A Hybrid Wired and Wireless Network Infrastructure to Improve the Productivity and Quality Care of Critical Medical Applications

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***Abstract*—While medical instruments have benefited a great deal from the technological advances of the couple of decades, many practices and day-to-day activities in medical environments remain virtually unchanged. The process of penetrating IT advancements in the medical profession continues to be a very challenging problem. This is mainly due to concerns about security and reliability of new technologies. In general, sensitive applications, such as in the medical domain, have always resisting to adopting a new technology. However, healthcare can benefit significantly from incorporating various new developments, particularly wireless technologies. In this paper, we propose a secure and robust network infrastructure for critical medical applications and discuss the solutions to a number of problems related how to employ a wireless technology to solve problems in the medical domains.**

I. Introduction

Health care in Australia and other countries is capable of near miracle therapies and high technology treatments for life threatening disease. At the same time, a major challenge facing medicine is the ability to routinely provide an effective and uniform level of quality care across all levels of patient care including intensive care units, cancer treatment centres, geriatric care facilities and nurseries. To face this challenge a number of problems need to be addressed, including conflict detection, secure transmission of information and effective management of resources and personnel in medical establishments.

At the core of the challenges are medical therapeutic errors, many of which are avoidable. A variety of such errors exist such as medication given to the wrong patient, inaccurate dosage of drugs, operations performed on the wrong appendage, and blood products administered to the wrong person. Due to fact that these errors may potentially take place anywhere in a hospital setting, an intelligent wireless infrastructure with mobile devices appears to be the best way to address this issue. This can be achieved by integrating the wireless infrastructure with hospital information system.

Another area that can benefit from the existence of the proposed infrastructure is the problem of efficiently tracking patients and medical personnel particularly in emergency situations. Such prompt tracking would allow the hospital management to reach the needed personnel in short period of time and avoid unwanted (potentially fatal) delays. The presence of effective tracking system would allow the hospital management to device the optimal route for medical personnel and potentially reroute them.

A different important problem that could be addressed using our proposed system is related to product management. For example, since blood is initially obtained through donation by agencies such as the Australian Red Cross that are responsible for providing blood throughout the community, these agencies try to maintain the largest supply of blood at the central facility and only provide blood on an as needed basis. Unfortunately, when the hospital encounters a multiple trauma situations, the emergency results in an urgent call to the central blood bank and the dispatch of a blood shipment to replace the stores in the hospital blood bank. This can be addressed by the incorporation of RFID sensors and blood bags in the presence of wireless networks. Although having such infrastructure will provide better health care, there are a number of problems needs to be addressed prior to full employment of the infrastructure. Such problems include secure transmission of information in wireless environment, efficient multihop routing in wireless networks, integration of wireless sensors in various medical devices.

Wireless sensor networks are an emerging technology consisting of small, low-power, and low-cost devices that integrate limited computation, sensing, and radio communication capabilities [1][2]. This technology has the potential to have enormous impact on many aspects of emergency medical care. Sensor devices can be used to capture continuous, real-time vital signs from a large number of patients, relaying the data to handheld computers carried by emergency medical technicians (EMTs), physicians, and nurses. Wearable sensor nodes can store patient data such as identification, history, and treatments, supplementing the use of back-end storage systems and paper charts. In a mass casualty event (MCE), sensor networks can greatly improve the ability of first responders to triage and treat multiple patients equipped with wearable

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wireless monitors. Such an approach has clear benefits for patient care but raises challenges in terms of reliability and complexity[3][4][5][6]. In this paper, we propose a secure and robust network infrastructure for critical medical applications and discuss the solutions to a number of problems related how to employ a wireless technology to solve problems in the medical domains.

The rest of this paper is organised as follows. In Section II, we propose the architecture of a hybrid wired and wireless communication network which is suitable for medical institutions. In Section III, we describe the major components of the proposed architecture and problems which need to be solved before the adaption of the system. Finally Section IV concludes the paper.

