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A Proposal to Design a Location-Based Mobile Cardiac Emergency System (LMCES)

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Abstract. Healthcare for elderly people has become a vital issue. The Wearable Health Monitoring System (WHMS) is used to manage and monitor chronic disease in elderly people, postoperative rehabilitation patients and persons with special needs. Location-aware healthcare is achievable as positioning systems and telecommunications have been developed and have fulfilled the technology needed for this kind of healthcare system. In this paper, the researchers propose a Location-Based Mobile Cardiac Emergency System (LMCES) to track the patient's current location when Emergency Medical Services (EMS) has been activated as well as to locate the nearest healthcare unit for the ambulance service. The location coordinates of the patients can be retrieved by GPS and sent to the healthcare centre using GPRS. The location of the patient, cell ID information will also be transmitted to the LMCES server in order to retrieve the nearest health care unit. For the LMCES, we use Dijkstra's algorithm for selecting the shortest path between the nearest healthcare unit and the patient location in order to facilitate the ambulance's path under critical conditions.

Keywords. Telemedicine, mobile healthcare, remote patient monitoring, cardiac emergency services, global positioning system, location-based services, Dijkstra's algorithm

Introduction

Nowadays, healthcare for elderly people has become a vital issue. Control of chronic diseases such as hypertension and arrhythmia is possible by monitoring the physiological parameters of the patient. Further to this, professional medical care and support is needed to prevent these kinds of chronic diseases [1]. Telemedicine, which is used for delivering biomedical data and sharing medical knowledge over a long distance using telecommunication can be employed to prevent chronic diseases. As the computer-based patient record system has suffered from lack of mobility, bulky and obtrusive hardware, personal digital assistants (PDAs) are deployed in healthcare. Rapid growth in information technology and telecommunications has enabled these technologies to support advanced services for telemedicine. For instance, mobile technology improves telemedicine services in which biomedical signals (blood pressure,

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cardiac performance, insulin level etc.) can be received from the patient, therefore, the patient can be monitored at any place and any time [2, 3].

Generally, location-based services consist of a mobile device, a communication network, a positioning component, ~~a~~ service and application provider, and a data and content provider [4]. Location-based services can enhance mobile telemedicine in terms of assisting patients to search for nearby doctors or health centres and facilitating doctors to check information about the patient's health issues remotely and to track the patient's current location in case of emergency situation [5]. In this study, a Location-based Mobile Cardiac Emergency System (LMCES) is proposed for monitoring hypertension and arrhythmia patients and to improve healthcare services to assist hospitals and doctors.

Section 1 of this paper reviews related work on the different healthcare systems. Section 2 describes the architecture and locator system of the proposed LMCES. Section 3 discusses the details of the implementation of the proposed system which will be developed in the future along with conclusions in the last section.

1. Related Work

1.1 Mobile Healthcare and Cardio Telemedicine System

The robust wireless communication system can help facilitate remote medical treatment or health monitoring medical services at any place to make human life secure [6]. In advanced telemedicine systems, the information has been transferred as multimedia interactive video over wireless networks. The key features of the mobile wireless networks system are portability, large battery life, easy to use, full duplex support and optional encrypted communication [7]. Increasing healthcare costs and age have affected the improvement of remote patient's health monitoring to provide real-time health condition to the medical centre, professional doctors and the patient's family [8].

Chronic diseases such as hypertension and arrhythmia can be prevented by monitoring the physiological parameters of the patient and with professional medical care. Telecare medical monitoring by the transmission of physiological information is possible, since communication technologies are growing quickly every day [1, 9]. One of the essential factors in cardiac patient monitoring system is the Electrocardiogram (ECG) that can be helpful for cardiac disease detection. The cardiovascular monitoring system can be more efficient using wireless technology and the mobile phone both of which are improving rapidly. F.Sufi et al., (2009) [9] proposed a number of ECG compression algorithms that send lossless compressed ECG over wireless technology. In addition, L. Ren-Guey et al., (2007) [1] proposed and implemented an intelligent mobile care system with an alarm mechanism for the chronic care environment. As a result, they can observe the physiological parameters of the patient such as blood pressure, pulse, saturation of haemoglobin (SpO2) and electrocardiogram (ECG). Along with observation, important and abnormal physiological information can be uploaded to the health care centre. Furthermore, an alert management mechanism has been proposed in the health care centre to handle emergency cases by sounding the alert after receiving an emergency message from the patient's mobile device.

