How mobile IT- support and patient tags can improve information flow and patient tracking in prehospital medicine

Research based on FieldCare - a demonstrator developed by SINTEF ICT

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ABSTRACT:

In large scale emergencies with many casualties, personnel require an updated view of the situation at all times to contribute effectively to the rescue operation. Experience from full scale field exercises shows that the tools available today - mainly paper forms and radio communication - do not give the required support. SINTEF has developed FieldCare, a demonstrator to investigate how handheld terminals, wireless networks and electronic patient tags can improve information flow and patient tracking in rescue operations. In March 2005, a structured evaluation of FieldCare was carried out by an expert user panel, consisting of health and police personnel with relevant experience from large scale operations. From this and previous user feedback, we conclude that the FieldCare concept appears to have major potential for improving information flow between the site of an accident and relevant coordination centres, and for generating useful overviews. Electronic tags can provide simple patient identification, and be an effective enabler for much needed patient tracking support, even inside the hospital. It also seems feasible that such a tool could be adapted to everyday pre-hospital work, thus ensuring everyday use - which is a precondition for effective use in crisis situations.

Using Mobile IT Support in pre-hospital medicine

Dealing with major accidents with multiple casualties demands effective communication and coordination. Many people and places are involved: medical and other emergency personnel at the scene of the accident, coordinators on site and in coordination centres, ambulance personnel in transit to and from the scene, and hospital personnel preparing for the arrival of casualties. For all these people to contribute effectively to the rescue operation, they need to be able to share information rapidly and effectively.

Experience from full scale field exercises shows that the tools available today - principally paper forms and radio communication - are not sufficient to achieve the required degree of common situational awareness. SINTEF has been working for many years on how IT-support can solve these problems (1, 2). Specifically, we have developed FieldCare to investigate how handheld terminals, wireless networks and electronic patient tags could improve things. FieldCare is a working demonstrator (I), intended to show potential users what is feasible, and to trigger responses from them about detailed requirements.

In March 2005, a structured "evaluation" of the FieldCare demonstrator was carried out, with the participation of an expert panel consisting of 6 persons: the leader of an emergency medical communication centre, the leader of a county ambulance service, an ambulance worker, an anaesthetist from a major hospital, a police officer from a police operational control room and the leader of the national centre for emergency health-care communication in Norway. Their common ground was thorough knowledge about the needs of personnel in large scale emergency operations, but they each brought expertise on specific issues related to particular functions and roles.

This article describes the FieldCare demonstrator that was the basis for this evaluation, and the feedback that was obtained

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The abbreviation SINTEF means The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (NTH).

The SINTEF Group is the largest independent research organisation in Scandinavia. Every year, SINTEF supports the development of 2000 or so Norwegian and overseas companies via our research and development activity

SINTEF ICT offers integrated research-based knowledge through access to a broad competence and technology platform within ICT from the expert panel. Based on this, it identifies "Lessons learned" concerning the design of a system for supporting emergency crews responding to major incidents.

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Components and Functions of the FieldCare Demonstrator

Hardware - for casualties

The FieldCare demonstrator uses an electronic tag as a mechanism to uniquely identify casualties. One such tag is attached to each casualty found at the scene of an accident. The particular device used is an "iButton": a robust, miniature electronic tag that can store information about a patient. In the demonstrator, the only information stored on the tag is a number used to uniquely identify the patient (II).

Figure 1. iButton - an electronic "tag" for instant and reliable identification of casualties

Hardware - for emergency staff

FieldCare is based on the idea that each person dealing with an incident – regardless of role or location – is equipped with a terminal for entering and/or accessing information about casualties. Three different types of terminal are used in the demonstrator:

Type 1 Small hand-held PDA ("Personal Digital Assistant") devices such as iPAQ.
Type 2 Portable "tablet" PC with larger screens than PDAs.
Type 3 Standard laptop.

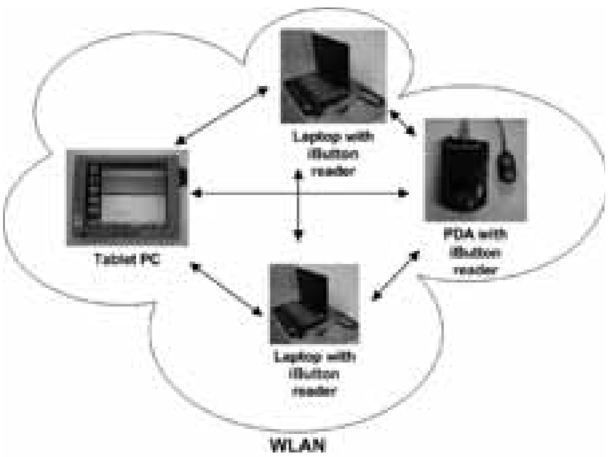

Figure 2. The FieldCare demonstrator connects different types of terminal in an adhoc WLAN network.

