Medical Applications of Wireless Networks

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Abstract:

Coming along with the urgent development of wireless technology, wireless devices have invaded the medical area with a wide range of capability. Not only improving the quality of life of patients and doctor-patient efficiency, wireless technology enables clinicians to monitor patients remotely and give them timely health information, reminders, and support – potentially extending the reach of health care by making it available anywhere, anytime.
In this survey paper we discuss advantages of wireless medical devices and challenges involved in this technology. We focus on Wireless Personal Area Network technologies, WiMAX, WiFi and Zigbee. We have also investigated standards being used in wireless medical applications and location of wireless network in a healthcare system. Finally, we identify innovative medical applications of wireless networks developed or being developed in research, projects and research groups on wireless medical application, and commercial products.

Keywords:
medical applications survey, wireless medical applications, wireless networks, sensor networks, wireless applications, wireless homecare, Zigbee, Bluetooth, WPAN, WiFi, patient management, CodeBlue, CIMIT, wireless medical solutions, MobileFi, IEEE 802.20.

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1. Introduction

Recently, interest in wireless systems for medical applications has been rapidly increasing. With a number of advantages over wired

alternatives, including: ease of use, reduced risk of infection, reduced risk of failure, reduce patient discomfort, enhance mobility and low cost of care delivery, wireless applications bring forth exciting possibilities for new applications in medical market.

Portable devices such as heart rate monitors, pulse oximeters, spirometers and blood pressure monitors are essential instruments in intensive care. Traditionally, the sensors for these instruments are attached to the patient by wires; and the patient sequentially becomes bed-bound. In addition, whenever patient needs to be moved, all monitoring device has to be disconnected and then reconnected later. Nowadays, all of these time-consuming jobs could be terminated and patients could be liberated from instrumentation and bed by wireless technology. Integrated wireless technology, these wireless devices could communicate with a gateway that connects to the medical center's network and transmits data to health data stores for monitoring, control, or evaluating in real time or offline after storage.

Continuous and pervasive medical monitoring is now available with the present of wireless healthcare systems and telemedicine services. In emergency situations, real-time health parameter is crucial. According to the American Heart Association, treatment of a patient experiencing ventricular fibrillation within the first 12 minutes of cardiac arrest brings a survival rate of 48%-75%. The survival rate drops to 2%-4% after 12 minutes have gone [Shih04]. With wireless continuous medical monitoring systems, patients' information such as blood pressure, heart rate, and electrocardiogram can be sent instantly to specialized medical centers to store and process properly. Medical emergencies can be detected sooner and proper treatment can be applied timely. Health care effectiveness in several situations is improved significantly with the present of wireless communication technologies.

Wireless technology could be the best solution for mass emergency situations like natural or human-included disasters and military conflict where patients' records such as previous medication history, identification and other vital information are necessary. With the assistant of hand held devices in which wireless network integrated, the amount of time the doctors need to identify the problem, trace back the medication history of the patient and consult fellow doctors will be reduced significantly. Moreover, databases of patients that can be built up by continuous medical monitoring will be accessed and updated easily. As a result, the amount of paper works required and the duplication of patient record will be dropped down.

With all of these potentials, wireless systems for medical application are now not only focused by healthcare provider and the government but also by researches and industry. Significant academic and corporate resources are being directed towards researching and development of novel wireless healthcare systems. Several innovative applications based on this technology are developed or being developed in research. In this paper, we will discuss several of these projects, highlighting their architectures and implementation.

This paper is organized as follows: We will briefly discuss the base wireless technologies which current applications are using. We will discuss benefit of wireless healthcare system in detail. After a brief discussion of standards being used applications and location of wireless network in a healthcare system, we will identify projects and research groups on wireless medical application, and commercial products.

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2. The base technologies of medical applications

The rapid growth of the technologies extends the potential for exploitation of wireless medical application market. Nowadays, thanks to the large-scale wireless network and mobile computing solutions, such as cellular 3G and beyond, WiFi mesh and WiMAX, caregivers can access into vital information anywhere and at any time within the healthcare networks. The present of pervasive computing, consisting of RFID, Bluetooth, ZigBee and wireless sensor network gives innovative medium for data transmission for medical applications. In this section of the paper, we will highlight current uses of various wireless communications in healthcare domain.

