A Swedish Approach to Network Based CBRN Decision Support in Future Missions

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Abstract

The management of chemical, biological, radiological, and nuclear (CBRN) threats requires integration of information from a variety of sources, both horizontally across multiple agencies and jurisdictions and vertically between organizational levels. For this reason, preparedness to deal with CBRN events could gain immensely from network-centric approaches to command and control and decision-making. At the same time, this diversity of participants poses challenges, as a solution must accommodate many views on problems, priorities, and procedures. The Swedish concept of Total Defense serves as the starting point for the transition into the network-centric future. The paper presents a test bed approach for bridging the gap between vision and reality in the CBRN area. Using the test bed to conduct experiments and demonstrations makes it possible to bring together practitioners, designers, and developers in a creative environment to explore future concepts and services in CBRN decision support.

Introduction

The way we look at chemical, biological, radiological, and nuclear (CBRN) threats has changed in the light of recent world events. New types of carriers can deliver weapons of mass destruction in non-traditional ways to inflict casualties and create havoc in civilian communities. Responding to this challenge requires new approaches to crises management. In particular, the capability to manage CBRN events must become an integral part at all levels of both military and civilian operations. Interoperability and integration of services are fundamental to leverage the resources available across organizations. The development ahead requires coordinated efforts from people in multiple disciplines, including researchers, subject-matter experts, system operators, system developers, and decision makers. To this end, we describe steps towards integrated CBRN decision support in crisis management. We also outline the first steps towards realizing a test bed, which will be used to visualize and verify both updated and new functions.

The central tenet of our approach is that agile management of CBRN events requires effective and efficient information sharing between all actors engaged in the response. The goal is to achieve and maintain situational awareness during the whole crisis management cycle. The development of information technology enables this transformation, but technology alone is not sufficient. Civilian and military agencies must adapt their organization structures, command principles, support systems, and training methods in a process of co-evolution. Our contribution to this process is a test bed that supports experiments with information-enabled network services for acquiring and combining information from multiple sources to provide timely CBRN decision support. The approach provides a way of demonstrating new technology in the context of a relevant scenario. The combination of real and simulated entities can increase the complexity of the scenario to present a more realistic situation, which can stimulate discussions about our preparedness, and how to improve it.

The ongoing process of information age transformation in the defense area requires that people start thinking and acting in new ways. Not only does this development process require visions of the future, but it also calls for practical and tangible examples. We believe that our project can contribute to bridging the gap between vision and reality.

In the rest of this paper, we present an approach to developing a CBRN decision support system commissioned by the Swedish Armed Forces and outline the road ahead for the coming years. The approach is based on a conception of our society as well as on what type of techniques and methods are available today and in the coming 10 years that can contribute to the network centric defense.

Aspects of CBRN

Historically, the prospective enemy's ability to use CBRN warfare agents had a very strong influence on defense planning in Sweden during the cold war. This planning not only involved the Armed Forces, but also the civil society to a great extent. As early as the beginning of the cold war, a special agency for Homeland Defense was established. This agency got funds to promote the building of common shelters dimensioned and adopted for CBRN-protection in all towns throughout the country. Sweden also carried out a number of other programs in the civil defense sector including the production of redundant power supply systems for authorities, the building of command and control centers, and the production and stock-piling of protective masks for all Swedish citizens (Rejnus, Thorpsten & Abrahamsson, 2001). Training and education on a voluntary basis have been a continuous activity in Sweden to develop and maintain preparedness to manage vital services during a national crisis or war. Even today, everyone between the age of 16 and 70 living in Sweden must serve in the Total Defense if required, either through military service, civil duty, or general service.

However, the threats that Sweden faces today differ from the threats that it experienced during the cold war. The former well-defined prospective military enemy has vanished and given place to various asymmetric threats to our society, core values and lifestyle. Our adversaries can be non-governmental organizations and terrorist networks. Nevertheless, the threat from CBRN attacks remains, although the enemy and the carriers have changed.

