Wireless Sensor Networks for Smart Healthcare

Mohammad Ilyas
College of Engineering and Computer Science
Florida Atlantic University
Boca Raton, Florida, USA 33431
ilyas@fau.edu

***Abstract*—Surging popularity of wireless sensor networks is being propelled by rapid advances in hardware/software technologies, smaller size of sensors, increased connectivity, ease of mobility, and societal needs. As a result, wireless sensor networks are becoming a part of almost all applications that are commonly in use leading to significant improvement in quality of life. Healthcare is no exception and wireless sensors networks are being innovatively deployed to make healthcare smart, cost-effective, and efficient. This paper discusses some of the applications of wireless sensor networks for smart healthcare. The paper also includes discussion future research related to applications of wireless sensor networks in healthcare and future research directions.**

Keywords—Sensor networks, smart systems, smart healthcare, wearable devices

I. INTRODUCTION

Wireless sensor networks are emerging as communication networks of small devices that are referred to as sensors or sensor nodes. A sensor is a tiny device that has capabilities of sensing its surroundings, collecting information about parameters it is programmed to collect, processing information, receiving information, and transmitting information. There are tremendous opportunities for innovative applications of wireless sensor networks including smart healthcare.

The scope and depth of applications of wireless sensor networks are broad. This paper focuses on applications of wireless sensor networks to healthcare where sensors are used to monitor and collect healthcare related information about individuals. The information may include vitals, mobility, location, food consumption, fluid consumption, and sleeping time, etc. This could be at home, office, hospital, or anywhere else. Radio Frequency Identification (RFID) can be used in conjuction with sensors to keep track of individuals's identities and location [1,2,3,4].

Smartness of sensor networks for healthcare comes from analyzing the information collected by the sensors, and identifying patterns therein. If the collected information about an individuals points a critical situation, appropriate help can be asked for or provided in a timely mannaer. The response time can be reduced significantly and precious lives can be saved. Small flying vehicles (drones) are being used as medical ambulances to provide rapid assistance in emergencies and that is possible when location information is available.

These days almost everyone carries with him/her a smart phone and many carry smart watches too. These smart phones work beutifully as sensors that are well connected and can monitor many health-related parameters including location.

The rest of the paper is organized as follows. Section II provides backgroud and some technical details of wireless sensor networks. Section III elobaroates on smart healthcare. Section IV discusses some future researfch directions in this field. Section V concludd the paper.

II. SENSOR NETWORKS

A wireless sensor network consists of a large number of sensors or sensor nodes. Each sensor node of a wireless sensor network is connected to at least one and possibly several other neighboring nodes and each sensor node is capable of collecting, processing, transmitting, and receiving information. Therefore, each node must have an antenna, a processor, source of energy, and some mechanism to be uniquely identified. The size of sensors is limited by the power consumption, processing power, complexity of functions to be performed, communication range, and bandwidth [1]. A typical wireless sensor is shown in Figure 1.

Figure 1: A typical sensor and size [source: Google].

Many of such sensors are deployed to form a sensor network. The network topology is dynamic in wireless sensor networks that are mobile. There are well-defined communication protocols and routing procedures that guide the process of forwarding and delivering the information to the user. A typical wireless sensor network with several sensor nodes is shown in Figure 2.

978-1-5386-4427-0/18/$31.00 ©2018 IEEE

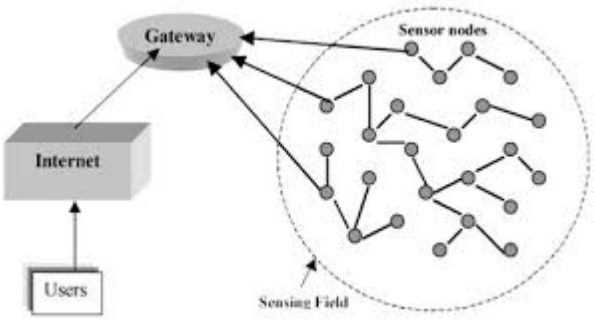

Figure 2: A typical wireless sensor network [source: Google].

