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Bridging Resources and Agencies in Large-Scale Emergency Management

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D4.1 BRIDGE Summary of Technologies and Standards of Existing Emergency and Crisis Management Systems

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The goal of BRIDGE - Bridging Resources and Agencies in Large-Scale Emergency Management - is to increase safety of citizens by developing technical and organisational solutions that significantly improve crisis and emergency management. The key to this is to ensure interoperability, harmonization and cooperation among stakeholders on the technical and organisational level. Technical interoperability is crucial for improving multi-agency collaboration and continuous training, but its full potential can only unfold, if technology can be integrated and sustained into agency workflows and communication processes. Making available an increasing amount of data for crisis response systems has to be accompanied with developing intelligent human-computer interaction models to make this data usable.

This deliverable presents an overview of products in the field, including middleware, Triage technology, mobile technology and support for fire fighters. Included are products from the consortium partners, existing commercial of the shelf products and open source products used in practice.

Furthermore, an overview of R&D projects aiming at products related to BRIDGE is given. The development of the BRIDGE project is not realized in isolation. Related European Projects presented in this deliverable can be taken into account for pinpointing common research goals, overlapping domains, and opportunities for connecting or adapting to technologies and practices in emergency response and crisis management from related projects.

Finally, architectures, models, standards and protocols developed by organisations oriented towards command and control (C2) are presented. They form an invaluable source of information for the implementations of the BRIDGE project, since they provide already applied knowledge in the field.

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SEVENTH FRAMEWORK PROGRAMME

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1 Introduction

The goal of the BRIDGE is to develop a crisis management system to support interoperability – both technical and social – in large-scale emergency management. The system will serve as a bridge between multiple First Responder organisations in Europe, contributing to an effective and efficient response to natural catastrophes, technological disasters, and large-scale terrorist attacks.

The results of BRIDGE should not force development of new devices, applications and technology in order to be used by developers. To embed our services and components on existing devices and to connect our services to existing applications and technology, they are analysed and interfaces to devices and applications tested. As a side effect, a deeper knowledge is acquired about drawbacks of existing technology to avoid falling into similar traps.

Therefore, in this deliverable, an overview of state-of-the-art devices, device classes, network communication technologies, existing services and applications, and standards is provided. The deliverable focuses on available commercial/open source commercial of the shelf products and freely accessible products of BRIDGE partners, and of national, European and international R&D projects within the emergency response and crisis management domain.

The deliverable is organized as follows. Chapter 2 presents the products readily available in the field, including those from the consortium partners, emerging commercial of the shelf and open source products. Chapter 3 provides an overview European projects which deliver products relevant in the context of the BRIDGE project. Finally, in Chapter 4 an overview of architectures, models, standards and protocols is provided.

2 Overview of Existing Products

This chapter provides an overview of state-of-the-art technology and technology-related knowledge related to crisis management, brought in by consortium partners, or available as existing commercial of the shelf products and emerging open source products. The overview includes a range of existing middleware solutions (Section 2.1), solutions for triage (Section 2.2), mobile technology based on sensors and smartphones (Section 2.3) and specialized support for fire fighters (Section 2.4).

2.1 Middleware

2.1.1 Hydra/Linksmart

The Hydra project researched, developed, and validated a middleware platform for networked embedded systems that allows developers to develop cost-effective, high-performance applications for heterogeneous physical devices.

The middleware constitutes a software layer between the operating system of software enabled device and a user application that communicates with that device. The middleware provides protocols that execute on top of the transport layer and provide services to the application layer. “Hydra Managers” constitute the major building blocks that make up the middleware. A Hydra Manager encapsulates a set of operations and data that realise a specific functionality.

The Hydra/LinkSmart [1] middleware offers a large collection of reusable core software components to experienced developers. Based on these software components, programming abstractions allow for programming with well-known concepts from the field of networked embedded systems applications through reducing the complexity and details of the underlying implementation.

It has to be noted that due to trademark rights, the name “Hydra” couldn’t be used for the middleware when marketed after the end of the project. So the partners registered the commercial name LinkSmart.

2.1.2 AgentScape

AgentScape [2] is a middleware layer that supports large-scale agent systems. The rationale behind the design decisions are (i) to provide a platform for large-scale agent systems, (ii) support multiple code bases and operating systems, and (iii) interoperability with other agent platforms.

The overall design philosophy is “less is more,” that is, the AgentScape middleware should provide a minimal but sufficient support for agent applications, and “one size does not fit all,” that is, the middleware should be adaptive or reconfigurable such that it can be tailored to a specific application (class) or operating system/hardware platform.

Agents and objects are basic entities in AgentScape. A location is a “place” at which agents and objects can reside. Agents are active entities in AgentScape that interact with each other by message-passing communication. Furthermore, agent migration in the form of weak mobility is supported.

Objects are passive entities that are only engaged into computations reactively on an agent’s initiative. Besides agents, objects, and locations, the AgentScape model also defines services. Services provide information or activities on behalf of agents or the AgentScape middleware.

2.1.3 CHAP Toolkit

The CHAP toolkit [3] is a collection of tools for building multi-agent software solutions. It has been developed by Almende, and incorporates years of experience of the research and development of the company.

A fully functioning self-organized system makes use of the autonomy of individuals to achieve its goals, thereby creating a network of people who can act independently. Software agents can be used to represent and aid each person in this network. Agents may also represent an object, an organization, a concept or a specific goal; any action or object in the real world.

Agents function in *"hypertime"*: they can communicate and coordinate much faster than humans can. An agent functions like a personal assistant to the person or object it is assigned to, working to achieve the goals for their real life counterpart. Individual agents can facilitate quick and frequent communication, help making and keeping appointments, negotiate deals and track activities.

There is no central structure which is implemented from above. Each agent determines its own actions and negotiates and coordinates with other agents in the system. They can adapt to new situations and information, which is important if the software is to be implemented in a real dynamic environment. Agents are designed to ask for feedback if they are confronted with a problem they cannot solve by themselves. They are not programmed for each eventuality, but to learn from experience and implicit feedback.

EVE, a multipurpose web based agent platform, and CAPE, a context-aware programming environment, are two of the technologies under the CHAP's technological umbrella and are presented in the following subchapters.

2.1.3.1 Eve

Eve [4] is a multipurpose, web based agent platform. It envisions being an open and dynamic environment where agents can live and act anywhere: in the cloud, on smartphones, on desktops, in browsers, robots, or home automation devices. Eve tries to mimic human society in the way people interact and work together.

Eve agents are connected with each other via a web-based communication protocol. Each agent has its own unique URL on the web, and can be located on any server. The agents communicate with each other using simple, existing protocols (JSON-RPC) over existing transport layers (HTTP, XMPP). The used protocols are language and platform agnostic, which gives complete freedom to develop, run, and interconnect agents anywhere, anyhow. In general, Eve aims at:

- Robustness: Get system robustness through loosely coupled, asynchronous, self-contained elements.
- Flexibility: Flexibly add and remove system capabilities.
- Reduced complexity: Reduce the complexity of designing, developing and managing a distributed software system.
- Scalability: By designing the application around the local "worldview" of the agents, no scalability limitations are imposed by the shared datastructures and locking requirements.

Eve is a free open-source platform, and the public is encouraged to help extending the platform by providing new libraries, create implementations in other programming languages, and improve existing code.

Eve is able to set up the platform of agents for the BRIDGE project, always parameterized in the needs of consortiums' goals. Additionally, Eve can be used to set up a large simulation environment under crisis conditions. Making use of the scalability and options for parallel and asynchronous processing of Eve's agent platform these simulations could be easily implemented. Furthermore, web services can be made available for the emergency management software agents by creating a simple "wrapper agent" for them.

Moreover, existing emergency management software systems can be linked to the world of software agents by creating "wrapper agents" for these systems as well. This way it is possible to link completely separated software systems together via agents, even when the software systems are developed in different development environments or are deployed on different locations. In that way all of the already developed technologies could be utilized by being merged from Eve.

Finally, Eve can be used as the intermediate to link different services that are acting on the emergency management all together. For example one can abstract from different notification systems by creating agents having the same interface but linked to a different notification system.

At the moment, in the BRIDGE project Eve is used to model and support the various emergency response resources involved. Through negotiation between Eve agents, ad hoc groups of resources are formed to handle tasks. The agents also obtain, aggregate and interpret sensor data, which is then communicated to field commanders and to other agents, thus providing situational awareness. The Eve agents are run on a cloud platform and on mobile smartphones, whereas the communication between the Eve agents and other components of the BRIDGE platform is done through the EDXL-RM protocol. [108]

2.1.3.2 CAPE

CAPE [5] stands for Context-Aware Programming Environment. It offers an interface both in the cloud and on mobile devices to contact or notify a user via any available media, access real-time status information of a user, and retrieve past and future planning of the user. The information sources can be for example calendar information, sensor information, and information from social media.

CAPE's framework bridges the gap between cloud and mobile devices. Via a low-level message bus it synchronizes the users' state and available media channels between mobile and cloud representation of the user. The CAPE framework makes it possible to contact a user from both mobile or cloud, via any available media such as chat, mail, phone, web app, or social media. In the same way, any of the users contacts can be contacted from everywhere via any media channel. The state of a user or any of its contacts can be retrieved immediately via the API.

Alternatives or supplementary of the CAPE could be the AWARE and COMPASS frameworks, which are briefly explained below.

AWARE [6] is an Android framework dedicated to instrument, infer, log and share mobile context information, for application developers, researchers and mobile phone users. The framework follows a multiple layers theoretical architecture, and each one of them emphasizes on specific research areas. At its current state the software is designed in order to collect information provided by the sensors of the Android device it runs on. Additionally, AWARE gathers information relevant to the user through the cloud as well, e.g. social networks and profiles.

COMPASS (COntext-aware Mobile Personal ASSistant) [7] on the other hand, is an application that provides the tourists information and services of any possible kind at any given time, based

on the interests and the requirements of them. The COMPASS software is open source; its openness makes it easier to be implemented in other domains further than this of tourism. COMPASS is able to capture information relevant to the position of the user and additionally his profile and goals. Taking advantage of this information the software can assist the tourist to call nearby friends of his, reserve tables at restaurants close to him, or even book tickets for the cinema and the theatre.

The AWARE framework at its current state is a well implemented solution for hardware sensing and tracking of the user's physical activities. Additionally, the COMPASS framework comes to fill in the gap of the POIs proposals to the user. In this sense, CAPE could incorporate in its code features of these two open frameworks and evolve to an even more complete solution.

CAPE could be integrated in the BRIDGE project as an enabler for connecting context awareness and communication / information exchange. The agents of CAPE can enable the automatic communication between the injured personnel and the rescuers. Rich content information may be delivered to the rescuers, including the health status and position of the injured people. And this content could be delivered to any device the rescuers have available at the time. Since multiple platforms are supported from the framework, the possibilities for it to be utilized in case of emergency are multiple as well.

2.2 Triage

Triage is the process whereby, in a mass-casualty situation, with scarce medical resources, priority of treatment is determined for the victims. The aim is to achieve the maximum number of survivors, even if this might mean deliberately withholding treatment from people whose chances of survival are minimal no matter how much help they get. There are several methods to determine treatment priority. The best-known one is START.

2.2.1 The START triage method

Simple Triage and Rapid Treatment (START) [8] is a method developed in 1983, but whose simplicity stood the test of time. It helps first responders have a grip on the situation and assign emergency resources to where they are most needed.

The START method divides victims into four groups according to seriousness of their injuries. Each victim is marked with a *triage tag* -- a piece of paper, clip, ribbon, or tape with one of the following colors:

- Black: Deceased or Expectant, i.e. with such extensive wounds that chances of survival, even with medical care, are very low. Treatment shall not be given to these victims, except comfort care (painkillers or similar measures).
- Red: Immediate care required. Victims who are alive and who will survive if care is provided to them immediately.
- Yellow: Delayed. Victims whose injuries are serious, but will survive without treatment for the next hour. Therefore, their treatment may be delayed to free resources for the red victims first.
- Green: Minor, or "Walking Wounded". Little care is required for these victims like, for instance, bandages or disinfectant. They may be treated days later, as their wounds will not impact their survival.

In the START method, the person performing the triage gives no treatment. The only intervention allowed is to unblock the throat and position the victim so that s/he has no impediment to breathing. Victims who do not breathe on their own are automatically assigned black. Victims who breathe on their own are checked for breathing rate and pulse. A rate of more than 30 breaths a minute or lack of pulse categorises the victim as red. A victim who does not follow simple commands, or whose capillary function takes longer than 2 seconds to balance blood circulation under the fingernail (blanch test) is also tagged red. The mnemonic for red is "30, 2, can do", meaning if breathing is more than 30, OR capillary refill is more than 2 seconds, OR victim does not follow commands, then the victim is tagged red. An overview of the START algorithm is given in Figure 1.

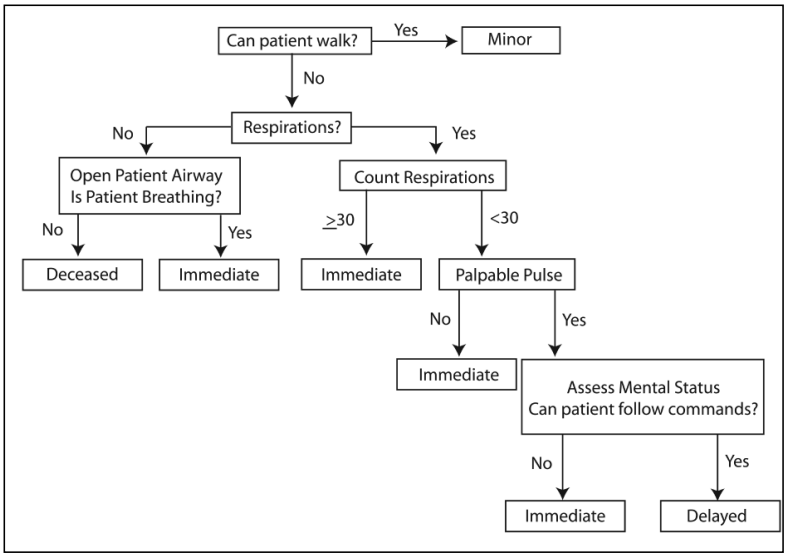

Figure 1: START algorithm

The START system is not appropriate for children, whose breathing rates are normally elevated and who may not respond to commands simply because they do not understand them. Therefore Paediatric START was developed, to take this into account.

