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CURRENT TRENDS OF COMMUNICATION SYSTEMS IN MEDICAL MONITORING SERVICES: THE CASE OF WSNS OPERATING SYSTEM DESIGN

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ABSTRACT

Wireless communication services are now in use right across the world and in particular in the health sector. The need for quality healthcare means that different individuals have to cooperate through sharing of information and discussion of patient management. This has led to increased need for quality information and communication technologies that support such cooperation. Unfortunately, a lot of interest and investment in information technology has largely focused on communication systems with very little focus on systems that apply to medical field. Even adoption of such simple technology as wireless sensor technology has not taken root in the medical field. This paper therefore presents studies and reviews of different networks in relation to the OS design of WSNs for monitoring.

Keywords: *Wireless Communication. WSN, OS Design, Zigbee*

1. INTRODUCTION

A monitoring application is required for diagnosis and prevention of serious disease in varied healthcare environments. Such an application would allow for remote monitoring of patient status (Alemdar & Ersoy, 2010). Use of such an application requires development of wireless communication channel. Such a channel would appropriately meet the need for quality healthcare services that would turn out to not only be cheap but also a smart way of managing patients such as those suffering from chronic diseases that are age-related (Alemdar & Ersoy, 2010).

Regardless of any permanent or temporary constraints, wireless network systems differ greatly from traditional healthcare services in terms of functionality. Such systems offer services that are delivered through per-to-per or from other types of e-services. A good example is an e-service, which is an online service (Jang et al., 2012). In this service, delivery of packets is linked to a network or a location fixed at the local level. According to Lin et al. (2004), there is an increasing number of academic research that focus on wireless services. The use of wireless communication in different healthcare environments therefore denotes the different ways through which communication technology can be used. Additionally, it helps addressing other related health issues that both patients and doctors need to access (Song et al., 2013).

Present healthcare monitoring systems employ several techniques such as “Bluetooth” that acts as wireless communication protocol, wireless “WiFi” as a P2P communication protocol and ZigBee, which is one of the most powerful wireless communication system for sending and receiving data (Dhawan, 2007). ZigBee provides for high dependency on wireless body area network (WBAN) in obtaining body temperature on the basis of wireless structure (Hill, Troshani, Goldberg, & Wickramasinghe, 2014). Use of WBAN in healthcare systems allows for continuous physiological signal monitoring (Lee, Kim, & Yi, 2010).

Furthermore, WBAN also supports health consultation information at any time anywhere (Barua, Alam, Liang, & Shen, 2011). In addition, Wireless Sensors Network (WSN) presents multi node classification for ad hoc network that can be used together with other communication systems. Biomedical area provides for reliable monitoring and accurate analysis of medical status within healthcare systems (Liang et al., 2012). Whether

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one or several sensors, each node in a sensor is made up of a radio transceiver or a wireless communication gadget, a microcontroller and an energy source, which in most cases is a battery. Depending on sensor network size and complexities of each sensor node, cost varies and range from cents to hundreds of dollars (Lubrin, Lawrence, & Navarro, 2005; Romer & Mattern, 2004).

For continuous monitoring of patents out of a healthcare grid Akyildiz, Su, Sankarasubramaniam and Cayirci (2002) suggested evaluating different RF gadgets and techniques that measure body temperature remotely. Therefore, in this paper, we explained the issues of monitoring in healthcare settings in the next section.

2. MONITORING RELATED ISSUES

Telecommunications market and use of healthcare systems are driven by wireless systems and the Internet, which supports both with the necessary communication tools. There is therefore need to have quality communication service for measuring patient body temperature placed in different range distance (Kateretse, Lee, & Huh, 2012). Mobility is made possible by a user having a mobile or any other sensor node that connects to an access point (AP) that is connected to Internet. In efficient digital signal transfer has been properly addressed by challenges in ascertaining patient body temperature over various wireless communication means. It has also been realized that traditional wireless sensors are incapable of delivering accurate patient body temperature based on the fact traditional sensors are single parameter gadgets. Moreover, another loophole of current measurements and monitoring services is the disability in providing a continuous measurement of body temperature (Chengcheng et al., 2009). Different researchers have addressed these challenges to the lack of understanding the settings and probability of a definite wireless sensor applied in healthcare settings (Ko et al., 2010; Lane et al., 2010; Xiao, Dhamdhere, Sivaraman, & Burdett, 2009).

