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OpenKnowledge Deliverable 6.5: Emergency response in an open information systems environment

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Abstract. The role of the OpenKnowledge system is to support and enhance the sharing and the effective use of information and services among different actors. In this document we analyze and present a set of scenarios related to emergency response upon which to test the OpenKnowledge system. In particular, we describe the general requirements of the emergency scenario that we are planning to investigate in the OpenKnowledge project.

1 Introduction

The need to harness the potential of electronic networks in emergency situations is recognized as a relevant research priority. Quoting from the EU “Emergency Response Grid” programme [11]:

“In times of crisis - be it a natural disaster, terrorist attack or infrastructure failure - mobile personnel need to work together in time-critical and dangerous situations. Real-time access to information and knowledge, powered for example by Grids, will help save lives. Crises are complex situations, with large numbers and varieties of mobile personnel - medical and rescue teams, police, fire fighters and other security personnel - appearing on the spot at short notice. These different teams come from different organizations, and generally have incomplete or even contradictory knowledge of the crisis situation.”

Emergency management activities - that in the following we will reference as emergency response (e-Response) activities - are developed and implemented through the essential analysis of information. Usually such information is accessible through distributed data sources, the majority of which is spatial and can be mapped. Once information is mapped and data is linked to the map, e-Response planning can take place. Typically, life, property, and environmental values are combined with hazards or disaster data, and based on this information emergency personnel can begin to formulate mitigation, preparedness, reaction,

and recovery program needs. Current Geographical Information Systems (GIS) allow emergency response needs to be identified prior to an incident. Disaster data and events, such as wildfires, tsunami, floods, earthquakes, hurricanes, epidemics, chemical cloud dispersion, and oil spills, can be acquired, modeled and displayed in state-of-the-art GIS. Emergency response personnel can also use real data and appropriate models for training, for actual tactical deployment during a disaster, or to analyze the consequences of a possible disaster. All phases of emergency response management depend on data from a variety of sources. The appropriate data has to be gathered, organized, processed and eventually fused with other sources, and displayed sensibly to determine the size and scope of emergency response programs. Moreover, during an actual emergency it is critical to have the right data, at the right time, displayed logically and contextually, to respond and take the appropriate actions. At present, state-of-the-art GIS provides a mechanism to centralize and visually display critical information during an emergency. However, emergency monitoring and management activities usually involve a range of different organizations and teams at various administrative levels with their own systems and services. The application of numerous and different actors, policies, procedures, data standards and systems, results in coordination problems with respect to data analysis, information delivery and resource management, all critical elements of emergency response management. At present, most of the sharing of relevant information that is required for dealing with emergency is often limited to a raw data exchange with all the syntactical and semantical conversion problems. True efficiency, in most cases, is thus hindered by lack of interoperability on the technical and semantical level as well as by administrative and legal boundaries. In order to support the full use of advanced methodologies and technologies, there is the need to remove or at least lower the various barriers present in the adoption of current technologies and supporting information systems. Such barriers can have both technological aspects (standards, licenses, interoperability issues), but also syntactical and semantical (numerous and different policies, procedures, data and systems contextual representation) and of a social nature dealing with the specific models of interactions in this emergency situations.

In this specific domain (e-Response), the OpenKnowledge project is interested in eliciting and exploring functional and non functional requirements, in particular:

- to support real-time access to contextual information, knowledge and services before and during emergency events;
- to sustain collaboration of teams (agencies, experts, emergency personnel, normal citizens,...) in emergency situations.

Current technologies and information systems can provide parts of the solution with ad-hoc and mostly centralized systems. What we want to explore in OpenKnowledge is a test of the flexibility and adaptability of an open and distributed system capable of reacting effectively to emergency needs and of dealing with the intrinsic (semantic) heterogeneity of the involved different data and services support the (semantic) interoperability between them. The challenge of

such a testbed in this domain is in the rapidity of formation of emergency coalitions - often very intense and opportunistic “communities of practice” where judging the quality of answer is critical and dynamic. Unlike existing Grid efforts in the field [11], in OpenKnowledge we do not assume any special gridded infrastructure - instead we focus on simplicity of coalition formation and use of inference to form and sustain interaction.

The rest of the deliverable is organized as follows. Section 2 introduces in some detail emergency response aspects, typical phases and relevant issues. Moreover it presents a brief overview of current applications of state-of-the-art information systems supporting emergency response activities. Section 3, 4 and 5 describe a number of application scenarios. After a brief introduction (Section 3), the scenarios are divided into two main categories: natural disaster emergency scenarios (section 4) and metropolitan accident scenarios (section 5). In these sections we present and discuss the type of overall general requirements such scenarios pose towards an open and distributed information system such as OpenKnowledge. For clarity of presentation, we have decided to present in two separate Annexes a detailed description and analysis of a selected number of relevant scenarios (one natural disaster scenarios and one metropolitan accident scenarios). Section 6 concludes the report and addresses some open issues and challenges towards an open environment for emergency response.

2 Emergency Response

Emergency protection and response can be defined as the application of knowledge, procedures and activities to anticipate, prepare for, prevent, reduce or overcome any risk, harm or loss that may be associated with natural, technological or man-made crises and disasters during peacetime.

In this section we will present briefly a generic and shared framework for civil protection. Individual local and detailed civil contingency plans of the emergency services - developed by local authorities, government departments and other statutory, commercial and voluntary organizations at local, regional and national level - generally share such common framework.

Various terms are in common use to refer to different types of major emergency disaster, crisis and major incident are among the most commonly used. In the following we will use the term *major emergency* following [7]:

“any event or circumstance (happening with or without warning) that causes or threatens death or injury, disruption to the community, or damage to property or to the environment on such a scale that the effects cannot be dealt with by the emergency services, local authorities and other organizations as part of their normal day-to-day activities.”

So the central property of a *major emergency* is that no single organizational arrangement will be appropriate. Thus, we can say that there is no single agency which has all the skills and resources which may be needed. It is clear that, in the majority of cases, prime responsibility for handling major emergencies remains at

the local level where the primary resources, expertise and knowledge are found. However, specialist advice and expertise is needed and hopefully available both at central government level and within neighboring emergency services and other organizations which may be called upon in support of the local level response.

Moreover, major emergencies have a variety of effects on society and the environment. Thus they demand a combined and coordinated response, linking the expertise and resources of institutional organizations (emergency services, local authorities and central government, health service, armed forces, etc.) private sector organizations (transport, utilities, etc.), and voluntary agencies. Appropriate support has to be coordinated at local, regional or sometimes national level. This coordination of planning, training and exercising for an effective combined response to any type of emergency is fundamental to the achievement of a successful outcome for all who may be involved in responding to a major emergency. While many major emergencies may be sudden and unpredictable, certain kinds of activity carry known risks and are subject to legal requirements for assessing risks, putting prevention and mitigation measures in place, and planning the response to an incident. These include known chemical or nuclear hazards at fixed locations, where the most probable types of incident and their likely consequences are largely foreseeable. For this reason it is possible to make detailed plans for appropriate measures and actions in advance. The existence of such plans reduces the likelihood of errors resulting from decisions being taken under crisis conditions.

2.1 A general framework for Emergency Response

The following five activities are fundamental to an integrated approach and can be found in almost every local civil contingency plans of the emergency services:

Assessment. Emergency management programs begin with locating and identifying potential emergency problems. This involves assessment activities from organizations of different types (local, central, etc.) to analyze and document the possibility of an emergency or disaster and the potential consequences or impacts on life, property, and the environment. Anticipatory assessment activities should mainly (1) identify measures which may prevent an emergency occurring in the first place (2) identify the possible emergencies facing an organization or community for which joint arrangements should be made.

Prevention. Certain kinds of activity carry known risks and are subject to legal requirements for adopting prevention measures which aim to eliminate, isolate or reduce those risks as far as is reasonably practicable. Legislation, regulations, codes of practice and guidance documents stipulate or recommend measures that are appropriate to preventing many dangerous occurrences or reducing their severity.

Preparation. Preparation involves planning, training and exercising. Plans must provide the basis for an effective integrated response to major emergencies. A plan should provide a prepared and agreed framework within

which organizations and individuals can work in a concerted manner. Contingency plans are not simply the domain of contingency planners - they should be seen as an integral part of overall management strategy. Crisis management structures must define roles and responsibilities clearly at all levels. Potentially involved organizations need to establish and test call-out and activation arrangements. As already underlined, the overall response to a crisis will invariably need input from a number of different departments. Effective planning should therefore ensure that arrangements and activities of different departments within an organization are cohesive.

Wherever possible, people should perform in an emergency those tasks with which they are already familiar. Nonetheless, personnel will require some additional training to prepare them for the special circumstances experienced during a major emergency and for any extra dimensions to their role. It is no use having plans in place if people are not trained to perform in accordance with them. Regular exercises should test the effectiveness of arrangements for responding to major emergencies. Any lessons learned should then be incorporated into revisions of the plans.

Response. The initial response to a major emergency aims to deal with the first effects. In this phase collaboration, co-ordination and communication are vital. With sudden impact emergencies (explosions, major transport accidents, earthquakes,...) the initial response is normally provided by the institutional emergency services and, as necessary, by the appropriate local authorities and possibly voluntary organizations. A key consideration when assessing and planning appropriate response frameworks for emergencies is therefore to identify the trigger points that will prompt an organization to activate its emergency management arrangements. The aim must be to mitigate the effects of the emergency by implementing measures that provide the necessary resources for the longer term response and for ensuring the continuity of critical services.

Recovery management. The effects of the emergency may be continuous and ongoing, but as soon as the immediate threats are halted, basic services and vital needs need to be restored. This is when recovery efforts begin. Recovery efforts are often in two phases, short term and long term. Short-term recovery restores vital services and systems. This may include temporary food, water, and shelter to citizens who have lost homes in a hurricane or large wildfire, assuring injured persons have medical care, and/or restoring electrical services through emergency generators, and so forth. Long-term recovery restores all services to normal or better than before. Long-term recovery (replacement of homes, water systems, streets, hospitals, bridges, schools, etc.) can take as long as several years.

These five activities have collectively been labelled as an Integrated Emergency Management approach (IEM) following [7] and that is how we will refer to them hereafter.

2.2 Geographical Information Systems supporting emergency response

All phases of an IEM depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of emergency management programs. During an actual emergency it is critical to have the right data, at the right time, displayed logically, to respond and take appropriate action. By utilizing a centralized or distributed GIS, all departments can share information through databases on computer-generated maps in one location. Without this capability, emergency workers must gain access to a number of department managers, their unique maps, and their unique data.

Most emergencies do not allow time to gather these resources. This results in emergency responders having to guess, estimate, or make decisions without adequate information. This costs time, money, and-in some cases-lives. GIS provides a mechanism to gather, publish, find and visually display critical information during an emergency. Most of the data requirements for emergency management are of a spatial nature and can be located on a map. The remainder of this section will illustrate briefly how state-of-the-art GIS can fulfill data requirement needs for planning and emergency operations and how GIS can become the backbone of emergency management.

