Interlinking National Tsunami Early Warning Systems towards Ocean-Wide System-of-Systems Networks

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ABSTRACT

For the integration of national tsunami warning systems to large scale, ocean-wide warning infrastructures a specific protocol has been developed enabling system communication in a system-of-system environment. The proposed communication model incorporates requirements of UNESCO Intergovernmental Oceanic Commission tsunami programme to interlink national tsunami early warning systems. The model designed to be robust simple is based on existing interoperability standards. It uses the Common Alerting Protocol (CAP) for the exchange of official tsunami warning bulletins. Sensor measurements are communicated via markup languages of the Sensor Web Enablement (SWE) suite. Both communication products are embedded into an envelope carrying address information based on the Emergency Data Exchange Language Distribution Element (EDXL-DE). The research took place within the context of two European research projects. The reference implementation of the presented results was tested independently in deployments at two early warning centers.

KEYWORDS

Tsunami Early Warning, Disaster Management, CAP, EDXL

INTRODUCTION

In the domain of tsunami early warning systems (TEWS) significant progress has been achieved within the last years mainly resulting from innovative developments in sensor technologies, tsunami simulations, and wave propagation models; a thorough overview is provided by Wächter et al. (2012). Nations around the world have started to construct national TEWS, such as depicted by Hammitzsch et al. (2012). Because of the regional, mostly basin-wide character of possible tsunami disasters the national warning centers have to be integrated into a regional tsunami warning infrastructure.

A main objective of the UNESCO Intergovernmental Oceanographic Commission (IOC) Tsunami Programme is the integration of national TEWS to ensure information exchange during tsunami events. The current IOC implementation guidelines provide solutions to establish the communication between national systems. These solutions are based on established telecommunication standards just capable of transmitting all-caps ASCII text. They were not designed for a programmatic machine to machine (machine2machine) communication of complex data structures in critical situations.

The communication and data exchange between early warning systems (EWS) therefore is a key challenge for the construction of regional tsunami warning infrastructures. We believe that the growing number of available sensor data and the increasing warning message exchange rate, the overabundance of information in combination with a high degree of urgency will make it nearly impossible to be handled manually by humans in proper time.

In the last years the evolution of system-of-systems approaches especially suited for the communication and data exchange between systems became very important for the development of IT-infrastructures in earth system sciences (ESS) but also for spatial data infrastructures (SDI) supporting improved business processes in and interactions between authorities. Technologically, system-of-systems are concepts for the integration of independent, loosely coupled information systems to fulfill complex, cross-system tasks.

This paper proposes a new, specific communication protocol for warning systems communication model to fill the identified gap. Our goal was to provide a solution that enables the programmatic integration of numerous national warning centers supporting the automatic interaction of warning systems on a machine2machine level.

The first part of this paper identifies core requirements for the communication between regional warning centers. In a first step a review of IOC guidelines, specifications, recommendations and meeting notes has been carried out complemented by an online questionnaire that was communicated among several communities related to the research area. In a second step an in-depth investigation of related projects, early warning systems architectures, and standards of the emergency management domain to identify relevant best practices and standards was conducted.

Based on these requirements and preconditions the second part of this paper addresses system-of-system communication and data exchange. The proposed C2C Interlink Protocol itself includes the specification of a communication model, the standards-based interchange format and the reference implementation. The protocol has been validated in a virtual test scenario based on real event data.

2. REQUIREMENTS AND PRECONDITIONS

2.1 System of systems in earth system science

The term system of systems addresses a collection of pooled systems whose capabilities together create a new, more complex system that provides more functionalities than the sum of all constituent systems. Systems of systems are still being investigated within current research. Jamshidi (2005) provides a comprehensive overview about that research area. In ESS the European initiative Global Earth Observation System of Systems (GEOSS, http://www.earthobservations.org/geoss.shtml) is the predominant framework programme dealing with system of systems. It is described on the webpage as follows: “This ‘system of systems’ will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets.” The focus of GEOSS lies on the integration of earth observation systems which also play an important role in the context of early warning system.

2.2 IOC Requirements

The Intergovernmental Oceanographic Commission was founded 1961 as part of UNESCO. The IOC provides Member States of the UN a platform for exchange of scientific knowledge and technical expertise, to coordinate state programs and for global cooperation in ocean research. The IOC Tsunami Programme consists of four Intergovernmental Coordination Groups (ICG) corresponding to the regions Pacific, Caribbean, Indian Ocean and Atlantic + Mediterranean. They have been established to address regional needs and to coordinate the development of ocean-wide TEWS, standard operating procedures (SOP) and to exchange knowledge among member states.

