Electronic Triage Tag and Opportunistic Networks in Disasters

Abraham Martín-Campillo*, Ramon Martí
Dept. of Information and Communications Engineering
Universitat Autònoma de Barcelona
Bellaterra, Spain
abraham.martin@uab.cat,
ramon.marti.escale@uab.cat

Eiko Yoneki and Jon Crowcroft
Systems Research Group
University of Cambridge
Cambridge, United Kingdom
eiko.yoneki@cl.cam.ac.uk,
jon.crowcroft@cl.cam.ac.uk

ABSTRACT

The use of electronic devices such as sensors or smartphones in emergency scenarios has been increasing over the years with new systems taking advantage of their features: mobility, processing speed, network connection, etc. These devices and systems not only improve victim assistance (faster and more accurate) but also coordination. One of the problems is that most of these systems rely in the existence of a network infrastructures, but usually in big disasters, or mass casualties incidents, these infrastructures become saturated or destroyed by the very nature of the emergency. In this paper we present MAETT and Haggle-ETT, two applications that provide electronic triage tags (ETTs), a digital version of the classics triage tags, based on mobile agents and opportunistic networks, respectively. These systems are able to work even without network infrastructures using ad-hoc networks to forward the ETTs to a coordination point where they will be processed.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and DesignWireless Communication; C.2.2 [**Computer-Communication Networks**]: Network ProtocolsRouting protocols

General Terms

Design

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Keywords

Delay Tolerant Networks, Emergencies, Triage Tag, Opportunistic Networks, Disasters

1. INTRODUCTION

With the increase in the usage of the Internet and smartphones in recent years, their role in the recovery of emergencies has become essential [22]. One of the most important elements in emergencies is the information generated during the emergency, e.g. triage data or location of a victim. Having this information helps the coordination of the emergency recovery and provides a fast response. But these data suffer from two problems. Firstly, some data are usually not transmitted, or transmitted by traditional mechanisms like voice radio or even written annotations, as is the case of paper triage tags for triage information. Secondly, some systems used in emergency scenarios rely on a network infrastructure that may have been destroyed by the very nature of the emergency or may be unstable or inaccessible due to its over usage [2]. Because of this, the use in these scenarios of ad-hoc opportunistic networks, focused on scenarios with intermittent network connectivity in the absence of end-to-end communication infrastructures, is very appropriate.

In this paper, we present MAETT (Mobile Agent Electronic Triage Tag) [13][9][21] and Haggle-ETT [14], that allow the triage data to be collected and represented in an electronic format and to be transmitted, to a coordination point where they will be processed and made available for the managers of the disaster recovery, even if no network infrastructures are present. Thus, these applications provide a collection of additional information for a better coordination and a faster response.

MAETT and HaggleETT provide the same features but are based on different paradigms. MAETT uses Mobile Agents [5] for storing the Electronic Triage Tag information. Moreover, Mobile Agents are used as the mechanism for forwarding the information. They can carry data and jump from platform to platform using different strategies in their code. Each Mobile Agent can have its own code, different from others Mobile Agents (with other algorithms, forwarding mechanisms, etc), and can carry data generated in different visited nodes. On the other hand, HaggleETT is based on Haggle [1] networking architecture for content-centric opportunistic communication. Haggle allows mobile devices to exchange content directly between themselves whenever they happen to come in close range without requiring a network infrastructure.

2. DISASTERS RECOVERY PROCESS

The two systems presented in this paper are specially useful on mass casualty incidents (MCIs), whose main characteristic is the large number of victims. In these cases, the triage of these injured victims is needed to sort them into groups based on their need for immediate medical treatment. This triage is done by the first response personnel arriving at the emergency scene, so the medical personnel arriving later know those victims who need more urgent attention. The victims are stabilised in triage colour order (black, red, yellow and red) before they are evacuated to the hospital or to the advanced medical post where they will be treated widely.

There are a number of triage protocols for emergency situations, however, the START protocol [7] and the Triage Sieve and Sort [23] are the most widely used. Both create four groups of victims based on their condition. The first group, from worst to best condition, is the black one, that is assigned to those victims that are dead or in a very bad status, impossible for the medical team to do something to save their lives. The second group, red, are victims who need immediate attention. The victims in the third one, yellow, do not need immediate but urgent medical attention, that can be delayed for a short period of time. And finally, the green group, is for victims with minor injuries who do not need urgent help.

