RECONSURVE: JC3IEDM and EDXL based Emergency Management Service Oriented Architecture for Maritime Surveillance

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Abstract. Effective response to emergencies and crises depends on timely available, reliable and intelligible information. To achieve this, many different services from heterogeneous information sources, systems and organizations have to co-operate. Especially, the coordination of government/civil agencies and military organizations are required to handle crises situations. Hence, the interoperability of Command and Control (C2) systems of the military organizations and Emergency Management (EM) systems of the government/civil agencies is crucial. In this context, the interoperability means the ability of systems, units or organizations to provide the services to, and accept services from other systems, units or organizations and to use the services so exchanged to enable them to operate effectively together. The major bottleneck in this interoperability is the difference of the information models (and/or standards) that these two types of systems use. Currently, Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) of Multilateral Interoperability Programme (MIP) is the most widely used data standard in military C2 systems, whereas it is OASIS Emergency Data Exchange Language (EDXL) in the governmental/civil organizations. In this paper, we propose an EDXL and JC3IEDM based Emergency Management Service Oriented Architecture to cope especially with the maritime crisis situations cooperatively by the military organizations and government agencies. The work is realized in the scope of RECONSURVE (Reconfigurable Surveillance System with Communicating Smart Sensors) project supported by ITEA2 at the international level and by TUBITAK at the national level.

1. Introduction

Management of crises and emergency situations require timely and collective response by government organizations, civil agencies and military organizations. In such complex situations, a collaborative information environment is required to help decision makers to effectively share/exchange information about on-going events, collaboratively develop shared situational awareness and common operational picture of the emergency situation and effectively plan and monitor operations. Presently exchange of information between a military Command and Control System (C2), which is normally classified, and a civil emergency management system is difficult due to different security policies and fear of accidentally releasing sensitive information to the public [1]. However, in order to achieve the full vision of collaboration in crises, cross domain information exchange is crucial so that all actors have the same situation awareness. Interconnecting these two information domains requires interoperability at all levels of communication as shown in Figure 1 and technical aspects of interoperability are as important as organizational aspects, such as policies, procedures, operations and strategies.

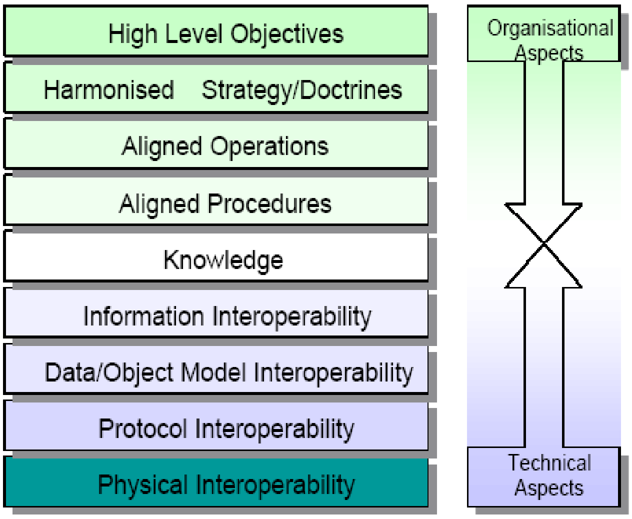

Figure 1 Interoperability Stack [2] in Collaborative Emergency Management

The main barrier to achieve technical interoperability is the divergence of data/object model interoperability layer standards and specifications used in military domain and civil emergency domain. For example Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) [3] of Multilateral Interoperability Programme (MIP) [4] supported by NATO is the prominent standard in the military domain. On the other hand, OASIS [5] Emergency Data Exchange Language (EDXL) [6] is the most widely used standard in the civil emergency management agencies.

Significant research has been realized towards achieving interoperability at the technical level for emergency management applications; however, most of them focus on a single domain (i.e. either military or civil domain) or they do not use the mentioned prominent standards effectively. In this paper, we propose standards based Emergency Management Service Oriented Architecture for the interoperability of the military and civil organizations. Although the framework is generic, as the application domain maritime domain is selected. The work is realized in the scope of RECONSURVE Project [7] supported by ITEA2 [8] at the international level and by TUBITAK [9] at the national level. The objective of the RECONSURVE project is to improve European Union (EU) maritime security including reduction of the number of illegal immigrants crossing EU sea borders by developing an open interoperable maritime surveillance framework with multimodal sensor networks.