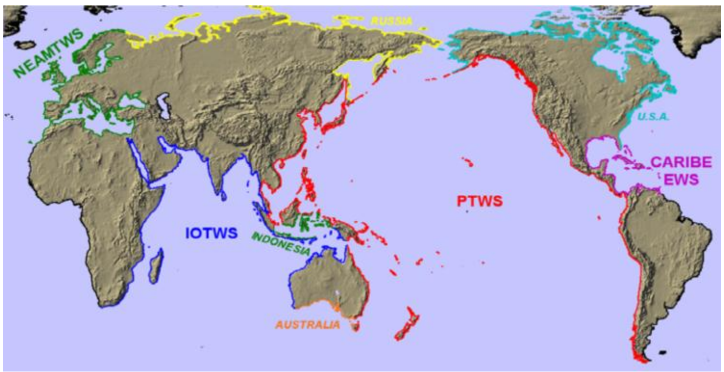

Figure 1. The four IOC ICG regions (UNESCO 2011a)

The ICG for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) was established in 1968. Traditionally, Japan and the U.S. are leaders in the field of tsunami early warning in the Pacific region and both play an important role supplying other countries with bulletins. IOC activities in other regions started after the destructive tsunami of 2004 in the Indian Ocean which caused more than 225 000 fatalities. The ICG Indian Ocean Tsunami Early Warning and Mitigation System (IOTWS), the ICG for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) and the ICG for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (NEAMTWS) were established 2005. Due to higher research activities in the Indian Ocean both CARIBE EWS and NEAMTWS back in their development compared to IOTWS which shows the most advanced progress. Among these ICGs, the IOC has established the permanent global Working Group on Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems (TOWS-WG) which is responsible for harmonization “to review the governance and organization of the ICG’s of all Tsunami Warning Systems to ensure common operation explore synergy effects and mainstream […]” (UNESCO, 2011a).

Lauterjung et al. (2010) recap the mission of IOTWS: “It was clear from the beginning of ICG-IOTWS activities that all Indian Ocean countries wanted to operate their own national warning centers and did not want to rely on the information of one or more dedicated warning centers for the Indian Ocean. Therefore, the concept of Regional Tsunami Watch Providers (RTWP) was conceived. The basic idea is that some of the national warning centers which have certain capabilities […] commit themselves to serve as a basin wide information provider to secure that warning information is distributed to all Indian Ocean countries, especially those who do not operate their own monitoring infrastructure.”

The initial implementation guide (UNESCO, 2008a) was released in 2008. It compiles requirements, lists operational elements and standard operating procedures (SOP) and outlines the phased implementation. Several additional documents provide more detailed information on certain specific aspects such as standardized coastal forecast zones used to establish a common referencing scheme.

Because of the large number of ICG and TOWS-WG guidelines and reports it is impossible to cover all aspects in full detail here. Even a summary of the main requirements and specified warning products (bulletins) would exceed the length of this article.

Within the DEWS project about 120 requirements based on IOC documents were extracted, assessed and accounted. For our review, the following documents were most important: UNESCO (2008a, 2008b, 2011a, 2011b), USAID (2007) and INCOIS (2011). Briefly summarized: It is foreseen to communicate different message products such as sensor observations (earthquake and sea level measurements), and bulletins with tsunami predictions for coastal zones. Spatial reference in warning products is established via referencing forecast points or zones. Communication must follow international standards.

However none of the documents foresees machine2machine interchange formats. This has historic reasons: The international exchange of sensor measurements mostly relies on old-established telecommunication standards such as the Global Telecommunication System (GTS) or the Aeronautical Fixed Telecommunication Network (AFTN), both requiring old teletype standards with all-caps ASCII text. Since these standards are widely-used and well known by meteorologist and oceanographers, they have significantly influenced the IOC specifications.

Currently (November 2011) ICG/IOTWS has accredited Australia, India and Indonesia as Regional Tsunami Service Provider (RTSP, harmonized name for RTWP). As proposed by UNESCO (2011a) RTSP to NTWC communication is realized by password protected web sites. Official IOTWS bulletins are visualized and downloadable as plain text files. None of the RTSP provides them in any other format. Also both tsunami warning centers operated by the US National Weather Service (NWS) are providing their bulletins in plain text. They also rely on aforementioned GTS and AFTN standards not capable of ingesting other formats.

