Proposal of a Web Based Ambulance System in Saudi Arabia

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Abstract - *This paper proposes a new Ambulance System that automates all the processes of pre-hospital activities. Automation starts from allocating and dispatching the right ambulance, supporting the carried patient treatment by accessing the electronic health record, identifying the right hospital and communicating with the emergency department. The system has been developed by integrating several components. It has been found that the proposed web based ambulance system can provide a strong backbone for pre-hospital management process and gain competitive advantages. The system may reduce the response time and the human errors.*

Keywords: Ambulance, Dispatching, GPS, Emergency Department, Pre-hospital

1 Introduction

Pre-hospital patient treatment satisfaction has a huge impact on saving humans lives. Many studies wrote about the importance and possible advantages gained from reducing response time, and early specialized pre-hospital patient management. Moreover, it is realized that quick response time of pre-hospital patient management decrease the percentage of death and improves patient effect [5]. In a crowded area such as London, UK, it has been found that 49% of wounded people need 2 hours to reach a sufficient hospital care, 79% are victims of accidents in rural roads die in the accident place, and other 11% dies during their transportation to the hospital. And 8% of these accidents had chance of 50% to survive if enough pre-hospital management existed [10].

Saudi Arabia (SA) is a country in Middle East that has a large population, and thus crowded traffic in its main cities roads, about 26660857 populations was estimated in 2009 and, 27563432 in 2010. Riyadh as an example is the capital of SA and one of its main crowded cites. In 2009 it had about 42 of Ministry of Health Hospitals and 26 of private sector hospitals. Moreover, The Saudi Red Crescent Authority (SRCA)'s in 2009 had 274 first aid centers and 1097 ambulances [17]. Due to it's crowded roads many people become victims of car accidents and long response time. In Riyadh because of car accidents, in 2007 about 353 deaths was reported, in 2008 about 357 and 266 deaths was reported in 2009 [18]. Thus, the critical role of pre-hospital treatment has a very important and critical impact on reducing the number of victims; their role could rescue many lives if it was fast and reliable.

Dealing with this amount of car accidents in such busy roads is a challenge for ambulances to arrive at the accident location in a short response time, and react to the patient with the best treatment. Therefore, this paper presents a solution to improve the management of ambulance dispatch and pre-hospital treatment with the fast response time and least amount of human mistakes for ambulance and hospital allocation process. The proposed Ambulance system automates the whole process (by using SOA, GPS and other technologies) from the time accident is reported by a caller to the time the patient is picked up and reaches the suitable hospital.

The paper is divided into four parts; first part includes a literate review of current systems that automates some of its processes, other research studies and human error and system failure. The second part describes the contribution which is a proposed Ambulance System, its components and how it functions. The third part includes the discussion and finally the conclusion and future work in last section.

2 Literature Review

Communication using computerized technology in many emergency medical systems (EMS) especially ambulance systems has been developed during the last two decades [4].

2.1 Current Systems

One of the first computerized systems was developed to manage the communications such as Computer Aided Dispatch (CAD) that was used in 1995 in Victoria-Australia. In 1998, this system was enhanced and introduced with a Medical Priority Consultant's Advanced Medical Priority Dispatch. It was one of the best emergency systems that provided to the hospital clinical information of the patients and included an automatic vehicle location system (AVL) in their ambulance [4].

Moreover, in 1998 due to the lack of communication between agencies, a project was developed to gain communication interoperability network by using different technologies. It is called Silicon Valley Regional Interoperability Project (SVRIP), that respond to emergency incidents with the nearest and most appropriate emergency response resource [6].

In 2007 CADIP (Computer Aided Dispatch Interoperability Project) was launched by the department of Homeland Security's Office for Interoperability and Compatibility (OIC). CADIP is created to solve the concerns of difficulty that occurs when an emergency response agency is trying to respond to multi-jurisdictional emergencies that are not linked to them. This in term happen when the time-consuming phone calls that is usually done to link such emergencies (incident) to the nearest resource is eliminated, and replaced by automatic dispatchers [5].

