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Ubiquitous Healthcare: A New Frontier in E-Health

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ABSTRACT

The Center for Medicare and Medicaid Service projects that by the year 2011 the total healthcare expenditure would reach $2.8 trillion and would amount to 17% of the GDP. Several surveys in the past equivocally agree that the population of the world is aging and this is resulting in increased healthcare utilization/expenses. The current research evaluates ubiquitous healthcare as a strategy that can be deployed as a means of pushing prevention and disease management in the hands of the patients where intervention from the healthcare sector is provided as and when needed. Wireless communication technologies, biomedical sensors/monitoring technologies and ad-hoc networking are some of the primary technologies that form the foundation to promoting ubiquitous healthcare. The current research develops architecture of ubiquitous healthcare depicting enabling technologies and interaction of the patients in a ubiquitous healthcare environment. The technologies that enable various facets of ubiquitous healthcare are evaluated in terms of technical as well as non-technical issues and a classification framework is produced. The current applications of ubiquitous healthcare are evaluated and challenges opportunities and future research areas associated with realizing the vision of ubiquitous healthcare are discussed.

Keywords

Ubiquitous healthcare, Technologies, Ubiquitous computing, Biomedical Sensors

INTRODUCTION

Ubiquitous healthcare is a concept that stemmed from the vision of Mark Weiser, who is considered to be the father of ubiquitous computing. Healthcare seems to be the most apt domain for ubiquitous computing, because it holds the promise of providing quality healthcare, disease management, prevention and treatment of illness along with emergency intervention anytime and anywhere to a large population of patients. Ubiquitous healthcare can be defined as the environment where healthcare is available to everyone, everywhere without any dependence on time and location and where the technologies enabling ubiquitous healthcare will be assimilated flawlessly in our daily lives such that the technologies become invisible. The definition of ubiquitous healthcare involves two perspectives, one being the domain of application of the technologies enabling ubiquitous computing and the other being the concept that integrates healthcare more seamlessly to our everyday life [8].

The following quote produced by Mark Weiser almost a decade ago describes his vision of ubiquitous computing "*The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it*". The essence of the vision lies in the creation of a computing environment where the users would become an integral aspect of the computation, where technology would become pervasive and invisible enabling the users to focus away from the technology towards higher goals [1][3][4]. The objective is to surround a user with a large number of application-specific, network-connected appliances/applications that unobtrusively provides them with information and services with respect to their environment and relevant to a context useful to the user [5]. The computer as a device with a cumbersome interface consuming most of the user's attention will be replaced by intelligent user interfaces which will enable users to interact with their environment as in addition to using IT services without being distracted by information technology. More than ten years have passed since the introduction of ubiquitous computing paradigm but the vision hasn't become fully achieved yet. However, we are definitely better positioned to achieving the objective today, than we were a decade ago as is evident from the technical advances made in the field of ubiquitous computing [3][5].

Healthcare seems to be the fertile ground for the ubiquitous computing applications to thrive since there is no other domain where the importance of obtaining the right information at the right time irrespective of time and location dependency is more critical than the healthcare sector. Ubiquitous healthcare has the potential of saving large sums of money associated

with care and delivery of healthcare along with it being instrumental in saving lives of the patients. Healthcare is the largest service industry in the world which touches most if not all of us during the course of our lives [6]. In the wake of the 21st century healthcares systems around the world are faced with the aggravating challenge of exponential rise in healthcare costs, the need to provide healthcare to a larger population base using limited financial as well as human resources and a shift from curing to prevention of diseases [6][7]. Ubiquitous healthcare holds the promise to curing the healthcare sector of its terminal problems along with providing a means to continue quality healthcare provision to all in need of healthcare services [5]. The objective of the current research is to address the challenge of providing quality healthcare to the aging population and the ever increasing patient base, supporting independent living, wellness and disease management anytime, anywhere without an increase in healthcare cost by leveraging the benefits of the ubiquitous computing paradigm

The research objectives addressed by the current research are tackled in three ways. First the current status of healthcare is evaluated; the potential of ubiquitous healthcare as a possible solution is assessed, an architectural framework developed and challenges associated with the ubiquitous healthcare are identified. Second the technologies enabling ubiquitous healthcare are evaluated and classified. Finally the current status of ubiquitous healthcare is assessed by a survey of current applications and identification of future research. The architectural framework shows the various interactions of patients with the ubiquitous healthcare environment and the consequent potential for reduction in healthcare expenses associated with promotion of ubiquitous healthcare. The potential of quality healthcare provisioning as well as the risks/challenges associated with ubiquitous healthcare are high as seen from the discussion of the challenges. The classification of technologies provides an in-depth analysis of various enabling technologies that have the potential of making a ubiquitous healthcare environment a reality. The assessment of current ubiquitous healthcare applications show the various facets of ubiquitous healthcare which are addressed by the applications along with the technologies that have enabled the deployment of each application.