Each sensor node is responsible for collecting the information for what it has been programmed. The collected information is routed towards the gateway. The routes for information may vary based on prevailing conditions and mobility patterns. The gateway collects the information and forwards it to the user either directly or through Internet [1,5].

The node where information is collected is also called sink node. This node is responsible for collecting and aggregating the information before sending it forward through a gateway. Deployment of sensor nodes and their initial location depends primarily on the nature and requirements of an application. The nodes are also responsible for making routing decisions.

III. Smart Healthcare

A wireless sensor network has the capability of sensing and collecting information for smart healthcare. When healthcare systems use the collected information and analyze that information to derive some patterns and make some decisions, they become smart systems. When these capabilities of a sensor network are deployed in a healthcare system, a powerful smart system is created that gathers ambient information, processes it, makes some decisions, and implements these decisions via actuators or other means. Such autonomous systems are referred to as smart systems. These system can make decisions and call for necessary help as needed. Figure 3 shows a typical smart healthcare system.

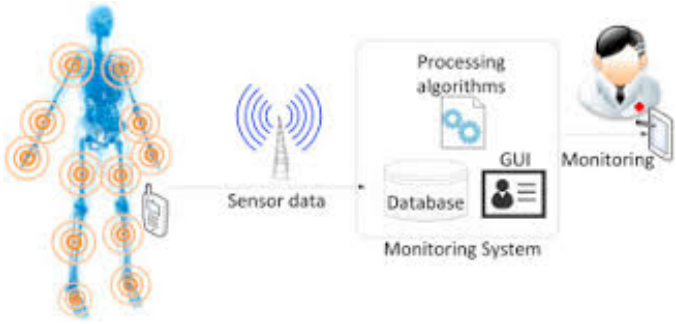

Figure 3: A typical smart healthcare system [source: Google].

These systems are very attractive in using the emerging technologies for improving the quality of life of people around us. A few examples of such smart systems are presented in this section. The discussion in this section is limited to the use of smart systems in healthcare.

A. Smart Health moinitoring

Advances in semiconductor technologies continue to reduce of size of hardware devices with increased processing power. Advances in communications with an added dimension of mobility have provided ubiquitous access to information. The demand for such devices has also been a factor propelling the growth. The demand is created due to increased longevity of human life and a larger population requiring health monitoring. This subsection discusses a few examples of smart health monitoring [6].

Wearable health monitoring devices are becoming very common [7,8]. These devices are built with embedded sensors to sense specific parameters. Medical professionals that would like to monitor their patients for a longer duration for longitudinal data collection, prescribe use of a wearable device for a specific function such as monitoring heart/pulse rate, glucose level, physical activity etc. The patient wears that devices for several hours/days. The device with embedded sensors collects the data for a specified duration and the data is either retrieved from the device or transmitted to a medical professional for analysis and assessment. The data can be used for analysis, assessment, and/or for diagnosis. Having different components of data available to a medical professional over a longer duration of time, gives and added advantage to analyze and diagnose some of the conditions that occur infrequently or occur only under certain conditions [9,10,11,12].

If multiple devices and multiple sensors are being used for monitoring multiple parameters and/or conditions, these devices/sensors can be networked to share information with each other, analyzing the information, and making some decisions, thus creating a smart health monitoring system. These devices can be a part of the garments. For instance, any vulnerable patient with a need to be monitored, may have a networked wearable dress that has devices/sensors monitoring his/her vitals. The information collected by the dress can be analyzed on a regular basis and immediate medical help can be requested as needed. Some weable devices are shown in Figures 4.

Figure 4: Examples of wearable devices [source: Google].