The colors used in triage tags vary by state and region, but most agencies agree at least on the usage of red-yellow-green. Hopeless and deceased victims are tagged with either black or blue, but agencies tend to differ in this.

One of the most used tag formats is the MET tag, made of paper, as depicted in Figure 2. Paper tags usually feature empty fields to be filled in with personal data and observations, enabling communication between responders and doctors in the hospital.

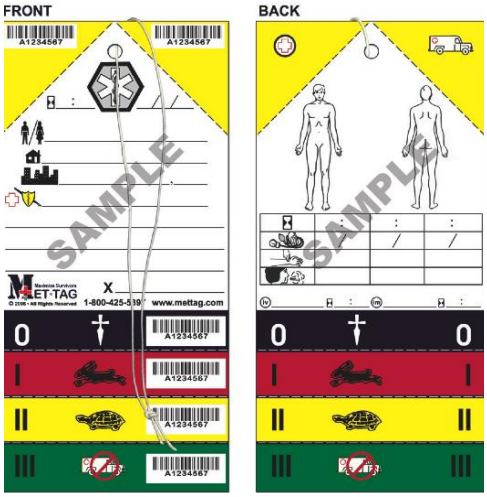

Figure 2: The MET triage tag

In addition to the color coding, this tag provides space for:

- time and date of triage (to help determine the progress of the victim's situation; victims may be retriaged at a later time if their condition changes or the available resources are less than previously thought)
- victim's personal data
- location of injuries as well as two small triangular tags (upper left/right) for attaching to severed body parts
- History of medication for this particular incident (IV/intramuscular medicines, blood pressure, other vital signs)

For Bio/Radioactive/Chemical hazards, the MET tag is augmented by another one detailing the particular danger and the decontamination history.

There is no standard for triage tags and the information that must be on them. This has allowed competing companies to put forward competing designs. So, additionally to MET tag, there is the SMART tag (cf. Figure 3), where color categorisation is achieved by folding the tag appropriately rather than tearing off the unneeded colors.

Figure 3: The SMART triage tag

Because the most important element in triage is the severity, any suitably colored object can be used to improvise a tag. Figure 4 shows Capt. Anthony Jarecke from the US Military during a triage exercise, using clothespins as triage tags

Figure 4: Clothespins used as triage tags

A third company has developed LED lights that can be programmed to light up in any of the four triage colors (cf. Figure 5). According to the inventors, they are better than chemical light sticks and can also indicate a series of conditions via blinking.

Figure 5: Electronic triage lights

There are, however, no published studies or references on the website showing whether such lights, beyond their long battery life, have any measurable advantage compared to traditional triage.

2.2.2 Alternative methods of assigning a priority

While the basic triage process remains the same, alternative methods of assigning priority have been proposed. They aim to improve categorization and reduce over- and under-triage.

2.2.2.1 Revised Trauma Score

The Revised trauma score is based on a combination of the Glasgow Coma Scale, Blood pressure, and respiratory rate. Tables exist that translate each of these values to a number of points. The sum of such points (0-12) categorizes someone as green (12), yellow (11), red (10-3), or black (2-0). While this method is more objective, the calculations needed to carry it out are relatively complex and time-consuming. Specially constructed tables are used to make it easier, but the potential for mistakes is still not negligible.

2.2.2.2 Injury Severity Scale

This scale is based on human anatomy; it divides the body into six regions and assigns a score to each of them. The total score is then the sum of squares of scores for the three most injured regions. If any of the three scores is 6 (Maximal damage), then the total ISS score is set to 75

(the maximum). This method is objective but can pose problems in times of stress and emergency, when doing calculations in the head may not be easy for all first responders.

2.2.2.3 CareFlight

When time is of paramount importance, the CareFlight system may be used, since it requires on average only 15 seconds per victim. The system is based on a simple flowchart that takes into account whether the victim can walk, obey commands, has a pulse, and is breathing. It requires no calculations and has a straightforward application (cf. Figure 6).

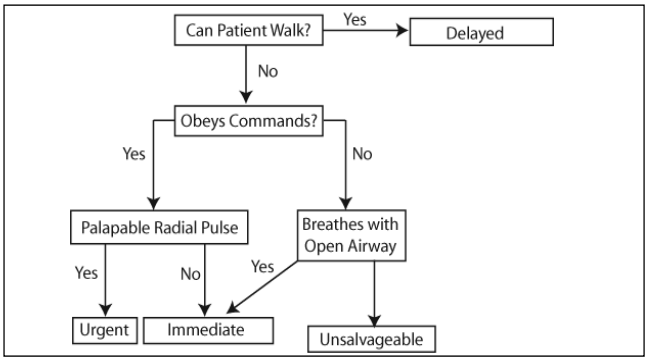

Figure 6: Flowchart of the CareFlight system

2.2.3 Electronic Triage

Triage tags have several inherent disadvantages [10]. Firstly, they may be unavailable at the time of need. Second, they may be unreadable because of darkness/weather. Third, for MET-like tags, as portions of tags are torn off, they can show a worsening condition of the victim, but not an improving one, thus resulting in overtriage. Such tags are best for situations in which victims can be transported directly to a care facility.

Several attempts have been made to augment or change the process of triage, to incorporate electronic data processing and gathering. They have tried to replace the paper tag by an electronic version, or to use PDAs and other mobile devices to gather data. Massey et al. [14] investigated many of the same challenges that we have ahead in BRIDGE. The authors built a hardware tag incorporating signalling and communication capabilities. The tag has its own operating system which has been optimized to build a mesh network between tags (since it cannot be assumed that there will be connectivity in the disaster area). Patient triage category is shown via LEDs and set via repeated pressing of a hardware button. The tag has an extra LED that blinks in sequence with the patient's heartbeat, and yet another one that can be set to light if decontamination is necessary (e.g. in a chem/bio/radioactive incident). The tag also has a password button to prevent victims from changing the triage category themselves in order to receive preferential treatment. Sensors are included to monitor blood pressure, heartbeat, and victim's geographic position (for tracking victims who are in need of help, yet able to walk on their own.) A user study was carried out with several first responders. The important points found -- which may also be important for Bridge -- were as follows:

- Locating the patient was not very important, since the area is cordoned off anyway and each paramedic typically checks a relatively small area. This situation may be different for BRIDGE, as the commanders will need location info for resource planning purposes.
- Setup time for the system had to be very short.

- Operation time should be in the several days range.
- Sensor packaging must be resistant to decontamination procedures if sensors are to be reused. They also must be resistant to dirt, weather, blood, and other typical contaminants at an incident scene.
- The connector for the tag should be attachable to any of several points in the body, as the wrist or the neck may be too fragile or too damaged to move, thus making it impossible to hang the tags there.
- Red/Green/Yellow tags may be problematic for color-blind responders. The tag should be designed in such a way as to make the category unambiguous and immune to color-blindness.
- As much ID data as possible should be gathered as soon as possible about the victim. This includes reading the drivers' licence or ID card data on the spot; the systems developed should integrate such abilities.

Kojima et al. developed an electronic triage tag intended to replace the paper tag [15]. After being attached to an injured person, the tag continuously senses the vital signs. So, medical staff is able to monitor changes in conditions in real-time. This is a huge advantage over the traditional way of doing triage because the conditions of victims can change rapidly. In the traditional way of triage this can often be overseen. The new system, however, alarms the medical staff in case of rapid deterioration of health.

The information can be accessed via iPhone (cf. Figure 7). The app also offers the possibility to determine the tag color when doing the triage. The tags use LED lights to visualize the color of the category like the triage lights do [12].

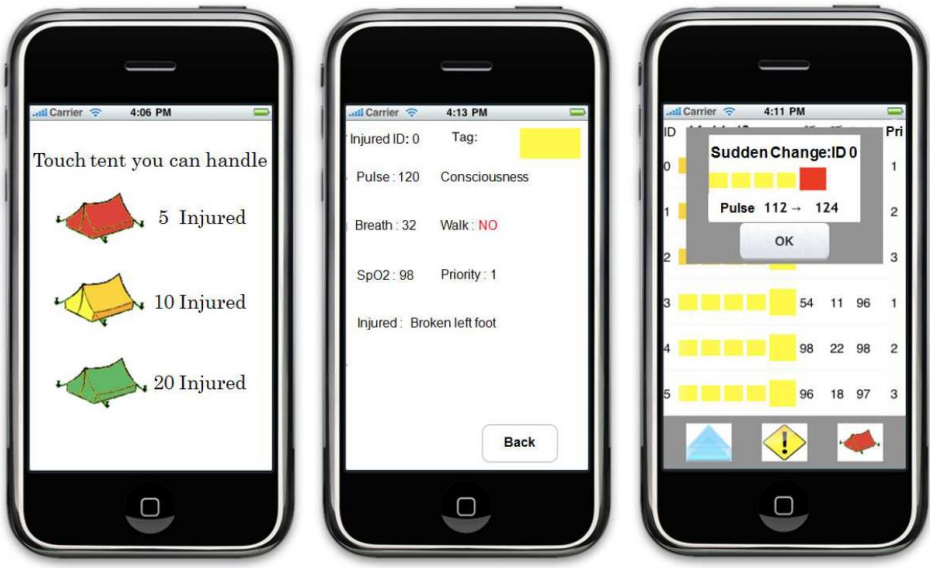

Figure 7: User Interface of work of Kojima et al.

Besides monitoring of health conditions of individuals, the App can also give an overview how many people are assigned to which category. This is also information which is harder to access in the traditional way of triage.

Inoue et al. replaces the traditional paper tags with RFID based tags [16]. They also introduce several new devices like RFID readers and terminals for the different stations of ambulance, hospital and operation point. Information which has been read by any RFID reader is distributed to all relevant stations. This offers not the continuous supervision of the system of Kojima et al. [15] but speeds up the distribution of information and makes it more robust. The assumptions were evaluated in an experiment with professional first responders.

2.2.4 Challenges

First responders usually come to unfamiliar environments where they have to orient themselves first. Information which could serve as a basis to orient and take decisions is often incomplete and unreliable, for instance, reported information about number and status of victims may be incomplete or wrong [11]. There is often time pressure and seconds can be crucial for life or death. Hence, quickly understanding a situation is an important and difficult task for first responders. It is also important to share information among distributed team members and between first responder teams so that information does not need to be acquired twice and time can be saved, and a shared sense of the situation can be produced [8]. Moreover, the provenance and design of information matters: Information from team members can be more concise, 'fit for purpose' and reliable than information that bystanders can provide. In this stressful situation, the single process steps are well-known, clearly defined and easy so that the work is performed as routine [13].

Since the work processes of first responders are so special and have their very special requirements, introducing new technology must be designed keeping the characteristics of first responders' work in mind. Having this in mind, related work that attempts to enhance triage did not analyze the current work processes in enough detail. Several challenges to interface and triage process which have been identified in the surveyed works have not been addressed:

1. The less the current work process is changed, the higher is the probability that the new process is adopted
2. Interaction should be simple, to be easier to integrate in work process routines
3. Only relevant information, no information overload
4. Interaction should consider first responders' equipment, e.g. gloves
5. Technology must not be held in the hand all the time to guarantee hands freedom for the rescue work

Within the BRIDGE project, these challenges are being addressed extensively. There will be two focuses: How can the actual process of triage be enhanced? How must the interface be designed to access the information electronically?

2.3 Mobile technology

In the last decade mobile products decreased in size, though at the same time became increasingly powerful regarding their central processing unit, data storage, graphical representation and more. Simultaneously, recent progresses in sensor network research allow for the deployment of small and cheap sensor nodes. Therefore, two necessary steps for mobile data collection have been achieved in order to attach different types of sensors on a carrier medium as a human, a vehicle, or a robot.

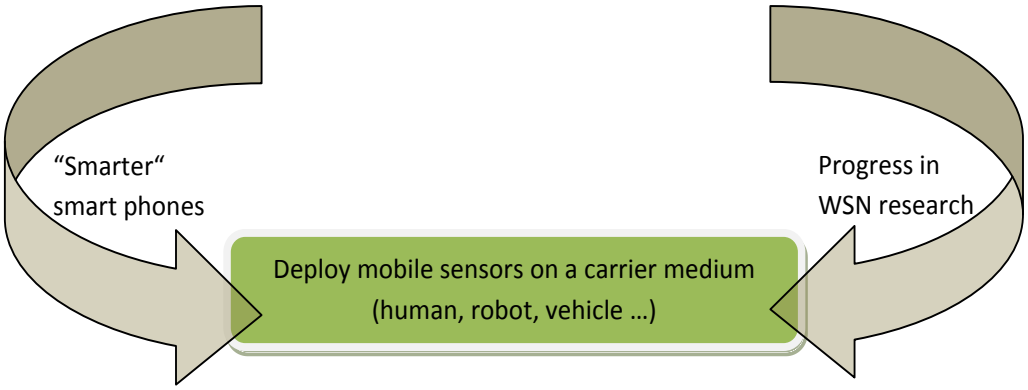

Figure 8: Technical Progresses facilitates to develop mobile sensing applications

A wireless sensor network (WSN) facilitates to observe actions in the real world. Each sensor node sense changes in its environment, then processes on behalf of it, forwards it to another sensor node or to a central unit. By deploying several sensors in a given scenario a lot of data is obtained about physical values, e.g. temperature, humidity, lightning condition, carbon dioxide level, magnetic field, heart beat etc, and additionally measurable are acoustic and visual impressions. A huge choice of options offers using WSN applications in a number of scenarios, e.g. environmental monitoring, e-health care, military surveillance, emergency response, smart home, or tracking animals in wild life or preserved lands.