The contribution of the current research is the architectural framework of ubiquitous healthcare environment, assessment of risks/challenges, potential of reduction in healthcare expenses, evaluation and classification of enabling technologies and current applications of ubiquitous healthcare. The direction of future research is also identified.

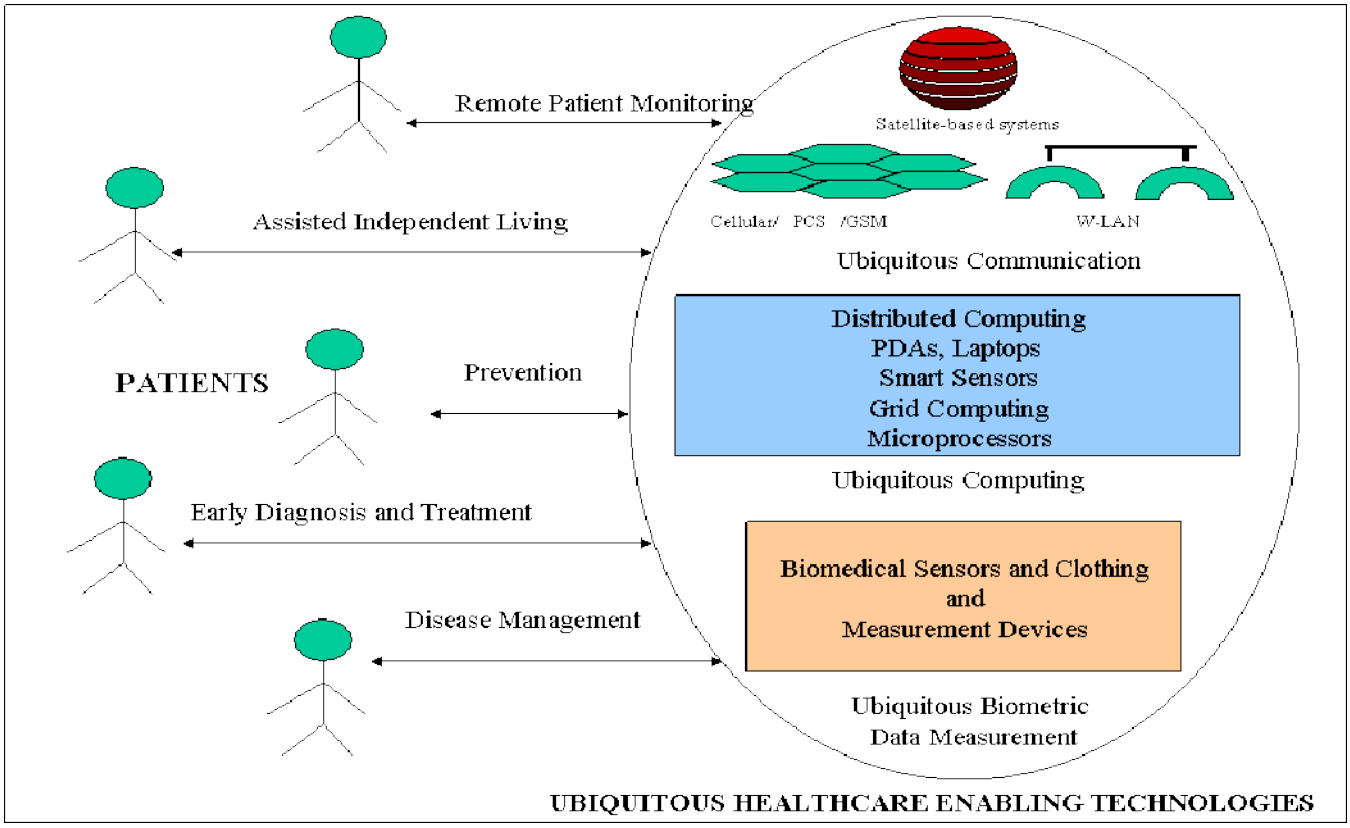
KEY CHALLENGES FACED BY THE HEALTHCARE SECTOR

Healthcare, the largest service industry on the globe, faces an undeniable need to leverage the benefits of the information and communication technology revolution which has impacted the global economy in numerous ways. Healthcare system in most developed countries in United States, Europe and Asia are faced with exponential rise in healthcare cost caused by an aging population who typically suffer from chronic diseases requiring long term treatments, hospitalizations and monitoring. The hospitalization costs associated with monitoring and providing quality care to the patients is one of the primary factors driving healthcare expenses (Kohli et al.). The worldwide population of adults over 65 years of age is predicted to reach 761 million by 2025.