The organization of this paper is as follows: In Section 2 and Section 3, JC3IEDM and EDXL standards are introduced respectively. Afterwards, an application scenario is presented in Section 4. In Section 5, the objectives and results of this paper is discussed. Finally, Section 6 concludes the paper.

2. Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM)

Unilateral capability is important to nations but most planning is made on the assumption of alliance and coalition operations in scenarios that are difficult to predict and which often arise at short notice. Thus the nature and composition of a force structure to meet military requirements will be based upon a general and flexible military capability. To achieve this, an assured capability for interoperability of information is essential. The successful execution of fast moving operations needs an accelerated decision-action cycle, increased tempo of operations, and the ability to conduct operations within combined joint formations. Commanders require timely and accurate information. Also, supporting command and control (C2) systems need to pass information within and across national and language boundaries. Moreover, tactical C2 information must be provided to the operational and strategic levels of command including other governmental departments. Additionally, forces must interact with non-governmental organizations, including international aid organizations. In this respect, the Multilateral Interoperability Programme (MIP) aims to deliver an assured capability for interoperability of information to support joint / combined operations.

The aim of the Multilateral Interoperability Programme (MIP) is to achieve international interoperability of Command and Control (C2) 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 digitization in the international arena.

Towards this aim, MIP produced Joint C3 Information Exchange Data Model (JC3IEDM) which is a model that when physically implemented aims to enable the interoperability of systems and projects required to share Command and Control (C2) information.

The JC3IEDM data model contains 271 entities. The entire structure is generated from 19 independent entities, that is, entities whose identification does not depend on any other entity. All other entities are dependent entities. Independent entities are presented in Figure 2.

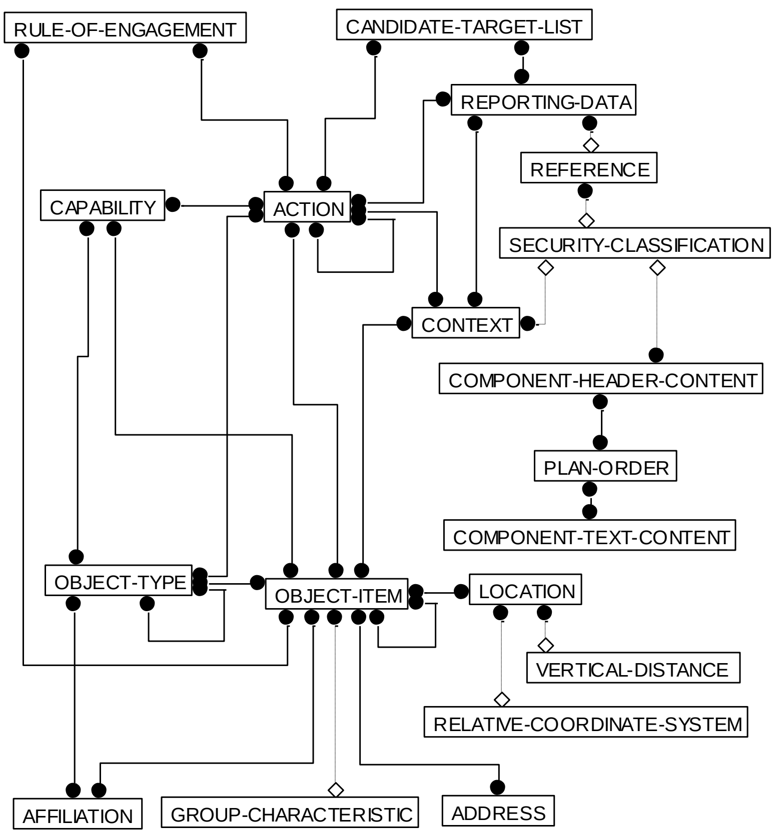

Figure 2 Independent Entities for Creating the Data Specification

3. Emergency Data Exchange Language (EDXL)

The Emergency Data Exchange Language (EDXL) is a suite of XML-based messaging standards that facilitate emergency information sharing between government entities and the full range of emergency-related organizations. The standard includes the following specifications:

