Ad Hoc Networks and Mobile Devices in Emergency Response – a Perfect Match?

(Invited Paper)

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Abstract. In this paper we use findings from three empirical studies to analyze how the use of wireless ad hoc networks as part of an ICT solution for emergency response imposes requirements to the user interface of these solutions. The analysis starts by arguing that explicit details about the network used (like availability, coverage and connected nodes) should be visualized for the user and may be used by applications to obtain useful information. It continues by discussing requirements to user interfaces for local leaders and field workers, identifying cross-platform support as an important need for the leaders and supporting different modalities as an important need for field workers. These and other requirements are used as input to an analysis of challenges when developing these user interfaces, concluding that handling flexibility is essential. Finally, we turn around and look at ad hoc networks from a user interface perspective. In particular, we present requirements to ad hoc networks used in ICT solutions for emergency response, focusing on size, speed and providing awareness of network status through the nodes in the network themselves.

Keywords: Wireless ad hoc networks, User interfaces, Emergency response

1 Introduction

Acute emergency situations are characterized by high levels of uncertainty combined with a need for fast and reliable action. Rescue work will usually involve several public and private actors in need of access to a wide range of information. It is of utmost importance for the on-site operational leader to have easy and immediate access to all critical information, as well as decision making support for efficient handling of complex scenarios. This information includes information collected from sensors deployed in the operational area, information from personnel and other actors, as well as information from applications and services located far from the incident scene. A necessary means for being able to provide the required information is a working network solution.

Operations during emergency response [15, 17] are usually lead from a local control post, which is close to the scene of the incident, often outdoors or in a car, caravan, tent, etc. As soon as the leader at the local control post obtains a situational overview, an operational area is defined. It is the responsibility of the local control post to assign responsibilities and tasks to field workers and other local leaders. Today, this is usually accomplished through voice communication. The local leaders also communicate with one or more central control posts or operations centers. Field workers perform given tasks inside the operational area, including placing or exploiting sensors for gathering information.

Emergency response imposes special requirements to ICT solutions; this includes how applications should work, as well as the deployment and use of networks to support the applications. These requirements cover needs for flexibility, reliability and speed; the latter both when a solution is established at an incident scene, and when information is transferred and presented to the user once the solution is working, thus making wireless ad hoc networks well suited. In this paper we focus on the interplay between using ad hoc networks on the one hand and designing and developing user interface solutions supporting emergency response on the other hand.

The remainder of this paper is structured into nine sections. In Section 2 we present the research method use. The findings from the empirical studies are presented at two different levels: the observations and characteristics of tasks, information exchange etc. are presented in Section 3, while the results of the analysis with regards to network solutions and user interfaces are presented in Sections 5-8. Before going into the user interface discussion, Section 4 motivates why we focus on wireless ad hoc networks. In Section 5, we look into how user interfaces for applications supporting emergency response are influenced by the use of wireless ad hoc networks. In Section 6, we concretize this by investigating requirements to user interfaces for local leaders and field workers when using wireless ad hoc networks. The consequences these requirements have for how user interfaces should be developed is analyzed in Section 7. In Section 8, we characterize requirements ICT solutions for emergency response pose on the ad hoc networks. In Section 9 we discuss related work. Finally, in Section 10 we summarize our conclusions and outline plans for future work.

2 Research Method

The findings, information and analysis presented in this paper are largely based on three empirical studies in which we have investigated emergency response work in different contexts. Table 1 summarizes how the empirical studies have been conducted.

In all three studies, preparations and/or analysis of the findings included analysis of tasks performed by local leaders, and the information involved in performing these tasks (and thus the information that is needed by an ICT based system that supports the tasks).

We have extracted the major requirements and observations regarding communication needs and information exchange from the findings in the three studies. These requirements and observations have been used as input to our analysis of how user interfaces for emergency response are influenced by wireless ad hoc networks. This analysis leans heavily on our knowledge and experience in design and design patterns for user interfaces on mobile devices [18].