Until today, much of the CBRN defense activities have concentrated on fast detection and identification of classical warfare agents. The idea is to be able to alert our forces to give them time to carry out their standard protection procedures. Rapid detection and timely warning remain key components for effective defense against attacks with CBRN weapons, but the target audience is now the whole population in the affected area. The new situation highlights some unsolved problems in this process. Depending on a lack of information the precision and situational awareness have been doubtful, affecting the ability to conduct missions. In the future it will be possible to take into account a number of new information sources to improve situational awareness as a basis for decision making. Furthermore, the integration of the data into a single processing network has the potential to speed up the dissemination of mission-critical information to multiple locations. Also, the introduction of validated simulation models has the potential to make the decision process more manageable. However, it is important to remember that, ultimately, human decision makers have to grasp the data, comprehend the information entailed, and make wise decisions in a stressful situation. Human factors and cognitive aspects must receive a lot of attention in the design of our future command and control processes and their supporting tools.

Some of the information types needed for decision support in case of CBRN incidents are:

- *Geographical information*. This includes topography and demographical data that can be used for prediction of dispersions and risk assessments.
- *Meteorological data.* Information about the present weather forecasts on a local and regional basis with winds, temperatures and precipitation, which are vital for different models and simulations supporting the CBRN decision support system.
- *Detection data.* Data from fixed and mobile detection systems must be used to increase the accuracy in the calculations and predictions.
- *Intelligence information on possible threats and targets.* The availability of knowledge on the criminal market to produce CBRN weapons together with the lessons-learned from previous terror attacks can guide our defense, preparedness, countermeasures and protection.
- *Protection.* The ability of our units to protect themselves in case of a CBRN attack heavily depends on their training and the availability of protection gear. Knowledge of the protection level is used to support accurate risk and casualty calculations.
- *Domain facts.* A lot of basic domain facts are available from different databases stored either local or reachable via the network. Information about agents, spectra, threshold values, thumb rules, protection factors, pictures, checklists etc.
- *Experts.* National and regional availability of experts that can support the decision makers in case of a CBRN attack is a critical resource.

The mere knowledge that various terrorist organizations have the resources to produce CBRN weapons implies that there is a threat to our society. Knowledge about countermeasures and protection together with an agile response organization is crucial to keep our nations as safe as possible now and in the future.

CBRN in Network Centric Defense

CBRN decision support uses raw data from sensors, interpreted information from human and computational sources, organizations on a local, regional and national level, algorithms, simulations, and heuristics to generate situation pictures, prognoses, and analyses that help decision makers assess emerging situations, coordinate response, and plan for contingencies in case of a CBRN threat. One of the reasons for exploring the possibilities of Network Centric Defense (NCD) and applying them to the special problems and situations that occur in the CBRN area, is the need to integrate information that originates in multiple locations in our society. The ability to instantly collect, retrieve, and process information has a decisive effect on the ability to respond appropriately to a CBRN attack. Rapid response is critical for minimizing the effect of the attack.

We expect the NCD approach to facilitate this undertaking by making locally available information globally accessible in all parts of a secure information network (Stenbit, 2004). Multiple information services can be used to support decision support in a command and control process. Instances of information services can be updated or exchanged without jeopardizing the core function of the net centric command system. To meet the demands for interoperability and adaptability, future systems must facilitate seamless interaction between loosely coupled, heterogeneous subsystems, organized in a network and built from components that can be modified and replaced independently of each other (Alberts, Garstka & Stein, 1999; Alberts & Hayes, 2003; Alberts, 2002).

The network centric defense implies a paradigm shift for the Armed Forces, where the CBRN issues will be of common concern. In addition, the civil society's ability to manage a CBRN incident must be supported. If used by the civilian authorities, the different rescue organizations can both utilize the network centric decision support system and simultaneously provide it with valuable information on a daily basis. In the early phase of a military attack on our country, the society has to rely on the civilian responding organizations for protection and aid.

The test bed approach

People are central in the transformation towards network centric defense, because they are innovators, developers, and users of the resulting systems. Moore (1991) discussed the difficulties an organization encounters when it attempts to adopt new practices. Success requires that a sufficient number of people embrace the change. However, many people resist changes until sufficient evidence exists that they are necessary and beneficial. Alberts and his colleagues (Alberts, Garstka & Stein, 1999) pointed out the need for users to become better acquainted with technology and its possibilities before they can begin to realize ways of leveraging its full potential. Our approach is based on the assumption that prototypes and simulations are useful in this transformation process, because they allow users to get a tangible representation of the future. Such representations can demonstrate the usefulness and benefit of novel concepts as well as provide glimpses of new technology in a relevant context.

