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SEMANTIC ONTOLOGY DESIGN FOR A MULTI-COOPERATIVE FIRST RESPONDER INTEROPERABLE PLATFORM

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Abstract. Natural and man-made catastrophic events appear be steadily increasing in intensity and frequency. Proper preparation, response and recovery are essential if mankind and its vital systems are to cope with and survive large-scale disasters. The organisations responsible for delivering emergency response services often under-perform due to a lack of proper interoperation and collaboration. This paper discuss the interoperability issues for data interchange among first responders agency participating in emergency situation and provides exhaustive overview of the recent studies and attempts to solve the problem. The approach taken by the EU funded REDIRNET project for development of a core ontology enabling exchange of data among first responder agencies is presented. The novelty included in

the ontology tree is described and the implementation in the meta-data gateway is introduced. The paper provides insight in the implementation of the REDIRNET platform and the designed semantic interoperable services. The paper ends with the discussion of the presented work and the concluding remarks.

Keywords: Interoperability, emergency ontology, meta-data gateway, first responder platform

1 INTRODUCTION

Primary challenge in responding by the first responder organizations to both natural and man-made disasters is communication that enables effective rescue management. This has been highlighted by several world known disasters cases problem and was frequently cited by the first responders that must work together to form a cohesive plan of response. The communication challenges in emergency response are identified as three categories of communication challenges: technological, sociological, and organizational. These three major areas are key to developing and maintaining effective disaster communication systems. The primary technological challenge is the rapid deployment of communication systems for first responders and disaster management workers. This is required regardless of whether the communications network has been completely destroyed (power, telephone, and/or network connectivity infrastructure), or, as in the case of some remote geographic areas, the infrastructure was previously nonexistent. Deployment of a new system was enabled by the FREESIC platform [24]. Although it is complicated, the current developed wireless telecommunication technologies including devices with multiple network capabilities, such as smart phones, enable setting up of ad hoc wireless networks based on different technologies enabling voice and data communication through common IPv6 gateways.

Sharing and dissemination of information is another critical and problematic issue for effective responder management, beginning with which information is reliable and whom to trust in unfamiliar settings. Even after a level of trust is established among the participating agencies, security issues need still to be considered. Collaboration and coordination across organizational and jurisdictional boundaries typical for large emergency response can be achieved only by interoperable technologies based on standards and agreements achieved in advance. Interoperability may come in different levels but the collaboration and cooperation can happen if there is understanding of the exchanged information which can be assured by the semantic interoperability of the used information systems. Although the participating agencies are dealing with the same incident or disaster, the information needed by different response teams may be very different. For example, in case of a large forest fire, the fire brigade needs access to all roads (paved and unpaved) leading into the area, whereas the police and ambulance would only need access to the paved

roads. In addition, the municipality where the incident has happened should have a clear understanding of the locations of buildings and the numbers of people inside to prepare evacuations. All of this information should be extracted and processed from spatial data sets and distributed to different response units accurately and quickly [20].

The operation of task forces of an emergency service is typically legislated at state, national and international levels [57, 56]. Unfortunately, merely instructing organisations to cooperate using high-level generic directives has not brought true collaboration and/or interoperability. The consequences are extended response times, confusion in the situation on the ground, dispute/competition as to who, where and when is in charge, difficulty in coordination with other teams' systems due to incompatibilities in infrastructure and difficulty in filtering/validating the flood of information generated during disaster events. For example, lack of consistency in the alert notice type and delivery format may delay warnings or flood the population with ambiguous/irrelevant messages [12]. This leads to sub-optimal preventative action and response by the intended recipients and potential property and life loss.

Therefore, it is widely accepted [40] that data interoperability in emergency response is a must. A word in common to two or more domains may have different meanings; or, conversely, different terms may represent the same concept. For example, the word 'Person' can have different meanings – a 'displaced person', 'recipient of aid', or 'victim' or 'acting officer'. For example, a fire brigade may use 'house' for the same real-world feature that is usually indicated as a 'building' on the topographic map.

Despite the extensive efforts on the development of the semantic interoperability in the emergency area by different organization in the last decade [43] it is still a source of controversy in comprehensive emergency management. On the one hand the domain is very diverse as many different responder agencies participate in an emergency situation and on the other hand there are scattered solutions [54], not integrated under cohesive framework or difficult to be adopted by the industry. Interoperability is understood as exchange of information and its use but is also understood as the ability to perform a function on behalf of another entity [11, 58]. Previous research and practice have identified various aspects of interoperability such as the one developed within the European Interoperability Framework (EIF) [18], the ATHENA Interoperability Framework (AIF) [2, 5, 7] defining data, processes, services and business and the IDEAS (Interoperability Development for Enterprise Applications and Software) [29]. In this paper we focus on the design of the semantic interoperability and the core ontology developed for a platform intended to provide the emergency responders with on-time delivery of data relevant for efficient rescue management [62] meaning common understanding of the concepts and terms by the employed responder‘s systems. The concept of the semantic ontology and information representation as meta data are in-build in the platform intended to meet the interoperability needs of the participants involved in the emergency situation management.

The paper presents the recently designed core emergency ontology implemented in the REDIRNET project [50] interoperable platform developed to enable cooperation among the first responders agencies acting in any of the European countries. Emergency situation can happen anywhere in Europe and the borders in EU are not considered as an obstacle for the agency cooperation, but the different rescue agency systems and the lack of the exchange of information due to missing data interoperability are considered as the major obstacle within the rescue operation. The paper is organized as follows: the next section introduces the related works in the area and the specification of the addressed problem, the section that follows introduces the design consideration for a core ontology model for a specific platform; the presentation of the core ontology is followed by implementation considerations of the developed ontology in the first responder cooperative interoperable platform designed within REDIRNET project from EU FP7. The paper ends with a discussion and concluding remarks section.

2 PREVIOUS WORKS ON EMERGENCY ONTOLOGY AND STANDARD TERMS

2.1 Data Interoperability in Emergency Area and the Existing Standards

In an emergency situation the information is collected from different sources: emergency response team, public and automatic monitoring devices, local authorities. This information, moreover, may come in many different forms: written reports, oral reports, photographs, sketch maps, numerical measurements, etc. Bringing together such diverse kinds of information from so many disparate sources presents a major problem [25]. The importance of having a common understanding within the emergency management field has been recognized early [26] and was addressed as semantic interoperability being considered as a key challenge to interoperability. The term "semantic interoperability" refers to the ability of computer systems to communicate data with unified meanings [51]. Although significant progress has been made regarding the systemic and syntactic heterogeneity of data within emergency management, semantic heterogeneity remains still insufficiently addressed [20].