2.1 WiMAX

Based on the IEEE 802.16 standards, so-called WirelessMAN standards, WiMAX is created by the WiMAX Forum, which has strong-security wireless data transmission over long distance, up to 50km, with high data rate, up to 70 Mbps, and high mobile capability, up to 150km/hour. The standard is the incorporation of several advanced radio transmission technologies such as adaptive modulation and coding (AMC), adaptive forward error correction (FEC), well defined quality of service (QoS) framework and orthogonal frequency division multiplexing (ODFM). Another standard which is being designed specifically for MBWA services, a so-called IEEE 802.20 or MobileFi, has the wider range and higher mobility capability in comparison with WiMAX. IEEE 802.20 will use the licensed bands below 3.5 GHz and provide data transmission speed over 10Mb/s for user speeds up to 250 km/h.

With advantages in mobility, transmission speed, QoS and security, WiMAX technology is an excellent choice for telemedicine service providers in both fixed and mobile environments [Niyato07]. Transmission delay for high quality images such as ultrasound and radiology images can be reduced significantly with high-bandwidth transmission. Many monitoring and diagnostic processes can be executed simultaneously with the present of large network capability. Strong QoS increase the reliability and efficiency of data transmission. As an example, in prehospital management system in an ambulance, diagnostic images could be transmitted from the ambulance to the hospital and doctors can start diagnosing while patient are on the way to the hospital.

In practical and researching domain, WiMAX has various deployment scenarios. On a large scale, WiMAX networks can be established and operated by a regional health authority to provide telemedicine services among regional clinics, hospitals and drugstores. On a smaller scale, such as hospital-size area, WiMAX networks can be used to provide an intranet for the hospital. In replacement of several WLAN access points, only a few WiMAX base stations can cover the whole hospital. This will not only trim down the deployment cost significantly but also enhance the quality of the network. As mentioned above, the other application of WiMAX-based network is prehospital management service. The number of application of WiMAX is rapidly increased and some other applications of WiMAX will be discussed in the later sections of the paper.

2.2 WLAN

The first and oldest wireless technology used in medical application is wireless local area network (WLAN). The standards of WLAN was

first introduced in 1997, namely IEEE 802.11. The capacities of IEEE 802.11 standards evolved from 1- 2Mbps in the initial version to 54Mbps in IEEE 802.11a and IEEE 802.11b. IEEE 802.11a has a range of 100 feet and 802.11b has coverage of 350feet outdoors and 150 feet indoor. After the introducing of 802.11a and 802.11b, WiFi alliance formed and started its work certifying wireless based devices. Sine that time, 802.11 has been developed much further. Many extensions of 802.11 were released, including 802.11g, added in 2003 with capacities of 54Mbps transmission working on 2.4GHz band at range of 350ft outdoors and 150 feet indoors; 802.11n with higher throughput of up to 200Mbps; 802.11i, added in 2004 with enhanced security; and 802.11s added for Mesh Network.

Nowadays, WLAN are provided in almost US hospitals. By using this transmission media, communication between departments within hospitals, from hospital to hospital can be made on the fly. Patient's data is easily transferred around the hospital. WLAN are widely used in telemedicine, healthcare data transmission, and many other applications which will be discussed in the later sections.

2.3 WPAN

WPANs using Zigbee or Bluetooth standards are gaining in popularity, with wireless motes available from industry. A number of physiological monitoring systems based on the motes have been proposed and deployed in real clinical settings. In addition to patient monitoring these systems can be used for patient tracking in situations where location information is essential, such as mass casualty incidents.

Started with Erission's Bluetooth Project in 1994, Bluetooth technology is considered a Wireless Personal Area Network (WPAN). Bluetooth operates in frequencies ranging from 2402 to 2480MHz with channel bandwidth of 1MHz in US. The data rate is defined at 720 kbps per user. Time division multiplexing technique divides the channel in to 625 micro second slots, 1600 times RF hopping per second. Working in one of three transmission mode, from 1-3 which have transmission output powers are 20dBm,4dBm and 0dbm with range from 100m to 10m respectively, Bluetooth is a technology designed for cable replacement and short distance ad-hoc connectivity. A Bluetooth network, a so-called piconet can be formed by a master, up to 8 active slaves and up to 255 parked slaves. Upon connection establishment, a slave synchronizes frequency hopping and its timer to the master's and then waits for the polling from master to transmit.

Another technology using in WPANs is Zigbee, a so-called IEEE 802.15.4. The standard is an ultra-low power, low-data rate which is used for monitoring and controlling applications. Devices using Zigbee has less than 1% life time in active status. In most of the life, the devices are in sleep mode to save device's power. A Zigbee network can be formed by three types of devices which are PAN coordinator, Full Function Device, Reduced Function Device. The number of nodes in a network can be as many as 65000 nodes.