2.3 Surveys and Questionnaires

A checklist for developing early warning systems has been developed by the United Nations International Strategy for Disaster Reduction; see (UN/ISDR 2006). Even though one of the four key elements addresses “Dissemination and Communication” all items on the checklist only affect the dissemination towards the people and communities. The document does not include any guidelines for system to system communication.

Therefore a questionnaire “Design and Architecture of Tsunami Early Warning Systems in International Context” (http://goo.gl/byZuN) was prepared to collect the missing answers. The surveys among experts consisted of more than 50 questions not limited to this specific problem but incorporating several open questions of our related research projects. The questionnaire was divided into four sections covering the aspects: i) workflows, ii) system architecture, iii) information logistics, and iv) spatial reference in warning messages. Due to the limited space only a subset of the relevant results can be presented here.

A first set of question addresses aspects of TEWS architecture: a) whether standards should be used for interchanging warnings, b) whether components should be re-used of/by other early warning systems, c) whether reference architectures should be used, d) whether a component or monolithic approach should be used and e) whether free and open source software or commercial software should be used. The results are presented in Figure 2.

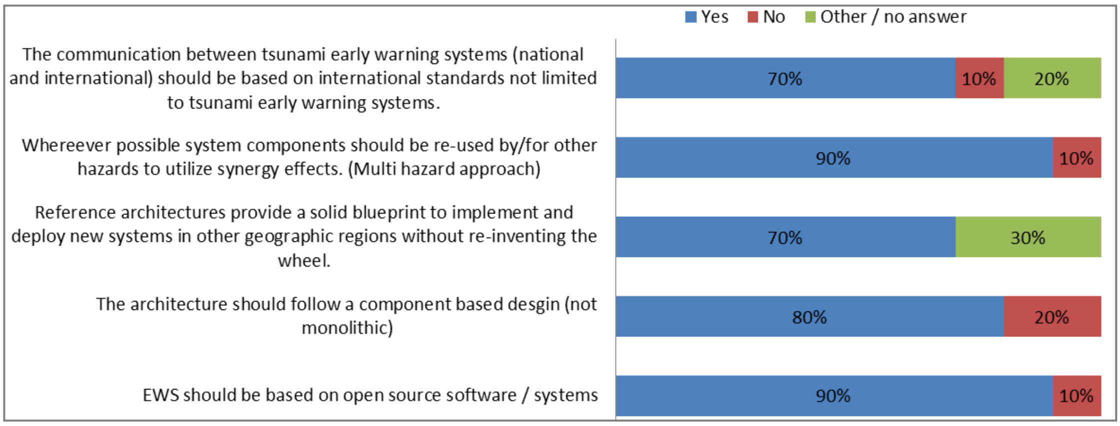

Figure 2. Questionnaire results addressing architectural aspects of TEWS

The results presented in Figure 2 reveal that the respondents prefer a component based architecture for TEWS that relies on international standard, open source and that is neither bound to a certain geographic area nor to a certain hazard type.

The question presented in Figure 3 was posed to identify the message products that are intended to be exchanged between national and international TEWS. This is a relevant question since we had the impression that it was not clearly specified in the IOC documents.

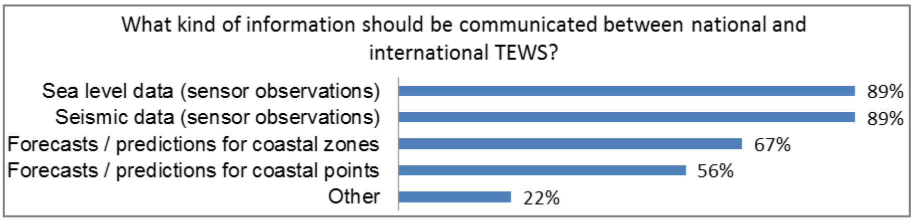

Figure 3. Expected data exchange between national and international TEWS

Figure 3 shows that the interviewed experts expect both sensor products and forecast products to be exchanged. The differentiation in coastal zones and coastal points is not relevant for this article but was used in the context of other aspects of our research.

The last question presented here in Figure 4 addresses whether incoming and outgoing communication products shall be processed either manually or automatically. This is a key question because the selected procedure determines how the systems will be coupled. If automatic processing is foreseen only a full integration on a machine2machine level will afford it.