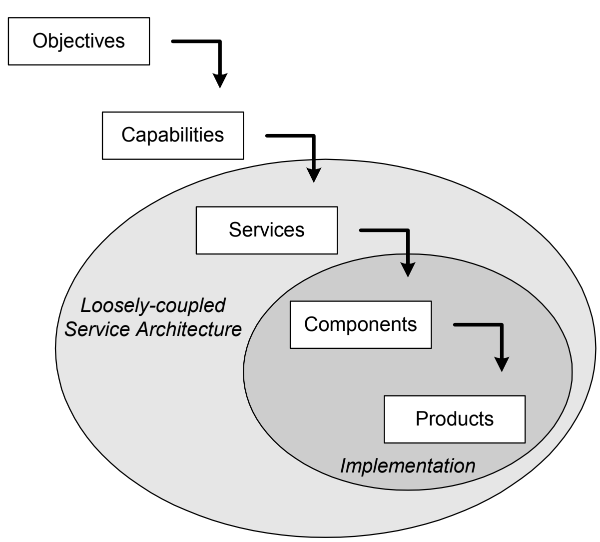

Figure 1: From objectives to products in a component-based decision support system (adapted from Rejnus & Morin, 2000).

For our test bed we use commercial-off-the-shelf (COTS) products to a large extent. The main design goal is to provide an information space supporting an extensible network environment that can accommodate a variety of sensors, information services, decision models (Morin, Axelsson, Rejnus & Jenvald, 1999), simulations, and presentation tools. Some of the components are commercially available, whereas others are standalone research systems at the Swedish Defense Research Agency. For the components we develop interfaces and common data formats. We develop existing models and decision rules to fit into the network environment. Together they serve as building blocks of a prototypical NBC decision support system (Rejnus & Morin, 2000).

Figure 1 provides a schematic view of the development process of a decision support system. The focus of our present research is on defining capabilities and identifying key services of a CBRN decision support system. To this end, the test bed provides a provisional and prototypical service architecture, which enables experiments with various service implementations and configurations in the early phases of development. The final implementation of the system will use the common service architecture commissioned by the Swedish Armed Forces.

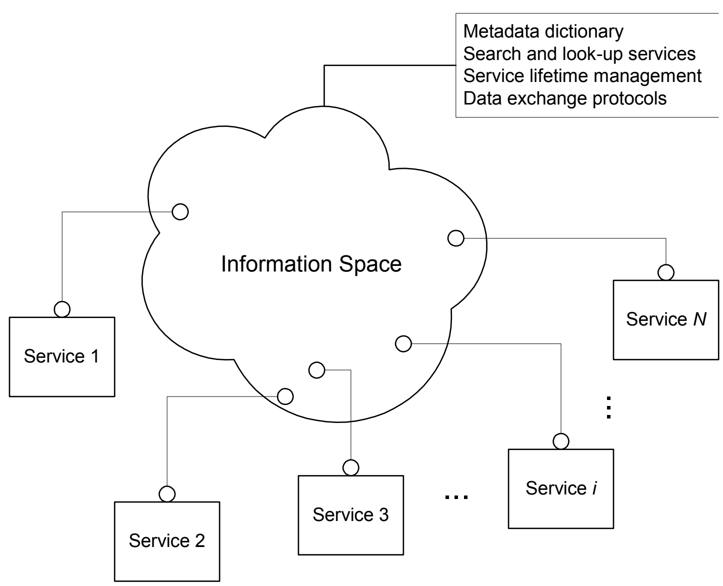

Figure 2: Principles of the Information Space. The Information Space is an abstract model for defining the interaction between information-processing services. This model regulates metadata requirements, service discovery through search and look-up, service lifetime management, and data exchange protocols. The test bed includes a basic implementation of the Information Space.

