Using Haggle to Create an Electronic Triage Tag

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ABSTRACT

Forwarding data in scenarios without connectivity, Pocket Switched or Opportunistic networking can be difficult without a mobility model, or a history of node contacts. One of these scenarios is a disaster, where forwarding victim's medical information to a coordination point is critical for the good and fast intervention. "Time To Return" (TTR) forwarding was used in combination with mobile agents in MAETTS to provide early resource allocation during such emergencies. In this paper, we propose to apply TTR forwarding in Haggle to create an Electronic Triage Tag. This approach allows us to take advantage of short connectivity opportunities between nodes.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Network communications; C.2.2 [**Network Protocols**]: Routing protocols

General Terms

Design

Keywords

Delay Tolerant Networks, Pocket Switched Networks

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1. INTRODUCTION

When a mass casualty incident occurs, many rescue personnel are involved in caring for victims. The coordination of these personnel is vital to speed up the rescue process and to minimise the loss of lives. Having information about the number of victims, their location, and their injury level is essential to prioritise individual treatment.

Medical aid for victims must be prioritised based on their condition. For this reason, the medical personnel arriving early to the emergency scene perform triage, to determine injury levels. As a result, victims are sorted into groups based on their need for immediate or urgent medical treatment. Consequently, medical personnel arriving later know those victims who need more attention. The victims are stabilised and prepared, in injury level order, to be evacuated to hospital, where they can be treated more thoroughly.

In the great majority of mass casualty incidents, infrastructure becomes unstable, inaccessible, overused or is even destroyed. Hence, communications in the emergency area cannot rely on existing wireless network infrastructures. In consequence, emergency personnel may deploy and use their own infrastructure, for example using a wireless mobile adhoc networks (MANETs), to transmit triage information. However, if the area is too large, it may not be feasible to have a fully connected MANET.

The aim of this paper is to present a system based on Haggle to triage victims in a mass casualty incident, transmitting this information to the emergency Coordination Point (CP) from the emergency area, without relying on unstable communication infrastructure, nor on the deployment of a new infrastructure or the a fully connected MANET.

2. BACKGROUND

The proposed system is based on various existing technologies, including: triage protocols; Haggle; and DTN forwarding schemes. We present background information on these next.

2.1 Triage

There exist several triage protocols for emergency situations. The START protocol [9] is the most widely used. This classifies victims into one of four groups depending on their condition. In order of from worst to best condition, the first group is black. Victims triaged in the black group are deceased, or in such bad condition that it is impossible for the medical team to do anything to save them. The second group, red, contains victims who need immediate attention. The victims in the third one, yellow, do not need immediate medical attention, and can wait for a short period of time. Finally, the green group is for victims with minor injuries, who need help less urgently.

Handheld devices are frequently used in emergency scenes by rescue personnel to triage victims [5][3].

2.2 Haggle

Haggle [7] is an autonomic networking architecture designed to exploit opportunistic communications (i.e., in the absence of end-to-end communication). When an application wants to send some data, a direct connection to the receiver or receivers is not required, and even the identities of the receivers can be unknown. Haggle implements improvements over classic communications architecture by using a data-centric communication model with a publish-subscribe API. The representation of data in Haggle is as DataObjects, which are made up of attributes with corresponding values. An application can subscribe its interest to DataObjects with a specified attributes, or to only these DataObjects with a specified value of an attribute. When an application subscribes to one or more interests, it will receive all DataObjects matching these interests. This is known as interest based forwarding.

Furthermore, Haggle provides underlying functionality for neighbour discovery, resource management and resolution, thus removing the need to implement such features in applications. The architecture of a Haggle platform is composed by a kernel and a group of managers. Each manager performs dedicated tasks in parallel sharing data with the other managers as the neighbours list, the opening sockets and the data send by the applications. Managers can be added or deleted from the kernel any without negative impact on, or complex interaction with other managers.

