Smart Cities

Smart Mobility , Smart Environment, Smart People, Smart Living and Smart Governance. The enablers of the smart cities can radically improve through the power of Internet of Things (IoT)

technologies categorized into seven categories: Instrumentation and Control, Interoperability, Connectivity, Security and Privacy, Data Management, Computing Resources and Analytics.

Nowadays, India is setting up 100 new smart city projects across the nation in cooperation with multinational companies under Public Private People Partnerships (PPPP) model by using two ways. Firstly, the government converts the existing cities into the smart cities by deploying technologies into the existing infrastructure and the system of the city. Secondly, the government constructs the entire new smart cities from the scratch. However, the six dimensions of the smart cities are fairly completed and oversimplified when we come to the deep understanding. The smart mobility, smart living, smart economy as well as smart environment should be either smart services or the yield of the smart services produced. The smart people should involve with the smart governance as the citizen engagement to implement the smart strategy, solutions, vision etc. to build the smart cities. Furthermore, the model diagram of IoT technologies for building the smart cities are revealed separately without giving an interpretation the supportive level for one another.

P. Datta and B. Sharma in New Delhi, India conducted "A survey on IoT architectures, protocols, security and smart city based applications" [12]. The basic architecture of IoT consists of five core layers: perception, network, middleware, application and business layers. Firstly, the perception layer consists of sensor devices viz, RFID, ZigBee, Quick Response (QR) code, etc. with the functions of the device management and collecting information. Secondly, the network layer forwards information from the perception layer to the upper layers. Thirdly, the middleware layer is the service management and stores information into the database. Forthly, the application layer manages IoT applications. Finally, the business layer covers the entire IoT applications and services management.

The IoT data protocols are used to interact with the IoT gateway such MQTT, XMPP, CoAP, AMQP etc. Message Queuing Telemetry Transport (MQTT) protocol runs over TCP/TP as the lossless connections to deliver message with minimized transport overhead, and to ensue message delivered according to availability of the operating environment and exactly once. Extensible Messaging and Presence Protocol (XMPP) is a protocol for real time communication for voice, video calls etc. The IoT security measures are used in the smart cities like ZigBee, RFID etc. ZigBee is one of the IoT security measures developed by ZigBee Alliance for personal area networks (PAN) and two-ways wireless communication standard with low cost, low power and reliable communication between smart devices and gateway.

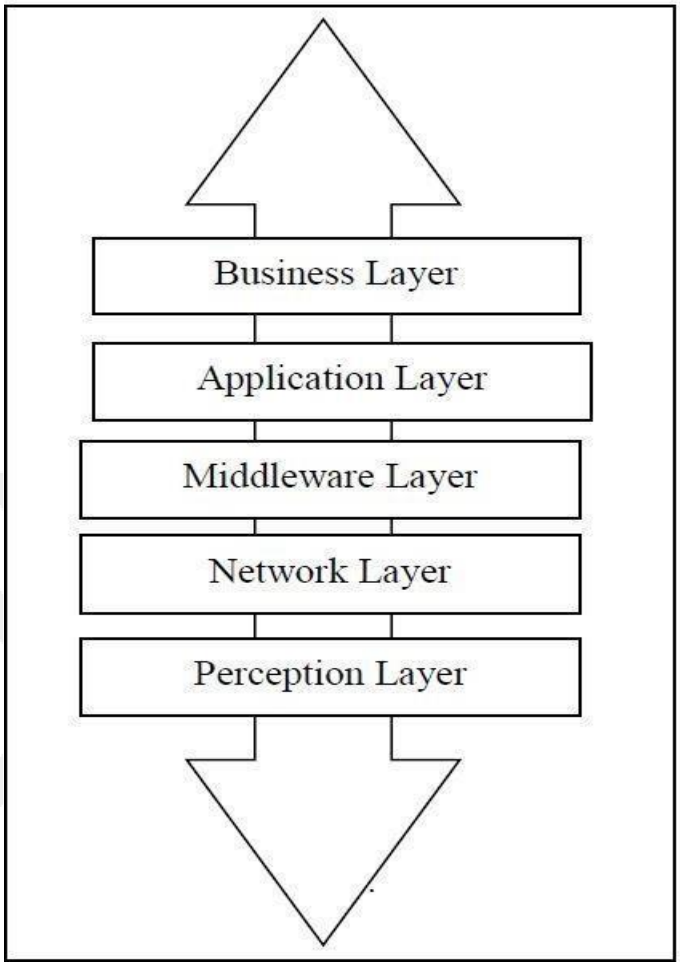

Figure 2.2: IoT Basic Layered Architecture

The basic architecture of IoT consisting of five layers doesn’t appears to the right orders, dependencies and functionalities. The network layer should be in the position of the lowest layer that mainly provides the physical infrastructure with the function of wire and/ or wireless communication with the layer of sensors. Furthermore, the middle layer shouldn’t have two functionalities. This layer should be responsible for only the big data management. Finally, the fourth and fifth layer seems to have the same roles and functions.

2.3 SMART CITIES IN UNITED STATES OF AMERICA

N. Mohamed, S. Lazarova-Molnar and J. Al-Jaroodi at Pennsylvania, United States of America (USA) proposed “Cloud of Things: Optimizing smart city services” by using the Cloud of Things as a powerful platform for implementing and operating the smart city services with the enhancement from Fog Computing to extra value-added features for the smart city services [11]. The architecture of the proposed model has four core layers: perception and action, the Internet of Things (IoT) network and Cloud Infrastructure, the Cloud of Things (CoT) platform as a service, and the smart city services. At the IoT network layer, all objects of the smart cities such as people, vehicles, streets, buildings, hospitals, energy etc. are interconnected through the IoT, which is integrated with cloud computing systems as the physical infrastructure. The CoT platform as service layer links the IoT and the CC infrastructure and services to provide the services to implement and operate the optimization application for the smart city services, which is the powerful cloud platforms to run the smart city services as can be seen in Figure 3.

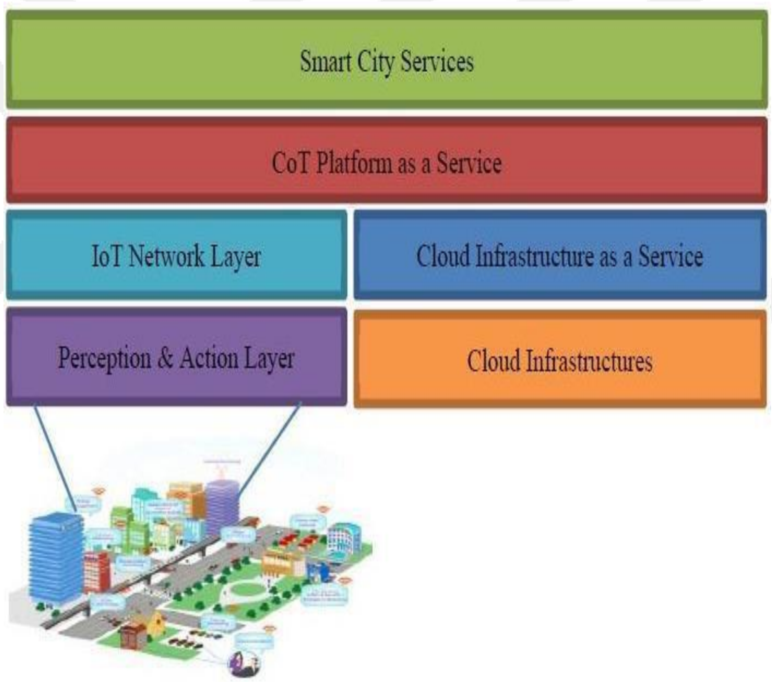

Figure 2.3: The Cot layers for smart cities

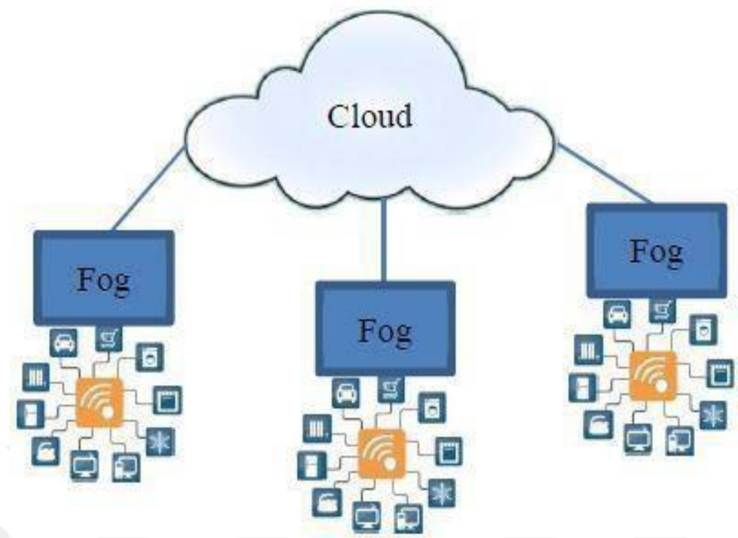

Figure 2.4: Integrating Fog Computing and the CoTfor smart cities

The Fog computing can enhance the CoT paradigm by providing the small platforms located at the network edges in the smart cities, which is the fast control mechanisms and service available geographically for the areas of the IoT application. The architecture included the Fog computing into the CoT for the smart cities is shown in the Figure 2.4; the fog provides more localized real time monitoring, control, and optimization for the smart city applications while the cloud provides global monitoring, control, optimization, and future planning for the smart city applications. On the other hand, there are some issues with the proposed architecture. In the reality, it is hard to integrated between IoT network layer and Cloud infrastructure as a service to provide the physical infrastructure for perception and action layer to collect real-time data and for CoT platform as a service for implement the smart city services. Furthermore, the architecture doesn’t detail the complexity of the smart city services on the layer four.

Amany Alnahdi at Kent State University and Shih-His Liu at California State University, USA proposed “Mobile Internet of Things (MIoT) and its applications for Smart Environments” by allowing fully mobility hardware and software devices of the IoT technology within the smart IoT environments [13]. The smart IoT environment can be the cities or the buildings that are built, rebuilt or improved by using the MIoT model, and the Mobile Internet of Things (MIoT) is an IoT system that is moved and reused within the smart IOT environment. The MIoT model is composed of three main components including MIoT stakeholders (human resources), software as well as hardware. Firstly, the MIoT stakeholders are people who work on the building and maintain tge MIoT systems. They can be MIoT experts, MIoT programmers as well as MIoT system supports

Secondly, the MIoT software mainly consists of services, Operating systems, scheduling services, auditing services and feedback services. The scheduling services will be enable the business owners and the system users to find available time to lend and utilize the system or to move the system to another location. Furthermore, the feedback services will allow the business owners and the system users to understand their customers' requirement and enhance their services for the future business by communicating directly with their customers. Finally, the hardware isincluded sensors and mobility devices.