- EDXL (Emergency Data Exchange Language) Common Alerting Protocol (EDXL-CAP): CAP defines an XML format for interoperability in alerting and public warning systems. The intention is to promote consistency in the information produced by all kinds of sensor and alerting systems, thereby reducing confusion and helping to get crucial warning information to the public faster. CAP messages carry message identifiers; information about the sender and the time sent; message status, type and scope; and the event category, urgency, severity and certainty. CAP has had good early uptake in the USA and is emerging as the common information standard for general incident messages.
- EDXL Distribution Element (EDXL-DE): EDXL-DE captures information required to enable routing of XML (and other) payloads, in order to facilitate information exchange between the various organisations involved in emergency management and response. This routing information includes elements such as the target area for a message (in order to support location-based message delivery); information about the sender; the target address for the message, if applicable; keywords describing the message content; and the type and "actionability" of the message (actual, exercise, test, etc.).
- EDXL Hospital AVailability Exchange Language (EDXL-HAVE) enables hospitals to exchange information about their bed availability, status, services and capacity.
- EDXL Resource Messaging (EDXL-RM) aims to provide a comprehensive set of message formats for resource management across all areas of the emergency sector for purposes such as requesting resources and responding to resource requests; requisitioning and committing resources; offering unsolicited resources; requesting and reporting resource deployment status; and releasing resources.
- EDXL-Situation Reporting (SitRep): EDXL-SitRep standard is for sharing general information across the disparate systems of any public or private organization, about a situation, incident or event and the operational picture of current and required response. The purpose of EDXL-SitRep is to guide more effective preparation, response, management and recovery through seamless summary-level information-sharing before, during and after emergencies and disasters of any scale.
- EDXL- Tracking of Emergency Patients (TEP): EDXL-TEP is primarily for exchange of emergency patient and tracking information from patient encounter through hospital admission or release. TEP supports patient tracking across the emergency incident continuum of care, as well as evacuations from hospitals and day to day hospital patient transfers. It provides real-time information to the emergency responders, emergency management coordinating organizations, care facilities involved in incidents and the chain of care and transport.

4. Search and Rescue (SAR) Application Scenario

In this section, an application scenario where the proposed architecture is used is presented step-by-step:

1. An emergency signal is received by Maritime Search and Rescue Coordination Center from "OGAN Bey" ship, which sails from Novorossiysk/RF to Sarkoy/Tekirdag with flag of Kampuchea. According to the signal the ship is at 8nM offshore waters in the west of Kdz.Eregli. (41 25.11N-031 00.36E).