Table 1. Summary of how the empirical studies have been conducted

	Context	Data collection method	Documentation
Avalanche rescuing	Course on how to lead avalanche rescuing operations conducted by the Norwegian Red Cross	Practical exercises and theoretical education Interviews with participants Expert evaluation	Notes Photos Video recordings
Rescue operation with many actors (police, fire, ambulance)	Full scale crisis training exercise conducted by the National Police Directorate in Norway	Observations of local leaders at different levels	Notes Photos
Fire fighting	Meeting with field commanders and fire fighters in fire department	Interviews with field commanders and fire fighters	Notes Audio recordings

3 Findings from Empirical Studies

3.1 Findings from the Avalanche Study

In the study of avalanche rescuing [17, 20], observations showed that information and communication was mainly conducted locally in the operational area. There was a high density of personnel in the rescuing area, very high focus on the primary task of finding and rescuing missing persons among the field workers, and the local leader (field commander) had a corresponding (but not quite as intense) focus on coordination and communication. Of the two main providers of infrastructure for cellular communication in Norway, one had absolutely no signals in the area in which the training took place, while the other had very poor signal quality, probably not good enough to provide data communication.

Based on interviews and observation during the study, we identified the following needs for non-intrusive ICT support:

- Use GPS tracking to make map of operational area automatically.
- Use GPS to obtain accurate position of findings in the avalanche.
- Use GPS tracking to make map of how well the different parts of the avalanche has been examined.
- Use GPS to communicate location of tasks more efficiently and effective.
- Use GPS together with motion sensor to report every point examined using the searching poles.

- Use RFID or bar code scanners to register available personnel, where different persons are located, especially who are inside and outside the operational area.
- When interaction is indeed needed, speech/sound based user interfaces should be utilized for communicating location of tasks and activity status.

3.2 Findings from the Rescuing Operation Study

In the study on rescuing operations involving a number of emergency response agencies [19], we focused on tasks and information needs for field commanders in the police. Assuming ICT support, the information requirements for solving the field commanders' tasks would be collected from five different sources:

- The field commanders themselves, i.e. information that the users need to enter themselves, like the extent of the operational area, location of various bases, and log of events and actions.
- The central, i.e. information that is available in the operations centers, either because it is entered by personnel situated there, or because it resides in information systems controlled from the operations centers. This includes information like critical concentration of people, dangerous substances involved in the incident, and available resources (equipment and personnel) including their location and allocation.
- Other actors, i.e. information that must be collected from actors like the owner of a building or an other object involved in an incident. This information includes information about which people that may be involved and dangerous substances involved.
- Services, i.e. internal or external ICT based solutions that contain information that is relevant for local leaders. This includes information about weather (forecast) and details about dangerous substances.
- Sensors, i.e. various fixed or mobile devices collecting information, usually in the vicinity of the incident. Such sensors may already be available before an incident (like surveillance cameras, and temperature and pressure sensors), or they may be put out as part of the rescuing operation (like location sensors on personnel).

For all these information sources to be valuable, available communication means is crucial, as all the information involved needs to be communicated to or from the field commander.

3.3 Findings from the Fire Fighter Study

In the study on tasks and information needs for local leaders in firefighting [8], possible electronic transmission or exchange of the information involved in solving the tasks may be divided into the following categories:

- Sensor values showing biometric data that indicate physical parameters of the fire fighter that are important for assessing their health condition.

- Sensor values indicating the position and posture of the fire fighter; this information may also be used to automatically map which parts of a building that has been "cleared" by the fire fighters.
- Live pictures transmitted from the fire fighters, e.g. picture from infra-red camera giving a temperature "picture" in the building that is burning or picture from camera on helmet (see what the fire fighters see).
- Sensor values showing the status of the fire fighter's equipment, primarily the oxygen level in the oxygen cylinder.
- Information about the building (or other object) that is burning, like the position of shut-off cock for gas.

