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Medical emergency alarm dissemination in urban environments

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ABSTRACT

During medical emergencies, the ability to communicate the state and position of injured individuals is essential. In critical situations or crowd aggregations, this may result difficult or even impossible due to the inaccuracy of verbal communication, the lack of precise localization for the medical events, and/or the failure/congestion of infrastructure-based communication networks. In such a scenario, a temporary (ad hoc) wireless network for disseminating medical alarms to the closest hospital, or medical field personnel, can be usefully employed to overcome the mentioned limitations. This is particularly true if the ad hoc network relies on the mobile phones that people normally carry, since they are automatically distributed where the communication needs are. Nevertheless, the feasibility and possible implications of such a network for medical alarm dissemination need to be analysed.

To this aim, this paper presents a study on the feasibility of medical alarm dissemination through mobile phones in an urban environment, based on realistic people mobility. The results showed the dependence between the medical alarm delivery rates and both people and hospitals density. With reference to the considered urban scenario, the time needed to delivery medical alarms to the neighbour hospital with high reliability is in the order of minutes, thus revealing the practicability of the reported network for medical alarm dissemination.

1. Introduction

The expansion of information and communication technologies led to new models for healthcare management and delivery (Boric-Lubecke and Lubecke, 2002; Lin, 1999; Pattichis et al., 2002). The potential to reduce the distance between patient and health care providers, together with the ability to obtain information to better manage individual wellness, could improve the efficiency and quality of care (Dishman, 2004; Fratini et al., 2013; Lin, 1999; Ruffo et al., 2010; Varshney and Vetter, 2000). In this framework, the emerging mobile wireless technologies have been pervasively integrated in health care systems (Stanford, 2002; Varshney, 2003), improving the effectiveness of medical professionals in:

- Routinely activities: concerning patient's condition and therapy monitoring (Pasquariello et al.,2010; Fratini et al, 2014).
- Communications: allowing health care workers to be always reached for consultation.
- Information access: to examine medical records and general patient data anywhere and anytime (Ammenwerth et al., 2000; Cesarelli et al., 2011).

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Mobile devices such as smart phones or Personal Digital Assistants (PDAs) reached a great diffusion in the last decade (ABI, 2009) and their number is increasing (Coda, 2010). The hardware characteristics of such devices allow direct wireless connection with medical equipments, wearable monitoring systems (Bifulco et al., 2011) and other similar architectures (Anliker et al., 2004; Dabiri et al., 2009; Wac et al., 2009). Moreover, wireless networking solutions, such as wireless LANs, ad hoc wireless networks and GSM/3G infrastructure oriented networks have been tested and proven to be reliable in emergency situations or simulated critical events (Martí et al., 2009; Monares et al., 2011; Scott et al., 2002).

Numerous are the examples of mobile health research in the field of medical emergency. Consistent challenges were found for rapid emergency response (Blackwell and Kaufman, 2002; Pons and Markovchick, 2002) and information management (Chan et al., 2004; Monares et al., 2011): "*applications that combine timely, clinical information with accurate geographic localization may result particularly useful*" (Chan et al., 2004).

Different strategies have been proposed to manage a medical emergency during critical events or disasters. Some examples are based on 3G networks or radio communications: in (Kwan and Lee, 2005), the authors explored the use of Universal Mobile Telecommunication System (UMTS) in connecting building sensors in a three dimensional real-time analysis of urban scenario to help rescuers in coordinating rescue operations. In (Plischke et al., 1999), the authors analysed the potential of telemedical support in pre-hospital management of emergencies and transmission of data via digital radio network to overcome obsolescence of paper based documentation and enhance medical treatment workflow. Operation through network infrastructures was also proposed in (Dai et al., 2011). The authors argue that the first and most effective intervention can be offered by the people surrounding the disaster area so that a first-aid instruction given by medical experts, thorough the use of 3G mobile network can minimize casualties. An interesting solution was similarly suggested in (Martí et al., 2009). The study proposed a mobile triage system, based on patient tagging at the site of emergency, operating through a mesh network formed by medical emergency personnel handheld devices and able to work in absence of network infrastructure.

Although the different solutions proposed represent valuable approaches, the risk that during critical events, disasters or mass gathering medical emergencies, they do not work properly, due to failures or congestion of traditional infrastructure-based networks (i.e., GSM/3G cellular networks), is high (Maningas et al., 1997).

In case of mobile triage scheme moreover, it is worth mentioning that such a system would be effective only at the time when field medical personnel arrive on site after the emergency medical systems (EMS) intervention request.

In case of difficulty of medical alarms transmission, an alternative message dissemination system may result precious, especially when the need to request a rescue action or to inform approaching rescuers on the state and the site of the injured individuals is vital (e.g., in mass emergency).

Mobile phones-enabled ad hoc networks represent a feasible way of dissemination of alarm messages in emergency events. Nevertheless, the usefulness of adopting such a solution to the medical field has not been evaluated yet and the potential implications and limitations of this approach should be assessed.

With this study, we aim at analysing the feasibility of medical alarm dissemination through ad hoc wireless networks formed by mobile phones. In particular, we intend to present the expected delivery times for alarm dissemination in an urban environment based on realistic people mobility.

2. Methodology

This paper presents an evaluation of the feasibility of a partially connected ad hoc network established by mobile phones carried by human beings for disseminating medical emergency information in urban environments. To obtain realistic medical emergency information dissemination, we model the human mobility according to the results of an experiment involving one million mobile phone users of a US telecom operator in the Boston Metropolitan area, whose positions have been anonymously traced during the month of July 2009 (Cacciapuoti et al., 2013).

More specifically, a set of 200 millions of anonymous location measurements have been considered. Such a dataset covers a region spread over 8 counties in East Massachusetts (Middlesex, Suffolk, Essex, Worcester, Norfolk, Bristol, Plymouth, Barnstable) with an approximate population of 5.5 million people, and it involves one million mobile phones (corresponding to a share of 20% of the population approximately), traced for roughly a month. The location measurements have been recorded each time a device connected to the cellular network, and each location measurement represents the position, i.e., the latitude and longitude, of a certain device estimated through triangulation.

As in (Cacciapuoti et al., 2013), we select as event representative of a possible medical emergency the Boston Independence Day Celebration on July 4th 2009[1]. During this day people usually congregate around the Charles river (the area depicted in Fig. 1) to attend the concert and watch fireworks organized by the city administration.

The choice of the Independence Day was not arbitrary, since it allows us to evaluate the feasibility of a partially connected ad hoc network for disseminating medical emergency information during a crowd gathering event when:

- Emergency events likely happen.
- The knowledge of the accurate location of the emergency event has high relevance concerning the severity of the possible injuries or the crowding of the access paths.

[1] http://www.july4th.org.