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ARCHITECTURAL DESIGN SOLUTIONS FOR REMOTE HEALTHCARE MONITORING SYSTEMS

Hussein Khairallah, Lubna Alazzawi
Department of Electrical and Computer Engineering,
Wayne State University, Detroit, USA

ABSTRACT

Remote Healthcare Monitoring System (RHM) represents remote observing of patient's wellbeing and providing medicinal services. Sensors play an essential part in RHMS. They measure the physical parameters and give continuous information to health organizations, doctors etc. The presence of smart phones and other portable devices have allowed us to utilize remote healthcare monitoring system for an assortment of structures. In addition, Wireless Sensor Network (WSN) advances considered as one of the key research factor health care application for enhancing the standard of living. This paper represents three tiers operating in the remote healthcare monitoring system; Body Area Network (BAN), PAN Coordinator and Back- Medical End System (BMEsys). This paper also focuses on several patients PAN coordinators which include Wireless Sensor Network that can be used at fixed tale-monitor location and periodic measurements, Personal Digital Assistant (PDA) can be used in patients own home or community setting with continuous measurements and smart phones can be utilized anywhere with wide range parameters. The main aim of this paper is to provide a meaningful utilization comparison between Wireless Sensor Network, PDA and smart phone in RHMS architecture design.

KEYWORDS: *Remote Healthcare Monitoring System, Smart phone device, BAN, PAN, PDA, WSN.*

I. INTRODUCTION

Most recent innovative improvements in remote systems monitors, miniaturized scale gadgets reconciliation, sensors, and the web permit us to overhaul and change the method for human services administrations work. The main aim of remote health monitoring is to give restorative administrations organizations to anyone at whatever point, overcoming the necessities of spot, time and character. Generally patients have heath issues like weight, hypertension, erratic heartbeat, or diabetes etc. In these cases, people are typically urged to irregularly visit their experts for routine remedial check-ups. In mobile healthcare system the patient's wellbeing information is gathered by the body sensors. This data is transmitted to remote healthcare monitoring system. With this information given by the patient, the specialists help in the treatment [1]. Advances propelled cellular telephones have an enormous impact on our standard life. Convenient advancement is helping with conceivable time and gives remedial staff with consistence remote access to patient's wellbeing data [2]. In case of an emergency like heart attack, the person's health information such as heart rate, blood pressure, temperature needs to be updated within a short time before the dispatch of ambulance and medical professionals arrive [3]. This paper is organized as follows: Section 2 gives the relate work description. Section 3 discusses proposed network layer architecture of M-health monitoring System and brief description of Body Area Network, Personal Area Network and Back- Medical End Systems (BMEsys. Section 4 describes Multi- Patient Network Coordinators, which includes description of Wireless Sensor network, Personal Digital Assistant and Smartphone. Performance evaluation of Multi- patient network is presented in section 5. Section 6 provides description of proposed system components. Finally, this paper is concluded in Section 7.

II. RELATED WORK

The main goal of remote health monitoring system is to monitor medical parameter of patients from everywhere. Because of the advancement in wireless technology implementation of mobile health care is not difficult. Wireless communication is used on a large basis in health care environment to transfer the data. In [4] the study ensures a marvellous workforce in human healthcare areas using smart phones, which in terns helps the patient to reduce the medical expenses and improves the health of the people. Mobile health can connect mobile device and health and takes it to another level, especially smart phones. In [5] an artistic state, pocket based PC, affordable, handy, portable, reliable wireless monitoring of health and alarm system is proposed. Human's electrocardiogram (ECG), Body temperature and heart rate information taken into account and its being sent to a personal digital assistant (PDA) using IEEE 802.15.1 Bluetooth. The main benefit from the proposed system is to low the intervention time for the patient in emergency cases. Accordingly the proposed low cost system can increase quality of life of the patients. In [6] the proposed system the medical sensors are portable depending on the patient's requirement. This feature makes the system flexible to all medical applications such as home monitoring and hospital health care. The fundamental task of the sensors is to gather physiological information and send them to the individual server. A few generally utilized therapeutic sensors are ECG, EEG, EOG, and EMG. In [7] the system was capable of monitoring multi patients simultaneously to check on their physiological parameters, the Wireless Sensor Network (WSN) system includes wireless relay nodes which are responsible for transferring the data sent by the coordinator node. Coordinator nodes are attached to patient's body which collect all the signals from wireless sensors and transmit them to the base station.

III. ARCHITECTURE OF REMOTE HEALTHCARE MONITORING SYSTEMS

The RHMS system is aimed to developing a set of modules which can facilitate the diagnosis for the doctors through tele-monitoring of patients. It also gives the facility of continuous investigation of the patient for emergencies looked over by doctors. Medical and environmental sensors are used to monitor the health and the surrounding of the patient. The sensor data is relayed to the server using a smart device or a base station in close proximity. The doctors and caregivers monitor the patient in real time through the data received through the server. The architecture of the RHM system composed of three tiers; the Body Area Network(BAN), PAN Coordinator and Back- Medical End System (BMEsys) as shown in Figure 1.

