Abstract

Wireless networking is relatively new and exciting technology for health care. Using handheld peripherals and wireless networking technologies, medical professionals can have omnipresent access to patient information, clinical functions, and business functions. Wireless networks bring information access, data collection capabilities, and clinical applications closer to the point of care than is possible using wired networks. State of the art health-monitoring devices using wireless technologies offer a convenient means to monitor and manage patients with chronic diseases in their homes. Hand-held applications present convenient, non-invasive solutions for meeting new requirements to reduce errors and to increase patient safety. Wireless devices also enable medical professionals to access patient data in the hospital’s clinical data repository. This on hand means to access data would increase productivity, reduce billing errors, and improve the quality of care. Wireless networks are also attractive to the information technology (IT) professional because they are relatively easy and inexpensive to deploy, with minimal disruption to operations.

Maintaining the security, performance and reliability of a wireless LAN is challenging due to the uniqueness of the healthcare setting. In the mission-critical environment of healthcare, delivering the very best in patient care requires all medical professionals to be accessible and instantly able to reach colleagues as well as access all patient data.

A disconnect does exist between the healthcare industry’s enthusiastic endorsement of wireless technologies and existing vulnerabilities in wireless technology. Health Insurance Portability and Accountability Act (HIPAA) ensures regulations of protecting patient records, especially private information against unauthorized access. However, the increasingly popular wireless network devices used in healthcare facilities, though convenient and timesaving, increases the administration difficulty of network security. This paper provides an overview and guide for healthcare managers with limited IT resources yet greater need to deal with the information security threats through wireless communication.

The Growth of Mobility
The world is in the midst of a wireless communications revolution. The most visible aspect of this global revolution is the explosive growth of cell phones, both in the United States and abroad. Other key elements of the revolution include advances in short- and medium-range digital networks that expand the power of cell phone networks, in sensors that enable remote monitoring, and in the batteries that power portable devices.

Together, these innovations are creating a pervasive broadband wireless environment that can support a wide range of new uses. While most wireless applications to date have focused on providing mobile communications, information, and entertainment, a growing number of applications related to health are appearing. These applications hold the potential to improve health care delivery, reduce costs, increase the efficiency and effectiveness of health care providers, and make services more convenient for patients.
Wireless technology enables clinicians to monitor patients remotely and give them timely health information, reminders, and support — in short, to greatly extend the reach of health care, ultimately making it available anywhere, anytime. However, if this potential is to be realized, a number of issues must be addressed. These include health industry issues, such as uncertainty about provider reimbursement, unproven clinical benefits, a health system that is not well-configured for wireless innovations, and concerns about maintaining privacy and security; technological issues, such as potential information overload for providers and a lack of standards; and issues arising from a fragmented cell phone market and differences between that market and the health care market.

During the last decade, mobile phones have evolved from being a novelty to being a necessity for a substantial majority of Americans. In 1984, there were just 340,000 cell phone subscribers in the United States. By 1990, more than 5 million cell phones were in use; in 2006 the number had grown to 233 million, and nearly three-fourths of Americans older than 18 had one.¹

As the popularity of cell phones has increased, so has their functionality. Cell phones are doing much more than simply providing mobile voice communications; they also have become a platform for delivering a growing variety of applications. Mobile devices are rapidly evolving from a device just for making mobile voice calls into something much more versatile: a personal, portable, multipurpose, multimedia computing and communications device. A good example of the current state of the art device is Apple’s iPhone, introduced in June 2007. In addition to serving as a conventional mobile phone, the iPhone can be used to store and play music and videos; take, store, and view photos; keep track of contacts and appointments; find a location on a map; send and receive email; and surf the Web.

As cell phone networks become more pervasive and more capable, they are creating opportunities to deliver mobile health care applications. Part of the potential value of cell phones for delivering health-related applications is their ability to leverage several related technologies, including short-and medium-range wireless networks and miniaturized sensors, which also are evolving rapidly. Also important is battery technology; it plays a role in determining which mobile applications are feasible.

Combinations of these technologies are creating a variety of opportunities for remotely monitoring patients’ physiological functions and for providing information to and support for patients in managing their own health. A variety of short-range digital network technologies have allowed computers and other devices from being tethered to wires and cables. Technologies like Bluetooth can transmit data from a physiological monitor on the body to a nearby external receiver.

**Wireless Data Networks**

Wi-Fi is a medium-range network standard that enables laptop computers and other devices to connect wirelessly to the Internet from “hot spots” in millions of homes, offices, and public facilities at great distances. This standard has evolved through several generations, each operating faster and over a greater range than prior generations. Nearly all recent laptop computers and many other mobile devices, including a growing number of cell phones, have
Some medical devices use Wi-Fi to link monitoring sensors to a nearby receiver that can connect to a long-range cell phone network for transmitting data to a remote site, such as a physician’s office.