Recent emergency ambulance systems EAS have appeared with a good impact on health sector. The Victorian Ambulance Cardiac Arrest Registry (VACAR) is a leading system in cardiac arrest CA registries. This system has two parts of ambulance services. The first service is Metropolitan Ambulance Service (MAS), which uses a computerized, protocol-based dispatch system. And the second system is the Rural Ambulance Victoria (RAV) that uses a manual call talking and dispatch process [1]. Another area in Australia - north Victoria- employs a pre-hospital service known as Ambulance Service of New South Wales (ASNSW). This system dispatches its ambulances by CAD and provides them with Mobile Data Terminals (MDT) for messaging and Automatic Vehicle Location (AVL) for keeping track of their location. Moreover, for prioritization of dispatching tasks, a Medical Priority Dispatch System (MPDS) has been presented [2].

In 1977 Emergency Ambulance Services (EAS) was developed without the use of computerized system. Its emergency department doctors provided ad hoc advisory services, without a formal medical control. In 1989 EAS was attached to Singapore Civil Defense Force (SCDF) and stuffed with more specialized crew, but still without electronic communication technology. Singapore EAS continued developing until the pilot project HEAL (Hospital and Emergency Ambulance Link) was launched to improve data collection and communication. HEAL presents a wireless information technology system to support existing voice links between the ambulance crew and the emergency department (ED). This system include a touch screen with easy data entry, mobile computers to automatically capture vital signs and other medical data, then send them to the target hospital via warless communication network. Where these collected data creates an electronic pre-hospital record for the patient. And it uses a user-friendly client server application. HEAL is composed of: 1) Advanced patient details model; that capture patients medical data and send it to ED, 2) Ambulance incident management module; that save and store all received records from the ambulances, 3) Drug request and authorization model; this supports the paramedics by physicians approved drugs, 4) Text communication module; this is responsible for message exchange between ambulance crew and ED staff. This system had a huge impact on the pre-hospital system quality; such as reducing the waiting time for critical care patients to be seen at the emergency department (ED) from 35 to 17 min. Also, the time spent by paramedics in the ED after handing over the patient to the ED staff was decreased from 15 to 8 min. therefore, HEAL showed the great possibility of electronic communication and data collection in the pre-hospital environment [3].

In Amsterdam EMS was employed to manage the pre-hospital care delivery, known as the Dutch EMS that depends on phone calls. This system is concerned with the dispatching and treatment level, and characterized as a nurse driven triage system. A dispatch center is responsible for receiving emergency phone calls on "112" phone number and redirect them to fire and police departments. This dispatch center doesn’t have an automatically EMS. It updates the beds information by a computerized updates from the participating hospitals. The phone calls prioritizing are done by the dispatch nurse that dispatches the ambulance and present pre-arrival instructions. And the ambulance average arrival time to the incident is 8 min [6].

An ambulance with highly implemented design project is delivered as a partnership between the university of Texas Health Science Center at Houston, and Texas A&M University System and the U.S. Army Medical Research and Materiel Command, known as the Disaster Relief and Emergency Medical Service (DREAMSTM) project. This system use wireless internet access in its ambulances to gain a wide cellular coverage and transfer audio (voice), text communication, video, and vital signs, with a high quality transmission. It also, can create a real time communication between the moving ambulance emergency medical technicians and emergency room physicians in the hospital to share patient information. Transforming these several types of data can be achieved by wireless internet access that transfers data from the ambulance to the internet then to the emergency room. The ambulance communication system contains several third generation (3G) wireless cards system from different cellular service providers. This improves its ability to benefit from these distinct service providers by a wider coverage, and different technologies. It also, has the advantage of keeping the highest priority patient information inside the ambulance in the case of loosing communication [7].

Another system in managing pre-hospital health emergencies sector was developed by the Regional Health Information Network (RHIN) of Crete across the island, it's known as the integrated pre-hospital emergency management system (PEMS). It provides several functionalities: ambulance tracking and route guidance, optimal resource management, management of emergency records, and real time patient multimedia data transmission and visualization. The ambulance tracking and route guidance functionality is achieved by a geographic information system (GIS), where each ambulance type, description, and current status (available, occupied, est.) are identified. These services were provided by adopting the GPS system, position monitoring technologies and intelligent rout guidance [8].