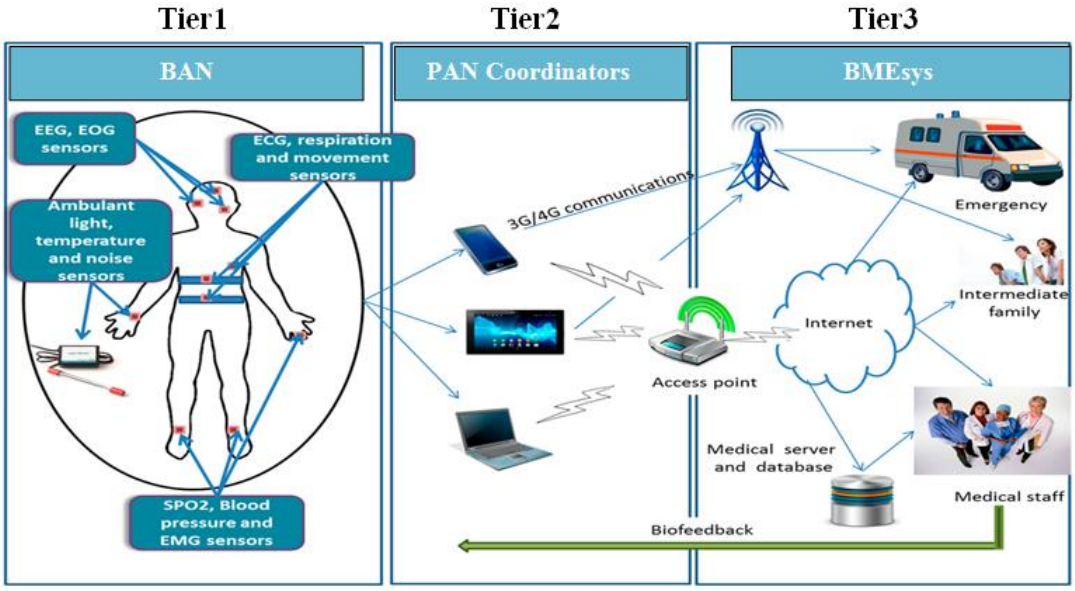

Figure 1. Architecture of the remote healthcare monitoring system

The BAN consists of wearable sensors. Patients are surrounded by different variety of wearable sensors which collects information from human body like heart rates, blood pressure, and temperature etc. The data collected and transmitted wirelessly to the PAN coordinator for processing. PAN coordinator such as smart devices forward the data to remote servers using long range communications. Clinical back end servers received and processed all the patients' data. Depending on the situation action will be taken by doctors or nurse. For emergencies patient's family can be notified and required facility is provided to patient [8], [9], [10]. The following subsections describe the RHM system architecture in details.

3.1. Body Area Network (BAN)

Body Area Network (BAN), is additionally called as Body Sensor Systems (BSS) or Wireless Body Area Network (WBAN). It's a stand-alone structure where the sensors might be embedded into patient's body or mounted on the body surface. The central idea driving wireless body range system is to evacuate all wireless joining sensors on the patient and creating remote system access between sensors. Every patient in this gadget is associated without links, without decreasing patient's comfort. BAN is a standard advanced for low power gadgets and operation on, in or around the human body to serve utilizations including medical, consumer electronics personal entertainment and other. Mobile healthcare has built up a versatile BAN and nonexclusive administrations for patients and health professionals. Remote monitoring service is the only sort of administrations that can be given. The healthcare BAN is an imaginative health observing device that comprises of sensors and correspondence. Correspondence between elements inside of a BAN is called intra-BAN correspondence. To utilize the BAN for remote checking outer correspondence is obliged which is called additional BAN correspondence. A BAN is a system which imparts a few attributes to customary WSNs however contrasts in numerous others, for example, strict security and low-control utilization. It is obligatory to comprehend the kind of BAN applications before the reconciliation of a suitable security instrument. The right comprehension will lead us towards an in number security instrument that will ensure the structure from conceivable dangers [11], [12]. A sensor is in charge of the information obtaining procedure. Figure 2 gives the graphical description of BAN. Sensors are attached to the human body for measuring breathing, heartbeat and different activities. Different types of sensors include thermal and temperature sensors like Calorimeter, Thermocouple, Thermistor, Proximity & Presences sensors. These data is collected and stored in smart devices, and then it is sent to hospital server via WAN network. This information is analysed by the professionals and the required suggestions are given. Each patient's data is stored in hospital database. In figure 2 the body area network architecture is shown.

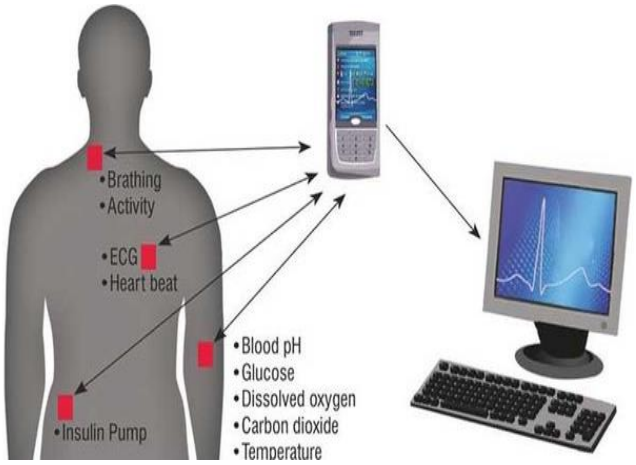

Figure 2. Body Area Network (BAN)

3.2. PAN Coordinators

The Personal Area Network Coordinator (PANC) plays an important role in overall RHM systems. It is designed as an interface unit between medical sensor nodes and remote hospital server and related

services. A PANC typically involves mobile devices such as a cell phone, a hand held computing device, PDA etc. PANC electronic gadgets hold persistent confirmation data and are arranged with the medicinal server IP address keeping in mind the end goal to interface the restorative administrations. It gathers physiological imperative signs from BAN, forms them, and prioritizes the transmission of basic information. When there is sudden clinical change in the patient's condition and information content for instance changes in cardiovascular signals, temperature, oxygen immersion, and forward it to the restorative server. Also, the PANC has the capacity to perform the role of investigating the physiological information and decide client's wellbeing status taking into account information got from MSS and give input through an easy to use and intuitive graphical client interface. Figure 3 shows an example of PAN Coordinator architecture designed for home monitoring application. Different kinds of environmental sensors deployed are integral part of this personal area network. In this Figure the PAN subsystems are connected to Wide area networks and mobile devices through gateway subsystems. The mobile devices are carried by the user or sensor nodes with WAN interface. The network congestion in the gateway is highly dependent on local processing capabilities of PAN subsystems [11], [13].

