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Abstract

Current healthcare services respond to emergencies with little more than the address and information provided by the callers. This is a study to find ways of improving the successful outcome of an emergency call-out. Ambulances run the risk of being stuck in heavy traffic, road works, accidents at intersections, not being prepared, and ever more densely populated cities and streets. Consequently, it is becoming more difficult to promote the successful outcome of emergency call-outs. The results of this project indicate that with the help of global and mobile applications, and ubiquitous computing, more people’s lives’ might be saved and there would be fewer road accidents involving emergency vehicles.
1. Introduction

This project is about increasing the safety and promoting the viable treatment options provided to patients by ambulance paramedics. In order to clarify these issues and the other associated topics related to them we have separated this essay into three main sections. The first piece briefly outlines the overview of the main hypothesis and motivations for this project. We also discuss the assumptions we have had to make in order for this application to remain realistic.

The second section, which follows describes the different design options we could have used. Since there are many design options we have split this piece into various parts consisting of communication, route planning, interaction and location-based systems. Each of these subsections discusses and compares various currently available technologies, which provide numerous possibilities either alone or in combinations.

This leads to the last piece, which is called conceptual design. In it we have outlined our choices for the pieces of equipment we would use and why. Throughout conceptual design we have attempted to relate several factors to each of our choices. These are safety, cost and practicality. The project is then summarized in our conclusion.

We intend to argue that by increasing the amount of information, which is provided to ambulances en-route to a medical emergency site, and by controlling several influential factors, the chances of promoting a patient’s health is improved.
2. Application area

2.1. Overview

The aim of this project is to improve overall assistance by:

- Lowering response times
- Improving coordination and integration between vehicles and bases
- Eliminating the need for vehicles to ‘run’ red lights

The solutions will focus on location-based services and other forms of context-dependent computing. These three areas can be applied to all emergency services. We will focus on ambulances and their bases.

Reducing the time taken to complete a round-trip will increase the likelihood of successful patient treatment. Ultimately, lives will be saved because of the quicker response rates. We will also focus on giving the paramedic better means to help the patient and giving the hospital better information before the ambulance arrives. The benefits for the paramedics, doctors and patients, are as follows:

- More effective treatment with broader options
- Improved safety for the ambulance crew and public
- The hospital and the crew are given the best possible preparation

2.1.1. Setting

The actors, in this work setting, are the mobile team of paramedics and the hospital staff. An outline of the potential scenario follows:

_The paramedics must reach the emergency location as quickly as possible and in a safe manner. Onsite they will attend to and then transport the patient to the nearest hospital. The hospital staff must prepare themselves for the incoming patient._

There are many activities associated with this outline. The ambulance crew must travel quickly and safely to the target location. This task involves selecting the shortest and fastest
route. This demands that variables such as traffic density and flow be taken into consideration. Warning other vehicles of an impending emergency vehicle increases the safety and responsive time of drivers on the road. Negotiating the traffic light signals in favor of the ambulance can enhance the selected route.

Ideally the paramedics have been informed, and therefore know, what they are about to encounter. This includes the type of accident, patient medical history and the potential for any specialized equipment. While onsite the paramedics should be able to transmit video, audio and other information about the emergency back to the hospital via the ambulance. Real-time video of the accident will give hospital personnel a first-hand account of the situation. This will allow additional resources to be allocated if required by the hospital. Physicians should be able to direct the paramedics, correctly diagnose and start treatment of severe conditions. The latter is becoming more important as paramedics have begun actually treating patients during transportation [Sütcü, 03]. In summary, the objective of this project is to find a solution to improve and optimize the travel times, overall coordination and integration of ambulance vehicles, increasing the performance and efficiency of the mobile ambulance workers.

2.1.2. Assumptions

The time limitations of this project means that it has not been possible to make a thorough investigation of the actual work setting emergency personnel operate in. In the interest of having a well-defined setting we have formulated the following assumptions.

Ambulance crew

When discussing the crew of the ambulance, we will assume that it consists of an ambulance technician and a paramedic, thus we will not take into account ambulances with a physician.

Patient and traffic information

We will assume there is a national database of patient information. This is a reasonable assumption since such a system is currently being developed in the Danish healthcare system1. Similarly we assume that a traffic information system is in place that can provide details on traffic density, traffic jams or other significant information that affect travel time. Again this is not an unreasonable assumption; such systems already exist2, though not as detailed as could be utilized by our system.