One way to tackle this problem was the approach regarding the ontology developments [60]. Due to the fact that the ontology provides a unified explanation of concepts and relationships used by the application field, makes them shareable by different users and in the same time allows the information to be integrated at information system level. Ontologies are similar to conceptual schema in database systems. A conceptual schema provides a logical description of shared data, allowing application programs and databases to interoperate without having to share the data structures. While a conceptual schema defines relations on data, ontology defines terms to represent knowledge – a meaning of an object or an action related to the particular domain. When a disaster strikes, there is a need for acting entities to combine the information from different sources for efficient management [47] which

implies the common representation of the knowledge for any particular element important in the rescue action.

Despite an extensive effort on the development of the semantic interoperability by some authors [53] the interoperability appears to be still a source of controversy in a comprehensive emergency management. On the one hand, the domain is very diverse and the industry is still exploring various needs of different sectors of the society in order to reply to the identified needs. On the other hand, there are scattered solutions that are not integrated under a cohesive framework or are difficult to be adopted by industry. In the related work presented in this section two different approaches are recognized:

1. bottom-up approaches that try to provide interoperability through various data standards with the support of various automation tools,
2. top-down approaches that try to facilitate interoperability by providing an overarching conceptual model for the domain.

The problem of interoperability created a need for a set of common standards or more precisely a standardization of terms, across all participating organizations. A difficulty with this is that the set of participating organizations is not necessarily fixed and defined and anyone may become involved if the disaster is extremely big. Another problem is that standardization may be difficult for political and historical reasons; and even if human terminology is standardized, this does not assure that communication at ICT level – e.g., between local resource databases and the instance generated data – is possible, too. Maintaining all details within a single globalized database is often not desirable for reasons of data privacy; the maintenance is often impossible for technical or political reasons, or because it simply causes too much overhead. Finally, in a world of quick technological change, standards are aging too fast [6]. However, some of the successful attempts should be listed here, the first one to mention are the standards developed by the Organization for the Advancement of Structured Information Standards (OASIS) dedicated to standard transporting and routing of emergency messages: Common Alerting Protocol (CAP) (a data interchange standard for alerting and event notification), Emergency Data Exchange Language (EDXL) (for routing messages including requesting or deploying resources or communicating their status), and Customer Information Quality (CIQ) (a set of specifications for parties (person/organization) and their relationships). All OASIS standards use XML as an enabling technology [41, 42, 53].

Another attempt of standardisation is the Universal Data Element Framework (UDEF) developed by The Open Group consortium based on the ISO/IEC 11179 specifications [30]. [55] categorizes objects in an enterprise based on the high-level concepts such as entity, asset, document, enterprise, etc. It also classifies attributes of these objects, such as amount, graphic, picture, date, etc., in a separate hierarchy. It assigns a number or alpha character to the nodes of both hierarchies and uses this structure to generate identifiers for uniquely labelling the data elements in an enterprise. US Department of Justice and the Department of Homeland Security

have developed the National Information Exchange Model [39] which is based on the ISO/IEC 11179 specifications. The centre of this exchange framework is its meta-data repository. The core concepts of the meta-data specification include person, address, organization, etc. They define the high level artifacts that are universally shared across all subject matter domains. The domain data elements, on the other hand, extend the universal data elements with addition of new data elements according to the specific needs of the given domain. NIEM is still not sufficiently specific for the specific requirements of the first responder agencies. One notable difference between NIEM and UDEF is that UDEF separates the definitions of the attributes from the objects. Within this context, it is important to mention the Joint C3 Information Exchange Model produced by MIP-NATO Management Board (JC3IEDM) adopted by several nations. Joint Consultation, Command and Control Information Exchange Data Model is a model that, when implemented, aims to enable the interoperability of systems and projects required to share Command and Control (C2) information. JC3IEDM [31] is an evolution of the C2IEDM standard that includes joint operational concepts similar to the Land Command and Control Information Exchange Data Model (LC2IEDM). The overall aim of JC3IEDM model is to enable "international interoperability of C2 information systems at all levels from corps to battalion (or lowest appropriate level) in order to support multinational (including NATO), combined and joint operations and the advancement of digitisation in the international arena". According to JC3IEDM's documentation, this aim is attempted to be achieved by specifying the minimum set of data that needs to be exchanged in coalition or multinational operations. Each nation, agency or community of interest is free to expand its own data dictionary to accommodate its additional information exchange requirements with the understanding that the added specifications will be valid only for the participating nation, agency or community of interest.

With the appearance of data provided by different sensors during the rescue operation attempts shown that are known as Sensor Web aimed to enable exchange of data. Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces [8]. The approach is illustrated in Figure 1.

The idea was launched by Open Geospatial Consortium (OGC) [1] with the aim to bring the sensor resources to the Web and make them available to different applications. The framework is known as the Sensor Web Enablement (SWE) which focuses on developing standards to enable discovery, exchange, and processing of sensor observations, as well as tasking of sensor systems. However, despite the success in defining the necessary standards this domain [9] is just one segment in the necessary information domains for emergency management.

2.2 Data Interoperability Through Development of Semantic Ontologies

The importance of the semantic ontologies arose with the appearance of the Semantic Web technology where the ontologies are considered as one of the pillars.