With many advantages including low-power consumption, small size, simple protocol, wide compatibility, and so on, WPAN is applied to many medical applications including telemedicine system, pervasive and continuous patients monitoring and wireless-integrated medical devices. For example, in a mass casualty or disaster, medics can place tiny sensors on each patient to form an ad hoc network using Bluetooth, relaying continuous vital sign data to multiple receiving devices (e.g. PDAs carried by physicians, or laptop base stations in ambulances) [Shnayder05]. As another example for application of Bluetooth, wireless electroencephalograms (EEG) use Bluetooth wireless interface to transfer EEG to PDAs[Sarikaya06]. Many other applications of Bluetooth and Zigbee in medical application will be discussed in the later sections.

2.4 WBAN

Recent technological developments in low-power integrated circuits, wireless communications and physiological sensors promote the development of tiny, lightweight, ultra-low-power monitoring devices. A body-integratable network, so-called WBAN, can be formed by integrating these devices. WBAN with sensors consuming extremely low power is used to monitor patients in critical conditions inside hospital. Outside the hospital, the network can transmit patients' vital signs to their physicians over internet in realtime. WBAN usually uses Zigbee, or UWB standard

One of many applications of WBAN in medical domain is computer assisted physical rehabilitation [Pubmed05]. Intelligent sensors wearing by patients transmit vital signs to personal server, which is running on a PDA, laptop or 3 G cellphone. Sequentially, the data is transmitted from personal server to servers of the healthcare system, such as weather forecast, medical database or emergency server over Internet. Algorithms may be executed on the healthcare system servers to give instant and patient-specific recommendations. Figure 1 illustrates an example of data flow in integrated WBAN system.

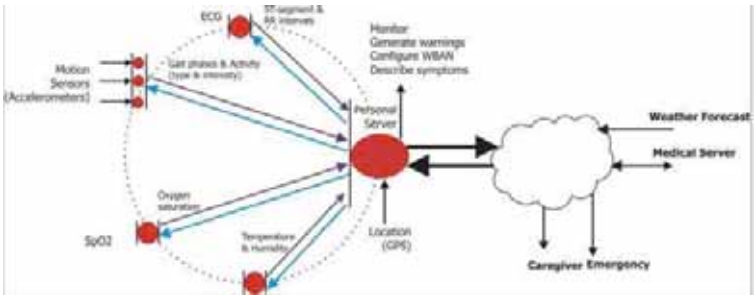

Figure 1: Dataflow in computer assisted physical rehabilitation system [Pubmed05]

2.5 Other technologies

Many other standards, technologies are applied to medical applications, including RFID, sensor network, 3G, 4G, and so on. In this section of the paper, we will identify briefly these technologies.

The first RFID chips were approved by Food and Drug Administration in October 2004[RFID], which opens the door for applying RFID in

medical applications. Since that time, a number of U.S. hospitals have begun implanting RFID tags into their patients to identify them. RFID is not only the efficient method to keep track medical equipments but also have potential in positioning patients and hospital staffs.

Sensor networks have been applying in various aspects of medical care [Shnayder05]. By equipping patients with tiny, wearable vital sign sensors, physiological status of patients can be obtained easily. In emergency or disaster scenario, sensor networks can be used to track healthcare personnel and patient status as well as location continuously in real-time mode. Figure 2 illustrates a medical sensor network application [Yuce07].