4 Network Solutions in Emergency Response

We distinguish between four main network solutions for emergency response:

- Wireless ad hoc networks
- Cellular networks
- Special emergency networks
- Router-based networks that are being deployed for the operation

By wireless ad hoc network [28], we mean a network that is intrinsically available through the nodes in the network, being sensors and devices with networking capabilities, and possibly portable and stationary devices whose only task is providing network connection between other sensors and devices. This solution provides local communication, and Internet connection may be provided using a gateway (in which case it may be viewed as a hybrid network). The network is up and running as soon as the first two nodes are deployed and complete as soon as the last node is deployed. As the agencies using the networks are the same as the ones deploying them, connectivity of devices and sensors can be planned in advance. It is therefore often argued that wireless ad hoc networks are well-suited for the setting of emergency response [10].

The three main alternatives all have major drawbacks not shared by wireless ad hoc networks. The main problems with using *cellular networks* are their availability and that connecting sensors is not trivial. To work in this setting, sensors need to have functionality for connecting to a cellular network; functionality that is present in some GPS trackers and other equipment that is constructed for remote monitoring, but usually not in small and simple sensors. The main problems with using *special emergency networks* [9] (i.e. a secure common communication network for emergency services, e.g. using TETRA technology) are that they are primarily aimed at secure vocal communication, so communication speed for data traffic is very slow and connecting devices and sensors is not trivial. Furthermore, such networks may not be available for voluntary organizations like the Red Cross. The main problem with using *router-based networks that are being deployed for the operation*, typically a wireless mesh network [1] or a pure wireless LAN, is the time needed for establishing the network.

5 How User Interface Solutions for Emergency Response Are Influenced by Ad Hoc Networks

Conventional users in an office or a mobile context have low awareness of details regarding the network used as well as connected nodes, i.e. other computers, devices and sensors connected to the network. Accordingly, network connection state (including failure) is only considered an external condition by applications.

For users in emergency response exploiting wireless ad hoc networks, the situation is different. We claim that applications in emergency response should make details about the current network status available to the user instead of hiding it as much as possible, and in this way exploit the dynamicity and variation in the network, and thereby make it an asset.

5.1 Applications Should Make the Current Network Status Available to the User

Handling information about available sensors and devices is the responsibility of the application. There are a number of reasons for presenting this information explicitly. The size and structure of an ad hoc network of sensors and devices is limited, the information about both sensors and devices that are connected to the network may be useful, and this information may be exploited by the user in ways that are not initially intended by the application. E.g. in an application where visualization of the presence of some sensor type is included to show how well a search area is covered by this sensor type, putting the same sensor on key personnel may be used by a local leader to keep track of these key persons even though this was not an intended functionality of the application.

Another important use of explicit information about network details is to make the extent of the ad hoc network, as well as a visualization of the types of sensors and devices available in different parts of the network, available as an aid for a local leader to keep track of and monitor the progress of deployed sensors and personnel in an operational area. The same information and visualization may also be used to reveal lack of communication or communication failure in parts of the network that was operational at an earlier stage. Generalized, this pin-points the need for local leaders not only to get information from sensors and devices through the ad hoc network, but also to have information that makes it possible to assess the status of the network, and through this also assess the quality of the information collected through it, which may be further processed and transformed by the application(s) used.

5.2 Applications May Obtain Useful Information in Alternative Ways

An ad hoc network may also be used to provide alternative means for obtaining information that is usually provided through an Internet based service. Consider a traditional buddy service in which sensor values describing details about the user's device is combined with an Internet based service to provide the position of buddies so that their position, direction and distance may be visualize on a map or imposed on a live camera image. To handle the positions of all involved user, such a service relies on a working Internet connection. In cases where such a connection is not available, the ad hoc network may be used by an application to get in contact with the devices of the buddies (in an emergency response case typically personnel or equipment), and prompt the devices regarding their position instead of having it pushed by the Internet-based service.