2.3 Pattern based forwarding

In PSNs or DTNs scenarios, data about social networks, node contacts and the history of movements between places, are commonly used to support decisions for forward packets. Some examples of different forwarding approaches are given next.

2.3.1 Social attraction

Musolesi et al [6] proposed a forwarding method based on a mobility model founded on social network theory. The authors propose to use the social relations between individuals to create a matrix. Each relation is associated with a weight depending of the strength of the social relation. This weight will be later used to take forwarding decisions.

2.3.2 Levy walks

Levy walks [8] consist of routes that a creature follows during over some period. During a week, an individual usually does the same movements each day: commuting from home to work, from work to restaurant, from restaurant back to work, and then, back to home. These walks or *flights* can be modelled, and later on used as routing information, predicting individuals' contacts.

2.3.3 Time To Return (TTR) forwarding

In *Martí, R. et al* [4], a new routing protocol, Time To Return (TTR), is proposed. Medical personnel in an emergency scenario are coordinated by a leader. The leader, or a group of leaders, tells personnel where to go to, or in which area to work [4]. When they leave the coordination point, a maximum time to return to the base is assigned to them. They are required to return to base for security reasons, before this time has passed.

2.3.4 Delegation forwarding

TTR forwarding is an example of Delegation forwarding [1]. *Vijay Erramilli et al.*, a proposed generalisation of forwarding methods such as BUBBLE Rap [2] or TTR. This generalisation applies to mobile opportunistic networks with unpredictable mobility, heterogeneity of contact rates and lack of global information. Achieving delivery of messages without flooding in such network is challenging. In Delegation forwarding, each node has an associated value which is created using a metric that represents the quality of the node as relay. The metric used depends of the scenario where it will be used.

3. HAGGLE ELECTRONIC TRIAGE TAG

In this paper we present Haggle Electronic Triage Tag (Haggle-ETT), an application dedicated to the triage of victims in emergency scenarios where there is no infrastructural network, and a fully-connected MANET is not feasible due to the large geographical extent of the scene. Our application uses Haggle as middleware. Haggle allows the application to run in Pocket Switched Networks (PSN) or Delay and Tolerant Networks (DTN) without relying on the state of the network. Haggle is in charge of managing the network, connectivity, contacts, neighbours and more. Because of these features, Haggle was chosen as the base architecture for our system.

The default forwarding method in Haggle is simply sending DataObjects that match the interest of the target whenever a node contact occurs. This forwarding method is effectively epidemic in our emergency scenario, since all nodes have interest in delivering this information to the coordination point. However, sending data in an epidemic way in emergency scenarios may not be efficient. Battery has to be preserved as much as possible and, furthermore, sending data in an epidemic fashion may waste opportunities for forwarding data to better choices of nodes who could deliver the data sooner to the coordination point. For instance, if two node contacts occur at the same time, and both contacts are short in duration, it is possible that the sender node only has time to forward the data via one of these nodes. Data sent in this manner will go via the first node contacted in an epidemic manner, and not the second; but in our scheme for TTR forwarding, data is sent to the node that will deliver the data soonest to the coordination point.

TTR forwarding is a novel method for forwarding[4], using Haggle. It can provide faster delivery of triage information to the coordination point, and therefore accelerate the treatment of victims. We have developed a Haggle manager to implement TTR forwarding support, together with an application that is in charge of creating the Electronic Triage Tags (ETTs).

The aim of this whole system, the application plus the Haggle middleware with TTR forwarding, is to route triage