Assessment and Prevention. As we have seen above, emergency management programs begin with locating and identifying potential emergency problems. Before an effective emergency management program can be implemented, thorough analysis and planning must be done. A GIS facilitates this process by allowing planners to view the appropriate combinations of spatial data through computer-generated maps. Using GIS, officials can pinpoint hazards and begin to evaluate the consequences of potential emergencies or disasters. When hazards (earthquake faults, fire hazard areas, flood zones, shoreline exposure, etc.) are viewed with other map data (streets, pipelines, buildings, residential areas, power lines, storage facilities, etc.), emergency management officials can begin to formulate mitigation, preparedness, response, and possible recovery needs. Lives, property, and environmental values at high risk from potential emergency or disaster become apparent.

Preparation. Preparedness includes those activities that prepare for actual emergencies. GIS can provide answers to questions such as : Where should fire stations be located if a five minute response time is expected? How many paramedic units are required and where should they be located? What evacuation routes should be selected if a toxic cloud or plume is accidentally released from a plant or storage facility based on different wind patterns? How will people be notified? Will the road networks handle the traffic? What facilities will provide evacuation shelters? What quantity of supplies, bed space, and so forth, will be required at each shelter based on the number of expected evacuees?

GIS can display real-time monitoring for emergency early warning. Remote weather stations can provide current weather indexes based on location and

surrounding areas. Wind direction, temperature, and relative humidity can be displayed by the reporting weather station. Wind information is vital in predicting the movement of a chemical cloud release or anticipating the direction of wildfire spread upon early report. Earth movements (earthquake), reservoir level at dam sights, radiation monitors, and so forth, can all be monitored and displayed by location in GIS. It is now possible to deliver this type of information and geographic display over the Internet for public information or the Intranet for organizational information delivery.

Appropriate use of GIS can assist in collecting past and current information and provide it for to the planners in the development of the preparation plans and to the personnel for training with real emergency data.

Response. GIS can provide one of the primary components for computer-aided dispatch systems. For instance Emergency response units based at fixed locations can be selected and routed for emergency response. The closest (quickest) response units can be selected, routed, and dispatched to an emergency once the location is known. Depending on the emergency, a GIS can provide detailed information before the first units arrive. For example, during a commercial building fire, it is possible to identify the closest hydrants, electrical panels, hazardous materials, and floor plan of the building while en route to the emergency. For hazardous spills or chemical cloud release, the direction and speed of movement can be modeled to determine evacuation zones and containment needs. During multiple emergencies (numerous wildfires, mud slides, earthquake damage) in different locations, a GIS can display the current emergency unit locations and assigned responsibilities to maintain overall situation status.

Recovery management. A GIS can play an important role in short-term recovery efforts. One of the most difficult jobs in a disaster is damage assessment. A GIS can work in concert with GPS to locate each damaged facility, identify the type and amount of damage, and begin to establish priorities for action (triage). Laptop computers can update the primary database from remote locations through a variety of methods. GIS can display (through the primary database) overall current damage assessment as it is conducted. Emergency distribution centers' supplies (medical, food, water, clothing, etc.) can be assigned in appropriate amounts to shelters based on the amount and type of damage in each area. GIS can display the number of shelters needed and where they should be located for reasonable access. A GIS can display areas where services have been restored in order to quickly reallocate recovery work to priority tasks. Action plans with maps can be printed, outlining work for each specific area. Shelters can update inventory databases allowing the primary command center to consolidate supply orders for all shelters. The immediate recovery efforts can be visually displayed and quickly updated until short term recovery is complete. This visual status map can be accessed and viewed from remote locations. This is particularly helpful for large emergencies or disasters where work is ongoing in different locations.

Also long-term plans and progress can be displayed and tracked utilizing a GIS. Prioritization for major restoration investments can be made with the assistance of GIS. As long-term restoration is completed, it can be identified and visually tracked through GIS. Accounting for disaster costs can be complicated. As funds are allocated for repairs, accounting information can be recorded and linked to each location. Long term recovery costs can be in the millions (or more) for large disasters. Accounting for how and where funds are allocated is demanding. A GIS can ease the burden of this task.

To conclude this section, it is important to underline that all the above applications are delivered with different architectures (centralized or distributed), platforms and software (proprietary and open source). Key issues are: integration of the various datasets (most often maintained by different actors), support for the interoperability among the different systems, fast and accurate discovery of the relevant data present in separate institutions.

3 Emergency Response Scenario: introduction

Disaster scenarios are not, at heart, predominantly P2P. Large amounts of pre-organization will inevitable be done between disaster teams in the area and standard methods of interacting during the emergency will be developed. Additionally, emergency teams would not normally be autonomous but would report to and be given directions from a control center whose task would be to manage the emergency; thus the structure would be more hierarchical than P2P. However, disasters, by their very nature, are chaotic and unpredictable and the preparation for the disaster will not necessarily be sufficient. Not only will plans and strategies have to be amenable to change, but also the way in which units and individuals interact and the people that they interact with may also need to be flexible. Lines of communication may be down unexpectedly and communication bottle-necks, such as through command centers, may mean that units are left without instructions at vital moments and may need to turn to others in the vicinity who are not, in the original scheme, supposed to be supplying them with information or assistance. Also, individuals or units who would not be expected to take part in the disaster effort may be called in unexpectedly: fire units from other areas in case of the fire being too much for the local units; doctors who happened to be in the area. In these situations, the ability of units or individuals to switch to working in a P2P manner, with on-the-fly information sharing and interaction, at moments when the expected hierarchy breaks down, could be crucial. Moreover, as we have seen in the previous section, the GIS data is often available but in the majority of the situations needs to be located, intergraded and fused together from very different sources.

We will illustrate the above consideration focusing and describing in some details two type of emergency response scenario, namely:

- metropolitan accident scenario

- natural disaster scenario

In particular in the following, we will provide, for each scenario, an intuitive description, a preliminary analysis of the main actors involved and an outline of a number of relevant use cases. In the two related annexes, we have collected the organizational and technical details of the two analyzed emergency response scenarios. There we have collected and presented more information about the details of the involved peers, of the main organizational models and interactions. We have also included some preliminary instances of interaction models for a selected number of interactions to be used as first examples for the analysis of the typical matching and searching activities as well as the typical complexity of the actual interactions.

4 Natural Disaster Scenario: Flooding in Trentino, Italy

In this section, our goal is to describe, as an example of a natural disaster scenario, a possible flooding event and to show how a system such as OpenKnowledge in combination with an appropriate GIS infrastructure, could be useful to manage both the sharing of the information and the coordination activities between the different actors involved in this event.

We will focus on a realistic scenario provided by past experiences and local plans of the Autonomous Province of Trento (PAT) as collected from interviews of the involved institutions personnel and related documents. As discussed in Section 2, PAT has developed guidelines for the activities of planning, prevention, preparation, response and recovery (e.g Integrated Emergency Management) for the whole province and for every municipality of Trentino [5] in the case of a civilian emergency. Thus, the description of the event, is based on [6] and [5]. The main civil protection terms of the paper are taken from [4]. In particular, we have based the description of the non functional requirements on [6]. The individuation of the flooding area is based on the analysis of the past flooding events (1882 and 1996 flooding events) and over various morphologic and geologic observations. Document [6] reports the identification of three main classes of flooding: from 0 to 1 meter, from 1 to 3 meters, and higher than 3 meters. In this document, for the identification of reasonable non-functional requirements (for instance the number of persons involved in the emergency situation) we are going to consider the most probable situation: a flooding lower than 3 meters, but higher than 1 meter.

The emergency intervention plan of the Autonomous Province of Trento (PAT) is composed by different parts. The following scenario intuitive description contains the goals of the plan, the detailed description of its phases, the main actors involved in the emergency response and the description of the PAT Geographic Information System useful to support the activity in the case of emergency response.

4.1 Scenario intuitive description

At 23:00 on November 4th, 1966, the river Adige, the main river of the Trentino region, broke its banks at different sites and flooded the majority of the territory of the Trentino main town, Trento. The main reason was a particularly intense period of rainstorm. Moreover a considerable amount of oil, from housing heating systems and fuel depositories and petrol stations, mixed with the mud waters of the river. The majority of the Trento population as well as surrounding areas had been affected.

Today, in 2006, the flooding of the Adige river is still the most probable emergency event in the Trentino region. Therefore here we will focus on such flooding emergency in the city of Trento.

Trento is a city situated in the north of Italy and its area covers about 158 km². Its territory is mainly composed by mountains (altitudes from 181 meters to 2090 meters over the sea). A lot of rivers pass through the city area and, among this, the most important river is the “Fiume Adige” river. Along this river, there is a high concentration of human activities and population. For these reasons, the main hazard for Trentino is represented by a flooding of the “Fiume Adige” and its related fluvial network.

The main goal of the municipality emergency plan [6] is to organize the evacuation of the population. In Trento town the resident population in 2001 was about 104.000 individuals. The potential number of persons affected by a flooding of class 2 (see previous section) is estimated around 19.000 (19% of the total residents). About 2.000 are older than 70 years. In this situation the knowledge of the state of the viability structures affected by the flooding event is fundamental. The information about the viability permits to the civilian protection actors to choose the proper viability structures for the evacuation plan. For Trento province the most important ways of communication are situated along the “Fiume Adige” valley (“Brennero Highway”, “Brennero railroad”, and “SS 12”), so they are subjected to a high flooding hazard, too. All public buildings that are contained in the flooding area are considered critical sites and potential risk factors since they might contain a high number of persons. It’s therefore mandatory to have a census of such buildings (such as technical offices, libraries, schools, churches, museums, hospitals etc.) and to locate the affected buildings. Also here, the primary goal is to evacuate the persons in such buildings effectively and rapidly.

As a secondary goal, it’s mandatory to preserve cultural and historical heritages affected by the flooding event. Knowledge about such sites and their content, located in the flooded area, could permit the relocation of the main assets in more secure places. Moreover, knowledge about the service infrastructures - such as the electricity network, the waterworks network, the pipeline network, the telecommunication network is of uttermost relevance during emergency events.

4.2 Parties involved

In an emergency situation in the Trentino region, there are two main levels of coordination: the provincial level and the municipality level. Only in cases

of extensive emergencies, other levels have to be coordinated (national level, European level, international aids) with the province (PAT) and municipality levels. For the case of our scenario, flooding emergency in the city of Trento, our scope is limited to the above two main levels. In the case of such an emergency a PAT (provincial level) coordination center is the responsible institution for the emergency response. The main actors indicated in the current PAT emergency plan are:

- PAT Emergency Coordination Center (PECC, “Sala Operativa Provinciale”). The Coordination center is directed by the chief of the Civilian Protection and Fire Department. It coordinates all others PAT agencies. The most important are:
 - Civilian Protection and Fire Agency (5886 units)
 - Emergency Event Prevention Agency (“Servizio Prevenzione Calamita’ pubbliche”)
 - Geologic Survey Agency.
- The PECC coordinates the municipalities involved in the emergency response. For every municipality a Municipality Coordination center needs to be formed in a very short time (COC: “Centro Operativo Comunale”). The COC is composed by:
 - The municipality Mayor (chief of the COC).
 - Municipality Volunteers Fire Unit (“Corpo volontari vigili del fuoco”).
 - Other technical municipality resources and structures.
- PECC also involves other institutions. The most important one are:
 - The Provincial Health Agency (“Azienda Provinciale per i Servizi Sanitari -APSS”).
 - The government commissariat (“Commissariato del Governo”).
 - Other volunteers agencies:
 - * Helicopters unit
 - * Alp corps Volunteers Group (“Nucleo Volontari Alpini”- Nu.Vol.A.)
 - * Alp aid unit (“Soccorso Alpino”)
 - * Italian Red Cross (“Croce Rossa Italiana”)
 - * ...
 - Other Government and Military institutions.