Providing quality healthcare to the aging population is putting enormous strain on the dwindling financial as well as human resources of the healthcare sector. U.S. alone spends approximately $600 billion annually in meeting the needs of the aging population. With the cost of healthcare services touching approximately 15% of the Gross National Product (GNP) [11], one of the critical challenges faced by healthcare providers, policy makers, hospitals and insurance companies is to discover means to providing quality healthcare services to an increasing number of patients utilizing the limited financial as well as human resources of the healthcare industry [14]. The Center for Medicare and Medicaid Service projects that by the year 2011 the total healthcare expenditure would reach $2.8 trillion and would amount to 17% of the GDP. Healthcare utilization depends largely on the demographics of the population, consequently a steady rise in the aging population as reported by several surveys in the past [12] has led to increased healthcare utilization/expenses [15]. Additionally, a large number of preventable medical errors are caused because of lack of correct and complete pertinent information at the time and place it is needed, resulting in wrong diagnosis and drug interaction problem [19].

A possible solution to the terminal maladies faced by the healthcare sector is a move beyond the traditional healthcare, from managing illness to maintaining wellness in addition to promoting evidence-based medicine and collaboration among physicians to provide the best possible care to the patients, through ubiquitous technologies [17]. Ubiquitous healthcare is not merely a technological innovation; it involves a paradigm shift in healthcare practices, delivery and view. It heralds the advent of an era where healthcare will be substantially enabled by ICT and will become increasingly digital and virtual and where patients will play a more active role in managing their own healthcare using physicians and healthcare providers as consultants [16]. This paradigm change means technical applications of consumer-operated interoperable standard technologies for health and wellness by the usage of ubiquitous computing technologies such as: PDAs, mobile phones, communication networks etc. At the level of the healthcare organization, ubiquitous healthcare implies a change from physician centric systems to patient centric operational models [18].

Figure 1, below shows a conceptual model of the ubiquitous healthcare environment. The enabling technologies and the various facets of patient interaction and potential for cost saving that could result from efficient and quality healthcare delivery is depicted in the architectural framework. Remote patient monitoring and assisted independent living has the potential of saving large sums of money that is spent in long term hospitalization and care of elders needing assistance. Prevention, early diagnosis and treatment along with disease management can further help in decreasing the incidence of hospitalization while providing continuous healthcare monitoring and alerting the healthcare sector when an anomalous condition is detected, thus reducing healthcare expenses while providing quality healthcare to everyone, everywhere, all the time.



UBIQUITOUS HEALTHCARE ENVIRONMENT

Figure 1: Framework of a Ubiquitous Healthcare Environment depicting Enabling Technologies and Patient Interaction

Some of the key technical as well as non-technical challenges faced by ubiquitous healthcare for e-health provisioning are summarized below:

•**Invisibility** – One of the most promising concepts of ubiquitous healthcare is providing healthcare services pertaining to monitoring, treatment (reminders to take medication), prevention and management of diseases in a manner that causes minimal distraction and is unobtrusive in nature. The devices/computers promoting ubiquitous healthcare should disappear in the background, removing distractions by computers such that the patients can continue with their daily activities without being obstructed by the computers [3], [1], [6]

•**Proactivity and Transparency** – Proactivity and transparency refers to the intelligence in the ubiquitous healthcare environment which will be able to sense the current intent of the patient and proactively take certain actions on behalf of the patient. For instance: if the device senses that the patient's ECG has gone beyond a pre specified threshold then the intelligence in the device may want to alert the doctor of the situation and schedule an appointment as soon as possible along with informing the patient of the appointment. But this proactive action should be transparent to the patient as far as possible. Proactivity shouldn't become a source of annoyance.

•**Context awareness** – Context awareness is in synch with proactivity since a computing environment cannot be proactive in assisting a user in decision making unless the right context information is available. For instance: if the patient's hear rate has gone up then the device must be aware of the context where and when the heart rate was high. If the patient was watching an exciting football game which caused the heart rate to go up while the vital signs from other sensors were within the normal range then the device should be able to detect the context and not send alerts. Context information can be recovered from sensors and would essentially contain information about who, what, when and where.