This literally means that only a part of body temperature (humidity, vibration, sound, pressure and motion) can be obtained using wireless body network gadgets. Most of the devices only measure incoming patient signal from other monitoring gadgets, which in some cases leads to challenges in identifying patient status in case of movement. In particular, measuring body temperature using a WSN remotely does not produce accurate signals that inform on a patient's body status (Soontornpipit, Furse, & Chung, 2004). Furthermore, WSN is not capable of measuring patient body status when a patient is mobile. This is made worse by the fact that WSN does not provide for high level of communication.

Therefore, next section is presented in order to show the different use of different tools in medical supported communication in general and in temprature monitoring in particular.

3. TEMPERATURE MONITORING SYSTEM

Applications used in such areas as entertainment, industry, travel, medicine and in management of emergencies can be positively overhauled by use of wireless sensor network technology. Such technology includes wireless sensors, sensor networks, pervasive computing and artificial intelligence research. All these technology have in-built interdisciplinary concept of ambient intelligence (AmI), which eliminates challenges encountered every day (Cook, Augusto, & Jakkula, 2009). The increasing number of the elderly in the developed world has been one of the greatest challenges in the world in the past decade. According to forecast by Population Reference Bureau, the number of people aged 65 and above in the developed world in the coming 20 years will constitute 20% of the overall population. Delivery of quality health care for the elderly is therefore very important while cutting down on health care costs (Panescu, 2008). According to Arnon, Bhastekar, Kedar and Tauber (2003), integration of sensing in consumer electronics technology holds great promise because such integration allows for continuous monitoring.

Both local residents and care givers can play a critical role in providing continuous medical monitoring, control of home appliances, memory enhancement and access to medical data (Stanford, 2002) by simply using In-home pervasive networks. Continuous monitoring will ultimately make it possible for emergencies and other diseases to be detected in good time. This is in addition to providing several healthcare services for those with physical and cognitive disabilities (Stankovic et al., 2005). These systems provide valuable benefits not only to the elderly and those with chronic illness but to working families as well (Goldsmith, 2005).

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The benefits extend to delivery of quality healthcare services for children.

Researchers in computing, temecommunicating, networking and medical fields are cooperating with the aim of making smart healthcare possible. Many researchers have already noted the importance of integrating large-scale wireless telecommunication technologies including WiFi, 3G and WiMAX with medicine (Golmie, Cypher, & Rébala, 2005). In addition, further improvements can still be realized by integrating small personal area technologies such as radio frequency identification (RFID), Bluetooth, ZigBee and wireless sensor networks with large wireless networks for the purpose of providing context-aware applications (Ng, Sim, Tan, & Wong, 2006). An example of using ZigBee in temperature monitoring can be found in Figure 1.

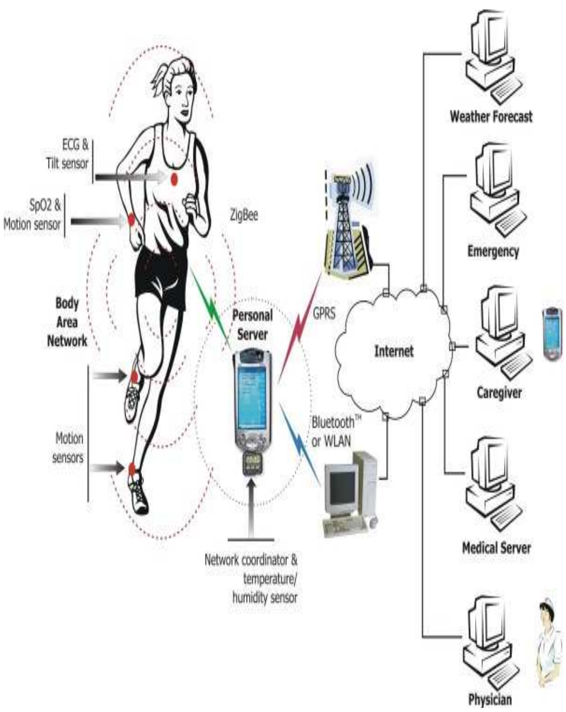

Figure 1: Zigbee And Wireless Sensor Networks In Monitoring

However, the development of un-obstructive small sensor gadgets allow for capture of accurate information and reliability in delivery of data, which is of critical importance. In addition, such gadgets will also provide for pervasiveness with present wireless network technologies that are otherwise superior. What integrates all these is the application, which acts as the coordinator between health caretakers and caregivers (Alemdar & Ersoy, 2010). The application also connects sensor to gadgets and other players in the system cycle. Because it is the core of quality healthcare service, the application must be of very high quality. Therefore, we presented the main applications of RFID and WSNs in the next section.