The MIoT system could be fully utilized in multiple domains including smart cities, smart health environment, smart entertainment cities, smart homes, smart educational system and smart marketing systems by providing the benefits such as sharing technology system resources which lead to the efficient and effective utilization of these resources from the perspective of the business owners and providing a fast way when the business owners develop new systems for the customers. On the other hand, the MIoT model proposed with three layers doesn't reveal the further detail of each layer such as hardware (which hardware is used in the smart cities) etc. Furthermore, the smart services and features doesn't mention within this research.

Figure 2.5: Components of MIoT system

.

3. METHODOLOGY

3.1 COMPARISON WITH RELATED WORK

In this chapter we proposed our architecture for e-Health in smart cities as shown in figure 3.1, we will go through for every part in this architecture.

Amjad et al. propose a framework for protecting privacy [55] and Jinglin et al. Use the Blockchain mechanism to provide health care security for smart cities [56] but none of them proposed a completed architecture for e-health as we proposed.

Daojing et al. Instead, he used the method of integrating cloud computing and the Internet of things for health care [57]. Houriyeh et al. recommended to use the method of combining the cloud model and the Internet of things model [58]. But none of them discussed the smart health care and smart service as we include them in our architecture.

Parag et al. proposing a model based on the Internet of things for an intelligent and widespread electronic health system to reach a model system for clinical information capable of automated decision-making by making use of patient-related data available to the concerned health care personnel as an aid in the treatment stages. [61]. But the author did not in include the energy efficiency in his work but we discussed in our work.

Ahmed et al. Use the platform SM-IoT to allocate personal smart healthcare to patients and caregivers in smart cities. The platform is based on the Internet, the proposed structure of the platform SM-IoT consists of four functional layers: 1) data layer,2) network layer,3) data processing layer, 4) application layer. [62]. This work is somehow close from our work but the author did not include the smart participants as we did.

Yi Liu [80] propose an architecture for fine-grained EHR access their architecture to secure the data between the sources of the system but they didn’t provide a complete system for others part of e-health.

JIAN PING LI [81] proposed only a framework for heart diseases detection using machine learning for e-health systems.

Sources [82][83][84][85] they discussed only security and privacy issues in e-health systems.

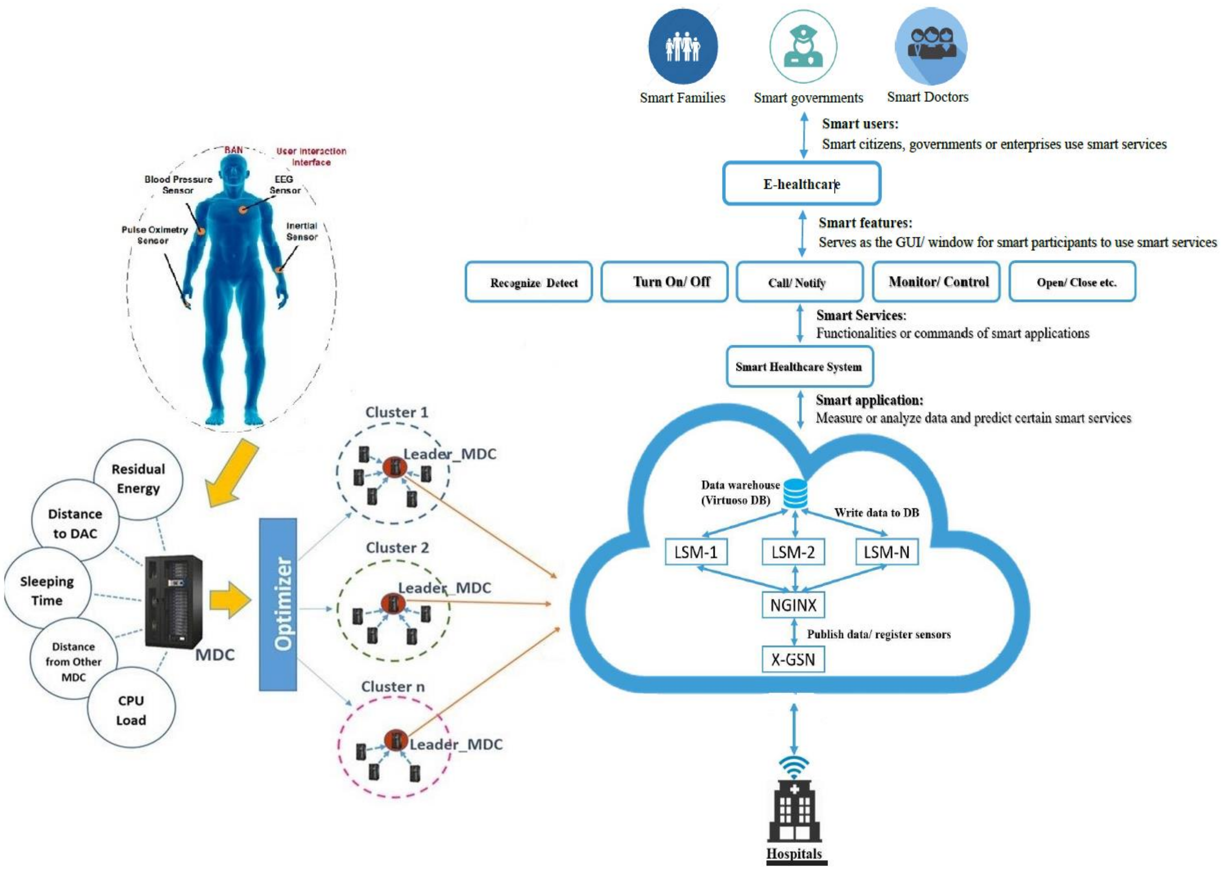

Figure 3.1: Proposed Architecture

3.2 PHYSICAL INFRASTRUCTURE

The physical infrastructure is generally known either as the exiting physical city infrastructure or/ and the ICT infrastructure, which is widely considered as the City as a Platform used as one of the smart enablers to transform the traditional cities into the smart cities around the world. The exiting physical objects including home appliances, buildings, parks, traffic roads, social facilities, vehicles, portable devices, gadgets etc. used in daily life are being equipped with the electronic smart devices such as sensors, actuators, GPS, Camera etc. to be able to sense, collect, exchange, analyse and produce the intelligent services for the smart users through connecting to cloud computing to inter-operate within the exiting ICT infrastructure [22], [23] and [24]. On the other hand, using the right exiting physical city infrastructure or/ and the ICT infrastructure for the smart city solution is essential to design and implement the smart city projects and initiatives. With the emergence of innovation technology such as Internet of Things (IoT) [27], we can connect any exiting physical objects around us with the intelligent devices to the internet to enable these objects to connect, exchange data and control remotely [20] and [21]. The Internet of Things (IoT) is defined as a concept and a paradigm considering pervasive presence in the environment of a variety of things/ objects that wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach the common goals [25] and [26]. The main goal of the Internet of Things is to enable the exiting physical objects to be connected anytime, anyplace, with anything and anyone ideally using any network and any service by transforming the traditional cities into the smart cities that make energy, transport, health, education, public services and many other areas more intelligent or in short, the Internet extends into the real world embracing everyday objects. Integrated networking, information processing, sensing and actuation capabilities allow the exiting physical devices/ objects to operate in the dynamic/ changing environments with tightly interconnection and coordination with or without the human in the loop.

3.3 NETWORK MODEL

Micro Data Center (MDC): A micro data center is a ruggedized modular unit which is ideal for edge deployments and responsible for solving different problems or handling different workloads at the edge of the network. MDCs are principally designed for deployments in more remote locations such as disaster-stricken or war-torn areas around the world. It is expected that in future edge market will boost demand for micro data centers. In the proposed system, each MDC has been associated with a significant number of IoT devices or sensors within a geographical area and deployed under a fog layer. As different IoT devices transmit data in different forms, thus in the proposed model, each MDC is responsible to prepare those collected data in a suitable form for processing and transmit it to the cloud server for further analysis. In the proposed system model, a group of MDCs act as a set of fog layer edge devices that have been distributed within predefined positions under proper observation by confirming a continuous and efficient health data delivery. A MDC can be classified as either trigger based or periodic. The trigger-based MDCs transmit data only when an event is fired while periodic MDCs collect and transmit data at regular intervals or on request.

The following properties have been considered for the simplification of the network model in this work:

a- Random distribution of MDCs in the geographic area

b- Deployment of static MDCs in the work environment.

c- The MDCs deployed are homogeneous having equal capabilities.

d- All MDCs have capabilities to control power and each node has the ability of changing power level and communicating with DAC directly.

e- DAC is placed far from the sensing field at the center of the problem space and is not constrained by energy.

3.3.1 FZSEP-E Clustering

The need to achieve a prolonged wireless sensor network lifetime deployment, has fueled further research into FZSEP-E clustering algorithm that can better optimize the energy consumption in a more efficient manner. The FZSEP-E design architecture is shown in the Figure 3.2.

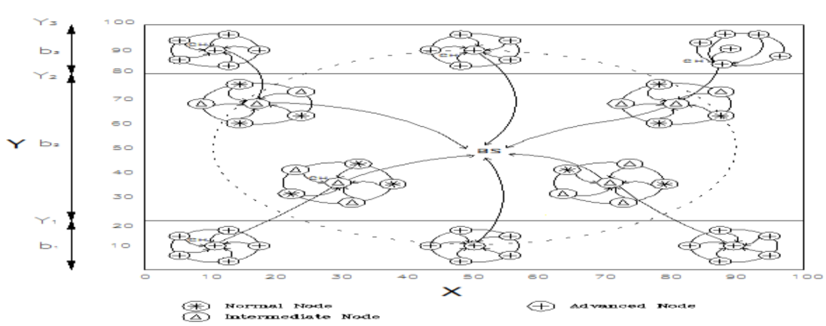

Figure 3.2: FZSEP-EDesign Architecture

FZSEP-E Clustering – Pseudocode

The algorithm is given below:

Input:

N: a network

C1 : List of clusters in Zone1 and Zone3. C2: List of clusters in Zone2.

K1: Nodes that are cluster heads of respective Clusters in C1. K2: Nodes that are cluster heads of respective clusters in C2. a1: any node in C1

a2:any node in C2 k1: any node in K1

k2, k3: any node in K2

Initialization:

min_dis_CH_BS ⟵ 0;

dtoBS ⟵ 0;

isClusterHead(Node) ⟵ false;

radius ⟵ $(b_1+b_2/2)$;

Main:

For each cluster ‘C’ in C1, populate the cluster head of ‘C’ in K1 as below. for each node ‘a1’ in a cluster ‘C’,

if isClusterHead(C,a1) == true then add the node ‘a1’ to K1

endif. endfor

For each cluster ‘C’ in C2, populate the cluster head of ‘C’ in K2 as below. for each node ‘a2’ in a cluster ‘C’

if isClusterHead(C,a2) == true then add the node ‘a2’ to K2

endif. endfor.