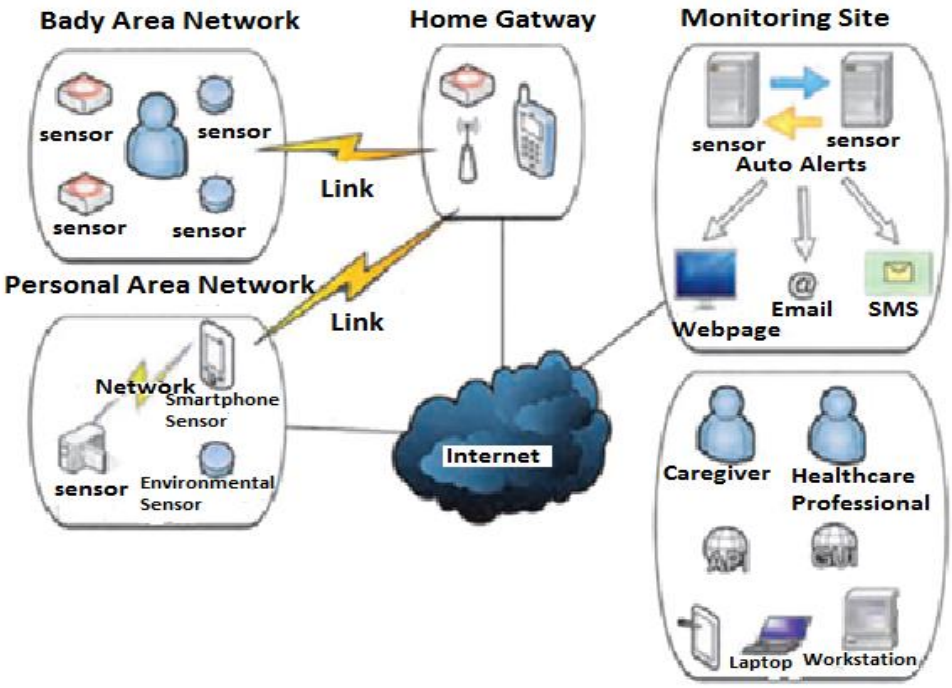

Figure 3. PAN coordinator

3.3. Back- Medical End Systems (BMEsys)

The Back-Medical End System (BMEsys) is the backbone of this entire architecture. It is receive data from all the PAN Coordinators. Whenever the data received from the patients, the results are stored in the central database. The BMEsys keeps patient specific records. It can infer any trend of diseases for patient, family even locality [14]. Back end terminal has a graphical interface used by doctors and any emergency contacts associated with patients like ambulance, police, hospital, and etc. The Back-Medical End System (BMEsys) is shown in Figure 4 below. Ambulances are informed when the patient's condition cross the maximum limit set on the sensors. Doctors access the data stored in back end system to monitor the patient's health. Hospitals fetch the information from back end data for the full pledged information regarding patient.

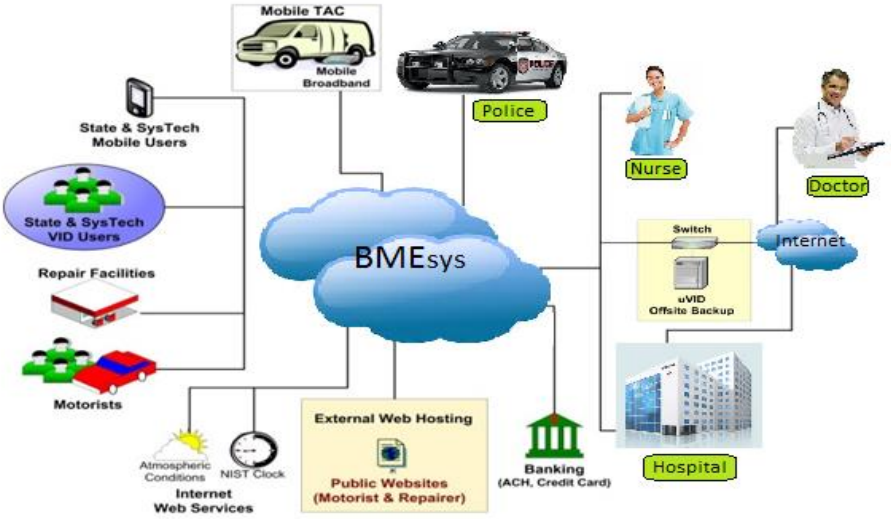

Figure 4. Back-Medical End systems (BMEsys)

IV. MULTI-PATIENT NETWORK COORDINATORS

In this section, we provide an overview of technologies used to collect and transmit vital physiological data from the patient to the remote monitoring station. With the expanding of portable society, the remote structure can bolster numerous present and rising health awareness organizers. Multi patients' network includes more than one patient in the centre region. The patients network coordinators responsible for gathering and bundling the entry signals from alternate sensors, and sends them to the therapeutic focus [15, 16]. The centre region is distinguished by a special ID which is utilized to recognize every patient in the system. The accompanying sub-areas depict the distinctive sorts of patient organizers innovations and their usefulness. Tracking scenario is focused on the estimation on the patient's position and movements. WSN can be utilized at altered story screen area and occasional estimations. Personal Digital Assistant PDA can be utilized as a part of patients own home or group setting with persistent estimations and advanced mobile phones can be utilized anyplace with wide range parameters. Figure 5 shows multi patients PAN coordinators scenario. The following subsections describe the multi-patient network coordinators in details.