The same software (III) is installed on the different types of terminal, with the user interface adapting automatically to the available screen size. Types 1 and 2 are primarily aimed at users in the field, while type 3 is aimed at users in ambulances and coordination centres.

All terminals are equipped with a wireless communication capability – specifically, WLAN. This allows wireless transfer of data over distances of up to a few hundred metres. An example of a small test setup is shown in Figure 2.

Terminals can also be equipped with an iButton reader. This cable-based device connects to a casualty's iButton with a simple click, and allows the data on the iButton to be read immediately by the user's terminal. This establishes an unambiguous association between the information shown on the screen and the casualty being treated.

Data Replication in the FieldCare Wireless Network

When a new *FieldCare* terminal is switched on, it automatically establishes contact with any other *FieldCare* terminals that are within radio range, and any data about casualties that is stored on the other terminals gets copied to the new terminal. Any new data entered into the system is automatically replicated to the other units in the system. Should a unit fail, or move outside the range of the other units, the data is automatically replicated as soon as it enters the radio-link network again. All terminals in the *FieldCare* network have equal status: there is no concept of a "server" or "master node", as this would constitute a single point of failure (5).

Functional overview

Registering new patients: The primary way of doing this is to connect a new tag to a terminal. The system then creates a unique patient id associated with that tag. It is also possible to register a new patient id without using a tag.

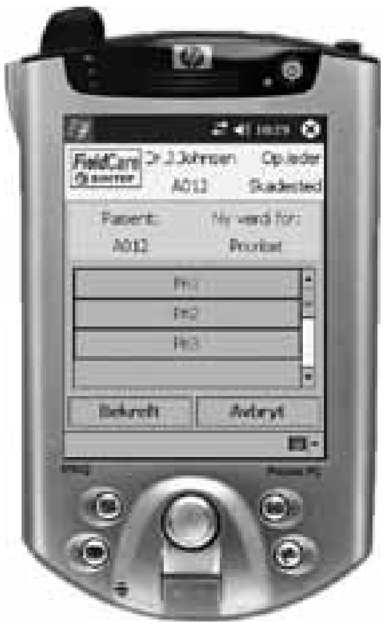

Figure 3. Screenshot of demo application on PDA: Dr J. Johnsen is about to enter priority for casualty A012

Location sensing: Using an electronic tag enables patient tracking because the tag leaves an electronic trace every time it is connected. Every terminal has a defined location, and when the tag is connected, the system stores this location and the time in the patient electronic field journal. The replication protocol immediately makes this information available on all other terminals in the network.

Patient documentation: The user can enter observations and treatment given for the patient currently connected to the tag, using a set of predefined procedures. All observations are registered with a time stamp and the name of the user. Figure 3 shows the screen for entering priority of a patient.

Information browsing: The application provides functions for viewing the electronic journal for just one patient, or choosing from predefined overviews; e.g. a list of patients sorted by priority or a list sorted by location; see Figure 4.

Figure 4: Screenshot of demo application on laptop: By pushing the "Ambulance A1" button, data on the two patients in it are displayed.

Lessons Learned & Design Suggestions

Evaluation methodology

The evaluation was carried out by running the software on two computers communicating wirelessly, and using projectors so that all present could constantly observe what was happening. This was done in several phases, corresponding to tasks that would be carried out in a real incident (e.g. triage in the field, documenting patient status, forming an overview picture at the coordination centre, etc.). During each phase, users were encouraged to contribute freely with observations and suggestions. At the end of each phase, the panel were asked to write down individually what they considered to be the most crucial points. These were then discussed in the group, before moving on to the next phase.

Communication network

The WLAN technology used in the demonstrator is obviously not sufficient for communication between the scene of the accident and the hospital due its limited radio-range. The panel agreed that GPRS or a dedicated emergency radio network such as Tetra could be used (IV).