For each node ‘k1’ in K1,

dtoBS Distance (k1,BS) if dtoBS<= radius then

Send(data,k1,BS)

```
else
/* Get relay node from K2
k3 Get Relay            Node( k1);
Send(data,k1,k3);
 Send(data,k3,BS);
endif.
```

Cluster heads were elected in Zone1, Zone2 and Zone3, by using the fuzzy logic parameters like energy, density, and distance of the node to the BS. The CHs or the nodes in Zone1 and Zone3, which were further away from BS consumed more energy to transmit the data because of the distance as described by Jiang et al. (2013). The threshold radius was calculated based on the zone settings in ZSEP-E, in which the CHs, within that value only, communicated with BS directly. Here, the radius was taken as (b1+b2)/2 i.e., the maximum radius from the BS within the centre of Zone1 or Zone3. Other CHs in the zones communicated through the BS, through the CHs in Zone2. The CHs in Zone2 for next hop were determined by the distance of CHs in Zone1 or Zone3 to the CHs in Zone2 and its distance to the BS. The CH in Zone2, which was at a less distance to the BS from the CH in Zone1 or Zone3 was taken for the next hop.

To get both endpoints of interval, linear interpolation was used in Trapezoidal function including Triangular Membership function, which is a particular case of trapezoidal membership function. It works well in all the applications and widely used in all fuzzy systems Aditi et al.(2014).

The trapezoidal membership function represents the very weak inference and a triangle membership function represents all the other inferences, as in Figure 8. The membership function, for trapezoidal fuzzy number, for the fuzzy set A1= {a1, b1, c1, d1} where $a1<b1<c1<d1$ is given below in Equation (3.1).

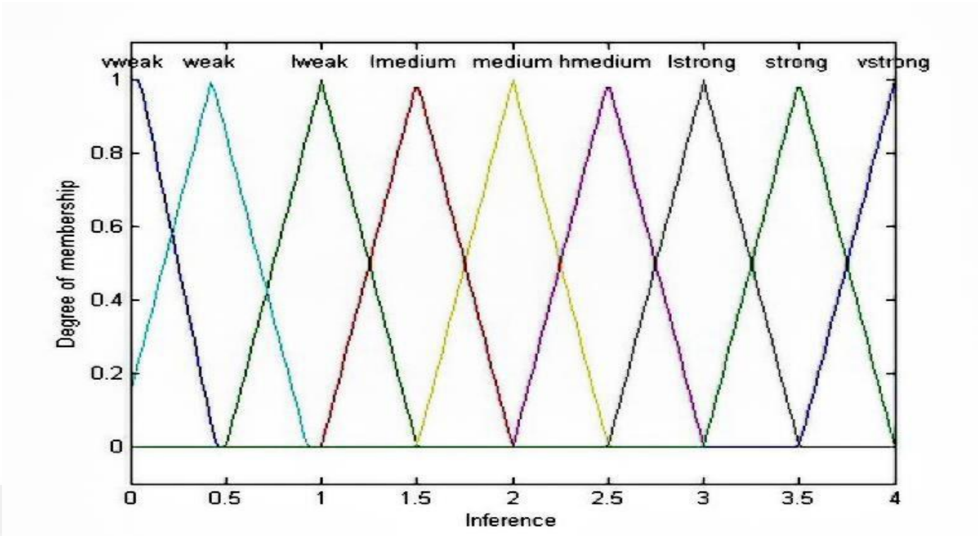

Figure 3.3: Degree of membership vs inference

$$\mu_{A_1}(x) = \begin{cases} \frac{x-a_1}{b_1-a_1} & if\ a_1 \le x \le b_1 \\ 1 & if\ b_1 \le x \le c_1 \\ \frac{d_1-x}{d_1-c_1} & if\ c_1 \le x \le d_1 \\ 0 & otherwise \end{cases} \tag{3.1}$$

The membership function for triangular fuzzy number for the fuzzy set $A_2 = \{a_2, b_2, c_2\}$ where $a_2<b_2<c_2<d_2$ is given below in Equation (4.2).

$$\mu_{A_2}(x) = \begin{cases} \frac{x-a_2}{b_2-a_2} & if\ a_2 \le x \le b_2 \\ \frac{c_2-x}{c_2-b_2} & if\ b_2 \le x \le c_2 \\ 0 & otherwise \end{cases} \tag{3.2}$$

Knowledge Base

The fuzzy inference consists of 27 rules and the rules of the form IF premise, THEN consequent where premise is a set of fuzzy input variables, joined by logical function (AND). The maximum values for the parameters can be computed by using the following Equation (3.3), where *e* is the energy of the node, *ds* is the density, *dt* is the distance of the node to the BS.

$$Inference = 2e+ds + 1- dt \tag{3.3}$$

The rules fall between the range 0 to 4 where 0 is the very weak inference and 4 is the very strong inference, as detailed below.

Very Weak Inference (0): If (energy level is low) and (distance to the BS is far) and (density of nodes is scattered) then (Inference is very weak).

Very Strong Inference (4): If (energy level is high) and (distance to the BS is close) and (density of nodes is crowded) then (Inference is very strong).

Defuzzification Module

The conclusions from each rule are aggregated and the centroid defuzzification method is used to transform the fuzzy variable into a crisp value output. The center of area method, which finds the centroid of the area Z* under the respective membership function, is given in Equation (3.4).

$$Z^* = \frac{\int \mu_Z(x) * x dx}{\int \mu_Z(x) dx} \tag{3.4}$$

where$\mu Z(x)$ is the degree of membership function for the fuzzy set A defined in Equations(3.3) and (3.4).

Performance Evaluation of FZSEP-E Protocol

The performance evaluations of FZSEP-E protocol for the various zones are analyzed under this section. The energy consumption of a node was always high when it performed the role of a CH, so careful election of CH was necessary.

Analysis of FZSEP-E on 100m × 100m in Zone1 or Zone3 with Initial Total Energy 102.5 J

To analyze the FZSEP-E on 100m ×100m in Zone1 or Zone3, the following Table 3.1 and 3.2 display the fuzzy input crisp values for distance and energy.

Table 3.1: Fuzzy input crisp values for distance

	Zone 1	***Zone 2***	***Zone 3***
Max distance to BS from	70.7m	58.3 m	70.7m
Min distance to BS from	40 m	0m	40 m

Table 3.2: Fuzzy input initial values for energy

102.5J	**M**	**q**	**α**	**µ**	E_{in}	E_{im}	E_{ia}	N_n	N_i	N_a
FZSEP-E	0.2	0.3	3	1.5	0.5	1.25	2.0	50	30	20

Analysis of CH Election in *Zone1 or Zone3* of and FZSEP-E Protocol

The initial energy of CH of an advanced node was 2.0 J in Zone1 or Zone3. The degrees of membership functions were calculated for energy (advanced node) as shown in the Figure 3.4.

$$\mu_{low}(x) = \begin{cases} 1 & if\ x \ \leq 0.4 \\ \frac{0.6-x}{0.2} & if\ 0.4\ < x \leq 0.6 \\ 0 & otherwise \end{cases}$$

$$\mu_{medium}(x) = \begin{cases} \frac{x-0.5}{0.3} & if\ 0.5 \leq x \leq 0.8 \\ 1 & if\ 0.8\ < x \leq 1.2 \\ \frac{1.5-x}{0.3} & if\ 1.2\ < x \leq 1.5 \\ 0 & otherwise \end{cases}$$

$$\mu_{high}(x) \quad = \begin{cases} \frac{x-1.0}{0.5} & if\ 1.0 \leq x \leq 1.5 \\ \frac{2-x}{0.5} & if\ 1.5\ < x \leq 2 \\ 0 & otherwise \end{cases} \qquad (3.5)$$

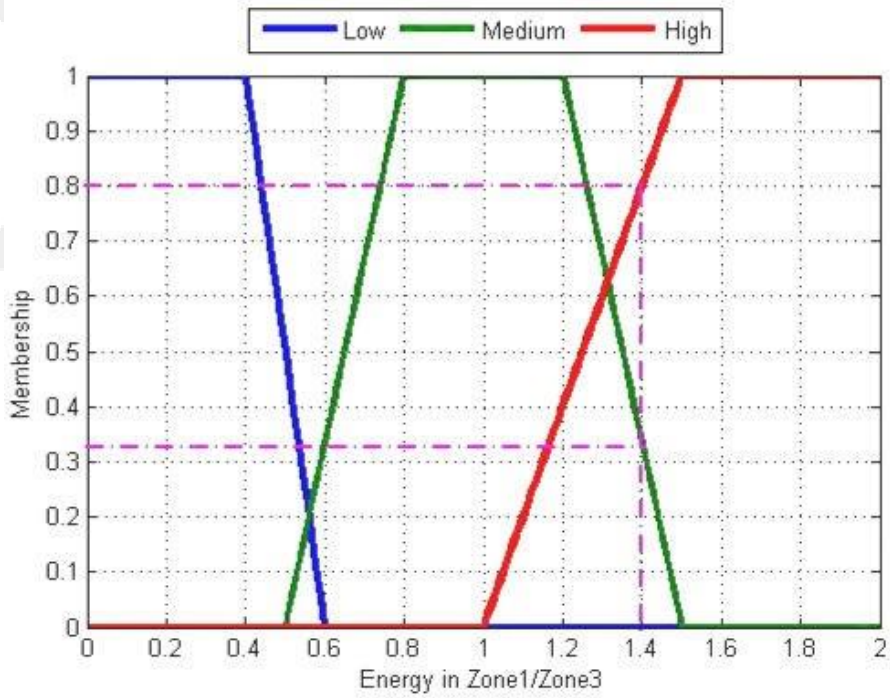

Figure 3.4: Degree of membership for energy

Maximum distance of any CH from *Zone1* or *Zone3* to the BS was 70.7 m and the minimum distance to BS was 40 m from both *Zone1* and *Zone3*, as per Table 1. The degrees of membership functions were calculated, for the distance to BS of any node in*Zone1* or *Zone3*, as shown in the Figure 3.5.