•**Privacy, Security and Trust** – These are the three pillars of the ubiquitous healthcare which have the power to make or break the system. All these requirements are two ways, which implies that the computes need to be able to trust the delegated user (doctor, patient or other authorized users) as well as the user needs to have trust in the system before it can be put to practice [2][4][7]. The ubiquitous healthcare environment where a patient might be continuously monitored creates a large amount of e-knowledge associated with the patient's health condition, location, physiological condition etc. This data can make the patient very vulnerable if accessed by unauthorized users. Thus security is of paramount importance in collecting, analyzing and transmitting e-health information. There is a need to create policies and laws regarding ownership of user information in ubiquitous healthcare environment. The usage and diffusion of the ubiquitous healthcare concept with tons of private information depends to a large extent on the patient's trust in the system. The existence of (Healthcare Information Portability and Accountability Act) HIPAA has legal sanction on healthcare information thus making it an essential requirement to safeguard privacy, security and trust.

•**Power Management of low powered mobile devices** – Mobile wearable devices used for sensing, collecting, analyzing and transmitting health related information of the patient is an indispensable component of the ubiquitous healthcare environment [5][7][9][10]. Since most of the mobile devices will be battery powered thus power management becomes a critical challenge, for instance if a device runs out of power at the critical moment when it needs to transmit an alert would mar the usability and trust in the system. Hence innovative ways to conserve power and get the devices charged at a regular interval is fundamental for the continuous usage of ubiquitous healthcare.

•**Reliability** – The essence of reliability lies in the correct functioning of a system. Reliability, for the purposes of ubiquitous healthcare, forms the cornerstone of its success since an unreliable system can have fatal consequences. Thus it is imperative to built redundancy in the system with respect to data collection and analysis, transmission and application.

TECHNOLOGY ENABLING UBIQUITOUS HEALTHCARE

Technologies promoting ubiquitous healthcare is not merely a technology that can be bought off the shelf and used in healthcare setting, instead it is a novel holistic concept of integrated application of modern technology embedded in everyday settings. The momentum for ubiquitous healthcare to a large extent is created by several technologies enabling ubiquitous computing and some specific technologies related to modeling and measuring medical data related to patient's physiology. The three classes of technologies that have played the enabling role in laying the foundation for ubiquitous healthcare to becoming a reality are: ubiquitous computing, ubiquitous communication, biomedical sensors and monitoring devices.

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Ubiquitous computing seeks to bridge the gap between the virtual and physical world by incorporating computing power (microprocessors) and sensing (sensors) into anything, including not only conventional computers, personal digital assistants (PDAs), mobile phones, printers, etc., but also everyday objects like white goods, toys, plates, cups, glasses, houses, furniture, or even paint ("smart dust"). Ubiquitous computing is a critical evolutionary step in a line of technological advancement that started in the mid 1970s. Two of the previous steps in this evolution of technology include distributed computing and mobile computing. The opportunities and challenges associated with ubiquitous computing subsume distributed and mobile computing and go much beyond the precursors [3][4].

The Figure 2 below gives a framework depicting the classification of technologies enabling ubiquitous healthcare.