Similarly, an infant's dress can have embedded sensors that monitor the heart/pulse rate and create an alert or sound an alarm to avoid sad consequences of Sudden Infant Death Syndrome (SIDS). Another common example is for individuals that have obstructive sleep apnea. Patients with this condition stop breathing as they sleep, lowering the blood oxygen levels, and creating a condition that could potentially be life threatening. A common approach to help patients with this condition is to use a device called Continuous Positive Airway Pressure (CPAP). The level of CPAP pressure needed for each patient is different based on the severity of his/her sleep apnea. The newer CPAP devices have sensors and have become smarter. These devices continuously monitor the sleep apnea condition, assess the pressure level needed to help the patient enjoy his/her sleep, and adjust the pressure accordingly.

Another example of using smart health monitoring is for individuals who are severely diabetic and must use insulin to control their glucose level. In general, these individuals will keep a supply of insulin with them and use as they start feeling the symptoms. That is fine as long as such an individual is awake or physically able to inject insulin as needed. In some critical cases, smart monitoring systems may help. In such cases, a smart system regularly monitors the glucose levels along with other parameters including vitals. The systems assess the need for insulin and decide to automatically inject an appropriate amount without an intervention from the patient. Such a smart system can certainly address critical situations and play its role in saving lives.

B. Smart Homes

The fraction of aging population is rapidly growing. It was reported in [11] that by year 2050 the number of people aged 60 years and over is expected to reach 2 billion. This represents a growth from 12% of the world population in this category in 2015 to about 22% in 2050. To serve this segment of the population and to maintain their quality of life, world will need to adjust their approaches and develop new models to serve their needs and to assure their independence. The healthcare needs for this segment of population are expected to increase. It is understandable that elderly population will be spending a larger fraction of their time in their homes. It is also understandable that the geriatrics healthcare workforce may not grow as quickly as needed to serve the population that needs frequent health monitoring. To address these needs, emerging technologies can be used to help in developing assistive devices and smart homes [13].

A smart home is dwelling that deploys emerging technologies including sensor networks and IoTs to facilitate healthcare monitoring of its residents and facilities their independence leading to an improved quality of life. The smart home technologies cover many aspects including smart appliances, assistive devices, smart controls, and integration of health monitoring with smart systems. This subsection discusses a few examples/features related to smart homes.

A smart home must be equipped with smart appliances. As a fundamental feature of a smart home is a communication network, all the smart appliances must have networking capability. The appliances include refrigerators, dishwashers, cookers, toasters, and coffee makers. medicine chests, beds, and many more. These appliances can be programmed to communicate with each other and to implement any desired level of smart functionality including healthcare features. In addition, their internet connectivity (possibly through Internet of Things) making them accessible essentially from anywhere. Being accessible provides two-way communication; you can use alerts about the status of an appliance and you can also control (and change its settings) from anywhere. These aspects are particularly beneficial to elderly population with limited mobility.

Such a smart collection of smart appliances in a smart home can make life a bit easier and improve many aspects daily living. For instance, residents can be alerted about taking their medications in a timely manner, refrigerators can alert if certain items are low on quantity or are about to expire, the appliances can ever order items to replenish supplies, washing machines or coffee makers can send a text when their activities are done, and many other similar actions. These smart appliances such as a washer/dryer can even decide, whenever there is flexibility, to turn on in accordance with the conditions in the power grid thus optimizing the energy use and helping in maintaining the stability of the power grid.

Residents with physical disabilities can make use of assistive devices that are connected to the home network. For instance, eye movement can be used to type commands, Radio Frequency Identification (RFID) can be used in conjunction with sensor networks to open doors, or call for help, if needed, and provide identification information stored or appropriately implanted somewhere on a human body. These assistive technologies are priceless for individuals that are unable to communicate through normal channels.

As the level of smartness increases in homes, the services will become increasingly automatic and will make decisions in accordance with the prevailing conditions or surroundings. These are also referred to as ambient technologies or context-aware systems. A typical smart home is shown in Figure 5.