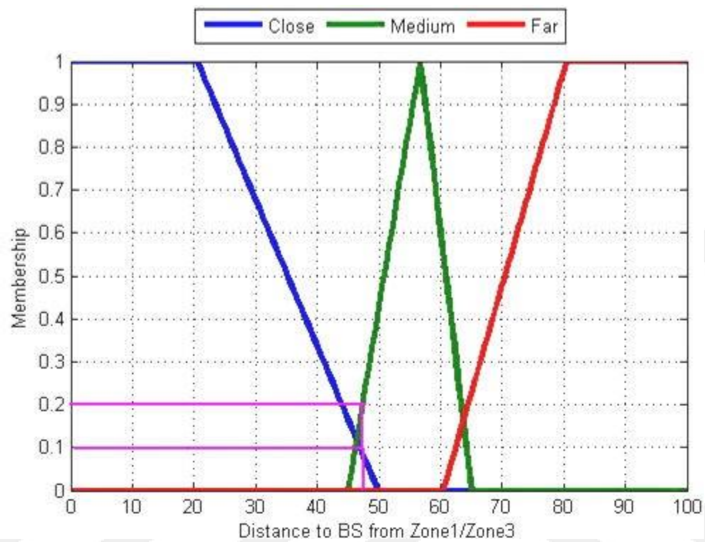

Figure 3.5: Degree of membership for distance

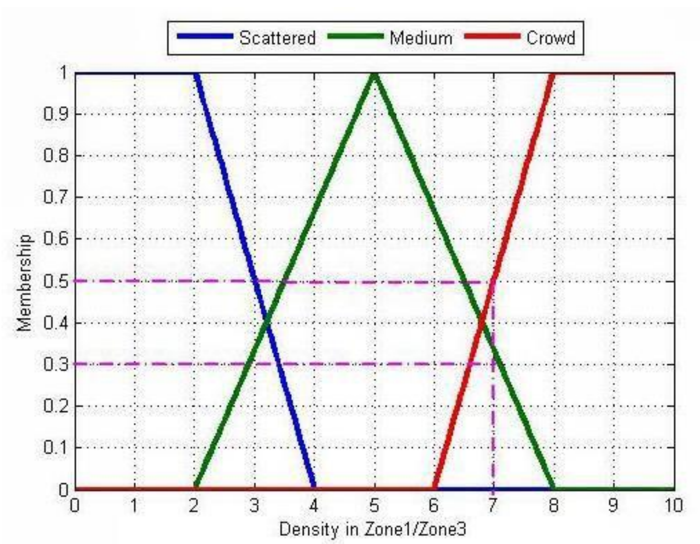

Figure 3.6: Degree of membership function for density

Based on the membership values of energy, distance and density, the new output fuzzy set was derived by evaluating the rules, using the AND operation for the values of energy = 1.4J, distance to BS was 47 m and no of nodes in a cluster was 7.

The union of all the outputs, from the above rules, aggregated by OR operator to get a new set of fuzzy set and with the centroid defuzzification method, the final crisp inference value was derived. The inference value, for selecting CH, is shown in Table 3.3.

Table 3.3: Inference value for selecting CH

Initial Energy	Distance to BS	Density	Inference
0.5	47	7	0.2253
0.5	41	5	0.1116
0.5	62	2	0.1499
1.0	47	6	0.4673
1.0	55	4	0.5000
1.4	47	7	0.6974
2.0	70	5	0.8750

CH Election in Zone2 of FZSEP-E Protocol

Once the CHs were elected in *Zone1, Zone2, Zone3*, using fuzzy logic approach discussed earlier, as in FLZSEP-E, certain CHs in *Zone1 or Zone3* were communicated with the BS, directly or through a CH in Zone2.The Table 3.4 illustrates an example of nodes which were elected as CH, through the fuzzy logic in *Zone1, Zone2 and Zone3*. Let CH11, CH12 and CH13 be the elected CHs in *Zone1 or Zone3.* The areas in Zone1 or Zone3 where the CHs communicated with BS directly, was the intersection of the circle, with the radius (b1+b2/2). Here the radius was (20+60) / 2 and the routing took place, as shown in the Figure 3.8.

Table 3.4: Selected CHs in Zone 1 and Zone 3

	Location	**Distance to BS**	**radius<=40**	**Direct to BS**
CH_{11}	(15,10)	53.15	No	No
CH_{12}	(55,15)	35.36	Yes	Yes
CH_{13}	(70,12)	42.94	No	No

The distance to BS from CH11is calculated as follows.

$= \sqrt{(50-15)^2+(50-10)^2} = 53.15$

Let CH21, CH22 and CH23 be the elected CHs in Zone2. Table 3.5 shows the CHs in Zone2 and its distance to BS.

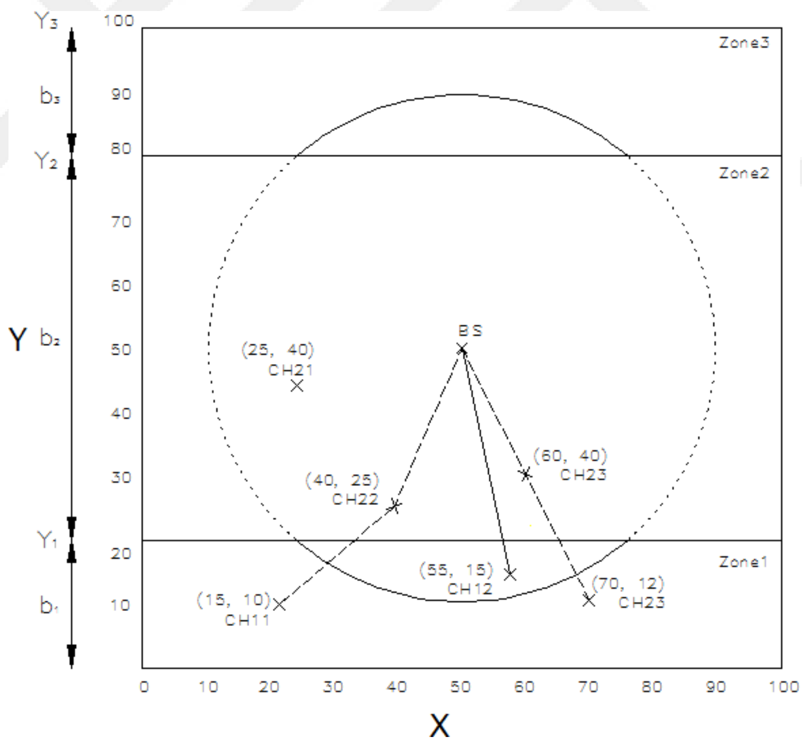

Figure 3.7: Routing in FZSEP-E protocol

Table 3.5: Selected CHs in Zone 1 and Zone 3

	Location	**Distance to BS**
CH_1	(25,45)	25.50
CH_{22}	(40,25)	26.93
CH_{23}	(60,30)	22.36

The distance to BS from CH11 through the CH21was calculated as below.

$= \sqrt{(25 - 15)2 + (45 - 10)2} + \sqrt{(50 - 25)2 + (50 - 45)2}$

= 36.40 + 25.50= 61.90

Hence the gateway of CH11 is CH22 which was the optimum path of CH11 to BS and CH22, was the next hop for CH11. Similarly, all the distances, from the Zone1 or Zone3 CHs to BS, which should communicate to BS via a hop in Zone2 .CHs were populated as displayed in the Table 3.4.

Table 3.6: Gateways in Zone 2

To BS	**Via CH_{21}**	**Via CH_{22}**	**Via CH_{23}**
CH_{11}	61.90	56.08	71.6
CH_{13}	81.30	59.63	42.95

According to the Table 3.4, the respective CH in Zone2 was at the minimum communication distance with BS. The next hop for CH11was CH22; CH13 was CH23 and so on.

3.4 DATA MANAGEMENT

One of the key innovation technologies nowadays supporting data management and smart applications in the smart cities is the Cloud Computing [63]. The cloud computing provides the powerful independent platform for transformation, clearing and storage big data collecting from the smart devices into the virtual data warehouse databases for utilization by the smart applications, and implement and operate multiple types of the smart city services. The more challenges for the data management are the dynamic and characteristics of the big data such as volume, velocity, variety and volatility, heterogeneity and complexity [65] and [66].

The OpenIoT platform is an open-source cloud-based IoT middleware using a three- layered service-based architecture to support the smart city paradigm by enabling the integration of the smart sensor data and facilitating the large-scale smart applications and software [67] and [68]. The OpenIoT can be deployed on any Cloud Computing such as NeCTAR cloud, the Cloud of Things (CoT) [69] etc. In the data management, OpenIoT involves with the virtual and/ or physical sensors, X-GSN, LSM and Virtuoso database (data warehouse DB).

a. Sensor Middleware: the sensor middleware gathers, filters, transform and combines the sensor data from both virtual sensors and physical sensors. It uses Extended Global Sensor Network (X-GSN) as the gateway between the smart devices and the Cloud Computing. X-GSN abstracts all physical smart sensors as the virtual smart sensors and register every virtual sensor with Linked Stream Middleware Light (LSM-Light) so that each physical smart sensor can get a unique sensor ID. The sensor ID helps in sensor discovery, sensor data update and read by different smart participants. Then it streams data from the physical smart sensors into the wrapper (NGINX) and publishing the sensor data in parallel into LSM-Light before storing to the data warehouse databases (Virtuoso DB). It also supports the semantic annotation of sensor data and metadata.

b. Cloud Data Storage: the OpenIoT uses the Linked Stream Middle Light (LSM- Light) for the sensor registration and discovery, data visualization and analyze, as well as storage and management of the sensor data streams and metadata received from the sensor middleware before projection into the data warehouse databases (Virtuoso DB). The LSM-Light uses the W3C standard SSN (Semantic Sensor Network) ontology [70] to widely publish the smart sensor data in the form of Resource Description Format (RDF) triple and store this triple in the Open Link Virtuoso database [71].

c. Security Management: the OpenIoT uses the Single Sign-On solution based on Central Authentication Services (CAS) [72] where multiple CAS enabled web services can be assessed by issuing and validating the tickets/ tokens to CAS clients like X-GSN or third-party applications when storing and retrieving the sensor data.

3.4.1 Cloud Computing

There are many definitions of cloud computing, in this work I will use the official definition, provided by the National Institute of Standards and Technology (NIST): "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [29].

3.4.2 Elements of cloud computing

3.4.2.1 Essential Characteristics

NIST identifies five essential characteristics of cloud computing [29]:

On-demand self-service allows a customer to increase and decrease computing capabilities like servers, network, and storage based on current workloads without human interaction with a service provider.

Broad network access provides a customer the possibility to have access to IT services at any time, from anywhere and through any user-chosen device.

Resource pooling allows cloud service providers to pool computing resources

to serve multiple users by dynamically assigning and reassigning different physical and virtual resources (storage, networking, processing, bandwidth, and virtual machines) based on customers' workloads. Although consumers do not have knowledge about the location of the provided resources, they have possibility to specify it.

Rapid elasticity ensures that cloud applications have the exact number of needed resources. It provides functionality to provision and releases cloud resources on demand.

Measured service allows cloud system to measure automatically computing resource usage. It can also be monitored, controlled and reported with transparency for client and cloud provider.

3.4.2.2 Service Models

Cloud service providers offer many cloud services and according to NIST they can be divided in three standard models. Each service model assigns certain responsibility to the cloud service provider and allows customers to focus more on their business. Below are presented cloud service models [29]:

Software as a Service (SaaS) represents a software distribution model in which customer uses applications running on a cloud provider's infrastructure. Access to applications can be gotten from different client platforms. A customer does not manage and does not have control of cloud infrastructure, including servers, network, storage or individual applications.