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1 [http://www.arf.dk/DigitaleAmter/SundhedsLt/ElektroniskePatientjournaler/Index.htm](http://www.arf.dk/DigitaleAmter/SundhedsLt/ElektroniskePatientjournaler/Index.htm)
2 [www.trafikken.dk](http://www.trafikken.dk)
Dispatch and centre of operation

We will not discuss how the dispatch system itself is to be implemented, or how it should be modified to interact with the new system, and we will assume that all dispatch information is available to the central operating base of our system. The centre of operation is assumed to cover the entire operation area of the system, and have high-bandwidth access to government databases containing patient and traffic information. Finally we will assume that the hospital itself is either the centre of operation, or has a high-bandwidth connection to the central that operates in its area. While this at the time of writing might not be entirely accurate, it will certainly be the case in the near future with the introduction of a proper national patient information database, which will necessitate a high bandwidth network infrastructure between hospitals and other relevant entities. Finally, we will assume that all ambulances originate from hospitals. This is not correct in Denmark, but it can be justified by noting that other origins of ambulances only produce complications in the design of the high-speed network connections between dispatch-hospital-centre and does not add any issues pertaining to the work setting.

Actor overview

With the above simplifications and assumptions the following diagram can summarize our scenario:
3. Design Options

3.1. Overview

The purpose of the design options section is to present alternative solutions for the problem area outlined previously. We have divided this area into a number of subsections. These consist of communication, route planning, interaction and location-based systems. The outline below demonstrates where each of these segments falls into the larger scenario.

A crew must leave the hospital with as much relevant information as possible. This information needs to be transferred to the ambulance unit whilst the unit is located in the vicinity of the hospital. This includes information regarding patient records, route plans and any supplementary emergency data.

The ambulance crew must travel quickly and safely to the target location. This task involves selecting not only the shortest, but also the fastest route. This demands that variables such as traffic density and flow, be taken into consideration. The resultant optimal route is transmitted to the ambulance via either a local or global network, depending on its current location. Deviations in the route, due to unexpected circumstances, must be incorporated into this scenario so that the estimated time of arrival may be re-calculated. This enhances the integration of the ambulance crew and hospital personnel.

For data communications in and around the ambulance at an accident scene, there are a number of possible solutions. Ideally two separate communication channels would allow for transmission of audio and raw data for patient diagnosis, queries, images and patient statistics respectively. The devices that collect this type of data must be pervasive in order to allow the paramedics to complete their tasks with little intrusion. Obtrusive and complex devices will only hinder their performance in the long run. Medical devices that aid paramedics in collecting important data are transparently connected to a mobile network, allowing patient statistics to be monitored centrally.

Location based technology provides the exact location of the ambulance at all times. As the ambulance departs the scene, the hospital is kept up to-date not only with a continuous stream of patient data, but also the exact location of the moving ambulance. Traffic light signaling
improves ambulance travel times as well as reduces many risks associated with passing through congested intersections.

### 3.2. Network Communication

An ambulance must receive and transmit a wealth of vital data that can only improve the probability of saving lives. This consists of receiving route plans and transmitting critical life-sustaining measurements, including pulse, blood pressure and overall condition of the patient. There are many feasible technologies that offer this capability. However we have selected several of the more prominent networks that have been deployed today.

The data can be transferred by means of a local or global network. We will explore the proliferation of the wireless LAN technologies as a potential local network candidate. The global networks that will be discussed are Mobitex, GPRS, UMTS and TetraNet. The section that follows will provide information concerning the advantages and disadvantages associated with local and global networks.

#### 3.2.1. Local Networks

**Hospital Wireless LAN**

A WLAN would provide high transmission rates of data and offer a reasonable degree of mobility. The ambulance unit will be updated with the patient's medical journal, the abbreviated emergency call information, the route plan and any supplementary information that the hospital might think is pertinent. Beyond the range of the hospital WLAN the ambulance would seamlessly switch over to a global network that primarily manages two channels for voice and data communication.

Virtually all private WLAN’s installed today are 802.11b, which operates in the 2.4GHz band and supports a maximum data rate of 11Mbps, with real throughput in the 5.9 Mbps to 7.1 Mbps range [Atheros, 03]. On average mobile workers using the WLAN will need to be within 30 metres of the access point (AP) for practical purposes. This range may be satisfactory inside an ambulance bay as vehicles are preparing to depart. However, there are many devices that also operate at this frequency, the so called “free band”. These consist of
Bluetooth devices, 2.4GHz cordless phones, microwaves and hospital equipment. This interference will cause poor WLAN performance.