Once the triage is complete, rescue teams extract those victims who are trapped or cannot move from the hot spot to a safe place. The incident location is also known as zone 0. In this area the medical personnel cannot work because of a risk of danger such as explosion or contamination. Because of this, it is important for everybody to evacuate this area and for the rescue teams to extract the victims that cannot move. While rescue teams are doing their job, the medical personnel treat those victims in the red group that have already been evacuated and are in the patients' waiting for treatment area, also known as zone 1.

If Advanced Medical Posts (AMPs) or casualties clearing stations are installed, the victims are evacuated to this place (see Figure 1). An AMP is a mobile hospital to treat the victims before they can be transferred to an hospital. In mass casualties, where it is necessary to treat lots of victims in a serious condition, AMPs are essential and have to be installed near but in reasonable distance from the zone 0 to be a safe place.

The main objective of the medical personnel in the area regarding the victims in the red group is to stabilise them. Once the stabilisation is done, the rescue vehicle is called to pick up the victims to transfer them to the hospital. After the red victims, the yellow ones are treated in the same way. Regarding the green ones, they are arranged together and then transferred with low priority to other hospitals or medical institutions using any available transportation.

The Advanced Command Post (ACP) is where the coordination team is, and where all the decisions about actions to be carried out by rescue and medical teams are taken.

It is necessary to consider that in a big emergency more than one hot spot or local emergency can exist. During these local emergencies, for instance in a hurricane, each house devastated or vehicle crashed, can share the meeting point, AMP and/or ACP or have its own for each one if they are big enough. Usually, if the emergency has multiple hot spots or local emergencies, a crisis committee is created to manage and coordinate all the emergency in collaboration with different ACPs installed.

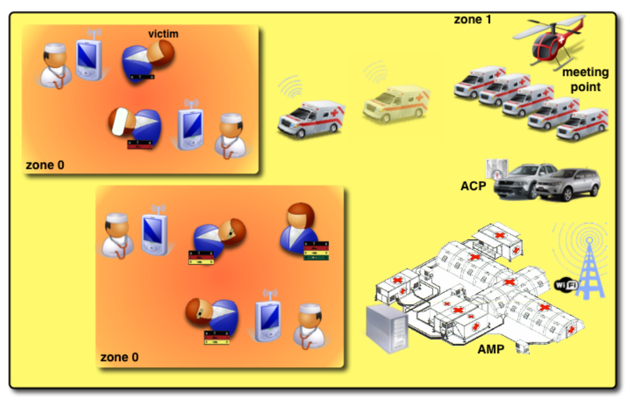

Figure 1: Emergency Scenario

2.1 Communications in the emergency scenario

Previously emergency communications were only a matter of walkie-talkie communications, but nowadays they are becoming more and more advanced. This is due to the greater use of Internet enabled devices or mobile phones by the emergency personnel, that require mobile networks such as mobile phone network (3G) or WiFi. In the great majority of emergency cases, hurricanes, terrorist attacks, flooding, etc, these networks become unstable, inaccessible, overused or even destroyed. As a consequence, emergency personnel cannot rely on the use of existing network infrastructure and may deploy and use their own [12][11], or simply use wireless mobile ad-hoc networks (MANETs) [16][20][15][11]. These networks create routes by request of the nodes that are maintained as long as they are needed or the link is available.

Anyway, all these solutions have the same lack: because of the mobility of the devices (or if the area of emergency is big enough) a continuous end-to-end connection cannot be guaranteed. As a result, an attempt to communicate from one point of the network, for instance, a first responder, to another point, for example the AMP, could be unsuccessful as this kind of networks needs an end to end communication. In these cases, opportunistic networks can be used; even if a message is required to arrive as soon as possible once it has been generated, the time to arrive to any part of the disaster area will require less time than deploying all the nodes necessary to create an infrastructure network or a fully-connected MANET

Regarding the AMP and ACP, it can be supposed that they have always Internet connection even if the network infrastructures are destroyed or unusable. They use their own deployed network infrastructure, for instance, satellite connections. For the AMP and the ACP, it is very important to have Internet connection for coordination or information communications (f.e. with another coordination point or with hospitals assigned to victims). From this point of the paper we will talk about AMPs and ACPs as coordination points, the only points of the emergency scenario where there are network connection.

