Smart Healthcare

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Abstract The healthcare system is being transformed from reactive and hospital-centered to preventive and personalized. Wireless technologies are the backbone of the smart healthcare systems. The familiar technologies such as the smart phone and smart watch will be developed further to include reliable health technology sensors and abilities. This review provides brief information about smart healthcare.

Introduction

The healthcare system is being transformed from reactive and hospital-centered to preventive and personalized. This has led to the emergence of the smart healthcare (SH).

Smart healthcare is one of the core infrastructural components of smart cities, as shown in Figure 1 [1]. It enables a doctor to monitor a patient's vitals from the office while the patient remains in home care. Smart healthcare is a huge market opportunity because it improves lots of lives with the smart health solutions. Stakeholders around the globe are seeking innovative, cost-effective ways to deliver patient-centered, technology-enabled smart health care, both inside and outside hospital walls. SH empowers patients to self-manage some emergency situation [2]. Interactions between parties are efficient and patient centered.
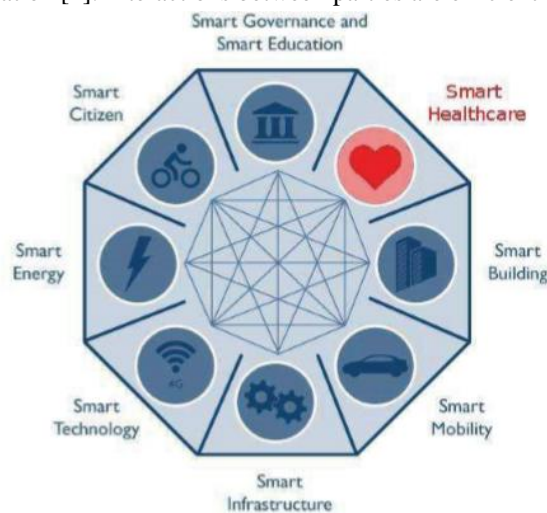

Figure 1: Smart healthcare as part of the smart city concept [1]

Wireless technologies are the backbone of the smart healthcare systems. Different wireless technologies such as Wi-Fi, Bluetooth, radio frequency identification (RFID), wireless sensor network (WSN), wearable medical devices, smart mobile technologies, etc., as shown in Figure 2, play a vital role in exchanging the information among different physical elements [2].
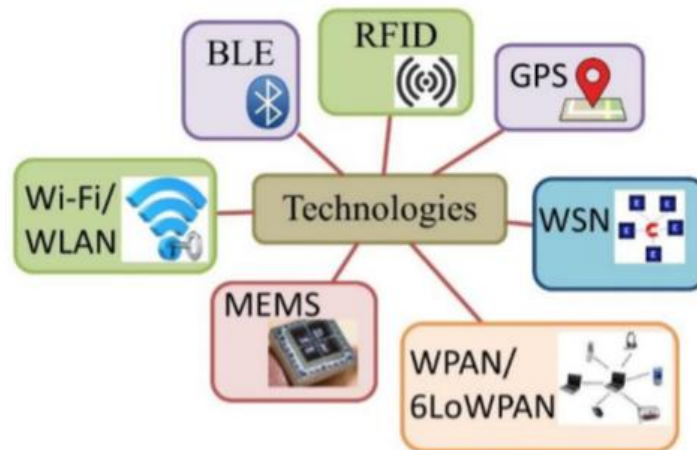
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Figure 2: Technologies used to deploy smart healthcare [2]

RFID implant allows for user identification, movement detection, and automation, and enables the smart environment to react to the presence of the user. Wearable sensor nodes are those that measure vital and other important signs, including pulse, respiratory rate, and body temperature - as these are the essential signs for determination of critical health. Mobile technologies will play a crucial role as they have become the patient's constant companion. Wearable sensors are capable of sensing even very small changes in vital signs, which a human cannot easily observe. The familiar technologies such as the smart phone and smart watch will be developed further to include reliable health technology sensors and abilities. These new technologies will allow remote monitoring of patients, health data collection, medicine administration, medication compliance, and access to medical records [3].

This chapter provides an introduction on smart healthcare. It begins with discussing traditional or current healthcare. It introduces the concept of smart healthcare and the key enabling technologies. It also covers the seven major features of smart healthcare. It presents some applications and services of smart healthcare. It covers the benefits and challenges of smart healthcare. The last section concludes with comments.

Overview of Healthcare

Healthcare is an important aspect of our life. It has a significant role in the economy of a nation. It promotes physical and mental well-being through various health services. Healthcare services are used to cure illnesses and health conditions, to prevent or delay future health care problems, to maintain vitality, and increase quality of life. Healthcare systems have a vital and continuing responsibility for people`s health. They are crucial to the healthy development of individuals, families, and societies everywhere.