A new generation of WLAN, 802.11a established by the IEEE, may solve these problems of low speed and interference. Operating in the 5GHz band, 802.11a supports a maximum data rate of 54Mbps, with 24.4Mbps to 30.5Mbps (ref: “802.11 Wireless LAN Performance”) of real throughput. The problem with 802.11a is that it is not on the “free band” and that means that companies require a permit to transmit on the 5.0 GHz frequency. The Danish law BEK1005 of 10/12/2002, prohibit use of the 5 GHz band without express permission.

The 802.11g standard has the same throughput as 802.11a and it operates on the same frequency as 802.11b. However 802.11g is backwards compatible with 802.11b, if an 802.11g AP sends to an 802.11b device the throughput will be lower. Experiments have shown that 802.11a has a better range than both 802.11g and 802.11b. The experiments also demonstrated that 802.11g had a better range than 802.11b [Atheros, 03]

<table>
<thead>
<tr>
<th>802.11a Atheros Turbo Mode&lt;sup&gt;1&lt;/sup&gt;</th>
<th>6</th>
<th>OFDM</th>
<th>108 Mbps</th>
<th>429 Mbps</th>
<th>54 Mbps</th>
</tr>
</thead>
</table>

<sup>1</sup> 6 non-overlapping channels in the United States and up to 19 non-overlapping channels in Europe depending on local regulations.

Ambulance Wireless LAN

The ambulance itself may become a roving wireless LAN. This could present numerous benefits for the transmission of data from wireless devices the paramedics may be carrying. The data is theoretically returned to the ambulance, filtered and then transmitted to the hospital on request. Rather than potentially flooding the communication channel and consuming valuable bandwidth the supporting physician could specifically request data. For example, high-resolution images of injuries will take much longer to send than standard numerical data. This implies that the mobile devices carried by the paramedics need to have an interface for this local network. Once the data is transferred to the ambulance, a global network will be responsible for completing the last leg of the route to the hospital.
3.2.2. Global Networks

The Mobitex Network

The Mobitex system is a technology for data communication. It is used to supplement traditional voice communication via radio so that all patient data can be transferred to the hospital with no loss of privacy or risk of errors and without interruptions of communications. If the data transfer is unsuccessful, the system ensures that it is retransmitted. The Mobitex system then enables two-way data communications with the central database network.

A legacy realization of this network is the Mobimed application used in Gothenburg, Sweden. It is a PC-based system for the digital transmission of patient records, status reports, messages and 12-channel EKG. The Mobimed application specifically monitors patients with heart conditions. We have been unable to find any scientific documentation of Mobitex, the only source of information appears to be Ericsson\(^3\). Because of this we have been unable to investigate any further and have decided to not consider Mobitex for our system.

GPRS and UMTS

A public service offered by many leading mobile companies is General Packet Radio Service (GPRS). It allows large amounts of data to be sent over mobile networks at speeds three to four times greater than conventional GSM systems. GPRS enables simultaneous, data-rich services, and is always connected to the net. This type of connection may eliminate the lengthy delays required to reconnect to the network to send and receive data. The drawback from this is that the emergency services will be sharing the resource with the public sector. Under times of heavy congestion the propagated delays may be unsatisfactorily long. GPRS performance will vary, depending on factors such as GPRS network, device and current radio conditions. As radio conditions deteriorate for example, near the edge of a cell, the network compensates by decreasing throughput which increases latency. The following table compares the performance of typical user applications over a 9.6-Kbps GSM network and a 56-Kbps GPRS network.

\(^3\) [www.ericsson.com/network_operators/mobitex/about.shtml](http://www.ericsson.com/network_operators/mobitex/about.shtml)
A table comparing GSM and GPRS data transfer times with common application formats.

(From [Dell 2002])

An emerging technology known as UMTS (Universal Mobile Telecommunications System) offers the ability to deliver even faster data services than GPRS. The standard is able to provide a peak theoretical data rate as high as 2 Mbps [Pearson, 30]. An application that can be enabled by such speeds is video streaming (due to guaranteed QoS), a likely candidate to become an indispensable component of ambulance communication. However UMTS is only in the early stages of deployment.