3. ELECTRONIC TRIAGE TAG SYSTEM

Previously in this paper two applications have already been introduced: MAETT and Haggle-ETT. Both applications make use of the same core, our Electronic Triage Tag System, that is in charge of the creation of the Electronic Triage Tags (ETTs). MAETT and Haggle-ETT will have different methods for carrying, storing and forwarding the ETTs to a coordination point using opportunistic networks but both share the core system in charge of the creation of the ETTs.

Triage personnel is equipped with handheld devices with GPS, and a RFID reader units (Figure 2). When a victim is found, she is labeled with a paper triage tag containing an RFID tag attached that provides the ability to uniquely identify the victim within the emergency. The paper triage tag allows a quick visual identification of the victim's injury level. An RFID tag is a good and fast solution to combine both Electronic and Paper Triage Tag and identify the victim in both of them in a

Figure 2: Nokia MAEMO n810 and RFID reader

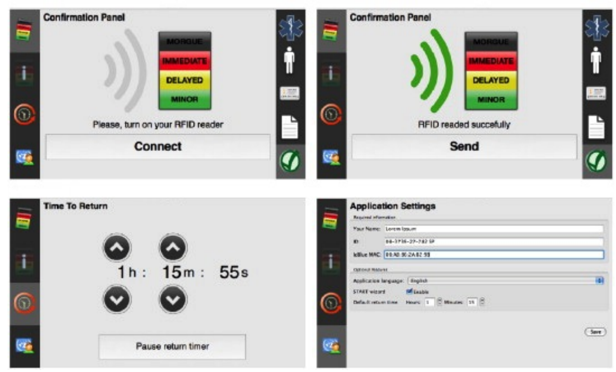

Figure 3: RFID reader software, TTR and software settings

uniquely way. Before labelling the victim, the staff shall approach the electronic triage tag to the RFID reader that will read their unique ID (Figure 3). After that, a software assistant is activated to help staff to assess the state of the victim (Figure 4). This software provides all the steps required to follow the START protocol (breathing, pulse, answers to simple questions, etc.) to perform the triage.

The software interface of the wizard (Figure 4) is simple, with intuitive icons, short and understandable text, and large buttons that facilitate the use of the touch screen. Furthermore, its use is optimal for triage because it does not increase the time devoted to follow the START protocol (which must be as short as possible) and benefits from the available data already digitalised.

Once the process has been completed, an injury level is proposed by the application based on the data provided by the user using the wizard: green for *MINOR*, yellow for *DELAYED*, red for *IMMEDIATE*, and black for *DECEASED*. This status can be accepted or may be changed to another one that the user considers more appropriate. The wizard can be turned off if the situa-

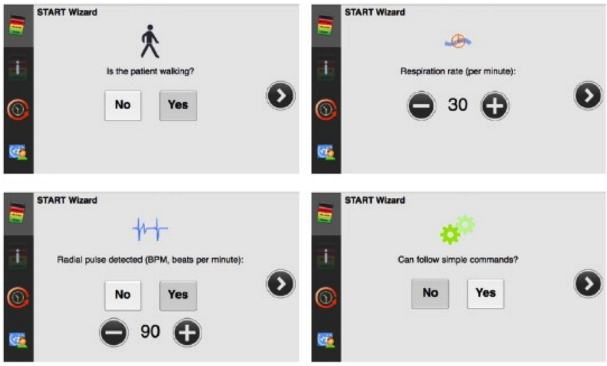

Figure 4: START protocol assistant for the triage of victims

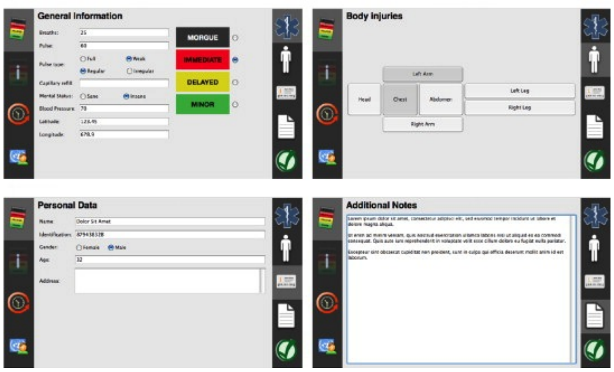

Figure 5: Electronic Triage Tag

tion requires it to show the selection screen color (state) just to read the RFID associated with the paper triage tag.