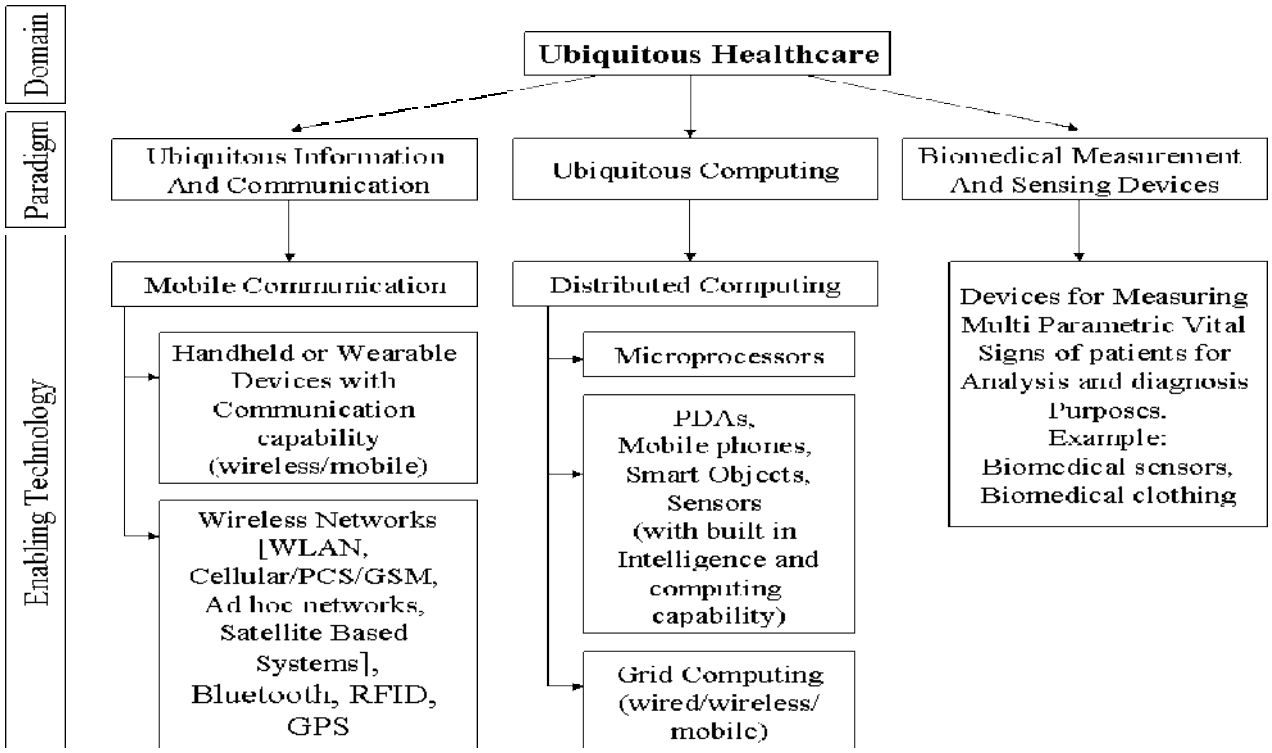

Figure 2: A Classification Framework showing the technologies enabling the realization of Ubiquitous Healthcare

The distributed computing research between 1970s and 1990s has created a large amount of conceptual framework and algorithms that have proved extremely useful in all work that involves communication between two or more computers connected via a network. A relatively recent advancement in distributed computing is brought forth by "Grid Computing" which has taken the distributed computing paradigm to a much higher level. The initial definition of grid computing was introduced in the mid 1990s however the definition has evolved since then and is currently defined as "coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations" [27]. Grid technologies are concerned not only with file exchange, but also with access to resources such as computers, software and data in a highly controlled setting where both users and providers clearly define what is shared, who is allowed to access it and under what conditions [27]. Given these characteristics, grid technologies create dynamic and secure environments for computing and storing resources which is very conducive for ubiquitous healthcare where doctors from across the globe can not only access patient's data but run complex simulations and virtual surgical procedures. Grid computing has the potential to revolutionize resource sharing the way the internet has revolutionized information sharing [26]. In a typical hospital there is a large amount of computing resources available but only 5-10% of them are in use at one point in time. In a ubiquitous healthcare environment there will be a large amount of computing resources both wired and wireless around and on the patient not all of which have the same computing power. Mobile grid computing can couple all these computational resources and create a network architecture that supports and pervades our lifestyle in incomprehensible ways [40] The attached benefits translate into an improvement of the quality of the data, a decrease in development costs for integrating data and an efficient sharing of electronic patient-related information [28].

In the mid 1990s the field of mobile computing was born with the appearance of laptops and wireless LANs. Mobile computing brought with itself unique characteristics of mobility which led to further research in this area. The research and development efforts in these areas laid the groundwork for ubiquitous computing [3]. Ubiquitous communication is enabled by mobile computing which allows continuous access to data and communication power of anything with anything else, including not only people but also artifacts with computing and communication capabilities. Mobile and wireless communication technologies and ad-hoc networking are perhaps the most important technologies with respect to ubiquitous communication [7][8]. The increase in processing power and communication bandwidth along with the corresponding decrease in the cost of processing and communication, with respect to both hardware and software and power consumption have been the fundamental trend in information and communication technologies (ICT) [8][7][6]. This trend is making it both technically and economically possible to integrate processing power and communication capacity to more simple and

inexpensive devices and objects than was feasible before. With 350 million mobile devices worldwide and 80 million in United States itself it is evident that the PDAs and mobile devices are slowly becoming an integral part of our lives. Furthermore analysts expect the number to exceed 1 billion in the next few years [9]. The plethora of mobile devices surrounding us with computing and processing capacity offer a mobile wireless platform for running healthcare applications, a user interface and data logging potential for health sensors and monitoring devices and a gateway to connect local devices collecting health related information to global services such as hospital databases etc. RFID (radio frequency identification technology) allows simple wireless communication with nearby objects to obtain information such as product code, URL or sensor reading. The current RFID tags are very cheap to produce in mass scale and do not require battery for operation since they use backscattering in communication.