**TetraNet**

TetraNet is a digital mobile radio network standard that has been developed to provide the emergency services, public utilities, transport organizations and other users of mobile communications, with improved communications compared to analogue technologies, allowing both voice communication and data transfer [Poulsen, 00]. TetraNet attempts to cater for the emergency services by offering high security virtual networks inside the national network. Furthermore the technology allows user groups that generate large volumes traffic to utilize the unused bandwidth of other user groups. Unfortunately TetraNet currently only offers low bandwidth (twice that of GSM), though it is suggested that it will increase in the future. Because of security concerns very little further information is forthcoming from the TetraNet providers, making it hard to properly evaluate the system.
3.2.3. Pervasive Aids

Handheld computers or similar devices must have the appropriate interface for the local or global network responsible for transmitting the raw data. Ideally these devices must be small and lightweight so as to not interfere with the paramedics work. Devices for collecting this information could communicate via the Bluetooth standard. To establish a connection, two Bluetooth-equipped devices simply have to come in a 10m to 100m range of each other. It operates in the 2.45 GHz frequency band and has a theoretical bandwidth of 1Mbit/s, giving 3 voice channels of 64kbit/s and 721kbit/s for data [Kurose et al, 02]. This range is small, but may be adequate for devices located inside the ambulance or in close proximity to a patient. The only current alternatives are the various wireless LAN systems, but none of these have been designed for very small devices, and will usually require larger components, which is inconvenient for small sensors.

3.2.4. Interference with medical devices

A matter of great concern when integrating wireless networks into a work setting is interference with other wireless devices operating at the same frequency. This is especially important in a hospital setting where correct operation of medical devices is essential to the survival of patients. TetraNet has given cause for concern as it has been revealed that under certain circumstances it can cause pacemakers to malfunction [SN2001]. Wireless LAN, UMTS and GPRS have been tested against 76 different medical devices in [Håkansson, 00] [Håkansson, 00] shows that GPRS can cause interference, causing problems in 11 of the 76 devices. WLAN and UMTS only caused problems with 2 of the 76 devices and only when the transmitters were in extreme proximity to the device. Neither of these devices could endanger the patient directly. Even so, this illustrates the need for testing the chosen network against all employed devices to ensure proper operation. Similarly [Salzstein, 02] indicates that there theoretically could be problems with Bluetooth when used near medical devices, but that there are very few real problems using the technology. In fact medical devices that utilize Bluetooth are already in production [Paoloni, 02].

3.3. Pervasive devices

Pervasive devices can provide additional functionality to the mobile paramedic. By offering different services such as communication or the collection of vital data on the state of the patient, the paramedic may give greater attention to the task at hand. The paramedics could
have a hands-free communication device attached to their chest. This allows for continuous voice communication. Handheld computers or similar devices must have the appropriate interface for the local or global network responsible for transmitting the raw data. Ideally these devices should be small and lightweight so as to not interfere with the paramedics work. Paramedics will monitor patient statistics from a number of aids. A thin lightweight LCD screen embedded in the sleeve of the worker could provide visual output of patient statistics. If used conjointly with wireless micro sensors to monitor patient state this could theoretically provide the paramedic with all the vital information at a single glance and necessary alarms for critical conditions.

3.4. Location Based Services

Estimating the time of arrival is very important on the return trip, so that the medical staff can be alerted to incoming ambulances. This will improve the overall integration and performance of medical and ambulance staff. In this section we will give a short presentation of the various current technologies for positioning, and their relevance to our system.
3.4.1. Positioning system requirements

It is a requirement in emergency vehicles that the positioning system provide fast updates of current positions. We require a precision of a few meters so that the signal is unambiguous as to which road the vehicle is on.

3.4.2. Satellite triangulation based systems

The most widespread positioning technology in use today is Global Positioning System (G.P.S.), which works by triangulating the position using signals from four satellites. GPS is used in both military and civilian navigation systems, such as car route planners, and must therefore provide updates at an acceptable frequency for a moving vehicle. The GPS service promises little regarding the accuracy of the system, since the precision of the civilian unencrypted signal can vary without warning. In general the precision is in the order of 10 – 100m. Using correctional signals from ground stations with known positions, this can be improved to a few meters, which is acceptable for our intended use. This expanded GPS system is called Differential GPS (DGPS). Other systems based on the same idea, such as the Russian GLONASS [Enge et al, 99], could also be used.