Platform as a Service (PaaS) represents a cloud service model where cloud provider provides to customers a platform with the ability to run, manage and develop applications. A customer does not manage or control background infrastructure, but has control of applications.

Infrastructure as a Service (IaaS) represents a cloud service model where resources are provided as a service. A consumer does not manage the cloud infrastructure but has control of storage, applications, operating systems and limited control of selected networking components (host firewalls.). Services which are provided to customers include storage, networks and other resources where the customer is able to deploy and run the software, including an operating system and applications. Cloud service models are shown in Figure 3.8.

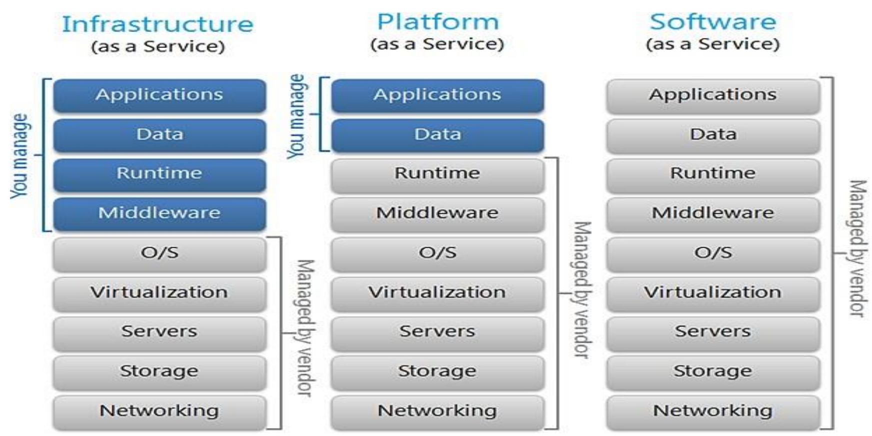

Figure 3.8: Cloud Service Models [30]

In addition, cloud computing technologies can be divided into several groups based on deployment models, which can be found in the upcoming section.

3.4.2.3 Deployment models

Deployment models divide cloud computing into different categories, based on proprietorship, access, and size. In this section are considered cloud computing deployment models, for the purpose of selecting a deployment model for eHealth cloud.

Cloud computing in healthcare domain is represented in three deployment models: private cloud, public cloud, and hybrid cloud. Cloud computing deployment models work in healthcare domain in the same way like in any other domain [31].

- Private cloud

Resources in private cloud are usually accessible and owned only by a single company. And it means that cloud infrastructure is commonly managed by the organization or by the third party company. Private cloud is considered as the most secure cloud deployment model to store Electronic Medical Records. Access to data have only medical staff members within one healthcare organization, who can be considerate as trusted users, except some exception [32]. Illustration of private cloud is shown in Figure 3.9.

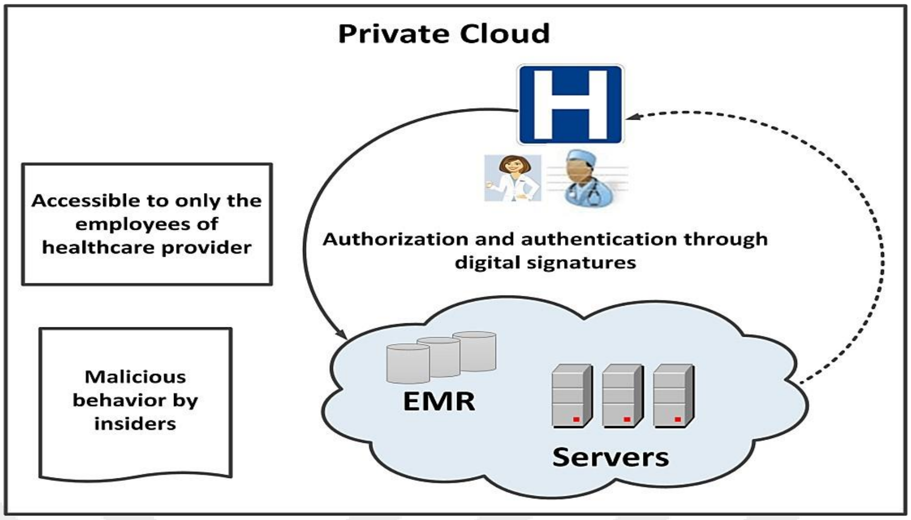

Figure 3.9: Illustration of private cloud in healthcare domain [32]

Public cloud infrastructure, compare to the private deployment model, can be used by multiple clients. In this case, cloud services are provided by Cloud Service Provider (CSP) in a virtualized environment and accessible over a public network (the Internet). Public cloud services, in terms of eHealth, can be accessible for many healthcare organizations, such as hospitals, insurance companies, research institutions simultaneously. Electronic Health Records stored in public cloud and managed by CSP have high privacy risk. EHRs can be accessed from inside (organization) as well as from outside (through the Internet). It represents a vulnerability to malicious attacks [31]. Illustration of public cloud is shown in Figure 3.10.

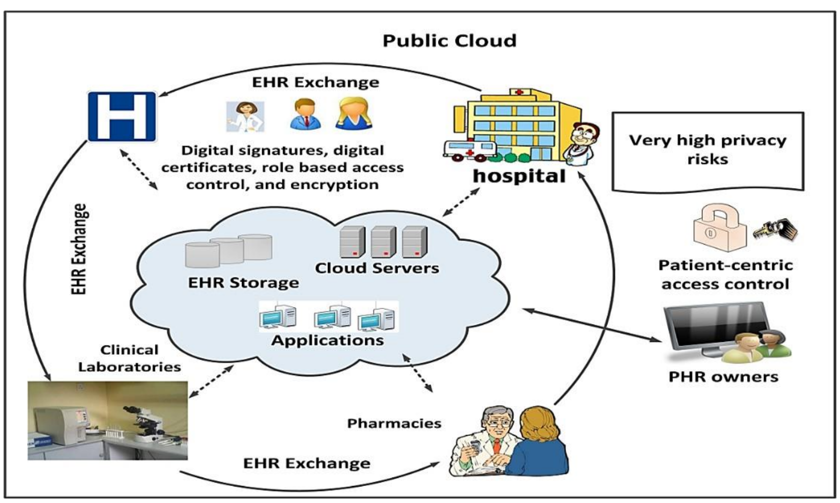

Figure 3.10: Illustration of public cloud in healthcare domain[31]

- Hybrid cloud

Hybrid cloud deployment model employs private and public cloud services, which can be provided by different Cloud Service Providers and connected together through the standardized technologies. Hybrid cloud combines different types of cloud services in order to meet customer needs and to create integrated, automated and well-managed computing environment. Medical organizations can use private and public cloud services. Although, this cloud deployment model is not considered to be secured; therefore, it is necessary to implement special security protection technics [32]. Illustration of hybrid cloud deployment model is shown in Figure 3.12.

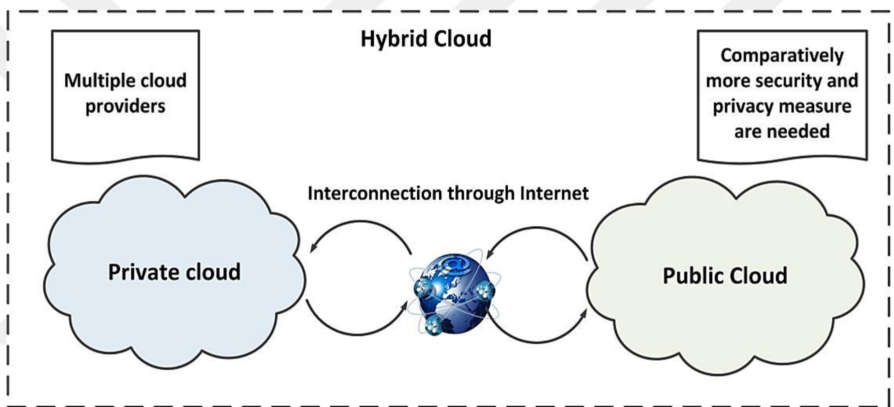

Figure 3.11: Illustration of hybrid cloud in healthcare domain[31]

The next section covers information about the second main component of eHealth cloud – eHealth.

3.5 E-HEALTH CLOUD

There is no specific definition of eHealth cloud, however, the research "e-Health Cloud Privacy Concerns and Mitigation Strategy" [32] provides an overview of the eHealth cloud and it claims that "the eHealth cloud can be regarded as a standard platform that offers standardized services to manage large volumes of health-data". eHealth cloud stores and processes healthcare data originated and used by different cloud users, such as healthcare providers, pharmacies, insurance providers.

Based on the literature review and related information to cloud computing and eHealth can be determined that eHealth cloud is a regular cloud computing technology used for the medical purposes.

The next section covers information about benefits of eHealth cloud for healthcare organizations, patients, and society in general.

3.5.1 Benefits of eHealth cloud

This section provides the beneficial aspect of cloud computing technologies in healthcare, the reasons why it should be implemented and used.

Improvement of patient care: eHealth cloud provides global access to the patients' medical records with 24/7 availability. It allows healthcare professionals to access patients' data from any location at any time and provide the suitable treatment [8].

Cost reduction and increase of efficiency: The use of cloud computing technologies exempts healthcare providers to keep hardware inside the organization. Instead of purchasing hardware, healthcare organizations pay for that to the Cloud Service Providers according to the pay-as-you-go model. Moreover, implementation of cloud computing technologies reduces overall cost and it provides scalability and elasticity to healthcare services. Energy consumption can be reduced up to 30% due to the optimization of the server utilization, which can in turn reduce expenses by up to 60% compared to non-cloud solutions [32,34].

Support of researchers, national security, and strategic planning: In the eHealth cloud can be stored a massive amount of medical information that can be globally accessed. All the information can be stored on the integrated platform, offered by eHealth cloud and be beneficial for healthcare sector. The information can be used in the researchers to discover diseases, to create and improve new medicine, medical procedures, and healthcare services. Moreover, monitoring system implemented in eHealth cloud can use data to monitor the spreading of dangerous diseases, it can predict epidemics and determine infected areas as well as help to identify the reasons. In addition, medical data stored in eHealth cloud can be used by decision makers, for the strategic planning of medical facilities, healthcare services' needs, such as hospital equipment, lab and operation rooms instruments, etc. [33].

Enhancement of security safeguards: Information security is a strong and a weak side of eHealth cloud. On one hand, in eHealth cloud can be stored a huge amount of medical data attractive for attackers. The leakage of data from eHealth cloud can have a big impact on citizens. From another hand, cloud security protection can be more robust. For instance, cloud providers can allocate more IT resources in order to avoid server failure and ensure disaster recovery. Furthermore, Cloud Service Provider can provide better security and more professional equipment compare to healthcare IT services [34].

