An Efficient Emergency Patient Monitoring Based on Mobile Ad Hoc Networks

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ABSTRACT

Medical sensors are implanted within the vital organs of the human body to record and monitor the vital signs of pulse rate, heartbeat, electrocardiogram, body mass index, temperature, blood pressure, etc. to ensure their effective functioning. These are monitored to detect the patient’s health from anywhere and at any time. The wireless sensor networks are embedded in the form of body area nets and are capable of sensing and storing the information on a digital device. Later this information could be inspected or even sent to a remotely located storage device specifically (server or any public or private cloud for analysis) so that a medical doctor can diagnose the present medical condition of a person or a patient. Such a facility would be of immense help in the event of an emergency such as a sudden disaster or natural calamity where communication is damaged, and the potential sources become inaccessible. The aim of this paper is to create a mobile platform using mobile ad hoc network to support healthcare connectivity and treatment in emergency situations.

KEYWORDS
Chronic Diseases, Human Vital Signs, MANET-Based Emergency Patient Monitoring System Application (MEPMS), Mobile Ad-hoc Networks (MANETs), Wireless Routing Protocols (WRP)

1. INTRODUCTION

There has been enormous development in health informatics in the recent past mainly due to the huge progress in computer technology. The technology is used by physicians, pharmacists, managers and other healthcare professionals to understand the demand of stakeholders including patients through the specialized computer interactive media in the field of human computer interactions and these tools are designed with the help of wireless sensor networks (WSN) (Andrew, 2002) as shown in figure 1. The modern technological and scientific advances has made our life unexpectedly easier and comfortable. The developments are so rapid and notable that they can be witnessed in almost every field (Education, Medical, Agriculture, Transport, etc.). The most significant recent time electronic

DOI: 10.4018/JOEUC.289435

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device which is gaining popularity, called sensor has the capability to perceive and sense various factors like intensity of light, moments among objects, speed, magnetism, under earth seismic waves, temperature, pressure and also medical vital signs among patients. These sensors has the ability to interact with other devices as well as themselves, collect data and store it for future processing whenever required. These sensors may communicate with a wired or wireless network. The extraordinary developments in computer technology has given rise to micro-electro-mechanical (MEM) systems that has enabled creation of small low-powered sensor nodes could form a wireless network. WSN is a infrastructure less network with a number of sensor-devices that work in coordination to achieve the intended result. They consist of a sink or a base-station and several sensors (sensor nodes). The base station collects data from all the sensors present in the network. The sensors are capable of processing information locally while interacting with the environment. A gateway node is a sensor node that collects information from other sensor nodes and sends it to the sink. The components of a sensor node are shown in figure 2.

Sensor nodes can be created as medical sensors and they will be designated several task related to monitoring human vital organs data by sensing them. These medical sensors will store, process and analyze this information to make important conclusions about human body conditions. They can detect any variations of the human vital signs (like a person’s blood pressure, eeg, pulse rate, body temperature, etc.) from their normal range and hence transfer this data to a medical practitioner or remote systems for further processing which will be used to determine the patient health. These medical sensors are could be either wearables or implanted on human organs/body(Darwish & Hassanien, 2011) (Dishongh, 2010).

Figure 1. Structural design of a WSN

Figure 2. A sensor node
Some categories of WMSNs are given below:

1. Monitoring Clinical patients
2. Elderly patients care monitoring
3. Chronic patients monitoring
4. Clinical data collection regularly
5. Emergency Patient Monitoring