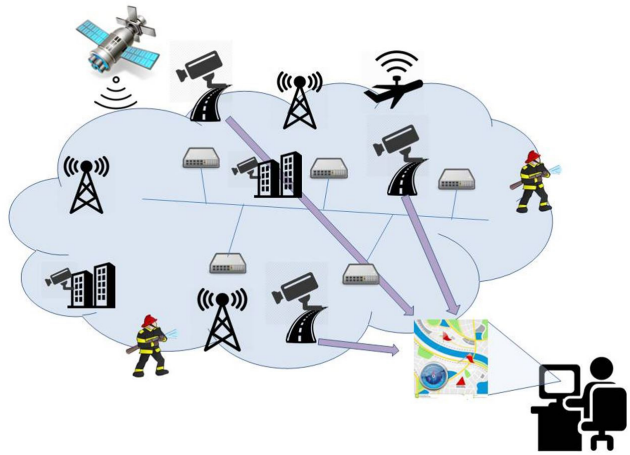

Figure 1. Sensor Web concept

The problems that were addressed with the semantic ontologies were related to the needs for finding fast, reliable, and efficient methods of storing and retrieving necessary information for interchange or processing [4]. Semantic ontologies provide machine process ability by defining formal information semantics in addition to the machine-human understanding. They specify the conceptualization of the real world and link the machine process with human meaning using a consensual terminology as connecting element [21]. Each ontology contains hierarchical and non-hierarchical relationships that link different concepts together into a large conceptual network [3]. Hierarchical relations demonstrate the generalisation of the relationships between similar concepts. Non-hierarchical relationships demonstrate other relationships between concepts for example such as aggregation. In other words, ontology is a network of concepts and relationships that provides specifications of the knowledge in a domain within which people communicate. In that context there is a need to differ among several terms dealing with the ontology concepts such as: controlled vocabularies – which is a finite list of preferred terms used for the purpose of easing content retrieval; taxonomies – which are defined as a set of controlled vocabulary terms and thesauri – which is similar to a dictionary with the difference that it does not provide word definition having as entry terms single-word or multi-word entries and facilitating limited cross-referencing among the contained terms, e.g., synonyms and antonyms and finally the ontologies representing relations among terms [38]. Ontologies offer a much richer meaning representation mechanism for the relationships among concepts, i.e. terms and attributes compared to the other approaches. This is the reason why they are, nowadays, the preferred mechanism to represent knowledge. Another approach addressing the virtual organizations data interoperability was elaborated in [33, 37, 52]. The ontology extension for integration of heterogeneous data resource was suggested.

2.3 Languages for Ontology Encoding in the Area of Emergency Management

The ontology of a particular domain is usually encoded by use of ontology language. The currently known used ontology languages are Resource Description Framework (RDF), Web Ontology Language (OWL) and Ontology Interchange Language. The commonly used ontology editors are Protege3 and KAON24 editors.

The Web Ontology Language (OWL) [44] is a family of knowledge representation languages for authoring ontologies that are characterized by formal semantics and RDF/XML-based serializations for the Semantic Web. OWL comprises three language variants, namely, OWL Lite, OWL DL and OWL Full. The OWL Lite is the least expressive and logically complex variant. It is intended for users needing a classification hierarchy and simple constraints. Rapid language adoption is achieved by way of tool development and the easiness to migrate from thesauri and other taxonomies. OWL DL is an intermediate version where the descriptions logic variant of OWL DL provides maximum expressivity while keeping full computational completeness and decidability. OWL Full offers maximum expressiveness with no computational guarantees and the OWL which is endorsed by the World Wide Web Consortium (W3C). With this label OWL Full has attracted academic, medical and commercial interest.

The RDF (Resource Description Framework) [48] is a general purpose language for representing information about resources in the Web. Resource Description Framework Schema (RDFS) provides the means for defining the semantics of RDF modelling primitives. The combination of RDF and RDFS is commonly known as RDF(S) which is not considered semantic language per se, but rather a general purpose language for describing metadata on the Web.

2.4 Ontology Developed for an Emergency Response Systems

The design of ontologies for emergency response information system was approached by several authors. For example, Little and Rogova [34] have used a highly formal upper ontology framework to model detailed concepts and relationships in a disaster situation for situational awareness. There are other models like the ones by Hoogendoorn et al. [28] or Matheus et al. [36] which are more tailored to the requirements of the disaster management. Another proposal was developed by Peng et al. [46] known as the Emergency Case Ontology Model (ECOM) which is organizing the emergency case knowledge by taking into consideration the relations existing among different emergency cases. Castorini et al. [10] proposed the Knowledge Base System (KBS) founded on ontologies with the main goal of modelling critical infrastrucure and their interdependencies. The proposed framework consists of: MKIONT (Meta Knowledge Infrastructure ONTology) which defines a template for conceptualization; IONT (Infrastructure ONTology) which represents knowledge of a specific critical infrastructure domain (e.g. water distribution or telecommunication); FONT (Federation ONTology) which describes interactions between

infrastructures and the Gateway which provides a connection between the KBS (Knowledge Based Systems) and the simulators. Grolinger et al. [26] have used the knowledge stored in the domain glossaries, vocabularies and dictionaries for the creation of a lightweight disaster management domain ontology. Babitski et al. [6] followed the guiding principles of the foundational ontology known as DOLCE ontology and devised an ontology stack that provides description of the damages (caused by the disaster), resources (available to organizations fighting the disaster), and their connection (e.g. which resources are relevant for which damage). The same author developed technology that, rather than forcing everybody to use the same terminology on the ICT level implementation, is facilitating the integration of heterogeneous information appearing in disaster cases. From the point of view of an individual organization, this means that data from heterogeneous sources (where new sources may become relevant dynamically) needs to be mapped onto the organization's data schema. For such data schemata, Babitski et al. [6] propose to use formal ontologies. Malizia et al. [35] present an ontology for accessibility of emergency notification systems. These systems are designed to inform people about the incidents and are part of the emergency response information systems. The authors particularly highlight the need to design systems that effectively provide information to the socially vulnerable groups. In their presentation the authors summarize the proposed ontology, called SEMA4A (Simple Emergency Alerts 4 All), consisting of three basic classes: that include information related to the concepts and relations needed to model the organization, structure and navigation of the information contents; provides accessibility guidelines, user's profiles and actions that users can perform, as well as, information related to emergencies, notifications and devices.

The most sophisticated and deeply elaborated ontology model for first responder systems is certainly the EMERGEL (Emergency Elements) ontology [19] developed within the DISASTER project from EU FP7 programme in the area of security [14]. The EMERGEL ontology is modularised and consists of core ontology (upper-level ontology) [15], transversal modules (space-time representation) and vertical modules (associated with specific domains) [16]. The EMERGEL core ontology contains all the common knowledge and concepts related to the emergencies and the stakeholders involved in a crisis situation. In addition, its core is enriched by transversal contents with description of general concepts such as time and space. The DISASTER authors have selected the W3C OWL 2 [45] ontology language to describe the EMERGEL data model. The ontology is hosted by CTIC (2016) and is published according to W3C best practices.

The EMERGEL authors have used some upper-level classes from the DOLCE DnS Ultralite (DUL) ontology [17] which is a simplification and an improvement of some parts of the DOLCE Lite-Plus library and of the Descriptions and Situations ontology (DnS) building up the set of upper level concepts that are the basis for an easy interoperability between many middle and lower level ontologies. The EMERGEL ontology covers the following broad-scope issues regarding a crisis situation:

What. Describes an event.