After estimating the state (colour) of the victim, the software will read the GPS device position where the staff, and therefore the victim, is at that time, and an Electronic Triage Tag with all this information (Figure 5) will be created. Additionally, the staff will assign the same injury level colour to the paper triage tag of the victim.

3.1 Electronic Triage Tag

The electronic triage tag (ETT) created after the triage (Figure 5) will include the status (color of the triage tag) of the victim, the GPS position, the unique identifier of the triage tag, and the patient's vital data (pulse, respiration, etc). Other possibilities could include an additional photo of the situation of the victim or the victim itself.

The ETTs will be stored in the personnel smartphone for later being transferred to the coordination point. While the personnel is working in the Zone 0, the system will forward the ETTs stored in their smartphone to other emergency personnel's smartphone in order to allow the ETTs to get to the emergency coordination point as fast as possible. Mobile Agents and Haggle accept any existing opportunistic routing protocol but this is an important part of the application as it has a high impact on the message delivery performance. Hence, choosing the appropriate forwarding algorithm is critical. This algorithm will be in charge of making the decisions of relaying or not an specific ETT to another emergency personnel's smartphone in order to make it arrive sooner to a coordination point.

3.2 Coordination point

The coordination point system is where all ETTs are delivered. This system may be distributed, i.e., it may comprise more than one server that will be able to exchange data, since they are connected to each other. The coordination point has a wireless network access point to allow communication with the smartphones arriving from the emergency, as well as a wired or wireless internet connection for coordination outside the emergency area.

Furthermore, the coordination point system keeps all the information gathered by all the staff. It may know the position of the victims, their status, and whether there are special needs for each one. This eases the task of planning routes for the collection of the victims by placing higher priority on those that have been selected for such, and helps the emergency organisation and management staff to have a clearer idea of the distribution of victims.

4. FORWARDING

Smartphones usually have three network interfaces: HSPA/GSM, wifi, and Bluetooth. The first one can not be used for opportunistic networks. Bluetooth has only a range of 10 m and the transfer speed is very low. In big scenarios with a low density of nodes, nodes will not approach each other at these small distances. In mass casualty incidents there are a lot of victims and the first responders are fewer in number, hence they are far from each other. Moreover when two first responders approach each other, the contact time will be small because they usually run in those scenarios, so the faster the transfer speed, the more data will be interchanged.

Hence, even though wifi has a high energy consumption, it will be the best option for opportunistic communications in emergency scenarios. Furthermore, the wifi will be working in opportunistic mode, therefore it will not be able to enter into low energy mode. That said, in order to reduce this high energy consumption (very important in mobile devices running on battery) and also have a good delivery ratio we should use an appropriate routing algorithm.

Regarding data, one can think that using an epidemic method is the best option, but the use of broadcast-based forwarding approaches (where multiple copies of the same data is spread throughout all the network) has two problems. The first one is the energy efficiency. Since data transfer using wifi is the most energy consuming process in a handheld device [18], each data transfer consumes a lot of energy. For this reason it is important to select a forwarding algorithm that does not waste a lot of energy relaying unnecessary data. The second problem occurs in cases with a high number of messages because due to the short contact times it is not possible to forward all the data in a node, so it may also require some kind of data forwarding priority management.

But choosing the right forwarding method for the application depends also on a number of factors: the number of first responders working in the zone 0, the number of victims, the size of the ETT, the buffer of the device, and the energy consumption of the device using the network.

For these reason we created the Time To Return (TTR) routing method, a simple mechanism to forward data only once per node (energy efficient) with good delivery performance thanks to taking advantage of the use of a time that it is usually used in disasters but never used in applications.