Remote patient monitoring have improved to perform clinical patient monitoring and management of issues related to patients in recent healthcare systems. Remote monitoring uses digital technologies to gather health data of patients from a specific location, may be their home and later this monitoring information is transmitted electronically to healthcare systems that are operative from remote area. The received information is useful for assessment and future references when needed. Most of the recent technologies are based on integrated strategies for disease management to present added patient information so as to improve decision-making in healthcare systems. Patient management is making progress through the use of digital technology to store and retrieve patient information on regular basis and strive to give the patient the best possible cure or treatment. The patient data is recorded and even shared by the medical practitioners remotely to manage treatments of chronic patients after their consultation by medical experts or doctors which saves the time of both the doctor and the patient. The data can be collected by a variety of methods and will be communicated to other healthcare experts in hospitals, test laboratories and intensive care units. For instance, the sensors could be used for remote monitoring of chronic diseases that will be capable of capturing data automatically and they further transmit it to another digital device without the involvement of the patient. Even the patients can access or modify their information online through a web application or a mobile application (using smartphone or personal digital assistant). The sensors transmit the information received via the digital devices capable of capturing clinical data such as body weight and temperature, heart rate, blood pressure and oxygen levels on regular instants. As the computer and information technology are rapidly developing, remote patient tracking has modified the methods of data capturing and transmitting with the help of more advanced and varied The WMSN (Darwish & Hassanien, 2011) has to maintain an energy efficient, consistent, mobile and multicast communication support among its nodes and disseminate quick and precise data transfer. In this paper we discuss about the variety of WMSNs that supports the practical health care systems and have become essential to monitor the patients for assessment of their medical health.

2. BACKGROUND

Medical informatics field is concerned with the information processing and communication of medical education, practice and research (Kumar et al., 2012). Till recently the medical informatics (MI) field had a prolonged focus on medical application development rather than on the patients’ satisfaction related priorities and perspectives, whereas the medical informatics preliminary focus ranged from areas of education to research practice. According to the researchers in (Bertocco et al., 2007) the development of information systems after long time has started supporting the framework of medicine and bigger focus is made on other health care arrangements and professionals. This focus offers support to the areas of education, communication and research decision making and many other professional communities (Bertocco et al., 2007). Consumer Health informatics (CHI) (Tabassum & Damodaram, 2011) analyzes consumers’ needs for information, similar studies and implements policies thus allowing the consumers to access the available information. It also assimilates the users’ desires with MI Systems. CHI is most inspiring field that encompasses different disciplines (SmartDust, n.d.) such as nursing, patient healthcare, public health, health campaigning and education, healthcare library and communication. MI Systems and CHI have introduced a patients record system referred
to as Electronic Health Records (EHR) through which complete patient health information is made available to patients, healthcare persons and doctors. EHR allows the patients to perform Computer aided decision making and provide various options to exercise their choice suitably. Also these fields are offering a number of programs (Tabassum & Damodaram, 2011) to educate the patients in collaboration with modern technology of internet.

In addition there may be situations of emergency in case of some disastrous scenarios that requires different situations to monitor patients. Such systems have to be sufficiently scalable, economical, and extremely efficient. They are installed with excessive provisions for example they consist of paper triage or MI-Tags to assess patient data (Tabassum et al., 2013), USB receiver and a specific patient observing software. According to Nihon Kohen the limitations on wireless network technology can accommodate limited number of patients per network as given in (SmartDust, n.d.). Also the medical monitors available suffer with poor workflows set-up and are expensive, therefore MI systems are inclined towards creating much economical patient monitoring systems that could be commercially made available. They are developed by embedded sensors (Ko et al., 2010) such as Life Shirt, Sensatex and MagIC, mostly found in fashion apparels. In (Tabassum & Damodaram, 2011) there are certain notable sensors mentioned related to academics and research for example ACT in Alabama University and Body Nets (BN) of UCLA. The BN sensors are capable of perceiving and routing data via a WiFi enabled mobile device. The existing project models with the above mentioned capabilities are constrained with certain limitations where there are cases of emergency scenarios. The model discussed in section III in this paper is based on MANETs which makes a successful attempt to get over the problems act as a more powerful structure to support the communication in case of casualties.