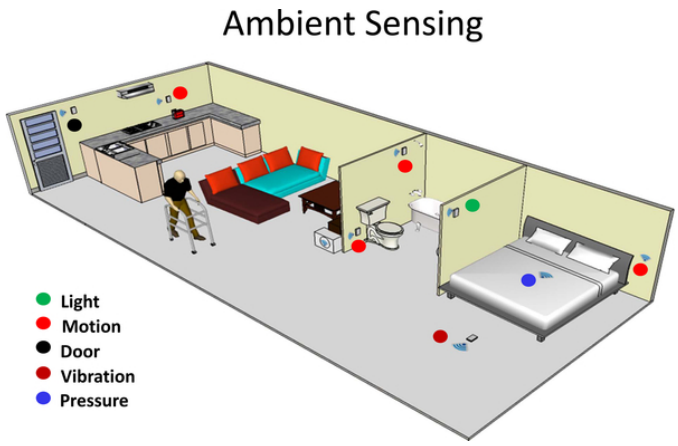

Figure 5: An example of a smart home [source: Google].

C. Smart Systems for Behavioral Adjustment

Another expectation from smart systems using sensor networks is that the real-time information available from smart homes (or other settings) may be effective in influencing behavior of residents. For instance, we are frequently reminded how many trees have been killed when we print a large document. The intent, of course, is to educate so that we may print minimally and save the trees so that environment can be improved. The same approach can be extended that knowing the information may lead to a positive change in our behavior. In this subsection, we discuss some examples of gathering real-time information in a smart home and making it accessible to the residents with a hope of altering behavior [14].

Many of us read labels on food items before we purchase. The information provided in the food labels is already influencing in our purchasing decisions. A smart home equipped with smart appliances, can provide additional and enhanced information in a simplified format about patterns of caloric intake and fluid consumption over a longer duration of time. It can correlate this information with physical activity and assess possible consequences. Having this information readily available is not a far-fetched idea and is easily doable. An individual who is willing to translate this information to disrupt the patterns can do so and expect healthy outcomes.

Similarly, a smart garbage can compute the amount of food being wasted, establish a pattern over a longer duration of time, and assess how many people could have been fed if that amount of food was saved and possibly redirected. Correlating this information with some additional statistics about the number of people/children who do not have enough to eat and sleep hungry, will create a powerful educational incentive to avoid wastage. The same approach can be used in assessing the water wasted because of unnecessary and excessive usage while many others do not have adequate drinking water available to them. These issues are going to become even more urgent as the world population continues to grow particularly in less affluent parts of the world [15].

Many elderly individuals forget to take their medicine regularly and on time. A smart medical chest in a smart home can send alerts/reminders to the residents about the time to take a specific medicine. In addition, it can also assess if some of the medications should not be taken together and avoid serious medical errors. As an educational component, it can also provide a pattern of medicine intake and in case of some lapses, it can assess and share potential health risks. Such an information can possibly lead to more regular pattern of taking prescribed medicine as needed [16].

IV. Future Research

With the technological advances, our society is increasingly becoming an information-based society. Wireless sensor networks are becoming prevalent. Ubiquitous communication is infiltrating deeper in our daily activities. This is continuously impacting our life style and quality of life. With longevity of life span, a larger fraction of the world population will need frequent access to healthcare. Their social needs will also need to be addressed. Densely connected smart homes equipped with smart appliances, and context-aware or ambient technologies will be useful to meet these needs.

The potential for future research in this field is enormous. This research will need to focus of data gathering through sensor networks, identifying patterns, making smart decisions, and implementing those using actuators. Future research will also need to address meaningful interactions with the residents of a facility such as a smart home to provide routine services including healthcare, and hopefully provide an information platform to serve as mechanism for altering behavior for the betterment of the residents of smart home and for the society at large. Privacy and security of information in smart systems and particularly in smart healthcare systems is a constant cocern. People will need to have a confidence that their information is safe before they feel comfortable using smart systems.

V. Conclusions

The trend of integrating emerging technologies and healthcare is growing rapidly. Information based applications are leading to creation of smart healthcare systems and are improving the quality of life.