In general, three types of mobile communication in emergency response settings can exist (see below):

- First, the underlying infrastructure, i.e. cell towers providing GSM/UMTS communication.
- Then, there is ad-hoc deployment of diverse dedicated devices at a disaster site, e.g. sensor nodes placed by fire fighters or a WiFi access point on top of a fire truck.
- Finally, there might be devices being capable to interconnect, even if the underlying infrastructure is unavailable. For instance, cell phones might be able to interchange messages via Bluetooth or WiFi communication.

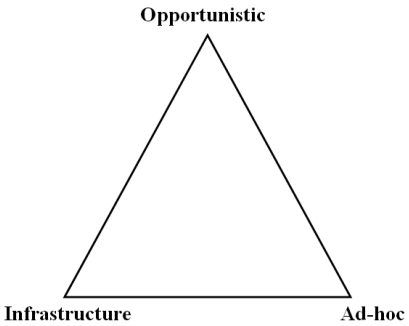

Figure 9: Three Types of Network Communication

For response work at a disaster site it is beneficial to gather and retrieve data through a mobile network. This network can be represented either as an ad-hoc or opportunistic network (see Figure 9). All collected data is fed into a so-called *backbone system* where it can be used to perform risk, impact and threat analyses outside the actual network, because it would require more processing power than sensors in the field possess. An example of such an analysis is the process that aggregates data and visualizes it in 3D models. The first part of this section deals with the concept of mobile sensing, and the latter one lays out the topic wireless ad-hoc networks.

2.3.1 Mobile Sensing

People carrying smart phones are enabled to collect data in ways previously impossible. This technological instrumentation is described as *mobile sensing*. The key benefit of mobile sensing consists in the mobility of a carrier medium collecting data over a wide region and a given period of time. A backbone system receives data from each mobile sensor node, aggregates and processes it, for instance to enable people in charge to better cope with highly dynamic and complex phenomena, such as traffic jams in and around large cities [69]. Further, mobile sensing can provide coverage in environments where it is difficult to deploy and maintain static sensors due to natural weather conditions or terrestrial conditions [72]. In the sense of the BRIDGE project, mobile sensing is a relevant technological approach, able to offer dynamic services upon an opportunistic network infrastructure. The following delimits the terms *participatory sensing* and *opportunistic sensing*.

2.3.2 Participatory and opportunistic sensing

Participatory sensing describes the collection of data via mobile sensor nodes in close cooperation with the owner of a device. In this case, the user is fully involved in the process of collecting data, and consciously and actively in control of what type and amount of data is captured by the system. Hence, such personal data collection does not automatically represent a real benefit for the common good. Only, if this data is shared with other users, new perspectives on the dataset arise from aggregation and analysis. However, employing handheld devices as sensor nodes poses new challenges for privacy, data security, and ethics as well. In this context, Shilton et al. introduce the concept of participatory privacy regulation arguing that privacy must be a participatory process that takes into account both individual preferences and social settings [79]. As the individual needs and preferences change according to social situation, negotiations over data capture and sharing this data cannot be separated from a user's context. For instance, in terms of emergency response a victim may fill out a survey encompassing several observed data describing the critical environment, or a bystander can take a photo from a specific angle of a disaster site.

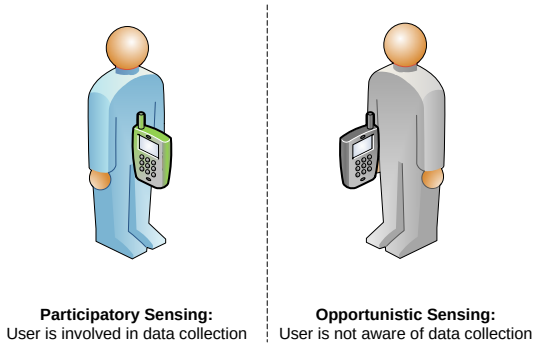

Figure 10: Differences between Participatory Sensing and Opportunistic Sensing

Opportunistic Sensing, in contrast, describes the data collection via mobile sensor nodes without requiring permanent input from the owner of the phone, i.e. the user remains unaware of the data being collected while she is interacting with her environment [77]. For example, with regard to emergency response an application running on a smartphone may facilitate continuous remote access to the microphone and GPS sensor data of a moving citizen inside the crisis zone. Of course, an opportunistic sensing application needs to provide the user with means for configuration, in order to maintain a pre-defined accepted level of privacy, but compared to participatory sensing the user does not intervene in the application's process of collecting data. Opportunistic sensing does not interfere in the user's private processes and activities. Applications that are based on a continuous acquisition of data would be hampered by permanently waiting for a user to react to system requests. To which extent a user is willing to react to requests within a sensor network or to gather data using the sensors available is a central question that has been partially answered in literature (Lane et al., [74]). The preliminary analysis of Lane et al. shows that an opportunistic sensing design approach yields a system that rather supports large-scale deployment and application diversity.

2.3.3 Smartphones as Sensor Nodes

Living without a smartphone has become nearly impossible nowadays. Increasingly, smartphones become smarter and smarter, as they are equipped with a range of sensors: GPS, compass, temperature, acceleration, integrated camera, light sensor, accelerometer, and more [73]. Each sensor allows the gathering of potentially rich data of the environment and of the person using the phone. As people carry cell phones nearly everywhere they go, these phones can act as nodes in a WSN and thus may represent an opportunistic source for collecting meaningful data in favor of the common good. With the ubiquity of cell phones and their (cellular) networks, the infrastructure is already provided for diverse applications that may explore and exploit the context of their users. For instance, smart phones allow perceiving contextual data about the location of the user that is mapped to a certain instant of time.

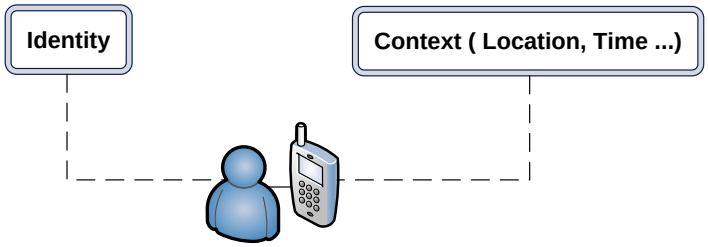

Figure 11: Smart Phones embedded with sensors support to infer contextual data

2.3.4 Mobile Sensing Applications

The leading organization in research of mobile sensing is the CENS institute [81]. Mobile sensing applications have been deployed in diverse scenarios, though not yet in the critical and dynamic domain of emergency response. With regard to the BRIDGE project below we focus on three domains: environmental monitoring, urban planning, and healthcare.

2.3.4.1 Environmental Monitoring

In the CommonSense project, cell phones are deployed as environmental sensors that allow citizens to collect pollution data in their neighbourhood and actively participate in influencing environmental regulations and policies [82]. Smartphones are equipped with gas sensors for carbon monoxide (CO), NOx and Ozone (O_3), and sensors for measuring temperature and humidity. The sensor board communicates the measurements every 60 seconds via a Bluetooth

protocol to the smartphone (see Figure 12). From there the data, including the GPS position, is sent via SMS to a remote central server where it can be visualized.

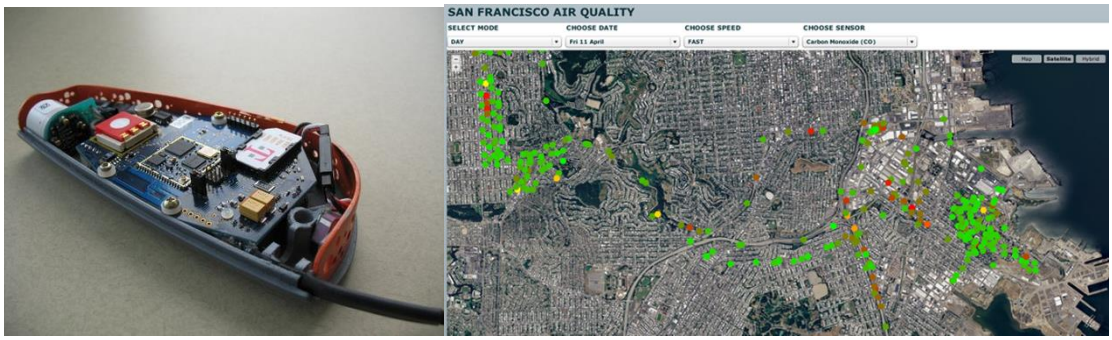

Figure 12: CommonSense: (a) Environmental Handheld Device (b) Air quality of San Francisco

With a similar goal, Paulos et al. in 2008 described how taxi drivers attached environmental sensors to the outside of their cars in order to collect data dynamically over the city of Acra in Ghana; they shared this information among each other [76].

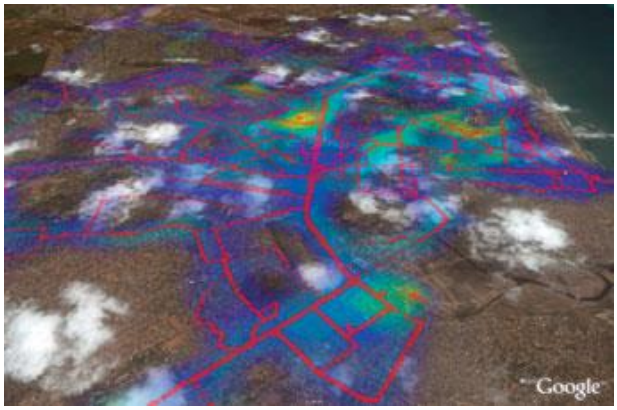

Figure 13: A heat map visualization of CO readings across the city of Accra rendered atop Google Earth

2.3.4.2 Urban Planning

The walkability project, started in 2007, launched a campaign to measure the degree of how walkable sidewalks are in a community of Los Angeles, California, USA. Through the campaign, people have been encouraged to report sidewalks with structural problems by taking photos with the camera integrated in their phones (see Figure 14). Pictures get tagged with geographic coordinates, which can be displayed in Google Maps; after submission the photos become input data for urban planning in the community.

Figure 14: CENS a) Walkability Project b) Cyclesense Project

Similar to the walkability project, local cyclists are involved in the Cyclesense project to document routes. For instance, they may discover en route impediments that they would like to report; additionally, cyclist can share their routes in order to help other cyclists to find better routes.

2.3.4.3 Health care

In health care, mobile sensing can be applied for long-term monitoring of patients outside the hospital. In that case, a suite of sensors can be deployed to monitor vital functions of patients. Using this concept, the MobiHealth project enabled patients to be mobile while being monitored for vital functions [83]. This is achieved by an infrastructure that facilitates continuous monitoring of patients outside the hospital environment by developing the concept of a 3G-enabled body area network (BAN). The MobiHealth (or: 3G-enabled BAN) infrastructural services are based on GPRS and UMTS technology for wireless broadband data transfer, that encapsulates all the complexity related to security, hand-over or quality-of-service [80].

Gravina et al. and Seto et al. describe an opportunistic sensing approach that is applied in environmental health monitoring, called SPINE [71][78]. Heartbeat and temperature sensors are attached to the human body (Figure 15). Via a customized phone system interface - supplied by Intel Research - the patient's cell phone can communicate using ZigBee with other sensor nodes (Figure 16).

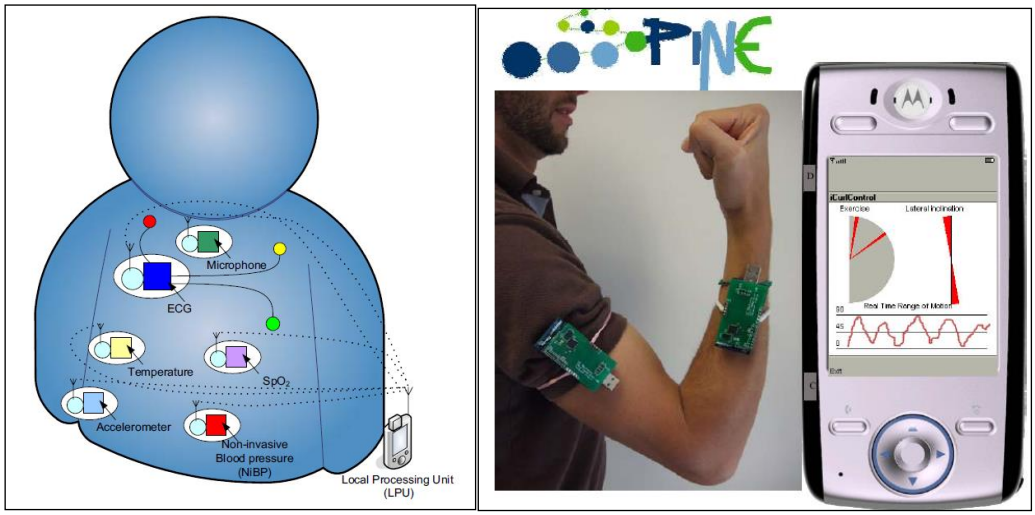

Figure 15: Body Sensor Network (a) Sensors placed on human body (Lo, Thiemjarus et al. 2005) (b) SPINE: BSN using ZigBee enabled phone as communication gateway

For this the SPINE framework is utilized to establish a body sensor network (BSN) that handles the intercommunication between heterogeneous devices (see below). SPINE distinguishes itself as a mobile platform for BSNs by providing flexibility in integrating different sensors, or on-the-fly reconfiguration of the BSN.