Information about available sensors and devices in an ad hoc network may of course also be used in more traditional and implicit ways. A related example to the positioning example in the previous paragraph, is to use information regarding the presence of devices in an ad hoc network instead of an Internet based server to determine what personnel that may be contacted via an instance messaging type of service, or an IP-based voice communication service (again given that there is no Internet connection available). This information would typically be presented to the user implicitly via the list of personnel that may be contacted through the service.

The examples involving position outlined above mostly rely on the sensors and devices knowing their own location (typically using a GPS receiver). An ad hoc network may also be used as an implicit positioning aid for sensors and devices without positioning capabilities. Just the fact that some node is present in the network acts as a coarse positioning of the node. For applications exploiting only this network, this is normally of limited benefit (except for the fact that the device/sensor is present, which may be very useful). This coarse positioning may however be useful if the applications also access other networks (through a gateway), e.g. by providing the positioning information about devices (and thus implicitly personnel and equipment) to services and applications in a centralized staff. Using more advanced means, information like network topology and/or signal strength received from different nodes may be used to do more accurate positioning, information that indeed may be very valuable for an application accessing only the ad hoc network. For even more fine-grained positioning, specialized, dedicated positioning nodes may be added to the network. If these nodes know their own position, they may use the fact that they are able to connect directly to other nodes to determine and provide the position of these other nodes. The precision of such a positioning mechanism is inverse proportional to the signal strength of the positioning node, but this does not necessarily mean that the signal strength will be very low, as stronger signals will facilitate positioning of a larger number of devices (with less precision) using a lower number of positioning nodes. A yet more advanced solution is to use information from a number of positioning nodes to determine positions with the help of triangulation (in a service running on the device being positioned or as a special service running on a dedicated node in the ad hoc network).

6 Requirements to User Interfaces for Emergency Response When Using Ad Hoc Networks

In this section we focus on the user situation for local leaders (typically at a local control post) and field workers operating in operational area where a wireless ad hoc network is deployed, using or wearing equipment that is part of the network.

6.1 Local Leaders

The tasks performed by the local leaders are highly attention requiring, and are often time critical. The leaders need to consider and overview large amounts of information in order to make the right decisions. Thus, it must be possible to give different priorities to different categories of information, to filter and to have optimal visualization of relevant information.

When designing user interfaces for a local leader, it is important that these do not draw the attention away from the primary tasks of the local leader. This must be balanced with the potential of using ICT systems to relieve the local leader from some of the stress and attention demands of the primary tasks. Many of the tasks are better supported when run on a portable computer than a mobile device, as the screen size should not be too small. But in many situations a local leader need to move around outside the local control post from time to time, in which case the local leader will also benefit from using mobile devices. This means that user interfaces need to scale to the screen sizes of different kinds of equipment, which involves much more than just adding scroll bars when the screen size is reduced. If a local leader changes equipment, it is also important that as much as possible of the context of use is kept on the new equipment, like the active dialog, selected information, etc. State and visualization of an ad hoc network used is an important part of this context.

As already discussed, an important aspect of the information that should be presented is explicit information about the state of the network, as well as information derived from this state, and functionality rendered possible through the ad hoc network.

A special user interface challenge in this context is how to present information about *changes* in the network. Being dynamic is one of the main characteristics of a wireless ad hoc network, and informing the local leader in the same way about all changes will draw too much attention towards unimportant changes and too little attention towards important changes. Determining the degree of importance of a change is very challenging and depends to some degree on the application and/or the specific type of emergency response being conducted, as well as the type and role of the sensors and devices used in the network. This means that when developing the user interface of applications tailored for specific type of operations, as well as more generic applications, information regarding the type and role of the involved nodes in the network must be taken into account. Handling this type of information involves both characterizing the information (at design time), and entering the actual information about the concrete nodes that may be part of a network. The latter must be done at run time, preferably before an emergency response is conducted.