3.4.3. Inertial navigation

Some military rockets and jet planes navigate using a fixed start position and update their current position in relation to the start position using gyros (or similar technology) and accelerometers. Certain car navigation systems combine the use of G.P.S. and low-quality inertial navigation. When the G.P.S. signal is lost, or is updated infrequently, the inertial system may be used as a backup. High precision inertial navigation equipment would not be suitable for emergency vehicles, since the cost is too large, and the gain in precision is too small. On the other hand, the tandem system using low-quality inertial navigation could be adapted for emergency vehicles due to the fact that frequent updates are essential for vehicles traveling at high speed.

3.4.4. TRAPRIO Project

The TRAPRIO project is an intelligent traffic system that is able to monitor the location of vehicles. It has been implemented in a number of cities in the U.K. and Kolding in Denmark. The Automatic Vehicle Location (AVL) system uses low frequency radio communication
between embedded tags in the infrastructure and onboard tag reading equipment. A unique code is read in the tag memory, when passing a tag location. This code refers to position information stored in a database. Calculations for the position between tags can be achieved by using odometer readings of the vehicle. The vehicle transmits a vehicle I.D. code, position tag I.D. codes, odometer readings and a timestamp to a central location. The AVL system provides real-time position data with accuracy below one meter at speeds up to 180km.

3.4.5. Other positioning technologies

Most radio-networks already in operation such as GSM could theoretically be used for positioning, and GSM positioning systems are in development, but the only reliable reference available only guarantee 200m-270m precision. [Salcic, 97]

3.5. Navigation System

Given the necessary map-data, it is a computationally well understood problem to find the shortest weighted path from a point-of-departure to a destination. Many factors, apart from the length of the trip, influence how long it will take to arrive at the destination, and should therefore be incorporated into the road weights used in the path finding algorithm. Below we shall discuss the factors we believe should be taken into consideration in addition to the route length.
3.5.1. Route factors

There are many factors, which influence journeys to and from any destination. One of these is traffic jams and traffic density, which have a huge impact on travel speed. It’s essential that they be taken into consideration when planning the ambulance route. Other factors are intersections and turns, which force vehicles to slow down. A longer route with less turns and intersections may be quicker than a smaller route with many turns and intersections, even with synchronized traffic lights.

Another factor is speed limits, which influence the speed of the public. Roads that are assigned higher speed limits are typically built to accommodate traffic moving at high speeds even in heavy use. A road with a higher speed limit could be considered as being faster to traverse if not congested. But when congested, high speed limit roads might add time to a journey because of the traffic volume involved in the resulting traffic jam. Road works usually cause congestion because members of the public must negotiate unusual or potentially hazardous obstacles and attend to more signs than normal. A potential hazard on the road, which could occur at any time, is an accident. Accident sites are renowned for slowing traffic for a multitude of reasons such as curiosity, debris, other emergency vehicles and a plethora of potential possibilities.

In order to increase traveling safety, there must be a system which alerts emergency vehicles to one another if they are in the vicinity. In many emergency call-outs there are numerous emergency services converging on one site and the ambulance will not always take the exact planned route, which could have been given to other services if required. Since speed is of the utmost importance, secondly only to public safety, a system that changes traffic lights to always show green for ambulances is paramount. If there were multiple emergency vehicles converging on one intersection then they would need to be given some sort of hierarchical placement allowing for the most important to have the green light. This would reduce the danger to the public and allow the drivers of emergency vehicles some respite because driving through a red light cannot be something undertaken lightly.

3.5.2. Route plan calculation

The calculation of the route plan requires knowledge of the traffic situation in the area around the source, destination and a wide part of the area in between. The initial route plan can be calculated centrally or locally. In the first instance the route is calculated and then transmitted
to the ambulance from a traffic control centre. In the latter the ambulance must determine the route with respect to all the global information collected concerning route-plan calculation.

3.5.3. Flexibility

A common flaw in many systems is the inability to handle unexpected events, in this case deviation from the planned course. This could be due to a change in traffic conditions, obstacles blocking the road or the driver intuitively selecting an alternative route. In any case the route must be re-evaluated, and the relevant actors need to be made aware of the new situation. A driver will only be aware of the conditions he can see. By supplying supplementary information concerning the area around him, he will envision a more complete picture of the scenario.

However there can be no substantial delays as this will make the result obsolete. One possible solution is to give the driver multiple routes with approximately the same efficiency, allowing the driver to choose between them. Alternatively a single route could be presented to the driver with surrounding traffic incidents including the option of requesting a new route given the present location of the ambulance.