Information Space

The conceptual foundation and service architecture of our test bed is the Information Space. The Information Space is an abstract computational model of how loosely- coupled, distributed services can execute and exchange data. Figure 2 presents a conceptual overview of the Information Space. In this view, a service is any well-defined computation that adheres to the principles of lifetime management, data exchange, and metadata annotation. In an implementation, a service is realized by a software component that executes as a process on a computer in a network. This component exposes a number of interfaces that supports the implementation of the service's obligations both as a member of the Information Space and as a provider of functionality according to its service contract.

The major underlying principle of the Information Space is that services can begin and end execution independently of each other. Therefore, the Information Space must incorporate mechanisms that enable services to discover what other services are available, to establish connections to services of relevance, and to exchange data with them. To this end, the Information Space includes support for metadata, service discovery through search and look-up, service lifetime management, and protocols for data exchange.

Another principle is encapsulation to promote reuse of existing models. Vast resources have been invested in various models in the CBRN area. These models have been implemented using a range of techniques and programming languages, often as standalone tools. To leverage this investment it is necessary to develop mechanisms that enable the integration of proprietary models in an information-processing network. The service concept together with suitable protocols for data exchange can provide such mechanisms.

There are two mechanisms for data exchange between services in the information space: *data flow* and *queries*. In addition, various proprietary mechanisms are used by services to access external systems or special devices. The purpose of data flow exchange is to facilitate rapid dissemination of essential data in a parallel fashion. For example, services may operate in parallel to process incoming sensor data. The result of this processing, in turn, provides new data for subsequent services. In this way, incoming data are propagated through the service network and refined and aggregated in a series of computations. The Information Space provides a subscription mechanism to manage the data flow. Whenever a service enters or leaves the Information Space, the other services are notified according to their data requirements.

Whereas data flow exchange is typically triggered by sensor data and lead to data-driven computations, a user generally initiates query exchange. Queries are synchronous in the sense that a well-defined question is transformed to an answer to that question. Many analytical and explorative tasks are triggered by events detectable in the flow of data. However, such tasks may involve deliberation, hypotheses, assumptions, and conclusions that must be supported by additional data. To this end, a user may request additional information by issuing a query. Query services typically connect to databases, resource directories, and model repositories.

Figure 3 illustrates the various mechanisms for data exchange. The figure shows a small data flow network where two sensors services monitor two different sensors. Whenever a sensor provides a new sample the corresponding sensor service sends it to its subscribers. In this case, there are two: a data fusion service and a logging service. The data fusion service combines data from the two sensor services to form aggregated data of interest to a user. It sends the result to a presentation service and to the logging service. The presentation service provides a point of user interaction by transforming data in the information space to a form suitable for human access. It also accepts user requests for historical data and transforms them into queries issued to a retrieval service that accesses the logging database. This combination of data flow for rapidly propagating incoming data and queries to access stored data is typical.