**Sensors**

Miniature sensors are available that can accurately monitor a variety of physiological functions, including physical activity, respiration, body temperature, heart rate, muscle function, blood glucose levels, and oxygen saturation. Increasingly, many sensors are small enough to be worn on or implanted in the body. When their output is linked to external networks, the sensors provide opportunities for remote patient monitoring. A critical element in the effectiveness of sensors is the accompanying software that processes their output and aids interpretation of the data they generate by tracking trends or detecting important events. Thanks to hardware and software improvements, the accuracy and sensitivity of sensors have been steadily increasing while their size and cost have been declining.

**Batteries**

Portable wireless devices depend on batteries to power their operations. Bigger batteries provide more energy, but they may not meet the size and weight requirements of many portable devices.

Although research is leading to improvements in battery performance, no major breakthroughs appear likely in the near future. Reducing their power needs rather than increasing the capacity of batteries has achieved much of the recent gain in the performance of portable devices such as cell phones and health monitoring devices.

**The Demographics**

The aging of the U.S. population and the increasing occurrence of chronic diseases are creating an urgent need for better tools to monitor patients’ health status and help them manage their health. Thirty-eight percent of Americans, or 125 million people, have at least one chronic condition, while 11 percent have three or more. The likelihood of having at least one chronic condition increases with age: Fewer than 10 percent of Americans younger than 44 years old have a chronic disease, compared to 23 percent of those between the ages of 44 and 64, 34 percent of those from age 65 through 74, and 45 percent of those 75 years or older.

Caring for patients with chronic conditions accounts for more than four-fifths of all health care expenditures, or more than $1.4 trillion annually—an amount that is projected to increase by at least 25 percent over the next two decades as the baby boomers age.

Many of the wireless applications are designed to improve chronic disease care. Those for remotely monitoring physiological conditions can give clinicians detailed and timely information about a patient’s illness, while other applications can support and encourage patients to do a better job of managing their own health.

**Why Wireless Health Care?**

In the last few years, dozens of health-related applications for cell phones and other wireless technologies have been introduced in the United States and elsewhere. Most of these applications are relatively new, and evidence from controlled trials regarding their effectiveness is limited. Moreover, applications that work well in other countries may be less viable in the United States.
because of differences in health care delivery, legal issues and technological infrastructures.

These technologies could benefit the healthcare industry by:

- Increasing the convenience of diagnostic procedures while improving the speed and accuracy of diagnoses, particularly in detecting intermittent problems that more limited, short-term clinical tests may miss.
- Supporting continuous monitoring of patients’ chronic conditions, thus enabling providers to detect and respond to problems as they occur, which reduces costly medical complications.
- Reminding patients to keep medical appointments and helping them to comply with prescribed medical regimens.
- Encouraging better patient self-management of chronic conditions via timely, personalized feedback about the patient’s health status and support for self-care.
- Increasing providers’ efficiency and effectiveness by giving them access to current information on patients’ health and a convenient way to deliver appropriate advice and support.
- Enabling earlier hospital discharges while maintaining a high level of patient surveillance through remote monitoring.
- Providing a new channel for targeted public health campaigns, particularly those aimed at groups such as young people, who are generally difficult to reach through conventional campaigns.

Although these benefits seem compelling, realizing them will require significant investments in new technology. In addition, integrating wireless applications into health care will require new procedures and processes entailing significant changes in how physicians and other providers do their jobs, a prospect that is likely to meet resistance. Finally, a number of technological, regulatory, economic, and structural issues will have to be addressed before wireless technologies become part of mainstream medical care.

**Types of Applications**

There are two major categories of wireless applications for health care: (1) applications that monitor physiological functions (in cardiac and diabetic patients, for example) and send the information to physicians; and (2) applications that provide information and feedback directly to patients, thus encouraging them to pay attention to and take a more active role in managing their health.

Applications that enable remote monitoring of various physiological functions are among the most mature wireless applications. Monitoring applications vary in terms of the physical placement of the sensors they employ. They also differ in terms of the direction of information flow and the types of communication they use. Monitoring applications, such as those for heart function, blood glucose level, and vital signs, rely on sensors that are portable, wearable, or implantable. Communications for these applications are typically “upstream” (from patient to
provider); they offer opportunities for faster and more accurate diagnoses, particularly of intermittent problems, and for more rapid response to medical emergencies.