Figure 1 illustrates the simplified overall organizational schema of the PAT emergency coordination plan.

Alongside the above operational institutions, in Trentino a separate institution named SIAT (“Sistema Informativo Ambiente e Territorio”) is also operative. It is responsible for the management of all geographic information in Trentino. SIAT is divided into different agencies. Each agency is responsible for a subset of the datasets, so the Geology Survey agency is responsible for geological datasets, the Urban Planning agency is responsible for the urban planning cartography, etc. Some datasets are defined as “basic cartography”, in the sense that these datasets are the base on which all the other datasets (“thematic” datasets) are built upon. The basic cartography contains, for example, the aerial digital photos, the topographic map, the elevation points, the digital terrain

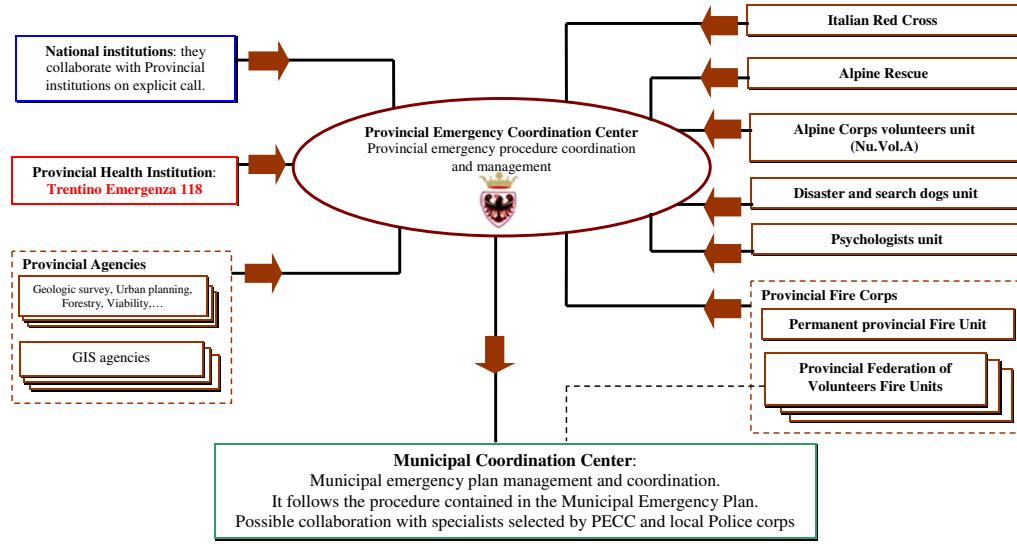


Fig. 1. General organizational schema for coordination and control in the Province of Trento

model, the administrative boundaries, etc. There is an agency responsible for the basic cartography. Examples of thematic datasets are the geology risk, the natural parks, the location of the hydrants, the location of the schools, etc. Every agency produces its datasets, and provides a number of GIS services.

In our example of emergency scenario, we can identify a number of organizations that are involved in the specific scenario. The first group of organizations is related to the GIS environment. In our case the GIS system is a distributed system composed of about ten similar GIS agencies. Every GIS agency is responsible for the management of a subset of PAT GIS data. In Annex A, we present the details of a GIS agency main roles.

Hereafter, we restrict our analysis to the main organizations that participate to the real emergency system (figure 1), namely:

PAT Emergency Coordination center. It has the responsibility to coordinate all the others organizations using the information received by the municipality coordination center (COC, see below) as well as by institutional emergency signalling channels (e.g. emergency numbers). It must receive those information and it has to decide whether and when to activate other emergency actors involved in the event situation.

The Civilian Protection and Fire. The main structure coordinated by the PECC is represented by the “The Civilian Protection and Fire” agency that is divided into two main organizations:

- **The Permanent Fire Corps:** “Corpo Permanente VVF di Trento”, 169 individuals.

- **The Volunteers Corps:** provincial federation of about 240 Corps, approximative one corps for each Trentino municipality.

Municipality Coordination center of Trento. It's the organization responsible for the emergency response in the municipality of Trento. It has to coordinate its directives with PECC decisions. It can control the Volunteers corps of the Trento municipality.

The citizen society. It's compound by the citizen of the municipalities involved in the emergency event.

We can treat the environment in terms of abstract computational resources. The main resources for our systems are at present:

- **The GIS data repositories:** it contains the GIS maps for the Trentino region. For each map there exists a description (GIS metadata). Each GIS agency has its own repository.
- **The Civilian Protection and Fire Database:** it contains much information such as data concerning Fire corps in Trentino (general data such as people, phone numbers, photos, addresses, etc), the local military station (“Carabinieri”), the forestry stations, emergency resources (tanks, rafts, etc) and their location, the hydrants map, etc.. At present, such a database is logically distributed but physically centralized database. Every Trentino Fire Corps can read all the information and can write/modify only the information related to its corps.
- **The Emergency Plan of the Municipality of Trento:** it contains, among others, information about emergency procedures; numbers of residential people for each area; list, number and the location of the public common structures (churches, schools, public offices, pools, etc); list and position of hazard multipliers (Gas stations, factories, supermarkets, garages, etc); list and numbers of storehouses (equipments, materials, etc); evacuation center (school buildings, sport centers, institution buildings); people meeting points (list and maps), etc.
- **The Network of hydrographic stations (sensors):** to control the hydrographic water level. It's compound by different sub-networks:
 - Main controlled network: about 100 stations connected (real time) via radio (radio bridges) and GPRS.
 - Secondary sub-networks: provided by the forecast weather local office (“Meteo Trentino”).
 - Electricity agencies sensors (national and local companies: “ENEL”, “Edison”, “Trentino Servizi”) to monitoring water level for each dam.
 - Information provided by boundary regions and institutions (“Veneto” region, “Magistrato della acque di Venezia” institution, “Friuli Venezia Giulia” region, “Bolzano” province).
 - The actual stations number is 474 (it's still growing). The average update period is 15 minutes.
- **Local repositories:** it is reasonable and realistic to suppose that most actors involved will possess and maintain contextual information about emergency procedures: some of these will be from previous emergencies, others

will be stored during the current emergency. The majority of such information is probably a duplication of information existing in other resources (however not entirely); nevertheless it is useful to consider it and share it during the emergency.

4.3 Use Case

From the overall local flooding emergency scenario situated in Trento and in the surrounding areas we have selected three relevant use-cases (sub-scenarios) to focus on that illustrate different level of complexity:

GIS management scenario: it consists in the coordination and GIS data integration and distribution among the GIS agencies of PAT. The GIS data peers provide the GIS data to the GIS data requestor. This is a “preparedness” scenario, in the sense that, it is a prerequisite for an accurate data usage during the actual run-time emergency scenario. The main issue here is that every agency produces a large number of datasets, but, even if they are published as “public data”, often the availability of the data isn’t known by the other agencies. Moreover, the agencies could provide some additional services (conversion between different coordinate systems, digital maps, ...) but most often they do not explicitly provide at present the sequence of operations needed in order to use those functionalities.

Emergency signaling scenario: we could think that in an emergency scenario the signaling could come from different sources, such as, e.g., a fireman, a citizen, a sensors network connected to an alerting system. In our scenario we’ll consider initially the first two cases:

- a fireman sees a flooding break of the Adige river and advertises the event to his fire-unit. His fire-unit enriches the information with local data, if possible, and pushes it to the coordination center of PAT.
- a citizen that uses the emergency phone number (for Trentino region the number is 115) to alert the Civilian Protection Coordination center.

Coordination for citizen evacuation scenario: this complex activity contains a number of steps, among which:

- Step 1: the coordination center of PAT decides to build a map for assisting the people that are subjected to flooding risk and to organize their evacuation from their houses. The main activity of this step is to ask for a map to GIS system that permits the individuation of the flooded areas as well as information relevant to the involved population, main public buildings and main infrastructures. Then, the emergency coordination center has to identify the citizens involved in the emergency.
- Step 2: the PAT coordination center asks for the intervention at the Municipality level and, in parallel, it asks for the intervention of the Permanent Fire Corps. It then sends the map of the interested area to both the organizations.
- Step 3: the Municipality level Coordination center asks for the intervention to the Municipality level Fireman Corps to help in the citizen evacuation.

- Step 4: the Municipality level coordination center sends a message (for instance: *go towards the church, stay at home and wait for help*, etc) to alert the citizens involved in the flooding risk. The choice of the citizens and the type of the message are based on their location and situation.

Details of these use-cases, with an explicit description of the involved interaction, can be found in Appendix A.

5 Urban Disaster Scenario: Cargo Plane Crash in Central London

This scenario was developed by the AKT (Advance Knowledge Technologies) project [3]. Here, we give the overview of the scenario and consider how OpenKnowledge could provide useful functionality to improve emergency response in such a situation. We then go on to consider in more detail a particular interaction that might occur as part of this scenario. More details of this interaction can be found in Appendix B. This section ends with a short presentation of a simulation tool (Kobe simulator [8]) that we consider useful for the evaluation and testing of the OpenKnowledge system in the emergency scenario.

5.1 Scenario intuitive description

One hour ago an aeroplane crashed on the City of London. The aeroplane, a civil cargo transport, had begun to break up before impact, scattering debris and fuel over the entire area. As a result, multiple fires have broken out, roads are blocked, and a number of people, many injured, some seriously, are now trapped in burning buildings.

The City of London is home to the ‘Square Mile’, the main financial district of London, and as such many of the buildings are given over to office use, with residential use relatively low. Nonetheless, the City has around 8,000 residents, many of whom are concentrated in the Barbican Estate, the City’s largest residential sector. The Estate, home to around 4,000 people, contains three of London’s tallest buildings (Cromwell Tower, Shakespeare Tower and Lauderdale Tower, each 42 stories and 123 metres high), as well as the Barbican Center, a center for the arts, drama and business expositions, the City of London School for Girls, the Museum of London and the Guildhall School of Music and Drama. In addition, located within the City are a number of famous landmarks of historic, cultural or symbolic significance, including St. Paul’s Cathedral, the Old Bailey, the Inns of Court, St. Bartholomew’s Hospital (no A&E), the Bank of England and, on the fringes of the City, the Tower of London, as well as a number of more recent prominent additions to London’s skyline, such as the Tower 42 (the “NatWest Tower”) and 30 St. Mary Axe (the “Swiss Re Tower” or the “Gherkin”). Several important bridges across the Thames are located within the City, as are a number of mainline railway stations and Tower Gateway Docklands Light Railway station. The Central, Circle, District, Northern and Waterloo and

City underground lines and the London Post Office Railway (now mothballed) pass under the sector. In the response to the incident, it will be necessary to consider a wider area than that directly affected by the crash, both for useful resources (e.g., the closest hospital with A&E facilities - and also the base for the HEMS London Air Ambulance - is the Royal London Hospital, to the east of the City in Whitechapel) and for consideration of the wider implications of the incident (e.g., identifying major cross-London transport arteries could help to prioritise response).