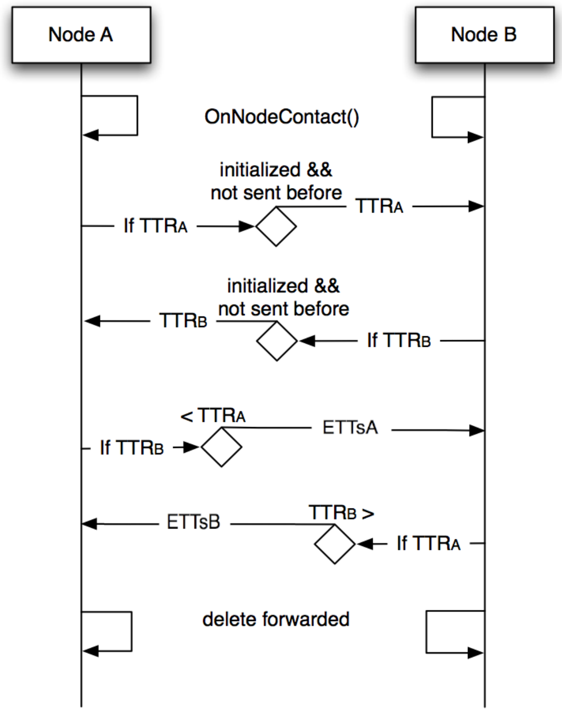

Figure 6: TTR protocol

4.1 Time To Return

Time To Return (TTR) routing protocol is based in the fact that for coordination issues, each actor in the emergency knows when she will return to the coordination point. When coordinating an emergency, the staff dedicated to the rescue must be controlled because there is a risk of danger. Therefore, protocols to follow and a time indicating when each staff must return to the coordination point are defined. This TTR is allocated by the coordinator of the emergency and set up into the smartphone rather manually or automatically from the software in the coordination point.

When a node finds several neighbours around, they will interchange their TTR. If there is one or more neighbour with lower TTR, the ETTs in the node will be forwarded to the device with the lowest TTR, indicating that this is the staff that will return to the coordination point earlier and therefore will deliver the ETTs sooner, a priority in emergency scenarios.

It is important to say that the TTR value of a node can be changed at any time if the schedule of the personnel is changed: if she has to return before than initially planned or if she has authorisation to be in the emergency scene a longer time. Furthermore, other factors can force decisions to change the TTR value, as the battery life of the mobile device. The maximum time of the TTR always has to be the maximum time of battery left. Otherwise all the data in the device will not be forwarded and they will not be communicated to the coordination point until the battery is recharged, ending up in a critical medical information delay.

4.1.1 *Protocol*

The TTR has to be set up at the beginning of the emergency in each node. Once the node has a valid TTR value, each time two nodes come into contact they interchange their TTR. The TTR values are compared and the ETTs are forwarded, if required, to the node with the lower TTR.

The TTR of the contacted nodes is stored, so if two nodes come into contact again in the future they will not interchange their TTR again except in the cases when the TTR has been modified.

It is possible that a node does not come into contact with another node during their way. If this happens, the time that ETTs would require to arrive to a coordination point would be the TTR left in the node when the victim was found and triaged. A scheme of this protocol can be found in figure 6.

4.2 Evaluation

We have tested the performance of the TTR along with other opportunistic forwarding methods in a simulated emergency scenario. We have to take into account that the delivery ratio performance will be always 100%

as eventually all the nodes will come back to the coordination point. Hence, for measurements we will use the CDF delivery delay and the delivery cost (number of messages relayed per messages created), two important metrics used to evaluate opportunistic network and routing protocols performance. The CDF delivery delay represents the difference between the time when a message is delivered and its creation time.

The traces used for the simulation have been generated by the Bonnmotion tool. BonnMotion [17] is an application that generates traces of different types of scenario. One of these scenarios is disasters. They create mobility traces based on the analysis of the disaster scenario created for the preparation of the FIFA world cup in Germany [3]. This mobility model for disasters is useful for defining zones of an emergency. The incident location where the victims are found (Zone 0); patients' waiting for treatment area (Zone 1, where coordination point is); casualties clearing stations; the ambulance parking point and the coordination, or meeting, point. The parameters for the generations of traces can be found in table 1.

Once the traces are generated with the BonnMotion, we use them as an input of the ONE simulator. The ONE simulator [10] is a simulation environment specially designed for opportunistic networks simulation. It supports different routing algorithms in the nodes and sender and receiver types (with different characteristics in interfaces for example). A link speed of 54 Mbps and a radio range of 60m are the values defined for all the nodes. The link speed is chosen using the 802.11g standard, the simulator is in charge of changing the speed rate depending of the distance between the two nodes. As for the maximum radio range, we carried tests using iPhones 3GS that gave us an average result of 60 meters. We tested the radio range outdoor with obstacles (typically for disaster scenarios). The radio range is a parameter that can change depending of the device the user is using. We also tested the maximum data transfer rate for the wifi network (802.11g) of the iPhone 3GS with a result of 6,4 Mbps. The duration of the simulation is 6000 seconds.

