

# Mobile Computing in Healthcare

## Needs, Applications, Issues and Future Trends

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**Abstract**—Some of the key elements in revolution includes advancement in digital networks that expand the power of cellphones. These advancements in mobile computing has a potential impact to improve health care delivery, reduce health care costs, make health care services more convenient to patients and increase the overall efficiency and effectiveness of health care providers. Wireless technologies enable health care providers to monitor patients remotely, and give them timely health information, reminders and support. In this paper, we identify some key applications of wireless computing in healthcare environment, challenges and issues in bringing mobile computing to everyday practice and future trends.

**Keywords**—component; healthcare; mobile; cellphone; ubiquitous; applications; health IT;

### I. INTRODUCTION

With the recent outburst of smartphone technologies and worldwide deployment of mobile and wireless networks, it has become quite obvious that wireless infrastructure can support many current and emerging healthcare applications. For an example, consider a clinician who has just provided an inpatient service to a patient. The clinician could enter a description of the service on a paper record at the patient's bedside. Alternatively, the clinician can simply enter specific parameters of the service in a mobile device. This data entered are automatically sent to the billing systems via wireless networks. How cool would be that? Another interesting application would be writing a prescription using a mobile device that transmits the order via the Internet to the appropriate pharmacist.

Cell phones were first introduced in US in mid-1980s. In 1984, there were just 340,00 cell phone

subscribers in US. This number has grown to nearly 303 million by 2011 and nearly 96% of US people have cell phones. Global cellphone penetration is continuing to grow rapidly. As the popularity of cell phones increased, so has their functionality.

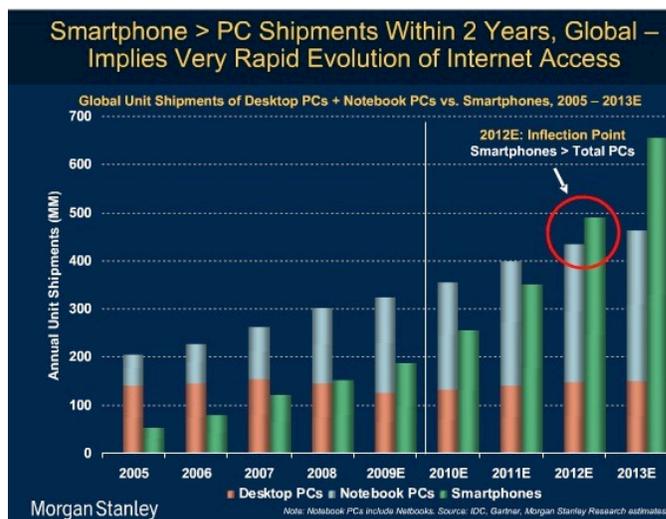


Figure 1. Mobile Computing facts from MorganStanely.

In the first year of its existence, 1981, the IBM PC sold 100,000 units. Most of those buyers were geeks or leading-edge business users. Apple's iPad sold 1 million units in less than one month and 2 million units in just two months. iPad users still include geeks and business types but they are just as likely to include your six-year-old and your grandmother.

The introduction of telecommunications technologies in healthcare environment has led to an increased accessibility to healthcare providers, more efficient processing, and a higher quality of healthcare services. While the current and emerging wireless technologies could improve the overall quality of service for patients

in both cities and rural areas, it also reduces the stress and strain on healthcare providers while enhancing their productivity, retention and quality of life and reduces the long-term cost of healthcare services. Due to lack of accurate and comprehensive information at the location and time when it is needed, lots of medical errors occur which ultimately result in wrong diagnosis. The required information can be made available at any time any place using urbane devices and wireless networks. Although these errors cannot be completely eliminated, but some of the informational errors can certainly be removed by such technologies. Some of these technologies include location tracking, user interfaces, body sensors, and short-range wireless communications of health monitoring, universal wireless access to increase the accessibility of healthcare providers, and trustworthy communication between devices, patients, and healthcare providers.

In this paper, we present the trends and applications of mobile computing in healthcare industry. We also present a vision of pervasive healthcare that includes requirements and applications of pervasive healthcare.