In contrast, patient communication and support applications—for appointment reminders, health education and promotion, and the like—are primarily “downstream” (from provider to patient), although more advanced applications may involve two-way communication. Many of these are based on text messaging on cell phones using short message service. Newer applications make use of multimedia message service or two-way video on more advanced phones.

The FDA (Food and Drug Administration) has approved use of several of these applications; they include:

- **Cardiac monitoring**: When it was introduced in 1947, the battery-powered monitor improved cardiac diagnosis by enabling continuous recording of heart function outside the clinical setting. Patients typically wear the monitor, which includes a set of electrodes attached to their chest and a recording device, for a period of up to 24 hours, and then return it to their physician for an analysis of the readings.

- **Blood glucose monitoring**: If not properly controlled, diabetes can lead to a variety of serious problems, including heart disease, stroke, blindness, kidney failure, pregnancy complications, and limb amputations. To avoid complications, diabetics must carefully monitor and control their blood sugar levels. Conventional glucose meters have become smaller and more accurate over time, and the most recent generation of “smart meters” can store multiple results and display them in chart form, giving patients more information about their condition. Wireless applications can help diabetics and their care providers manage the disease even better. For example, the some devices enable users to send their monitoring data to an online repository and immediately share it with clinicians, who can track patients’ health status and, if necessary, recommend changes in medication. Efforts are under way to automate the sampling process by means of implantable wireless devices that provide continuous blood glucose readings. More frequent measurements increase the likelihood of detecting and correcting changes that less frequent monitoring may miss. It is likely that future generations of glucose meters will incorporate similar wireless capabilities.

- **Multiple vital signs monitoring**: Many patients, particularly those who are elderly, have more than one health problem or chronic condition. Wireless systems under development can monitor multiple physiological functions, providing a broader spectrum of information that gives physicians greater opportunities to manage variety of health problems. Multifunction monitors may supplement or even replace some clinical services, and may help reduce costs as a result of more timely treatments, earlier hospital discharges, or fewer emergency room visits.

- **Wearable Physiological Monitoring Applications**: An emerging type of remote monitor is in type of wearable garments that incorporate strategically placed sensors and a wireless transmitter to send monitoring data to an external receiver. These garments automatically collect data on multiple vital signs and enable wearers to engage in normal activities.

- **Implantable Physiological Monitoring Applications**: These wireless devices are
intended for longer monitoring use—in some cases, for the patient’s lifetime.

- **Wireless pacemakers and defibrillators:** Implanted in the chest, pacemakers use electrical pulses to regulate heart rhythm, and defibrillators provide an electric shock to restore normal heartbeat. Pacemakers and defibrillators save lives by responding instantly to abnormal cardiac activity and restoring normal heart function.

**Patient Communication and Support Applications**

In addition to remote monitoring, mobile devices can expand the opportunities for patients and providers to communicate with each other. Via simple text messaging, emerging applications in this category can remind patients about appointments, promote information on medicine interactions, and deliver information and encouragement to help patients manage their health. Such applications not only enable providers to communicate more frequently with patients, but also—at least in theory—to deliver health-related messages at precisely the times when, and places where, they can have the greatest impact. The goal is better patient outcomes and lower health-related costs. Few applications of this type have been experimented with in Europe and Asia, where cell phones are more pervasive and text messaging is more common.

- **Appointment Reminders:** Reminding patients of upcoming appointments by sending text messages to their cell phones is a relatively simple, straightforward application that could improve administrative efficiency and increase the effectiveness of physicians’ time. This could generate substantial savings for health care providers. A 2005 survey by the British Institute of Healthcare Management found that patients in Great Britain who missed general practitioner, practice nurse, and hospital appointments cost the National Health Service about $1.58 billion a year. According to a study, missed clinic appointments among dermatology patients declined by 50 percent where patients received appointment reminders via text message. ⁴

- **Health Education and Promotion:** Young people are among the most active users of cell phones and text messaging. Given that health educators have had difficulty reaching this group through conventional channels, campaigns that deliver messages by cell phone may be a promising alternative.

- **Public Health Alerts:** Text messaging also can help track disease outbreaks and provide timely alerts regarding potential health hazards. For example, during the 2003 SARS outbreak in Hong Kong, a local cell phone company provided subscribers with access to a government database of buildings where the disease had been reported. This service leveraged the GPS capability of cell phones to pinpoint a subscriber’s location. ⁵

- **Compliance Reminders and Treatment Support:** Noncompliance with drug regimens is a serious, widespread problem. Surveys have found that only about half of all patients adhere to a regimen after they leave the doctor’s office with a prescription. Forgetfulness is the most common reason for noncompliance. ⁶

**Issues and Implications**

Numerous issues must be addressed if mobile technologies are to gain a firm foothold among providers and patients. These issues include the role of wireless innovations in health care, technological hurdles, a fragmented cell phone market, and differences between that market and the health care market. Nevertheless, some experts believe that wireless health care applications are promising.
Some key forces are driving momentum for wireless applications in healthcare:

- Wireless devices and networks allow continuous and real-time link between the patients and the healthcare system. Remote monitoring enables healthcare providers to rapidly identify signs of abnormal function and provide timely intervention to avoid severe problems. Indeed, wireless applications may be the most cost-effective way to manage millions of chronically ill patients.