2. The emergency signal is received by Istanbul Turkish Radio. Black Sea Regional Coast Guard Command and Undersecretariat of Maritime Affairs are informed on the situation through JC3IEDM and EDXL respectively.
3. It is concluded that the ship is being sunk as AIS is not operating and the communication with the ship cannot be established via radio, although the EPIRB signal is still active. Considering the situation, Undersecretariat of Maritime Affairs Main Search and Rescue Coordination Center announces "Dangerous Phase".
4. In order to perform SAR operation, Black Sea Regional Coast Guard Command is assigned as Search and Rescue Coordinator.
5. Black Sea Regional Coast Guard Command retrieves the last location coordinate of the ship sent via AIS.
6. Taking the data gathered from AIS and RADAR Interface into consideration the possible location of the ship is found via data fusion algorithms and the closest available resources are discovered. These available resources can be either maritime surface vehicle or aircraft and it can also be any commercial vehicles near to the sinking platform. When discovering resources from military organizations, JC3IEDM is used and when discovering resources from civil organizations, EDXL-RM is utilized. The system will assign priorities to the resources according to their current workload and proximity to the sinking platform and these priorities will be respected by the system while recommending an available resource. Furthermore, the priority level of the resource will be adjusted according to arrival time of the resource to the place of SAR operation and their response capability. According to these priority calculations, the system assign DOST maritime surface vehicle of the Turkish Coast Guard Command (TCGC) for the SAR operation through JC3IEDM message.
7. TCGC-DOST is informed on the task and it sends acknowledgement to Black Sea Regional Coast Guard Command through JC3IEDM.
8. After the approval of the task by TCGC-DOST, SAR Action Plan (SAP) including the most appropriate search pattern, task field details, the name list of the crew of the sinking ship, meteorological and oceanographic data are retrieved from corresponding civil organizations through EDXL-SitRep and converted to JC3IEDM, and sent to TCGC-DOST.
9. When TCGC-DOST arrives at the scene, it begins to perform the operation according to SAP-SAR Action Plan.
10. In previously defined time periods situation report related with SAR operation is sent to Black Sea Regional Coast Guard Command by TCGC-DOST through JC3IEDM.
11. As this operation is performed in the evening, IR camera is used to detect the shipwrecked over the water surface. Four shipwrecked and two life boats are detected via IR camera.
12. The shipwrecked are taken to the boat and it is concluded that there is no other shipwrecked according to declarations of the shipwrecked. Therefore, SAR operation is completed.
13. TCGC-DOST sends SAR Result Report including recorded video, images and data gathered during operation to the Black Sea Regional Coast Guard Command, which is Search and Rescue Coordinator, through JC3IEDM. After that this JC3IEDM message is converted to EDXL-SitRep and forwarded to other related civil organizations.

5. Objectives and Results

The objective of this work is to expose the functionalities of existing emergency applications/organizations as semantically enriched Web services. The input and outputs of the Web services are described in terms of the concepts used in EDXL and JC3IEDM standard according to the deployment location of the Web service. In other words, if the Web service is hosted by a civil organization, EDXL is used, whereas JC3IEDM is used if the Web service is deployed to a military organization. On the other hand, considering the interoperability of EDXL and JC3IEDM, a Situational Awareness Ontology is developed from them by using description logics reasoners. To be more specific, first JC3IEDM is converted OWL [10] format and then the EDXL specifications are converted to OWL format and finally these two ontologies are harmonized into the Situational Awareness Ontology using a description logics reasoner. In this harmonization process the mapping between the concepts of the two standards is discovered semi-automatically. These mapping are used to developed XSLT [11] documents that are used to convert messages from EDXL to JC3IEDM (or vice versa). In addition to EDXL and JC3IEDM specifications, other standards such as Open Geospatial Consortium's Sensor Web Enablement (OGC-SWE) [12] and Automatic Identification System (AIS) [13], which are used widely in maritime surveillance, are also included to the Situational Awareness Ontology.

As the data format, Web Ontology Language (OWL) is used. The OWL is the most widely used knowledge representation language for authoring ontologies. It allows the description of a domain in terms of classes, their properties and the relations among the classes. Furthermore, with supported tools it becomes possible to realize advance processing on the ontology. For example, the above-mentioned standards have some overlapping concepts having similar structure. With Description Logics (DL) Reasoners – one of the tools to process the ontology – it is possible to identify these overlapping concepts automatically. This allows the elimination of the redundancy. This process is also called as ontology harmonization or ontology merging/alignment. One precondition to feed an ontology to Description Logics Reasoners is that the ontology should be in description logics level (i.e. it should be rich enough). Therefore, the Situational Awareness Ontology is designed to be at the OWL-DL level.