Why. Describes causes for an event.

Where and when. Space-time representation

Who. Agents involved in a crisis situation

The disaster is interpreted as a kind of event denoted as (emergel:DISASTER) and the ontology is adapting existing disaster classifications widely used in the security domains, such as insurance, freight transport and critical infrastructures (ports, airports, etc.). The subclasses of emergel:Disaster are thematically and hierarchically grouped as the events liable to cause other events, and a simple landing operation of a plane can lead to a disaster like an airplane crash in an airport. Additionally, each accident may have direct and collateral consequences (like fire, chained explosions, chemical accident, full airport block, etc.) so the causality chain is semantically captured between the diverse events. As many agents (with different descriptive granularity and resolution) are involved in a crisis situation: from a rescue army brigade to the technical specifications of a fire truck – within the EMERGEL ontology they are understood in a broad and generic way and are presented as organisations, groups of people, individual profiles, equipment, affected buildings, casualties, etc. To model agents and roles EMERGEL uses vocabulary specified as FOAF [22] and WAI [61]. FOAF is a vocabulary that describes people, the links between them and the things they create and does the modelling of people and groups. WAI is a vocabulary that extends the FOAF specification through introducing the concepts of roles and profiles. For modelling what is involved in an emergency situation EMERGEL uses DUL class dul:PhysicalObject which includes buildings, facilities, affected infrastructures, trucks, planes, equipment, tools, resources, etc. The vocabularies used were designed by the W3C consortium and the European JoinUP platform [32]. These vocabularies allow EMERGEL to incorporate into a general description framework standardized vocabularies at the European (or international) level. On the other hand, their top-level structure enables domain-specific classifications and vocabularies (vertical modules) to be connected and integrated in the single semantic space of EMERGEL. These vocabularies are: RADion2 (Repository Asset Distribution) – a high-level vocabulary intended to facilitate the federation and co-operation of semantic assets repositories. It aims to act as a common layer among repositories that want to exchange data. DCAT3 (Data Catalogue Vocabulary) which is an RDF Schema vocabulary for metadata about structured data resources, such as datasets or catalogues and the ADMS4 (Asset Description Metadata Schema) which is an OWL vocabulary that describes semantic assets and their repositories. It has been specially designed to favour SKOS type of taxonomies (Simple Knowledge Organization System) and classifications reuse. The transversal modules used in EMERGEL are Space and Time. The other modules, such as magnitudes, may be included in the future as EMERGEL provides means to temporally describe a crisis situation in the RDF format. This space is addressed as features, geometries and feature-types classifications, related with a cartographic visual repre-

sentation (maps). Every physical entity can be geographically located in order to be interpreted as spatial features. A feature is understood as an entity in the real world with some spatial extent, such as airports, monuments, hospitals, hotels, lakes... Geometry is a geometric shape, such as a point, polygon or line. Geometries are used to capture a feature's spatial location. Time in the EMERGEL approach is based on a 4D (four-dimensions) view of the reality sometimes called a perdurantist perspective and is the temporal extension to the OWL language known as tOWL. The basic idea is that everything in the reality, on universal and microscopic scale, is an event: from the birth of a new born baby to a chair in a room.

Every emergency operation in EMERGEL consists of concepts that can interact with each other, e.g., objects that are having an effect on other objects, constructs that are a description of something more complex than a plain object, activities that represent the effect of a respective object on other objects. Therefore, an object is only capable of acting towards another object by using an activity, which is property of the specific object.

EMERGEL uses the SKOS (Simple Knowledge Organization System), a standard vocabulary from the W3C to model the basic structure and content of concept schemes. Because several EU thesauri and vocabularies are available in SKOS, EMERGEL concepts can be easily mapped to any other concept. This follows from the fact that there are a number of non-ontological resources where different symbolisms are used. These differences pose a problem to interoperability in both international cross-border cooperation and national coordination of stakeholders. EMERGEL incorporates these in-use schemes (taxonomies, data catalogues, cartographic symbolisms, and so forth) into a common representation format, i.e. RDF, to enable the specification of semantic equivalences to drive data translation processes between ICT crisis management systems.

3 FIRST RESPONDER INTEROPERABLE PLATFORM AND THE CORE ONTOLOGY DESIGN

3.1 EU Initiative for Deployment of First Responder Cooperative Platform

First Responder organizations across Europe have considerably improved their communications and information communication systems with the deployment of new technologies including innovations known as unmanned surveillance and sensor systems that assist them in preventative actions and in enhancement of the responses to major crisis events. However, a number of major incidents have highlighted the challenges first responders face, most notably concerning the interoperability barriers which were contextualised against the current economic and financial situation especially when the reality is that such cooperation between agencies is not required on a frequent basis. As a consequence a conclusion was drawn that if the agency interoperability is enhanced then a cost-effective solutions will follow. The interoperability on network level was relatively easy achieved by development of IPv6 gate-

ways that enabled seamlessly interconnection of the communication systems despite the fact that every rescue agency in a country is using different system and different implementations even in cases where the systems are based on the same standards (but the encryption keys are always different). The need of interoperability between different agencies often resulted into development of one-to-one interconnection solutions that are suffering maintenance problems. Moreover, such ad hoc solutions often do not consider emerging aspects related to security and privacy. The recently launched REDIRNET project (Emergency Responder Data Interoperability Network) from EU FP7 program [23] is developing a Common Meta-Data Gateway platform combined with a cooperative first responder socio-professional networking system where each agency can exchange data and can set the visibility and controllability of its data per partner agency and per data field. The socio-professional networking component provides a decentralised and self-building interoperability network to be set. It also allows the operation of the interoperability network to be run without major operational cost since the collaboration rules are set by the agencies themselves according to the accepted and agreed basic rules of the system. Collaboration rules are set according to mutual agreements between the agencies involved and cover issues such as the visibility and controllability of data fields, data streams and the switches enabling the data exchange between each other. The concept is including end-to-end encryption set by the agencies themselves (in terms of encryption algorithms and keys). The most important component of the concept, the Meta-Data Gateway which is the main part of the REDIRNET platform, is an open source software based connector with sample codes and documentation. Every emergency response organization needs to be integrated only once to the platform in order to access the interoperability gateway for exchanging information with every other system regardless of regional location or vendor. The access to the agency owned data through the platform has to be authorized by both parties. The approach is illustrated in Figure 2.