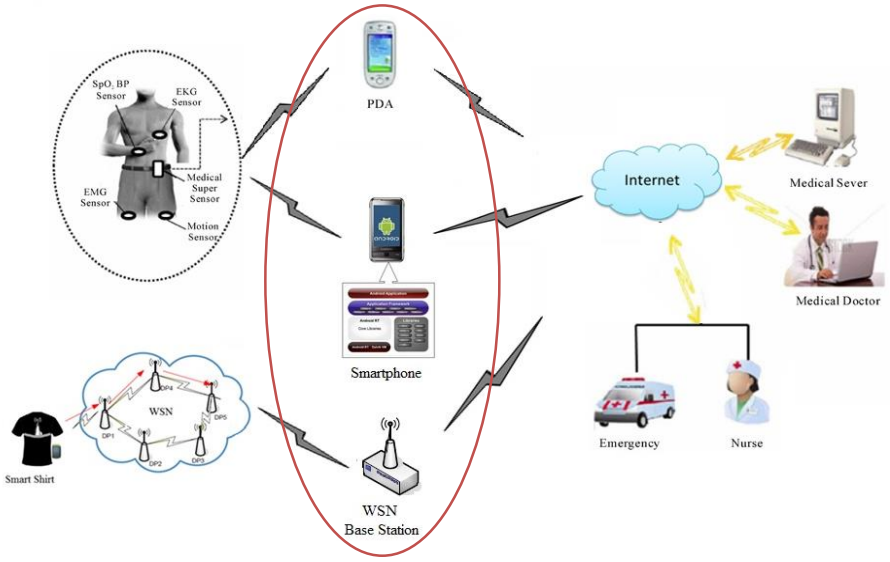

Figure 5. Multi-Patient PAN coordinators

4.1. Wireless Sensor Network (WSN)

Wireless Sensor Network is a group of sensors which convert variation in physical quantity into electrical signals with a communication infrastructure for monitoring and recording patient's condition. Commonly monitored parameters are temperature, blood pressure, heart beat rate etc. Sensor systems are taking into account physically little sensors trading for the most part measured data. Sensor arranges that are made out of wearable or embedded sensors. The sensor networks need not be designed or pre-decided. This permits irregular sending in or out of calamity help operations. Then again, this likewise implies sensor system conventions and calculations must have self-sorting out abilities. Another extraordinary component of sensor systems is the helpful exertion of sensor networks. Sensor networks are fitted with an on-board processor. Rather than sending the crude information to the hubs in charge of the combination, sensor network utilize their handling capacities to locally complete basic calculations and transmit just the required and halfway prepared information [17, 20]. Figure 6 shows the architecture of wireless sensor networks. In this Figure the Base station is act as a PAN coordinator.

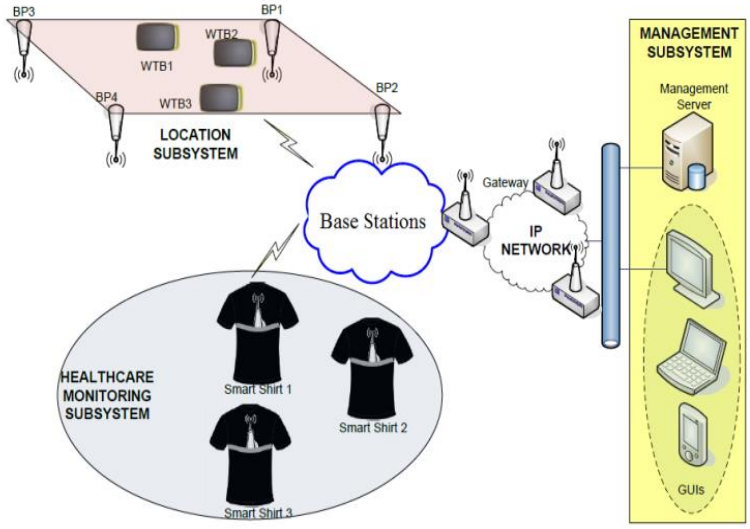

Figure 6. Wireless Sensor Network (WSN) [17]

The health sensor devices and the smart shirts which collect and process the physiological parameters are assuming a base station collects all data. The Location Subsystem consists of a set of Beacon Points, which are deployed in well-known positions, and a set of end devices which are carried by targeted users. The Management subsystem connects to the Information Technology foundation that handles the data connected with each and every patient. It comprises of a management server, which procedures and stores all the information connected with the patients, and a Graphical User Interface (GUI), which permits the healing centre staff to screen the status of the patients. This subsystem can be incorporated into business healing centre administration frameworks. In the architecture the Base Station serves as ccoordinator, it is placed in between the Location and Healthcare-Monitoring Subsystems and the Management Subsystem. It is responsible for carrying data from the former to the latter and commands from the latter to the former [17].

4.2. Personal Digital Assistant (PDA)

Personal Digital Assistant (PDA) is a small hand held electronic device that provide computing, information storage and acts as a PAN coordinator that links between patient and back end medical system. The ECG signals, temperature, heart beat etc. of individual patient is transferred to personal digital assistant. PDA displays the information collected from sensors and stores it. In case of emergencies, data is sent to central server using wireless communication [18]. Figure 7 shows the PDA layout. Different icons and features available in a simple PDA are mentioned as follow:

- **Application screen:** Display which shows the application installed in PDA.
- **Battery life:** shows how much power is there in the PDA to run the application.
- **Home icon:** If we tap the icon, it shows the application installed.
- **Menu icon:** Tap to view options for PDA or current application.
- **Address book:** Shows the contact information of people stored in the assistant.
- **On screen key board:** individual letters and numbers can be tapped to enter the data.