4. APPLICATIONS OF RFID AND WSNS IN MONITORING

RFID is basically a one-way communication system. In the system, data flows from tags and delivered to reading equipment (Nawaz, Ahmed, & Mujahid, 2013). RFID network can be employed as signal detector. It can also be employed to specify the distance between devices by making available details related to location of such devices. Use of triangulation and signal processing techniques can further improve estimated position of RFID tags so long as a location is within range of identification process (Ho, Moh, Walker, Hamada, & Su, 2005).
WSNs are in most cases used to sense the environment, position and identification of people or objects (Snyder, 2013). In this context, they are mainly used to sense temperature, vibration intensity, pressure, sound intensity, power line voltage, chemical concentration and pollutant levels among other things. When sensors are attached, WSNs can be employed to sense the environment and other phenomena that relate to people or objects (Ho et al., 2005). The following table shows a presentation of comparison between RFID and WSNs in terms of components, purpose, protocols, communication mobility, programmability, price and deployment.

According to Cheekiralla and Engels (2005), in integrating RFID with wireless sensor network technologies, several integration issues have been identified through surveys and classifications, issues that have already been published in many publications. Most integrations are however outdated. Customizing some monitoring equipments also brings up order and unordered classifications. In line with the indicated standard, define, as stated by (Cheekiralla & Engels, 2005), the likely ways through which integration of WSNs into RFID network can be effected. This standard covers only integration of WSNs into RFID frameworks. In addition, integration on the RFID side aims at justifying EPC Global-based RFID technologies. On experimental basis, several useful classifications and architectures are defined on the basis of fixed RFID tags alongside variable function sensor tags. Variable function sensor tags can alter their function and act as air protocol. A different study was conducted in other

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organizations, a study that examined taxonomy of wireless sensor network gadgets including RFID gadgets (Lingfei, Meng, & Huawei, 2009). They examined the main issues in WSN and RFID gadget integration. When it comes to communication, memory, energy and sensors, the study provides for flexible classification that is applicable to integrated WSN and RFID gadgets. For the purpose of classifying wireless gadgets, every attribute is again sub-divided into sets of sub-attributes. In communication, attributes are divided into protocols/standards, modes, modules and support for mobility. According to Dyo et al. (2009); Otsuka, Bernardes and Rocha (2004) D, modes of communication include "Device talks first", "beacon", "ad hoc" and "human control" based standards which explained in the following section.

5. WSN STANDARDS

A number of standards for wireless networks have already been ratified or still undergoing development. There are also many classifications when it comes to translation of signals received from different channels (Pradhan, Routray, & Behera, 2006). A good example of WSN is EnOcean. This system whose basis is hardware ports is used for communicating in the automated building industry. It is used to send data to several ports. It identifies the required connection standard by any of the approved standardization organizations (Anis Ibrahim & Morcos, 2001).

5.1 WSNs Operating System

This part discusses the major issues that relate to design of WSN OS.

5.1.1 Architecture

Arrangement of an OS involves its structure. The structural architecture of an OS has great influence on not only the size but also the OS kernel in addition to the way it functions to offer service to application programs. Some of the most popular OS architecture include monolithic, micro-kernel, virtual machine and layered architectures (Bansal, 2013).

There is no standard structure in a monolithic architecture. Services offered by an OS are implemented individually with each service providing an interface for the other services. This type of architecture allows for grouping of all the required services into a single system image, leading to a smaller OS memory footprint. One great advantage of monolithic architecture is the low cost associated with module interaction (Peng, Huang, Long, Du, & Xie, 2012). This architecture however has several disadvantages including system complexity that is difficult to understand and modify, it is unreliable, difficulties with maintenance. These disadvantages make monolithic kernels inadequate OS design choice for common sensor nodes.