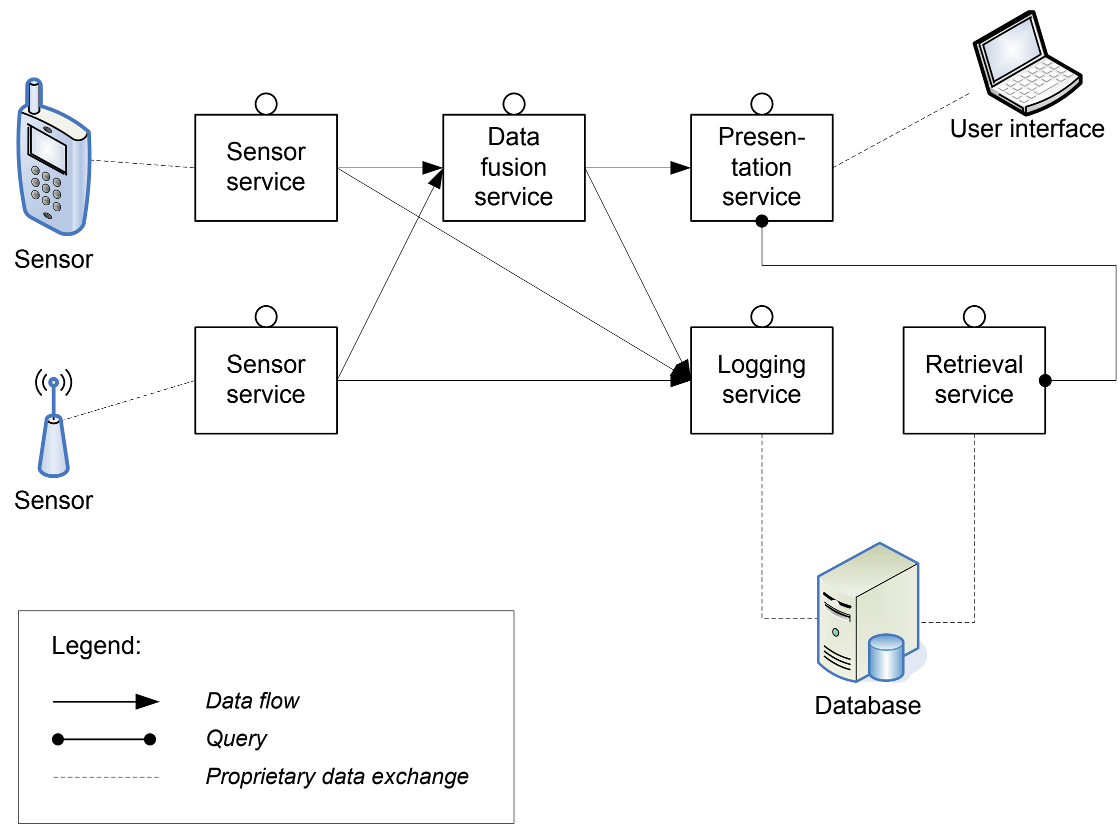

Figure 3: Information Space example. Six services collaborate to deliver user adopted sensor data to an end user. Sensor services monitor sensors using whatever protocols are required to retrieve data. They convert sensor data to a format defined in the Information Space and publish the data using a data flow mechanism. A data fusion service receives these data flows, aggregates them, and passes aggregated data on to a presentation service. The presentation service monitors the flow of aggregated data and presents it to a user. It also provides a means of retrieving historical data from a database using a query mechanism. The database is filled by a logging service, which captures the data flows from sensor services as well as from the data fusion service.

With the test bed, we seek to demonstrate the effects of providing NBC decision support based on dynamic configuration of network services. Moreover, mixing real instruments and models with simulations of virtual devices can enable us to explore the potential of future concepts for CBRN decision support in a network environment. The ultimate goal for the CBRN decision support system is to assist a decision maker to make as wise decisions as possible in time-critical situations. To continuously test the applicability and usefulness of the developed models and implemented components, it is possible to evaluate them using dynamic scenarios in the test bed. To secure the relevance of the scenarios, we include human operators and subject matter experts who interact with the systems that affect the information space. It is possible to combine real units, for example a detection vehicle on the proving ground, with virtual detection vehicles operated by personnel in mock-ups. The ability to mix real and virtual units increase the possibility to create scenarios of a size that create increasing complexity to be managed by the decision makers. Experts can be consulted on demand through the information space and participate as a "read only member" on the network, on telephone or video-conferences to support the decision makers and their staff.

Initial demonstration of the test bed

The core of the test bed is an information space that defines common data formats and provides wired and wireless communication links. Several network services use the information space to provide sensor data, decision models, and means of communication between experts, decision makers and members of various field units. We configured and used the test bed during an early demonstration to illustrate the information and data management during a CBRN scenario. The test bed included the following services (see Figure 4):

- Real and simulated weather sensors that provided regional and local weather data.
- Detection vehicles that detected and reported hazardous substances, simulants, in the air.
- Simulated detection instruments.
- Observation and alert support implemented in a hand-held Personal Digital Assistant (PDA).
- An audio, video, and data link to remote a NBC expert for consultative support.
- A model-based decision support system that used information from sensors and experts to present valuable information to decision makers.