The healthcare industry across its entire spectrum of organizations and services is one of the largest and fastest growing industries in the world. In addition to providing important and critical services to patients, it also brings large revenues to the healthcare sector. With the rapid increase in population comes in an increase in the number of people requiring healthcare services. The healthcare delivery system of today has undergone tremendous change.

Healthcare is a data-intensive sector where a large volume of data are collected, stored, and accessed daily. The healthcare industry generates massive amounts of data including patient Electronic Health Record (EHR) or Electronic Medical Records (EMR), drug development data, and patient survey data.

The traditional healthcare field faces some pressure to reduce costs while increasing the quality of services. Due to the ever-increasing world population, the traditional patient-doctor interaction has lost its effectiveness and the traditional healthcare is unable to accommodate everyone's needs. The healthcare services are not affordable to everyone.

The healthcare industry is changing rapidly around the world due to breakthroughs in digital technologies that are being adopted to meet various challenges. Physicians, hospitals, insurance companies, and pharmacies are seeking ways to better understand their practices so they can identify opportunities to reduce costs and streamline processes.

The adoption of ICT in the healthcare sector led to the concept of electronic health (e-health). The generalized use of mobile devices (e.g., smartphones) opened the door to mobile health (m-health). The emergence of Internet-of-things (IoT), new computing/networking paradigms (such as cloud computing and fog computing), and machine learning has revolutionized traditional healthcare and led to the dawn of a new era of smart healthcare, which is built on the foundations provide by smart cities and IoT [4]. With the integration of these technologies in the healthcare system, the system has seen a surge of interest from both the academia and industry and in many nations around the world. Adopting smart technologies in healthcare environment helps us to improve the quality of care and provide smarter and more cost-effective healthcare services.

Concept of Smart Healthcare

The concept of "smart healthcare" originated from the related concept of "smart planet" proposed by IBM in 2009. Smart Planet is an intelligent infrastructure that uses sensors to perceive information, transmits information through the internet of things (IoT), and processes the information using supercomputers [5]. Smart healthcare is one of ten priority areas in the development of smart city. Other components include smart government, smart education, smart transportation, smart grid/smart energy, smart surveillance, smart environment, smart society, smart reporting, smart payment, and smart commerce [6]. The integration of healthcare and smart cities has led to the utilization of smart healthcare technology into medical practices around the world.

Smart healthcare involves using smart technologies for health purposes. It is using smart technologies for better diagnosis of the disease, improved treatment of the patients, and enhanced quality of lives. It provides healthcare services through smart gadgets (such as smartphones, smartwatch, wireless smart glucometer, wireless blood pressure monitor) and networks such as Wi-Fi, Zig-Bee, Bluetooth, 5G, body area network, and wireless local area network.

Smart healthcare is an interdisciplinary field that includes sensing, networking, computing, radio frequency identification (RFID), wireless sensor network (WSN), and artificial intelligence. Smart health technologies (mobile and electronic) include sensors, medicine dispensation, smart pills, smart surgeries, wearables, and early registration devices [7]. These technologies provide the opportunity to build novel and fascinating smart, connected healthcare systems. Smart healthcare combines smart technologies within the home, hospital, patient, and information exchange. A typical smart healthcare system is shown in Figure 3 [8].
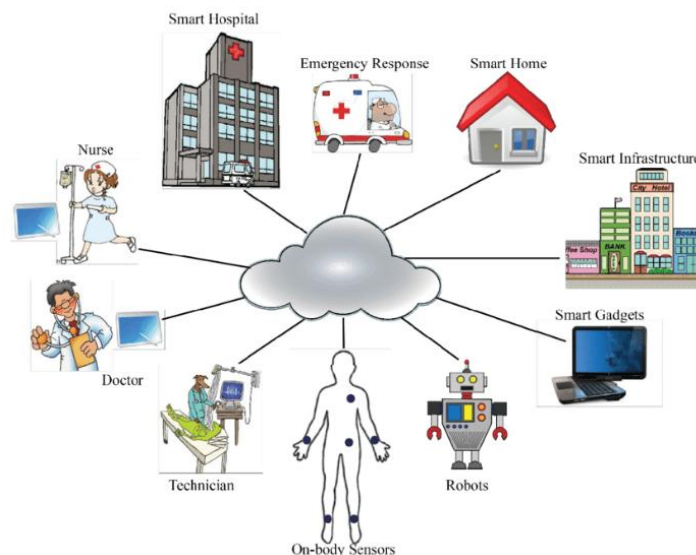

Figure 3: A typical smart healthcare system [8]

There are different ways technologies are changing smart healthcare. Top healthcare technologies such as IoT, cloud computing, big data, machine learning, and advanced analytics have turned the traditional healthcare into smart healthcare. These are major technological innovations which have added the element of "smartness" in the healthcare industry [9].