LIFENET system that lay's in the hospital gives the EMS team ability to send data from their LIFEPAK (ambulance device) directly to the hospital. At the hospital, LIFENET receives alert and displays the patient data before he arrives. This gives the ability to the hospital to re-route the patient to another hospital if needed due to the received data, without an unnecessary stop at this hospital. Data transfer is done through wireless link via the internet. Clearly the system reduces time and improves efficiency. Moreover, it has many other capabilities such as storing information for a long time, etc. [12].

2.2 Novel Studies

New studies are competing and progressing toward advanced wireless communication in the health care sector. A novel study has been made at TEXAS AT DALLAS University, were a software system was developed. This is an online based software system that is accessed via internet connection. It interacts with several actors: accident caller for '911', an ambulance dispatcher and an emergency room. It is composed into five subsystems: 1) user interface subsystem, 2) main subsystem that is responsible for interactions between the UI and hospital subsystem, 3) hospital subsystem, 4) emergency subsystem, and 5) ambulance subsystem. The Ambulance Subsystem is in charge of any communications concerning ambulances. This include ambulance List class and ambulance classes/objects which are responsible for using the specified methods in the related database class to insert, read, update and delete any related data. Each ambulance includes the software, and a set of hardware such as location tracking hardware, ambulance laptop, ambulance communication device (such as radio). The wireless communication between the dispatcher computers and the Ambulance Dispatch System (ADS) server is done vie HTTP/HTTPS protocols by the web browser in their computers. Moreover, the ambulance uses Wi-Fi internet to communicate with ADS server. The ADS server includes a GPS mapping software, and communicates with Emergency Department Server (EDS) [9].

Another wireless acquisition system for ambulances is presented by (J. Liao, 2009 and others). This paper suggests equipment for the ambulance vehicle by wireless technologies to support pre-hospital treatment. The system has a wireless biomedical sensor network for collecting patient's physiological data. It also have multimedia interactive information, and a wireless transmitting backbone sensor network. The system can not only send text medical data in real time to the hospital, but it also presents a multimedia interactive communication including audio and video information [10].

Usually one of the main uses of GPS in ambulance vehicles is the Automatic Vehicle Location (AVL) technology to keep track of it. A newer AVL system has emerged; it's now integrated with an emergency vehicles display computer, or data terminal, records management and video systems. The data terminals job is to state the ambulance engine status in real time. This can support dispatch centers with helpful updated information of their resources condition [11].

2.3 Human error and system failure

Information System (IS) failure can happen due to human development error or/and use error. A clear example of IS failure in ambulance system due to human error is the London Ambulance Service Computer Aided Dispatch (LASCAD) system. The system was put in use in October 1992, and failed after 2 weeks only. Almost 20-30 people have lost their lives due to LASCAD failure. Many argues on the causes of its fail; where some referred it to software engineer's inaccurate work on following the development methodology, lack of the system user's practice or any other reasons. The study of (P.Beynon-Davies, 1999) has identified two failure causes for LASCAD system; 1) error of use, 2) criticality. Error of use happened due to the weak relationship and communication between the managers and the workforce, and the resistance of the workforce to learn a new system. Criticality was another cause of failure via visibility issues. As the LAS problems reporting and the system safety nature were not sufficiently discussed [13][14].

(M.Hougham, 1996) have stated LASCAD system failure due to several reasons related to inaccurate information. These reasons are: 1) weak coverage of radio signals blocked the system from gaining all the data, and radio communication bottlenecks because of busy periods or when crew change shift and log in by their ambulance MDT, 2) ambulance crew mistaken pressing the right status button, due to the pressure of certain incidents and frustration feelings they get because of poor training, 3) insufficient personnel taking calls and lack interaction between operators and the system and its different parts, 4) and a single technical programming error related to full server memory space [14].