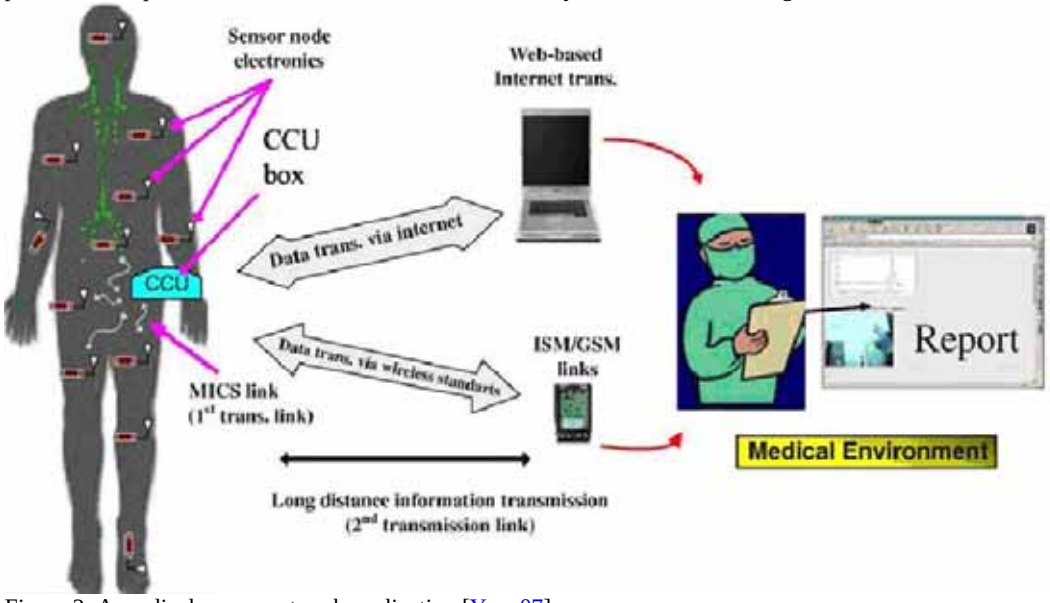

Figure 2: A medical sensor network application [Yuce07].

Cellular systems (2.5G, 3G and beyond 3G) have the potential to greatly improve telemedicine services by extending the range of healthcare system, enhance the flexibility and heterogeneous network with an end-to-end telemedicine framework[McLoughlin06]. The system consists of a cellular network platform, which gathers the information from wearable sensors, monitoring devices and server platform, which receives, stores, processes collected patients' vital data and forwards them to the existing information systems. Advances of mobile technology increases data rate and reliability of the mobile platform. As a result, applications of cellular systems in medical domain, specifically telemedicine, will be a promising field for researchers and industries investigating in next generation of mobile systems.

With its own advantages and disadvantages, each technology fits to certain types of medical applications. We have discussed about base technologies used in healthcare domain. The next section of the paper will be reserved to present potentials and challenges of wireless technology in medical care.

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3. Potentials and challenges of wireless medical applications

With the advancement of wireless technology, wireless devices can be used to reduce medical errors, increase medical care quality, improve the efficiency of caregivers, lessen the caregiver-lacking situation, and improve the comfort of patients. Although the technology has found ways into various fields, medical domain has very strict quality and assurance requirements, which causes many challenges that are faced when implementing and operating the systems. The following part of the paper will be reserved to identify potentials and challenges of healthcare system using wireless technology.

3.1 Potentials of wireless technology in medical applications

Wireless inside-body monitoring is a hot application of wireless network in patients' monitoring. Using WBAN technologies to transmit data from monitoring devices, such as Capsule Endoscope [Takizawa08], to outside body, these applications used to monitor the digestive organs such as the small intestine by video or successive image data. The system uses IEEE 802.15.6 and wearable WBAN to guarantee the quality of system. Details about Capsule Endoscope will be given in the later section of paper.

Operation assisting is very new application of wireless network [CIMIT]. In an operation, doctors have to monitor the patient's vital signs to have timely actions. These signs can be obtained by applying to the patient adhesive electrodes so that the signs are transmitted over wires to display monitors. The large number of wires used around the operation table prevents the medical team's access to the patient. Moreover, the adhesive can be detached from patient what is caused by strong enough impact to the wires. To help surgeons and medical teams operate more freely, the Smartpad [CIMIT] is presented. A device displays patient's signals without adhesives or wires.

Although real-time patient monitoring field is not a new topic in wireless medical applications, researchers and industries are investing a lot of effort and money to it. These applications basically use biomedical sensors monitor the physiological signals of patients such as electro-cardiogram (ECG), blood oxygen level, blood pressures, blood glucose, coagulation, body weight, heart rate, EMG, ECG, oxygen saturation, etc.

Home monitoring systems for chronic and elderly patients is rapidly growing up in quantity and quality [Otto06]. Using the system can reduce the hospital stay of patient and increase patient safety and mobility. The system collects periodic and continuous data and then transmits it to the centralized server. Patients' information is accessed by physicians remotely. These applications save large amount of time for doctors as well as patients. The doctors can monitor several patients simultaneously which is can not be done by traditional monitoring, in which the patients are monitored directly by the doctors. The patients are no longer required to be present at the hospitals periodically.

Wireless sensor network can be applied to medical applications to build up databases for long-term clinical uses [McLoughlin06]. It also can be used for emergency medical care [VitalDust] and many other applications. The section presented the fields that wireless networks can contribute. The following part will identify challenge of deploying wireless networks based solutions in medical care.

