COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 126 (2016) 89–97

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

# A seamless ubiquitous emergency medical service for crisis situations

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ARTICLE INFO

*Article history:*
Received 15 July 2015
Received in revised form
12 November 2015
Accepted 9 December 2015

*Keywords:*
Emergency medical service (EMS)
Cognitive radio
Mobile middleware
Seamless communication
Stream control transmission protocol (SCTP)
Embedded system

ABSTRACT

In crisis situations, a seamless ubiquitous communication is necessary to provide emergency medical service to save people's lives. An excellent prehospital emergency medicine provides immediate medical care to increase the survival rate of patients. On their way to the hospital, ambulance personnel must transmit real-time and uninterrupted patient information to the hospital to apprise the physician of the situation and provide options to the ambulance personnel. In emergency and crisis situations, many communication channels can be unserviceable because of damage to equipment or loss of power. Thus, data transmission over wireless communication to achieve uninterrupted network services is a major obstacle. This study proposes a mobile middleware for cognitive radio (CR) for improving the wireless communication link. CRs can sense their operating environment and optimize the spectrum usage so that the mobile middleware can integrate the existing wireless communication systems with a seamless communication service in heterogeneous network environments. Eventually, the proposed seamless mobile communication middleware was ported into an embedded system, which is compatible with the actual network environment without the need for changing the original system architecture.



## 1. Introduction

In crisis situations such as earthquakes, tsunamis, fires, floods, and terrorist attacks, many people become injured and need urgent medical attention. At this time, many communication channels can be unserviceable because of damage to equipment or loss of power (Fig. 1). Thus, the vital data of a patient in an ambulance may not be transmitted to the hospital smoothly, continuously, and seamlessly before arrival. To manage patients in the prehospital time (golden hour) and increase their survival rate, prehospital emergency medical service (EMS) is crucial.

Before a patient is transported to the hospital in an ambulance, transferring all critical parameters of the patient to the hospital in real-time, including video and still-images of the scene, is indispensable. Thus, the involved physician can determine the state of the patient in advance and advise the EMS personnel [1]. Sending real-time information to the hospital, in addition to determining the state of the illness, can facilitate preparing medical apparatuses and the operating room in advance. If heart stop occurs more than 3 min, or respiration stop occurs more than 10 min, or massive bleeding occurs more than 30 min, the death rate may more than 50% [2]. Managing patients in the golden hour can increase their survival rate. To achieve this goal, the main challenge is stable

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http://dx.doi.org/10.1016/j.cmpb.2015.12.017
0169-2607/

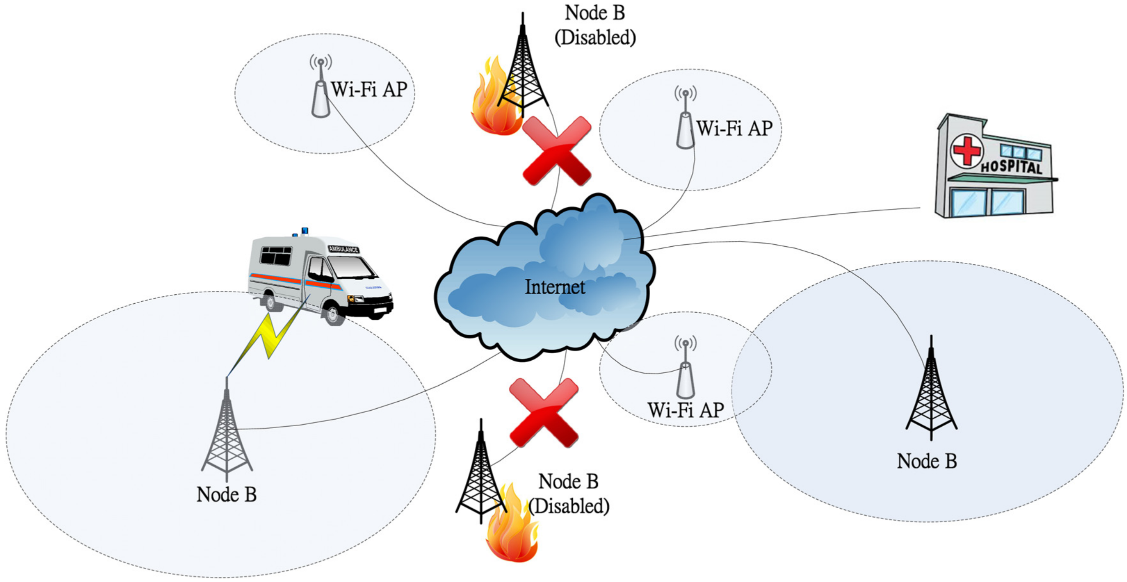


**Fig. 1 – Wireless communication in a crisis situation.**

and uninterrupted communication between the hospital and a moving ambulance.

In recent years, numerous studies have proposed middleware for EMS. In [3], a new concept of mobile middleware (MM) was proposed. The primary feature of MM is to provide services that can be transmitted over a mobile network to a moving client. In addition, adding a new functionality to MM is simple. Arunachalan et al. demonstrated an agent-based mobile middleware architecture designed for reliable medical data transmission over a cellular network [4]. These studies have focused on integrating wireless communication with EMS while ignoring the quality factor of wireless communication such as seamless communication.

Wireless communication has undergone a tremendous change in the past dozens of years. Widespread free Wi-Fi hotspots are a breakthrough for prehospital EMS because they enhance the mobility of communication and the feasibility of real-time features. Nevertheless, the stringent requirements and real-time requirements of medical applications introduce the need for quality of service (QoS) provisioned in wireless medical networks [5]. In addition, because many wireless network services currently exist, another crucial concern for real-time communication of EMS involves selecting an optimal wireless channel in ambulances and maintaining a reliable transmission [6]. To select a proper transmission path with multiple wireless links between an ambulance and the hospital, a new architecture of wireless communication based on the concept of cognitive radios (CRs) has been proposed [7–9]. Although these studies have focused on selecting an optimal transmission path by using CR techniques [10], maintaining high QoS by using one optimal transmission path in a moving ambulance is difficult because the coverage of a wireless network is limited and the ambulance may move into different wireless network service areas. Therefore, it is essential to switch the wireless network according to the available wireless network services and maintain continuous communication during a network switch.

To overcome the aforementioned problems, we propose a novel MM based on CR techniques for prehospital EMS, which can select an optimal transmission path with multiple wireless links also in addition to supporting a reliable transmission to avoid losing data during a network switch.

## 2. Methods

### 2.1. *Channel selection approach*

In mobile communication, "seamless" refers to uninterrupted switching between access networks, a process hardly noticed by a user [11]. Therefore, the challenge of seamless communication is to choose an acceptable network link for the selected service according to quality, cost, and accessibility.

In the sophisticated seamless communication concept described in [11], the decision algorithm plays a crucial role in reducing the handoff delay for mobile medical services. For seamless communication, the idea of CR, which can sense the operating environment and optimize the spectrum usage, was proposed in 1999 [12]. There are three tasks in a cognitive cycle. The first is radio-scene analysis, which senses the respective environment conditions and probes different configurations. The second is channel identification, which estimates the channel state information and predicts the performance capabilities of configurations. The third is radio configuration selection, by which the transmitter sends the signal.

A cognitive engine is an intelligent core that manages the cognition tasks in a CR. An adaptive reasoning and learning framework (ARALF) was used as a cognitive engine [13]. The ARALF is different from the common cognitive engine because it receives not only the data on its surroundings, including signal strength, link quality, and location, but also the information of user preference. Therefore, the ARALF can adjust the radio parameters according to the user preference,