3. PROPOSED SYSTEM AND METHODOLOGY

This research paper proposes an MANET-based Emergency Patient Monitoring System (MEPMS) for helping patients in emergency situations like a surge scenario so that they could access ambulances to arrive at hospitals. In such situation there exists chaos in the affected area due to the destruction of resources. The communication and infrastructure facilities in the area are damaged giving rise to unreliable surroundings. The MEPMS is a novel patient monitoring system that is accessible in emergency via a mobile application available in the mobile devices and is based on MANET technology. Human body conditions are monitored with the help of WMSN and are analyzed in case of deviations from normal rate are detected. These could be studied by healthcare professionals or doctors to write health improving prescriptions or suitable predictions may be done to determine the medical conditions of patients for further treatments. The data is stored and assessed on regular basis by the doctor to know the up-to-date health condition of patients. Since early treatments are the safest and better solutions to avoid serious medical health conditions. The advantage with such method is to reduce the patients waiting and avoiding regular visits to the hospitals until a specific situation becomes prevalent and is a threat to some serious consequence. WMSNs provide quality healthcare for patients by the use of wearables or implantable sensors on patients.

This paper discusses the implementation of a patient monitoring system (MEPMS) in the emergency situations that a patient can depend on so that before reaching hospitals they can keep the treatment procedure ready for the casualty patients. Also the required medication could be provided on the way to the hospitals when they are moved in the ambulances. The MEPMS is a novel patient monitoring and tracking system in case of emergency and is based on MANETs. A special wireless sensor (emergency tag or e-tag) is being circulated to casualties at a catastrophe scene instead of paper triage tags which lack more functionality as compared to the emergency tag. The e-tags has a priority number and they transmit sensor data with other significant data (triage status of patients, location) to a Mobile Adhoc network (MANET) which forms network with other MANETs thus creating a network for information exchange. MANETs is an infra-structure less wireless ad-hoc network that is self-configuring. It can deploy comparatively reliable and scalable ad-hoc wireless networks without
relying on existing infrastructure as in the case of catastrophe there is possibility of the communication infrastructure failure. The e-Tags have several add-ons and supports duplex communication. The sensor information at the emergency location is perceived and transmitted between the MANETs for processing among the mobile nodes in the MANET. The Medical MEPMS within the mobile node generates the reply by connecting to the web server. The information on the server will be accessed by the medical team members, receiving hospitals, public health officials so that they can review it, and relay the treatments and suggestions. Thus this model can offer the patient better synchronization and pre-hospital diagnosis to the treatment suggestions by the doctors/specialists.

3.1. Routing Protocols for Emergency Mobile Application Patient Monitoring

MANET is a Wireless network (WN) is a network that allows connectivity of devices for transferring and communicating information without a network cable being attached to the devices with appropriate standard protocols. WNs use a mobile network may it be a local Wi-Fi network or a microwave network and they enable communication via specific Wireless Routing Protocols (WRP). These protocols are based on different topologies of WNs. Few of them such as standard hub use wireless access points (WAPs) or the others called spoke networks are based on wireless routers that serve as a gateway to establish connection among nodes within WNs. In the latter form the nodes structure doesn't provide any transfer services. The complete communication is accomplished through the wireless access point. The nodes and Access points (APs) present on the network communicate using famous protocols 802.11 b (802.11g or both). The APs may use a mix of the protocols to support heterogeneous communication. Therefore the communication is complex since the APs communicate with various communication protocols that are non-uniform. The Ado Network topology lacks in a central hub or central AP and each node directly communicates with other node within the WN.

3.2. Mobile Ad-Hoc Network

Mobile Ad-Hoc Network (MANET) is self-configuring and decentralized network that uses wireless and infrastructure less connection for communication among mobile nodes/devices. Some of the features of MANETs are as follows: a) MANET is infrastructure less ii) New nodes join and leave network on a regular basis i.e. Network topology is not constant but is updated to accommodate routing. iii) Implementation of Security measures are challenging due to dynamic topology. Iv) Every node has dual behavior as router forwards unrelated information and as an individual. v) Uses Low bandwidth and low power wireless links.