3.2 Challenges of wireless technology in medical applications

The use of wireless technologies in medical environments is bringing major advantages to the existing healthcare services. However, these have several key research challenges such as various types of network communication infrastructure[VitalDust], fault-tolerance, data integrity, low-power consumption, transmission delay[Natarajan07], node failure, etc.

Reliability is one of the most important factors in a successful healthcare system. To ensure this factor, system designers have to care about adaptation of nodes when its location, connection and link quality is changed [Soomro07]. Different network communications infrastructure should be used in appropriate situation. For example, with high-risk patients, the services with higher QoS should be used.

The integrity of distributed data system and fault-tolerance should be given a proper consideration also. Every device can operate differently at different times, especially sensor-based devices. One node in a system can be failure at anytime for number of reason including natural issues, human-related issues or batteries exhaustion. Ensuring a seamless service during life time of the system could be a big challenge.

How to manage the transmission delay of various types of communications in the system is an undoubted challenge. With the system using WBAN or wireless sensor network, data must go through a number of hops before it reaches the sink. In addition, these hops are sometime located in very critical conditions, such as magnetic field or areas bearing interference of radio waves. As a result, various delays occur and require extra effort of system designer to synchronize the whole system.

In many mission critical applications, it is vital that devices do not fall into battery exhaustion. As the mater of fact, most wireless network based devices are battery operated; therefore, the design of a system must not require devices to expend excessive energy. The developers have to consider the longevity of the devices and extend it by using such scheduling algorithms and power management schemes that energy consumption should be shared over the whole network, rather than having a few devices or nodes carrying the whole network's load.

The mentioned challenges are associated with technical implementation [Stankovic05]. However, there are many other challenges associated with deployment of a new technology. Specifically, the new system should be low cost and not interfere with existing infrastructure. So managing interference between the old system and the new one and using spectrum properly are challenges of wireless technology applied to medical applications.

From patient's aspect, one of the most important issues is how comfortable they feel when using these new applications. Therefore, the applications must be not only helpful but also unobtrusive, specifically small, lightweight, etc.

Last but not least, patients' information must be private and secure, but remain accessible to authorized persons [Townsend05]. Power and process availability of wireless-based network is very limited while to ensure privacy of information, extra power and computation must be used to encrypt transmitted data. Thus guaranteeing information security can be an issue and challenge for system developers.

Many challenges for wireless medical system designers and developers are discussed in this section. These issues could be a motivation for developers to create the better solutions. The next section of the paper will be reserved to discuss standards used in wireless medical applications.

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4. Standards used in wireless medical applications

Coming along with a rapid increase of wireless systems for medical applications, significant academic and corporate resources are being directed towards development of standards. Significant progress in issuing industrial standards has been made by organizations, such as IEEE, Bluetooth SIG, ISO, ASTM, etc. In this section, we will identify some standards that have been developed or are currently being developed in the research community for the wireless medical care.

4.1 IEEE standards

A set of standards, so-called ISO/IEEE 11073 or X73[Yao05], identifies nomenclature, abstract data models, service models, and transport specifications for interoperable bedside devices. The standards' primary goals are "providing interoperability for patient-connected medical devices and facilitating the efficient exchange of vital signs and medical device data in all health care environments"[Cooper02]. The standards classify devices using conceptual model shown in Figure 3. Based on this model, a set of sub-standards were developed to map to the full seven-layer ISO/OSI model. Table 1 illustrates the mapping between IEEE11073 sub-standards and the OSI reference model.