1.2 Location-Based Services in Healthcare

Location-aware healthcare has been achievable as positioning systems and telecommunications have been developed and fulfilled the technology needed for this kind of healthcare system. I. Maglogiannis and S. Hadjiefthymiades (2007) [10] proposed a system, called EmerLoc, which is based on positioning technology. This system consists of a set of sensors, a micro-computing unit and a central monitoring unit. The sensors are attached to the patient's body—a micro-computing unit task processes the sensor readings, and a central monitoring unit duty coordinates the data flow. Another example of location-based healthcare system is a hybrid mobile-based patient tracking system proposed by S. H. Chew et al., (2006) [11] as a personal healthcare application. Global Positioning System (GPS) and cellular mobile network infrastructure are two main technologies that have been used in this system in order to track the patient's location.

1.3 Shortest Path and Dijkstra's Algorithm

One of the most popular algorithms for finding the shortest path in route guidance system is Dijkstra's algorithm which utilizes the search graph for routing. This algorithm was designed by the Dutch computer scientist, Edsger Dijkstra in 1959. It can produce a graph of the shortest path between source and destination nodes. Using the fast planning algorithm will assist vehicles to reduce the time to reach their destination [10]. In our proposed LMCES, Dijkstra's algorithm will be used to select the shortest path between the nearest healthcare unit and the patient's location in order to inform the ambulance's path in critical conditions.

2. Proposed System

The proposed system is a location-based mobile cardiac telemedicine system (LMCES) to assist hospitals and doctors to monitor their hypertension and arrhythmia patients. In the emergency situation, this proposed system can facilitate hypertension and arrhythmia patients to locate the nearest healthcare points (HP). LMCES consists of three main subsystems: (1) a monitoring system for the hypertension and arrhythmia patient, (2) an emergency system to track the location of the hypertension and arrhythmia patients in emergency situations and to guide them to the nearest hospital for Emergency Medical Services (EMS), (3) HP locator system to show the nearest healthcare points (HP) to the patient. In the emergency system we will use 'Ellipse Model' for location tracking of the patient as has been used by P. Keikhosrokiani (2011) [11].

2.1 Architecture

Figure 1 shows our proposed LMCES architecture that has five components, namely: location and cardio-patient, mobile doctor, telemedicine server, hospital and medical care and network infrastructure. In the location and cardio component, a Bluetooth-based hemadynamometer will send the statistics of the cardio system that includes heart beat rate (body pulse) and blood pressure to the mobile device. If the statistics are alarming then the current location can be calculated through mobile GPS. The GPS, coordinated with the patient healthcare information (blood pressure and heart rate) will be sent to the LMCES server and the information will be immediately forwarded to the designated physician. If the patient-designated doctor is busy or out of reach then the management system of the health care unit will search for the secondary physician from the same healthcare unit. The hospital administration unit will be in charge of the secondary physician allocation for the patient. For an emergency case, EMS will be activated and the ambulance will be sent immediately to the patient's current location. The nearest healthcare centre will be selected from the database along with the shortest path to that allocated centre to send an ambulance. Afterwards, the ambulance will navigate the location of the patient by using Dijkstra's [14] shortest path algorithm and take the patient to the nearest healthcare centre.