- *IoT in Healthcare*: IoT helps extend the benefits of Internet such as remote access, data sharing, and connectivity to various other application domains such as healthcare, transportation, parking activities, agriculture, and surveillance. IoT in healthcare technologies is also popularly known as Internet of Medical Things (IoMT). The Internet of things (IoT) allow all entities be connected to each other through wired or wireless communication means. The healthcare industry is among the fastest to adopt the Internet of things. The primary goal of IoT in healthcare is to connect doctors with patients through a smart device. Healthcare providers are expecting the IoT to revolutionize the gathering of healthcare data and care delivery [10]. Communications related to Internet of things for healthcare can be classified into two major categories: short-range communications and long-range communications. ECG data are gathered using a wearable monitoring node and are transmitted directly to the IoT cloud using Wi-Fi. IoMT is particularly a boon for a burdened healthcare system. IoMT devices on the other hand not only help the elderly to keep a close track of their medications and vitals like heart rate, glucose levels, and sleep patterns. Designing a wearable sensor for continuously monitoring blood pressure remains a challenge in healthcare IoT [11].

- *Big Data in Healthcare:* The healthcare industry is responsible for generating an unprecedented amount of data on daily basis. This big data is partly related to patient healthcare and well-being. It is created by mass adoption of the Internet and digitization of healthcare information, including health records such as demographic data, historical data, illness related information, test results, imaging data, costs, discharge summaries, pharmacies, insurance companies, medical imaging, genomics, social media, smart phones, wearables, sensors, and other IoT devices. Big data is commonly characterized by the so-called 5 V's - volume, velocity, variety, veracity, and value. It has been noticed that the governments across the globe are working towards building an effective healthcare infrastructure, with big data being the very foundation.

- *Cloud computing in Healthcare:* Cloud computing is a new means of providing computing resources and services. It offers large scalable computing and storage, data sharing, on-demand anytime and anywhere access to resources. It encourages cost savings, scalability, and system flexibility. Application areas include emergency healthcare, home healthcare, assistive healthcare, telemedicine, storage, sharing and processing of large medical resources. There three primary services that can be provided by cloud technologies in healthcare environments: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Cloud computing can support healthcare organizations to share information such as EHR, prescriptions, insurance information, and test results. The cloud makes it easier to archive and use patient records and medical images. The cloud also makes it easier to collaborate and offer care as a team. The demand for cloud computing healthcare solutions has grown exponentially.

- *Machine Learning in Healthcare*: Machine learning (ML) is the discipline that gives computers the ability to learn without being explicitly programmed. In medicine, the bottom line is to use machine learning to augment patient care, save more lives, improve more care, while saving money at the same time. ML can automate the manual processes carried out by practitioners, which are usually time-consuming and subjective. Machine learning performs diagnostics or treatment plans would be extremely valuable in a healthcare scenarios. Thus, using ML can save time for practitioners and provide unbiased, repeatable results [12]. The application of machine learning in the healthcare systems has opened up new avenues in the smart healthcare market. Personalized care has been the hallmark of smart healthcare solutions, which can be easily gained through machine learning.

- *Nanomedicine:* This is a unique branch of medicine that involves the development and application of materials and technologies with nanometer length scales. It is an interdisciplinary discipline that combines nanoscience, nanoengineering, nanotechnology, nanoelectronics, and life sciences. The interest in nanomedicine spans a wide area in medicine such as drug delivery, vaccine development, antibacterial, diagnosis and imaging tools, wearable devices, implants, and high-throughput screening platforms. The most prominent areas of nanomedical research and drug approvals are cancer

treatments, imaging contrast agents, and drug delivery. Nanodevices can repair DNA or replace the defective part of DNA. Nanomedicine will lead to many more exciting medical breakthroughs [13].

Features of Smart Healthcare

Smart healthcare uses a new generation of information technologies to radically transform the traditional healthcare system, making it more efficient, more convenient, and more personalized. The important features of smart healthcare are depicted in Figure 4 and can be broadly summarized as 7Ps [14]:

1. *Personalized:* The smart healthcare provides a unique and suitable treatment plan for each patient

2. *Persuasive:* The smart healthcare system can change the behavior of the user for improving his/her healthcare management.

3. *Predictive:* Smart healthcare enables a kind of predictive maintenance for humans.

4. *Participatory:* The smart healthcare represents a new participatory care paradigm.

5. *Preventative:* The smart healthcare provides solutions to help people stay away from diseases rather than treatment.

6. *Perpetual:* The perpetual awareness system in smart healthcare is characterized by continuous monitoring.

7. *Programmable:* The smart healthcare systems should allow users to set programs when dealing with some sophisticated medical cases.