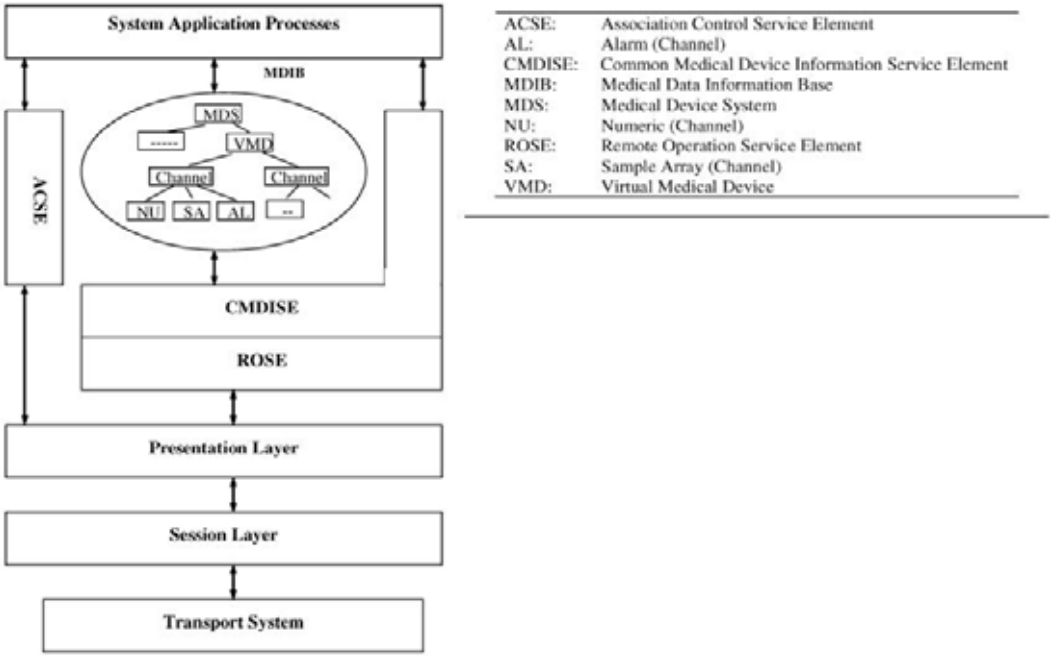

Figure 3: Conceptual model for X73-based medical devices [Yao05].

OSI layers	**ISO/IEEE 11073 standards**
Application	ISO/IEEE 11073-10xxx: Medical Device Data Language (MDDL) ISO/IEEE 11073-10101 MDDL Nomenclature ISO/IEEE 11073-10201 Domain Information Model ISO/IEEE 11073-1030x Device Specializations ISO/IEEE 11073-20xxx: Medical Device Application Profile
Presentation	In ISO/IEEE 11073-20101
Session	In ISO/IEEE 11073-20101
Transport	ISO/IEEE 11073-30xxx: Transport Profile
Network	ISO/IEEE 11073-30xxx: Transport Profile
Data link	ISO/IEEE 11073-30xxx: Transport Profile
Physical	IEEE 1073.4.1 Physical Layer; Cable-Connected Mode (Withdrawn)

Table 1: mapping between IEEE11073 sub-standards and the OSI reference model[Yao05].
Some other IEEE standards are:

1. IEEE 1073.0.1.1 "Health informatics - Point-of-care medical device communication - Technical report - Guidelines for the use of RF wireless technology"
2. IEEE 1073.3.5 (Health Informatics -Framework and Overview Structure for Wireless Medical Data Transport using Personal Area, Local Area, Wide Area, and other Wireless Networks)
3. IEEE 1073.3.5.3 (Health informatics - Point-of-care medical device communication - Transport profile - RF wireless - Local area network (wLAN))
4. IEEE 1073.3.5.5 (Health informatics - Point-of-care medical device communication - Transport profile - RF wireless - Wide area (Mobile Phone) Network (wWAN))
5. IEEE 1073.2.1.3 (Health informatics - Point-of-care medical device communication - Application profile - Clinical context management

(CCoM))
6. IEEE 1073.1.3.16 (Health Informatics - Point-of-Care Medical Device Communication - Device Specialization - Dialysis Device)

4.2 ISO Standards:

Many standards issued by ISO to provide guidance for implementation, use and management of wireless communication and computing equipment in healthcare facilities "*The recommendations given recognize the different resources, needs, concerns and environments of healthcare organizations around the world, and provide detailed management guidelines for healthcare organizations that desire full deployment of mobile wireless communication and computing technology throughout their facilities"*[ISO].
The following standards are some of the up-to-dated standards issued by ISO:
- ISO/TR 21730:2007 - Health informatics -- Use of mobile wireless communication and computing technology in healthcare facilities
- ISO 17090-3:2008 - Health informatics -- Public key infrastructure -- Part 3: Policy management of certification authority
- ISO 13606-1:2008 - Health informatics -- Electronic health record communication -- Part 1: Reference model
- ISO 11073-90101:2008 - Health informatics -- Point-of-care medical device communication -- Part 90101: Analytical instruments -- Point-of-care test
- ISO 21549-6:2008 - Health informatics -- Patient healthcard data -- Part 6: Administrative data

4.3 Bluetooth SIG standards

The Bluetooth Special Interest Group (SIG) issued the Medical Device Profile for *Bluetooth* wireless technology at Medica, the 39th World Forum for Medicine in Düsseldorf (14-17 November 2007) [Bluetooth]. A *Bluetooth* profile provides guideline of how different applications use *Bluetooth*
wireless technology to set up a connection and exchange data. The profile is developed by the Medical Devices Working Group to ensure that devices used in medical, health and fitness applications can transfer data between devices in a secure and well defined way via *Bluetooth* wireless technology.