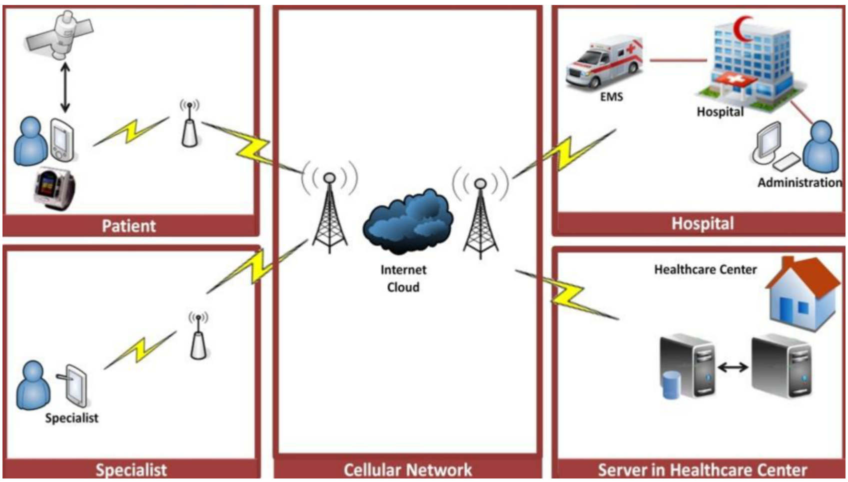

Figure 1. Proposed System Architecture

2.1. (a) Emergency System

In case of the critical situation when the patient's blood pressure or heart beat is at a critical point, the notification of the bio-signal will be transferred to the mobile device that gets its current location through GPS technology and send it immediately to the doctor and LMCES server. The LMCES server will search for the nearest healthcare unit for the patient. In a critical situation, EMS will be activated and an ambulance from nearest healthcare centre will be sent immediately to the current location of the patient. The location coordinates of the patient can be retrieved by GPS and sent to the healthcare centre using General Packet Radio Service (GPRS). Similarly, the ambulance will calculate the shortest path that contains less traffic by using Dijkstra's algorithm in order to reach the patient's location as soon as possible. Figure 2 depicts the healthcare emergency system in our proposed system.

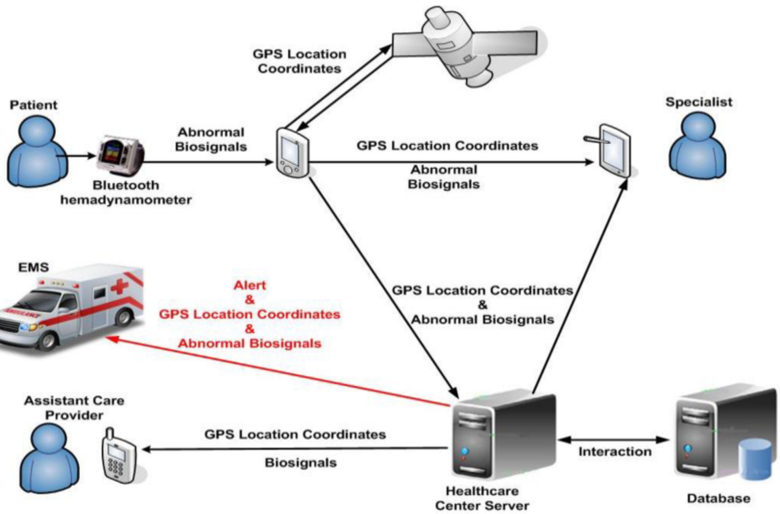

Figure 2. Healthcare Emergency System Architecture

2.1. (b) Healthcare Locator System

In Figure 3, we have divided the geographical area of the country into several predefined ellipse-shaped sections that include the different cities of that country. In each city, the number of ellipses will be assigned to different geographical areas based on the presence of healthcare centres (hospital, pharmacy, clinic and cardiovascular centre, etc.)

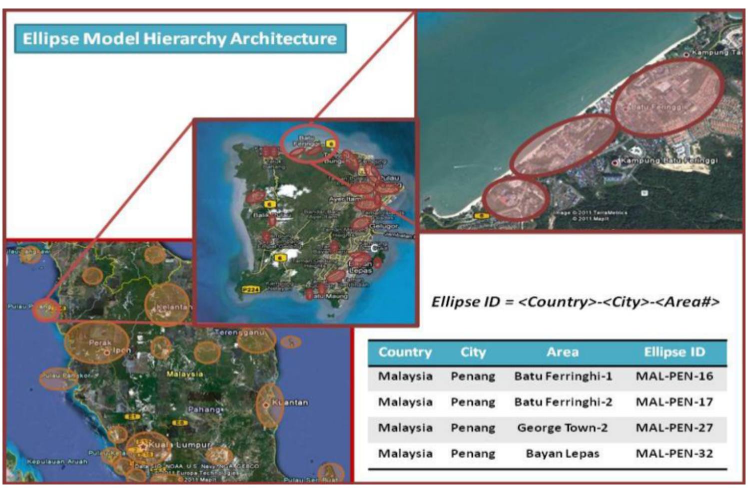

Figure 3. Ellipse Model Hierarchy Architecture

Each Ellipse ID represents a unique number composed of country code, city code and area code. Each ellipse has been divided into cells based on the Global System for

Mobile Communications (GSM) Cell ID (CID) which uses a unique number to identify each Base Transceiver Station (BTS) within a Location Area Code (LAC), if not within a GSM network. Figure 4 depicts the Ellipse model hierarchy that shows the different cells of each area based on the BTS.