We have chosen a message size of 225kB. We have calculate this size for a message containing text and a small size photo. We have supposed a mass casualty incident hence a total number of 2000 messages are created during the simulation (100 minutes). The messages can be Electronic Triage Tags or messages with information about the emergency scenario. A size of 10 MB has been chosen for the buffer size of each node, so each node will be able to store up to 45 messages each node before it starts rejecting messages because the buffer is full. Each node will create an average of 33 messages throughout the simulation, so each node has buffer space to store more messages, even if it is not able of deliver any of his created messages.

Using bluetooth v2.1 + EDR included in most of today's smartphones (with a maximum practical data transfer rate of approximately 2Mbps) would require 1 second to transmit a message under optimal conditions (sender and receiver very close one each other). Using 802.11g would require 274 ms based on the maximum data transfer rate measured. But the best advantage of using wifi is that the radio range is 8 times larger than the bluetooth, so more contacts will occur. We also have to take into account that as larger the distance is between the sender and the receiver, the lower the data transfer rate is. Therefore, the average data transfer speed will usually be much lower than 6,4Mbps.

Table 1 sums up the simulation parameters.

Parameter	**Value**
Number of nodes	60
Zone 0	1300x250 m
Zone 1	100x40 m
Simulation time	6000 s
Radio range	60 m
Buffer size	10 MB
Number of messages	2000 messages
Message size	225 kB

Table 1: Default parameters

The following routing methods have been tested in the simulations: Epidemic, First contact, PRoPHET, MaxProp and TTR. Epidemic method has been chosen because of its fast message spread but also because it floods the network due to the replication of each message to the rest of the nodes. It's a reference for other routing methods. First contact is different from others methods as it only keeps one copy of the message in all the network. So, when a node sends the message to another node, it deletes its copy of the message. This in an interesting routing method for its very low delivery cost. It is very simple and follows no intelligent algorithm so we cannot expect good results. PRoPHET is a probabilistic routing method that aims to improve Epidemic routing with lower overhead and higher delivery ratio due to the use of probabilities. It is interesting to see how it works in disaster areas. MaxProp does an estimate delivery likelihood and adds some rules to the decision as to give forwarding preference to low-hop-count messages, to free up storage of delivery messages or to not forward the same packet twice to the same next hope destination. This add-ons are important as they give a congestion control to MaxProp interesting to test. This method has very good results applied to vehicular networks and we'd see if they achieve similar results in disaster areas. TTR is a routing method specific for disaster areas, so it is interesting to see its performance. It only keeps one copy of the message in all the network as First contact, hence it is important to compare its performance in delivery versus cost.

4.2.1 Results

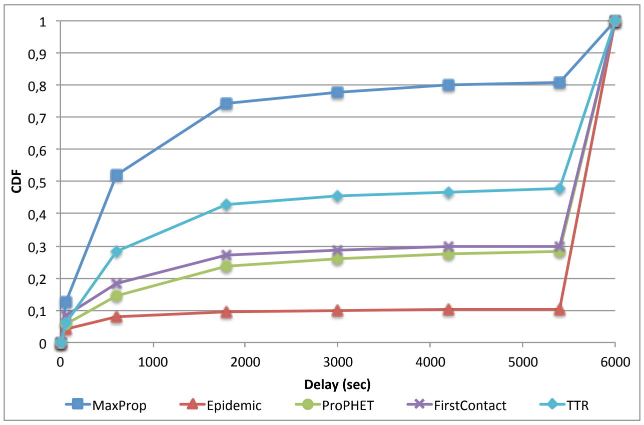

Figure 7: Delivery Delay CDF

Routing	Delivery cost
MaxProp	382
PRoPHET	121
Epidemic	100
FirstContact	9
TTR	2

Table 2: Delivery cost

The results from the tests that can be seen in the figure 7 and the table 2 show that MaxProp is clearly the forwarding method with better delivery delay but also with a very high delivery cost. The TTR have a good delivery delay and the best delivery cost from the forwarding methods compared. Hence, it will be the method with less energy consumption as it interchanges less data than others.