## II. SUITABILITY OF UBIQUITOUS DEVICES FOR HEALTHCARE

Particularly cell phones have four attributes that make them well suited for delivering high quality health care applications. These attributes include:

### A. Personal

As each cell phone is personal to a particular person, applications can be targeted to that particular individual.

### B. Ubiquitous

Individuals take their cellphones wherever they go. Therefore, continuous physiological monitoring is possible everywhere and information and services can be delivered when and where they want.

### C. Connected

Cell phones provide direct access to valuable resources and information. They also provide support to peer groups.

### D. Increasingly intelligent

Smartphones are essentially as intelligent as small computers that can capture, store and process information.

Because of their ubiquity with low cost, cell phones and other mobile computing devices are very well suited for supporting and treating many diseases. These technologies make it possible for healthcare providers to monitor patient’s health and to guide patient’s self-care beyond the limits of clinic, improving overall outcome and reducing cost. Mobile healthcare are primarily driven by five forces:

- Providing medical and health related information to consumers via text messages or interactive applications is driven through large content becoming available through Internet. Because of cell-phone’s ubiquity and personal, they have ability to deliver content anytime anywhere.
- As the awareness about health concerns and risk grows among individuals, they are more open to technologies that can quickly signal them or provide alerts about potential hazards.
- As the size of sensors are reducing continuously, and becoming more reliable and less power hungry, they are likely to be incorporated into portable and ubiquitous devices like cellphones.
- Wireless networks are becoming more stable day by day. This extends the opportunities to connect patients with physicians or healthcare providers. Remote monitoring of patients has become possible and can aid providers in rapidly identifying signs of abnormal functions and provide timely medication or treatment.

The Bulletin Healthcare survey also found notable differences in mobile device adoption rates among different specialties:

TABLE I. MOBILE DEVICE ADOPTION RATES AMONG DIFFERENT HEALTH SPECIALIZATIONS (HIRSCH, 2011)

Specialty	Mobile Adoption
Physician Assistants	41%
Emergency Room Physicians	40%
Cardiologists	33%
Urologists	31%
Nephrologists	31%
Dermatologists	30%
Gastroenterologists	30%
Psychiatrists	28%
Optometrists	28%
Radiologists	24%

Specialty	Mobile Adoption
Rheumatologists	22%
Endocrinologists	21%
Oncologists	20%
Clinical Pathologists	16%

### III. APPLICATIONS OF MOBILE COMPUTING IN HEALTHCARE

There are two major categories of mobile applications for healthcare:

#### A. Applications that monitor physiological functions and send information to patients

Monitoring applications such as examining blood glucose level, heart functions, vital signs rely on sensors that may be portable, or implantable. Communications of these types of applications are primarily from patient to providers. They offer more accurate diagnostics and rapid response to medical emergencies.

#### B. Applications that deliver information and feedback to patients

Patient appointment reminders and health education are examples of this kind of application. Communications in these applications are majorly from providers to patients.

### IV. PHYSIOLOGICAL MONITORING APPLICATIONS

These applications enable remote continuous monitoring of various physiological functions as they go about their daily activities. This results in more up to date and accurate diagnoses, which ultimately improve patient's health problems. They make continuous monitoring of patients possible as they go about their daily life activities. Some of these applications include:

#### A. Cardiac monitoring

It was introduced in 1947. This device enabled continuous recording of heart function outside clinical setting. The patients typically wear the monitor, which includes set of electrodes attached to patient's chest and a recording device. The patient normally wears this device for a period of 24 hours and then returns it to their physician for analysis of readings. Newer devices have the capability of wirelessly communicating the readings. Researches have shown that extended cardiac monitoring can detect a larger range of problems than short-term

diagnoses. A device called *Vitaphone* which has sensors integrated into normal cellphone can collect electrocardiogram readings anytime and with its GPS capability, medical assistance to the patient can be provided if needed.