Once the importance of different changes is determined, making the right user interface design reflecting the classification of importance is an easier task. For most changes, just changing the presentation (being an outline and/or icons on a map, or a list in a forms based presentation) is sufficient. For more important changes, visual attention (e.g. using color or blinking), as well as sound and/or vibration may be used. For the most important changes, it may also be wise to require a confirmation from the local leader. Visualizing a change involving the addition of or an important change of e.g. the position of a node is easier than visualizing that a node is no longer part of the network. Independently of this, having special ways of visualizing the accuracy of important position information shown on the screen, e.g. by using a visual halo, may be quite useful.

6.2 Field Workers

The field workers operate at/inside the scene of the incident and move around most of the time. They are maybe even more focused on the primary task than the local leaders. In addition, these tasks may be performed in very hostile environments, e.g. extreme heat or cold, which both may require use of clumsy gloves and pose special requirements to the equipment (we will not discuss the latter). Suitable computer equipment is primarily mobile devices. In addition, field workers may be equipped with sensors reporting information automatically.

Given the level of attention on the primary tasks, there is need for efficient information flow, i.e. the field workers need to receive tasks from and provide information to the local leader, as well as getting/providing information from/to other field workers and local informants. When designing user interfaces for field workers it is important to make non-intrusive solutions. As opposed to the local leaders that are both information providers and consumers, the field workers are primarily information providers. Thus, they may have to perform tasks that are not directly beneficial for solving their primary tasks. Therefore, it is important to minimize the need for interaction, e.g. by providing information automatic through sensors, and reasoning based on sensor data. When interaction is needed, the choice of modalities to use is very important. Aural presentation of information, as well as speech control, possibly combined with dedicated hardware buttons (e.g. integrated in the clothing) is appropriate in many situations. If a visual interface is needed, it is essential to take the working situation of the field worker into account. A lightly equipped fire fighter handling a forest fire on a warm summer day may be able to operate a traditional touch screen interface on a mobile phone, while an avalanche rescuer waist-down in the snow in minus 20 degrees centigrade, wearing thick gloves and goggles almost opaque because a blizzard, needs a very simple and visual solution, preferable having its interaction mechanisms separated from the visual device (e.g. designated hardware buttons inside the gloves or integrated in other parts of the clothing).

Looking more specifically into using wireless ad hoc networks from a field worker perspective, such networks are important in the sense that they may facilitate functionality that relieves the field worker from having to interact with an application because necessary information is reported and/or provided automatically. To some extent, a field worker may also exploit the state of the network explicitly, like locating a fellow field worker, determining the right location for a sensor that should be deployed, or finding a specific sensor that needs attention or should be moved.

Like local leaders, field workers may also exploit information about the extent of the network, but in another way. For a field worker, the most important aspect in this respect is whether the field worker is connected or not (i.e. is part of the ad hoc network). This information is of course only important if the field worker is supposed to be connected, e.g. because the position is being tracked or because the field worker is deploying sensors. Finding an optimal way of presenting connection status is very challenging; it depends on the capabilities of the equipment used. On the one hand, the presentation should not be annoying, but on the other hand, it should not be easy to ignore. Although not obvious, it is probably more important to signal that the user is losing connection than that connection is obtained. Using visual signaling (e.g. a head up display on goggles or on the visor of a helmet) would probably work quite well, making it easy to distinguish between a connected and disconnected state. Enhanced with other sensors like digital compass and accelerometer, visual directions to reach a position with connection may be given. If it is feasible to use a device with display, visual directions can be given on the device through superimposing information on a camera image that is controlled by moving the device itself. Using aural signaling is more challenging. While signaling only loss of connection means that the signal need to continue until connection is reestablished (which may be very annoying), signaling both loss and connection requires different signals for each of the events. Using stereo sound, some directional aids for regaining connection may be provided. In any case, knowing when to use this kind of user interaction, and/or giving the user the opportunity to turn it on and off is essential. Interacting with a device through moving the device is a popular user interface trend for mobile phones. Using this type of interaction in an emergency response setting may be useful, but only as long as the intended interaction is not confused with arbitrary movement of the device while moving around.