An alternative choice would be a microkernel architecture that provides for minimal kernel functionality. Its kernel size is very small (Delicato, Portocarrero, Silva, Pires, & de Araujo, 2012). Most of its OS functionality is through user-level servers such as a file server, a memory server and a time server among others. Failure of one server does not necessarily lead to crash of the whole system. This architecture provides for improved reliability and ease of customization/extension. This architecture also has its own unique disadvantages including poor performance occasioned by frequent user to boundary crossings. Many embedded OS are designed with microkernel because of its small kernel size and the minimum number of context switches in a WSN application. Unlike with traditional systems, minimal boundary crossings exist in this architecture.

The main idea with the virtual machine architecture is exportation of virtual machines to user programs. The architecture has all the hardware features and has the advantage of being portable. Its main disadvantage is its poor performance.

From its name, a layered OS architecture provides service in layers. It has several advantages including reliability, manageability and the fact that it is easy to understand. It is however not a flexible design.

An effective and highly functional OS designed for WSNs needs to be of architecture with small kernel size that provides for small memory footprint. It must also allow for kernel extensions in addition to being flexible in which case services loaded onto the system are only those that are required by the application (Gámez, Cubo, Fuentes, & Pimentel, 2012).

5.1.2 Programming Model

The model of programming that an OS supports has a great impact on the development of application. WSN OSs are programmed in line with two models; event driven and multithreaded

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programming models. Most programmers tend to be familiar with threaded application development. It is however resource intensive and is therefore not recommended for such resource constraint gadgets as sensor nodes (Cinque, Di Martino, & Testa, 2012). On the other hand, event-driven programming is recommended for computing gadgets with limited resources but suitable for traditional application developers. Attention of researchers has therefore been directed to development of light-weight multithreading programming model for WSN OSs (Fortino & Galzarano, 2013). Majority of modern WSN OSs support multithread programming models discussed below.

5.1.3 Scheduling

It is the central processing unit (CPU) scheduling that determines the order in which tasks are processed in a CPU. In common computer systems, scheduler minimizes latency and maximizes throughput and utilization of resources in addition to ensuring fairness (Kwok & Kwok, 2012).

The appropriate scheduling algorithm for WSNs is selected on the basis of application's nature. Real time scheduling algorithm must be used with applications having real time needs.

WSNs are widely used in real time and non-real time environments. WSN OS must therefore provide scheduling algorithm capable of meeting application requirements (Raju, Huddar, Tanwar, & Patwardhan, 2013). Ideally, a proper scheduling algorithm should have memory and energy efficiency.

5.1.4 Memory Management and Protection

In traditional OSs, management of memory refers to the strategy employed in allocating and de-allocating memory for varied processes and threads. In this context, two popular memory management strategies employed are static and dynamic memory management. Static memory management is not only simple but also very useful when dealing with limited memory resources. However, it leads to inflexible systems because of the impossibility of run-time memory allocation occurrence (Taylor et al., 2012). Unlike static memory management, dynamic memory management produces a flexible system because allocation and de-allocation of memory is possible. Process memory protection is the protection of a process' address space from another. Initial sensor network OS such as TinyOS never had memory management. Likewise, initial OS for WSNs were designed with assumption that only one application processes on a sensor node and therefore no need to protect memory (Buttyán, Gessner, Hessler, & Langendoerfer, 2010). With emergence of new application domains for WSNs, traditional WSNs support multithread execution, which makes memory management an issue for WSN OS.

5.1.5 Communication Protocol Support

In OS, communication refers to the inter-process communication within a system and in network nodes. WSNs function in a distributed environment where sensor nodes communicate with other nodes in a network (Yang, Huang, Wong, & Deng, 2010). All WSNs allow application programming interface (API) that also allows application program communication. It is likely that WSN has heterogeneous sensor nodes, meaning that OS's communication protocol must consider heterogeneity (Casati, 2011). In network-based communication, the OS must provide for transport, network and MAC layer protocol implementation.

5.1.6 Resource Sharing

The function of an OS also includes resource allocation and sharing, which is very important in a case where several programs run concurrently. Most modern WSN OSs allow for multithreading, which requires a resource-sharing mechanism. This can be achieved in time like in scheduling of a process/thread in a CPU and in space like in writing data to system's memory (Canali, Renda, Santi, & Burresi, 2010). In other cases, serialized access to resources may be needed, which is obtained by use of synchronization primitives (Šoštarić, Horvat, & Hocenski, 2012).