The example in Figure 2 shows that the agency from Slovakia is offering data stream from the flying drone and from the camera to the agency in Belgium. Though there is no evidence on the picture, this exchange has been previously agreed between the two agencies as the request for the data provided by the drone camera. The information of the Slovak agency is made visible to Belgium agency using the REDIRNET socio-professional network (presented in as core network). The seamless interoperability means that upon right configuration, both data streams from the Slovak agency are displayed to the Belgium agency control centre. The same is valid for the data displayed on field officer's handheld devices.

3.2 The Developed Core REDIRNET Ontology

The open source common data gateway in REDIRNET enabling information interchange is composed from a set of sample applications, documentation and a general license agreement. The gateway interface is based on metadata models, mechanisms and elements required to communicate emergency situation among the first-

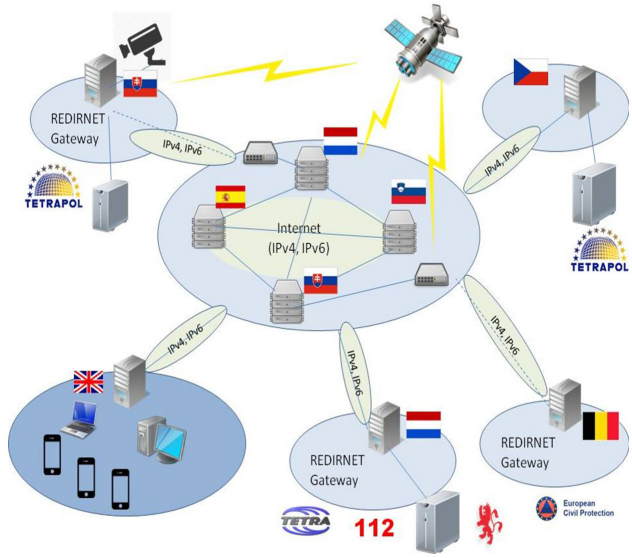

Figure 2. The REDIRNET concept for exchange of data and information

responders and their EMSs (Emergency Management System). The communicated meta-data provides a common information picture among the participating entities and shape the common information space in EU in the area of emergency information. The concepts involved are classified as basic, entity, incident, resource and communication related. These data can be data of past incidents or data from monitoring particular location, e.g. road and the live traffic. The entity in the system can be a person, device or a service. To align the entity related concepts they have to be properly named and their roles specified, items enabling authorizations must be labelled, responsibilities identified and modelled accordingly. The incident informations are related to the incident itself, its location, type, scale, casualties, the type of emergency response in the past and in progress and as well information about possible consequences. The resource concept is based on the participating entities with information about their capabilities and availability prior and during the incident response. The communication concept covers the messages exchanged between the entities and the information required for maintaining the communication, like discovery, routing, control and other management information. The messages exchanged can be alerts, data messages with necessary information about location, timing, resource announcement, reservation, released and removed messages, etc. The messages can contain metadata related to the other concepts as well. The interface is based on mechanisms that create, exchange, look up and accesses the REDIRNET metadata gateway. The concept and the mechanisms are illustrated in Figure 3.

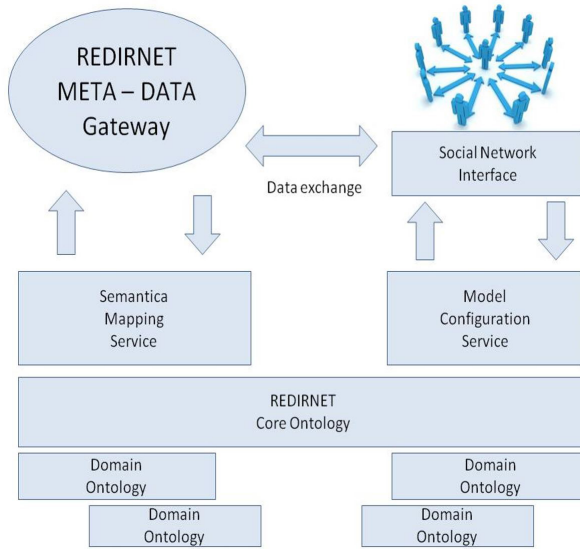

Figure 3. The REDIRNET concept of the core ontology

The approach applied in the design of REDIRNET core ontology is based on the EMERGEL specification. Terms that match well to the first responder scenarios regarding the analysed emergency cases where used, but some additional ontology trees were added to enable the implementation of the meta-data gateway and the platform as a whole system. The leading scope in the design was to develop core ontology which is well structured, easily manageable but build up of well-known and standard terms with well modelled respective emergency domains. The core ontology was designed with specification of the queries issued to the gateway in mind as they have to rely to known and standardized terms but in the same time linked to the originating ontology. The diagram of the core ontology is presented in Figure 4. All meta-data that build the ontology are presented in the leafs of the ontology tree. The stakeholders requirements that were collected during the project life required from the ontology designers introduction of new concepts that originated from their practice and use cases. As example, the Resource concept is described, which was designed with aim to provide necessary description of the Agency resources involved in the emergency management of particular event. Items belonging to the resource concept can be a sensor that provides data from the field, an agent of an emergency response agency that can be a person, a vehicle either manned or unmanned and driven by an agent or remotely controlled/autonomous system such as is a drone. The resource can be also an endpoint of information service that provides either documents or stream of data. The Resource concept within the REDIRNET ontology is provided in Figure 5. Additional envisaged Resources are the data available and offered from the regional governmental organisations. Their