7 Requirements to Development of User Interfaces for Emergency Response When Using Ad Hoc Networks

Above, we have looked at how wireless ad hoc networks influence use and design of user interfaces in applications supporting emergency response. When we in the following address what this means for the development of user interfaces, we look into some user interface characteristics that may be drawn from the previous sections. We start with the need for common user interface functionality in different types of operations, and continue with the need for having user interface functionality that may be specialized to different types of operations as well as characteristics of operation at hand, followed by the need for having user interfaces that work across platforms, screen sizes, modalities, etc. Finally, we focus on the need for adaptive behavior in the user interfaces.

7.1 Common User Interface Functionality in Different Types of Operations

The analysis and discussions above cover numerous examples of user interface functionality that is useful independent of the operation at hand. This includes components for presenting network status, connected nodes, the extent of the network, and the type of nodes connected, as well as functionality for locating nodes in the network, including mechanisms for giving directions. User interface component and mechanisms for handling this will typically be map and/or picture based. A similar need observed in two of our studies, is resource handling. This is a task that is fairly similar across different types of operations. A common need that is quite challenging to realize using generic user interface mechanisms is facilities for handling priority of information.

Such identified user interface functionality that is helpful in many situations indicates that the mechanisms for developing user interfaces for emergency response should support reuse, preferably at component level. This means that it should be possible to have ready-made user interface components that are easily integrated into a new application being developed.

7.2 User Interface Functionality that May Be Specialized to Different Types of Operations

As there are situations where the same user interface functionality is applicable in different types of operations, there are other situations where the user interfaces cannot be identical, but rather variants of a common user interface design. An example of this from the discussions above is a user interface providing awareness of changes in a network. The rules for which kind of changes that should be handled in which way are typically specific for different types of operations, but once the rules are specified, the actual user interface mechanisms implementing the awareness functionality may be identical. Another example is user interfaces for presenting additional information about devices and sensors, including their role and how they are used. Which information that should be presented for a sensor may differ from operation to operation, but the mechanisms for presenting the information may be the same. A third example is rules for turning different awareness functionalities on and off. These rules are typically different in different operations, but may be served by the same user interface mechanisms.

These examples may be generalized to a principle of having generic components that are parameterized for the aspects that differ between operation types and/or actual operations. To handle this in a development context requires more than ready-made components. There is also need for a model (which in simple cases can be implemented using a configuration file) that is able characterize different types of operations (typically specified as part of preparing for operations), as well as characterizing aspects of an operation type that may change during the operation.

7.3 User Interfaces that Work Across Platforms, Screen Sizes, Modalities, etc.

The need for user interfaces that are available on different kinds of equipment, including computers and devices with different screen sizes [4] was identified both for local leaders and field workers. For local leaders, it is important to have user interfaces that are available both on mobile devices and equipment with larger screen size, and keep the context of use when moving from one to the other. Having a user interface solution keeping the context when changing equipment is specially challenging if the involved equipment have different screen sizes and/or user interface capabilities, as information that is presented in one larger screen may be spread through different screens on a device with a smaller screen. Handling this may require special adaptation mechanisms.

For field workers, it is important to have user interfaces that exploit different modalities (possibly in parallel, and both for presentation and interaction). We also identified a need for using different display types like devices, and head-up displays on goggles or visor, as well as providing interaction also through sensors. Related needs are the possibility to present the information or getting access to special functionality regardless of the source and the transportation means used.

These needs focus on having user interfaces that are able to adapt to quite varying sets of technical conditions. Developing user interfaces with such abilities is either extremely resource demanding (if specific support for every combination of technical conditions is developed), or requires developing means that are able to operate with specifications that work across technical variations [16].