4.4 ASTM standards

ASTM issued ASTM F1220-95(2006), a standard guide for emergency medical services system (EMSS) [ASTM F1220]. The standard and its sub-standards provide guide for telecommunication practices, required performance standards to support all of the functions of community EMSS. In addition, the standards identify state planning goals and objectives for EMSS communications. The standards can be used for designing, integrating, evaluating and coordinating telecommunications resources in order to guarantee providing needed functions of EMSS systems.
Some ASTM standards used in wireless medical system:

1. ASTM E 2369-05, Standard Specification for the Continuity of Care Record (CCR)
2. ASTM F1220-95(2006) Standard Guide for Emergency Medical Services System (EMSS) Telecommunications
3. ASTM F1258-95(2006) Standard Practice for Emergency Medical Dispatch

Many other standards are currently being developed in the research community. The demand of up-to-dated standards is inevitable with the rapid development of wireless medical care. Some standards are discussed in this section. In the next parts of the paper, we will identify some projects and research groups working on medical field using wireless networks.

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5. Projects and research groups on wireless medical application

In this part of the survey, we will discuss groups and projects researching on medical applications.

5.1 CIMIT

CIMIT is a center conducting research in order to improve patient care [CIMIT]. CIMIT teams have produced truly novel, cost-effective healthcare solutions, many of them are networked sensor solutions, wireless monitoring, and tracking systems. These novel solutions will be implemented in real-world in the near future from hospital to home. CIMIT teams have been designing and constructing "Operating Room of the Future, a fully functioning operating room in which novel, integrated technologies and new processes are introduced, evaluated, and improved, and through which patients move with far greater comfort, speed and safety"[ORF].
The following are images of few of the devices developed or are currently being developed by CIMIT teams.

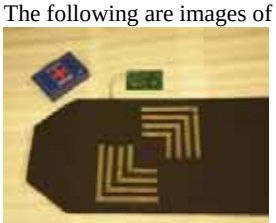

Figure 4: SmartPad - A Wireless, Stickerless EKG System[CIMIT]

Figure 5: Future clinical system [CIMIT].

5.2 Code Blue

CodeBlue is the project of Harvard University trying to develop novel applications of wireless sensor network technology to medical applications. Many products of the project have great potential to apply to practice such as: Intel SHIMMER motes (figure 6), UVa/AID-N "eTag" wireless triage tags (figure 7), UVa/AID-N wireless blood pressure cuff (figure 8), Limb movement in stroke patient rehabilitation monitoring system (figure 9)[CodeBlue].


Figure 6:Intel SHIMMER motes[CodeBlue]

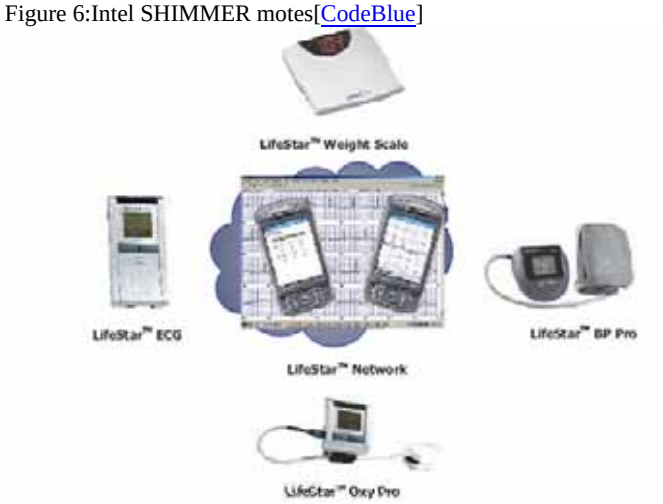

Figure 7: UVa/AID-N "eTag" wireless triage tags with pulse oximeters [CodeBlue].