3.3. Routing

Routing means transmitting information from a source to a sink or destination in a network. During this transmission there may be many challenges unlike former networks were very based on homogeneous communication but recently a complex and heterogeneous networks support has become

Figure 3. Model of proposed system using MANETs
essential since the networking could be based on large scale packet routing depending on the network application. Routing is used to determine optimal paths and then transmitting packets (information units) on a network. Routing uses metrics (hops, routing table containing route information) to find the best possible path for packets dissemination to its destination. Routing tables are generated by the source and destination nodes by the use of routing algorithms and may include information such as next hop, ip-address of intermediate nodes to be reached and destination node and so on. MANET Routing process means directing data traffic from one node to another within a MANET using the most efficient route. Since the dynamic evolving topologies are involved within a MANET, routing faces a number of challenges. The routing protocols are grouped into three categories:

1. Flat or hierarchical design.

In the first form of Hierarchical networks the nodes form two groups- two layers, the top layer is master of lower one. Each layer contains a cluster of nodes and any one of the node is designated as gateway of the cluster and have the responsibility to communicate with similar gateway on other side of the cluster. In this structure, the tasks are clearly distributed without any confusion. Gateway nodes perform the task of maintaining network topology and delivery of messages to other nodes in the cluster. In this architecture gateway nodes play an important role. An example of this structure is Zone-based Hierarchical Link State (ZHLS). The flat architectures are based on traditional routing protocols with less capacity and are not scalable.

2. Proactive or reactive design.

Most commonly MANETs support this topology of protocols since they rely on architecture of a network. In Proactive form of protocols the routing table is formed within the network and it contains complete routing information of each and every node and periodical route dumps are scheduled in the network to model changes in the network topology. DSR (Distance Vector RP), Link State Routing (LSR) protocol are variations in this category but they aren’t compatible with mobile environments. Destination Sequence Distance Vector RP (DSDV) is another variation of this and is capable of overcoming issues of looping and infinity count as can be found in Bellman-Ford routing algorithm. Examples of Proactive RPs are GSR, HSR and DSDVR. GSR-Global State Routing, HSR-Hierarchical State Routing, DSDV-Destination Sequenced Distance Vector Routing.

In Reactive form protocols a specified node is made responsible to contain information about the active form of a table. For communication purposes each time a new search is required which delays the task as well as increases the search time. In such a situation the network relies on Dynamic wireless-network-topology that will set up active route and reinitiate the search of the route or performs re-routing (Tabassum & Damodaram, 2011). Now we describe few widely used reactive RPs- AODV-Ad hoc On-demand Distance Vector Routing, DSR-Dynamic Source Routing, LAR-Location Aided Routing and lastly TORA-Temporally Ordered Routing Algorithm.

3. Hybrid design.

A Hybrid RP works on the principles of both proactive as well as the reactive protocols. The Proactive protocols are very efficient since they maintain up to date information about routes in a network whereas Reactive protocols are beneficial as they need very less bandwidth. They relief the network of high loads since they create the routes only on demand. The Proactive protocols constantly and continuously update the nodes with the new routes which results in excessive utilization of bandwidth and thus it is regarded inappropriate for larger networks whereas even reactive protocols
suffer from latency issues since they attempt to generate routes on demand. MANETs uses reactive protocol because of low bandwidth utilization. Some of these protocols are discussed in detail since they are suitable to set up the emergency patient monitoring system.

3.3.1 Ad-Hoc On-Demand Distance Vector - AODV

It functions as a customized protocol where the nodes can initiate the route when needed or demanded. If a node A is interested to transfer data to node B, then node A sends a request of connection to node B. The request is in turn routed from the intermediate nodes until it reaches node target node B continuously and node B acknowledges by sending a reply message to node A. Then node A selects of shortest length of hops from the replies it had received, unused entries are reprocessed on regular basis. Messages are interchanged once the connection is established among the nodes with this route as the active path. To check the miscommunication among nodes at any points i.e. if nodes do not receive replies from their adjacent nodes, a route error message is distributed to all nodes on the active path and subsequently the next available shortest hop route is nominated.