Wearable biomedical sensors and biomedical clothing and other monitoring devices have made possible the collection and analysis of physiological patient data while the patient is mobile. Inexpensive wireless heart-rate monitors have been available for consumers for several years. Additional on going research in this area has the potential of improving the usability of such devices [10]. Intelligent user interfaces enabling natural interaction and control of the environment are critical requirements for widespread diffusion of ubiquitous computing. Natural communication of the user via intelligent interfaces capable of interpreting speech and gesture while considering the context and user preferences is another technology that can make potential deployment of ubiquitous healthcare a reality. The wide spread influx of handheld and wearable computers, miniaturization of processors, development of new materials like intelligent textiles, smart papers etc. and improvement of power supply and wireless communication networks have given the needed boost to fulfilling the vision of ubiquitous computing.

Although the technology to support ubiquitous healthcare is still taking shape the main challenge lies in interoperability among the multitude of devices and applications and the short range low power communication occurring between non-computational devices such as sensors and the parallel devices running healthcare applications. Table 1 depicts how some of the challenges associated with ubiquitous healthcare are addressed by the enabling technologies

Challenges/Requirements of Ubiquitous Healthcare	Enabling Technologies
Invisibility - Maximize	Pervasive presence/disappearance of computing and mobile communication resources, miniaturization and presence of biomedical measurement and sensing devices in everyday objects such as smart shirts etc.
Proactivity and Transparency – Balance between Proactivity and Transparency AND Context Awareness - Maximize	Intelligent devices with the potential of learning from the patient, the environment with the capacity to react to certain anomalous conditions. Enabled by intelligence in computing devices and biomedical measurement and sensing devices.
Privacy, Security and Trust - Maximize	Technologies with built in secure authentication processes, secure fool-proof communication resources, biomedical measurement and sensing devices and patient specific computing devices with intelligence to identify the patient.
Power Management of low-powered mobile devices – Maximize	Mobile computing and communication devices with power conservation methods such as sleep cycles, emergency power reserve for emergency transmissions, utilizing solar energy, devising innovative ways of conserving and charging of devices.
Reliability - Maximize	Technologies built to have redundancy with respect to data collection, storage, analysis and transmission. Since computing resource is the cheapest among communication resources and biomedical measurement and sensing devices hence reliability can be increased by redundancy with respect to computing resources. Reliability is also needed with communication, hence use/access to multiple communication networks is required such as: Cellular PCS/GSM, WLANs, Satellite based, Ad-hoc network etc Use of multiple biomedical measurement and sensing devices can also be utilized for data collection in order to account for potential errors in one/two devices.

Table 1. Challenges/Requirements Addressed by the Enabling Technologies in Ubiquitous Healthcare Environment

APPLICATIONS OF UBIQUITOUS COMPUTING IN HEALTHCARE

The current section discusses the various application areas within the healthcare domain where ubiquitous computing can add value by increase efficiency, reducing healthcare costs and the cognitive stress of the healthcare providers, promoting independent healthy living among patients suffering from chronic diseases for a longer period of time. Table 2 shows some of the applications of ubiquitous healthcare. It definitely is not an exhaustive listing of all applications of ubiquitous healthcare and there could be many more that can be envisioned. The purpose of the table is to survey and analyze the various applications in the realm of ubiquitous healthcare, the technological components or the combination of technology used and the areas within the healthcare domain which is addressed by each application. These applications range from simple home monitoring to high-end mobile and ubiquitous patient monitoring using ad hoc wireless networks, treatment and management of diseases, detection and prevention of diseases and early diagnosis and consequent reduction in fatality. The range of applications and technologies used for creating ubiquitous healthcare environment suggest that we are gradually moving towards realizing the vision where healthcare will become a part and parcel of our daily life. This is likely to become a high-growth area as an increasing amount and diversity of healthcare applications will rely on one or more types of ubiquitous computing.