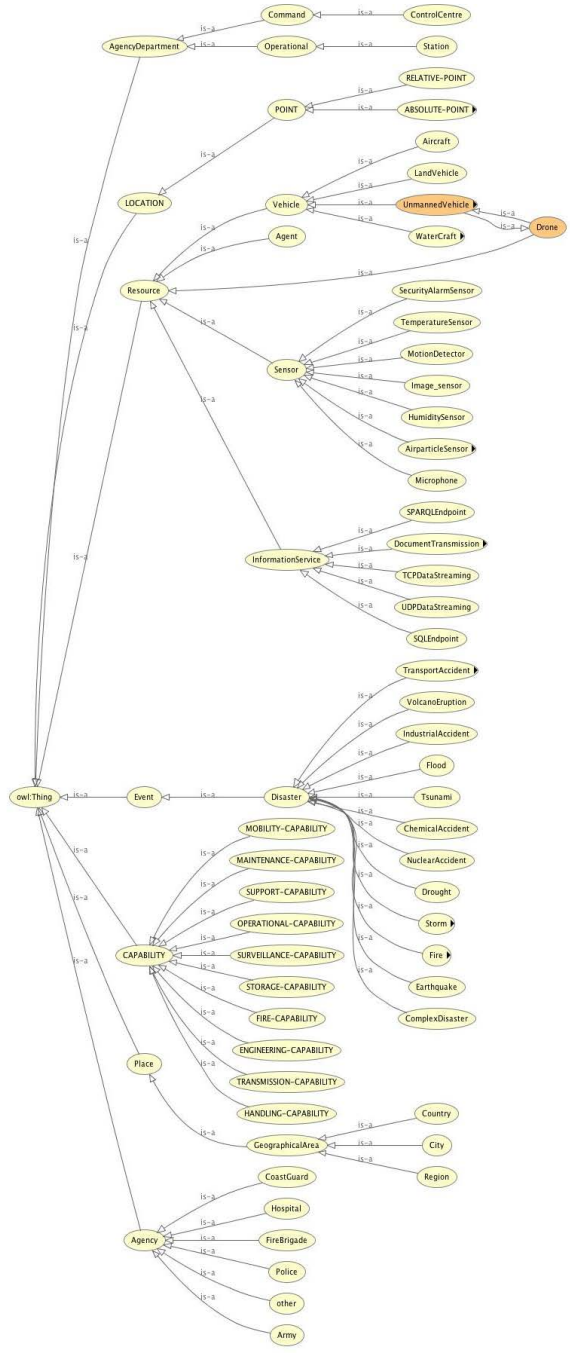

Figure 4. The Resource concept of the REDIRNET core ontology

sources are also considered to become data sources for the platform. As indicated by the relevant stakeholders such data are useful in the analysis phase of the crisis events.

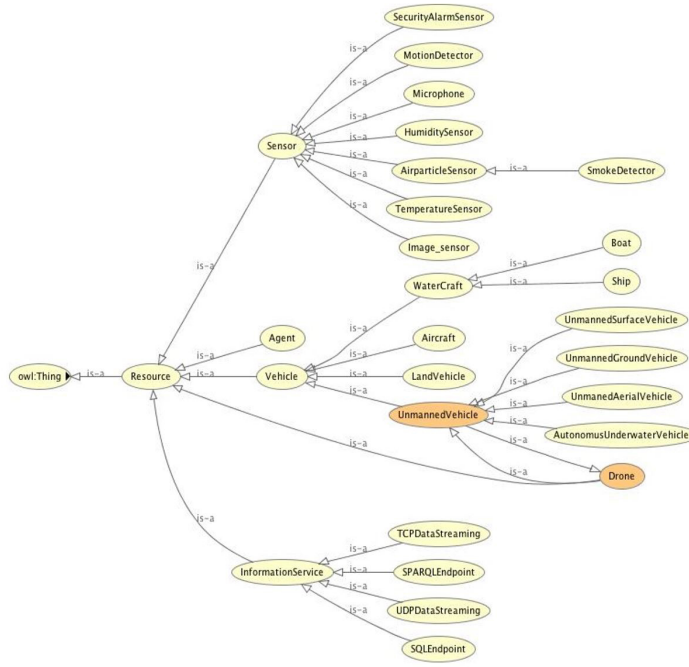

Figure 5. Resource branch in the REDIRNET core ontology

3.3 The First Responder Agency Resources Meta-Data

Rescue actions in emergency situation involves several agencies that usually have different structures, use different terminology to describe or to refer to resources owned and not always apply same operational protocols. In order to answer to that challenge the core ontology of REDIRNET was extended with additional novel branches that define each of the different agency expected to participate as first responders in an emergency situation. Each of these branches specifies processes and defines terms of the agency acting domain. These extensions are designed with links to the terms specified in the main core ontology tree. As an example of these ontologies the concepts for the Police Rescue domain actions and terms are presented.

The Police domain ontology was designed with a structure similar to the UK Police organization. In UK each police force is organised in a way that reflects mostly the local requirements where the Police force acts. In general, there is no

consistency or single approach in the structure of the Police forces at national level. Common footing of that kind of structure are the issues and the problems addressed. This organizational structure looks very similar to the organization of the Police forces in the EU as they address similar issues but the structure on national, regional or local level is not unified. From these circumstances, the Police ontology tree to be developed for REDIRNET ontology required mainly consistency in the information exchange in day to day policing both in terms of the Police Agency 'Operations' and 'Support'. All known police organisational structures act in similar way by operating and providing support but the terminology used to run the tasks differs from force to force. The specification of the Police domain tree was designed with an aim to specify the basic policing roles and responsibilities undertaken everywhere across Europe under different command structures to be mutually understood but to fit in the same time to the local requirements and understanding. In the case of REDIRNET the following terms were defined:

- 'Support' is addressing the numerous background functions such as training, estate management, recruitment, fleet management, communications systems, human resources, complaints, administration, etc. As noted before, the departments of the Police agency are organised differently and the Police staff is playing from case to case different roles in the incidents during their business as usual.
- 'Operations', i.e. operational staff, assets, vehicles – all this is specified as information defining the capabilities that are needed to a greater or lesser extent by any Policing agency in Europe (and in the world as well).
- 'Strategic command', 'Tactical coordination' and 'Field command' are terms related to particular responsibility during crisis event and the applied emergency management.

Strategic command is understood as the responsibility for setting the overall Police strategy at a major crisis event. Tactical coordination is a term denoting the responsibility of converting the event strategy into tactical implementations and the coordination of the overall resources. The field commanders are in charge of regional and for the specialist command field units deployed near to the event scene with tasks related to the tactical coordination. Strategic and tactical commanders at major crisis events often develop their respective plans, deployments, etc. in conjunction with the similar level commanders from the other involved agencies in rescue actions, so here the coordination is needed and is mandatory.

In Figure 6 the REDIRNET ontology terms and the operations of the Police domain are presented . The concept is based on the JC3IEDM model that enables operation presentations. The fields represent the Police Domain ontology concepts and the links the operation related to the Police tasks. The meaning of a particular operation is provided with the legend in the corner of Figure 6.