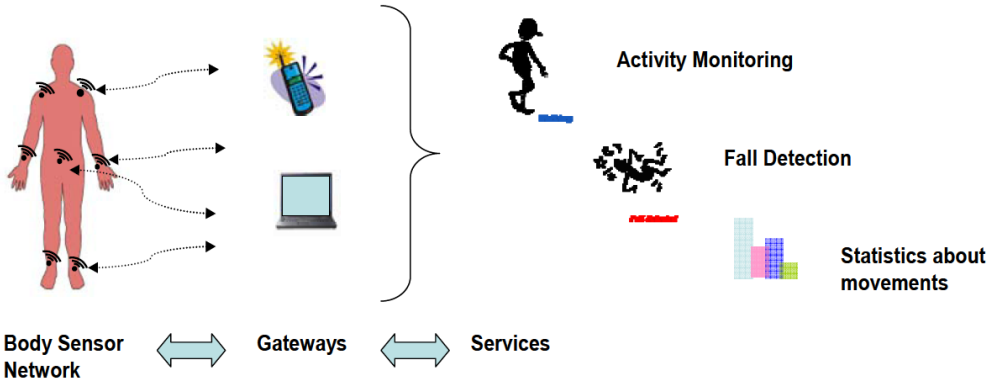

Figure 16: SPINE - Architecture of BSN

2.3.5 Mobile Applications for Police Support

The German police state department of North Rhine-Westphalia has launched in the beginning of 2011 an iPhone application. This mobile application strives for two comprehensive goals:

- Providing regularly reports to citizens about local incidents: Being optimized for smart phones, the app initially displays a web site representing local news; the user can personalize the web site [48]. Through a push mechanism the application provides daily press releases reporting crimes, investigation sought to call criminals or missing persons, information about traffic accidents and severe weather warnings (see Figure 17).

- Supporting an enhanced cooperation between the citizens and the state police:

    - For instance, the police publish images of wanted criminals or missing persons as well as to stolen or seized items.

    - A so-called “Police-Finder” enables the user to get directly in contact with the next local police station, e.g. to report a car accident or a theft. The app shows the way to the next police station (see Figure 17).

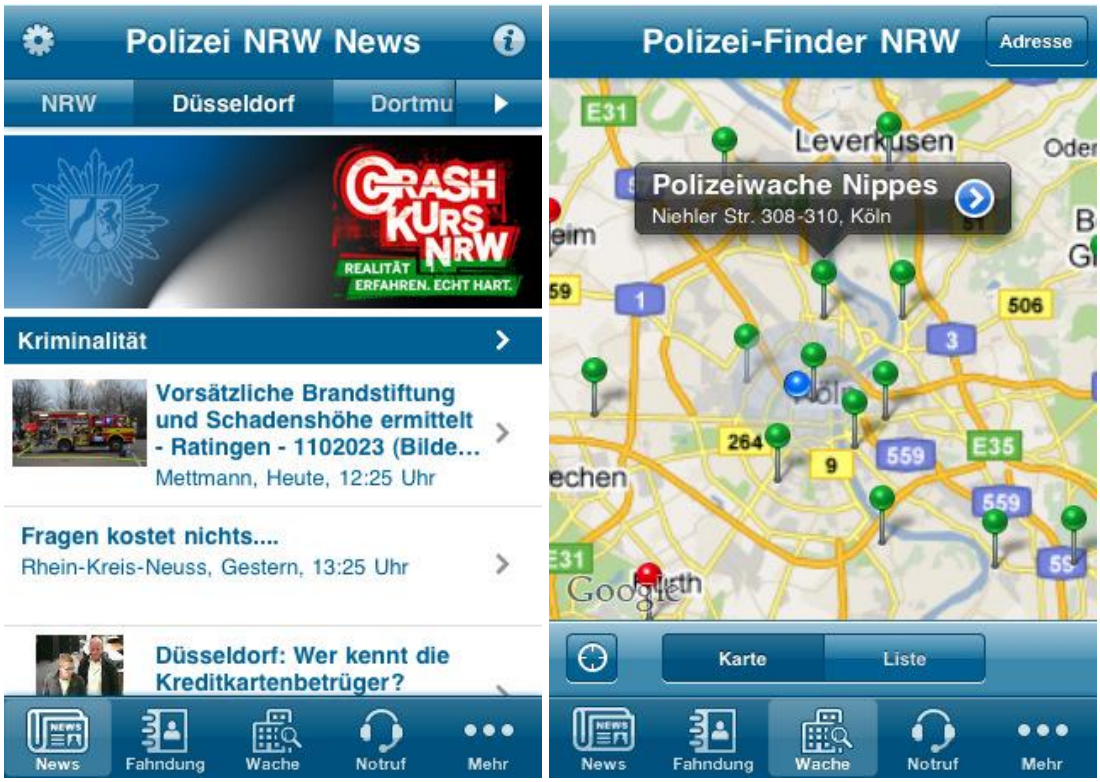

Figure 17: Police NRW App: a) List of Local News b) Navigation to next available police station

The Police NRW has received quite positive feedback among its users for applying a rather flexible, transparent data collection and transmission [50]. The strategy is to serve the user basically two possibilities:

- At first, to show the user explicitly the data content of a token that the application transmits.
- And second, to allow the user to configure which data flows into a token.

2.4 Fire Fighter support

The basics of firefighting in all domains are defined by norms and regulations. Almost every country has a body of norms and regulations defining the work, standards and strategies used by firefighters. Regulations provide a foundation and a resource to organize the work of firefighters. They don't describe, however, the ways in which work is enacted in a situated form [39], which makes important to have access to empirical accounts of the work of first responders. There are several empirical studies coming from diverse research disciplines, which focus on different aspects of the work of firefighters.

One of the seminal works in documenting firefighting work is the account of the Mann Gulch Disaster made by Norman Maclean in his book *Young Men and Fire [34]*, in which he describes the death of 13 men in a large wildfire occurred in 1993 in the Helena National Forest in Montana, United States. Desmond provides an ethnographical account of his work as a member of the Elk River Wildland Firefighting Crew in North Arizona, in the United States of America, focusing on unveiling the motivations of individuals to seek out high-risk occupations [23]. All of these studies address rural fires, but they can be used to research other aspects of

emergency response and collaboration in general. Weick in 1993, for example, used the account of Maclean to study the collapse of the sense making processes in organizations [45].

In the context of urban fires, Jonas Landgren conducted in-depth ethnographic studies centered on the work of firefighters, particularly in the processes of sensemaking and collaboration while attending a call, or working outside the incident. Landgren characterized the work of a fire crew using the concept of work rhythms and temporal structures [31]. Based on this analysis, Landgren provides a series of design implications pointing towards making communication visible and persistent along the temporal rhythms of the intervention to support the sense-making processes of firefighters.

In 2011, Denef, Keyson, & Opperman conducted a series of studies around practices of firefighters working in the danger zone of a fire [21]. The authors postulate three patterns of firefighting operations revolving around the social configuration of working teams: rigid structures, independent units, monitoring. The patterns are provided for designers to use as an inspiration for the design of supporting technology.

2.4.1 Ubicomp support for firefighters

There is an important amount of research focused on ubiquitous computing (ubicomp) technology designed for and motivated by firefighting. Ubicomp systems for firefighters can be roughly divided in systems supporting the work outside of the danger zone, such as command post systems, monitoring systems and decision support systems; and systems supporting the work inside the danger zone such as communication systems, information systems and navigation support. This division is a soft one, as many of the systems in the literature include and combine elements that move across both zones.

2.4.2 Working outside the danger area

An important part of the literature on Ubicomp for firefighters is focused on the work of commanding personnel. Much of these work represent extensions or specialization of previous work on other areas, such as collaboration and coordination system coming from the CSCW tradition. This is the case for example of Decision Support Systems designed to inform at different levels of the command line.

Based on workplace studies, Jiang et al propose three prototypes of Incident Command Systems based on the use of a large interactive display, focused on tracking of firefighters and assets and the assignment of tasks [25]. Although some of the prototypes provide visualizations of the active firefighters on area maps and floor plans, the authors do not answer the question of how the position of the firefighters is provided to the system.

Some other authors also approached the problem of identifying which information is relevant for team leaders and incident commanders [22]. Using this information, the authors developed the BIMS system, which provides real time tracking of firefighters. The authors describe a radar based system to track the movement of firefighters in an indoor context, but for the test of the BIMS system, the authors used a Wizard of Oz approach based on GPS in an outdoor location.

Jonas Landgren created in his works three different Tablet PC based prototypes of systems designed to support the sense making processes of firefighters [31]. Landgren evaluated these prototypes to assess their value as technology systems, but, as he explains, they were more important as exploration tools used to conceptualize the practices of firefighters. In this sense, the author takes some distance for his prototypes as a concrete technology solution, and centers his work rather on the reflection around guidelines for the design of technology for emergency response.

Monares et al present a map based mobile application to support ad-hoc communication and collaboration between firefighters involved in an incident, based on the use of GPS based location awareness [37]. The application is based on a geographic information system that support teams by providing shared location awareness of engaging units to support the coordination of response. The authors evaluated the system in real incidents by quantitatively comparing radio communication traffic between normal incidents and incidents using the proposed system. The evaluation showed significant reduction in radio traffic.

2.4.3 Working inside the danger area

2.4.3.1 Communication support

One area of work for IT and ubicomp systems has been the improvement on the communication infrastructure of firefighters. Camp et al. conducted an ethnographic study around radio communication and identified diverse problems with the existing radio system [19]. Using these results, the authors proposed a re-design of radio communication systems to better support the particularities of the work of firefighters, introducing organizational concepts to optimize the use of bandwidth based on the hierarchical distribution of roles in firefighting.

The Siren project developed an alternative communication system to complement radio communication [25]. The authors identified several weaknesses in the existing communication systems, and proposed an infrastructure-less, peer-to-peer architecture in which each component of the system stores and forward packets opportunistically to other peers as they are detected on close vicinity. The authors validated the system by presenting it to firefighters and brainstorming about its functionality. The response of firefighters was positive, but these results were not contrasted with empirical evaluations.

2.4.3.2 Navigation Support

Navigation in indoor spaces was promptly identified by researchers in the Ubicomp community as an interesting activity for technology support. An important part of the work focuses on providing location information to the firefighter taking into account the complex constrains posed by the domain of firefighting. Pedestrian Dead Reckoning (PDR), i.e. the use of inert sensors to estimate changes in the position of a subject, is identified as one feasible technology for location in firefighting [36]. Beauregard identifies a series of limitations of conventional ubicomp locations methods for firefighting scenarios and proposes instead the use of a specific technique of PDR based on sensing the three dimensional movement of the feet and a special technique for introducing corrections [18]. The author tested the system in the context of the rather complex patterns of movement of firefighters at work with promising results, although he recognizes that the solution is still far from being usable, and that further work is needed.

The FIRE (short for Fire Information and Rescue Equipment) project in the University of Berkley focused on the development of decision support tools for firefighters [46]. The project developed of a pre-deployed structural wireless sensor network (WSN) called SmokeNet, composed of a range of different sensors that track firefighters inside of a building and capture and distribute relevant information such as location, temperature distribution, health monitoring data and others. Location in SmokeNet is provided by “beacon” nodes which broadcast a constant signal used by a system mounted on the equipment of the firefighter to estimate his current position.

The idea of using deployable tokens to support navigation was recognized very early in the support for navigation in firefighting. The idea of nodes deployed during an operation has been proposed for example by Kumar as a complement for structurally embedded sensors and robots [29]. In his master thesis, Johannes Geissbühler proposes the use of an ad-hoc-deployed track of networked nodes to improve communication coverage inside the danger area [24]. A further

development of the idea is the concept of breadcrumbing. Proposed originally to support navigation of virtual worlds, breadcrumbing refers to the use of bread crumbs left behind as pathway markers by Hansel and Gretel in the popular fairy tale [20]. Most of the breadcrumbing systems proposed for firefighters are based on automatic deployment of small computing nodes, which are later used to provide location based on different algorithms. Klann et al propose LifeNet, a breadcrumbing system specifically created to support navigation of firefighters, based on a set of automatically deployed sensor nodes and a head mounted display [28]. The authors proposed a reference implementation, but the idea was only developed as a virtual reality simulation [27]. Many authors have assumed the relevance of the idea and focused on the technical requirement of securing the process of automatic deployment. Salam et al for example, explore strategies to optimize energy consumption to increase network lifetime [43]. Liu propose algorithms to trigger the deployment of nodes based on quality of link estimations [33].

Taking a different, human centred approach, Ramirez et al. argued that the automation approach of the proposed breadcrumbing systems disregard the knowledge emerging from manual deployment [40]. To explore this issue, the authors followed a participatory design approach to develop a manually deployed breadcrumbing system. The authors evaluated the system in real exercises with firefighters and showed the importance of manual deployment in the creation of landmarks in a path and consequently, in the creation of a useful reference [42]. A similar approach, based in augmented reality, is proposed by Magnusson, Breidegard, & Rassmus-Gröhn [35]. There, the breadcrumbs are spots marked virtually by inserting them in a geographic database. These markings are then used to guide the user with an auditory interface based on monaural audio and a pointing device.

2.4.4 Interaction Design

Another important track of research in support for firefighters is the development of interfaces to provide information in complex conditions. One technology proposed very often is the use of Head Mounted Displays (HMD, see Figure 18), which are small digital displays mounted inside the field of vision of the user, close to the eye, so they have a large apparent screen size. The FireEye Project, part of FIRE project, explored in depth the use of Head-mounted displays in close-to-real situations with firefighters [44]. The researchers evaluated different interfaces for the display of floor plans showing the position of firefighters and other assets based on the information coming from a sensor network, considering the aspects of usability, ergonomics and others. Naghsh and Roast take a minimalistic approach to HMD, using an array of LEDs mounted on a firefighter helmet, to convey route information [38].

Figure 18: The small Head Mounted Display developed within the FireEye project

Given the conditions under which firefighting navigation takes place, non-visual displays represent an attractive form to convey guidance information. The most relevant forms of non-visual displays are auditory displays and haptic displays. Both systems present promising features and have been proposed as feasible systems to display information in firefighting context [32][47].