II. A HYBRID MULTI-HOP WIRED AND WIRELESS NETWORK

In order to guarantee a reliable network infrastructure that supports the employment of wireless technology and mobile devices, a hybrid infrastructure that integrates wireless networks with the traditional wired local area networks (LANs) is needed. In a medical establishment, it is relatively easy to incorporate a high performance state-of-the-art LAN. The wired network will provide the backbone of the infrastructure that will also include a number of wireless ad-hoc networks connected via the backbone. The backbone will provide the stability to the network, improve the overall performance of the hybrid network, and provide an alternative to the mobile routes, hence increasing the degree of redundancy and reliability.

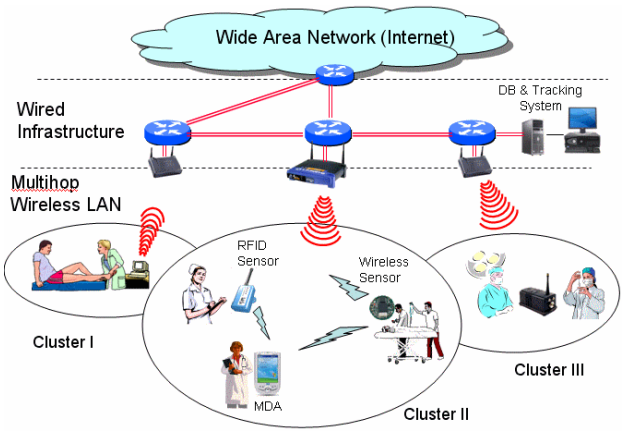

Fig. 1: A hybrid hospital network system

With such infrastructure in place, a number of critical medical problems can be addressed with the help of mobility of the wireless ad-hoc networks and the stability of the infrastructure backbone. These problems include the problem of detecting conflicts, tracking patients, medical devices and medical personnel, and provide an efficient way of managing the critical resources in the medical environment. Such integration will allow the development of digital bracelets to track personnel and the development of digital tags to track medical instruments.

A conceptual model of the hybrid multihop infrastructure is shown in Fig. 1. It is composed of three parts: Wide Area Network, Wired Infrastructure, and Multihop Wireless Local Area Network. The Wired Infrastructure connects the multihop system to Internet and integrates the protocols utilized by Internet and the sub-networks. The multihop wireless LAN consists of various wireless devices such as wireless access pointer, PDA, RFID Read/Write Sensor and biosensors. The model includes stationary sensors as well as mobile sensors.

III. MAJOR ISSUES AND COMPONENTS

In this section, we will describe the key issues/problems, components, and protocols for the proposed infrastructure. These issues if not solved will prevent the infrastructure to be adapted in the medical domain.

A. *Quality of Service*

Due to their critical nature, the medical applications demand that a network infrastructure to support medical applications must be extremely reliable, secure and perform at a high level. Several wireless environments offer various degrees of Quality of Service (QoS) parameters such as throughput, delay and security levels, however, there is no single wireless environment providing QoS parameters that are remotely close to that obtained by wired networks. Moreover, precise prediction of QoS parameters under various network traffics in different wireless environments is difficult without using explicit hardware implementations. On the other hand, using traditional local area networks limits the effectiveness of a hospital network since it will not address the issues of tracking and navigation and issues requiring the deployment of mobile devices. In this project, we propose to develop an infrastructure that integrates wireless ad-hoc networks with a local area network. In such hybrid network, the wired network will be backbone of the network with the wireless networks providing the flexibility needed for supporting the mobile/wireless devices to address the various tracking and navigation problems. For instance, a set of wireless subnets interconnected via a local area network would provide higher degree of mobility within each subnet (as compared to a pure wired network) and a better performance and reliability (as compared to pure wireless networks).