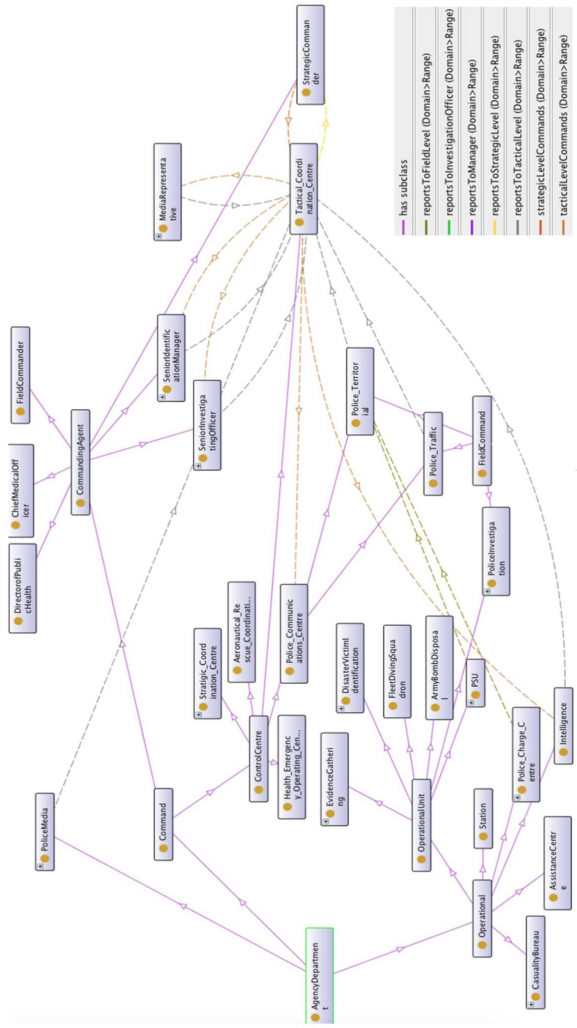

Figure 6. Police agency ontology branch

4 REDIRNET CORE ONTOLOGY IMPLEMENTATION

4.1 General Concepts

Agencies, business entities or emergency response teams that benefit from accessing each other's data resources by use of the REDIRNET platform will use the offered platform services through an application of the Collaborative Web [49]. Core ontology-based search engine as a main component of the platform is in charge for

the search of desired data resources and for partnership establishment. The users of the platform will need first to download REDIRNET gateway source code and to create a virtual user agent for its own agency's data resource (either as a data consumer or a producer by installing the user interface (UI) which is a plug-in to the REDIRNET platform. Depending on the type of service of the plug-ins for the consuming gateways in the systems of the participating external actors. These services are envisaged to be connected as they can be implemented with all possible technologies, engines, hardware or devices they are not provided as a part of REDIRNET platform. The interconnection details, routing, differences between particular systems, resilience and configuration are provided by tools which are part of the REDIRNET platform. The platform appears to a particular agency as a client-server system, the server, the REDIRNET platform has a form of a switching array of geographically distributed physical servers and virtual servers, with structure similar to a computing cloud solution. The underlying communication network is IPv6 based internet network but the connectivity to more expensive resilient networks (e.g. satellites or governmental networks) as a backup is provided as well. This approach together with virtual client-server architecture ensures the operational costs to not scale with the number of interconnected agencies and talk-groups but only with the resilience requirements during the absence of internet connectivity. The modular and robust architecture of the platform makes the solution easily maintainable, portable and extensible. The platform is composed from several components which are listed below:

- Main Switch, redirecting the communication, checking permissions and serving as a logging facility,
- Core Data Storage, utilizing ontological search engine and database services for all data that need to be stored,
- Collaborative Web, user interface for the system that manages the registration of the resources and the permissions and authorisation of use,
- Gateway, agency client, that takes role of a mediator between the Main Switch and the plug-in,
- Plug-in, sort of a driver for the end-point resource.

In the section that follows the main Core Data Storage component where the database with meta-data of the resources is located and the related information search services are presented.

4.2 Core Ontology and Search Services Implementation

The developed core ontology was designed as a main building block of the REDIRNET platform for enabling information exchange between first responder agencies and support to the management in emergency situations. The REDIRNET platform services are provided through integration of the systems connected to the main

component responsible for the exchange of data with different formats but identified through the semantic content specified with the REDIRNET meta-data repository. Figure 7 provides a high-level view of the REDIRNET Core Data storage component and the related operations. The main building blocks are the core ontology meta-data and the Agency domain ontologies which both reside in the RDF repositories. The repository stores the data required by the system and is built up from the core ontology terms and the relational database subsystems which support SQL query language such as MySQL, Microsoft Data Engine or the Oracle Database. The REDIRNET platform main component can be considered as the middle layer between the REDIRNET main components and the envisaged adhered systems and the plug-ins. The core ontology is presented as a graph with namespaces, concepts and attributes that link the resource descriptions and their meta-data. Once stored in the RDF resources repository they can be queried. The queries requiring a transformation of the term concept from the ontology of one agency to an another agency's ontology are done with the core ontology services. In that case the Meta data Gateway component negotiates with the system in order to obtain an access to the agency's RDF repository. These queries can contain questions about the structure of the agency or the agency resource definitions but they can also include queries with more specific requests such as the access to some part of the Agency databases. To answer to such queries mapping is required to be made between the terms from the agency ontology terms and the resources database schema. This process is visible in Figure 7.

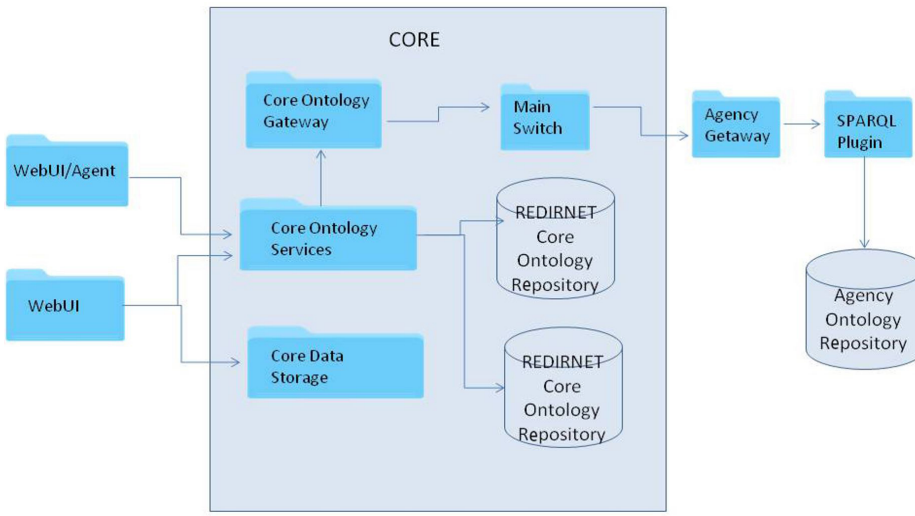

Figure 7. REDIRNET platform main concept

The REDIRNET platform is not yet operational as the final tuning of the component interconnection is still being tested. However, the current status enables

a discussion about the opportunity offered by the platform for more efficient management in emergency situations.