3 Overview of products from past and running R&D projects

The efforts of BRIDGE are not made in isolation. They are part of continuous research and development. To be able to link the questions and challenges of BRIDGE to other projects, this section provides an overview of the six major related European Projects: SHARE, OASIS, E-SPONDER, INDIGO, INFRA and WORKPAD.

3.1 SHARE

Project name	SHARE – Mobile support for rescue forces, integrating multiple modes of interaction
Type:	FP6-IST (#004218)
Duration:	November 2004 – October 2007
Website:	http://www.iais.fraunhofer.de/share.html?&L=1

The SHARE project was intended to offer an information and communication system to support emergency teams during large-scale rescue operations and disaster management.

At present, emergency forces use half-duplex channel walkie-talkie technology and are restricted to simple push-to-talk voice communication. All the status information, reporting and documentation for decision making are processed manually. After the introduction of the new service, rescue operations will benefit enormously from sophisticated multimodal interaction and on-line, onsite access to data services providing up-to-date operation status information, as well as details concerning aspects of the emergency, such as location and environment. [51]

3.2 OASIS

Project name	OASIS - Open Advanced System for dIsaster and emergency management
Type:	FP6-IST (#4677)
Duration:	September 2004 – August 2008
Website:	http://cordis.europa.eu/projects/rcn/92923_en.html

It was discovered that the civil protection organizations had not benefited as much as other professionals from the new information technologies. The identified problems were that this evolution was conducted at national level and in a great number of cases at regional level, different equipment where some have the latest technologies, while others only have previous generation systems. This generated increasing problems of compatibility and interoperability on both international and national level, and from these experiences the OASIS-FP6 project was initiated.

The objective of OASIS was to define and develop an Information Technology framework based on an open and flexible architecture and using standards, existing or proposed by OASIS that will be the basis of a Disaster and Emergency Management (DEM) system. OASIS is intended to facilitate the cooperation between the information systems used by civil protection organizations, in a local, regional, national or international environment. This DEM system aims to support the response operations in the case of large scale as well as local emergencies. In all cases, collaboration between a variety of different organizations and units is envisaged. The system should provide situational awareness, collaborative planning and tasking services and operational monitoring and resource management. The OASIS system is intended to cover the

DEM process elements of planning in preparedness and the coordination and cooperation in response.

The output of the OASIS project is the description of an open architecture largely based on a list of interfaces, either already existing or proposed by OASIS and an initial set of applications inside this IT framework which covers the main needs of a Disaster and Emergency Management system, and standards. The overall architecture is visualized in Figure 19 . The Tactical Situation Object (TSO) has been developed under the umbrella of CEN and provides the interoperability to exchange reports and mission information.

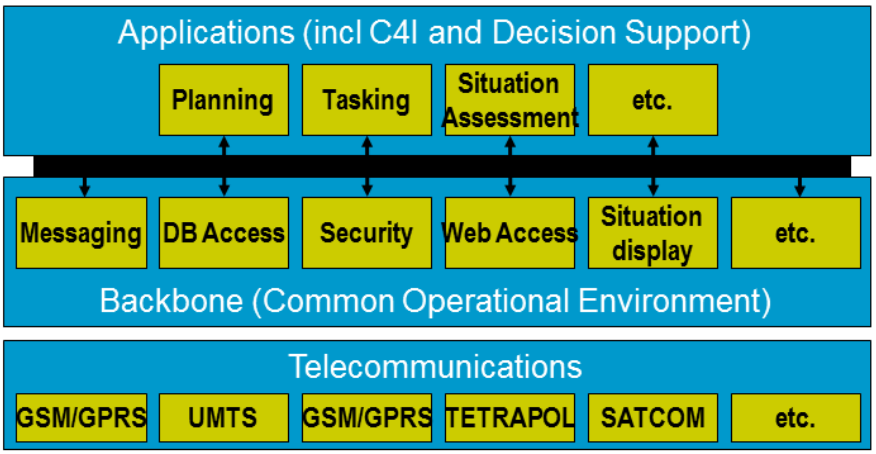

Figure 19: OASIS architecture

The OASIS project has developed and integrated a first version of an open, modular and generic DEM pre-operational system (POS). The first version of POS was evaluated in September 2006 in the context of exercises in the area of the partners' premises.

The conclusions of the first evaluation and the follow up of the development of OASIS system will lead to a second version of OASIS pre-operational system which has been evaluated in 2008, in the frame of the field exercises.

3.3 E-SPONDER

Project name	E-SPONDER: A holistic approach towards the development of the first responder of the future
Type:	FP7-SEC (no. 242411)
Duration:	started on July 1st, 2010, 48 Months
Website:	http://e-sponder.eu

The E-SPONDER platform is a suite of real-time data-centric technologies and applications, which will provide actionable information and communication support to first responders that act during abnormal events (crises) occurring in critical infrastructures. This information will enable improved control and management, resulting in real time synchronization between forces on the ground (police, rescue, fire-fighters) and out-of-theatre command and control centres.

The project has a three-fold focus linked to fully quantifiable results from a coherent set of

properly scheduled research and innovation related activities. E-SPONDER is set to:

- Provide a new generation *First Responder Support Platform*, comprising of a full-set of systems and services built in accordance to innovative, integrated standards and peer-to-peer architecture, supporting a vast variety of first responder operations.
- Study and develop the underlying *socio-economic environment* where the above technology is applied by addressing:
    - The emerging *training needs* for increased operational efficiency of FR Operations of involved players (operating crews and supporting personnel). E-SPONDER will develop a *computer-supported simulation environment* with an optimization module, to facilitate emergency response planning and training of first responders.
    - The *logistics* by designing, developing and running simulation data on an optimization module to precisely identify size, parameters and risk of "disaster area".
    - The *regulation framework*, legal aspects, and the *standardization* issues of operational procedures (including the certification of First Responder equipment) as well as the societal and procurement implications so as to generate an initial framework for the design and development of suitable First Responder approach in Europe.
- *Demonstration* of the developed system and *validation* of its operational characteristics in full-scale field trials that will *simulate realistic emergencies and crises*. The whole system will be tested against a variety of events in two countries. A specific testing users group has already been, covering the diverse nature of different first responders. Different scenarios simulating real life will be considered in order to highlight the added value the E-SPONDER system can bring for European or International cooperation.

The E-SPONDER website includes a “First Responder Area” that provides a user requirements questionnaire. This questionnaire targets first responders and crisis managers and tries to elaborate some initial requirements for the E-SPONDER project. Most parts of the questionnaire covers the equipment of first responders which is not a focus of the BRIDGE project. However it may be a useful starting point for a BRIDGE catalogue of question for relevant stakeholders.

3.4 INDIGO

Project name	INDIGO: Innovative Training & Decision Support for Emergency operations
Type:	FP7-SEC (no. 242341)
Duration:	started on May 1st, 2010, 36 Months
Website:	http://indigo.diginext.fr

INDIGO aimed to provide a revolutionary solution that will enable inter-organisational preparation and support response to transboundary crises and disasters, in any environment. INDIGO allows for inter-organizational exercising, information sharing and analysis – mining both horizontal and vertical relations. With regard to the latter, the relation between central command centers and field units is traditionally underdeveloped, both before and during crises. First responders are insufficiently involved in large-scale strategic exercises because these are very complex and expensive to organize and manage.

The proposed system will prove an essential and integrated tool for training personnel, planning operations, and facilitating crisis management and co-operation across organizations and nations. It will enable users to:

- display and manipulate an operational representation of the situation that is as complete and as easy to understand as possible, for indoor and outdoor situations; simulate different evolving scenarios for planning, training, and anticipating future states and impending developments during operations, and analyse events after the crisis;
- involve first responders and emergency field units in simulated exercises;
- enhance the work across organizational boundaries and decision levels.

INDIGO also develops a European emergency symbology reference that includes 2D and 3D representations and is supported by the European Committee for Standardization.

INDIGO provides some state of the art reports that may help the BRIDGE project during its domain analyses. A report about "Crisis Management Tools" lists and compares simulation tools, decision support systems for crisis management, logistical software, crisis communication technologies, tactile tablets and some state of the art case studies [57]. It also comprises recommendations for the INDIGO project that may be partially applicable for BRIDGE.

Another state of the art report covers "Symbols, Symbology and Systems" and may give some hints for the user interfaces that will be developed within the BRIDGE project [58].

3.5 INFRA

Project name	INFRA: Innovative & Novel First Responders Applications
Type:	FP7-SEC (no. 225272)
Duration:	started on April 1st, 2009, 24 Month (ended March 31st, 2011)
Website:	http://infra-fp7.com

Due to historic and organizational reasons, communications and digital personal safety applications are currently fragmented and operate in islands, with only very basic cooperation between the different First Responders (FR) teams and the Critical Infrastructures (CI) control center; usually in the form of voice communications (sometimes even their voice systems are not compatible with each other). Each type of FR (Police, Fire, and Medical) has their own equipment and their own applications. In a similar manner, there is no standardization of CI sites. So FR teams cannot rely on a standardized environment that is common to all CI sites. This situation is quite typical in Europe and globally. Project INFRA provides a major step towards a standard, seamless, effective and efficient FR environment, which will ensure interoperability with the CI control centre.

The **Critical Infrastructure Broadband Communications Base area** will cover advanced wireless broadband network technology that is specially adapted to the needs of First Responder teams in Critical Infrastructure sites. The network shall support video, data and voice communications, and it will consist of multi-radio mesh topology with self-adaptive and self-healing functionality.

The **Critical Infrastructure Open Interoperability Standard area** will cover the development of a highly dynamic system of systems made up of elements that interact with each other in unplanned and spontaneous ways. It will also cover the development of a First Responder oriented network-programming platform that will implement the systems-of-systems nature of First Responder applications and communications.

The **Communications Space** will provide an unprecedented level of interoperability for voice and data communications. All First Responder teams, First Responder command posts and the

Critical Infrastructure control center, regardless of their radio technology, will be able to communicate with each other. Furthermore, First Responders will be able to use their legacy equipment inside buildings with thick concrete walls and in underground tunnels where typically radio RF propagation is impaired.

The **Application Space** will provide novel technologies and applications for the use of First Responders in Critical Infrastructure sites. These shall be Site Indoor Navigation (based on inputs from three independent tracking sources for increased reliability and accuracy), Thermal imaging (including gas leaks detection and hidden fire detection), Advanced Sensors (robust and lightweight fibre optic based sensors for the detection of hazardous materials), and Video Annotation (annotated with symbols and graphical components through dedicated authoring tools and short textual descriptions that aim at focusing the attention of the First Responder on a specific part of the picture).

INFRA developed a suite of sensing and communication services tailored to meet the requirements of emergency responders. An overview of the different systems can be found in a research paper [61]. Apart from several sensor prototypes (hidden fire detection, gas leak detection, biometric sensors, radiation sensors, ambient gas sensors), INFRA developed a robust wireless ad-hoc mesh network infrastructure called RHINO that enables interoperability between standard radio equipment of first responders such as VHF radio, UHF radio, GSM, 3G or TETRA [62]. The "Publications" section on the INFRA homepage comprises all deliverables that have been produced during the project [63]. They cover topics such as field trials (planning and reports), broadband network design, communication interoperability design, end-user workshop conclusions and emergency industry surveys.

3.6 WORKPAD

Project name	WORKPAD: An Adaptive Peer-to-Peer Software Infrastructure for Supporting Collaborative Work of Human Operators in Emergency/Disaster Scenarios
Type:	FP6-IST (no. 034749)
Duration:	started on September 1st, 2006, 36 Month (ended August 31st, 2009)
Website:	http://www.workpad-project.eu

The WORKPAD project aimed at designing and developing an innovative software infrastructure (software, models, services, etc.) for supporting collaborative work of human operators in emergency/disaster scenarios. In such scenarios, different teams, belonging to different organizations, need to collaborate with one other to reach a common goal; each team member is equipped with handheld devices (PDAs) and communication technologies, and should carry on specific tasks. In such a case the whole team can be considered as carrying on a process, and the different teams (of the different organizations) collaborate through the exchange of integrated data and content provided by some back-end centres, thus supporting inter-organizational coordination (macro-processes). The project will investigate a 2-level framework for such scenarios: a back-end peer-to-peer (P2P) community, providing advanced services, data & knowledge & content integration, and a set of front-end peer-to-peer communities, that provide services to human workers, mainly by adaptively enacting processes on mobile ad-hoc networks.

- The back-end community is constituted mainly by static/traditional computers that interact in a P2P fashion. Such services, coarse-grained, require integration of data & knowledge & content. The interesting aspect is that the community is inter-

organizational (each peer belongs to a certain organization) and each system is enabled to act as service provider, requestor, or integrator. In particular, the integration should be dynamic, flexible, and non-intrusive.

- A single front-end community is constituted by the operators of a team, equipped with mobile devices, connected in an ad hoc and peer-to-peer fashion, that carry on a process, in which the adaptiveness to connection/ task anomalies is fundamental.

The objective of the WORKPAD project is to investigate how to create communities of Public Safety Systems (PSSs), and how to enable mobile teams to exploit such back-end PSSs through the interplay of Mobile Ad-hoc Networking (MANET) technologies, process management and geo-collaboration. In order to support such a complex scenario, from the provision of data & knowledge & content to front-end teams to their process executions, different research issues will be addressed:

- A *2-level peer-to-peer architecture*, including both the back-end peers and the front-end teams.
- Novel techniques for *P2P data & knowledge & content integration*, to be exploited on the back-end. P2P information integration systems don't rely on a single global view (ontology), but use mappings, dynamically established between peers, to collect and merge data from the various sources when answering user queries.
- *Adaptive process management*, by exploiting *context-awareness* and *process mining*, in order to manage coordination of team members.
- *Geo-referenced information management*.
- Solutions around *emergency communications*, wireless communications and robust links (i.e., connecting front-end and back-end networks), e.g., satellite-based, TETRA-based, etc., as they are key elements in helping emergency services respond in extreme situations.
- Solutions for allowing devices of a team to *communicate without relying on any infrastructure* (which in general is not available after disasters), through the use of the MANETs, and to *share reliable communication channels* in order to coordinate among different teams.