5.2 Parties involved

Such an emergency will be dealt with by many different kinds of people who have to be able to communicate, share information, send and receive tasks, and so on. These people will include:

- **Fire officers:** both in a control center and firemen on the streets;
- **Medical agents:** ambulance drivers, hospital organizers, doctors;
- **Police agents:** metropolitan police, transport police, etc.;
- **Possible other agents:** civilians on the street, people with access to helicopters, etc.

These humans will be supported by their peers, which could be connected to the OpenKnowledge system, and which can, to some extent, take over controlling the coordination when directed, as necessary. It would not in general be necessary for each individual to have their own peer, as they are often not operating as individuals but are working in teams. So, for example, each fire team would be represented by a peer, access to which would be located on their fire engine. However, a doctor may be considered to be working independently, and thus would have his own peer to represent him and this peer would be located on some tool he has easy access to, such as his mobile phone.

The role of the peers would be to pass information to each other (some of which, such as location, could be done automatically (for example, through GIS information) and some of which would require input from the human user through some kind of GUI) and to determine what the human user(s) of the peers were best to do next, given the information the peer has received, the tasks it has been given and its knowledge of the current environment. For example, a fire-engine peer might automatically publish information to all interested peers about where it was located and, from information input by firemen, if they had time to do this, what kind of fire it was dealing with. It might receive messages from the fire station, or from other sources such as other fire-engines, ambulance crews, etc. concerning relevant tasks. It could then decide what was the most important task for the fire-engine to perform next. This decision might be made repeatedly, as it may not be clear how long the fire-engine would need to remain at its current location. So as soon as it arrives at its location and the firemen begin to put out that fire, it would work out what the best thing to do next is, but this would be reconsidered at regular intervals as the information on

which the decision was based changes. Naturally, the fire team may well ignore this information and take orders directly from the fire center - under standard protocol, this would be the norm - but this information is available if necessary: for example, if they cannot get hold of the fire center. Additionally, the fire crew may notice some injured or potentially injured people, and could input this information to the peer, who could then pass this information on to relevant people (though, in normal circumstances, a call to the medical center would also be essential).

It is to be assumed that all the fire-engines from a given fire-station know how to communicate properly with that fire-station and use the same terminology and processes; likewise with ambulances from a given ambulance base, and that City fire crews will be able to talk to City ambulance crews, and so on. However, the scale of the emergency may require interaction with groups that are not normally part of the procedure, and thus may have different representations and ways of doing things. For example, the London fire brigade may not be sufficient for the task; perhaps fire brigades from all over the South-East of England may be called in. The local hospitals may not be able to take all the injured or may not have the facilities for particular injuries and more remote hospitals may have to be contacted. Blocked roads and potentially large distances to hospitals may require the use of helicopters; if those currently available to police and hospitals in the London area were not sufficient, additional helicopters may have to be commissioned from other sources, including, potential, private owners. All registered doctors within the South-East of England could be contacted to see if any of them happened to be in the area and could be of assistance. These doctors would then have to have their own peers created and joined to the network on the fly, probably through their mobile phones. Thus, although there may have been much coordination organized prior to the emergency, the number of new, probably mismatched, users coming onto the network during the operation would mean that this coordination would not be sufficient to ensure effective communication.

In such a scenario, there may be a large number of different parties involved, and their potential involvement, though largely predictable in advance, is not possible to fully predict in advance. That is, it is obvious who most of the key players will be before the disaster occurs, and these players can coordinate and prepare, but there will be a potentially large number of additional players whose importance can only be determined as the emergency unfolds. Below, we list some of these players - both the established key players and the unpredictable additional players. By their very nature, it is not possible to give a comprehensive list of the latter players, but we have attempted to consider some of the categories they may fall into and why their assistance may be required. Any large disaster may also include players that have not been considered in advance.

- Ambulance centre

- talks to ambulance teams: gives them tasks and status reports, and receives updates on where the teams are, what they are doing and any new

medical emergencies they may have sighted or been informed about by other peers;

- locates doctors that may be in the area and gives them tasks (sending them to medical emergencies). Initially, doctors will probably be called by a human at the ambulance centre, but once the situation has been explained to them and a peer representing them has been added to the network, further human involvement is not necessary;
- requests status reports from hospitals as to how many available beds/doctors/other resources they have available;
- accept tasks/status reports from fire center or fire teams that may have spotted medical emergencies;
- gather road information from police center so that they can inform ambulance teams;
- accept information from outside the system; for example, from people on the street.

– **Fire centre**

- give tasks to/get information from fire crews;
- get information/tasks from the police centre/ambulance centre/anyone

– **Police centre**

- gather information from any of the peers on the streets about the state of roads and road closures and collate the information so that it is available for interested peers.

– **Ambulance teams**

- prioritise the next task of the team;
- give information about current status to interested peers;
- allow information to be fed in from the ambulance men about new fires/problems/blocked roads/etc.;
- determine routes to get to next task location;
- use information input by ambulance men about casualties to communicate with hospitals and thus find beds.

– **Fire crews**

- prioritise the next task of the crew;
- give information about current status;
- allow information to be fed in from the ambulance men about new fires/problems/blocked roads/etc.;
- determine routes to get to next task location.

– **Hospitals**

- wait to receive requests for care and route them to other hospitals if they cannot be met

– **Doctors**

- prioritise the next task of the doctor;
- allow information to be fed in by the doctor about injuries;
- find an appropriate bed for casualties based on injuries and hospital information;
- determine route to next location (negotiate with an ambulance peer to get picked up if necessary)

5.3 Use Case

In this section, we describe a particular interaction that may occur during the disaster scenario described above. This interaction concerns a fire engine that is fighting a fire and requires more assistance from other fire engines. The fire engine has a peer on board which is part of the OpenKnowledge system and can be accessed by the firemen as necessary. The normal response to this situation would be for a member of the fire team connected to that fire engine to get in touch with the fire centre, either through getting the fire engine peer to contact the fire center peer or, more directly, through calling or messaging the fire centre. However, we are envisaging a situation in which this proves to be impossible: lines of communication may be unreliable, the control center may be swamped with requests for assistance, or be otherwise unable to help. Additionally, due to the extreme nature of this particular emergency, non-local fire teams may have been called in to help with the emergency and these may be the ones that are nearest at the time. In this case, there may have been no prior agreement as to how to communicate or what the protocol will be, and this will have to be established during communication. Since this is all occurring during an emergency, it is likely that all members of the fire team are needed for fighting the fire and do not wish to sit by the computer calling for help. Thus the ideal situation is for the peer, once a certain amount of basic information has been input, to proceed autonomously without the need for intervention. Likewise, the peers that it is talking to are not likely to have easy access to human advice and must behave autonomously.

In order to achieve the aim of gathering help to fight the fire, the fire engine peer must first broadcast a message to all peers requesting that they reply with information about their whereabouts if they are fire engine peers and if they are free to attend a fire. From these responses it can then choose the nearest fire engines to come to assist. If, at any point before they arrive, any of these fire engines find themselves unable to attend - perhaps they pass a more urgent fire on the way - they will send a message to initiate fire engine peer, which will then in turn attempt to summon one of the next closest peers, and so on. GIS technology can allow the peer to automatically detect when the appropriate number of other fire engines has arrived and that particular interaction has concluded.

Details of this scenario, with an explicit description of the interaction, can be found in Appendix B.

5.4 The Kobe Simulator

The RoboCup Rescue Simulator (Kobe Simulator) [8,9] was developed in response to the failure of emergency response teams during the Kobe earthquake disaster in January 1995, during which several thousand people died and over 400 billion dollars worth of damage was done. It was believed beforehand that the emergency response centres and teams should be able to cope fairly well with

this kind of emergency, but this proved not to be the case, with disastrous consequences. Some of the reasons for this failed response include a scale of disaster much larger than anticipated and difficulties of communication due to damage to control centres and interrupted and congested communication lines.

It was therefore decided to build a simulator of the events so that emergency response teams could test their ability to deal with such a crisis based on a realistic simulation, rather than on possibly erroneous suppositions. It is hoped that this will lead to the development of emergency response facilities that will be able to cope with future disasters of a similar scale with greater success.

In particular, the general, long-term goals of the RoboCup Rescue project that is based around the use of this simulator are:

- The acquisition, accumulation, relay, selection, analysis, summarisation and distribution of necessary information;
- The provision of adequate decision support;
- Ensuring reliability and robustness through the use of distributed systems;
- Ensuring a smooth transition from a state of readiness to full response mode.

The simulator itself has a modular architecture; this means the effort in building the simulator is similarly modularised (and distributed), and also allows different versions of the simulator to be configured through the use of different modules. In general terms, there are several modules which constitute the core of the simulator:

- The *kernel*, which manages the simulation, controlling the information that is passed among the various other modules;
- The *GIS*, which manages the description of the location;
- Various *sub-simulators*, which handle different aspects of the evolving emergency;
- *RCR-agents*, which attempt to respond to the emergency.

There are four basic sub-simulators within the Kobe simulator:

- The building collapse simulator;
- The road blockage simulator;
- The fire spread simulator;
- The traffic simulator

These cover the main aspects of a major urban disaster.

The RCR-agents correspond to both mobile and stationary agents within the simulated environment that together are set the task of dealing with the emergency as best they can. The mobile agents correspond to firefighting, police and ambulance units, each type of unit having its own stationary base and having different capabilities (firefighting units, for example, are able to try to extinguish fires). The Robocup Rescue “challenge”, then, is to harness these different capabilities in such a way as to minimise the overall human and material cost to the city. By encoding different control and organisational strategies within the RCR-agents, researchers can evaluate the effects of these within the simulated

world, and can compare the results to those gained when using the strategies of others.

The Kobe simulator can be a useful tool for work based in the emergency response domain because it allows for comparisons between different implementations of an emergency response solution so that users can determine what elements are really key and how much value their own contributions add when compared to the work of others.

In the continuation of the OpenKnowledge project (and in particular in Workpackage 6), we intend to implement our urban disaster scenario by layering the OpenKnowledge framework on top of the Kobe simulator, thereby allowing us to generate results informing us how useful our OpenKnowledge approach could be in an emergency situation.

6 Conclusions

The domain of emergency response has been chosen as an OpenKnowledge test bed because it currently demands a combination of geographical and geopresence knowledge alongside active support for collaboration and planning in multi-agent, dynamic situations.