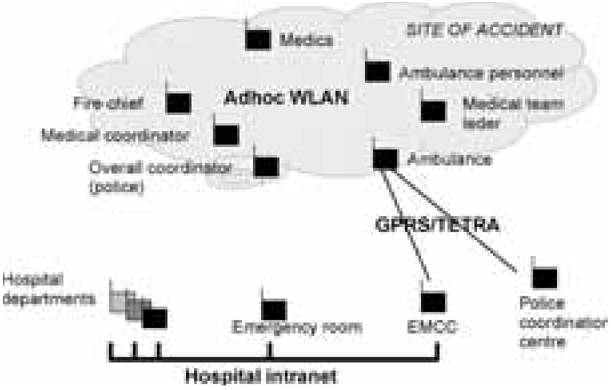

Figure 5: Single logical network combining different technologies to link all users and locations. (EMCC: Emergency Medical Communication Centre)

Our response to this, as illustrated in Figure 5, is that what is needed is a single logical network that combines different underlying radio networking technologies. To achieve this, some terminals would act as "gateways" by being equipped with several networking capabilities (e.g. both WLAN and Tetra). Terminals located in emergency vehicles would be obvious candidates for this, and other terminals dedicated to this function could be placed on site at an early stage. Using multiple gateway terminals would not only decrease the chance of failures, but also increase transmission capacity.

This logical network would need to be very flexible, and protocols for transmitting data within the network would need to be highly resilient to radio failures and changes in the topology of the network. The data replication protocol implemented in the *FieldCare* demonstrator is suited to this.

Scope: everyday pre-hospital work, catastrophe, or both?

As our user panel were quick to point out, day-to-day pre-hospital medical work rarely involves large scale trauma operations with tens or hundreds of casualties. Typical work involves a single ambulance and patient – such as a person suffering a sudden heart attack, or the scheduled admission of an elderly person to hospital. Familiarity with the operation of a system is a prerequisite for its effective use in handling large scale emergencies – and familiarity can only be gained by using it in everyday situations. This point was stressed strongly by the panel.

We believe it is a good design strategy to scale the system according to worst-case scenarios to establish the boundary conditions for its performance, and then adapt it for everyday work. The discussion with the users did not uncover any technical or functional points that would contradict the validity of such an approach.

Key issue: patient tracking

The volume of feedback and comments given by the user panel on the topic of patient tracking in large accidents confirmed our impression that this issue is crucial, for the police as well as for health personnel. The police are responsible for documenting the identity of all persons involved in an accident (not just casualties), and for providing updated information throughout the rescue operation to journalists and relatives. For medical personnel, the problem of patient tracking continues even inside the hospital. As one panel member put it: "It's when the patients arrive at the hospital that the chaos really starts".

The concept of using an electronic tag that leaves an "electronic trace" every time it is scanned seemed an attractive idea to all panel members. They had several ideas on how to improve the usefulness of this function.

In large scale emergencies, functions should be made available for defining customized locations for a terminal, to supplement those in the predefined location list. It should also be possible to annotate a location name with details: e.g. "Collection point – at private residence (red house), 23 Mill Road". This would be one way of adding information on the geographical position of an accident reference point. Another would be to equip field terminals with GPS/GIS (V). This was not discussed at the meeting, but it would give exact geographical positioning of the mobile terminals and hence of persons whose tags have been scanned by that terminal.

The panel agreed that it would be feasible to use "tag-scanners" as a way of tracking patients inside the hospital: terminals with scanners could be mounted in every hospital department patients would be likely to visit (e.g. x-ray, operating theatres). When the tag is scanned, the information registered about the patient would be immediately displayed, and the patient's location registered in the system. The panel pointed out that, for this to be feasible, the tag would have to be able to tolerate hazards such as x-rays and the strong magnetic fields experienced in MR scanners.

How long the patient should be tracked after admission to hospital was not discussed, but is certainly relevant to surveillance and privacy issues. Concerning privacy, tags which can only be read in close physical proximity to the patient (such as the iButton or bar-codes) may be perceived by patients as being less threatening compared to radio tags like RFID, which can be read from a distance.

Patient Identification – will tags suffice?

For everyday pre-hospital work, the panel agreed that the tag on its own would probably be sufficient for patient identification purposes. But in large scale emergencies medical personnel need to be able to tell – at a glance – which patients are "Pri 1", and to visually determine each patient's system-id (the number assigned to the patient when the tag is scanned for the first time). To achieve this, electronic tags would need to be complemented with some alternative system. The alternative system would also act as a backup for patients who lose (or never receive) a tag, or in cases where tag readers are faulty.
SINTEF is currently cooperating with AD Predoc AS, a Norwegian company producing paper identification systems for major accidents. Together we are confident that somewhere in the intersection between paper and IT, the optimal solution for patient identification and information flow will be found.