We would like to point out that the driver’s knowledge of the area and intuition will always prevail. The route plan is merely a complementary source of information. [Julien et al, 01]

3.5.4. Inter-vehicle awareness

It is beneficial for emergency vehicles operating in close vicinity to be aware of each other in order to avoid problems with sudden course changes and collisions at high speeds. The positions must be highly accurate and calculated in good time.

A possible implementation is to have each emergency vehicle continuously transmit its GPS position using direct broadcast to other emergency vehicles in close proximity. But, the range of such a signal changes dramatically based on the environment. Multi-path signals received this way, will however work in favor of such a system, because signal delay is not an issue. Another benefit is that it will be possible for civilian vehicles with the proper on-board navigation equipment to be alerted to approaching emergency vehicles.

3.5.5. Traffic lights

Changing traffic lights as an emergency vehicle approaches, demands good coordination. A centralized system would require that a central server be responsible for triggering traffic lights. It will be necessary to change the lights in good time and this requires that a central
server maintain an accurate position of all the ambulances. Communication between the server and the vehicles will undoubtedly suffer from network delays imposing a handicap on the responsiveness of the system.

Changing traffic lights locally from the emergency vehicle could be achieved by broadcasting an authentication signal to the lights, which avoids the delay issue, but opens a Pandora’s Box of potential security issues; the signal could be replicated and abused by civilian vehicles. A combination of the two options, where a control centre "activates" the lights only on active routes, could help avoid such abuse.

An entirely different approach, to the issue of emergency vehicles passing red lights, could be to avoid changing the lights altogether. Instead a blue siren, as used on the emergency vehicles, could be attached to traffic lights and activated when an emergency vehicle approaches (using either local or global control). This has many benefits, one being that drivers are already accustomed to stopping and making room when they see or hear such a siren. Furthermore it’s simple and can be implemented at only a minor expense.

3.5.6. User interface

There are various ways of indicating a map route to a person. If an individual is shown the way on a computer monitor they are more likely to remember the route. Conversely, a person might only have the possibility to hear verbal directions. Both arguments for and against will now be discussed.
Voice guided route plan

Some of the systems available on the market today audibly guide the user with verbal directions. Speed, however, is of the essence and verbal directions might not be fast enough to keep pace with an ambulance. The volume of the directions would also need to be heard above the siren. There are different issues which need to be considered with the visual presentation of a route plan. The information must be presented to the driver of an emergency vehicle who is already under considerable pressure.

Display options

There are different ways of presenting the visual route plan. The whole route may be shown on the screen, from departure to destination. But, details may be too small to provide the required information and might even be missed altogether. Another option is the indication of a limited section of the map following the vehicle wherever it goes. An alternative is to leave the choice to the co-driver as to what to see. He would have the choice to zoom in on any part of the map and take as long as required to gather relevant information to pass onto the driver. Another variation in the display of the route plan could be a split screen. The co-driver could view the whole journey on one side and move the other to relevant sections if needed.

Multiple emergency vehicles

It is possible that several emergency vehicles might attend the same emergency. To increase safety it would be beneficial if they were aware of each other. The system, could display vehicles in the vicinity. A more detailed solution could be that ambulances could have a priority system that indicates which vehicle takes precedence at crucial junctions. This could initially be given by the hospital and changed by the personnel at the scene, if necessary. If two or more ambulances meet at a crucial juncture with the same priority status then they would need to decide who gives way to whom on their own accord, as they do today. This priority system could be visually displayed using colors or numbers.

Interaction with the route plan

There are four ways ambulance personnel could interact with the route plan on the monitor. It could consist of a touch screen, a mouse controlled system, voice control or a combination of these. A touch screen would make it easy to choose the different features or ways of seeing the route plan. The co-driver could use a finger or another pointer to make choices and find answers to questions.
A computer mouse is a widely known interactive tool. But it could be hard to control a regular mouse in a rapidly moving vehicle and a mouse usually requires a flat surface to function. A rough ride would result in mistakes and wasted time waiting for smoother road surfaces to make choices. Another option could be a touch board. A third option is voice control. Voice control, however, again raises the siren issue. Perhaps a solution might be a combination of the touch screen and the touch board.