3 Proposed Ambulance System

According to earlier studies, Emergency Ambulance Systems are very critical that can save human's life or put it in danger. Where new technologies have emerged, still others are working to develop better systems. The proposed ambulance system is a wireless web based integrated system. It is designed to satisfy the highest effectiveness, efficiency, least response time, reduction of error and best quality decisions for resource allocation. The system is designed to eliminate any kind of human error during an emergency incident, by computerizing all the actions and functionalities and avoiding the human intervention as much as possible.

3.1 System components

The proposed Ambulance system is part of the "Comprehensive Medical Emergency System CME" [16] [15]. CME system is composed of five integrated subsystems; 1) Mobile device system, 2) Main Central System MCS (Ambulance dispatching system), 3) Ambulance system, 4) Online Health Record (OHR) system, 5) Hospital Emergency Department system (HEDS) [16], (see figure 1).

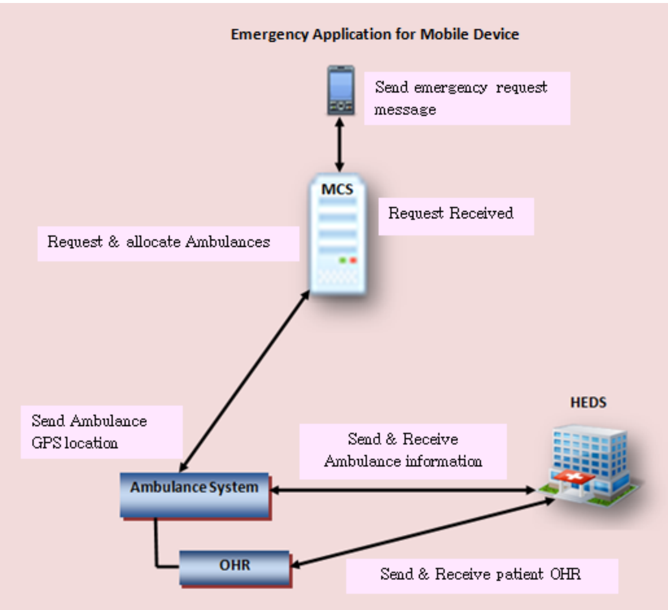

Fig 1 CME system components.

Each one of the CMS components has the following job:

Mobile device system: A mobile devise system is an application that gives ability to an accident reporter in the accident area to notify the MCS with caller information (coordination) and, accident information (as the number of wounded people) [16].

MCS: After accident information has been captured in the MCS, the information will be processed, several interactions with an ambulance server that gets the ambulances GPS coordinates. Then allocation of the most suitable ambulance for the accident is based on several issues such as availability, nearest and shortest time to arrive (which is based on the navigation system map not the direct distance) [16].

OHR: The OHR is created to transfer patient's data to the hospital in real time (immediately) and using online (wireless) communication. The OHR system is a decision support system that can support the ambulance crew with the most proper treatment for the patient due to its electronic health record information and new accident information entered by the crew [15][16].

HEDS: The HEDS in each hospital has the ability to receive patient information entered by the coming ambulance crew. Moreover, the roadmap of the coming ambulance is automatically displayed on the HEDS screen [16].

Ambulance System: The proposed Ambulance System main goal is to gain reliable satisfied patient transformation from the accident to the proper hospital with minimal risk and without human intervention. Each ambulance vehicle must include several components; these are:

1. GPS navigation device installed in each vehicle.
2. MDT for messaging communication with the ED.
3. A unique website URL stored at its ambulance server (ambulanceID.AmublanceServer.com), several information is stored in this page:
   - Ambulance ID.
   - Ambulance status (on mission, available, broken)
   - Real time location (road map determined by GPS).
   - Time to arrive to accident (null)
   - Accident location (coordination)
   - Accident road map
   - Hospital name (null)
   - Hospital location (coordination)
   - Hospital road map
   - Time to arrive to hospital (null)
   - Time to complete mission (null).
   - Time.
   - Date.