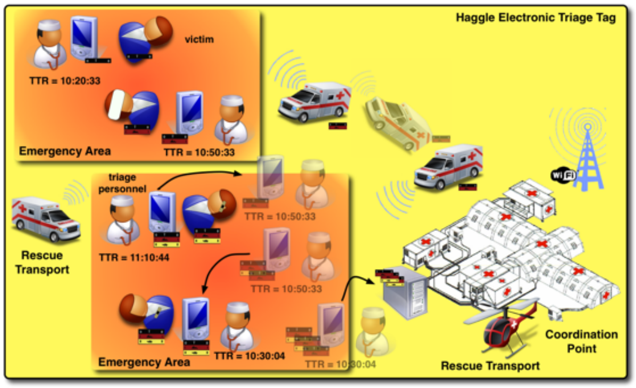

Figure 1: Haggle-ETT scenario

information of victims in the form of *Triage DataObjects* to a Coordination Point where this information will be used to treat the victims in a prioritised way according to their injury level. This system is designed to work in the worst emergency scenarios without any network connection, relying solely on node contacts, even over wide geographic areas. However, Haggle-ETT and the TTR forwarding method not only works in these type scenarios, but will also work even better where there is network connectivity.

3.1 Triage Process

Medical personnel are equipped with handheld devices, and use them to triage victims. The handheld, running the Haggle-ETT application and the Haggle middleware, displays a wizard that follows the START protocol. When the user has finished the wizard, an injury level is proposed by the application based on the data provided by the user using the wizard. The user can then accept this injury level proposal or propose another one if they think that the victim deserves it. Once the victim has been triaged and an injury level is assigned, a Triage Tag (paper Triage Tag) is attached to her, allowing a quick visual identification of the victim's injury level. This paper Triage Tag contains an RFID in order to identify uniquely the victim within the emergency scene. This RFID is read by the handheld device, which contains an RFID reader. An RFID tag is a good and fast solution to combine both Electronic and Paper Triage Tag, and identify the victim in uniquely. Next, the handheld device creates a *Triage DataObject* containing the injury level information and the GPS position of the victim provided by the handheld and the RFID of the Triage Tag. The *Triage DataObject* is a message created and formatted for the Haggle API. Once the message is created, it is handed to the Haggle middleware. Inside the Haggle system, the message is forwarded from one device to another following TTR forwarding. The destination of the *Triage DataObject* is the Coordination Point (CP) for the emergency. The CP maintains a prioritised list of victims that is updated each time a *Triage DataObject* is received. Furthermore, a map with the position and injury level of each victim can be created. As a result, routes can be traced using the map information. These routes try to take the medical personnel first to where victims with worst injury level are.

3.1.1 *Haggle and the TTR manager*

The TTR forwarding method [4] is implemented in Haggle. As stated before, the development of a Haggle manager (TTR manager) was needed to forward the messages using the TTR strategy. The combination of Haggle and the TTR manager provides Haggle with the functionality to look constantly for neighbours, and compare TTR values. If this node finds another node with a lower TTR, it forwards the *Triage DataObjects* via that node, with the aim of reaching the CP as soon as possible.

The TTR manager is in charge of forwarding messages between nodes using the TTR forwarding method. The first step is to set up a TTR on the platform. This value will be used later on for forwarding decision. A *TTR set up message* has to be sent by the Haggle-ETT application to Haggle in order to initialise this value. The TTR manager processes this message, and sets up the TTR value in the message as the TTR value of the platform. Once the platform has a valid TTR value, each time two nodes make contact, they exchange TTR values. Each TTR Manager (of each Haggle node) sends a message informing of the TTR value of the node and processes the TTR information message received from the other node. The TTR values are compared, and if the TTR value of the other node is lower, the *Triage DataObjects* in this node are forwarded to the other node with lower TTR. Each time a *Triage DataObject* is received from a Haggle-ETT application, it is stored in the TTR Manager. If one of the nodes in a node contact has no valid TTR value yet, there is no exchange, because there will not be any *Triage DataObject* stored yet.

The TTR values of other nodes that discovered in all contacts are saved. When recording this information, the TTR value is associated with the Haggle identifier of that node, identifying it uniquely in future contacts. Haggle maintains a list of messages sent. As a consequence, if two nodes are in contact again in the future they will not exchange TTR values again, unless the TTR values have changed since the last contact (because typically, the TTR value of a node will not change). Therefore subsequent node contacts will be faster, since *Triage DataObjects* will have be forwarded before via the node with least TTR.