Description of Project/Applications	Description of Ubiquitous Healthcare Concepts in Projects	Description of Enabling Ubiquitous Healthcare Technologies Used
Elite Home Care (www.elite-care.com) [20]	Project designed to promote independent living among elders with assistive technology usage.	Infrared and short-range wireless badges for location tracking, and sensors to obtain information about the physiological state of the elders
GatorTech Smart House [22]	Smart Home designed for the purpose of assisting elders live independently with the help of ubiquitous smart technology.	RFID for location tracking, sensors for sensing the environment, smart context aware ubiquitous computing to promote assistance on smart displays.
Motiva [24]	A secure, personalized healthcare communication platform that connects chronic disease patients at home to their care providers through their television sets and cable systems for IP access. This provides disease management and increased quality of life to the patients	Home monitoring devices that patients can use to measure their vital signs, such as weight and blood pressure. Two-way broadband IP data connection and a modem provided by Comcast to share personalized, non-emergency healthcare reminders and educational information with patients in a familiar, intuitive and interactive video-rich manner through the patient's television set.
LifeMinder [34]	Long term monitoring of health by evidence-based wearable healthcare assistant.	Wearable device, communication network
Smart Shirt [23]	Smart Shirt is lightweight and can be worn easily by anyone from infants to elders. Smart Shirt has enormous potential for applications in telemedicine, monitoring of patients in post-operative recovery, the prevention of SIDS (sudden infant death syndrome) etc. The principal advantage of Smart Shirt is its ability to provide a very systematic way of monitoring the vital signs of humans in an *unobtrusive* manner.	Wearable shirt with sensors, optical fibers and interconnects for incorporation of sensing, monitoring and information processing devices.
Wearable Stethoscope [29]	Monitoring of patients for heart	Wearable device (stethoscope), battery less,

Description of Project/Applications	Description of Ubiquitous Healthcare Concepts in Projects	Description of Enabling Ubiquitous Healthcare Technologies Used
	conditions, anytime, anywhere.	communication network
Ad-hoc network based patient monitoring [21]	Ad-hoc network based patient monitoring [21]	Wearable devices and wireless networks
CardioNet	Faster detection and treatment of hard to diagnose cardiac failures due to intermittent slowing of heart rate and very few or no visible symptoms	Wearable device to measure heart rate, a PDA to analyze the recorded ECG, and a cellular communication network to send the ECG signal to the healthcare service.
Micropaq by Welch Allyn [25]	Portable monitor that allows multi-parametric information to be transmitted over wireless LANs	Wireless LANs and Ethernets
Life Sync, Wireless ECG [30]	Wireless ECG monitoring of patients within a hospital	Wearable device to measure ECG, Bluetooth to route information within a hospital infrastructure.
A prototype for arrhythmia monitoring [31]	A prototype for continuous monitoring of ECG of patients virtually anywhere within the coverage of the network.	Wireless communication network for transmitting ECG signal from the patient to the healthcare provider, wearable device for measuring ECG, location tracking of patients using GPS
Smart Health Wearable research [33]	Research focusing on the usage of intelligent wearable devices to be used from prevention of disease to monitoring during rehabilitation.	Intelligence in wearable devices for monitoring, communication network.
Remote monitoring of Parkinson patients by intelligent wearable devices [12]	Intelligent monitoring of elders to detect anomalies with respect to Parkinson. On detection of an anomalous event the system send alerts to the healthcare center via a wireless communication network. The system promotes Parkinson patients to live outside of the hospital while being monitored ubiquitously.	Wearable device, intelligent agents, shakes measurement device. Bluetooth to send information from the measurement device to the PDA which acts as the gateway to the communication network.
Personal Stress monitoring [32]	Allows stress monitoring of patients using distributed intelligent (wireless) sensors on the patient's body forming a BAN (body area network).	Wireless intelligent sensors for sensing vital signs, usage of BAN.
Wireless ECG Monitoring [35]	A framework for ubiquitous wireless ECG monitoring of patients. The system provides scalability, reliability and uses intelligent agents for analyzing patient's vital signs and sending alerts to the healthcare provider if needed.	Wearable device for ECG recording, PDA with intelligent agents, wireless communication network for transmitting signals.
Aware Home Project at Georgia Tech [12]	Security, Privacy and Context-aware environment for assisting the people living in.	An extended Role Based Access Control mechanism is deployed to provide relatively simple, secure and context aware home environment which can perceive and assist the occupants. Request for assistance are