6. EXAMPLES OF ZIGBEE USES IN WIRELESS MONITORING

Many studies were conducted in order to develop the wireless monitoring performance by using a reliable sensor network. For instance, Froehlich, Everitt, Fogarty, Patel and Landay (2009) introduced the main elements for providing efficient wireless applications in term of personalization for monitoring the health changes remotely. Their research customized the possibility for performing the wireless network in multiple platforms for determining the body temperature changes. To do so, they used a medical sensors ZigBee/802.15.4 to sense the reading of body temperature within a low range distance. They also relied on Wifi network for providing a long range

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reading even with the movement of the object of the person. This was represented through mobile communication interface as shown in Figure 2.

The network was customized to filter the different signal received from the patient's body in which it reflects a definite reading that can help doctors to decide the patient's health status. Additionally, the study reported the integrated hardware and software components into the development. The outcome of the study was a software interfaces for integrated operation of a complete wireless tele-health system.

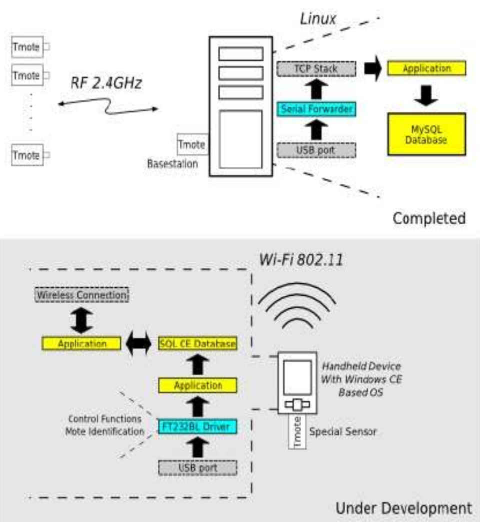

Figure 2: Data extraction from sensor Mote (Froehlich et al., 2009)

However, researchers example Baker et al. (2007) proposed LISTENse prototype that aimed to measure the body temperature at the home. The structural process as stated in the figure below presents the electronics integration that measure for certain number of users. The study was developed based on the corporation between wireless sensor networks and several electronic infrastructures that can produce combative applications in the area of health and monitoring systems. The significant of combining these areas back to the expected improvement in detecting and monitoring the body temperature of the patient more reliable and efficiency. The study reported the developing process of building several prototypes and discusses the driving force behind home health monitoring (Baker et al., 2007). Figure 3 presents the LISTENse prototype schema.

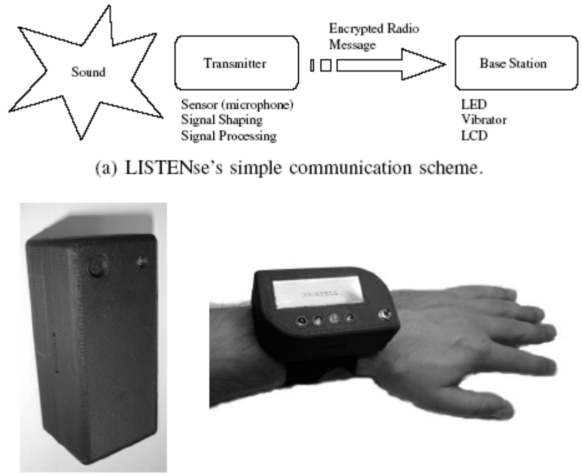

Figure 3: The LISTENse prototype schema (Baker et al., 2007)

Conclusion

The need for wireless communication systems particular in the health sector has never been that high. The fact that the number of the aged continues to rise makes wireless communication systems the answer to quality healthcare that the aged require. However, availability of wireless communication systems is not enough. There is serious need for quality wireless communication systems that provide for accurate capture of data and fast delivery of the same.

While it is appreciated that a lot of research has gone into wireless communication technologies, little research has been directed to development of wireless communication technologies specifically designed for the medical field. It is however encouraging researchers from different fields including the medical field are collaborating with the aim of developing specific wireless communication for use in the medical field for delivery of quality healthcare. Although there are various wireless communication systems that have been in use in the medical field for some time now, their inadequacies coupled with many challenges has meant that they cannot be used effectively in managing patients. Even the modern wireless communication systems that have been developed still have several challenges that must be addressed by researchers with the aim of developing high-performing systems.

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