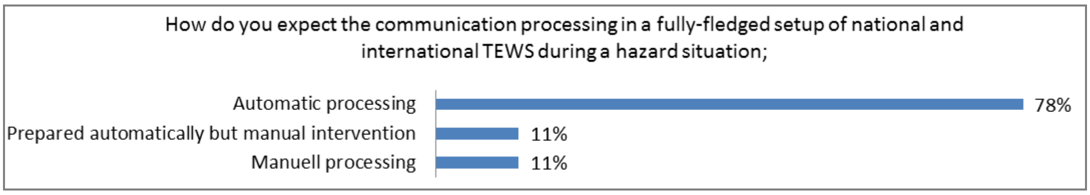

Figure 4. Expected data processing of incoming communication from external TEWS

Even we never doubted that the automatic processing will be the only alternative, we got the impression that on a political level this is not imaginable due to legal aspects.

2.4 IT Standards

Of particular importance regarding standards in the domain of emergency management is the Emergency Management Technical Committee (EM-TC) of the Organization for the Advancement of Structured Information Standards (OASIS). Their suite of XML-based messaging standards is called Emergency Data Exchange Language (EDXL). The members of this suite most relevant for our application scenario are:

- The Common Alerting Protocol (CAP): Intended to exchange warnings between alerting technologies. The International Telecommunications Unions (ITU) recognised CAP as an emerging global standard for alert and notification systems (ITU, 2007). A thorough summary of this standard was provided by Botterell (2006).
- The EDXL Distribution Element (EDXL-DE): An envelope standard for message-distribution among emergency information systems. It serves as container message providing addressing information to route the payload which can be any XML fragment, such as a CAP message.

Iannella and Robinson (2006) propose the Tsunami Warning Markup Language (TWML) for the communication of tsunami warnings. The XML schema has been developed within the SAFE project but has not yet been adopted by any TEWS.

Looking at the level of sensor integration and the exchange of observations and measurements existing standards are dividable into two groups: generic and domain-specific standards. The first group is dominated by the Sensor Web Enablement (SWE) suite which is a set of standards specified by the Open Geospatial Consortium (OGC). SWE comprises service specifications, e.g. Sensor Observation Service (SOS) as well as mark-up languages, e.g. Sensor Model Language (Sensor ML). Another mark-up language for sharing sensor data between remote environments is the Extended Environments Markup Language (EEML) developed by the International Alliance for Interoperability. However, international sensor networks rely on their own data formats and communication protocols. (USAID 2007) chapter 4 provides a thorough survey of international seismic, tide gauge and buoy networks and their corresponding data formats such as the Binary Form for the Representation of meteorological data (BUFR). This chapter also outlines worldwide communication systems used for data exchange, e.g. the aforementioned GTS maintained by World Meteorological Organization (WMO) and AFTN. However, these domain specific standards are not covered in detail here.

2.5 Discussion

The review and survey results revealed that technical implications on the machine2machine communication level were not foreseen during specification of IOC bulletins. The community, mainly driven by meteorologists, seismologists and oceanographers, is relying on old but proven teletype standards such as GTS for more than twenty years. In age of internet and smartphones, these plain text formats seem like relicts from a bygone era. The technological gap is evident but any new technology must master its way through official regulations and committees. However, although no related work could be identified that would directly solve the problem, interoperability standards exist and their applicability to create a communication model to enable an interlinked system of national early warning systems seems feasible.

3 THE C2C INTERLINK PROTOCOL

Based on review and survey results the communication model was developed resulting in specification of the “C2C Interlink Protocol“. The name (C2C stands for Centre to Centre) was chosen to emphasize the direct machine2machine approach. As a result of the surveys, the following design constraints were formed: the protocol (a) must be based on approved standards; (b) must focus on a simple, robust and easily extendable solution; (c) must rely on open source products; (d) must be based on XML instead of binary or plain text formats. Moreover, wherever possible generic approaches should be used rather than domain, hazard or implementation specific solutions.