If we also look at a not too distant future, we can imagine the evolution of an environment where sophisticated sensors, global positioning services, pervasive access to semantically enabled devices and autonomous or semi-autonomous diagnosis, protection and repair systems will be integral to clothing, communications devices, vehicles, transportation systems, buildings and the environment. These would form the basis for a distributed, adaptable and resilient 'Helpful Environment' [10, 1] for every individual and organization at personal, family, business, regional, national and international levels. Such environment would adapt and appropriately respond to emergencies whether communication were possible or not. Services would be provided to individuals , units or communities through this network to add value and give all sorts of assistance beyond the emergency response aspects. The infrastructure and organizations that would be required to make the vision of an "helpful environment" possible are being put in place. For example, the Galileo European Satellite Navigation System [2] and its mobile geo-location and emergency response services programme will be another spur to development. Both commercial and freely provided emergency response facilities are being interwoven to ensure active development and support over a long period.

Obviously, there are a number of technical challenges to be addressed to give such support and to make the vision a reality. A common issue is the need for flexible and extendible representations of knowledge with rapidly altering scope, and with changing versions and refinements. In such a global scale environment, there cannot be a single monolithically agreed representation of all the knowledge that will be involved. Since we cannot rely on a global shared knowledge ontology (or ontology mapping), the focus will need to shift to the dynamic mappings established opportunistically through component interaction. Therefore, interac-

tion models, dynamic knowledge management and related technologies will play a vital role in such environments.

In the continuation of this OpenKnowledge workpackage, we will explore such dimensions in the two scenario presented in the previous sections. In particular:

Natural disaster emergency scenario In this scenario, we want to interface the OpenKnowledge approach and system to real data and to current organizational models and legacy information systems in use in the actual management of local emergency response activities. Here we will test the level of support that our proposed system can deliver to the specific issues of:

- fast and accurate discovery of relevant data present in separate sources/institutions;
- integration and real-time fusion of various datasets, created, annotated and maintained by different actors/agencies;
- support for the interoperability among the different organizational models and technological infrastructures.

Urban disaster emergency scenario In this scenario we want to use the Kobe simulator, in order to test the OpenKnowledge system in an internationally recognised and thoroughly tested simulation environment. Baseline results can be developed through running the simulator with only the built-in abilities of the agents. These baseline results can then be compared with results that are generated when parts of the OpenKnowledge system have been layered on top of the simulator. We thus have a clear empirical method of determining which aspects of OpenKnowledge improve emergency response in such a situation, as well as a means of comparing our work against the work of others. The ability to test the protocols we develop to deal with such emergency situations should prove very useful in allowing us to understand what aspects of our work are successful and in analysing the failure of those that are not.

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³ <http://www.openk.org/>

8 Annexes

In the two following annexes, we have collected the organizational and technical details of the two analyzed emergency response scenarios presented in Section 4 and 6. Here, we presents in some details more information about the involved peers, the main organizational models and interactions. In particular, in Annex A we have focused on the preliminary analysis we have done on the current (as-is) organizational models of the flooding Scenario in Trentino. While, in Annex B, we present our preliminary analysis of some instances of interaction models for a selected number of interactions - relevant for the urban disaster scenario - to be used as first examples for the analysis of the typical matching and searching activities as well as the typical complexity of the actual interactions.

9 Annex A - Flooding Scenario

Here we are going to focus our analysis and design to roles, functionalities and organizational models useful to the specific overall flooding scenario. Moreover, for the sake of simplicity, we consider the existence of one coordinating GIS agency (super peer) that is responsible for the management of all the local (Trentino) GIS data.

9.1 Details of peers involved

Summarizing the situation depicted in section 4.2, the system is compound by a certain number of suborganizations and some environment resources. Suborganizations:

- **GA**: GIS Agencies (about 10 agencies, 5 individuals for each agency).
- **PECC**: PAT Emergency Coordination Center (1 center, about 10 individuals).
- **FPC**: Fire Permanent Corps (1 corps, about 160 individuals).
- **TVC**: Trento municipality Fire Volunteers Corps (1 Corps for each municipality, about 5900 individuals for all the Trentino Region Divisions, about 100 individuals for the Trento municipality).
- **COC**: Trento municipality Coordination Center (1 center, about 10 individuals).
- **CS**: Society Citizens involved in the flooding emergency (about 20.000 individuals over 104.000 Trento municipality citizens).

Environmental resources:

- **GISDB**: the GIS data repository.
- **FIREDB**: the Civilian Protection and Fire database.
- **PLANDB**: the Emergency Plan of the Municipality of Trento.
- **HNET**: the Network of hydrographic stations.

- **LOCDB:** the local repository.

Below, for each of the organizations involved in the scenario, we list the key roles.

PECC (PAT Emergency Coordination Center) :

1. **PECC Hazard receiver (PECC_R):** it answers to the emergency calling (e.g. institutional emergency signaling channels, such as 115 phone number in Italy) and alerts the PECC coordinator.
2. **PECC coordinator & chief (PECC_C):** it receives all event signaling, calls the other participants to the PECC, and once the PECC is built it is responsible to coordinate the directives to respond to the emergency.
3. **PECC technical staff responsible (PECC_T):** it reads FIREDB, HNET, it answers to queries about these resources, signals the emergency situation, etc. It can ask information and data to the GA organization (it can assume the GA_SR role).
4. **PECC link with FPC (PECC_FPC):** alerts the FPC, using the coordinator directives.
5. **PECC link with COC (PECC_CO):** sends/receives information to/from the COC.

FPC (Fire Permanent Corps) :

1. **FPC coordinator and chief (FPC_C):** it's the chief of Permanent Fireman Corps. He takes all the decisions related to the directives given by the PECC. It maintains a link with the TVC to better coordinates the emergency activities.
2. **FPC technical staff responsible (FPC_T):** it can access to FIREDB resources to read the information or to signaling/make modifications (only for the information stored in the FIREDB that are related to its corps).
3. **FPC link with PECC (FPC_PECC):** it takes the directives from the PECC and informs the FPC_C.
4. **FPC link with TVC (FPC_TVC):** it's the link with the TVC. It sends and receives information to/from that organization.
5. **FPC Fireman (FPC_F):** it's a component of the FPC fireman crew. It receives the directives from its FPC_C and takes information from the FPC_T in order to execute its orders.

TVC (Trento municipality Volunteers Corps) :

1. **TVC coordinator and chief (TVC_C):** it's the chief of Trento municipality Fireman Volunteers Corps. He takes all the decisions related to the directives given by the COC. It maintains a link with the PECC to better coordinates the emergency activities.
2. **TVC technical staff responsible (TVC_T):** it can access to FIREDB resources to read the information or to signaling/make modifications (only for the information stored in the FIREDB that are related to its corps).

3. **TVC link with COC (TVC_COC)**: it takes the directives from the COC and informs the TVC_C.
4. **TVC link with FPC (TVC_FPC)**: it's the link with the FPC. It sends and receives information to/from that organization.
5. **TVC Fireman (TVC_F)**: it's a component of the TVC fireman crew. It receives the directives from its TVC_C and takes information from the TVC_T in order to execute its directives.

Municipality Coordination Center (COC) : its roles are similar to PECC roles, the difference is about the organizational structure; COC is an organization that has to coordinate its activity to PECC directives, as shown in figure 1):

1. **COC coordinator & chief (COC_C)**: it receives the event signaling, calls the other participants to the COC, and once the COC is built it gives the directives in order to response to the emergency. It's represented by the mayor of the municipality.
2. **COC technical staff responsible (COC_T)**: it reads PLANDB, it answers to queries about this resources, signals the emergency situations, etc. It can retrieve information, data from the GA organization (it can assume the GA_SR role).
3. **COC link with TVC (COC_TVC)**: it alerts the TVC, using the coordinator directives.
4. **COC link with PECC (COC_PECC)**: it sends/receives information to/from the PECC.
5. **COC information sender (COC_CS)**: it can transmit information to the citizens interested by the emergency.

CS (Citizen society) :

1. **CS information sender (CS_S)**: it can send information about the emergency to PECC.
2. **CS information receiver (CS_R)**: it can receive information about the emergency from COC.

GA (GIS Agency) :

1. **GIS dataset provider (GA_DP)**: the GIS dataset provider can share its public datasets with its requestors. The GIS dataset provider has to publish its dataset (using, e.g., a web service) using the GA_SP. For every dataset it must build a description using one of the standard techniques (ISO, TC 287, Dublin Core, etc). There are some types of information that are mandatory (core information). It can access to GISDB in order to read/write the GIS data information.
2. **GIS metadata provider (GA_MEP)**: this provider can provide some information about the data and can redirect the data request to GIS_DP. It can access to GISDB in order to read/write the GIS metadata information.
3. **GIS service provider (GA_SP)**: this role acts as an interface from the external world to the GA organization. It can answer either to simple queries like, for example, the query for a map, or to complex request as, for example, "*locate the nearest hospital*", or "*give me the datasets about*

rivers covering Trentino and Veneto regions areas”. In order to provide its services it can ask for GIS map, metadata and dataset to GA_MAP, GA_DP and GIS_MEPM.

4. **GIS map provider (GA_MAP):** it can build a map composition “on the fly” using different datasets provided by different entities.
5. **GIS service requestor (GA_SR):** it can ask for a service. A query could be, for example: “*locate the nearest (to my position) river*”, or “*give me a map of the Trentino area*”.

Here we precise each role refining its functionalities, activities and interactions.

The preliminary description of the functionalities provided by PECC roles follows:

1. **PECC Hazard receiver (PECC_R):**
 - (a) Answers to the emergency calling.
 - (b) Alerts PECC_C, sending the alert message.
2. **PECC coordinator & chief (PECC_C):**
 - (a) Receives the event messages from PECC_R.
 - (b) Calls the PECC participants, in particular PECC_T, PECC_FPC, PECC_COCC, extending them the event messages.
 - (c) Asks for some GIS information to GA_SP.
 - (d) Asks to PECC_T for the FIREDB and HNET resources information and for GA_SP (population information, flooding area information, viability, hydrography, etc) and GA_MAP information (map services).
 - (e) Gives the directives in order to response to the emergency. In particular it activates COC and gives directives to FPC using PECC_FCP and PECC_COCC roles.
3. **PECC technical staff responsible (PECC_T):**
 - (a) Receives the queries from PECC_C.
 - (b) Answers to the PECC_C queries and to do this:
 - i. reads FIREDB in order to retrieve information about the Fireman corps,
 - ii. reads HNET in order to analyze the flooding situation,
 - iii. reports the emergency situations to PECC_C.
 - (c) Asks for information to GA_SR or to GA_MAP.
4. **PECC link with FPC (PECC_FPC):**
 - (a) Receives messages (coordinator directives) from PECC_C and sends them to FPC_PECC.
 - (b) Receives messages from FPC_PECC and send them to PECC_C.
5. **PECC link with COC (PECC_COCC):**
 - (a) Receives messages (coordinator directives) from PECC_C and sends them to COC_PECC.
 - (b) Receive messages from COC_PECC and send them to PECC_C.