Figure 4: 7Ps features of smart healthcare [14]

Applications and Services

Healthcare is undergoing a transformation from traditional hospital focused approach to a distributed patient-centric approach. With the increasing demand for automated, remote, and real-time healthcare services in smart cities, smart healthcare monitoring is necessary to provide complete care to residents. Smart healthcare applications and services require collection and analysis of raw sensory data.

- *Smart Home Healthcare*: This centers on providing care in the home for outpatients, the elderly, and those with disabilities. It allows patients to communicate their current health status to healthcare provider from home. It has the potential for managing chronic illnesses of the aging population. The technology is designed to assist the homes' residents accomplishing their daily-living activities. An elderly person should be monitored constantly if he/she has health-related issues. Smart Homes can be cost-effective and allow greater independence and quality of life while reducing the chance of social-isolation. Robotics is an area that has merits in the field of home assistance. A robot at home is a robot which takes care of patients at home. The home of tomorrow will be substantially different and smart [15].

- *Patient Monitoring:* Smart healthcare monitoring is necessary to provide improved and complete care to residents. This allows the doctor to monitor patients' conditions for providing treatment even from remote locations. (This may be done using cognitive computing.) Wireless body area networks (WBANs) are the basic components of community healthcare monitoring. They entail having small sensors placed on body of a patient to monitor various health parameters like blood pressure, heart beat, temperature, and prolonged electrocardiogram [16].

- *Pathology Detection:* A smart healthcare framework uses IoT sensors attached to a patient to acquire data, such as electrocardiogram (ECG), ECG, and body temperature, and determines the patient's state. An EEG-based pathology detection method uses scalp EEG recorded through EEG sensors. The EEG signal is transmitted to the deep learning system, which performs pathology detection. Healthcare specialists can study the result generated and monitor the patients [17].

- *Smart Healthcare in Hospitals:* Smart hospitals rely on information and communication technology-based environments. Due to cost pressure, hospitals are facing challenges like less financial resources. As a result, reduction of labor cost becomes the critical criterion for the implementation of smart items infrastructure in a stationary setting [18]. Integration and automation are the future directions of smart hospitals.

- *Virtual clinics:* These are online clinics that provide 24-hour online access for patients. Smart mobile devices now have an application called "Virtual Clinic" that allows doctors in the healthcare network to answer questions to patients in real time.

- *Pharmaceutical Industry*: Smart healthcare is employed in the pharmaceutical industry for drug production, inventory management, and other processes. Clinical trials of drugs may involve combining the use of the IoT, big data, and artificial intelligence.

Benefits

Smart healthcare technology has many obvious advantages in system integration, information sharing, and intelligent processing. With the Internet of things, mutual sharing of information becomes easy and convenient. With Internet-enabled smart devices, smart healthcare has become reality in which patients receive medical treatment from anywhere across the globe. Smart healthcare systems analyze patient data to both enhance the quality of patient care and reduce the cost of care. Smart healthcare can relieve personnel pressure, achieve unified management of information, and improve the patient's medical experience. Smart healthcare systems can help improve security, simplify maintenance, make effective use of staff, and improve the user experience.

Challenges

There remain definite technological and societal challenges to be addressed before smart healthcare technologies are widely adopted. Integration of new technologies into existing healthcare systems can be challenging. There needs to be the infrastructure and competencies needed to incorporate smart health technologies in daily operations. Medical institutions lack uniform standards across different regions and organizations. Sharing patients' sensitive information over the Internet leads to serious security and privacy concerns.

Security is a challenging requirement during data collection from patients. The blockchain is a potential technology that can be used to reinforce the security practice in the healthcare. It may eliminate the risks of user experience when they store their health information on their smartphone [19]. Confidentiality is an important security requirement in smart healthcare. The smart healthcare system is vulnerable to cyber-attack [20].

A major challenge is practitioners' hesitation and unwillingness to use these new technologies in medical practice. Today's shortages of nursing providers will become more acute as the population continues to grow and age. The solutions to these challenges depend on technological progress and the joint efforts of patients, doctors, health institutions, and technology companies.

Conclusion

The integration of healthcare and smart cities has led to the utilization of information and communication technologies (ICT) into medical practices around the world. The integration has improved the quality of the

residents in the smart cities [21]. The smart healthcare systems are constantly developing and providing better healthcare services in smart communities. It is not exaggeration to say that smart healthcare systems have become one of the most sought-after technological innovations by healthcare organizations.

Smart health technologies will be commonplace in the near future. They are still in their infancy and their prevalence is still limited. Demand for smart healthcare engineers is anticipated to grow. There is a need to continuously adapt engineering curricula and foster future generations of smart healthcare engineers [22]. More information about smart healthcare can be found in the books in [23-25].

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