5. MOBILE AGENT ELECTRONIC TRIAGE TAG

Mobile Agent Electronic Triage Tag is the version of the Electronic Triage Tag System based on mobile agents. Mobile agents are software entities that can suspend their execution on a host, move to a different location and resume their execution. The agents use platforms as an run-time environment. These platforms can be distributed in different hosts or in the same. The agents will move, or jump, from platform to platform, if needed, until they have accomplished all their tasks. Mobile agents technology [24] has its origin on two different disciplines: artificial intelligence (intelligent agent) [25] and distributed systems (code mobility) [6]. The main characteristics are: Autonomy, reactivity, proactivity, sociability and mobility. Mobile agents can give the application the following advantages: task delegation, asynchronous processing, dynamic environment adaptation, flexible interfaces, fault tolerance, parallelism and local data processing.

The ETTs are created in the form of a mobile agent. The mobile agent includes all the information of the ETT: the status (color of the triage tag) of the victim, the GPS position, the unique identifier of the triage tag, and the patient's vital data (pulse, respiration, and so on).

This mobile agent will be stored in the personnel smartphone. If a mobile agent finds a neighbour with a lower TTR, it will jump to this platform. This decision is taken by the application level routing protocol used by the mobile agent, the TTR, as explained before on section 4.1.

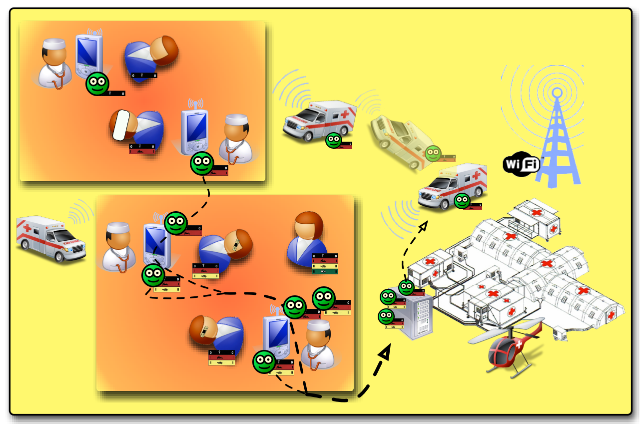

Figure 8: Electronic Triage Tag based on Mobile Agents

Routing, from the viewpoint of the mobile agent, is a decision algorithm, at application level, to decide which platform to jump from a set of platforms or devices, or whether it is better to stay on the current platform.

In the same way that the routing algorithms at network level, the initial step is to exchange information between nodes, in the case of mobile agents exchange is done through ACL messages. The platform is the agent that is responsible for providing a service for reporting information and the mobile agent to carry out a request to obtain this service.

It is worth mentioning that mobile agents can move through more than one device without having to jump one by one to all platforms agent devices from location to destination. Using the coverage of the smartphones of the staff a network can be created able to reach the

Figure 9: Android Version

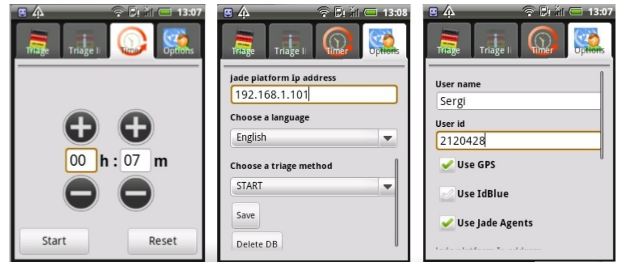

Figure 10: Android Version

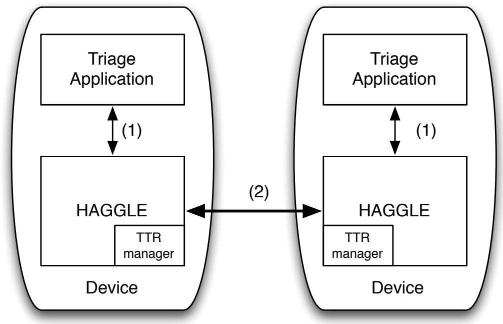

Figure 11: Haggle-ETT scheme. (1) Communications intra device between Haggle application and Haggle platform (2) Communications inter devices between Haggle platforms

coordination point.

5.1 Implementation

There are two implementations of the MAETT. Both implementations use JADE [8] platforms for the agents creation and management and JIPMS [4] for the mobility of the agents. JADE and JIMPS are written in JAVA.