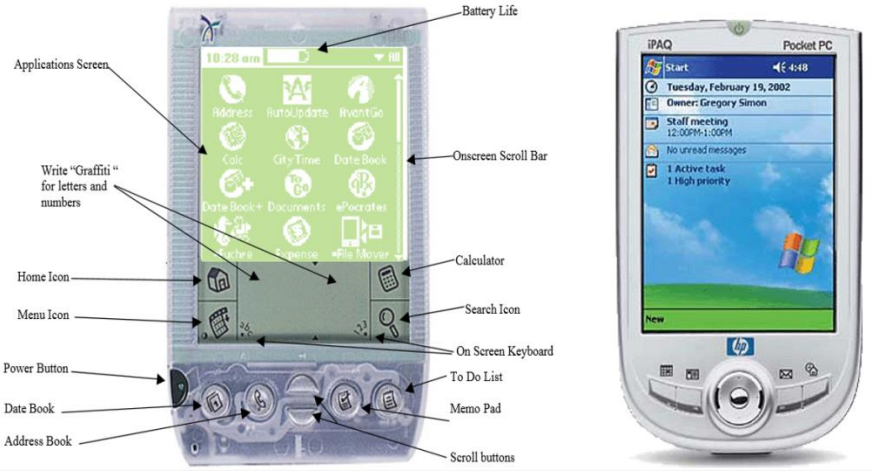

Figure 7. Basic PDA layout [18]

Almost all PDAs can associate with the Internet. A PDA has an electronic visual presentation. Which empowers it to incorporate a web program, all models likewise have sound capacities empowering use as a versatile media player. PDA use windows working framework and they likewise can have synchronization of information between a PDA and a desktop PC has incredibly expanded the convenience of PDAs. There are a few elements of handheld PCs that make them attractive in medicine. The capacity to have a PDA or "strolling library" accessible at all times can significantly affect patient consideration. Moreover, the capacity to get to patient-particular information, as through connection with an electronic medical record (EMR), is a powerful tool. Quick and secure remote associations will make this conceivable, and a several industries have started to perceive this. The expanding acknowledgment of PDA will add to the formation of future portable programming for radiology use. Most present occupants and colleagues have some PDA encounter, and are all the more tolerating of the little screen size and stylus interface, permitting continuous move to a paperless division and additionally a film-less one[18, 19].

4.3. Smart Phone

Cell phones are quickly turning into the main personal computer and specialized gadget in individuals' lives. Today's cell phone not just serves as the key figuring and correspondence cell phone of decision but it may establish its own network and become the PAN coordinator. It accompanies a rich arrangement of embedded sensors, for instance, an accelerometer, digital compass, GPS, amplifier and camera. These sensors are empowering another class of uses to rise over a wide assortment of spaces, for occasion, social insurance, health care [21]. Figure 8 shows these sensors.Likewise, the Smartphone incorporates more traditional gadgets that can be utilized to sense, for example, front and back cameras, a microphone, GPS and Wi-Fi, and Bluetooth radios. A large portion of the more up to date sensors are added to bolster the client interface (e.g., the accelerometer) or augment location-based services (e.g., the digital compass), they additionally speak to a critical chance to assemble information about individuals and their surroundings. For instance, accelerometer information is fit for portraying the physical developments of the client conveying the telephone. Different pattern within the accelerometer can be used to automatically recognize varied activities (e.g., running,

strolling, and standing). The proximity and light sensors permit the telephone to perform basic types of setting acknowledgment connected with the client interface [22].

Figure 8. Smartphone sensors

The mobile phone sensing architecture is shown in Figure 9. This architecture comprises the following parts:

- Inform, Share, and Persuasion: represent a grouping of components with a common meaning. In Inform, only the user is informed in the case of personal sensing applications but a group of users are informed with a community sensing application, hiding the identity of individual users. Sharing is optimized through visualization of data. Web applications that connect with phone sensing applications sometimes allow the sharing of the widely collected data. Social media sites can leverage this data for example to allow users to compare fitness data. Sharing of data allows for user engagement as might be the goal of a social media company and allows for a better user experience. Sharing of data can allow for the persuasion of a user to quit smoking for example or reducing one's carbon footprint, through motivation of others in the community group doing so. In this way, persuasion models can increase the health of a community and environment over time.

- Learn: The sensor data collected from user phones can be analyzed and understood by applying machine learning and data mining techniques. Such tools can be used to present to the community knowledge about distance run by a group for instance. The applications are limited by the algorithms appropriate for the data but the potential will grow with increasing phone capabilities. These capabilities can already be used to tell where a user is as well as what activity they are doing.

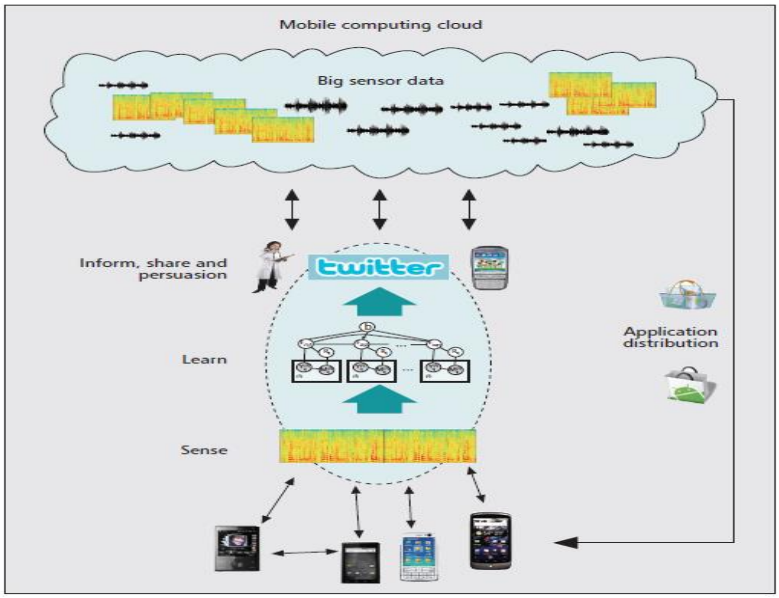

Figure 9. Mobile phone sensing architecture

Sense: During sense, individual smartphones collect data available through the sensors. These sensors include for example the microphone, camera, accelerometers, and GPS. This phase represents purely raw data collection. This phase is limited by current smartphone technology [21], [22].

V. PERFORMANCE EVALUATION OF MULTI-PATIENTS NETWORK COORDINATORS

One way to analyze the performance of the network coordinator is to compare the three coordinator types and their characteristics [19], [23], [24]. This comparison is given in Table 1.