The main functionalities provided by the FPC roles are:

1. **FPC coordinator and chief (FPC_C):**
 - (a) Receives the messages (event messages, data, directives, directives for CS.R, etc) from PECC using the FPC_PECC role (using the FPC_PECC role).
 - (b) Send messages related to the emergency situation to PECC using the FPC_PECC role.
 - (c) Calls all the FPC firemen participants extending them the event messages.
 - (d) Receive emergency messages from FPC_F, analyze them and send them to PECC using the FPC_PECC role.
 - (e) Asks / receives information to /from FPC_T.
 - (f) Sends messages to CS_R (i.e “evacuation”, “don’t go outside”, “go towards that point”, etc).
2. **FPC technical staff responsible (FPC_T):**
 - (a) Receives the queries from FPC_C.
 - (b) Answers to the FPC_C queries and to do this:
 - i. reads FIREDB in order to retrieve information about the Fireman corps,
 - ii. asks information to GA_SR or to GA_MAP.
 - iii. it can access to FIREDB resources to read the information or to signaling/make modifications (only for the to the information stored in the FIREDB that are related to its corps).
3. **FPC link with PECC (FPC_PECC):**
 - (a) Receives messages from PECC_FPC and sends them to FPC_C.
 - (b) Receives messages from FPC_C and sends them to PECC_FPC.
4. **FPC link with TVC (FPC_TVC):**
 - (a) Receives messages from TVC_FPC and sends them to FPC_C.
 - (b) Receives messages from FPC_C and sends them to TVC_FPC.
5. **FPC Fireman (FPC_F):**
 - (a) Receives messages from FPC_C.
 - (b) Sends messages to FPC_C about the emergency situation (e.g. signaling hazards, asking for help, asking for info, asking for help, etc).

The main functionalities provided by COC roles are similar to those provided by PECC roles. COC has an additional role in order to send information to citizens:

1. **COC information sender (COC_CS):**
 - (a) Receives information from COC_C and sends the messages to CS.R.
 - (b) Receives information from CS_S and sends the messages to COC_C.

The functionalities provided by the TVC roles are similar to those provided by the FPC roles, thus we’re not going to describe them.

The main functionalities provided by the CS roles are:

1. **CS information sender (CS_S):**
 - (a) sends information about the emergency to PECC_R.
2. **CS information receiver (CS_R):**

- (a) receives information about the emergency from the COC_T.

The main functionalities provided by GA roles are:

1. GIS dataset provider (GA_DP):

- (a) Provides a list of all available datasets (built by the provider).
- (b) Provides a list of all datasets that concern a keyword.
- (c) Provides the metadata description for every dataset.
- (d) Provides the datasets that covers either an area or a portion of an area.

2. GIS metadata provider (GA_MEPA):

- (a) Provides a list of the GIS classes , keyword, ISO classification terms, and thesaurus classification terms that concerns a GIS dataset.
- (b) Provides the GIS metadata that covers either a certain area (if the area is not covered it answers “null”).

3. GIS service provider (GA_SP):

- (a) Provides the list of its services.
- (b) Provides the covered area available from the GISDB.
- (c) Provides a list of keywords that concerns each GIS dataset.
- (d) Provides a list of the GIS classes , keyword, ISO classification terms, and thesaurus classification terms that concerns a GIS dataset.
- (e) Returns the position of a given feature.
- (f) Returns a list of objects near a given point.
- (g) Converts the x, y, z coordinate among different coordinate systems.
- (h) Asks for datasets to GA_DP.
- (i) Asks for maps to GIS_MAP.
- (j) Asks for metadata to GIS_MEPA metadata provider.

4. GIS map provider (GA_MAP):

- (a) Provides a map to MAP_SP, given some dataset references, and the area boundaries.
- (b) In order to compose the map, it asks for the datasets to GA_DP.

5. GIS Service requestor (GA_SR):

- (a) Queries for the list of functionalities to GA_SR.
- (b) Queries for a dataset, metadata, service, map provider description.
- (c) Queries for a dataset.
- (d) Queries for a list of datasets.
- (e) Queries for the geographical position of a feature.
- (f) Queries for a map, given its description and the area covered by the map.
- (g) Queries for the list of some features given an interval of values of its attributes.
- (h) Gives the specification of the used coordinate system.

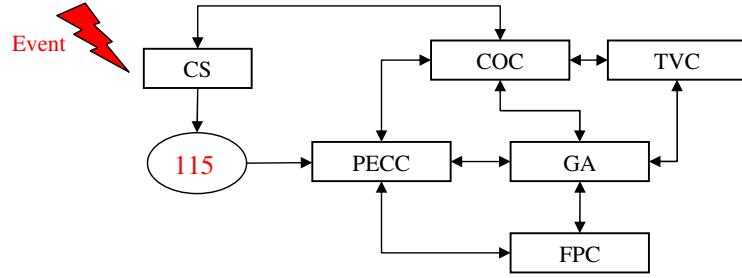


Fig. 2. Overall Organizational interaction model

9.2 Organizational Models

Overall emergency organizational model

We can suppose that the event is communicated by a citizen (society agent) that calls through the institutional emergency number (for Italy the number is 115) the PECC organization. PECC has in charge the activation and the coordination of FPC and COC. In parallel it has to analyze the situation by using the GIS support from GA.

The COC, after receiving the signalling from PECC, analyzes the emergency situation by querying PLANDB and, in agreement with the PECC coordination directives, organizes the tasks in order to response the emergency event. In particular it can alert TVC and use it for the most important operating instructions (for our scenario: the citizen evacuation). TVC and FPC collaborate with PECC and COC in order to give the information and the statements to the citizens (CS organization).

PECC organizational model

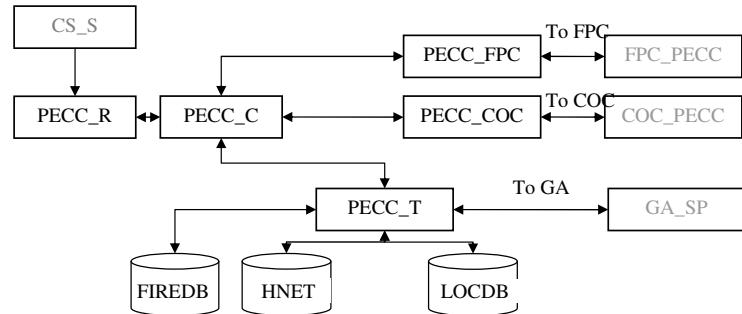


Fig. 3. PECC organizational model schema

In our scenario we suppose that the PECC_R receives the event from CS_S role. Then it alerts PECC_C sending a message that contains the emergency information. PECC_C activates all other roles of PECC: PECC_FPC, PECC_COC and PECC_T. The PECC_C sends messages to FPC (using PECC_FPC interface) in order to alerts and coordinates the FPC organization. Moreover it has to activate the municipality COC. Finally, to analyze the emergency situation it must use PECC_T role in order to retrieve static data from FIREDB and GA organization (and/or LOCDB) and dynamic data from the HNET sensor network.

FPC organizational model

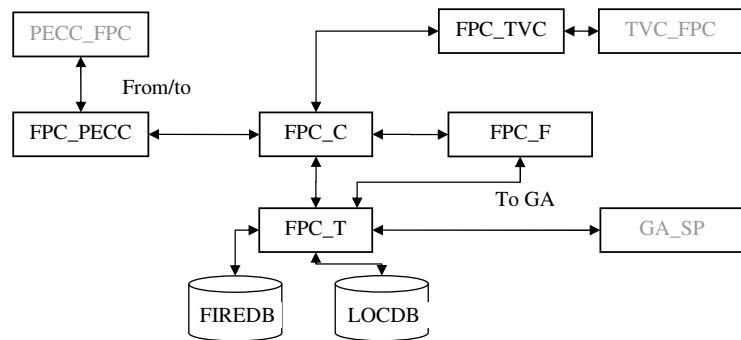


Fig. 4. FPC organizational model schema

The FPC_PECC interface role alerts the FPC_C and maintains the communications between PECC and FPC. FPC_C sends activation messages to the FPC_F roles (every component of the fireman crew has its own FPC_F agent in order to coordinate its activities with the FPC_C directives). The communications between FPC (the Province Fireman Corps) and TVC (the Municipality volunteers fireman corps) are established by the FPC_TVC role. In order to achieve information about the FPC situation FPC_C can collaborate with the FPC_T role that can access to FIREDB (and/or LOCDB) information. Moreover, FPC_T uses the GA_SP interface to retrieve GIS information from GA.

COC organizational model

The COC interaction model schema is similar to PECC model. The COC receives activation, directives and coordinates its operations with PECC. In order to exchange messages with PECC it uses the COC_PECC interface. COC_C activates all other roles of COC: COC_TVC, COC_CS, and COC_T. COC_TVC is the interface role between COC and TVC (the municipality volunteers fireman corps). COC_CS can exchange messages (directives, general information, viability situation, weather forecast, etc) with CS_R role, while COC_T supports COC_C for the analysis of the emergency situation retrieving data from

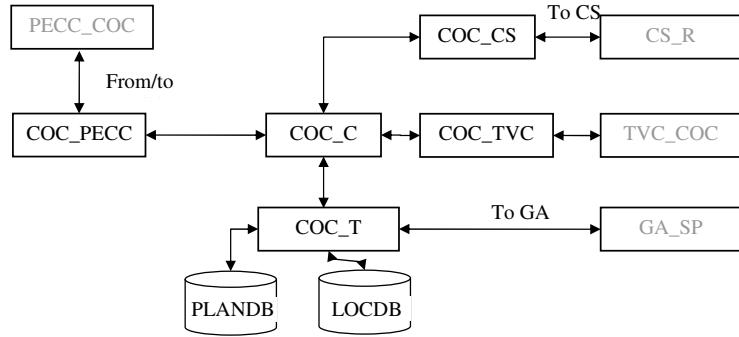


Fig. 5. COC organizational model schema

FIREDB (and or LOCDB) and GA organization.

TVC organizational model

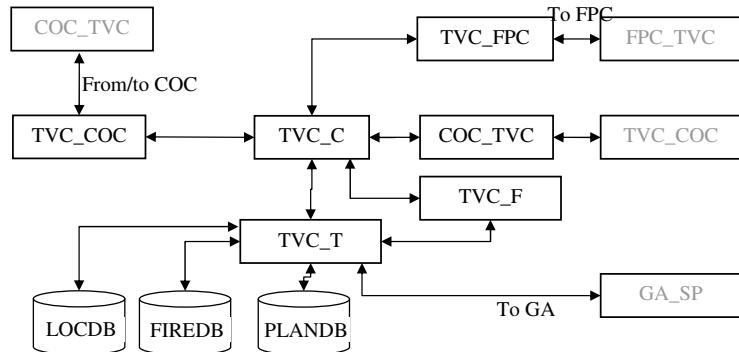


Fig. 6. TVC organizational model schema

The TVC_COC interface role alerts the TVC_C and maintains the communications between COC and TVC. TVC_C sends activation messages to the TVC_F roles (every component of the fireman crew has its own TVC_F agent in order to coordinate its activities with the TVC_C directives). The communications between TVC (the Municipality volunteers' fireman corps) and FPC (the Province Fireman Corps) are guaranteed by the TVC_FPC interface role. In order to achieve information about the TVC situation TVC_C can collaborate with the TVC_T role that can access to FIREDB, PLANDB and LOCDB information. Moreover, TVC_T uses the GA_SP interface to retrieve GIS information from GA.