7.4 Adaptive Behavior in the User Interfaces

Although the need for adaptive behavior has been touched upon also for the three user interface characteristics just discussed, it is also a need in itself. One example is user interface functionality for locating nodes in the network, which may be provided as a map-based visualization, by superimposing the information on a camera view, or through sound. The choice of which of the mechanisms to use may be determined by an adaptation mechanism based on information regarding the user's role and task, as well as characteristics of the device used. More generic examples are mechanisms for filtering information, as well as explicit and implicit choices of which information to present, which have been identified as important functions for local leaders. Handling this in the general case may require user interfaces that support adaptation of the presentation of information. The need for adaptive behavior in user interfaces is also supported by other requirement gathering activities that we have conducted for the emergency response domain.

A related functionality to adaptation is having mechanisms for composing user interfaces. This may be used by systems developers at design time, either as a means for developing systems more efficiently, or as a way of specifying which functionality or presentation that should be available for an adaptation mechanism at run time. Composition may also be done by end-users at run time. By this, users get the possibility (or are left the responsibility) to conduct some or all of the adaptation of the user interface themselves. This requires more interaction by the users, but it also leaves them with more control of their support tools.

Developing user interfaces that support adaptation and/or composition involves many of the same challenges as handling cross-platform user interfaces. While many cross-platform issues may be handled by development tools at design time, adaptation and end-user composition require special run time mechanisms as well.

8 Requirements to Ad Hoc Networks When Used in Emergency Response

So far in this paper, we have focused on how the use of wireless ad hoc networks as communication infrastructure in emergency response influence use, design and development of user interfaces for this domain. In this section, we will look briefly into which requirements ICT solutions for emergency response pose on the ad hoc networks.

In section 4, we motivated why wireless ad hoc networks are well suited to handle communication in ICT solutions for emergency response, but there are still challenges. One main challenge is using a technological solution for the ad hoc network that renders it possible to connect sensors and devices to the network, and that does not drain the batteries of these in a very short time [5].

There are also a number of challenges connected to the size of the network. For a network solution to be practical, it must be flexible with regards to the number of nodes that are needed for covering an operational area. E.g. in an avalanche rescuing operation, this area will be fairly small, and the density of sensors and devices will be high, making ad hoc networks well suited. On the other hand, in an operation where limited personnel resources are searching for a missing person in a large geographical area, ad hoc networks will be able to cover only parts of the operational area at any given time. In this case, there may e.g. be one ad hoc network for each search group, which means that these ad hoc networks must be supplemented with gateways to cellular and/or special emergency networks. For this to be feasible, the ad hoc networks must interplay with the networks with a wider range. In such a setting, it is important that applications exploiting information about the ad hoc networks are able to use this information also through the other networks.

Furthermore, regarding network size, some of the discussions on use and design of user interfaces above are based on an assumption that the number of nodes in the network is limited. In a situation with hundreds of sensors and devices connected, it is not practical for a user to deal with information about individual nodes in the network (but information and presentations based on aggregations of and reasoning on data collected from the nodes may still be valuable).

Issues regarding the speed of ad hoc networks are typically "hen and egg" kind of problems. On the one hand, one may argue that the speed limitations should be taken into account when designing application that are using the networks, thus restrain from including transfer of high resolution pictures and live video [3]. On the other hand, this kind of bandwidth-challenging data may be crucial for an application supporting special emergency operations, meaning that ad hoc networks cannot be used, or must be supplemented with other network solutions for these types of operations.

Lastly, we once more emphasize the need for awareness of the connectivity of nodes, both when deploying and using ad hoc networks in emergency response. As discussed above, this is an important issue when designing user interfaces, but to be able to make such user interfaces, the nodes in the network must provide the necessary information about their state. Above we discussed providing this awareness through the user interface of the applications used, but it should be noted that this may be supplemented by feedback provided directly through the nodes themselves. On example is that a device vibrate in a special way if it is not connected, another is the use of light or sound signals when sensors need attention.