An overview research paper that describes the goals and architecture of WORKPAD has been published [65]. Several deliverables describe the project in detail. The deliverable describing requirements and use cases of the WORKPAD project may be interesting for BRIDGE as they may partially overlap [66]. The WORKPAD Exploitation Plan comprises a chapter about technology trends which may be relevant for BRIDGE [67]. The WORKPAD architecture document1 contains information about several components such as a context monitoring and management framework, a mobile ad-hoc network management layer, a GIS module as well as the user interface [68].

4 Overview of Architectures, Models, Standards and Protocols

In this section, an overview is given of architectures, standards and protocols related to the BRIDGE project. In Section 4.1, an overview of standards for training and simulation is given. Section 4.2 focuses on standards for design, specification and integration of systems. In Section 4.3, an overview of standards related to multimedia is given. Finally, Section 4.4 concludes with an overview of trust models for crisis management.

4.1 Standards for Training and Simulation

4.1.1 IEEE Standards for simulation

The two commonly used standards used for simulation are the Distributed Interactive Simulation (DIS) specified in IEEE1278, and High Level Architecture (HLA) specified in IEEE1516.

4.1.1.1 Distributed Interactive Simulation

DIS is an IEEE standard for time and space coherent synthetic representation of world environments. It is designed for linking the interactive, free-play activities of people in operational exercises. A synthetic environment is created through real-time exchange of data units between distributed, computationally autonomous simulation applications. Additionally, computational simulation entities may be present in one location or may be distributed geographically. DIS is mainly used by military organizations but further applications are met in domains of space exploration and medicine as well.

The current version of DIS, the 7th, incorporates 72 Protocol Data Units (PDUs) divided in discrete 13 families. More specific the families are: warfare, logistics, simulation management, entity information/interaction, distributed emission regeneration, radio communications, entity management, minefield, synthetic environment, simulation management with reliability, live entity, non-real time and information operations family. [100]

4.1.1.1 High Level Architecture HLA IEEE 1516-2010

The High-Level Architecture (HLA) is an open international standard, developed by the Simulation Interoperability Standards Organization (SISO) and published by IEEE with the standard code number 1516. On March 25th of 2010 its updates were approved by IEEE and it was renamed to 1516-2010.

HLA enables several simulation systems to be utilised in the frame of interoperability. It aims into creating a federation of systems and this is achieved by combining them to simulate more complex scenarios and chains of events. Furthermore the architecture enables the reuse of different systems in new combinations.

HLA may mainly be used for training and secondly for analysis. On the subject of training, personnel could be trained to perform tasks. Regarding the analysis, different scenarios in a simulated world could be tested.

One example of HLA's utilization is the space applications where complex missions, possibly taking months and years, can be simulated in a shorter time and emergency situations can be trained without any real risk. HLA has also been used for space mission control training, such as the docking of automated transfer vehicles with the International Space Station. Additional areas of interest might be manufacturing, offshore oil production, national railroad systems, medical simulations, environment, and hydrology. [101]

4.1.2 Test and Training Enabling Architecture TENA

TENA is designed to bring interoperability to America's test and training ranges and their customers. Additionally, it promotes integrated testing and simulation-based acquisition through the use of a large-scale, distributed, real-time synthetic environment, which integrates testing, training, simulation, and high-performance computing technologies, distributed across many facilities, using a common architecture. TENA supports "LVC", the live – virtual – constructive, testing and training simulations and applications into a single distributed system.

More analytically, LVC includes for each one of the terms the following:

- Live: real, physical assets, including soldiers, aircraft, tanks, ships, and weapon systems.
- Virtual: simulators of physical assets that provide real-world operator interfaces and humans in the loop, such as aircraft simulators, tank simulators, etc.
- Constructive: Pure simulations either controlled by human beings or run entirely without human intervention.

The purpose of TENA is to provide the architecture and the software implementation necessary to enable Interoperability among Range systems, Facilities, Simulations, C4ISR systems in a quick, cost-efficient manner. Moreover TENA adopts Reuse for range asset utilization and for future developments. In addition, TENA provides composability to rapidly assemble, initialize, test, and execute a system from a pool of reusable, interoperable elements.

TENA is sponsored by USA's Department of Defence Test Resource Management Center (TRMC) and Joint Forces Command's Joint National Training Capability (JNTC). Furthermore all TENA specifications and software are owned by the United States Government, but are provided free of charge to any organization. [102]

4.1.3 Common Training Instrumentation Architecture (CTIA)

Mission of CTIA is to provide a flexible product-line architecture environment that will support the development and evolution of a common architecture to support Army live-training instrumentation systems. The product line provides integration and interoperability with legacy and emerging Army and joint architectures such as the Live, Virtual and Constructive Integrating Architecture (LVC-IA) and the Test and Training Enabling Architecture (TENA) that were mentioned in the subchapter above. The CTIA provides cost reduction across the total life-cycle of Army live-training instrumentation systems.

This architecture provides commonality across training instrumentation systems and interoperability across LVC and joint training systems. It consists of the architecture services, software components, standards and protocols to be used by system developers and is the core software component of the Army live-training instrumentation systems. With significant emphasis on commonality, the CTIA improves the quality of training while significantly reducing development, training, logistics and sustainment costs.

The CTIA-based systems are fielded and fully operational at the Army's Combat Training Centers (CTCs) and at numerous homestation training ranges. Additionally, CTIA systems are being fielded by the Marine Corps and Air Force. The CTIA systems are Information Assurance certified to operate at the secret classification level. [103]

4.1.4 Common Alerting Protocol (CAP)

The Common Alerting Protocol (CAP) provides an open, non-proprietary digital message format for all types of alerts and notifications. It will be described in detail in Section 4.2.8.1.

4.1.5 Tactical Situation Object (TSO)

TSO was analytically presented in Section 4.2.3 , and as most of the referred models it may be utilised for multiple purposes; including training and simulation as well.

4.1.6 Joint Consultation Command and Control Information Exchange Data Model JC3IEDM

JC3IEDM is created by the MIP NATO Management Board and it is a standard of information exchange data model for the sharing of command and control (C2) information. JC3IEDM is intended to represent the core of the data identified for exchange in a C2 environment.

The scope of the JC3IEDM is directed at producing a corporate view of the data that reflects the multinational military information exchange requirements for multiple levels in combined wartime and crisis response operations (CRO). The data model is focused on information that supports: Situational awareness, Operational planning, Execution and Reporting.

More elaborated, the data model is capable of incorporating the following information:

a. The structure should be sufficiently generic to accommodate joint, land, sea, and air environmental concerns.

b. All objects of interest in the sphere of operations need to be described to include organisations, persons, equipment, facilities, geographic features, weather phenomena, and military control measures such as boundaries.

c. Objects of interest may be generic in terms of a class or a type and specific in terms of an individually identified item. All object items must be classified as being of some type.

d. An object must have the capability to perform a function or to achieve an end. Thus, a description of capability is needed to give meaning to the value of objects in the sphere of operations.

e. It should be possible to assign a location to any item in the sphere of operations. In addition, various geometric shapes need to be represented in order to allow commanders to plan, direct, and monitor operations. Examples include boundaries, corridors, restricted areas, minefields, and any other control measures needed by commanders and their staffs.

f. Several aspects of status of items need to be maintained.

g. Composition of a type object in terms of other type objects needs to be specified. Such concepts include tables of organisations, equipment, or personnel.

h. Information about what is held, owned or possessed by a specific object needs to be reflected. [105]

4.1.7 Real Time Platform Reference - Federation Object Model (RPR-FOM)

The RPR FOM (Real-time Platform-level Reference FOM) is a reference Federation Object Model (FOM) that defines HLA classes, attributes and parameters that are appropriate for real-time, platform-level simulations. The RPR FOM was developed by a Simulation Interoperability Standards Organization's (SISO) Product Development Group (PDG). Its goal

is to provide an intelligent translation of the concepts used in Distributed Interactive Simulation (DIS) to a High Level Architecture (HLA) environment.

RPR FOM 1.0 became a SISO Standard in 1999, under the name SISO-STD-001.1-1999. RPR FOM 1.0 is based on the IEEE 1278.1-1995 version of the DIS Standard. RPR FOM 2.0, based on the IEEE 1278.1a-1998 addition is close to approval as a SISO Standard too. [106][107]

4.2 Standards for Design, Specification and Integration

4.2.1 Application Centric Integration

The common methods for integration are either Application Centric Integration is illustrated in Figure 20 or the Interface Centric Integration in Figure 21 [13]. The Application centric is best suited when there are only two systems to be integrated. It requires that each application is individually adapted to the selected protocol. These adaptations are usually also restricted to a minimum in terms of the information being exposed. The full capacity of each application will therefore not be available. The integration points are at each end and are usually hard coded into each system. Applied to the TSO (Tactical Situation Object) and C-BML (Coalition Battle Management Language) the protocol and information exchange with translations and transformations are implemented at one side of the system and that all those systems need to implement the information exchange mechanisms, together with an implementation of the other systems protocol for transporting the information. Since it is presumed that systems using TSO and C-BML will be in a highly dynamic context the application centric approach is not providing with the needed flexibility.

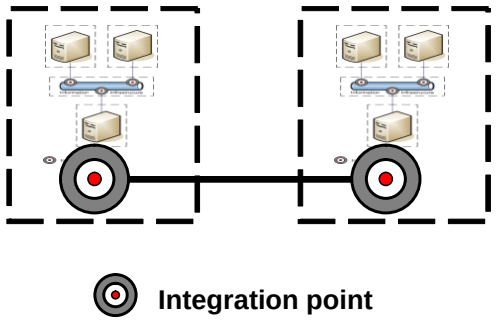

Figure 20: Application Centric Integration

When more than two systems are connected, the common solution is to identify a set of data elements in an agreed format with an agreed meaning using a specific protocol.

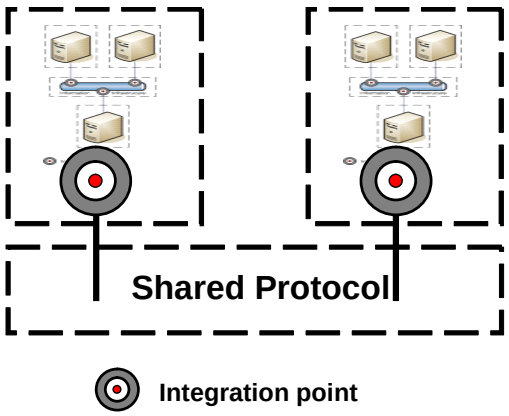

Figure 21: Interface Centric Integration

For simulation the two commonly used IEEE standards (DIS and HLA) have been addressed in Section 4.1.1. The DIS uses the well-defined Protocol Data Units (PDU) that holds the syntax and semantics. HLA is more flexible than DIS and the Object Model Template (OMT) is used as the common syntax to describe the meaning of all object and interaction classes within the Federation Object Model (FOM). Overall the focus is on the interoperation of systems and to exchange data and every system agrees to map their information exchange to the common information exchange model. For the TSO and C-BML CRM this means that the CRM will have a specific protocol for information exchange that each node needs to implement.

The integration points are still at each application's end and usually hard coded. Each application will still need to be adapted to the shared protocol which usually restricts the information being exposed to the shared protocol. The full capability of each application will still not be exposed.

The suggested method to integrate the three domains of DEM, C2 and M&S, i.e. civil and military using the same base core of M&S, is to use *Information Centric Integration* (ICI) - pronounced as the word *easy*. ICI offers the potential to move the system integration points into the information infrastructure giving the integrator full control of the integration. These integration points are configured and ***not*** hard coded into the information infrastructure. In Figure 22, Information Centric Integration is illustrated.

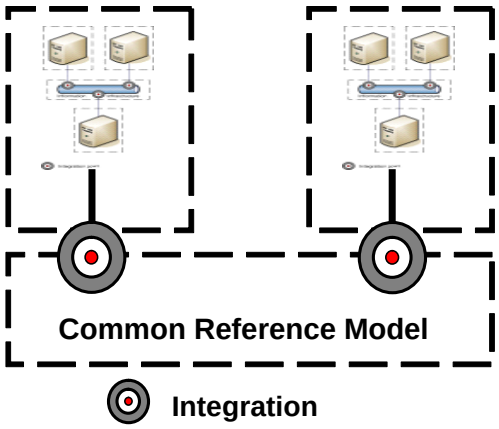

Figure 22: Information Centric Integration

The benefit of an ICI approach is that the information infrastructure is responsible for translating and delivering information between applications, each application only needs to communicate with the infrastructure. This communication is preferably made using the native protocol of each application thereby exposing the full data model of each application to the infrastructure. Applications are completely autonomous. Thus the CRM developed between C-BML and TSO enables the C-BML systems to communicate with TSO systems and their corresponding Simulations. For other information models and protocols the MBDE uses the CRM of TSO and C-BML to connect with the other systems of choice.

To integrate an additional application, the information infrastructure needs to support its communication protocol. However, the other integrated applications can continue as before. The information infrastructure takes care of necessary translations. This makes it easier to adapt to new protocols. For example to add DIS or HLA (a runtime infrastructure (RTI) with a federation object model (FOM)) then is simple. For HLA the first is to build the protocol driver for the RTI

of choice. The second part is to map the FOM towards the C-BML-TSO CRM. With this maneuver the simulation framework can fully communicate with both the C-BML and TSO systems, the utility of such a capability is purposely left for the reader to envision.