#### B. Blood Glucose Monitoring

Heart diseases, stroke, blindness, kidney failure, pregnancy complications, and limb amputations are all consequences of diabetes if not properly controlled. To avoid such complications, a diabetic patient must carefully monitor blood sugar level. Wireless and ubiquitous devices can be a useful tool to diabetics and physicians to help manage the disease better. With the use of *GlucoPhone*, users can send their monitoring data to online medical management database and also, at user's discretion, can be forwarded to personal physician. This can help physicians recommend a change in medication by tracking patient's health status.

### V. PATIENT COMMUNICATION AND SUPPORT APPLICATIONS

Along with supporting remote monitoring, cell phones and wireless devices provide a wide horizon for communication between patient and healthcare providers. Such applications not only allow providers to communicate with the patients anytime anywhere, but they also deliver-health related information at a time and place where they have utmost influence. The outcome is lower-health related costs. Some of these kinds of applications include:

#### A. Patient Records – EHRs and PHRs

Many systems like *eClinicWorks*, *LifeRecord*, *MacPracticeMD* offer smartphone capabilities. With the implementation of American Recovery and Reinvestment Act of 2009, stimulus funding will be distributed to health providers who implement Electronic Health Records (EHRs). Mobile EHRs could allow physician to access the patient's information that further allow physicians to communicate to the patients anywhere at anytime. Also, as consumers get more engaged to in tracking their health records, Public Health Records (PHRs) will gain acceptance. There are couples of PHR's that are available for smart phones. For example, *Polka* works for iPhone. It stores and analyses the consumer's personal health data, and offers health reminders. In addition to this app, there are several other emergency apps available.

### B. Health Education

Health educators generally face difficulty in reaching out young people to educate regarding health. Cellphones can be used as a promising tool to reach out young people. Several health campaigns that deliver messages to cell phone can be an assuring alternative. For an example, in 2006, the San Francisco Department of Public Health introduced SexInfo. SexInfo is a free service that answers youth questions about sex through text messaging. It also gives contact numbers and location of local clinics.

### C. Appointment Reminders

Giving out frequent reminders about patient's appointments through text messages or through an interactive application can improve administrative efficiency and increase the effectiveness of physician's time. This could ultimately result in healthcare savings.

### D. Public Health Alerts

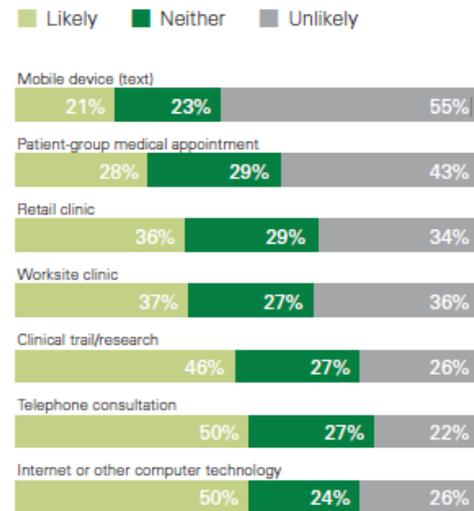
Text messaging can help in tracking disease outbreaks and also in providing timely alerts regarding health hazards or epidemics. Other potential applications could be to provide warnings of dangerous levels of pollution or notifying upcoming tsunami.

### E. Doctor-Patient Communication

Communication between doctor and patient is very important to as in to convey important information to patient or to update patient's health status to doctor so that doctor can act instantly. Live, two-way video conferencing app between doctor and patient would be a direct way of communication between doctor and patient. While these technologies can help physicians provide more timely diagnoses and treatment, it makes health care more convenient and pleasing for patients.

## VI. PROBLEMS AND ISSUES

There are many challenges and issues in realizing the usage of mobile computing in healthcare. A broader view of such challenges includes lack of willingness to use alternative methods to get care, lack of comprehensive coverage of wireless and mobile networks, reliability of wireless infrastructure, limitations of handheld devices, lack of medical sensors in mobile devices and privacy and security. According to *PriceWaterhouseCoopers* Survey, one half of US health consumers are willing to take online care and consultation with clinicians over a phone. Figure 2 cites the overall results.