Access to it expertise on the cloud: Cloud computing technology exempts healthcare providers from keeping IT technical team to support medical systems. Cloud Service Providers have IT professionals to support eHealth services. It allows healthcare organizations to get a professional support of medical services at any time from everywhere, instead of building a team within the organization [34].

As it is seen from this section cloud computing can significantly improve healthcare sector. However, implementation of cloud technology is followed by the list of challenges and obstacles, which are covered in the next section. Cloud Service Providers should know those challenges and establish mechanisms to prevent their occurrence. Also, healthcare organizations should consider those risks before moving to the cloud.

3.5.2 Challenges of Health cloud

This section covers eHealth cloud technical and non-technical challenges. The technical challenges are described below [33]:

Availability: Data and system availability represent a high risk for eHealth sphere. Consequently, healthcare providers require high availability of eHealth services, regardless of hardware fails, changes, reconfiguration or security vulnerability. However, cloud services are delivered through the Internet, for this IT infrastructure within an organization can offer better system availability that services running in cloud.

Data/Service Reliability: All eHealth systems require high system reliability. Healthcare organizations might use cloud services from different providers which increases a chance to have incorrect data. Moreover, this represents a risk for healthcare sector, because based on these data they make their decisions regarding one patient or all society. Data in eHealth cloud should be “error-free”. Software, hardware, networking fails should not affect data in eHealth cloud

Data management: eHealth cloud can store and share a lot of medical records and some data can be replicated in different locations. eHealth services require secure and reliable access to medical information. It requires from eHealth cloud infrastructure to have storage service that provides fault tolerance and support of many languages to simplify data processing.

Scalability: eHealth cloud services should be scalable, in order to handle a big amount of data. Scalability can be possible by increasing the amount of compute resources,

such as storage, network connections and compute nodes. Moreover, it should be possible to automatically resize virtualized hardware resources based on services’ workloads. In addition, the performance of eHealth services should not be affected regardless of the amount of data.

Flexibility: eHealth cloud is used by many healthcare organizations with different users, functions, management requirements. Consequently, eHealth cloud infrastructure and services should be flexible to be configured for different specifications. Furthermore, it should also provide the possibility to add new services and implement changes.

Interoperability: healthcare organizations can use services from different cloud service providers and one cloud provider can provide services to several healthcare organizations. Accordingly, eHealth cloud should provide interoperability, which involves the definition of framework, protocols/API with other Cloud Service Providers to facilitate the process of servers and data integration between different CSPs. One of the approaches to archive interoperability is to use Service-Oriented Architecture for implementing eHealth cloud. SOA uses standardized models and protocols to make services available without concern about infrastructure or implementation details.

Security: eHealth cloud services are used by many healthcare providers and should be protected by authentication and access control cloud services, including mechanisms to secure traffic between cloud and healthcare providers. In addition, cloud service provider should not have access to healthcare provider’s data. Moreover, different healthcare institutions have different security and policy requirements for cloud services which should be considered by eHealth cloud service provider.

Privacy: Data privacy is an essential factor for healthcare organizations and at the same time it is one of the biggest concerns in eHealth systems. While eHealth cloud services can be provided by different cloud providers and shared among many healthcare organizations using cloud technologies, the risk of data leakage is increasing. For instance, social organizations, insurance companies, government, healthcare organizations and patients require access to the specific parts of healthcare data and it is important to provide them the certain access to data and protect the rest of it.

Maintainability: eHealth cloud provides services to hundreds of healthcare providers which makes system maintenance complicated, due to different requirements and characteristics of healthcare organizations. In spite of the fact, that requirements might be different, the maintenance of infrastructure, platform or software in the cloud should be performed without negative impact to any cloud service. In other words, eHealth cloud should provide easy and reliable maintenance.

Incident management: In the report “Security and Resilience in eHealth. Security Challenges and Risks”, the European Union Agency for Network and Information Security published a research about common reasons of security incidents in eHealth, which includes human errors, natural phenomena, malicious actions (DSoS attack, etc) and system failures. The results are presented in Figure 3.12.

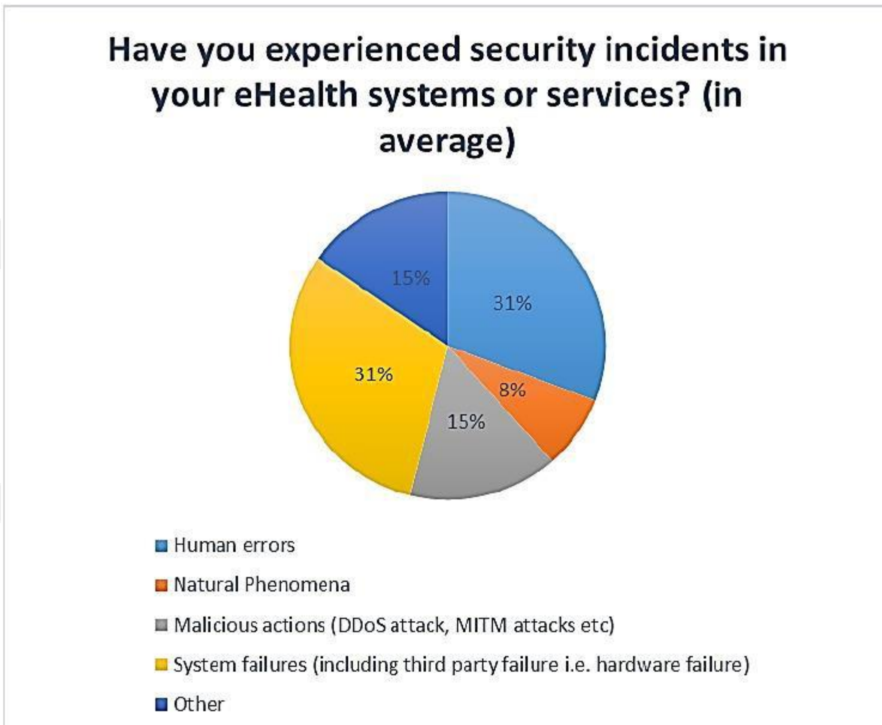

Figure 3.12: Common root causes of security incidents [35]

As it is seen from Figure 8, the number of reported incidents connected with system failure and human errors is equal. To “human errors” group also belong malicious actions caused by negligence that can make infrastructure vulnerable. Statistics shows the necessity to educate healthcare providers to use the system in secure manner.

The non-technical group of eHealth cloud challenges is described below [33]:

Organizational change: Movement towards eHealth cloud will bring a lot of changes in healthcare organization including organization documentation, processes, and policies.

Legislation and standards: eHealth cloud suffers from a lack of standards for medical informatics, policies and transformation methods. However, there are standards for medical informatics that can be applied in eHealth cloud to enable interoperability between different organizations. The International Classification of Diseases tenth revision (ICD-10) proposed by the World Health Organization (WHO) includes classification list with codes of diseases, signs, abnormal findings, social conditions and complains. Categorization of clinical medicine for storing and/or retrieving records is called Systematized Nomenclature of MEDicine (SNOMED). The International Organization for Standardization's (ISO) Technical Committee 215 (TC 215) [36] works on compatibility and interoperability in Health Informatics and Communication Technology. The Health Level 7 International (HL7) [37] organization is focused on the exchange, integration, sharing and retrieval standards of electronic healthcare information. It defines standards for eHealth infrastructures. Both organizations are also focused on formats for documents exchange and nomenclature of medical data objects [38].

Data ownership: Ownership of medical data is another challenge for eHealth cloud with many open questions. According to the future development of eHealth systems, access to eHealth systems should have doctors, medical personnel, patients and it creates a lot of complications. There are a lot of discussions about data protection in eHealth system: Who should manage EHRs? Should the person have full control on his data? Who else may have an access to patient's EHRs? What if a person is in a critical state and nobody else has an access to his data? Who should have the right to edit EHRs? etc. Those questions should be answered according to legislation and data protection in every country.

Privacy, trust and liability issues: In eHealth cloud environment there is a big risk of data loss, data leakage as well as a lack of knowledge about medical data location. Data loss or data leakage can cause serious problems for the healthcare provider.

Usability and end user experiences: Movement to eHealth cloud requires special trainings for healthcare organizations to introduce a new way of working and make people feel confident with using eHealth services.

As it is seen from this section cloud computing can bring not only benefits but also challenges to healthcare sector. This work is focused on cloud services availability challenge, as one of the most critical for healthcare sector.

Cloud computing has many established security mechanisms to protect cloud environment. In order to protect eHealth cloud from possible issues, we should determine eHealth cloud differences and similarities with the regular cloud. Therefore, the next section is focused on differences and similarities between cloud computing technologies in healthcare and in other domains.

3.5.3 Differences between regular and eHealth cloud

Cloud computing technologies offer many benefits for their customers and they are used in different domains for different purposes. For instance, it is used by banks, airline and insurance companies, in IT industry and etc. However, the use of cloud computing technologies in healthcare sector stays separately from any other domain. The reason is that eHealth is recognized as a critical sector by most of the countries and according to the European Union Agency for Network and Information Security [35], it should be protected on the national level. The incidents in eHealth sphere may have a huge impact on the society.

According to the National Institution of Standards and Technology [29], cloud computing is represented in private, public and hybrid deployment models.

Cloud computing technology has many technical and non-technical challenges. The list of cloud computing challenges can be found in many resources. For example, the report "Cloud Computing in the Public Sector" performed by Cisco Internet Business Solutions Group [39], describes challenges of cloud computing, such as security, availability, interoperability, privacy, etc.

The document "Cloud Computing security requirements guide (SRG)" performed by Defense Information Systems Agency (DISA) for the Department of Defense (DoD) [40], is focused on security requirements for cloud computing technologies. It includes the following security objectives: access control ensures that only authorized users have access to data; all incidents in the system should be reported and handled by incident management group; disaster recovery mechanisms should be implemented to restore data and services in case of system incidents; physical security should be established to protect cloud infrastructure from physical damage. Cloud computing information security requirements in healthcare sector are similar to the cloud security requirements in any other sphere More information about cloud computing information security requirements can be found in the following resource [40].

Nonetheless, healthcare industry is a new sphere for cloud computing with many open questions, especially from the legal and standards point of view. There are institutions working to develop standards in the eHealth, including CEN/TC 251, DICOM, HL7, ISO/TC 215, ISO/IEEE. However, in contrast to a regular cloud, eHealth cloud is still under development and experiences the lack of standards.

Based on the analysis above can be made a conclusion that cloud computing technologies in healthcare sector work identically in any other domain. In literature eHealth cloud is addressed as a realization of cloud computing technologies in healthcare, not a separate technology. Which means that it has similar service models, essential characteristics and deployment models. This chapter covered all necessary theoretical information for eHealth cloud, including its main parts: cloud computing and eHealth.

Here was defined that eHealth cloud is the use of cloud computing technologies in healthcare domain. Also in this chapter were considered eHealth cloud implementation challenges and benefits.