The demonstration centered on a scenario where an unknown toxic agent leaked from the cargo bay of an aircraft. An airport security officer used a PDA to notify the crisis management staff about the hazardous leak. Initially, the command post was connected to military sensors only, which resulted in a preliminary dispersion plume based on regional weather conditions. The command staff started parallel tasks to (1) deploy detection vehicles to confirm contamination and identify the agent; (2) dispatch a Hazmat team to contain the leak; (3) prepare an evacuation of the areas in danger; (4) activate medical resources and prepare for care of possible victims; and (5) estimate the number of casualties. An important decision in this phase was to identify and connect other information sources, such as civilian sensors that could provide more accurate estimations of the consequences of the incident. In our scenario, a weather sensor at a fire station could provide local weather information that enabled a more accurate predication of the contaminated area. Improved accuracy allowed the commander to deploy the available resources where they were most needed. A detection vehicle was directed to the contaminated area to refine the initial estimations generated by the decision support system and to identify the toxic agent. The information from the detection report was forwarded to the medical services and to the field units in order to tailor medical aid and unit protection. A remote expert provided additional advice using video and audio. The expert could interact with the decision support system and collaborate with the staff members in order to solve the issues at hand. Network-connected simulated sensors and detection equipment were used to make the scenario more realistic and illustrate the possibility to seamlessly integrate both real and simulated services during demonstrations and exercises.

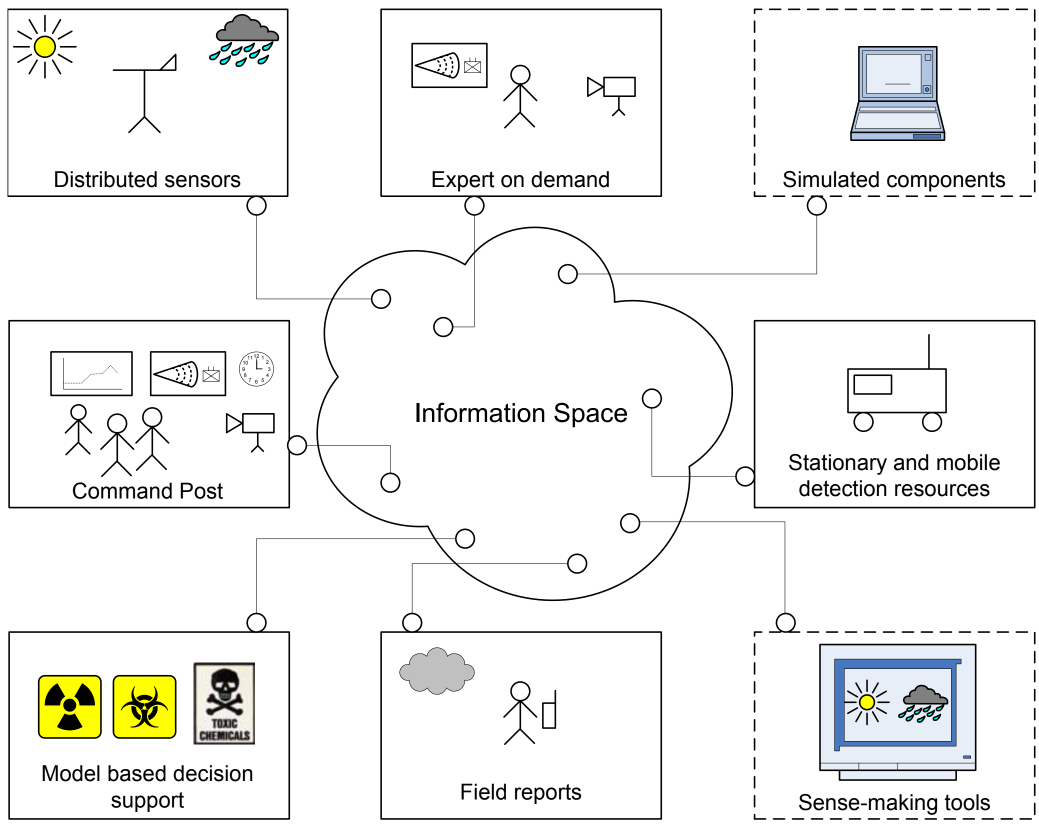

Figure 4: Overview of a test bed demonstration. The Information Space supports dynamic connection of various services such as sensors, models, experts and units. The lines in the figure between the functions and the information space illustrate communication links.