4. A laptop that grants the crew access to the ambulance system (that communicates with MCS, OHR, and HEDS) via internet WIMAX wireless connection (using web browser).

3.2 System design

The Ambulance System is designed to communicate with each one of the CES components (accept Mobile Application) to satisfy its goal.

1. The MCS starts looking for the suitable ambulance car (available, nearest) by contacting the ambulance server to retrieve available cars locations.
2. MCS then matches the accident location with an appropriate ambulance.
3. MCS then sends a request message to the allocated ambulance car, with the accident location.
4. If the car accepts the mission, its status changes from available to on mission.
5. After, the ambulance reaches the accident and carry the patient, the ambulance crew starts entering the patient injury information into the OHR system.
6. This info will be sent to the Ambulance server with accident location.
7. Ambulance server then decides the appropriate hospital and sends the resulted hospital ID to the ambulance car automatically.
8. The ambulance car then, contacts the hospital by its ambulance system, (see figure 2).

3.3 System process

The communication process is divided into two phases:

3.3.1 Phase1: Ambulance versus MCS

The ambulance server and MCS is able to keep track of any ambulance vehicle via its GPS system.

After the accident information is captured by MCS, it will start searching for a matching ambulance to take the mission. This is done when the MCS interact with the ambulance server that interacts directly with ambulance vehicle and retrieves its information.
The MCS triggers the ambulance server to retrieve all the available ambulance cars in the area. Each ambulance must have: one of the three vehicle statues; Available, non available, on mission. And real time coordination sited by its GPS.
When the MCS server finds the available nearest ambulance and defines its ID, it sends a request to the defined ambulance system.

The ambulance crew is then able to respond to the MCS call by the installed laptop touch screen, and choose accept, to confirm the mission acceptance (or reject otherwise). When it accepts the mission the vehicle status will be reset from available to on mission. But if the crew selects reject mission (for any reason); the MCS will start looking for another available nearest ambulance again. A road map to the incident location will be displayed on the ambulance system screen.

When the patient is inside the ambulance vehicle, the crew starts entering the patient injury information to the OHR system. This information and the accident location will be sent to the ambulance server.

3.3.2 Phase 2: Ambulance versus HEDS

The Ambulance Server already has the locations of all hospitals in all areas, and retrieved the accident location from the ambulance location (at the accident location).
The Ambulance server then matches the proper hospital due to three values:

1. Location (nearest to accident).
2. Specialty (according to the patient injury type).
3. Then it contacts the chosen hospital HEDS to check for bed availability to confirm the choice.