The need for customisation

The panel considered that digital information flow from the point of origin in the field into the patient's EPR would be a critical aspect of the usefulness of the system. Another point of enthusiasm was the possibility to aggregate patient data and generate overviews. It was pointed out that such overviews would be helpful for many people in the field (e.g. Medical coordinator), in the hospital (e.g. the anaesthetist) and at coordination centres. One suggestion was that users should be able to select several overviews, or even functions to define their own criteria for sorting and presenting the data. For example: the EMCC coordinator would want a list showing the ambulances that have left the site of accident - sorted in order of expected arrival time. Hospital doctors would want an overview of the most critical data about the patients in the first ambulance. The police would want tracking information for all persons involved in the accident - but not any medical information (VI).

On the topic of triage, the users had diverging viewpoints. One pointed out that some personnel lack training, and would benefit from the system helping them to remember the drill. For example: the system could require that the user push buttons to confirm that the required ABC(DE) (VII) assessment has been carried out before being allowed to enter the triage priority. Others underlined the risk of superfluous button-pushing wasting time and irritating users.
The above feedback highlights the fact that the users of such a system are not a homogeneous group and will have different needs, even when faced with the same task. One approach would be for the system to adapt its behaviour depending on the role the user logs on with. The role (e.g. "Police Coordinator") would trigger selection of the appropriate user interface and function set, and determine access-rights to sensitive patient information. In addition functions must be included to let each user personalize the application according to individual preferences.

Handheld computers: an altogether feasible tool for field work

The idea of introducing PDAs and/or tablet PC terminals for personnel at the site of an accident to connect to electronic tags and register/view information about patients seemed altogether feasible to our user panel. Points made with respect to usage were: (1) the terminal must be robust; (2) user input must be done with the finger (a stylus is inconvenient and easily lost); (3) text input should be avoided (but SMS-style input could be worth looking into); (4) the application should resemble today's ambulance journal where appropriate; (5) it must be possible to update or enter critical information at any time.

We believe that these conditions can be met. Through the project "EvacSys" (1) for the Norwegian military, SINTEF has been involved in specifying, testing and evaluating a similar system to *FieldCare*, but developed for the military battlefield evacuation scenario. A prototype system conforming to points 1-3 above (based on SD-card electronic tags and off-the shelf PDAs encased in a robust casing) was tested in a full-scale field exercise at Setermoen in northern Norway in December 2003. The overall conclusion from the users was that usability and system reliability in the field were satisfactory, even under the cold, dark and wet conditions of a Norwegian winter.

Conclusion

We draw the following conclusions from our work:

- It is feasible to design a system based on handheld terminals (PDA, tablet PCs) and wireless networks to improve information flow and situational awareness in large scale emergency operations.
- Electronic tags have great potential as a patient identification tool, and as an enabler of much needed patient tracking support.
- Everyday use is a precondition for effective use in crisis situations.
- More research is needed on security issues, and on how to integrate with existing systems and working practices.
- The use of a working demonstrator (like *FieldCare*) to demonstrate concepts and gather user requirements is a good way to advance the design of a system. However, prototyping and testing in real scenarios is the only way to ensure that all aspects of a system and its use are considered.

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4. Experience documents from the TETRA pilot project in Norway 2001-2002. "TETRA pilot: Brukernes erfaringer", "Erfaringsrapport for Helse" , http://www.nodnett.no
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Footnotes

I. FieldCare is not proposed as a commercial product, but may result in the development and successful deployment of a product in the future.

II. Each tag is capable of storing more than the identification number, such as the patient record. While this could provide a more robust solution in case of network failure, we don't delve into this in this article.

III. The application is programmed in Java and runs on Microsoft operating systems.

IV. In Norway the procurement process for a new public safety radio network, including control room delivery and radio terminals, is currently in the pre-qualification process. A formal Invitation to Tender is expected in Summer 2005.

V. GPS: Global Positioning System; GIS: Geographic Information System. GPS is already implemented in many ambulances in Norway.

VI. Fire personnel would also be users of the system, but their requirments have not yet been analysed.

VII. The ABCDE drill for paramedics: Airways, Breathing, Circulation, Disability (consciousness) and Exposure (temperature) must be assessed.