It is presumed that when integrating additional applications the required work effort is roughly the same as the last one. The difference is if the infrastructure has to support a new communication protocol, or not. This makes integration costs increase linearly. Further, integrating an additional application will not affect other applications. Thus, life-cycle costs remain at a lower level.

To satisfy a new requirement, applications can be integrated in new ways. Since integration is simpler, this will take less time. The time-to-market will be shorter therefore operational procedures and methods can be evaluated, verified, trained early in the process.

Using an information infrastructure makes it possible to configure how applications are integrated. To satisfy a new requirement by changing the integration, the only change is the configuration. There is no need to modify and thereby integrate the applications all over again. Integration is flexible.

Since integration is flexible, it is easier to create new capabilities. Instead of creating a totally new system, or changing existing systems, it can be sufficient to combine information from existing systems in a new way. All that is needed to do is to create a new configuration [13].

4.2.2 ISO/TC 223 Societal Security

ISO is the world's largest organization for standards founded in 1947. It is constituted by a network of 156 national standard institutes. The ISO standards are voluntary, based on consensus but might be demanded of the market as the well-known ISO 9000 QM and ISO 14000 EM. ISO standards are developed by technical committees (TC).

ISO/TC 223 was first initiated in 2001 under the title Civil Defense. After a period of non-activity, the secretariat was given to the Swedish Standards Institute (SIS) at the end of 2005. The first plenary meeting was held in Stockholm, Sweden, in 2006, attended by 68 delegates from 30 countries.

The overall aim of ISO/TC 223 is to produce an international standard in the area of societal security, that is aimed at increasing crisis and continuity management and capabilities through technical, human, organization, operational, and management approaches as well as operational functionality and interoperability as well as shared situational awareness, amongst all interested parties. This standard should be applicable for situations where threats and vulnerabilities require comprehensive crisis management and business continuity systems which are multi-sector, multi-national and multi-continental and it has an all-hazards perspective.

The ISO/TC223 Societal Security committee has at the moment 29 participating members and 22 observing members, and is organized in three working groups (WG) and one task group (TG2).

WG1-Framework for Societal Security Standards has the objective of developing a framework standard on societal management. It shall establish a common basis for related security management standards and provide a reference for standard development and/or to harmonize existing related documents. The framework shall also include a bibliography of related standards that can be referred to for guidance. This standard will not require any management system processes, specifications, or certification. Task group 2 is coordinated with WG1 on publishing the ISO/PAS 22399.

WG2-Terminology has the objective of producing a glossary and definitions of terms in the area of societal security. They have presented a proposal for fundamentals and vocabulary.

WG3-Command Control, Coordination and Cooperation has the objective of developing a

standard on command and control, which might include information gathering, information sharing /processing, information flows, interoperability, structures and procedures, decision support and warning. The WG 3 is organized in three work items (WI).

- WI 1: Principles for Command, Control, Coordination and Cooperation describes principles for all involved actors before, during and after a crises /disaster. The document is focusing on the fundamentals for an efficient minimal level of cooperation, coordination and control mechanisms between and within crisis management actors.

- WI2: Essential information and data requirements for command, control, coordination and cooperation identifies the need for relevant, adequate and role based information in time in order to minimize the risk of information overflow to the different crisis managers and citizens. The group also works with enhancing the flow of information between the actors.

- WI3: Inter/Intra organizational warning procedures the scope of which is to identify requirements on warning procedures and models for inter- and intra-organizational purposes. They also support development of organizational infrastructure that take 'good practice' into account in warning systems.

TG2-Preparedness and continuity have published the ISO/PAS 22399 Guidelines for incident preparedness and operational continuity management (IPOCM) in late 2007 [5]. The next step for TG2 is to make the ISO/PAS 22399 a full standard; it will hopefully take approximately 9-12 months, and be public in late 2008. There is also a project suggestion dealing with management systems for continuity systems.

WG 1: Upcoming suggestions for projects are 1) Principles for exercises and training, encompassing training of the whole chain of management cooperation 2) Private/public partnerships.

WG 2: The next is to publish a draft for a standard on fundamentals and vocabulary.

WG 3: The coming work is publishing drafts on

- principles for command, control, coordination and cooperation in resolving incidents, which is intended to be an encompassing document for WG3;

- essential information and data requirements for command and control, coordination and cooperation and

- inter/intra organizational warning procedures.

The restart in ISO/TC 223 has put new energy to the work in building an international standard for crisis management. The large number of participants that partnered in the retake and those who during 2007 have joined and become full members shows that the there is a broad engagement in developing crisis management standards. The ISO/TC 223 will be forming how the future systems of crisis management will look like and guide operational crisis procedures and business. This development will also have impact on the way of education and training from municipal affairs towards multi-agency and multi-organizational at the international scene.

4.2.3 TSO from OASIS-FP6

The Tactical Situation Object (TSO) defines an information structure to record a view of a situation seen by a particular observer at a particular time. It is used to transfer this view to another observer. Here an observer can range through a machine such as a transponder, a human

with a hand held device, to a complex computer system providing command, control and planning functions. This information contributes to the situational awareness of the various parties, that is, their awareness of the current state of the world, the actions of the agents involved in the crisis and the plans of the responding organizations. The message can be used peer-to-peer for observers at the same level of command hierarchy, or used to send information up and down in the hierarchy.

The TSO is of one the key means to reach a minimum level of interoperability between agencies during the disaster and emergency operations. In the future the TSO could be extended progressively, allowing agencies to collaborate more efficiently during operations by sharing a timely and comprehensive Common Operational Picture. It provides the capability to exchange pieces of information which participate to the Common Operational Picture, but it is not intended to provide all detailed information. There are many ways to increase the interoperability level between several agencies that are working jointly. The ideal is to share the same data model and have access to a common database. This is not able due to the complex technical environment, the concern about how information will be shared and that there is a large spectrum of agencies with different constraints regulated by laws and policies. The OASIS project proposed a set of flexible exchange channels. The definition of the TSO is inspired by the experience of the military domain, where interoperability has been a long standing issue. There are two intended usages of the TSO; the primary use is the exchange of information between two (or more) different operational entities from different command and control levels within the same organization and of different organizations. The secondary use is the exchange of information between components in the same OASIS node.

In Figure 23, the basic structure of the TSO is presented and consists of four parts Context, Event, Resources and Missions.

Context: Identification information, it shall be possible to refer to a TSO instance, and it shall describe who and when the information was created and the relations to other TSO instances.

Event: Description of the event, here the type of event, its extent, the number of causalities, the consequences on the environment is described.

Resources: Description of the resources includes a list of resources, their availability, position and capabilities.

Missions: Description of the missions, for efficient coordination information on on-going tasks, status, engagement and planning are included.

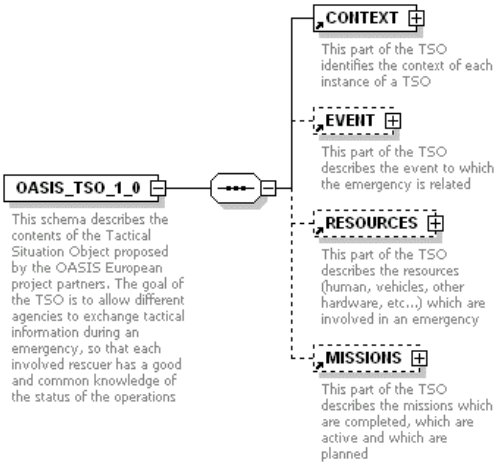

Figure 23: Tactical Situation Object

The TSO uses a "hierarchical dictionary", as it already exists for the military applications. One advantage of this kind of dictionary is to allow an application to "know" only the part of the dictionary which is interesting for it (it shall also know at least the first level of the hierarchy). For parts of the dictionary which are not relevant for one module, it will have at least the capability to identify and to display some minimum information on this piece of information.

Below, an example is provided of event that is stored in 4 levels. At the highest level details, it allows to define an accident which occurred inside a tunnel of a motorway. The TSO denotes this:

```
ACC/ACCTRF/HGHWAY/MOTTUN
```

Where ACC is an event of type Accident, ACCTRF is an accident of the type traffic accident, HGHWAY is a traffic accident which occurred on a highway and MOTTUN finally is that an accident occurred inside a tunnel [95].

4.2.4 DEM to Simulation Interoperability

When designing Modeling and Simulation (M&S) support for DEM the ongoing work and the results from the military domain cannot be neglected. The initial driver to develop mechanisms to provide interoperability between Command and Control (C2) systems and simulations was driven by the need to reduce the costs associated with inputting data into simulations that supported C2 training. Furthermore, the development of digitized C2 systems and the utilization of M&S tools for Course of Action Analysis (COAA), Mission Rehearsal and work on robotic forces have meant that there is an increased requirement for interoperability across these systems. The change from single services and a single national force towards joint coalition efforts also increase the need for interoperability.

4.2.5 Coalition Battle Management Language

Within NATO the Multinational Interoperability Programmer's (MIP) have developed the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM) that enables C2 to C2 interoperability [96].

The ongoing standardization of a Coalition Battle Management Language (C-BML) has the objective to define an unambiguous language as possible to describe a commander's intent so it can be understood and used by soldiers and systems in training and in real-world operations [93]. The resulting language is intended to be applicable not only to simulation systems, but also to operational command and control systems, and robotic systems.

The standardization of C-BML is currently in its first phase addressing a JC3IEDM based standard containing of XML-schemas describing the five Ws (When, Where, Who, What and Why) and corresponding web services. In the coming two phases a grammar will be developed followed by an ontological framework. The debate about what kind of grammar to use can be read in several publications presented at the SIWs. Currently the two major schools in research are the Model Based Data Engineering (MBDE)[97, 98] and the Multi Agency Operational Language (MAOL)[99], which has been developed from the work with the Command and Control Lexical Grammar (C2LG)[100, 101]. The MBDE builds aggregates and composites of the representation from phase one and provides both a method for building 5W expressions that reflects the information within the extended JC3IEDM and a way to manage the information model, i.e. the heart in MBDE. The view of the usage of the C-BML is between systems (machines). The MAOL uses a lexical functional grammar to describe the 5Ws for both machine and human. The starting point is from an operational view and seeks the corresponding constitutes in the 5Ws representation from phase one. The MAOL also addresses crisis, disaster and emergencies. The C-BML Product Development Group has to decide whether the scope of the C-BML is machine to machine communication or if it also should include human to human and human to machine communication. The base of phase one shall however be rich enough to

support both approaches.

The main challenge for C-BML is to prove that it is unambiguous. If the goal for C-BML is that the representation is unambiguous, i.e. that it is machine interpretable, then the main issue is to assure that it is not possible to construct two or more representation of the same originating Commander's Intent and that the Commander's Intent can be reproduced, i.e. "Symmetric" 1-1 conversion. If the goal for C-BML is to also include human interpretation it becomes complex, first the C-BML must be good enough to capture the human expressed intent, then shall it only be able to be represented and transformed above but also to quantify the readability of the C-BML by humans. Therefore the C-BML PDG needs to clearly define to which degree it will be unambiguous, whether it will address only machine or it will address both machine and human; then the choice of grammar approach can be determined for the standardization.

4.2.6 Military Scenario Definition Language

The Military Scenario Definition Language (MSDL) is an XML-based language designed to support military scenario development. The MSDL provides the M&S community with a common mechanism for validating and loading military scenarios. MSDL is said to deliver the ability to create a military scenario that can be shared between simulations and Command, Control, Communications, Computers & Intelligence (C4I) devices. MSDL also provides a way to improve scenario consistency between federated simulations.

The first MSDL specification consists of an XML schema that describes the initial state of the military situation. Future versions of the standard are expected to include additional organizational structures, electronic order of battle information, targeting information, and data structures to hold the planned activities of the organizations and entities defined within the scenario.

4.2.7 Crisis Management Language

In the paper [92] a proposal for a Crisis Management Language (CML) was initiated. The CML idea is to reuse the work in the development of C-BML. This implies there will be a much closer connection between civil and military information models. One such unifying approach is described in the MAOL where a common representation of a lexical functional grammar is expressed that can be used in both military and civil domain.

4.2.8 EDXL

The Emergency Data Exchange Language (EDXL) is a suite of XML-based messaging standards that facilitate emergency information sharing between government entities and the full range of emergency-related organizations. EDXL standardizes messaging formats for communications between these parties. EDXL was developed as a royalty-free standard by the OASIS International Open Standards Consortium. [90][91]

The EDXL family covers a wide range of emergency data exchange standards to support operations, logistics, planning and finance. The ones relevant for BRIDGE are explained in the next paragraphs.

4.2.8.1 EDXL Common Alerting Protocol (EDXL-CAP)

The Common Alerting Protocol (CAP) provides an open, non-proprietary digital message format for all types of alerts and notifications. It does not address any particular application or telecommunications method. The CAP format is compatible with established techniques, such as Web services, as well as existing formats including the Specific Area Message Encoding (SAME) used for the United States' National Oceanic and Atmospheric Administration (NOAA) Weather Radio and the Emergency Alert System (EAS), while offering enhanced capabilities that include:

- Flexible geographic targeting using latitude/longitude shapes and other geospatial representations in three dimensions;
- Multilingual and multi-audience messaging;
- Phased and delayed effective times and expirations;
- Enhanced message update and cancellation features;
- Template support for framing complete and effective warning messages;
- Compatible with digital signature capability; and,
- Facility for digital images and audio.

Key benefits of CAP will include reduction of costs and operational complexity by eliminating the need for multiple custom software interfaces to the many warning sources and dissemination systems involved in all-hazard warning. The CAP message format can be converted to and from the "native" formats of all kinds of sensor and alerting technologies, forming a basis for a technology-independent national and international "warning internet."[92]

4.2.8.2 EDXL Distribution Element (EDXL-DE)

The primary purpose of the Distribution Element 2.0 is to facilitate the routing of any properly formatted emergency message to recipients. The Distribution Element may be thought of as a container. It provides the information to route "payload" message sets (such as Alerts or Resource Messages), by including key routing information such as distribution type, geography, incident, and sender/recipient Ids.[93]

4.2.8.3 EDXL Hospital AVailability Exchange (EDXL-HAVE)

HAVE is a draft XML specification that allows the communication of the status of a hospital, its services, and its resources. These include bed capacity and availability, emergency department status, available service coverage, and the status of a hospital's facility and operations [94].