3.3.2 Dynamic Source Routing - DSR

DSR like AODV generates/initiates a route only on demand but the difference mainly is that it uses source routing strategy to discover the destination node. DSR do not transfer packets periodically to find the active path nodes rather uses unidirectional routes using any of the following mechanisms for making route discovery in network:

1. Route discovery
2. Route maintenance

3.3.3. Dynamic MANET On-Demand Routing Protocol (DYMO)

This protocol works with dynamic topologies by resolving the path between nodes using unicast and is used in ad-hoc wireless network for mobile nodes. Similar to DSR protocol DYMO also has two modes which are listed below:

1. Route discovery: The preliminary mode of the protocol it begins when a host node transmits, address of destination node with a route request packet, subsequently it is transferred to its neighbor and every node on the path add their neighbor information to the route request packet until destination node is located. On discovery of the path the lowest hops path is selected.
2. Route management: It is a strategy to maintain and build up an alternate route if a route broken an alternate route is considered. In case no route is found, route discovery mode gets activated and it initiates a new route. OLSRv2 NIIGATA (Optimized Link State Routing, version 2 Routing Protocol) OLSRv2 (Liu et al., 2008) preserves has various enhancements on original OSLR protocol since basic protocol architecture is modular and flexible permitting security extensions as adds-on whereas OLSRv2 comprises of three basic processes: Neighborhood Discovery, MPR Flooding and Link State Advertisements. Neighborhood Discovery needs every router discover all other directly connected routers with one hop adjacency and checks for bi-directional transmission. In MPR flooding each router broadcasts messages throughout the network and maintain a subset (MPR set) for transmitting a message and relaying it. The message would in turn be received by all neighbors just 2-hops distance away. Finally, routers make use of Link State Advertisement to find out the sample of the link state information to be advertised via broadcast on the network. With Link Advertising mandatory for every router and the associated MPR-selector-set with each node facilitates all routers to determine shortest path.
3.3.4. Routing Information Protocol - Rip

The Routing Information protocol is one of the conventional protocols developed for data routing on a network and it is based on Distance vector routing protocol. It uses hop counting method to discover any route. Due to its limitation of hop count up to maximum 15 hops per route, it cannot support large networks. To avoid route mismanagement it employs Split horizon and route poisoning thus avoiding wrong data-sharing in network. Additionally it uses a mechanism of hold down for smooth routing of information in the network.

3.3.5. Inter-Zone Routing Protocol - IERP

The Inter zone RP (IERP) belong to category of reactive routing protocols. It is a component of the ZRP (Zone Routing Protocol) and is capable of adapting itself with current available implementations of reactive protocols. Thus it benefits by the existing topology surrounding every node. Another variation of protocol called Intra zone Routing Protocol (IARP) presents an R-hop neighborhood namely routing zone, thus the routing zone is made available quickly. It allows IERP to suppress queries about the routing local destinations. It makes the discovery of a global route, activates border cast service on routing zone (Liu et al., 2008) and effectively supervises the outward route. It uses zonal routes automatically to handle the failed links, thus redirecting the data in network.

As the zone radius route increases its maintenance increases in a ZRP consequently the traffic due to it also requires bigger routing zone to maintain new understanding. But these routing zones finally get reduced to zero hops. With the demand for newer routes large routing zones become more suitable.

3.3.6. Fisheye State RP - FE

Fisheye State RP is a hierarchical routing protocol. It is a proactive routing protocol and its functionality can be applied to adhoc wireless environment. It is based on LSP. LSP provides the instant route information to by making topology map and stores it as link state table at each node in the network. Klein Rock and Stevens introduced the Fish Eye Technique that reduces data size if represented in graphical form.

3.3.7. Landmark RP - LANMAR

Landmark RP has a similar functionality as landmark hierarchical RP for carrying out operations in wired networks. This protocol relies on the existence of a set of nodes logically related to each other, every logical node group has a serving node marked as as a landmark. It uses Distance Vector strategy to determine the landmark-route announced/ propagated in network. To update a route of LANMAR, the immediate neighbors and every other node regularly exchanges the information of the topologies. They may use piggybacking strategy for numbering. Finally LANMAR is better at its performance than the AODV protocol.

3.3.8. Location-Aided RP - LAR

Location-Aided RP can be used to reduce the overhead of routing. For this purpose it uses the information of a location of nodes in network. It can be used with the emergency patient monitoring to determine the possibilities of solutions to service the patients. Through this protocol we can know the physical location of the patient via his mobile GPS Global Positioning System (GPS) and LAR becomes easy for to operate.