This paper has focused on applications of wireless sensor networks to smart healthcare. After an introduction of the subject, a brief discussion about wireless sensor networks is presented in Section II. Section III discusses the applications of wireless sensorm networks in smart healthcare. In three of its subsections, three different but related topics are discussed. The first subsection discusses smart healthcare monitoring with the help of sensor networks and making some smart decisions. The next subsection discusses smart homes with smart appliances and ambient context-aware system. The third subsection discusses potential use of smart systems in positive behavioral change of individuals. The idea is that the knowing about the consequences of our actions may lead to an urge to alter our behavior for the better. Finally, some future research aspects are discussed in the context of rapid advances in technologies and society's continuous migration towards an information-based society.

VI. References

[1] Mahgoub, I., and Ilyas, M., "Smart Duts: Sensor Network Applications, Architecture, and Design", CRC Press, 2006.

[2] Ahson, S., and Ilyas, M. (Editors), "RFID Handbook", CRC Press, 2008.

[3] Ilyas, M., "Advances in Healthcare Technologies", Fifth International Workshop on Frontiers of Information Technology, Islamabad, Pakistan, 2007.

[4] Lopez, G., Custodio, V., and Moreno, J.I., "LOBIN: E-Textile and Wireless-Sensor-Network-Based Platform for Healthcare Monitoring in Future Hospital Environments", IEEE Transactions Info. Tech. Biomed. 14(6): 1446-1458, 2010.

[5] Ilyas, M., Alwakeel, S., Alwakeel, M., Aggoune, H., "Sensor Networks for Sustainable Development", CRC Press, 2014.

[6] Bitterman, N., "Design of Medical Devices – A Home Perspective. Eur. J. Intern. Med. 22(1): 39-42, 2011.

[7] Pantelopoulos, A. and Bourbakis, N.G., "A Survey of Wearable Sensor-Based Systems for Health Monitoring and Prognosis", IEEE Transactions on Systems, Man. And Cybernetics, Part C: Applications and Reviews. 40(10: 1-12, 2010.

[8] Khandoker, A.H., Karmakar, C.K., and Palaniswami, M., "Comparison of Pulse Rate Variability with Heart Rtae Variability during Obstructive Sleep Apnea", Med. Eng. Phys., 33(2): 204-209, 2011.

[9] Anliker, U., Ward, J.A., Lukowicz, P. *et al., "*Amon: a wearable multiparameter medical monitoring and alert system", IEEE Transactions on Information Technology in Biomedicine, 8 (4): 415-427, 2004.

[10] Huang, H.P., Hsu, L.P., "Development of a wearable biomedical health care system", Proceedings of the IEEE/RSJ international conference on intelligent robots and systems, August 2, 2005, pp. 1760-1765.

[11] Nugent, C.D., Finlay, D.D., Fiorini, P., Tsumaki, Y., and Prassler, E., "Home automation as a means of independent living", IEEE Transactions on Automation Science and Engineering, 5 (1): 1-9, 2008.

[12] World Health Organization, "Ageing and Health?", September 2015, Retrieved from http://www.who.int/mediacentre/factsheets/fs404/en/

[13] Nugent, C.D., and Augusto, J.C., editors, Proceedings of the 4th International Confernece on Smart Homes and Health Telematic (ICOST), June 2006, Belfast, UK.

[14] Grossman, P., "The LifeShirt: a multi-function ambulatory system monitoring health, disease, and medical intervention in the real world", Studies in Health Technology and Informatics, 108 (2004), pp. 133-141.

[15] Matsuoka, K., "Aware home understanding life activities. Towards a human-friendly assistive environment", ICOST'2004. Proceedings of the international conference on smart homes and health telematics, IOS Press (2004), pp. 186-193.

[16] Ahson S. and Ilyas, M., "Location-Based Services Handbook: Applications, techniques, and Security", CRC Press, 2011.