To minimize the amount of data being transferred to the vehicle, there could be some indication of when the driver was not using the route plan. That could be done by making him push a button every time they arrive at a destination. This will, however, result in another external device requiring input from either of the crew who will already be extremely busy. Considering that ambulance crews have enough information to ascertain, and are under duress, then it would be bad form to increase the amount of energy or time required from them with more devices. Ideally, we need a device to trigger and stop the flow of traffic information from the hospital to the ambulance and back. Contextual aware computing is designed to increase a user’s potential options while reducing user input [Chen et al, 00]. A button nested in the drivers seat could be a trigger; a “butt” button. Then the system would know if the driver was not in the seat and there for not in need of updates on the route plan.

**Placement of the screen**

There are many different ways of placing the screen, but, only two optimal positions. One is in front of the co-driver and the other is in the middle of both the co-driver and the driver. Both of these positions will need a pivotal screen.

**4. Conceptual Design**

**4.1. Global network technology**

The global network will transfer large amounts of data, and this is a vital link for the system. We believe that UMTS is the better choice for data transfers. TetraNet might provide built-in security, but it does not add anything that cannot be done at the application level. Furthermore, even though UMTS is a public system prone to disruption from civilian use, it offers faster bandwidth and more channels. Thus, even with heavy civilian use of UMTS we think that the TetraNet will possibly congest more than UMTS when used for emergency services. Finally the price of data transfers for emergency services, at ~50kr per MB, is not
acceptable. In the future, however, TetraNet promises to increase its bandwidth, and is likely to become cheaper as the technology matures.

4.2. Local network technology

**Hospital**

We suggest using 802.11a in the hospital which runs in the 5 GHz range. It is thus less likely to interfere with legacy hospital equipment, which utilizes the public 2.4 GHz frequency band. Use of the 5 GHz frequency range requires special permission in Denmark. Permission can only be obtained if assurances are made that the signal will not propagate outside the hospital, but we think it would be possible for hospitals to ensure this with proper shielding. It might even be possible to get permission for using it on the entire hospital grounds.

**Ambulance**

Since the ambulance operates out in the open, it will not be possible to obtain a permission to use 802.11a. Therefore we suggest using an 802.11b/g access point in the ambulance for communication with the paramedics PDA’s. Since the ambulance needs to access the hospital network it will also employ a dual-band 802.11a/b network adapter.
4.3. Pervasive devices

The paramedics will have hands-free wireless radios, using UMTS, hung in a pocket around their neck or waists, which promotes communication while multitasking. The paramedics could have a headset, which they use to communicate. They will also use wireless PDA’s with a built in WLAN and Bluetooth interface. The PDA’s and the small, weightless display screens on the paramedic’s sleeve receive information from the hospital, via the ambulance, and the PDA relay.

The medical equipment should be display-less because the paramedic can see everything on his sleeve screen and all equipment will have Bluetooth capabilities. Therefore, all the information sent from the medical equipment is relayed to the ambulance. The information is then made available on request to the hospital staff, which will then be able to follow the patient’s condition until the ambulance arrives at the hospital.
In case of failure there will be a GSM backup system. This should ensure privacy and security for the patient. Furthermore they will have access to a Bluetooth-enabled digital camera that can transmit images or short video sequences to the ambulance so that the hospital staff can access them.

4.4. Positioning system

The positioning system is the backbone of many features of our system, and therefore choosing an accurate and stable technology to implement it is of the utmost importance. As previously discussed GPS is widespread, fairly cheap and in most situations reasonably accurate. We have chosen not to use GPS though, as we find that it’s problematic; it only works when there is line-of-sight to satellites and it’s under the control of a foreign military power. The military aspects can be problematic as the US military employs a policy of further degrading the civilian unencrypted signals while engaged in military operations. Instead we suggest using a system similar to TRAPRIO. The specific implementation could either be based on very dense distribution of position transmitters in combination with odometers, as in TRAPRIO, or with a less dense distribution coupled with gyroscopes and accelerometers as an improvement of the odometer. The final choice cannot be made here; it requires more information regarding the price of the equipment. Finally a TRAPRIO-like system also implies that anyone else is free to utilize the precise and robust system for positioning, which could be of great benefit to public transportation [Nielsen 99].

Ambulances send updates to the hospital with their new position every few seconds, saving bandwidth compared to a continuous update, but still giving the hospital a fairly precise location.