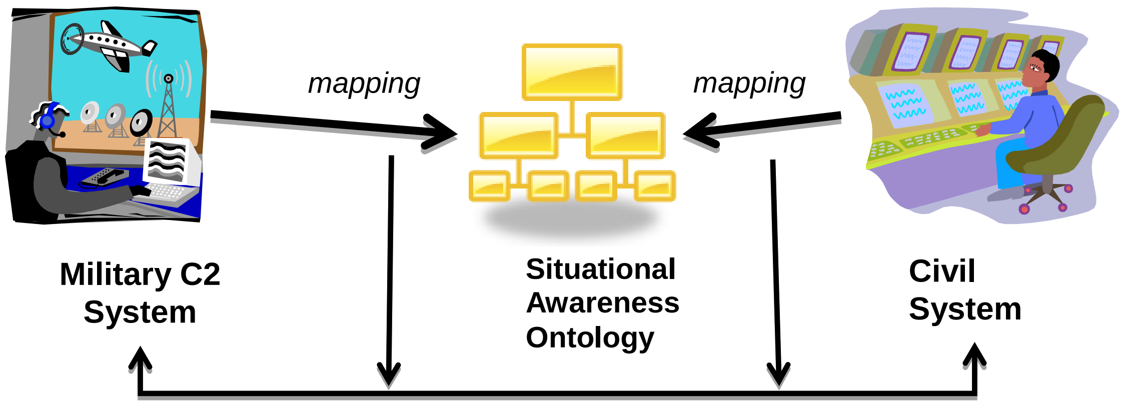

Figure 3 Interoperability of a Military C2 System and a Civil Emergency Management System through Situational Awareness Ontology

The development process of the Situational Awareness Ontology is as follows and this iterative process is followed for each of the standard to be included:

1. The OWL-DL model of the standard model is created. This can be automatic if there is a machine processable data model such as XSD or ERWin [14] data model.
2. After that this ontology, together with the Situational Awareness Ontology, is fed into the description logics reasoner (Racer Pro [15] is used in this work) to identify possible inconsistencies or overlapping concepts.
3. If there are any inconsistencies or overlapped concepts, they are handled automatically or semi-automatically.
4. Re-run the above process until there is no inconsistency or new overlapping concepts.

When generating the OWL Ontology from the JC3IEDM Specification, we have made use of the existing work [16][17].

In both of these work, the main idea is to parse the ERWin format that holds the JC3IEDM data model and reflect the semantic in this model to OWL Ontology. The first paper generates an OWL Ontology at the Description Logics level. However, the paper does not consider the business rules, which puts extra constraints on the JC3IEDM entities, defined by the standard. For example, the attribute object-item-address-transmit-receive-code is relevant only if the OBJECT-ITEM-ADDRESS is associated with an ELECTRONIC-ADDRESS (i.e. if address-category-code has the value 'ELECTRONIC-ADDRESS'). On the other hand, the second paper generates an OWL-DL ontology by also considering the business rules. However, the paper only gives an initial attempt for such a conversion and does not provide a complete OWL-DL ontology. In the scope of RECONSURVE Project, these two approaches are harmonized and a complete JC3IEDM OWL-DL Ontology is derived.

On the other hand, the EDXL Ontology is developed semi-automatically by first applying the following conversion rules (Table 1). After that the resulting OWL ontology is manually tailored in order to enrich it with more semantic.

Table 1 XSD to OWL Conversion Rules

XML Schema	**OWL**	**Shared informal semantics**
element|attribute	rdf: Property owl: DatatypeProperty owl: ObjectProperty	Named relation between nodes or nodes and values
element@substitutionGroup	rdfs: subPropertyOf	Relation can appear in place of a more general one
element@type	rdfs: range	The relation range kind
complexType|group |attributeGroup	owl: Class	Relations and contextual restrictions package
complexType//element	owl: Restriction	Contextualized restriction of a relation
extension@base| restriction@base	rdfs: subClassOf	Package concretizes the base package
@maxOccurs @minOccurs	owl: maxCardinality owl: minCardinality	Restrict the number of occurrences of a relation

sequence choice	owl: intersectionOf owl: unionOf	Combination of relations in a context

The current version of the ontology is available at [18]. In the latest version of the Situational Awareness Ontology, there are 2078 classes, 1546 object properties and 552 data type properties.

6. Conclusions and Future Work

In a crisis situation, collaboration between civil organizations and military organizations is crucial. However, current technical obstacles make the interoperability between the systems used by these organizations difficult and this prevents effective coordination. In this paper, we propose JC3IEDM and EDXL based Emergency Management Service Oriented Architecture and choose the maritime domain as the application domain. Currently, the data/object model layer of the Figure 1 is focused. As the future work, the rest of the layers will be investigated.

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