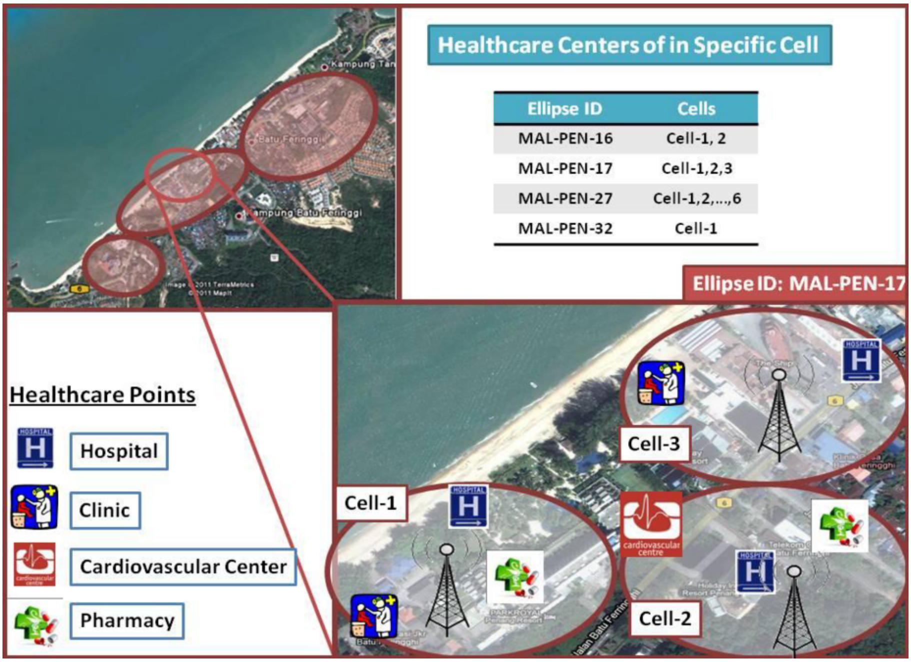

Figure 4. Healthcare Cells

Figure 4 illustrates the different cells of each ellipse containing information relating to the hospital, pharmacy, clinic and cardiovascular centres, etc. This information not only will help the patients who are unfamiliar with the nearby emergency medical centre but also will help the healthcare server, in critical situations, to inform the nearest healthcare centre to send an ambulance to the current patient's location.

GPS location coordinates as well as cell ID will play an integral role in retrieving the designated Ellipse ID in order to facilitate patients in the emergency healthcare unit. The patient's mobile device will send current location coordinates to the LMCES server that then, will generate a populated list of emergency medical care centres located inside that specific Ellipse ID. Different icons for the hospital, clinic, pharmacy and cardiovascular centre, etc. will be displayed on the LMCES server in the specific cells of each ellipse as shown in Figure 5. Thus, it will be easier for LMCES to locate the nearest healthcare centre for the patient in a critical situation. The ambulance will be sent from the nearest hospital to rescue the patient. The shortest route will be shown in order to assist the ambulance to reach its destination (Figure 5). The arrow path will be drawn from the patient's current location to the destination medical healthcare unit to assist the ambulance find the shortest path.

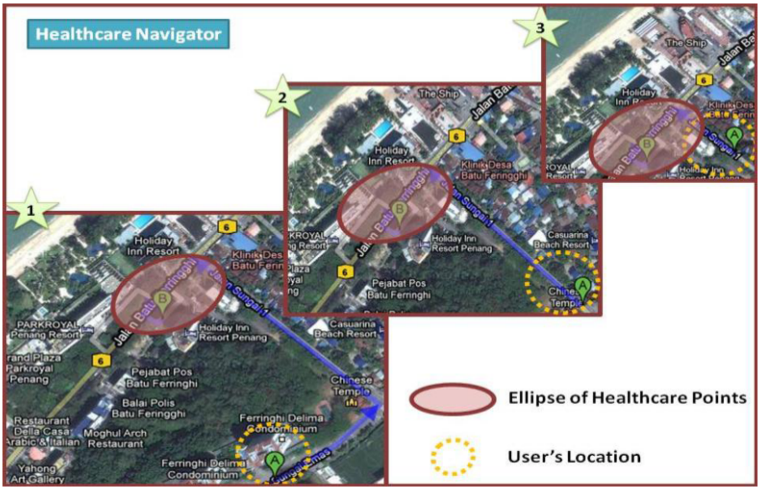

Figure 5. Patient's Navigation to Healthcare Points (HP)