4.2.8.4 EDXL Resource Messaging (EDXL-RM)

The primary purpose of the Emergency Data Exchange Language Resource Messaging (EDXL-RM) Specification is to provide a set of standard formats for XML emergency response messages. These Resource Messages are specifically designed as payloads of Emergency Data Exchange Language Distribution Element- (EDXL-DE)-routed messages. Together EDXL-DE and EDXL-RM are intended to expedite all activities associated with resources needed to respond and adapt to emergency incidents. The Distribution Element may be thought of as a container. It provides the information to route "payload" message sets (such as Alerts or Resource Messages), by including key routing information such as distribution type, geography, incident, and sender/recipient IDs.[95]

4.2.8.5 EDXL Situation Reporting (EDXL-SitRep)

The primary purpose of the Emergency Data Exchange Language Situation Reporting (EDXL-SitRep) Specification is to provide a set of standard formats for XML emergency response messages specifically aimed at transmitting situation reports. These situation reports are specifically designed as payloads of the Emergency Data Exchange Language Distribution Element (EDXL-DE). Together EDXL-DE and EDXL-SitRep are intended to expedite well-informed incident command decisions needed to respond effectively and adapt to emergency incidents, facilitating communication across various responding organizations and up the chain of command. The Distribution Element may be thought of as a container that provides the information to route "payload" message sets (such as alerts, hospital availability reports, resource messages or situation reports), by including key routing information such as distribution type, geography, incident, and sender/recipient IDs. [96]

4.2.8.6 EDXL Tracking Emergency Patients (EDXL-TEP)

The primary purpose of EDXL-TEP is an XML messaging standard for exchange of emergency patient and tracking information during patient encounter through admission or release. TEP supports patient tracking across the Emergency Medical Services (EMS) care continuum, as well as hospital evacuations and patient transfers, providing real-time information to responders, Emergency Management, coordinating organizations and care facilities in the chain of care and transport.

The TEP purpose is aimed at increased effectiveness of emergency medical management, patient tracking, and continued patient care capabilities during emergency care. TEP is driven by cross-profession practitioner needs (Practitioner Steering Group), and led by the National Association of State EMS Officials (NASEMSO). It also supports select goals of the HHS-Agency for Health and Research Quality (AHRQ), NDMS process and systems, and gaps identified by the Health Information Technology Standards Panel (HITSP).[97]

4.2.9 Multilateral Interoperability Programme – Data Exchange Mechanism MIP-DEM

Multilateral Interoperability Programme (MIP) is an interoperability organisation established by national Command and Control Information Systems (C2IS) developers with a requirement to share relevant Command and Control information in a multinational or coalition environment. [98]

The MIP Data Exchange Mechanism (DEM) supports the partial replication of operational data depending on their affiliation to a particular Operational Information Group (OIG). For each category of OIG, MIP defines specific distribution rules. [98]

DEM is a replication mechanism for the JC3IEDM. It uses a publish-subscribe method to distribute data, utilizing the concept of OIGs. This concept separates the information space into operationally distinct groups, which can be delivered to different receivers. Within each of these groups, referential integrity and semantic completeness of information is ensured. Furthermore, the DEM checks for the compliance to additional business rules. For instance, if an organization is added to an OIG, the DEM takes care of transmitting the organization's status as well. [99]

4.3 Multimedia Data, Formats, Components, and Interoperability

Multimedia data or information assets play an important role in emergency and crisis management operations. Examples of multimedia data are: images, videos, audio clips, text messages, and synthetic content like visualizations of sensor readings or of simulation results (e.g., those of work package 3 of BRIDGE). Multimedia information assets significantly contribute to an up-to-date and realistic operational picture in emergency situations.

In supporting multi-agency collaborative efforts, information sharing, and system interoperability, handling of multimedia data that becomes available in different formats and from different sources, destined for different "consumers" (end users), is an important issue. Multimedia data might become available in an emergency situation in an ad-hoc manner from *different sources*, i.e., mobile or stationary devices (e.g., sensors, mobile phones, surveillance cameras, satellites), mounted in fixed locations or on vehicles or aircraft, or operated by humans in different roles (e.g., first responders, bystanders who offer their help and information and even victims). Different devices will usually produce multimedia data in *different formats*. For instance, while the JPEG format is widespread for digital images (albeit there are proprietary formats as well), digital video might be captured in different compression formats (e.g. MPEG-1, MPEG-2, MPEG-4 AVC, vendor-specific formats) and different spatial resolutions (e.g., QCIF, CIF, SD, some "variant" of HD), and packed into different container formats (e.g. QT,

AVI, MP4, Flash). It is important to make such multimedia information assets readily accessible and perceivable for *different consumers*, most importantly for the response leaders and personnel in the field, in order to improve their situational awareness and the operational picture.

The situation sketched above is typical of a heterogeneous, distributed multimedia system. To support data interoperability, i.e. convenient and reliable multimedia data exchange among the end users in such a system, *multimedia data adaptation* must be performed. This function crucially depends on *multimedia metadata*, i.e. data about the multimedia data. Such metadata describes: on the source side, e.g., the source format and resolution of the multimedia data, the properties of the capture device, time and location of capture; and on the destination side, e.g., the required destination format and resolution of the multimedia data, the properties of the presentation device, the end user preferences and constraints. A high-level illustration of a multimedia adaptation component (or service), including the required metadata assets, is depicted in Figure 24.

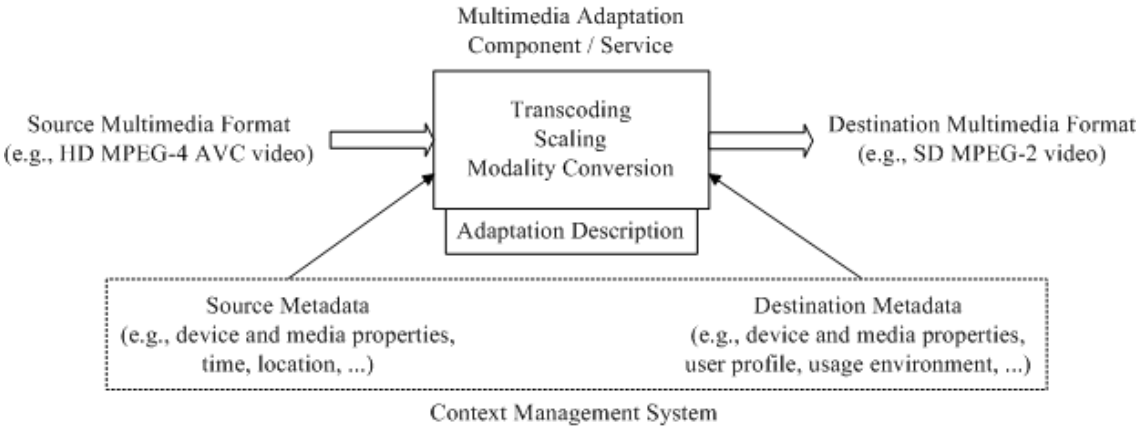

Figure 24: Illustration of Multimedia Adaptation Component / Service

The metadata typically comprise the *context* of multimedia data capturing (capture context, on the source side) and consumption (usage context, on the destination side) and are therefore depicted as being provided by a *context management system*, which in BRIDGE is being designed and developed in work package 5. Other metadata, e.g., data about the communication network (the delivery context in the distributed multimedia system), will be collected and maintained by the context management system as well, but is not further considered here. The adaptation capabilities (service) description specifies the functionality of the component (service) and how it may be invoked (e.g., as a Web service).

Basically, there are three forms that multimedia data adaptation may take (indicated in Figure 24):

1. *Transcoding*. This denotes an adaptation process in which the source media is being decoded from the original media format and re-encoded into a specific format, possibly with other parameters, as determined by the usage context (destination metadata). The decoding and re-encoding steps may be performed only partially, provided that the specific source and destination formats provide some form of "shortcut" adaptation option, which would clearly result in a performance gain as compared to full decoding and re-encoding steps. A transcoding example is depicted in Figure 24: transforming an MPEG-4 AVC video in HD resolution into an MPEG-2 video in SD resolution.

2. *Scaling*. Scalable media are encoded in a form where different representations (or quality variants) of the media asset are embedded in a single (scalable) media stream.

For instance, scalable video means that video variants with different frame rates, spatial resolutions, and quality properties are encoded into a single, highest-quality video stream; in other words, the scalable video provides scalability in the temporal, spatial, and signal-to-noise ratio/quality dimensions. Scaling such a media stream is as simple as extracting the specific sub-stream that corresponds to the target quality required in the usage context. In other words, the basic media format is unchanged, but the specific media coding parameters (e.g., frame rate, spatial resolution, quality) are modified with regard to the highest-quality variant of the media stream. While for scalable media there is usually a slight penalty to be paid in terms of reduced compression efficiency, the performance of such an adaptation step is usually excellent, since adaptation is reduced to extracting the correct sub-stream from the global stream. Examples of scalable media formats include: JPEG2000 for scalable images, MPEG-4 SVC (a recent extension of AVC) for scalable videos, and AAC Scalable in the audio domain.

3. *Modality conversion.* This type of adaptation, sometimes also referred to as "transmoding", denotes more involved modifications to a media asset, namely changing its modality. Examples of useful modality conversions include, but are not limited to: text-to-speech, speech-to-text, image-to-text (i.e., summarization or characterization of an image by means of keywords or tags), video-to-text or video-to-image (i.e., summarization/characterization of a video by means of keywords/tags or by a small set of still images). Such modality conversions may be of widely different complexity and sophistication: on one end of the spectrum, a conversion may be simply based on keywords/tags provided by the user who captured images or audio or video clips (made available as part of the metadata associated with the media assets); or a simple speech synthesis program may be used to achieve text-to-speech conversion; on the other end of the spectrum, sophisticated content analysis techniques may be involved to automatically extract relevant features or concepts from imager or audio or video clips.

4.4 Trust Models

In crisis management there are many areas where trust is required. We identify three main types of interaction which depend on trust for effectiveness. If members of emergency services have to create ad hoc teams it is necessary that the team members trust each other so they can achieve a quick cooperation. In today's world of terror attacks, emergency services have to create a trust relationship with the victims to ensure their own safety. On the other hand, for a good cooperation civilians need to trust the government and emergency services to avoid panic. If we plan to include crowd computing and IT supported interaction there needs to be strong trust between victims.

4.4.1 Inter-emergency service trust

Altschuller et al. explore elements which enhance trust in newly formed teams. In face to face interaction trust can be built easily and quickly; however, there may be occasions where only interaction over IT devices is possible [84]. Trust is still crucial for good teamwork; hence, communication systems have to provide ways to build it. Altschuller et al. identified four main factors to influence trust:

- Self-disclosure: People tend to feel trusted if someone discloses to them. Other findings show that self-disclosure is easier in computer-based media. As a result systems should provide ways for personal introduction via avatars and short texts.
- Impression formation: Trust is significantly based on collected impression. These impressions may miss in virtual communication and be exchanged by presumptions

which may have a negative effect. Thus communicating parties should be encouraged to provide personal information during conversations for smooth decision making.

- Self-awareness: When using computer-mediation people tend to focus on themselves. This leads to overestimating the performance of oneself. The increase of private self-awareness and decrease of public self-awareness may hinder cooperation. Hence, IT services should provide ways for following somebody elses' train of thought to turn attention away from oneself.
- Perceived social presence: Members of emergency forces should have a feeling of being collocated. For example, systems with high delay or unreliable channel may hamper the quality of cooperation.

4.4.2 Trust between emergency forces and civilians

Factors influencing citizens' trust in government and emergency services have been extensively studied over the past years. Wray et al. divide these factors into three main categories [85]. Public perception includes that officials who are knowledgeable, honest and dedicated are perceived as trustworthy. Personal experience gained from previous interactions with agencies may determine ones actions in case of a disaster. Some organizations are believed to be more trustworthy in certain topics than others leading to acceptance or refusal of communicated facts.

For our case the most relevant question is how IT may affect this kind of trust. Semaan et al. investigated previous disaster cases. If trust in government and public services declines, self-organization and information gathering over IT increases [86]. Also, if interpersonal trust declines, for example in disasters resulting in violent conflicts, IT is preferred as method to re-establish trust e.g. by cross-checking information.

While the direction of citizens' trust in government is well studied, the other way is new and unexplored. Emergency services have just started to use social media for emergency management and often lack methods to use information gained from public. An approach which may be a starting point is [87]. In this approach, link analysis and PageRank-like algorithms are used to measure the quality of answers at Yahoo! Answers. Finding high quality content is then assumed to be similar to determining trustworthiness.

4.4.3 Inter-victim trust

Cristen et al. studied disaster relief by coordination of ordinary people [88]. Normally trust is established over time through a history of interaction or by a trusted third party. However, this is not possible in case of victims interaction. A natural phenomenon between people in emergency conditions is swift trust. Swift trust is established based on simple category-based judgments. The establishing of swift trust requires sound ways for identification, introduction and hierarchy building. Also findings of Altschuller et al. can be applied for building trust for such relationships [84].

A technical solution to support trust building between victims is provided by *trust frameworks* for ad-hoc networks. These frameworks aim at creating reliable communication channels between devices. There are different ways to identify these channels but they are mostly based on observing message forwarding properties [89]. Every device keeps track of first hand observation and extends its findings by collecting reputation information. While this approach is more quantitative, it may not be as robust and responsive as trust based on social elements.

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