Description of Project/Applications	Description of Ubiquitous Healthcare Concepts in Projects	Description of Enabling Ubiquitous Healthcare Technologies Used
		generated based on the contextual factors rather than being initiated by the occupants. This offers a more ubiquitous environment than the previous project but the presence of centralized authorizations hampers scalability .
Visible Human Project [41][42]	Description of the project and its benefits for medical training.	Grid computing used to demonstrate the usability of the technology in promoting resource collaboration in a ubiquitous healthcare.
Asthma in home monitoring [39]	Allowing management of asthma among children diagnosed with the disease. The children are monitored for their peak flow breathing via video monitoring and a device that enables them to record the measurement. The benefits are not only the costs associated with long term hospitalization of the chronically ill children but also a better quality of life.	A measurement device, a video monitor to send information, a secure website where the information is uploaded.
IST Vivago Wristcare [44]	Allows for independent living and unobtrusive monitoring of wellness by the usage of a wireless wrist worn device with several sensors, alarm receiving and sending capacity to healthcare services.	Wireless wearable device, sensors, base station communication over telephone lines and automatic alarm triggers.
Effectiveness of remote asthma monitoring [43]	Outcome study for the effectiveness of an interactive electronic monitoring system for lung function and management of refractory asthma.	Monitoring device connecting asthma patients to the caregiver in a continuous manner by using mobile computing.
Secure Smart Homes using Jini and UIUC SESAME [38]	Provides secure smart living environment in ubiquitous computing.	Dynamically configurable devices which are intelligent and offer assistance to the users.

Table 2. Applications of Ubiquitous Healthcare

Although ubiquitous healthcare has caught the attention of researchers across the world and most of the components required for achieving the goal exist as is evident from the assessment of applications/projects in this domain and also conferences and workshops like UbiHealth 2003 [45], however the **whole vision** seems more than the sum of the individual components. The area of future work might include: ways to establish fault proof privacy, security and trust in the system, high level of context awareness and reliability. Power management of mobile devices with limited power and dependable communication networks especially in areas where coverage is spotty forms an important thrust of future work. Scalability and ways to promote collaboration as a means of sharing computing resources among devices with limited computing power are other critical aspects of ubiquitous healthcare that needs more research. Healthcare is an industry where errors can have fatal consequences hence it is imperative to build a system which is dependable and trustworthy.

CONCLUSION

Healthcare is an important constituent of modern societies, representing a large percentage of GDP (approximately 15% of GDP), sustaining a high political profile and a strong public interest. The healthcare industry today faces a crisis due to

spiraling healthcare costs coupled with a parallel increase in aging population. This phenomenon is not restricted to a country or culture but is common across the globe. Healthcare sector doesn't have the financial or human resources to meet the demands of the changing demography. Hence new innovative strategies are needed to deal with the current crisis. Given the current context this research presents ubiquitous healthcare as a remedy to the terminal ailments of the healthcare sector. The objective of the research is to assess the current state of healthcare organization and analyze the opportunities and challenges provided by a ubiquitous healthcare environment. The contributions made by the current research are multifold. First it provides an analysis of the healthcare environment and identifies potential opportunities and challenges along with an architectural framework for ubiquitous healthcare environment depicting the enabling technologies and the opportunities for patient interaction in the ubiquitous healthcare environment. The benefits arising from ubiquitous healthcare environment translate into quality healthcare with cost containment, efficiency in the usage of financial as well as human resources, better quality of life to the elders suffering from chronic ailments by providing ubiquitous monitoring in a secure, reliable fashion. Second, the research evaluates the myriad of technologies that could enable ubiquitous healthcare and develops a classification framework classifying the technologies. The challenges/requirements associated with ubiquitous healthcare environment are examined against the enabling technologies. Third, it evaluates the various applications in the realm of ubiquitous healthcare and provides a table outlining the different applications/projects. This helps in identifying the areas within the healthcare domain where ubiquitous healthcare is beginning to take roots, the technologies which have been the most critical, the facets of ubiquitous healthcare addressed by each application and the areas which need further research.

Although, ubiquitous healthcare is still in its infancy it is needless to say that the possibilities are vast and the realization process has merely begun. Future work will help to fine tune the concept and help to bring forth the realization of a ubiquitous healthcare environment. It is our hope that some of the current issues will open the door for future research. Future work may address the issue of issue of acceptability of the system along with the level of trust of doctors and patients in the ubiquitous healthcare environment. A research based on testable hypotheses can potentially provide some substantive finding with respect to adoption of ubiquitous healthcare. In the light of HIPAA, security and reliability of transactions made over a wireless network are important concerns. Since critical patient information is transacted in the wireless solution, hence there is a need to provide secure healthcare transaction environment while providing high quality healthcare (Sneha et al., 2005). Wireless networks still have a relatively lower level of security and reliability than the wired networks. Future research addressing the issue of increasing security and reliability of mobile communication is imperative to the success of ubiquitous healthcare.

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