CS organizational model

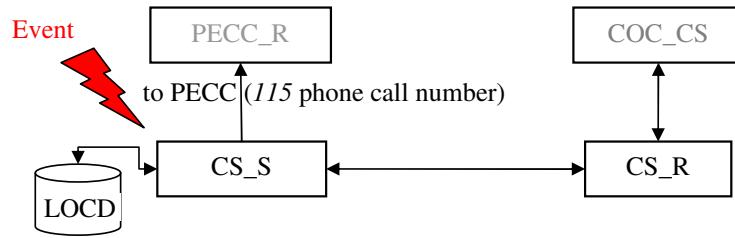


Fig. 7. CS organizational model schema

The CS schema is very simple. A citizen (human actor) has two types of roles within its “OK enabled” device: the first role (CS_S) sends messages to PECC in order to signal the event. It can use/send also information present in its limited LOCDB (location, personal profile - maybe fire volunteer- etc.). The second role (CS_R) receives information from the municipality organization (through COC_CS interface). Moreover, CS_R role can be enabled to ask more detailed information in order to execute the COC directives.

GA organizational model

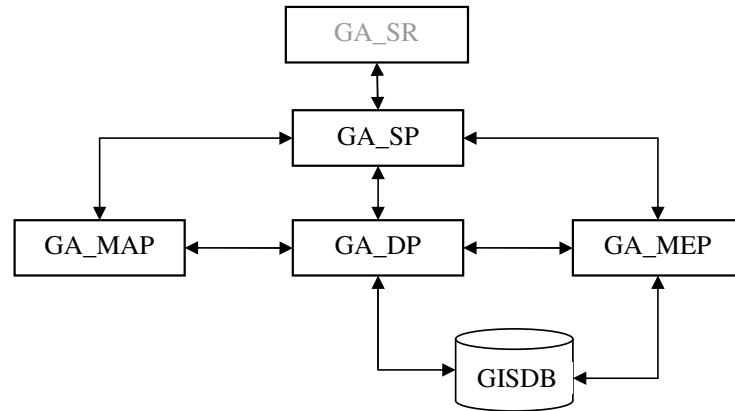


Fig. 8. CS organizational model schema

In the GA organization, each query is managed by the GA_SP role. Thus, GA_SP role, in order to provide its services can:

- Ask GA_MAP for digital map of the requested area,
- Ask to GA_DP in order to retrieve datasets (numerical or raster dataset) or datasets portions,
- Ask to GA_MEP to retrieve metadata information about GIS dataset of the repository.

GA_DP and GA_MEP roles has to access to GISDB repository to recover dataset ad metadata information.

9.3 Description of the interactions

In the following, we're going to describe a relatively simple possible sequence of activities that can be enacted, between the roles we describe in the previous sections. We suppose that the river "Adige" is near to produce a flooding in Trento town and that the initiator of the emergence activities is a citizen that alerts the emergency system (we could easily change our scenario substituting the citizen activator role with the fireman activator role).

Step 1: emergency activation

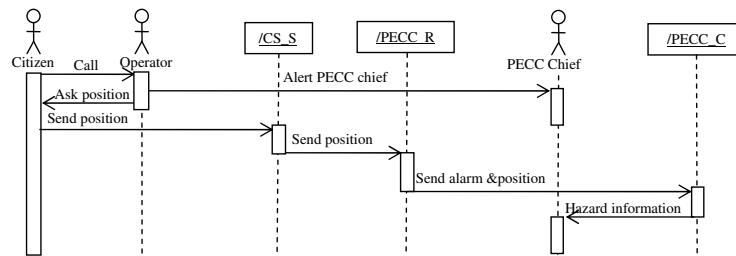


Fig. 9. Step 1: emergency activation

First a citizen advertises that an emergency event has happen near river Adige in Trento city. The river is breaking its boundaries close to the actual position of the citizen , and so, the citizen calls the 115 phone number and talks with a human operator. The human operator asks to the citizen to give its geographical position. The citizen uses its CS_S role to send a message that contains its precise position (automatically calculated by its GPS system) as well as other information if available (personal profile if useful, digital photos of the area,). The human operator, sends an alert message to the emergency responsible using the traditional communication systems (via radio, mobile phone, etc) and in parallel use its PECC_R role to send the alert flooding message and the possible flooding position to PECC_C role in order to transmit the exact position of the possible break. As an example, fig. 9 shows the sequence diagram for the first step.

Step 2: organizations formation

- **(PECC)** The PECC_C role, after the PECC chief confirmation (but we may think that this operation could happen without the human confirmation), calls the other PECC human operators sending an alerting message

to the corresponding digital roles (PECC_FPC, PECC_CO, and PECC_T). The alert message contains the type of emergency (flooding), the position of the event and some general information about the PECC formation (level of emergency, maximum time limit, meeting location, etc). In parallel PECC_C advertises the COC responsible and the FPC responsible (using the PECC_CO and PECC_FPC interfaces). After a short period of time, the PECC organization is formed and all the operators are located in the PECC emergency room (“Sala Emergenze”).

- **(FPC)** The PECC_FPC role contacts the FPC_PECC role that propagates the alarm to FPC_C role. As it looks at the alarm message, the FPC_C contacts its fireman crew and the other operators sending the alert messages to every FPC_F role, to FPC_T role and to FPC_TVC role. Each contacted FPC fireman prepares to emergency flooding and the FPC technical operator goes to the FPC emergency center location.
- **(TVC)** The COC_TVC role contacts the TVC_CO role that propagates the alarm to TVC_C role. As it see the alarm message, the TVC_C contacts its fireman crew and the other operators sending the alert messages to every TVC_F role, to TVC_T role and to TVC_FPC role. Every contacted TVC fireman prepares to emergency flooding and the TVC technical operator goes to the TVC emergency center location.
- **(GA)** We can suppose that, as we said when we described “a possible scenario”, GA organization is a permanent organization and that, in our case, the system always provides GIS services. Thus, no human GA operator is involved in the emergency scenario. Rather, all the digital roles are ready to provide GIS services requested by the other roles.

Step 3: Emergency analysis

The PECC chief wants to define the possible flooding area, in order to activate the coordination of citizens’ evacuation. In order to do this it needs a map of the area. It asks to COC the probable evacuation area (it’s described in the PLANDB) plus other emergency data. So, PECC_C role ask for the area to

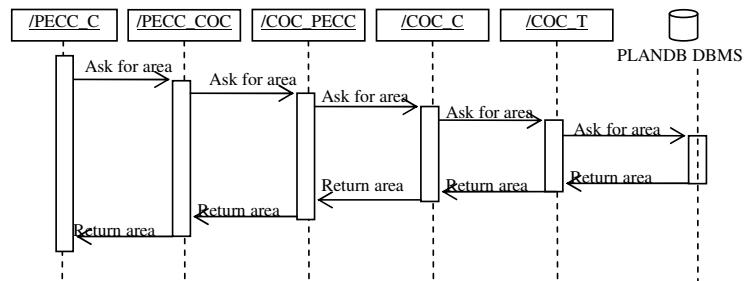


Fig. 10. Step 3: emergency analysis. Individuation of the flooding area.

vate the coordination of citizens’ evacuation. In order to do this it needs a map of the area. It asks to COC the probable evacuation area (it’s described in the PLANDB) plus other emergency data. So, PECC_C role ask for the area to

PECC_COC that propagates the request to COC_C. COC_C asks for the area to COC_T that retrieves the area, the number of the citizens involved in the emergency, the key (sensible) emergency points and the evacuation places to collect each group of citizens. COC_T retrieves these information by querying PLANDB and then it returns all the information to COC_C, COC_PECC and PECC_C.

PECC chief wants to define a map of the area, so it sends a request to PECC_T in order to retrieve GIS information from GA organization. PECC_T assumes the GA_SR role and it asks to GA_SP a map that contains a number of relevant thematic layers, covering the emergency area, among which:

- Topographic map,
- Public buildings,
- Cultural and heritages buildings,
- Viability (railroad and roads),
- Rivers,
- Hydrography situation (real time data from the sensors network),
- Bridges,
- ...

GA_SP, in order to provide the requested service, asks to GA_MER metadata information about the layers it needs. After GA_MER response, it chooses the right layers and it asks for them to GA_DP. After obtaining the layers it sends them to GA_MAP in order to obtain a map of the emergency area. GA_MAP builds the map and gives it to GA_SP. After the reception of the map, GA_SP sends it to the requestor (PECC_T). PECC_T can now send the map to PECC_C.

Step 4: directives propagation

PECC chief, after the map reception, decides to send the evacuation directive. In order to do this, it sends some messages to the other organizations. In particular:

- It sends a message to FPC organization. The message contains the directive for the viability managing and survey. The message contains also the map of the area. So, PECC_FPC sends these messages to FPC_PECC that propagates the directive to FPC_C. FPC chief decides how to distribute the workload to each fireman and so, helped by FPC_T role in order to retrieve the actual personnel and instrumental situation (reading the FIREDB information), FPC_C sends to FPC_F the operative instructions and the map of the area.
- It sends a message to COC organization in order to coordinate the citizens evacuation. Thus, PECC_C sends to PECC_COC the directives and the map of the emergency area. PECC_COC contacts COC_PECC that propagates the messages to COC_C. COC chief analyzes the situation (asking some emergency plan information through the COC_T collaboration) and decides how to organize the citizens evacuation. It sends to TVC organization the operational instruction for the intervention. So, COC_TVC sends

these messages to TVC_COC that propagates the directive to TVC_C. TVC chief decides how to distribute the workload to each fireman and so, helped by TVC_T role in order to retrieve the actual personnel and instrumental situation (reading the FIREDB information), TVC_C sends to TVC_F the operative instructions and the map of the area. Moreover, COC has to analyze the situation of every citizen and to give it the statements to go to a meeting place. In order to do this, COC_C asks to CS_R its geographical position and, if the position is within the flooding area, it sends to CS_R the evacuation message (by using the COC_CS interface role).

10 Annex B - Urban Disaster Scenario

10.1 Example of a Specific Interaction

In this section, we focus on a particular interaction within the scenario outlined in Section 5, in order to analyze how OpenKnowledge could facilitate interactions between participants in such an emergency situation.