3.6 SMART APPLICATION AND SOFTWARE

Smart application and software are a rapidly developing area in the smart cities nowadays. Majority of the smart city applications together with researches have been done by the universities, enterprises as well as government sectors. The smart city applications contain the main functions of analyzing the sensor data and producing certain smart intelligent services to provide the new and efficient ways to optimize or improve energy consumption, environment, health-care, public transportation, public services etc. in order to reduce operational cost, save time and human safety.

3.6.1 Smart Healthcare Systems

The smart healthcare systems can provide the high-quality and low-cost healthcare services to help any kind of the patients with higher demand for the healthcare services in the smart cities. With the smart sensors such as wearable smart sensors, emerging on-body sensors etc. the patient's health conditions can be measured and notified to doctors or hospitals anytime and anywhere Let us consider our methodology in Figure 4.1:

The patients use the wearable sensors in order to measure their health condition or status. In case, the patients have physiological sings or health problems such as blood flow, blood pressure, respiratory rate, heart rate, body temperature etc. The wearable sensors will detect and transfer the health data into the smart healthcare system in order to analyze and notify to their doctors or hospitals. On the other hand, the wearable sensors need to be light, small and highly energy efficiency.

3.7 SMART SERVICES

Smart services are primarily produced by layer four, the smart city applications, based on analyzing the sensor data either from the smart user commands or the physical real-time environment to provide certain actions or services. These smart services allow the smart users to monitor or control the smart devices by using smart phone application, voice command, schedule, automatic decision etc. These smart services are classified into general principally functions as following:

a- Open/ close

b- Recognize/ detect

c- Turn on/ off

d- Optimize/ sharing

e- Notify/ call

f- Monitor/ control

g- Automatic decision etc.

3.7.1 Data Mining in E-Health Sectors

The use of data mining is mentioned several times in the literature, however, especially in connection with the past - detecting duplicates in the system, or as a control against abuse (prescription). The author is convinced that at the moment when there will be overall health records for all residents in some form of EHR and the necessary infrastructure built, such a starting point will be reached these data began to collectively serve all parties in the healthcare system.

There are a practically unlimited number of possibilities for the future use of such data with unprecedented multiplication effects. All medical records, past illnesses, prescribed medications, injuries, allergies, chronic diseases, examinations of blood or other fluids and others, logically arranged, together, analyzed and compared on a larger scale with other patients with similar problems at different time intervals, provides the opportunity to enable target and select the most effective treatment at a disproportionately lower cost than anything else. Even to such an extent that it would be possible to predict the occurrence of a certain disease or health complication before it develops into a state of life limiting or even threatening.

For example, a citizen should have access to half-yearly reports on the Health Information Portal about all his examinations and tests at doctors, or those he would do himself as part of Home care, generated into summary recommendations on what to improve, What to look out for and other general, verified tips on the web portal just for him. This would further interconnect and integrate most of the eHealth services offered.

Not only that, such timely analyzes could improve the quality of life of a citizen. In the case of some patients, it can also contribute to the diagnosis of health problems. The patient repeatedly complains of certain health problems, undergoes several examinations, several drugs are used, but without significant improvement, on the contrary, the disease progressively worsens. Under normal circumstances, a doctor would continue to diagnose and search for the cause until he or she discovered the cause or the patient died earlier or recovered from sheer helpless despair. In any case, the patient would have undergone many examinations unnecessarily, would take up examination capacity for other patients who might need the examination much more, and would have undergone unnecessarily much stress. In the case of using data mining, it would be possible to find the cause of the patient's problems earlier and significantly shorten the entire treatment process, which would streamline the entire process, saving money on unnecessary medical procedures. It would be possible to reduce health insurance contributions or keep money in the system, invest it and offer patients better services. A similar system lacks human / medical intuition, but on the other hand is not limited by the knowledge of one specialist and does not have to rely on interdisciplinary cooperation .

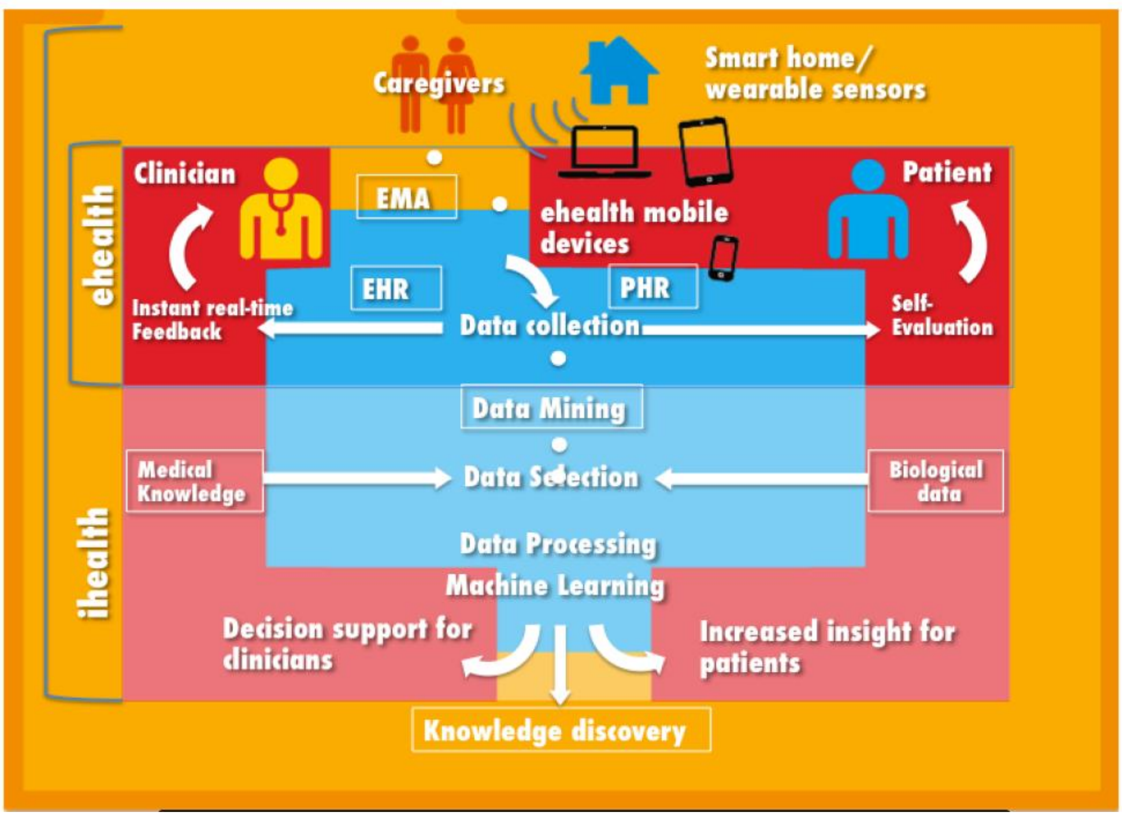

Figure 3.13: Cooperation of eHealth with iHealth[41]

The picture shows the process of finding out new knowledge about the patient by means of data mining. From capturing and storing patient information on the eHealth side (EHR or PHR records), to their processing and evaluation on the iHealth side (machine learning, data mining). This activity is not one-time, because the revealed knowledge is passed back to the doctor and the patient, he applies the knowledge, after a defined time there is another data acquisition, which evaluates whether changes have occurred and again analyzes and searches for new knowledge.

Portable sensors are also identified as data sources in Figure 3.14. Their use and integration into the state eHealth system is one of the possibilities for future development, just such cooperation at all levels, as shown in Figure 3.15, would lead to the most personalized possible health care in which the patient would be directly involved.

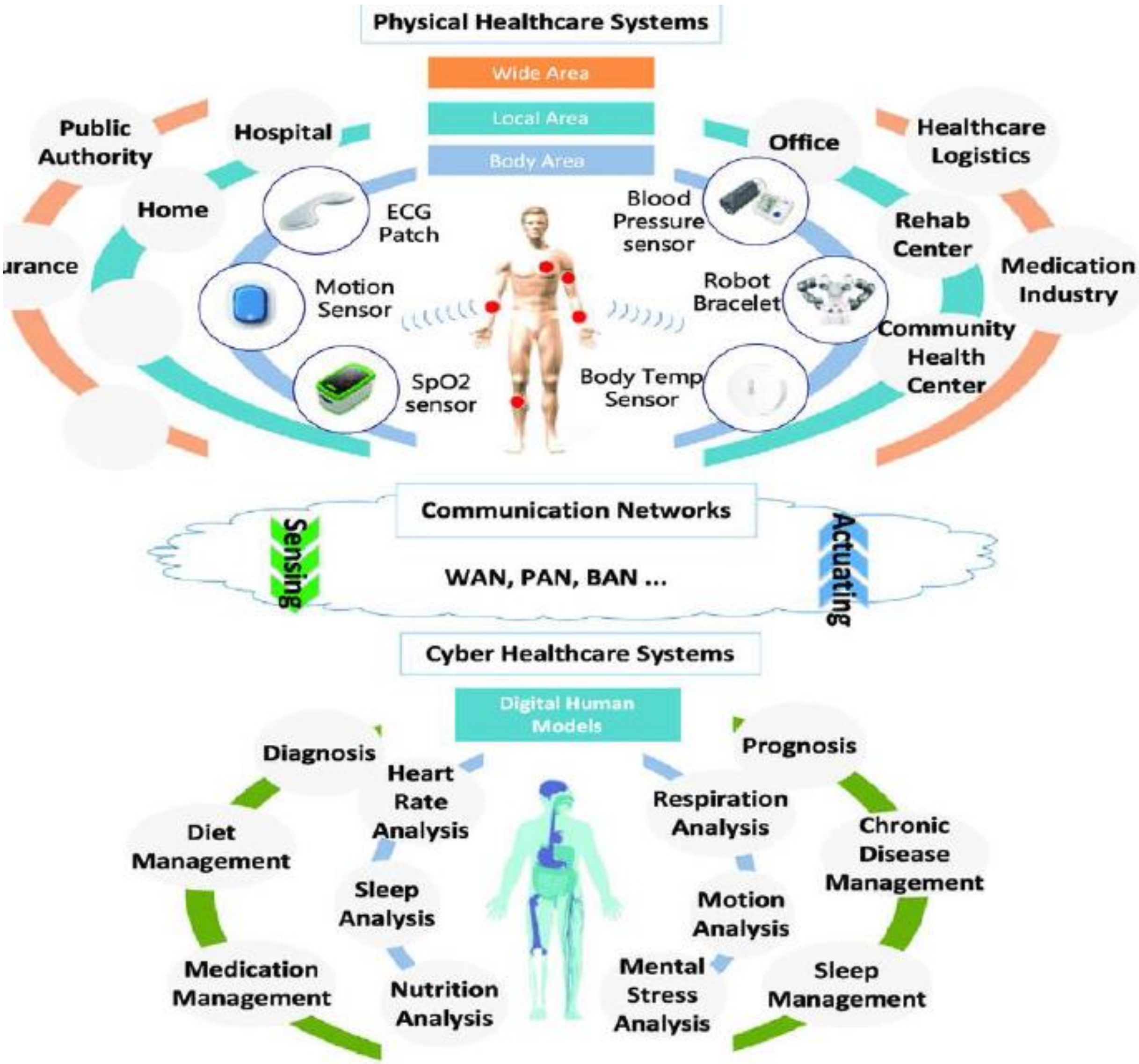

Figure 3.14: The future of care persnalization[42]

In such a system, the patient is voluntary (he does not have to use the blue layer at all - personal) and then nothing changes for him. But if he uses it, new possibilities will open up for him. Provided that there is agreement on how the communication between the personal layer and the higher level layers will take place. (data integration, security, reliability)

As with other data, there is a risk of their misuse, in addition to the standard set protections described previously, the entire data mining process could take place only with the patient's consent. Proper communication across the whole society would be extremely important for the implementation of such functionality (for the public in the context that no one wants to spy on them18 and for professionals that no one wants to replace them, but on the contrary, a similar system should help them.