Figure 8: UVa/AID-N wireless blood pressure cuff [CodeBlue]

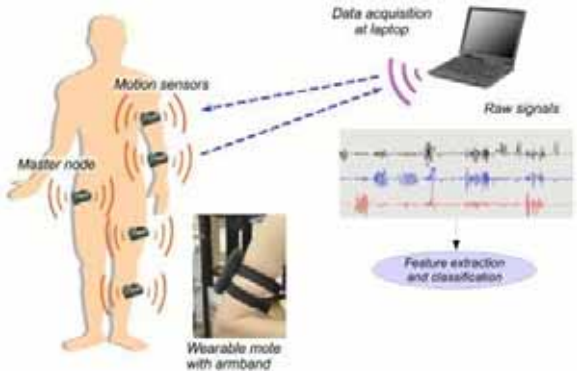

Figure 9: Stroke patient rehabilitation monitoring system [CodeBlue].

5.3 Capsule endoscope

This is a novel application of wireless technology into in-body patient monitoring [Takizawa08].
It is a result of collaboration among NICT, Olympus Medical Systems Corp., FUJIFILM Corp., Yokohama City University, and Yokohama National University. Capsule endoscope can be used to monitor digestive organs by video and images transmitted from inside body to the outside over WBAN. Figures 10 illustrates the collaboration between wearable WBAN and implanted WBAN of capsule endoscope-based monitoring system.

Figure10: Between wearable WBAN and implanted WBAN[Takizawa08]

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6. Industry applications

In this part of the survey, we will discuss about industrial products used in medical care domain.

6.1 Life Star® vital signs monitoring Systems

Life start monitoring systems is a combination of many measuring devices and wireless technologies [Lifestar]. The testing results are transmitted via Bluetooth technology to the LifeStar handheld device. Users' information can be used instantly on the handheld devices or transmitted again to the LifeStar Network, where the data is stored.


Figure 11: Wireless vital signs monitoring system [Lifestar].

6.2 The Wireless B.O.H.M. Center

Similar to LifeStar system, The Wireless B.O.H.M. Center is used for self-monitoring and management of vial signs by patients [BOHM]. The system consists of five healthcare devices integrated Bluetooth and cellular communications. The Wireless B.O.H.M Center can be used to monitor 5 patients' vital signs simultaneously, including heart rate, body temperature, blood glucose levels, body fat and 1-Lead ECG. Figures 12 illustrates architecture of Wireless B.O.H.M system.

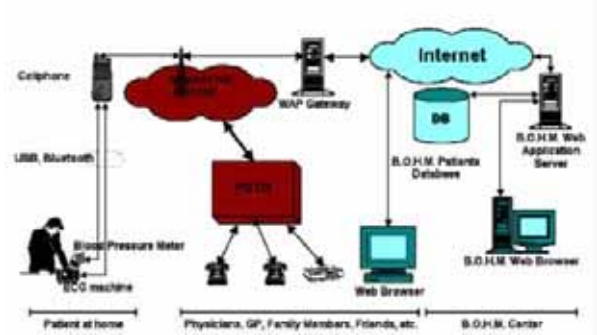

Figure 12: Patient's blood pressure and ECG monitoring [BOHM].

6.3 Quatech Airborne (TM) and AirborneDirect (TM):

Airborne modules are an effective method to integrate old machines, which do not have wireless communication capability, with modern wireless healthcare system. The interface modules allow the old machines last longer[Airbone]. Airborne modules help these machines have wireless communication, reduce wiring and make it compatible with modern network. Quatech Airborne and AirborneDirect support 802.11b/g are: Airborne(TM) 802.11b/g embedded Wireless Device Server Module, Airborne(TM) 802.11b/g embedded Wireless Ethernet Bridge Module, AirborneDirect(TM) 802.11b/g external Wireless Device Server, and AirborneDirect(TM) 802.11b/g external Wireless Ethernet Bridge

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7. Summary

Although wireless medical applications have been successfully implemented not only in research but in practice as well, there are still many challenges for developers and researchers. Potential of wireless technology in medical domain can not be exploited completely when mentioned challenges are not solved, which required a long term effort of researchers and investors.

In this survey paper we discussed advantages of wireless medical devices and challenges involved in this technology. We present deeply wireless technologies used in medical recently. We have also identified standards being used in wireless medical applications and location of wireless network in a healthcare system. We identified innovative medical applications of wireless networks developed or being developed in research, projects and research groups on wireless medical application, and commercial products.

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List of Acronyms

WiMAX: Worldwide Interoperability for Microwave Access
WiFi: Wireless Fidelity
WPAN: Wireless Personal Area Network
WBAN: Wireless Body Area Network
ASTM: American Society for Testing and Materials
CIMIT: Center for Integration of Medicine and Innovative Technology
QoS: Quality of service
ECG: electrocardiogram
EMSS: emergency medical services system
PDA: Personal Digital Assistant

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