B. *Security in Medical Environment*

Security is a vital aspect for the proliferation of localization and tracking systems in hospitals and health-related applications. Many current tracking systems practical for this situation require wireless communication between mobile and stationary devices. The mobile devices may be sensors, RFID readers, RFID tags, or similar technology attached to the target which is to be tracked. Usually, either the mobile or stationary nodes emit some beacon signal that

is processed by the other nodes and used to track the devices. When a mobile node sends a beacon signal, it renders itself vulnerable to any attacker that may be passively listening to the wireless communication. Security management includes providing privacy for patients and staff and protecting the network against malicious attacks and failure. We will investigate several key management schemes for providing confidentiality, authentication, and integrity of transmitted data. We will consider link-layer encryption to enable secure sensor-to-sensor communication, protect against routing disruption and provide security methods without dependence on trusted base stations. Our recent work shows that routing security can be considerably improved by following routes that are less likely to be compromised.

C. *Conflict Detection in Medical Environment*

In the hospital environment, extra care must be taken to avoid conflicts. Conflicts arise whenever allergies, blood types, or mixing of medications are involved. Human oversight has offered limited effectiveness in this area. Supplementing this with automatic controls and alarms could greatly reduce mistakes with such conflicts. The infrastructure includes a system for automatically detecting potential conflicts. By maintaining patient information in a secure, private database, the system will sound an alarm if an incorrect treatment is brought in proximity of a patient. Similarly, conflicting medications in proximity while not in storage will sound an alarm. To provide automatic conflict detection, an RFID tag or a sensor node is attached to every person, equipment, medicine, and other items in a hospital. False negative detection can arise in some situations. For example if two patients are present in one room, a medicine of one of them may be mistakenly designated to be in conflict with that of the other. Appropriate strategies/protocols need to be designed to increase true positives and reduce false negatives of automatic conflict detection. This includes studies of the ranges of RFID tags and readers and sensor nodes. Before this can be achieved, we will develop a theoretical framework for describing and detecting conflicts.

D. *Integration of RFID Reader/Writer and Wireless Sensor Networks*

A report by the Institute of Medicine estimates that as many as 98,000 people die in the U.S. hospitals each year because of medical errors. To ensure that patients receive the right treatment, RFID could be utilized as part of the solution in the near future. However, RFID systems require installation of receivers in key points, and an existing computer network in a hospital may have some difficulties integrating with the RFID information. Therefore, our project involves prototyping a sensor-based portable RFID reader by integrating both sensor network and RFID technologies. Using this sensor-based RFID reader, we can significantly reduce the installation cost of fixed RFID readers in a hospital. To provide seamless communication between the RFID system and Hospital Information System (HIS), we will design and develop software modules to glue the RFID sensor and WLAN technologies together.

E. *Hospital Personnel and Equipment Tracking System*

A patient tracking system is another key component in the infrastructure for hospitals. In the proposed system, important assets, patients and staff will be marked by small, electronic sensor tags for positioning and security purposes. By tagging all equipment, both the current position and the history of movements will be logged. Currently, some RF-based positioning systems with various routing stacks designed for multihop radio networks have been designed. However, the current solutions generally ignore the problems introduced by the barriers in a large hospital building. Further studying and developing algorithms for solving the layout problem that are robust to errors introduced by these barriers. We intend to improve these systems by developing better algorithms for tracking and localization. These algorithms will allow the system to adaptively change based on the mobility of the target. We will also develop methods for a completely self configuring localization system that operates with minimal prior location data. We will consider all aspects of a localization system such as energy-efficiency, cost, and ease of deployment. The proposed patient tracking system will be integrated into a hospital's information infrastructure to track patients in real time, and their locations are graphically displayed on a Web interface, which is updated periodically. In fact, the identification management systems track not just patients but personnel and equipment as well.

IV. CONCLUSION

In this paper, we propose a multidisciplinary architecture to build an innovative wired and wireless network infrastructure for employment in medical domains. The infrastructure integrated multidisciplinary new technologies in wireless communications, data security and medical engineering. It will significantly improve the quality and productivity of healthcare and security of information transmission in medical establishment.

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