Due to the topology variations it is challenging to secure MANET. It suffers active and passive security attacks. Passive security attacks may leak information since the eavesdropping, listening to traffic on open wireless communication channel and other attacks are encountered commonly. It may suffer from active attacks - Denial of service, IP spoofing, and other more specific attacks on ad-hoc networks - worms or viruses. These are capable of injecting false routes or divert the traffic on an unsecure communication channel. These attacks have remedies which allow countering these
attacks by the use of private keys, digital signatures or trusted certification. The methods to counter the attacks are not so much effective since they need setting up of secure channels/ policies between the nodes in advance before communication is active between the nodes. Since this constraint cannot be resolved in emergency or any disaster situations response.

4. SIMULATION ANALYSIS OF ROUTING PROTOCOLS FOR EMERGENCY PATIENT MONITORING USING MANETS

In the previous sections we discussed various routing protocol for MANETs. This section proposes solutions for mobile ad-hoc networks (MANET) suitable to be applied in emergency situations to rescue patients. This requires resource awareness for the solution to increase availability of services and information. Resource availability prediction for future connectivity in various nodes of network through the neighboring nodes is significantly useful strategy in the proposed solution. If two nodes are sufficiently close be a probability that they come towards each other in near future. The benefit of the approach is nodes do not require location information. The simulation is a means to analyze whether in future there can be valid predictions or not. In this section we will discuss simulation details of the Emergency Patient Monitoring System and assume that nodes are sufficiently away from each other. The network simulator is QUALNET. The development language used is C. The simulation models are shown in the Figure 4. The simulation model is created with WiMAX and WiFi networks and Random-Way point mobility model is activated for the mobile node. We have tested for Constant Bit Rate (CBR) and Variable Bit Rate (VBR) traffic. Figures 5 and Figure 6 state the end to end delay in different protocols that would be possibly the delay for the emergency patient monitoring information transmission within the network. The end-to-end delay is determined for both CBR and VBR traffic set-up.

The difficulty of MANETs in case of rescue scenarios is mainly the heterogeneity of nodes and networks. The proposed method solves the problem of heterogeneous networks but the size

Figure 4. Simulation model for routing protocols using MANETs
of network still poses challenges if the number of nodes is more. Since the network is not scalable beyond a specific size.

The difficulty of MANETs in case of rescue scenarios is mainly the heterogeneity of nodes and networks. The proposed method solves the problem of heterogeneous networks but the size of network still poses challenges if the number of nodes is more. Since the network is not scalable beyond a specific size. The proposed system was demonstrated with 50 nodes in the network since we considered the rescue size and rescue exercise based on several persons who were required to be rescued. Many different organizations normally participate in the rescue and their diversity of mobile node/devices may a challenging issue since the network should accommodate the heterogeneity of configurations w.r.t the devices on the scene.
5. CONCLUSION

This research paper presents a mobile adhoc platform for patient monitoring and tracking in an emergency state which could be operated with a mobile application downloaded onto a mobile and offer suitable emergency services. Wireless medical sensor networks are gaining enormous attention to make patient monitoring and tracking significantly. Sensors are implanted in human body to record medical data from various points in the human body and this is referred to as Body area network.

The existing patient monitoring systems designs uses additional hardware because they need to transmit data to receivers. The cost of such a wireless system may be increased due to scalability criteria since the increased wireless nodes may reduce performance. Also such systems suffer from interoperability issue and hence are less reliable and flexible. The MANET solution to transmit the information is better when compared to the previous since the use of mobile applications are common and stakeholders find it very easy to download the mobile application to monitor their health issues and in case of disaster or emergency situation would be available for use.

ACKNOWLEDGMENT

We are thankful to the Deanship of Scientific Research at Princess Nourah University to support this work. This work was funded by the Deanship of Scientific Research at Princess Nourah bint Abdulrahman University through the research Groups Program Grant no. (RGB-1440 -0018).
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