The demonstration was conducted at the NBC Defense Centre for a group of NBC officers and researchers. In the demonstration, the participants assumed the roles of staff members at the command post. We guided them through the scenario and demonstrated the various support services. The purpose of this interactive approach was to include the participants in the scenario and subject them to the flow of information through the information structure at the command post. In this way, we stimulated a discussion of the consequences of moving towards network-centric management of NBC events.

Investigation areas

In the following section we briefly describe areas that we have investigated and that we think have great potential in combination with our CBRN command and control test bed. Knowledge and experience in these areas can support the iterative development process of a future network-centric decision support system by illustrating the strength of dynamically connecting services and functions to solve complex problems during time-critical operations.

Dispersion models

Today, dispersion models are fundamental building blocks used in all CBRN decision support systems. A great number of models are available, although not all are adopted for operational use and validated for use with agents of mass destruction. In many cases, input data are impaired by uncertainty, which makes prognoses less valuable. An alternative to calculating dispersion areas using dispersion models is the use of a standard template, for example the ATP45B. New as well as encapsulated existing models for prediction of dispersion will be evaluated in the test bed using realistic scenarios. The concept of loosely connected services will allow for a straightforward approach to this problem.

Wireless information and warning of CBRN incidents

Warnings and instructions are functions that immediately can limit the negative consequences of an attack or incident by making military or civilians on their way into or passing through the incident area aware of the threat, thus increasing the possibility for them to avoid the hazard. With the increased use of individual cellular phones and the infrastructure of the emerging high-capacity wireless networks new possibilities arise to reach most of them in a specific area.

Already today, the wireless networks have increased the ability for the public to report incidents and emergencies to rescue authorities. Jenvald, Stjernberger, Nygren and Eriksson (2002) explored the possibility to take additional advantage of the wireless networks in order to deliver selective early warnings to people in or close to a hazardous area. Sending appropriate information in a comprehensible format requires that the target audience can be identified, for example based on geographical location, means of transportation, movement in relation to the incident, and language preferences. Stjernberger, Eriksson, Rejnus and Jenvald (2003) investigated criteria for selecting the target audience, means of customizing message contents, suitable media, and technical requirements and limitations.

Modeling and simulation support for development of tactics and technology

Modeling and simulation can support the development process in multiple ways (Jenvald, 1999b). By the development of virtual platforms it is possible for decision makers and their staff to improve the use of exclusive and limited resources during cost-effective trials with realistic scenarios. Further on in the development process it is possible to combine real units with virtual units controlled by operators in mock-ups (Hasewinkel & Lindoff, 2002). Finally, the system can be tested on real units during live scenarios. During these field trials modeling and simulation can be used to simulate hazardous substances and artifacts to provide a higher degree of realism without putting the participants at risk and to support monitoring of the participating units in order to provide accurate assessment of the performance.

New models for prediction of the dispersion of various agents can be evaluated in the test bed during tactically realistic scenarios. In this way it is possible to balance the accuracy and speed of the developed models to give the best operational value for a specific cost. New strategies for model use together with novel visualization techniques can also be evaluated and assessed in the test bed.

Wireless consumer products and services

The fast development of wireless consumer products affects our society and how we communicate with each other. New products that integrate positioning services, cameras, video cameras, voice and data communication can provide information from the public to emergency organizations as well as to the media. In recent emergency events, information has been sent live from individuals on the incident scene to news services and media companies for immediate broadcasting on television and the Internet.

To some extent, this technological development make it possible for every individual equipped with a more or less advanced wireless consumer product to become a live sensor in the information space. The challenge is still to take advantage of the information and to find and develop relevant mechanisms to retrieve, filtrate and use the information to limit the consequences in the emergency situation. Figure 5 illustrates this development in a hypothetic CBRN scenario.

Figure 5: Use of wireless consumer products as data sources in CBRN incident management. An incident has occurred and people in the neighborhood have used their wireless devices to provide information from the incident area to an emergency operation center, where the information is retrieved and made available to decision makers.

Information retrieval from the Web

Several organizations in our society have or are developing systems that contain information that can contribute to the decision making process during a crisis. Some of these organizations make their information public on the Internet, others distribute the information on a commercial basis, and some only use their information internally. Making this information available on the web enables other organizations to take advantage of it in their decision processes.

One strategy for sharing information is to agree on common data formats and metadata sets. The Semantic Web (Berners-Lee, 1999) initiative is in line with this approach.