It is possible that the user does not make any contact with another user during their trip. If this happens, the time that the *Triage DataObjects* would require to arrive the Coordination Point will be the TTR left when the victim is found and triaged.

3.1.2 *Haggle-ETT application*

The application is in charge of creating the Electronic Triage Tag, and send it using Haggle. When the application is opened, the user is prompted to set up the TTR value. Once the TTR value has been set up, a TTR set up message is sent to the platform, and then the user is able to start a triage process. This process begins with the START protocol. The wizard guides the user using the same steps that the START protocol and asks for victim's sanitary conditions. After completing the wizard assistant, a suggested triage level is shown. If agreed, the user accepts and a *Triage DataObject* is created. While the user attaches the paper Triage Tag to the victim, the handheld reads the GPS position and adds it to the *Triage DataObject*. Furthermore, before the paper Triage Tag has been placed its RFID is read by the handheld and the ID is also attached to the *Triage DataObject*. Finally, the message is passed to Haggle and the wizard's start again. An emergency scenario operational example is illustrated in figure 1.

4. IMPLEMENTATION

Our implementation is a proof of concept. All the functionalities of the TTR manager have been built, and are working within Haggle. The Haggle-ETT application has been implemented to show the performance of the TTR manager and Haggle. A series of tests have been done using this implementation to confirm the smooth running of the system. In this section we describe some of the implementation details.

- TTR Manager: The TTR Manager added to Haggle provides TTR forwarding method and is in charge of the TTR Interchange, forwarding Triage DataObjects, and the set up of TTR value on the platform.
- Haggle-ETT application: The Haggle-ETT application is written in C++ and uses the libhaggle library. It has been tested in Mac OS X (10.5 and 10.6) and Windows. This application has been used as a proof of concept to send the *TTR set up message* using the Haggle platform. Furthermore, it has also been used to create *Triage DataObjects* to test Haggle and the TTR forwarding.
- Triage DataObjects: *Triage DataObjects* in Haggle have three main attributes that can be added to the Haggle-ETT application. The injury level of the victim: black (deceased), red (immediate), yellow (urgent) or green (delayed); the GPS position of the victim (the same position as the user of the handheld when is triaging the victim) provided by the GPS module of the handheld; and the ID of the RFID attached to the paper Triage Tag assigned to the victim

5. CONCLUSIONS

Making information about the victims available within the emergency scene is essential for the prioritisation of the rescue process. However, due to the nature of the emergency scenarios, communications cannot rely in existing infrastructure, which may be unusable for various reasons. Moreover, the deployment of a fully connected MANET network may not be feasible because nodes are sparsely distributed over the emergency scene. In this paper, we have presented a system to forward triage information about victims in the emergency using Haggle. The triage is done using a GUI, following the START protocol. This process creates a *Triage DataObject* which is delivered, using Haggle with the TTR forwarding method, to the Coordination Point without relying in the communications infrastructure or the deployment of a MANET.

Mobile devices, held by the medical personnel, are in charge of keeping and forwarding the victims' triage information with the aim of reaching the coordination point as soon as possible. *Triage DataObjects* are forwarded using node contacts when the other node has a lower TTR value, which means that the other device will arrive earlier at the coordination point. Thus, routing decisions are made at the application layer. The proposed system is not limited to scenarios without infrastructure. It can also be used in scenarios where end to end connectivity is available. In this case, a Haggle node can communicate directly with the Coordination Point's Haggle node. If the network infrastructure becomes unavailable, or if there are delays and disruptions in the fully connected MANET, the system will go on working. This makes the system useful in any situation.

5.1 Future work

As future work it has been planned to carry out comparisons with MAETT: speed and minimum contact time are key features to test. Simulations of Haggle-TTR in different types of emergency scenarios are also been planned. The TTR model of communication can be viewed somehow, as like a very slow WiFi access point network, so a comparative evaluation based on 802.11 models can also be done. Furthermore, research about extend the TTR forwarding to other scenarios is anticipated.

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