The first implementation is for MAEMO devices (such as Nokia n810 in figure 2). The figures 3, 4 and 5 are screen captures from the MAEMO version of MAETT. The software is distributed under a GPL license and can be downloaded from its webpage[9].

The second implementation is for Android devices. The figures 9 and 10 show screen captures of the Android version of MAETT. It is also distributed under a GPL license and can also be downloaded from its webpage [21].

6. HAGGLE-ETT

Haggle Electronic Triage Tag (Haggle-ETT) [14] is the version of the Electronic Triage Tag System based on Haggle. Haggle [19] is an autonomic networking architecture designed to enable opportunistic communications. Haggle provides underlying functionality for neighbour discovery, resource management and resolution, thus removing the need to implement such features in applications. When some data wants to be sent by an application, it is not required a direct connection to the receiver or receivers and even it is possible that the identities of the receivers be unknown.

The representation of data in Haggle are the DataObjects. Hence, the Electronic Triage Tags are created in form of *Triage DataObjects* using the Haggle API. A *Triage DataObject* contains all the information of an ETT: injury level information, GPS position, etc. Once the ETT is created, it is sent to Haggle. Inside Haggle, the message is forwarded from one device to another following the TTR forwarding method. The destination of the *Triage DataObject* is the Coordination Point (CP) of the emergency.

The TTR forwarding method (section 4.1) is used in Haggle. Haggle is structured in managers that are in charge of carrying different tasks. The forwarding manager in charge of applying the TTR routing method is called TTR Manager.

This scheme can be seen in figure 11, where communications between the application and Haggle are presented as (1) and communication between Haggle platforms of different devices are represented as (2).

6.1 Implementation

The implementation of the proposal has been done as a proof of concept. All the functionalities of the TTR manager have been implemented and they are working within Haggle. Also the Haggle-ETT application has been implemented to proof the performance of the TTR manager and Haggle.

The Haggle platform is written in C++ and it is available for Windows, Mac OS X, Android, Windows Mobile and iPhone OS.

The Haggle-ETT application is written in C++ and uses the libhaggle library. It has been successfully tested on laptops running Mac OS X. This computers can communicate either using Bluetooth or WiFi. The implementation have also been tested on iPhones running iOS 3.0. All the devices were set up to work on Wifi network, even thought they can work on Bluetooth network in the same way. The tests confirmed the interoperation between the laptops and the smartphones and the proper use of the TTR forwarding method.

7. CONCLUSIONS

Having all the information about the victims in a digital format is essential for the prioritisation in the rescue process. However, due to the nature of the emergency scenarios, communications cannot rely in existing infrastructures because they can become unusable for different reasons. Hence, the forwarding of this data may become difficult and the data may arrive to a coordination point with an excessive delay.

In this paper, we have presented MAETT and Haggle-ETT, two applications that create Electronic Triage Tags with triage information of the victims in the emergency scene, and forward them to a coordination point using ad-hoc networking. The triage is done using an application with a GUI that follows the START protocol. This process creates an ETT which is forwarded, using the Time To Return (TTR) forwarding method, to a coordination point using opportunistic networks without relying in any communications infrastructure. The time to return to a coordination point, that is commonly used in emergencies, is assigned to each person working in the disaster in order to have a periodic security check. The TTR forwarding method uses this time as a forwarding decision: the ETTs will be forwarded to the node with the lower TTR, meaning that they will arrive earlier to a coordination point.

These applications are not only limited to scenarios without available network infrastructure, they can also be used in scenarios where end to end connections are available. In these cases, a node could communicate directly with a coordination point. If the network infrastructure becomes unavailable, or if there are delays and disruptions the applications will continue working. This fact makes the applications useful in any situation.

7.1 Future work

As future work, an extensive research about performance of opportunistic forwarding methods in emergencies scenarios is planned. Having a good method of forwarding data in disasters scenarios is critical. The characteristics of an emergency scenario cannot be predicted (density of nodes, number of messages, etc) and those elements have a big impact in the performance of the forwarding methods. Furthermore, other applications for disasters, different from ETTs, can be developed based on our research in Mobile Agents or Haggle in order to be able to use them even in worst cases scenarios where infraestructured networks are unusable.

8. ACKNOWLEDGEMENT

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