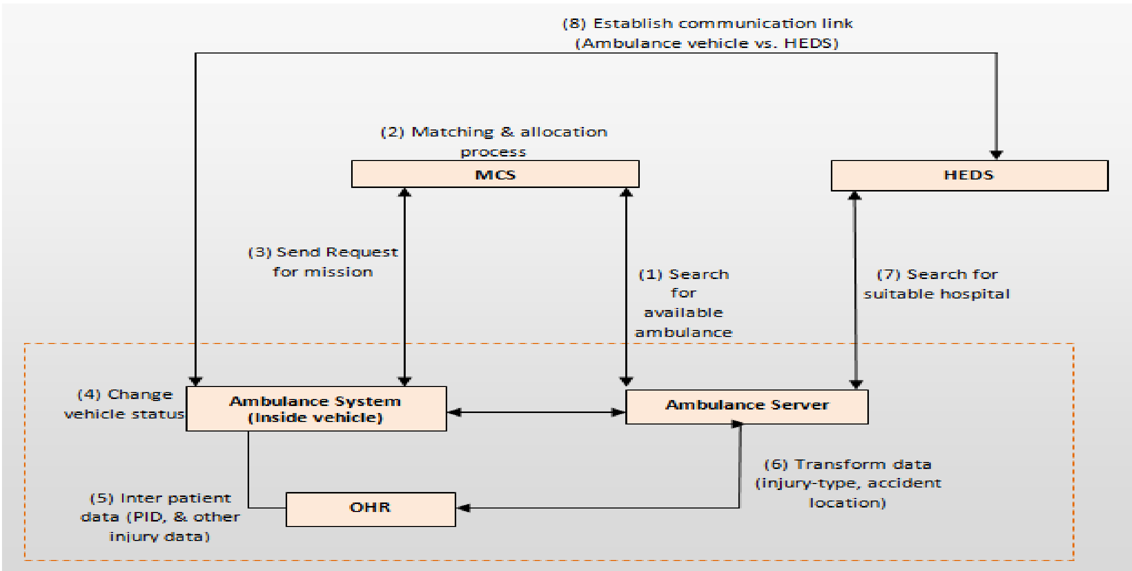

Fig 2 The proposed Ambulance System components interaction

Once the Ambulance car is allocated to the proper hospital, automatically a road map of that hospital will be shown on the ambulance system screen and contact it's HEDS by:

- Ambulance identification (ID) number will be displayed on the HEDS screen.
- The ambulance road map will be displayed on the HEDS screen.
- The ambulance arrival time is displayed on the HEDS screen with either one of three colors according to the Time Left to Arrive (TLA) to the hospital; as the ambulance alert colors:
    - Blue: 1 h => TLA > 30 min.
    - Orange: 30 min => TLA > 15 min.
    - Red: TLA <=15 min.
- Communication link is established between the ambulance and the chosen HEDS, to allow data, voice and text transformation.

Moreover, the OHR Allow the HEDS team to access online updated information for the coming patient during his delivery to the hospital. This is done automatically when the ambulance crew uses the OHR to transform patient identification number (PID) and injury information after the accident and any changes in his situation during the delivery.

It also, supports the ambulance crew with best decisions to handle patient injury, based on the system ability to get feedback from his medical record and make decisions upon it [16]. If the patient didn't have an OHR, then the ambulance crew will only send any patient identification (e.g. name and SSN, etc) and immediate injury information to the OHR (that will register him as new patient in the OHR automatically), and communicate with the HEDS for any support needed.

Furthermore, if there is no OHR established yet; the system can still function. So, the ambulance crew uses the Ambulance System to send any patient identification and immediate injury information, manually entered to transfer it to the HEDS.
After, few minutes (e.g. 4 min) from the ambulance arrival to the hospital location, automatically the ambulance status will be moved from on mission to available.

4 Discussion

In previous researches, many current emergency systems and novel studies are automating some of their functionalities and using wireless links in their communication. New researches are competing to develop advanced automated emergency systems due to its massive advantages. The proposed system has many features and advantages that can improve the processes performance and management of pre-hospital tasks. Thus, the Ambulance system will increase the percentage of rescuing human's lives. These features and advantages can be summarized as:

- Decreasing human error, so then increasing system efficiency. This is achieved by automating the system functionalities and avoidance of human interaction.
- Reduces response time. This in term increase percentage of rescuing humans' life, by decreasing the time to complete the rescue mission. This is achieved from the system automated capability to decrease the time of allocating a proper ambulance car (nearest and available), and a proper hospital (nearest, specialty, and available bed).
- Lower cost and human effort. This is achieved on the long term after establishing the system. There will be less human effort needed to dispatch ambulances.
- Best resource allocation decisions are made. This is achieved by the system computation capability to decide the nearest and appropriate ambulance care and hospital for the mission.
- Best pre-hospital treatment decisions. This is achieved from the system capability to support the ambulance crew with the suitable treatment, based on the medical history (from OHR) and current situation.

Moreover, in the case of sudden change or degradation in patient situation during his transformation, the HEDS team will be aware of any such change; and thus be appropriately prepared.

5 Conclusion

In this paper, a new fully computerized ambulance system has been proposed. It has been designed to facilitate the dispatching, and through the GPS, identifying the nearest ambulance to the accident. All components of the system have been explained and advantages of the proposed system over current and existing systems have been shown. By reducing the response time and the communication human errors, and by accessing the electronic health record and communicating information to hospital, this may make the proposed system one of the most efficient systems comparing to others.
The future work will be focused on completing the development and evaluating the system in real life.

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