However, the cost of redesigning web sites to adopt the common format may deter some prospective partners from participating in the exchange.

Another strategy is to use the information on the Internet as it is. Robot software can be configured to interact with web sites in the same manner, as would a human user. Applications can use the Internet as its database; if the information is there, use it. State-of-the-art products simplify robot programming to the extent that customized robots can be used regularly with a low frequency to make sure that the information retrieval will function if a CBRN incident occurs. The same principle can easily be used for gathering and storing domain information as a service in case of an international mission. The possibility to use either Internet or other communication channels increase to a great extent the flexibility and robustness of the decision support system. Our test bed will be used to evaluate services that use web robots to collect information.

Assessment and Training

In order to develop and maintain the readiness to respond to different emergencies the responding organizations in our society need to systematically develop and train in their different professional roles. In crises that affect large parts of the society, such as CBRN incidents or terror attacks, the organizations also need to cooperate efficiently in order to manage the crisis. Methods and tools are needed both to support efficient training of different taskforces, but also to support assessment of new tactics, organizations and technology.

To provide effective feedback, methods and tools to present representations of operations have been developed and used to support after-action reviews in military settings as well as in emergency management and response (Jenvald, 1999a). Morin and colleagues (Morin, Jenvald & Thorstensson, 2000) described how models of rescue operations built from multiple sources of data could support analysis and feedback. Applications of this method include training (Morin, Jenvald & Crissey, 2000, Crissey, Morin & Jenvald, 2001; Morin, Jenvald & Crissey, 2004) and real operations (Morin, 2002; Thorstensson, 2002). It has also been used to investigate communication in command and control (Thorstensson, Axelsson, Morin & Jenvald, 2001; Albinsson & Morin, 2002; Albinsson, Morin & Fransson, 2003).

Discussion and conclusion

To respond to present and future WMD threats, our society must make CBRN decision support an integral part of its crisis management network. The development ahead requires coordinated efforts from people in multiple disciplines, including researchers, subject-matter experts, system operators, system developers, and decision makers. The approach we have presented in this paper is a way of demonstrating new technology to key personnel in the context of a relevant scenario. The combination of real and simulated entities can increase the complexity of the scenario to present a more realistic situation, which can stimulate discussions about our preparedness, and how to improve it. Another goal of our approach is to illustrate how important it is to use different information sources and to exchange information between organizations, whether they are military or civilian.

In this paper we have presented a network-based approach for a future CBRN decision support system. We have presented the use of a test bed as a means of iterative development and given practical examples of how we have used the test bed for the illustration of the network centric approach during a live demonstration. This is one example how the use of a test bed makes it possible to include real users early in the research and development phase and how it is possible to test the various components through the common information space. Finally, we have also described six investigation areas that are relevant for the future development.

Interoperability between systems enables seamless data exchange, which, at least in theory, enables the integration of information. However, information is the result of interpreting data in the light of previous knowledge. In the difference between abundant data and useful information lies a great challenge for sponsors, designers, and users of future network-centric systems. Human factors and cognitive aspects of different data representations are therefore of critical interest, but often overlooked. Involving users in the loop is one way of ensuring that designers and developers pay proper attention to those issues. The test bed approach promotes this undertaking by offering an environment that is powerful enough to allow integration of multiple services, while being easy to use and reconfigure to shifting experimental needs. Alternative representation and presentation styles can be tested and evaluated to find effective solutions for supporting the decision makers.

Particularly in the CBRN area, multiple agencies must coordinate their efforts to meet the expectations of users of many professions with varying perspectives on problems and priorities. An experimental approach, using modeling and simulation to present believable representations of alternative scenarios and solutions, may enable users to reshape their own roles and those of their colleagues.

To conclude, the need for pedagogical tools in a time of great change must not be underestimated. We argue that it is crucial to explore new approaches and to expose them to experts and users in the work towards efficient methods and tools for future crisis management. The ongoing process of information age transformation in the defense area requires that people start thinking and acting in new ways. Not only does this development process require visions of the future, but it also calls for practical and tangible examples. We believe that our project can contribute to bridging the gap between vision and reality in the CBRN area.

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