5 DISCUSSION AND CONCLUSION

5.1 Improvement in Interoperability

Reasoning about an improvement the interoperability of first responder agencies in case of emergency raises several issues. The general one is to what extent is interoperability required and should be provided? What components and aspects of the participating agency need to interoperate? How can it be ensured that all necessary aspects are covered and interoperability is preserved over time as all participants evolve? Since each disaster event is unique the optimal interoperability at all levels to fit all crisis situations is difficult to be achieved. At minimum, the participating organisations should display compatibility and understanding, so at least they should be capable to enable coordinated operations and support. Full integration is certainly not desirable because in some cases it could imply that participating agency cannot function independently at full capacity. In an emergency situation, it is quite possible that one or several participants (or components) could be affected and may even cease to function; the rest must be able to continue without a significant performance loss (e.g. similar to the ARPANET resilient network concept [27]). Resilience and agility are essential in this case. Even if a central point of command (Emergency Command Centre) is secured and unaffected by the disaster event(s), the coordination provided by it could be severely affected by the unreliable communication and mis-interpretation of the exchanged information.

The agencies involved should be able to continue within acceptable operating information. The major components of the interoperability improvement presented in the previous section and illustrated with the implementation concept being developed by the REDIRNET project justifies the effort for interoperability provision in most appropriate way. To achieve interoperability several ways are considered, e.g. integrated (common format for all models), unified (common format at meta level) and federated way (no common format, with participants negotiating an ontology on the fly so as the meaning of models is understood the same way). It appears by many studies that the unified approach is the most suitable as the full integration and federalisation did not achieve the desired results due to organisational heterogeneity in the EU countries. Important issue here is the impossibility to properly negotiate in the limited time available in the case of a disaster event that additionally justifies the unified approach where major advantage is the system that enables ontology to be negotiated or adopted in advance, before the disaster happens. As a consequence, the core ontology with exact meanings about the terms and operations associated with the emergency concepts should be used in the exchange of information and knowledge prior to disaster events. Once this is achieved, the semantic requirements for proper interoperability in addition with standard communication gateways based on ARPANET specifications promptly meet the agencies and task

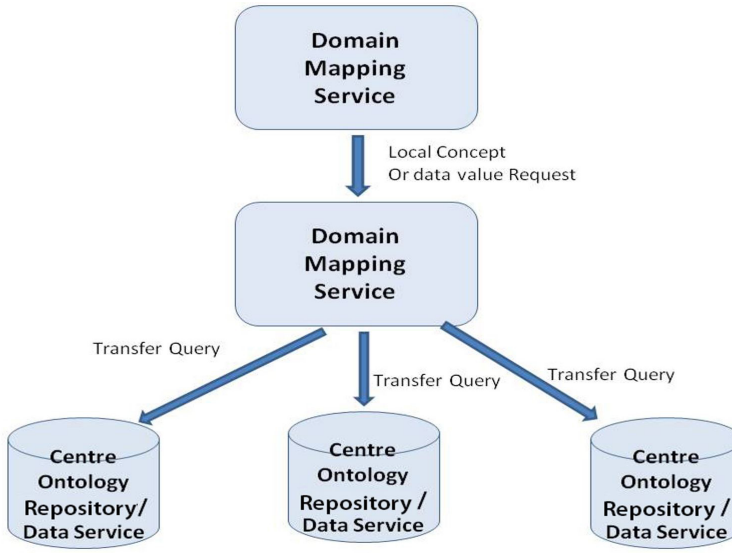

Figure 8. The transfer query concept of REDIRNET

forces needs that are formed in emergency situations. This approach is implemented within the development of the REDIRNET core ontology and its implementation in the REDIRNET platform.

However, it should not be forgotten that the pragmatic aspect of interoperability as defined in [59] in addition to the technical requirements relates to willingness, commitment, and capacity of the participants to interoperate. Although this aspect is mandated by governments, the human side needs specific attention prior to the agency task force formation to gain trust and knowledge of the other involved.

5.2 Concluding Remarks

The presented work about the ontology design of first responder interoperable platform is a contribution to the improvement of the interoperability without entering specific data formats and structure of participating parties. The developed ontology and its implementation in interoperable platforms provides to first responder agencies the expected compatibility and understanding of the exchanged information, so they become capable to run coordinated operations and to provide efficient support in a crisis situation. However, it should be added that organisational interoperability is also an important aspect in disaster management as participants usually have different organisational and management structures. These issues have been already identified by the EIF framework (namely responsibility, authority and type of organisation) as they impact heavily the functionality of the disaster management task forces. In a crisis situation, the roles (mapping of the human resources onto the

decisional structure) and hierarchy must be very clear to everyone from the start so that the task forces can focus on managing the disaster event rather than spending critical time figuring out its own modus operandi (who does what, who is in charge, etc.). The REDIRNET model and the developed Agency ontology provide a solid start up for implementing the improved interoperability by the platform also in the organisational setting. As most of the studies in this area have clearly identified that the data and processes appear to be the most relevant in the disaster management. The ability of task force participants to extract and exchange data from potentially heterogeneous data repositories is supreme in order they get awareness about the conditions in the disaster scene and avoid sending personnel into an unknown and potentially life-threatening situation. The volume and the erratic reliability of data in a disaster event can cause a groving problem, but prior agreements on data format and especially on their meaning assured by the adopted core ontology are essential and can help.

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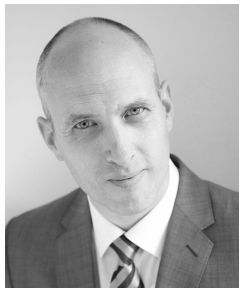

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