3. Implementation Detail

3.1. Shortest Path

The emergency system and health care locator make use of searching an optimum path between the source and the destination. In the case when EMS has been activated by patient, the ambulance will be the 'source' and the patient will be the 'destination'. Similarly, when the ambulance reaches the patient's location to take the patient to nearest healthcare centre, it will be the source and the healthcare centre will be the destination. In both cases, the ambulance wants the shortest route from the source to the destination. We propose to enhance Dijkstra's algorithm to be used in our location-based mobile health system in order to find shortest path between the source (ambulance) and the destination (patient/ healthcare centre).

Before executing the algorithm, firstly the area from source and destination will be converted to a graph, where cell ID will help to originate the health centre as vertices of the graph. The path will be computed from source to destination where each iteration adds another vertex to the shortest-path spanning tree. The pseudocode of our proposed algorithm is shown in Table 1.

Table 1. Pseudocode of The Proposed Algorithm

```
LMCES Dijkstra Algorithm: Emergency shortest path navigator

Input:
Px = Coordinates of the patient
Ax = Coordinates of healthcare  centre
CID = Cell-ID of healthcare  centre

Output:
Arr[num] = Array containing the x-axis and y-axis of the vertices
Num = Total number of vertices

Pseudocode:
Graph G                                 // Graph object
Integer TotalVertex = 0                 //Total number of vertices
// Get the location of the patient
Px = GetPatientLocation()

// Get the location of ambulance
Ax = GetLocationHealthcare()

// Initialization of converting coordinate points to vertices
For each vertex v in G
        Arr[TotalVertex] = GetPathPoints(TotalVertex)
        TotalVertex++
End for

Q = All graph coordinates
While Q != 0
u = vertex in Q that have smallest distance from Arr[]
If (Arr[u] == null)     // final node
        break;          // remaining nodes aren't connected with source

For each vertex v of u
        alt = Arr[u] + dist_between(Px, Ax, CID);
        if alt < Arr[v]
                dist[v] = alt
                previous[v] = u
                ReOrderQueue()
End while

Return Arr;
```

3.2. Application Side

On the mobile, server and hospital side, a Java-based application was developed because of its uniformity and ability to run cross-platform architecture whether Windows or Android. While on the server side the application could be run on Windows or Linux-based systems, we chose to use Oracle mySQL version 5.5, an open- source database that has the capability to support SQL, functional, stored procedure, virtualization, distributed database management. There is no license required as it is open-source software. The LMCES server will have a database management system that will store the patient's health information as well as information of associated primary and secondary doctors along with the designated hospitals. The Ellipse ID and its associated hospital, pharmacy, clinic, cardiovascular centre locations and details will also be stored for use in cases of emergency.

3.3. Communication Layer

The communication between the Bluetooth hemadynamometer and mobile device will be through the Bluetooth technology primarily used in the Personal Area Network (PAN) operating on Bluetooth version 4.0. The patient's current location will be calculated either by GPS or A-GPS technology that will be later sent to the LMCES server along with the statistics of the health information (heartbeat, blood pressure). The communication medium of the patient and LMCES server will be through GPRS.

4. Conclusion

The robust wireless communication system can support remote medical treatment or health monitoring medical services in all locations to make human life secure. The key features of the mobile wireless networks system may help to manage and monitor chronic disease and the healthcare information of elderly people. In this paper, we proposed the Location-Based Mobile Cardiac Emergency System (LMCES) to track the patient's current location in an emergency situation and to help ambulances locate the nearest healthcare unit to rescue the patient. The location coordinates of the patients can be retrieved by GPS and sent to the healthcare centre using GPRS. The location coordinates of the patient also will be given to the LMCES server in order to get the cell ID which later will be used to locate the nearest healthcare unit. Furthermore in this paper, we proposed to use LMCES-enabled Dijkstra's algorithm for selecting the shortest path between the nearest healthcare unit and the patient's location in order to assist the ambulance in critical conditions. The locations of the patient and healthcare unit will be given as parameters to the proposed LMCES-enabled Dijkstra algorithm that then will create a graph and populate the vertices based on the available coordinates. From there, the algorithm will choose the shortest path based on the coordinates of the graph. The proposed method will help to facilitate both the patient and the emergency system in order to deliver medical treatment in the critical time.

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