Note: Segments may not add up to 100 percent due to rounding.

Source: *Top 10 Health Industry Issues in 2010: Squeezing the Juice Out of Healthcare*, PricewaterhouseCoopers, December 2009.

Figure 2. Consumers willingness to Use Alternative Methods to get Care, 2009

### A. Health System Not Configured to Use Wireless Applications

To benefit from the wireless applications and mobile applications, the health care system has to adjust to the new technological advancements. The current system is not well configured to meet the health care needs. Wireless tools can help to overcome this shortcoming, but their usage will be limited because the tools are not linked to each other. There are several efforts being made towards this direction.

For example, *Alere Medical*, one disease Management Company, remotely monitored patients using a device called *DayLink* monitor. This act ultimately got success. Results showed that diabetic patients who received support through the monitor reduced medical costs up to 40%.

### B. Privacy and security

One of the primary concerns of mobile health computing is protecting the privacy and security of patient information. There are many issues of which providers or patients are unsure about. Some of these are: How can patient and providers be sure that only authorized persons will receive the data? What happens if wireless device that contains important data is misplaced or stolen? Has the information transmitted securely or not?

According to Health Insurance Portability and Accountability Act of 1996, wireless technologies must meet privacy and security provisions. Some of the policies that govern wireless health care applications at Yale University are:

- If protected health care data is stored on the handheld mobile device, it should be encrypted and also the access should be password-protected.
- There should be a user id/password level security to protect the data if the device is stolen or lost. There should be user/device validation during synchronization and encryption of data stored on the device.
- Before and data transmission, authentication should be enforced and the data should be encrypted during transmission.

### C. Lack of Standards

Most of the applications and technologies available in mobile healthcare industry are stand-alone tools. These all applications lack technological standard. This means some applications may not be compatible with other or some applications will work only on specific type of cellphone. One of the most important issues is ensuring that the data generated for monitoring devices are encoded in standard format, which may allow the information to be stored and managed by different types of data stores.

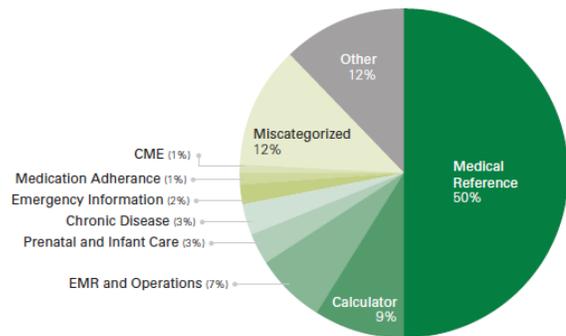
### D. Lack of Total Network Coverage

No cell phone networks offer complete network coverage across the entire United States. Many rural areas of the countries still lack network coverage, and even in major cities, the service is sometimes poor. These limitations may be problematic for wireless health care applications. Joseph Kvedar, M.D. director of the center for Connected Health in Boston mentioned: "If one the text message out of hundred messages between friends goes amiss, it doesn't matter. But if one heart reading of a cardiac patient is not delivered, someone could die." At the minimum, the applications should be designed such that devices should be able to store the data or messages whenever they are offline and to deliver the data or messages when they become online.

## VII. HEALTHCARE SMARTPHONE APPS

There are many smartphone applications being written for smartphones that are focused on professional health management or targeted at healthcare professionals. As of February 2010, there were 5805 health, medical and

fitness applications within the Apple AppStore. The figure 3 depicts different categories of medical apps and their share.



Source: "The World of Health and Medical Apps," *MobiHealthNews 2010 Report*, February 2010.

Figure 3. Medical iPhone Apps, 2010

Some of the apps are featured here:

### A. BMI

Developer: DVMagic Studios Inc.

This app simplifies many calculations necessary in determining various factors of your body health stats. This application helps to sort out the many factors (BMI, BMR, LBM, Body Fat%, Water Consumption, Body Shape, Body Measurements, weight, height, gender, activity level, etc.) into a quick and easy to understand summarized manner. This tool can be used in weight loss, gain, or maintenance for a healthier overall lifestyle.