- Providing medical information to consumers via cell phones and other wireless devices is the logical next step in the information evolution that began with such content becoming available on the Internet.

- Quicker access to information in cases of major outbreak of infectious diseases would make patients to be more receptive to technologies that quickly alert them to potential hazards.

- As sensors become more reliable and less power-hungry, they will be more likely to be incorporated into wearable or implantable devices that function for an extended period of time.

There are still many challenges in using wireless technologies in healthcare that must be addressed. These include a lack of comprehensive coverage of wireless and mobile networks, reliability of wireless infrastructure, general limitations of hand-held devices, medical usability of sensors and mobile devices, interference with other medical devices, privacy and security, payment and many management issues in pervasive healthcare. These issues and challenges can be grouped under the following categories: technologies, medical and management.

Technology Issues: The technology issues related to the introduction of wireless network technologies in healthcare includes networking support such as location tracking, routing, scalable architectures, dependability and quality of access. These issues also include how to provide patient monitoring in diverse environments (indoor, outdoor, hospitals, nursing homes, assisted living), continuous vs. event-driven monitoring of patients, use of mobile devices for healthcare information storage, update and transmission, sensing of vital signs and transmission using cellular networks and wireless LANs, formation of ad hoc wireless networks for enhanced monitoring of patients, managing healthcare emergency vehicles and routing and network support for mobile telemedicine.

Medical Issues: The medical aspects are very important in realizing a wide-scale deployment of wireless network technologies in healthcare. The issues of how patient care is delivered, how medical information can be represented and requirements of diverse patients must be addressed. Many important issues include the design of suitable healthcare applications, specific requirements of vital signs in healthcare environment, diversity of patients and their specific requirements, representation of medical information in pervasive healthcare environment (multimedia, resolution, processing and storage requirements), role of medical protocols, improved delivery of healthcare services and usability of wireless-based solutions in healthcare. The diversity of patients can range from uncontrollable energetic children, violent youth and midlife, depressed or frail seniors. The requirements presented by these people to wireless networks vary significantly from keeping track of the behavior of kids to how to avoid wandering and getting lost for dementia patients. It will be a major challenge to involve people with mental illness to use wireless infrastructure due to their limited functional intelligence or
their limited memory functions (such as Alzheimer’s). Many of these also suffer from psychiatric disorders such as paranoia resulting in a suspicion towards wireless technologies, especially those once requiring a patient to wear a locator or other device.

Management Issues: The management of pervasive healthcare could bring a mini-revolution in terms of how wireless network technologies in the healthcare environment is implemented, offered and managed. There are many challenging and diverse management issues that must be addressed including the security and privacy in wireless healthcare, training of healthcare professionals for pervasive healthcare, managing the integration of wireless solutions, increasing coverage of healthcare services using wireless technologies, legal and regulatory issues, insurance payments and cost aspects and potential implications of HIPAA (Health Insurance Portability and Accountability Act of 1996). The usability and integration of wireless-based solutions in healthcare is another challenge. The devices must be designed to offer intuitive interfaces that can learn with and from individuals. It has been shown that many less-technically savvy population segments are willing to learn and use mobile and wireless technologies for allowing them to live more independently.

The training of healthcare professionals to effectively utilize mobile and wireless technologies would be a less complex issue as an increasing number of those are using hand-held and wireless devices. Another major issue is how to reduce the cost of delivering healthcare services to as many people by using wireless infrastructure. Other challenges in the large-scale introduction of wireless infrastructure in healthcare are legal and regulatory issues such as the issues of liability and lawsuits in the USA and possibility of insurance companies not paying or paying differently for treatment via mobile devices. Another major issue is the privacy and the possible misuse of patient medical information. In the USA, a major regulation termed HIPAA (Health Insurance Portability and Accountability Act of 1996), which have been designed to protect such information, has received some controversy and has been interpreted differently by major players, healthcare providers, insurance people and attorneys. Some work is needed in addressing privacy and related concerns over wireless and mobile networks where security is still seen as insufficient.

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