Table 1. Comparison between the three types of the coordinator

Attributes	WSN	PDA	Smart Phone
Use	Fixed tale-monitor location	Patients home or community setting	Anywhere carried by patient
Portability	Low/Medium	Medium	High
Purpose	Prevention of long term reaching hospital	Hospital at home, Short-term	Early hospital admission
Parameters (examples)	BP, Weight, resp., glucose	EVG, SpO2, temp., BP	ECG, EMG, EEG, Body temperature and heart rate
Diseases (Examples)	CHF, COPD, asthma, diabetes	Acute exacerbations of chronic diseases, infections post OP	Unstable angina, pacemaker patients
Measurements	Periodic	Continuous	Continuous
Tele-monitor location	Fixed	Next to	Mobile
Staff assistance	Home: feasible, Residential: not feasible	Yes	Yes
User Friendliness	Medium	Medium	High
Alarm necessary?	No	Yes	Yes
Communications Medium	POTS, ADSL, ISDN	POTS, ADSL, ISDN	GSM, GPRS, Satellite
Data Analysis	Remote most of the time	On exceeding threshold (automated)	On exceeding threshold, on request
Power	Mains	Mains	Battery

VI. PROPOSED SYSTEM COMPONENTS

From the evaluation and the performance of multi-patients network coordinators our proposed system consists of these three from the assessment and the execution of multi-patients system coordinator our proposed framework comprises of these three segments; sensors, smartphone and medical end system components.

6.1. Sensors

Sensors are in charge of the information gathering process, and guarantees that a physical phenomenon, for example muscle action or blood flow, is initially converted. Sensors in the BAN can measure pulse, oxygen level, glucose level, and so on. Figure 10 shows the sensor network used in health care system. The system incorporates a progression of sensors coordinated into a sports bra for women and vest for men. By means of a lightweight and wireless module that snaps onto these clothing, the sensors communicate with system software to gather data, and send it over a remote systems. Electrical signs and other physiological information accumulated by the sensors are sent to the remote module. Information from the sensors then stream to cell phones and hand-held gadgets, which extend the utilization of the system in health care.

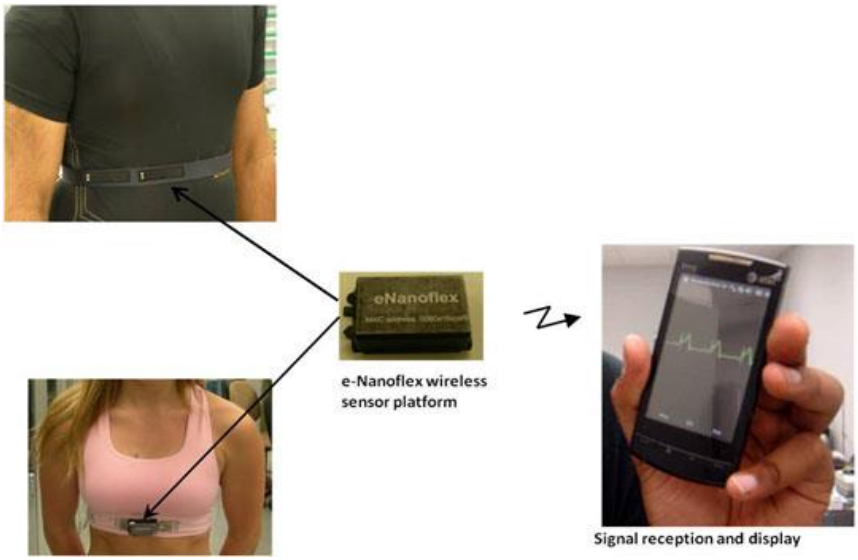

Figure 10. The wireless monitoring sensors integrated into garments

6.2. Smart Phone

Mobile phones are turning into a specialized gadget in individuals lives. Application conveyance channels, for example, the Apple App Store are changing cellular telephones into App Phones, equipped for downloading a heap of utilizations in a moment. With respect to scientific classification of the term apps VS applications and app classification plans, there are three sort of smart phone applications: native (operating system based) applications, Web applications, and hybrid applications that consolidate highlights found in both native and Web applications.

6.2.1. Mobile Browser or Web Apps

Mobile browser or web apps are basically websites that are conveyed utilizing the smart phones browser. The determination of content and the way in which it is shown are controlled by the logic contained in a system facilitated on a remote server (server-side). Likewise with desktop-based Web intercessions, Mobile Health mediations utilizing mobile Web applications can fuse refined levels of intelligence, customizing, and engagement tracking.

6.2.2. Hybrid Apps

Hybrid apps fuse features and usefulness found in native applications with the flexibility and productivity connected with utilizing versatile browser applications. They can show program content utilizing a browser that is embedded inside of the native application itself instead of just utilizing the smart phones browser. Thus, hybrid applications can offer more firmly incorporated environment (envelope) than versatile mobile browser applications for RHM systems. They can give various instruments some of which draw upon the intelligence and information that are just accessible from other native (built in) smart phone features.

6.2.3. Native Apps

Native apps utilize the advanced components and usefulness made accessible through the cell phone's operating system (e.g., iOS for iPhones and also Android). For instance, they can utilize GPS-derived area location, the system calendar, system alerts, and different notification. Some native applications can work adequately without constant or live Internet access. Since local applications use information accessible through the cellular telephone's operating system, they must adhere different outline and survey necessities of the organization administering the operating system, and be downloaded by means of application stores facilitated by the smart phone maker. The Figure 11 shows the three different applications; web, hybrid, and native.