Because of the constant communication the hospital will always know where the ambulance and the paramedics are. Given this information they will be able to calculate the ETA back at base and prepare the necessary equipment and personnel.
4.5. Navigation system

4.5.1. Route-plan calculation

As indicated in the design options, route plan calculations are best done at a traffic control centre, where updated traffic information is available at all times. We have also chosen to make the calculated route a suggested route, in order to prioritize driver intuition. Should the driver deviate from the route and later wish to use the route plan again, it will be possible to request a new route plan from the traffic control centre (see “user interface”). To still give drivers the benefit of the traffic information, the traffic control centre will send warnings about important changes in the traffic situation in the vicinity of the ambulance, which can then be displayed to the driver. It is then up to the driver to decide if the change is serious enough to warrant going another way and possibly request a new route. We are relying on the driver’s knowledge and intuition.

4.5.2. Inter-vehicle awareness

Inter-vehicle awareness is implemented by having each ambulance broadcast an unencrypted WLAN signal detailing its current position in GPS coordinates (we use GPS coordinates to better interoperate with GPS equipment) as well as a number indicating its priority. As discussed previously the priority is needed in order to decide who goes first across intersections when two or more ambulances all need to cross at the same time. Ambulances decide their own priority, as they have the best knowledge of the patient’s current status.

4.5.3. Traffic light management

Traffic lights usually run on a timed sequence. Ensuring that ambulances always have a see passage through an intersection will reduce travel time and increase treatment possibilities. There are several ways this can be achieved, such as mounting blue flashing lights with sensors, which should indicate to all drivers near an intersection that an emergency vehicle is approaching.

The TRAPRIO project mentioned above is currently active in three participating towns in the UK and Denmark. It uses sensors to activate traffic lights and allows for much more flexibility.
Both systems are relatively cheap once installed and both would allow passage for emergency vehicles. But TRAPRIO promotes an empty lane because the traffic moving ahead of the ambulance is driving on the green and thus continues to move through the intersection unhindered.

4.5.4. User interface

For displaying the route plan we will utilize a standard LCD touch screen. A touch screen without attached buttons have an advantage over a screen with fixed buttons in that changes in the software will not result in a need for changes in the installed hardware, such as adding new buttons or similar. We have ruled out a mouse or similar interface, since such a control device is hard to use in a moving vehicle. The suggested layout of the screen is shown below:

We have chosen not to use any voice guide or control because we think that it would be more confusing than helpful.

The other vehicles will be displayed on the screen as little dots (see figure). The vehicles with higher priority will be red, the ones with lower priority will be blue and the vehicles with same priority will be white.

We think the best placement for the screen is in the middle between the two seats because that would make it easy for the driver and the co-driver to look at the screen.
For the button that activates the route plan information stream we have chosen to use the “butt- button” because it is easy to “use” for the driver, we don’t think that he would have time to press a button when he arrives.

5. Conclusion

Increased safety and promoting the viable treatment options provided to patients by ambulance paramedics are the two paramount ideologies we have tried to insure in our application. Other issues, which we have taken into consideration, are costs and the practicality of the equipment.

In order to achieve these we have stated that ambulances need to begin their emergency journeys with as much information as possible to help the paramedics and that this should occur while they are in the WLAN boundary. Part of this information comes from databases such as traffic and medical history.

As ambulances leave the range of the local network, they seamlessly switch to the global network. This system will also allow the hospital to send any route plan updates to make sure that the ambulance can get there as quick as possible. The information is only sent if the driver’s butt button has been activated, to minimize the use of bandwidth in the global area network.

The paramedics will have both hands-free and utilise light medical equipment which communicate via the Bluetooth standard. All the information is relayed back to the ambulance via the WLAN 802.11b/g standard. Physicians are then able to request data and thus follow the patient’s vital statistic even before entering the ambulance. The doctors will be able to use video and audio, and make use of all the other information provided by the ambulance equipment.

The ambulance will experience a reduction of travel time, and less strenuous driving journey’s because the crew will always see green lights. Managing traffic light changes must be dynamic and ensure the safety of the ambulance crew.

Both WLAN and Bluetooth present a slight risk to interference with other medical equipment. However, with pervasive devices such as the sleeve screen and embedded Bluetooth sensors, paramedics shall be able to communicate efficiently and undertake other tasks at the same time.
The increased likelihood of further injury should at all times be limited when emergency health care workers attend to or deliver anyone requiring hospitalization.

We believe that mobile IT solution such as the application described above would be a great help to the paramedics and hospital staff.
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