### B. Epocrates

Developer: Epocrates

The company claims that more than 900,000 health care professionals regularly use Epocrates to make medical decisions and improve patient safety. This app provides access to things like clinical information on prescription medicines, effective treatments among over-the-counter products and drug interactions, information on things like alternative medicines, treatment guidelines and medical definitions.

### C. Medical Calculator

Developer: MarketWall.com

This application helps doctors and nurses compute useful formulas and equations. With more than 200,000 installs worldwide, this is the most popular Medical Calculator for the iPhone. This clinical calculator gives you quick access to calculations that are too hard to memorize or perform in your head.

### D. Calorie Track

Developer: SkyWolf Tech

This app helps you track your personal food intake. It allows easy entry of meal information on your iPhone or iPod where ever you go. It also keeps track of what you are eating and the nutritional values as you are eating. It graphs your food history to see trends.

#### *E. BP Tracker - Blood Pressure Tracker*

Developer: BHI Technologies, Inc.

You can use this to easily log your BP, HR, medication and other useful information on your iPhone. It provides powerful graphing that shows weekly/monthly/quarterly trends and logging your medication data. This app shows tips to help you maintain a normal blood pressure level and supports to write notes for each BP entry.

#### *F. BKS Medical Encyclopedia*

Developer: BEIKS LLC

The application enables anyone with an Android handheld to carry vast amounts of information in their pocket or purse. The encyclopedia includes medical terms, pertinent scientific items, abbreviations, acronyms, jargon, institutions, projects, symptoms, syndromes, eponyms, and medical history.

#### *G. Menstrual Calendar*

Developer: WITIZ

This app allows every woman to track period, ovulation, temperature & more. You can have cycle Report and Basal Body Temperature Chart. Also use historical data to forecast menstruation and ovulation.

### VIII. FUTURE TRENDS

There are several new healthcare applications that can evolve along with current applications such as mobile telemedicine. Some of these applications are:

#### *A. Intelligent Emergency Management System*

Intelligent Emergency Management System could be devised using the intelligence and information from mobile and wireless networks. This system would be able to manage a call received due to accident and effectively manage the emergency vehicles.

#### *B. Health-aware mobile devices*

Mobile devices could detect certain conditions by the touch of a user. Integration of handheld wireless devices with portable medical devices would allow detection of blood pressure, pulse rate and may be level of alcohol.

#### *C. Pervasive lifestyle incentive management*

Pervasive lifestyle incentive management involves giving a small mobile micro-payment to a user device every time a user exercises or eats health food. This incentive could then be used for donating to a charity, paying wireless monthly charges or paying healthcare expenses. Such a system can lead to healthier individuals and thus reducing the overall cost of healthcare services.

#### *D. Healthcare Information Access*

Pervasive access to healthcare information would allow a healthcare provider or patient to access the current and pass medical information. This will ultimately result in reduced number of medical errors by having access to current and complete information anytime anywhere by healthcare providers. Another application of this category can be "Mobile Healthcare Data Center" that can support a large amount of stored healthcare data to be made available to authorized decision makers for making healthcare decisions. Researchers maintaining patient anonymity can also use this data to carry out researches.

#### *E. Comprehensive healthcare monitoring services*

Comprehensive healthcare monitoring services would allow patients to be monitored anytime at any location. Using current conditions and his/her medical history, actions can be taken such as sending alert message to the nearest ambulance or a healthcare specialist. These services could reduce the time between the occurrence of an emergency and the arrival of needed help.

### IX. CONCLUSION

What we believe is that mobile and wireless technologies can prove a boon to healthcare. It can have a substantial impact, in general, or they may become a vital tool for improving disease management, in particular. The role of mobile technologies in healthcare applications is expected to rise and become more prominent with an increase in mobile society and deployment of mobile and wireless technologies. But realizing the real potential of mobile and wireless technologies will require significant changes in the way the health care is structured and how the medical services are delivered. It is expected that researchers will address several challenges and issues cited in the paper and developers and we will reach a step closer to realizing a prospect of mobile healthcare.

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