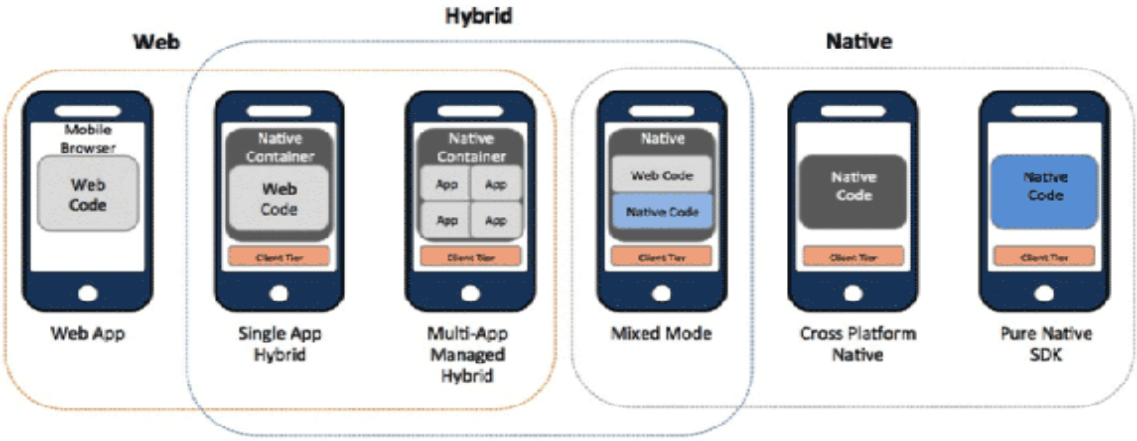

Figure 11. The three sort of smart phone applications

6.2.4. Email

Email fits inside of the more extensive classification of cellular telephone text notice apparatuses. Like text messaging and IVR calls, email proactively pushes substance to RHM systems members. Naturally, the arrival of email is far less notable because of not having audible or visible signal. In these circumstances, email might oblige members to search it out at their own drive. It is conceivable to build remarkable quality by requesting that program members change their default settings so as to be capable of being heard sounds or noticeable alarms that report its arrival.

6.2.5. Short message service (SMS) text messaging

SMS messaging includes the conveyance of brief instant messages that are shared between/among cell phones. Text messaging can achieve every single cell phone independent of service provider and is the most widely recognized non-voice utilization of cell phones. Sensing text messaging can acquire charges from the client's cellular plans, in spite of the fact that this expense differs by plan, and unlimited messaging is turning into a more ordinary packaged alternative. It is conceivable to maintain a strategic distance from per-message additional charges by utilizing the gadget's text message functionality accessible when sender and receiver(s) all utilize the same smart phone brand (e.g., the iPhone's iMessage ability).

6.2.6. Recording pictures, audio, and video

In mobile health applications, users can take photos of the meals they eat using the smartphone camera in order to determine meal portion size. They can also play tailored music to increase and motivate continued exercise or take images with the camera again of carbon monoxide meter in the area to confirm they are following their no-smoking program. In the Figure 12 below, an example is shown of such a mobile application for quitting smoking.

Figure 12. Quit Pal App for smoking cessation

6.3. Medical End System

The medical user's health information is gathered by the body sensor networks and transferred to the smart phone via Bluetooth or another application. This turn is transmitted to the remote health to remote healthcare system center. With this information provided by the medical user, the medical professionals assist them and save users lives. The Figure 13 below depicts the body sensor network. This systematic has three majors parts, described as follows: Wearable sensors, BSN manager and back end equipment (smart phone Server). Wearable body sensors continuously transmit the data about the patient's health and transmit it to the smart phone client, which is then collect all the data and send it to smart phone server using the cellular network. Finally, the smart phone server provides back support to the staff.

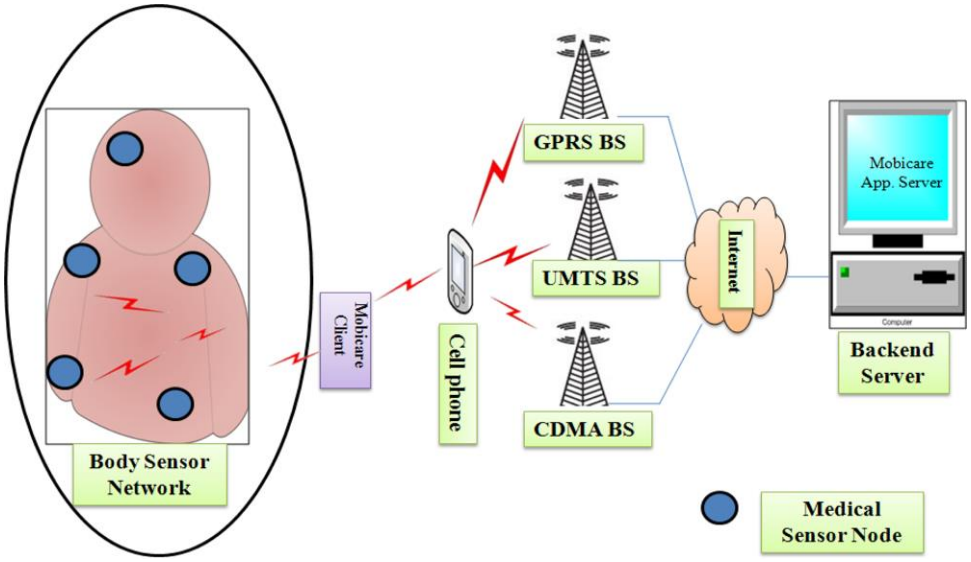

Figure 13. Proposed system components

VII. CONCLUSIONS

In this paper, we depicted the development of the Remote Healthcare Monitoring (RHM) Systems which epitomizes structured layers and the different sort of sensors through which various patients can be weighed meanwhile and can be given the obliged remedial care on time in the midst of emergencies. We have likewise discussed about the means through which the data from the patient can be traded to the health care reasons for living and how suitably the patient can be watched using

such contraptions. Smart phones give the best performance as it can be used anywhere and probability is too high. It gives early hospital admission and continuous measurements of the units are possible. Smartphones are turning out to be of great advantage compared to PDA and WSN. On the other hand exploring the future not simply wills these individuals really benefit by their improved wellbeing and flourishing. Once the advancement is refined, therapeutic costs for updating interminable remedial conditions will be diminished. We are completing the remote health monitoring system to help the individuals and what's more the whole mankind. Our destinations will be fulfilled if the RHMS can help a lone individual by watching his or her wellbeing and cautions him or her against any anticipated veritable infirmities.