The interaction that we consider is that of a fire engine team that is fighting a large fire calling for assistance in tackling the fire, as it is too large to be put out by a single fire engine. The fire engine has a peer connected to it that is part of the OK network. Under normal circumstances, we might expect a member of the fire crew to put a phone call through to a fire control center, which would then coordinate other fire engines so that an appropriate number of available fire engines were sent to the correct place. However, since we are considering a very large scale disaster, we have to consider the possibilities of lines of communication being down and centralized controllers being uncontactable or swamped. In this case, the fire engine crew might need to communicate directly with other fire engines. Coordinating this could be difficult, as many fire engines may be out of contact or otherwise busy, and so it is not practical for this to be done by a fireman, who will be needed to put out the fire. Instead, a fireman can input a small amount of detail to the fire engine peer, which can then take over the coordination and control of this.

The interaction model (IM) below shows how this interaction would proceed. In LCC, the language in which our IMs are written, $a(role_name, ID)$ indicates a peer with identifier ID which is currently playing role $role_name$. This $role_name$ is often simply an atomic name, but may also take arguments if there is information critical to this role that must be passed around. The IM consists of a series of actions which must be either message passing or instructions to a peer playing a particular role to take on another role. Single left arrows (\leftarrow) indicate constraints on these actions. Double arrows (\Leftarrow, \Rightarrow) indicate message passing: such arrows point towards a recipient peer and away from the message that is being passed. A complete IM has a role description for every role involved in the interaction. The IM below contains 5 different roles: *fire_assistance_request*, *find_available_peers*, *choose_peers*, *wait_for_arrival* and *fire_engine_peer*. The first four of these must all be played by the same peer, as *find_available_peers*, *choose_peers*, *wait_for_arrival* are all roles that must be taken on in order to fulfil the initial role *fire_assistance_request*. Since these four roles are performed by the same peer, it is not necessary to write them as separate roles. However, splitting roles up into sub-routines in this manner is often preferable to writing a single large role, as it greatly enhances the ease of writing and comprehending such roles. The fifth peer, *fire_engine_peer*, is a role taken on by any peer that is contacted by the first peer to provide assistance (whether or not they can provide assistance - if not, this role will terminate early). Thus there may be several different peers playing this role. In this case, the entire IM (including the four roles played by the first peer) will be sent to each peer playing the *fire_engine_peer*, and each peer playing this role will take

part in a separate interaction with the first peer. This in a particular interaction there is only ever one peer playing each role.

In this IM, the peer attached to the fire engine is identified by the ID *FEP1* (fire engine peer 1). This ID is thus the ID of the peer playing the first four roles. The first role *FEP1* takes on, *fire_assistance_request*, is in fact two different roles: *fire_assistance_request_0* and *fire_assistance_request_2*, with the first instance of the role merely calling the second instance with the necessary variables instantiated - these will be altered during the performance of later roles. This role does not require any interaction. Instead, the actions taken are the taking on roles: first, under if certain conditions are fulfilled, *find_available_peers* is taken on, then, after information has been updated and if other conditions are fulfilled, it takes on the role *choose_peers*, and finally it takes on the role *wait_for_arrival*.

The role *find_available_peers* involves contacting known fire engine peers to check their availability, their location and their ability to deal with fires of this type. Once the information has been received from these peers, *FEP1* then takes on the third role, *choose_peers*, during which it must choose which fire engine peers to summon to help by choosing the nearest suitable ones up to the required number and then waiting for their confirmation that they are coming. If this is not received, further peers are asked. Once a sufficient number have confirmed that they are coming, *FEP1* must monitor their arrival in the role *wait_for_arrival*. If it receives a cancellation message from any of them (perhaps they have received a more urgent request or discovered a new fire), then it must once again take on the role *fire_assistance_request_2* to find a replacement. Information about which fire engine peers have already been contacted (to avoid repeating invitations) and how many are already expected to arrive is sent back as arguments to this role.

The final role, *fire_engine_peer*, is taken on by any peer that is contacted by *FEP1*. This role does not involve the taking on of any other roles, but consists of message passing depending on constraints being fulfilled. The messages that are passed depend on which constraints are fulfilled; thus this role is not deterministic. For example, if the urgency of this new request exceeds the urgency of any other request the peer has, it will send an *available* message to *FEP1* and further messages will ensue; otherwise it will send an *unavailable* message to *FEP1* and the process will terminate.

10.2 LCC for fire engine calling ...

Roles for the engine requesting response (Requesting Fire Engine)

```
a(fire_assistance_request,RFE) ::  
    a(fire_assistance_request([],0),RFE)
```

RFE takes on the role of a *fire_assistance_request* and first calls a recursive procedure that requires information about the peers that have been contacted (`[]`) and the number of peers on their way already (0).

```

a(fire_assistance_request(Asked_peers,No_on_way),RFE) ::

    a(find_available_peers(Relevant_peers,[],Peer_info),RFE) <-
        known_peers(Peer_group) and remove(Chosen_peers,Peer_group,Relevant_peers)
    then
        a(choose_peers(Peer_info,Chosen_peers,Final_chosen_peers,No_needed),
           RFE) <-
            no_fire_engines(Size,Type,Urgency,Nec_no) and
            No_needed=Nec_no-No_on_way then
                a(wait_for_arrival(No_needed,0,Chosen_peers),RFE)

```

First, RFE must take on the role of finding which peers are available to attend through looking at its group of known peers and then removing from this group the peers that have already been contacted. We assume we are only contacting peers that are known to keep the RFE in order to simplify the example; broadcasting to all peers or getting known peers to forward the message could be incorporated easily. The fact that the name of all the peers contacted is known by RFE entails nothing about their ability to interpret the interaction model. Next, RFE must choose the right number of peers from this group and then it must wait for their arrival.

```

a(find_available_peers(Relevant_peers,Peer_info,Final_peer_info),RFE)::

(
    check_suitability(fire(Size,Type,Urgency),Location) =>
    a(fire_engine_peer,Peer1) <-
        first_peer(Peer1,Rest_peers,Relevant_peers) then
    (
        available(Location1) <= a(fire_engine_peer,Peer1) then
        a(find_available_peers(Rest_peers,[[Peer1,Location1]|Peer_info],
                               Final_peer_info),RFE)
    )
    or
    (
        not_available <= a(fire_engine_peer,Peer1) then
        a(find_available_peers(Rest_peers,Peer_info,Final_peer_info),RFE)
    )
)
or
null <- Peer_group = [] and Peer_info = Final_peer_info

```

To check the availability of peers, RFE asks each of them one at a time to confirm that they are available to deal with a fire of this type and to give information about their location.

```

a(choose_peers(Peer_info,Chosen_peers,Final_chosen_peers,No_needed),RFE)::

(
    request_assistance => a(fire_engine_peer,Nearest_peer) <-
        find_closest_peer(Peer_info,Location,Nearest_Peer) then

```

```

(
    confirm <= a(fire_engine_peer,Nearest_peer) then
        a(choose_peers(New_peer_info,[Nearest_peer|Chosen_peers],
                      Final_chosen_peer,No_needed-1),RFE)
        <- remove(Nearest_peer,New_peer_info,Peer_info)
    )
    or
    (
        disconfirm <= a(fire_engine_peer,Nearest_peer) then
            a(choose_peers(New_peer_info,Chosen_peers,Final_chosen_peer,
                          No_needed),RFE)
            <- remove(Nearest_peer,New_peer_info,Peer_info)
        )
    )
    or
    null <- Nec_no = 0 and Chosen_peers = Final_chosen_peers

```

RFE sends requests for assistance to the nearest peer, which either confirms or disconfirms its ability to attend. This keeps going until the necessary number of peers have confirmed.

```

a(wait_for_arrival(No_expected,Chosen_peers),RFE) ::

(
(
    cancel <= a(fire_engine_peer,Peer) then
        a(fire_assistance_request(Chosen_peers,No_expected-1),RFE)
    )
    or
    null <- arrive(Peer) then
        a(wait_for_arrival(No_expected-1,Chosen_peers))
    )
)
or
null <- No_expected = 0

```

RFE keeps waiting to see if any peers cancel their attendance until all the necessary peers have arrived. Note that this could be made considerably more complicated: if the nature of the fire changes (size, urgency, etc) the RFE may want to send cancel messages to some of the peers on their way or search for more peers to attend.

Role of fire engine waiting to be summonsed

```

a(fire_engine_peer,X) ::

    check_suitability(fire(Size,Type,Urgency),Location) <=
    a(find_available_peers(_,_,_),Y) then
    (
        available(Location1) => a(find_available_peers(_,_,_),Y)
    )
)

```

```

<- free and equipped_for(fire(Size,Type)) and
most_urgent_commitment(Urgency) and location(Location1) then
(
  move_to(Location) <- request_assistance
  <= a(choose_peers(_,_,_,_),Y) then
  (
    check_suitability(fire(Size1,Type1,Urgency1),Location2) <=
    a(find_available_peers(_,_,_,_),Z)
    (
      available(Location3) => a(find_available_peers(_,_,_,_),Z)
      <- free and equipped_for(fire(Size1,Type1)) and
      most_urgent_commitment(Urgency1) and
      location(Location3) then
      (
        move_to(Location2) <- request_assistance <=
        a(find_available_peers(_,_,_,_),Z) then
        confirm => a(choose_peers(_,_,_,_),Z) then
        cancel => a(wait_for_arrival(_,_),Y)
      )
      or
      null
    )
    or
    unavailable => a(find_available_peers(_,_,_,_),Z)
  )
  or
  null
)
or
null
)
or
null
)
or
unavailable => a(find_available_peers(_,_,_,_),Y)

```

All fire engine peers listen out for requests for assistance. When a suitability request comes in, they confirm they are available and give their location if they are currently free and not committed to anything more urgent and confirm they are unavailable otherwise. If they then receive confirmation that they are needed, they move to the correct location but continue to listen out for further requests; if they don't receive confirmation, they start the role again, waiting for an initial request to come in. If they have received confirmation (from Y), and subsequently receive another request (from Z), they reply that they are available if the urgency of this new request is higher than the urgency of the original request and otherwise do nothing (continue to do what they were doing). If they have replied they are available, then if they then receive a message to say they

are needed, confirm that they are coming and send a cancel message to the initial RFE (Y).

10.3 Requirements of Scenario

Fairly basic query routing is required, as it is likely that the location of the peers will be known in advance: even if unexpected peers are contacted (such as non local fire teams) these will have some known link with existing peers. However, it may be possible in the general scenario (though probably not in the specific interaction described above) that completely unexpected peers may become involved: for example, a private citizen with access to a helicopter. It is to be hoped that peers will be fairly stable: new peers will certainly be joining but peers that exist on the network are likely to remain throughout the emergency. However, the communication problems inherent in such a scenario mean that peers may drift in and out of the network and, although attempting to interact, may not be contactable. In this situation, the ability to locate other peers to work with will be key, and it may be that some of these peers were not identified as potential collaborators beforehand.

In the specific interaction above, there are unlikely to be more than ten or twenty peers involved. In the general scenario, these numbers are likely to rise to a few hundred but are unlikely to rise much higher than that.

Timely responses are crucial. As much as possible would be done off-line before interaction, but if new peers were brought in during the emergency, co-ordination may have to be done during run-time. Answers need to be of good quality as poor or slow information can be fatal.

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