3.8 SMART FEATURES

The smart features are a gateway or interface, which enables the smart users to utilize as well as manage directly the set of the smart city services produced by layer four, the smart applications and software via manual command, voice command, schedule etc. The smart features bring the core value of smart cities directly to the smart citizens, smart enterprises as well as smart governments. The smart features should be:

a- User friendly

b- Cross-platform

c- Highly responsive

d- Highly adaptive and intelligent by learning user's interests and preferences

e- Easy to use

f- Consistent

g- Meet smart users' requirements etc.

3.9 SMART PARTICIPANTS

The smart participants play an important role as one of the enablers to transform the traditional city into the smart city by being participated in the democratic process either from co- creating the strategic planning of the smart city projects, proactively utilizing the smart city services and/ or evaluation of the smart city services. In smart city research area, the participation of the smart users such as smart citizens, smart enterprises or smart governments in the strategic planning of the smart cities is widely considered as an essential factor for the smart city service quality to deliver the innovation solutions in the domains of the smart mobility, smart environment, smart economy, smart governance, quality of life as well as smart education. There is always a key challenge in coordination with the smart users since the smart users are not properly involved in the strategic planning, usage smart services or evaluation of the smart cities.

There is a framework to compare and evaluate the user participation as the enablers in the smart cities [73]. Figure 20: Citizen participation evaluation framework descripts briefly the three categories of criteria of the citizen participation, their main sub-categories and their reflection into criteria. This framework can be used in three different ways. Firstly, it can be used as an evaluation tool to assess the smart city strategy as the means to ensure the smart users' participation. Secondly, it can be used as the governance tool for the government officials to invest in the citizen-oriented smart city strategy considered guidelines for implementation. Finally, it can be used as the creatively tool by enabling comparative analysis of best practices for one criterion or category of criteria across the different smart cities to get new means for smart citizen participation involved in designing and implementation. Here are the three elements of this evaluation framework:

3.9.1 Citizens as Democratic Participants

Smart citizens as democratic participants can help prioritize the smart city projects to meet the budget limitations and reduce the chance for litigation or unhelpful smart city services unused by the public. Furthermore, there are multiple benefits from the smart citizens as democratic participants [74]. The smart citizens can deeply understand the difficulty of technical issues and become experts in matters of the public relevancy or services. The government administrators also learn from the smart citizens about the unpopular strategic plans of the smart cities and find out the compromised smart city plans.

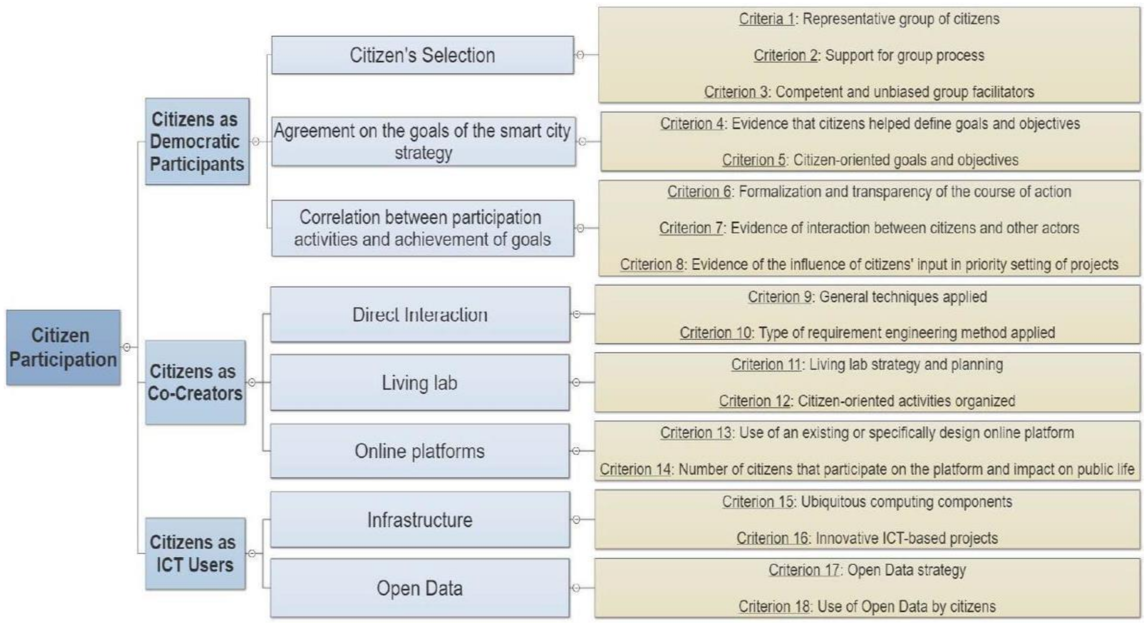

Figure 3.15: Citizen Particpation evaluation framework[73]

3.9.2 Citizens' selection

There are three main criteria to choose smart citizens as the democratic participants. Firstly, the group of smart citizens participated in the process of the smart city projects must be sufficiently population and have the good profits to avoid overrepresentation of the certain class, gender etc. Secondly, the criterion "Support for group process" are used to support the smart citizens during the decision-making process through finance or social rewards to motivate them and reduce their own money and time. Finally, the criterion "Competent and unbiased group facilitators" is added to check the participation activities are handled by the competent and unbiased group facilitators ensure the voice of the smart citizens heard.

3.9.3 Agreement on the goals of smart city strategy

The goal of the smart citizen participation could be to "involve the citizens in the planning, implementation and reporting phase of the smart city", to "develop a citizen oriented smart city strategy with transparency, participation and collaboration" or to develop the smart city to meet at best the citizens' expectations. There are two main criterions. Firstly, the criterion "Evidence that citizens helped define goals and objectives" checks the smart citizens contribute the definition of the smart city's goals. Secondly, the criterion "Citizen-oriented goals and objectives" checks the smart city's goals are citizen-oriented and consider the human resources in that smart city into account.

a- Correlation between participation activities and achievement of goals

Two main criteria ensure the correlation between participation activities and achievement of goals [75]. First, the criterion "Formalization and transparency of the course of action" checks that participation actions have been formalized and transparent to get the clearly decision-making process for all smart citizens involved. Secondly, the criterion "Evidence of the influence of citizens' input in priority setting of the projects" ensures that the citizens, their quality of life and participation are at the core of the smart city strategic plans.

b- Citizens as co-creators

Co-creating a smart city refers to the active participation of smart citizens in the variety of stages in the smart city process [76] and [77].

c- Direct interaction

Direct interaction focuses on the widespread techniques to collect smart citizens' opinions such as interviews, meetings, testing, real-time comments etc. There are two mainly criteria of the direct interaction. Firstly, the criterion "General Techniques applied" checks these techniques are used to gather smart citizens' opinions. Secondly, the criterion "Type of requirement engineering method applied" checks the smart citizen involvement in the requirement engineering method.

d- Living lab

Living lab is a technique of citizens co-creators, which implies that the smart users are participated in the development process of the smart cities by primarily analyzing the needs and brainstorming about ideas. Then the panel of the smart users test the prototypes of the smart cities from these ideas. The main goal is to achieve the smart users' expectation as well as to tests how these innovation prototypes are suited with the smart users' environment [78] and [79]. There are two main criteria. Firstly, the criterion “Living lab strategy and planning” checks the living lab puts the smart users at the center of its implementation. This criterion takes account of the citizen- oriented activities to explore ideas for the smart cities, innovation technology etc. Secondly, the criterion “Citizen-oriented activities organized” checks that the living lab is built to enhance the smart citizens’ participation in the smart city .

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4. CONCLUSION

In this thesis, we propose an E-health framework within smart cities Furthermore, we have conducted the practical research of smart city projects in both developed and developing countries namely Belgium, United States of America and Asia with concerning on the complexity of services and its structure of the smart cities.

Our strategic vision is to propose the new service-oriented reference architecture of the smart cities, which will help the city planners and the top-level decision makers in both private and public sectors for implementing the smart cities to provide the smart values to their smart participants. This abstract architecture is encapsulated within the seven layers namely physical infrastructure, smart devices, data management, smart application and software, smart services, smart features as well as smart participants in the main areas of urban planning, smart energy, smart mobility, public lighting, emergency, smart environment and e-government. The physical infrastructure is either the exiting physical city infrastructure or ICT infrastructure to provide an innovation physical platform for the smart cities. The smart devices are included with sensors, actuators, cameras, GPS, other Internet of Things (IoT) etc. are plugged on and scattered around the smart cities, allowing to quickly interact, surveillance and faster collect real-time data from the physical environment and the smart participants. The data management layer mainly consists a myriad of wireless technologies and cloud computing, providing the innovation technological capacity for faster data clearing, transformation and loading data to data warehouses (OLAP). The smart application and software layer performs data analysis as well as predict certain actions to provide specific smart intelligences. The smart city service is widely known as the functionalities or commands of the smart applications to perform specific smart actions including open/ close, notify/ call, monitor/ control etc. The smart features layer is used as the GUI/ window for smart participants to directly access the smart city services. In the final layer of the smart city

4.1 FUTURE WORKS

Implementation of this model and its validation were successful but in a limited environment. A lot of performance metrics and parameters can be studied, and different tools can be used. The literature explains very well the different parameters that can be changed, optimized in order to optimize the performance of the system. Combining this with challenges, that are not scientific but general challenges, a fully functional system for the future may be reached.

Many questions arise: Who should be mining? What is the mining cost? What is the mining reward? We are currently working on an implementation of this model combined with cloud computing as already mentioned in the previous section. Our next work will focus on IoT devices data rates, deadlines and block parameters in order to achieve an optimized performance in an eHealth context.

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