REFERENCES

[1] Reni R. Shetty, thagaraju. (2014) "Design Development of Mobile Phone Based Health care system for Emergency Situation", international journal of computer trends and technology (IJCTT), vol. 12 no. 3.

[2] Varshney, U. (2007). "Pervasive healthcare and wireless health monitoring", *Mobile Networks and Applications*, *12*(2-3), 113-127.

[3] Toninelli, A., Montanari, R., & Corradi, A. (2009) "Enabling secure service discovery in mobile healthcare enterprise networks", *Wireless Communications, IEEE*, *16*(3), 24-32.

[4] Conejar, R. J., & Kim, H. K. (2015) "A Design of Mobile Convergence Architecture for U-healthcare", *International Journal of Software Engineering and Its Applications*, *9*(1), 253-260.

[5] Aslantas, V., Kurban, R., & Caglikantar, T. (2007) "A Low-Cost Wireless Healthcare Monitoring System And Communication to a Clinical Alarm Station".

[6] She, H., Lu, Z., Jantsch, A., Zheng, L. R., & Zhou, D. (2007) "A network-based system architecture for remote medical applications", In *Network Research Workshop*, vol. 27.

[7] Aminian, M., & Naji, H. R. (2013) "A hospital healthcare monitoring system using wireless sensor networks", *J. Health Med. Inform*, *121*.

[8] Kamarudin, N. H., Yussoff, Y. M., & Hashim, H. (2003) "Two-Tier e-Health Monitoring System".

[9] Hussein Khairallah, Lubna Alazzawi. (2015) "Intelligent E-Health monitoring Systems Architecture", IEEE SEM Humanitarian Technology Conference.

[10] Hamida, S. T. B., Hamida, E. B., & Ahmed, B. (2015) "A New mHealth Communication Framework for Use in Wearable WBANs and Mobile Technologies", *Sensors*, *15*(2), 3379-3408.

[11] Ali, K. A., & Mouftah, H. T. (2011) "Wireless personal area networks architecture and protocols for multimedia applications", *Ad Hoc Networks*, *9*(4), 675-686.

[12] Rani R. Shetty. (2014). "Design and Development of Mobile Phone Based Healthcare System for Emergency Situation", International Journal of Computer Trends and Technology (IJCTT) – vol. 12 no. 3.

[13] Vouyioukas, D., & Karagiannis, A. (2011) "*Pervasive Homecare Monitoring Technologies and Applications*", INTECH Open Access Publisher.

[14] Lin, J. C., & Nikita, K. (Eds.). (2011) "*Wireless Mobile Communication and Healthcare", Second International ICST Conference, MobiHealth 2010, Ayia Napa, Cyprus, October 18-20, 2010, Revised Selected Papers* (Vol. 55). Springer.

[15] NA, A., A O, A., K K, A., & HO, N. (2011) "Using wearable sensors for remote healthcare monitoring system", *Journal of Sensor Technology*.

[16] Kumar, N., Aggrawal, A., & Gupta, N. (2012) "Wearable sensors for remote healthcare monitoring system", *International Journal of Engineering Trends and Technology*, Vol. 3 Issue1-2012.

[17] Custodio, V., Herrera, F. J., López, G., & Moreno, J. I. (2012) "A review on architectures and communications technologies for wearable health-monitoring systems", *Sensors*, *12*(10), 13907-13946.

[18] Sandy De Groote. (2002) "PDA User Guide", MLIS.

[19] Danaher, B. G., Brendryen, H., Seeley, J. R., Tyler, M. S., & Woolley, T. (2015) "From black box to toolbox: Outlining device functionality, engagement activities, and the pervasive information architecture of mHealth interventions", *Internet Interventions*, *2*(1), 91-101.

[20] Deborah Liddle and Stuart Smitton. (2011) "Wireless network", issue paper from the Networked Services Policy Task group Series editor: Penny Garrod.

[21] Al-Taee, M., Jaradat, N., & Ali, D. M. A. (2011) "Mobile phone-based health data acquisition system using Bluetooth technology", In *Applied Electrical Engineering and Computing Technologies (AEECT), 2011 IEEE Jordan Conference on* (pp. 1-6).

[22] Lane, N. D., Miluzzo, E., Lu, H., Peebles, D., Choudhury, T., & Campbell, A. T. (2010) "A survey of mobile phone sensing", *Communications Magazine, IEEE*, *48*(9), 140-150.

[23] Kumar, P., & Lee, H. J. (2011) "Security issues in healthcare applications using wireless medical sensor networks: A survey", *Sensors*, *12*(1), 55-91.

[24] Alshurafa, N., Sideris, C., Pourhomayoun, M., Kalantarian, H., Sarrafzadeh, M., & Eastwood, J. A. (2016) "Remote Health Monitoring Outcome Success Prediction using Baseline and First Month Intervention Data", *IEEE journal of biomedical and health informatics*.

AUTHORS

Hussein Khairallah received the B. Sc and M. Sc degrees in computer science from Warsaw University of Technology, Warsaw, Poland, in 1998 and 2000 respectively. He has been a Ph.D. Student Researcher in Wayne State University (WSU) since September 2009. He is currently working on his Ph.D. degree in computer engineering at WSU.

Lubna Alazzawi received her PhD from University of Technology and University of Michigan-Dearborn, USA joint program. Dr. Alazzawi is currently working in the Department of Electrical and Computer Engineering at Wayne State University, USA. Prior to joining Wayne State University, She was teaching in the Department of Electrical and Computer Engineering at University of Michigan, Dearborn, USA. She also worked there as a postdoctoral research fellow. Her research interests include Intelligent Systems, WSN, High-Speed Networks, Smart Sensors, Embedded Systems, Wearable and Biomedical Applications, Remote Healthcare Monitoring Systems and FPGA chip design.