9 Related Work

Research on ad hoc networks [1, 24, 28, 30, 33] focuses mostly on technical network issues like architecture, topology, routing, coverage, security, protocols, layers, and channels. User interface issues are seldom covered, except for topics like simulation [11, 31], quality of service [26, 29] and deployment [32]. Emergency response is sometimes put forward as a suitable application area for ad hoc networks [10, 24], and there has also been conducted work on network solutions targeted at emergency response [6, 13, 21], but most of this work also focus on network issues.

In human computer interaction research, networks are usually viewed as a means rather than a topic influencing the research, while the special challenges imposed by emergency response raise important research questions. This includes utilizing multi modality [7, 25] and supporting adaptive behavior in the user interfaces [14, 27], usually focusing on case studies, concrete solutions, and methods; more seldom on requirements and design advices.

Research on emergency response is by nature multidisciplinary, but there is usually more focus on user interfaces [12, 22] than network solutions [23]. Research papers discussing user interfaces tend to focus on concrete systems and concrete user interfaces solutions.

We have found little work addressing the combination of wireless ad hoc networks, user interfaces design and development, and emergency response. Bharosa et al. [2] address both user interface and network issues, but with a much broader scope, and thus being far less specific when handling these issues.

10 Conclusions and Future Work

In this paper we have investigated how the use of wireless ad hoc networks influences design and development of user interfaces for emergency response applications. We have argued that it may be helpful to make details about the state of the network explicit to the end-user. This includes information about availability, coverage and connected nodes, i.e. information that is usually hidden for the user or only shown implicitly in traditional usage situations using standard network solutions. In addition to being useful for the user, it may also be exploited by applications.

We have also argued that user interfaces for local leaders and field workers in an emergency response must fulfill a set of specific requirements. Even though a local leader has a very attention requiring primary task, an application with a well design user interface may relieve the leader from some of the demands for attention. Doing the same for a field worker is more challenging, so for this user group it is more important to have non-intrusive ICT support, possibly offering non-visual modalities as an alternative to or in combination with visual presentation and interaction. For local leaders, supporting user interfaces on equipment with different screen sizes is important to give optimal solution both when the leader is at a local control post and when the leader is moving around. For both groups, information about the extent of the network is potentially useful, and local leaders have special needs regarding awareness of changes in the network, while field workers have special needs for knowing their own connection state. Presenting all these kinds of network information in an optimal way is very challenging.

To meet these challenges when developing user interface solutions we see the need for generic components parameterized so that they may be configured to different types of operations as well as characteristics of actual operations. We also see the need for means facilitating development of adaptable user interfaces that are able to support different platforms, screen sizes, and modalities without requiring that each combination is developed separately. A common factor for handling all these challenges is flexibility, indicating that composition is a useful mechanism to exploit both at design and run time.

Emergency response has been put forward as one of the prime examples of application areas where ad hoc network is especially well suited. In addition to practical issues like connectivity and battery life of sensors and devices, we have made some considerations about the speed and size of the network. Regarding speed, we conclude that this can either be handled by reducing the needs for communication to the available speed, or by choosing a communication solution offering the required speed. Regarding size, we conclude that the size and character of the operation, and the density of sensors and devices, are important factors regarding the appropriateness of using wireless ad hoc networks, as well as how the networks should be configured.

Our future research will focus on handling user interface development for applications supporting emergency response, taking the requirements for flexibility into account. The solutions need to be flexible with regards to type of operation, special needs for the given operation, available and needed information sources, applications and services, available and needed sensors, available infrastructure, type of equipment to be used, work situation of the user, and modalities to exploit. The requirements for flexibility have at least two implications. Firstly, that developing optimal solutions for all combination of needs will be utterly expensive. Secondly, that it is almost impossible to specify an optimal end-user solution in advance. Our aim is to apply a model-based approach [16] to facilitate easy composition of support tools, partly at design time and partly at run time.

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