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Smart algorithms for patient assignment in disasters

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Abstract

We describe the design and implementation of a system to automate patient handling and assignment to hospitals in mass disasters involving a large number of injured victims over a wireless network. In addition, the previously developed MEDTOC system is modified and enhanced to include location-aware features at the disaster site, as well as quick classification and assignment of patients to nearby hospitals. We present the designed implementation and the results from a simulated disaster involving a fictitious 20-story apartment building located in Ras Al Khaimah, United Arab Emirates. It is expected that chaotic mass-disaster situations can be more suitably controlled and stabilized by using the techniques from this project, thus saving more lives.

Keywords: Mass disaster; Location aware; Disaster management; Revised trauma score; Vital signs

1. Introduction

In any mass-disaster situation such as a building collapse, earthquake, or flash floods, it is expected that many agencies would rush to aid the victims. Given the possible large number of victims, the situation can quickly become unmanageable, and chaos can reduce the chances to save lives. In addition, chaos can limit the ability of area hospitals to identify and treat the most critically injured victims in a timely manner.

The current procedure of dealing with disasters includes setting up triage rooms at the disaster site and nearby hospitals. Patients are tagged according to their condition, and the critically injured patients are immediately transferred to nearby hospitals, where the emergency room physicians treat them. The number of first responders to a mass disaster is naturally limited as the available medical equipment and resources are never sufficient to tackle these disasters. Moreover, there might be a considerable delay in the arrival of additional medical personnel and equipment, and in soliciting medical advice for the patients in critical condition. Consequently, there is a need to bridge this gap and reduce the delay, because human lives are at risk in such situations. In addition, the paramedics are not the decision makers for the most critical patients, and the lack of physicians on the triage site shortly after the occurrence of a mass disaster aggravates the condition of the critically injured patients.

The delay in the first encounter with the physicians can be substantially reduced using our previously proposed Medical Data Transmission Over Cellular Network (MEDTOC) System [1,2]. MEDTOC provides a mechanism to integrate the patient data collected on site using vital motes [3] and send it to hospitals using the cellular network. Vital motes are sensors that capture the vital signs of patients and transmit them wirelessly to a nearby on-site computer. A web portal is designed to let the authorized users obtain vital statistics about the overall disaster management scenario.

The idea of real-time wireless transmission of patient medical data has been presented earlier, and several schemes have

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been developed for this purpose [4–6]. However, most of these schemes are limited to single-patient data. On the other hand, the data aggregation for multiple patients tested in [3,6] is confined to internal usage in triage rooms either on site or within hospitals. The CodeBlue sensors [7] can be used to aggregate information in vital signs for multiple patients, including temperature, blood pressure, SpO2 saturation levels, and pulse rate. Similarly, in the MEDTOC system [1,2], the vital signs of a large number of patients can be integrated, optionally compressed, and transmitted over the cellular network to nearby hospitals for monitoring of patients. In the hospital, the received data are decompressed and segregated to be displayed to the physicians. MEDTOC features specific packet-header formats, patient-grouping criteria, and a web portal to provide a secure and familiar interface to the physicians.

In this paper, we outline an updated MEDTOC-based framework to manage the flow of patients to nearby hospitals in a situation resulting from a mass disaster. The previously defined system is modified and enhanced to adapt to the available resources. In the next section, we discuss the state of the art in mass-disaster management. In Section 3, we present the previously defined architecture of the MEDTOC system, the enhancements, and the algorithm to assign patients to hospitals based on their Revised Trauma Score (RTS) value and other factors. Section 4 discusses the regional hospitals in Ras Al Khaimah (RAK), United Arab Emirates (UAE) used as an example for conducting simulations and the simulation results of MEDTOC handling a disaster situation from the collapse of a fictitious 20-story building. Conclusion and future work are discussed in Section 5.

2. Current disaster management schemes

In [8], the design of a healthcare information system named Advanced Health and Disaster Aid Network (AID-N) is presented. This system facilitates patient care, resource allocation, and allows real-time communication for triage. However, AID-N is an expensive system due to medics training, system maintenance, and database system management at the server side.

The researchers in [9] focused on solving the logistic problems at the disaster site by proposing an emergency response system based on the Disaster Aid Network. The researchers in [10] designed an IT application to improve the care of patients at the disaster site. They designed the Wireless Internet Information System for Medical Response in Disaster (WISARD) to enhance the tracking and quality of the patient information in mass-casualty events. The WISARD has some limitations by factors such as the external bandwidth for communications and the complex design of the electronic health records. A disaster planning strategy for the management of medical records in health facilities is presented in [11,12].

The online Victim Tracing and Tracking System (ViTTS) was presented in [13] and is based on a wireless network using routers on the ambulances and the direct online registration of victims. The ViTTS challenges include linking the pre-hospital data to the in-hospital data that requires modification at some stage in the healthcare system. Other researchers [14] focused on developing an optimal response strategy to a catastrophic event by minimizing the response time and related costs. However, their model only considers transporting victims with non-life-threatening injuries needing medical attention.

In this paper, the extended MEDTOC system presents the following features. The system allows tagging each patient at the disaster site with an ID and a triage tag that represents an approximate RTS value [15]. It implements a disaster management algorithm at the client (disaster) side that finds the nearest hospitals and automates the process of patient data flow to the hospitals. In addition, it implements another disaster management algorithm at the server (hospital) side that assigns patients to nearby hospitals based on several factors including the distance, trauma rank and available capacity of the hospital.

3. MEDTOC architecture

MEDTOC has been designed as a client–server application to manage the processing of patients at a disaster site. MEDTOC was introduced as a system to establish communication between the triage site and the nearest hospital to exchange patient information and perform remote monitoring [1,2]. The vital signs being monitored as well as the associated data rates and packet headers were determined according to the CAN 2.0A (i.e., Controller Area Network Protocol). Furthermore, an integration, compression, and transmission protocol was specified to integrate the data before transmission and segregate it on reception. An OPNET simulation was conducted to configure the UMTS-based transmission of patient data from a moving ambulance to a hospital. The transmission passes through various node-B stations with medium to heavy loads and repeated handoffs.

This study was based on the use of vital motes, described in Section 1. However, after consultation with the emergency room physicians from a hospital and trauma center, we also considered the option of using triage tags. There are certain difficulties in the use of triage tags instead of vital motes, including the delay in the manual processing of triage tags, as opposed to the automated processing of vital motes and zero-delay updates of the patient condition. However, the vital motes are not widely available and the paramedics are well-trained to mark each patient's condition with a color-coded triage tag. Moreover, the paramedics are largely unfamiliar with the use and administration of vital motes. Hence, if a disaster management scheme is widely implemented, it cannot only rely on something that may not be universally available. The colors of the triage tags translate to approximate RTS values for patients. Therefore, the scheme for patient data transmission is greatly simplified, and only the information of patient ID and RTS value of the triage tag are transferred to the hospital. The emergency room physicians also recommended that the process must be location aware and it must act proactively to assign patients to suitable hospitals. Hence, we extended the MEDTOC system by introducing location awareness and specifying the parameters that control the assignment of disaster victims to area hospitals using a series of software programs.