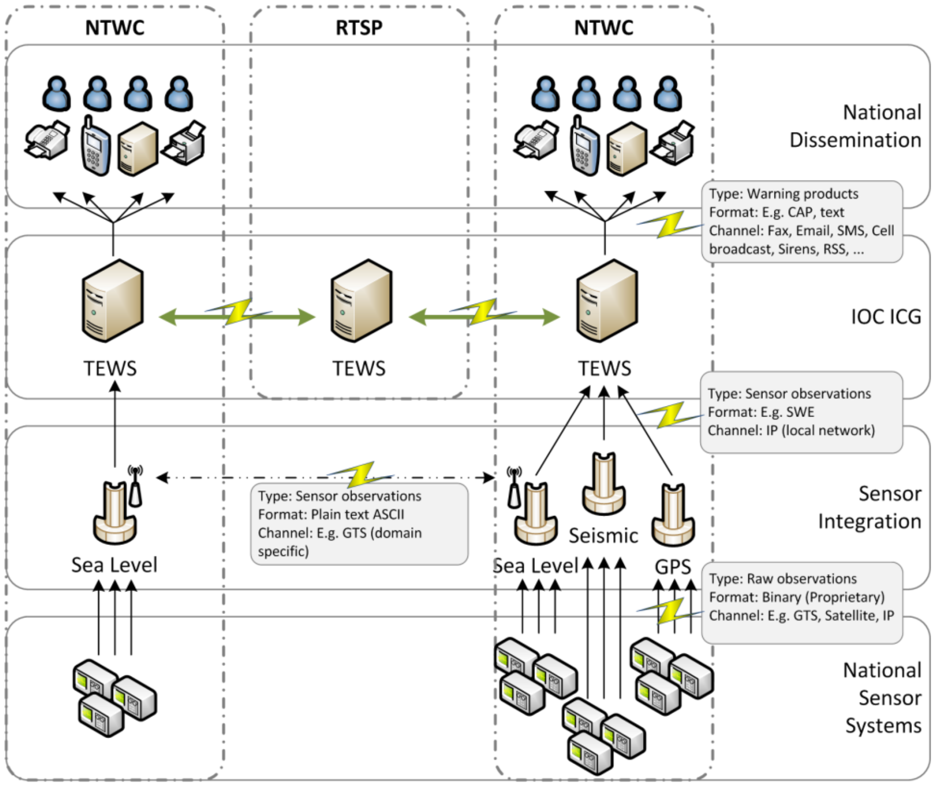

Figure 5. Schematic architecture of RTSP and NTWC with existing communication channels. Green arrows symbolize the new communication link presented within this paper.

Figure 5 visualizes the layered architecture of TEWS and the coupling of NTWC and RTSP. So far sensor systems use their specific networks for the exchange of sensor measurements. On the IOC/ICG level communication is relying on web frontends and GTS but missing an adequate model. Our solution addresses the green arrows to introduce a standardized communication model on the TEWS level.

3.1 Specification

We identified two different payload types that are required to be exchanged between RTSPs and NTWCs:

- Sensor measurements: RTSPs and NTWCs must exchange post-processed sensor measurements such as earthquake data and sea level heights. Post-processed means that no system specific raw data is communicated. Even there are existing communication channels to exchange certain sensor observations (e.g. GTS for the exchange of sea level data, see Fig.5) we believe that an integrated approach should be followed to leverage a stronger coupling of TEWS running at RTSP and NTWC. We decided to exchange sensor measurements with OGC SWE. It is an independent standard not bound to any specific sensor types. The standard is widely used and several open source software frameworks for encoding are available. Finally our decision was also influenced by the fact that our research group collected a lot of experience during development of the sensor integration platform for the German Indonesian TEWS (GITEWS) which also relies on the SWE suite. Messages with SWE payload are called Sensor Measurement Bulletin (SMB).
- IOC bulletins: RTSPs are responsible to send bulletins to connected NTWCs. These bulletins have to follow official guidelines. We were stuck between a rock and a hard place: On the one hand we have to provide the requested plain text format but on the other hand we aimed to encode the same information in a structured manner, preferably following a well-known markup language. Conveniently CAP perfectly fits to our needs and provides features to cover all requirements. Areas can be referenced by geocodes and coordinates, predictions such as ETA and EWH can be added as key value pairs and finally it provides three elements named title, description and instruction for ingesting a human readable message. This enables to embed plain text bulletins as CDATA segment in the description element. CDATA is taken to preserve white space which is used within bulletins to create a table like structure. Messages with CAP payload are called Wide Area Centre Bulletin (WACB). Side note: To avoid naming conflicts the terms NTWC and RTSP were not used within the DEWS project. Instead

National Centre (NC) and Wide Area Centre (WAC) were introduced following the same concepts. This has led to calling these messages WACB.

We decided to use EDXL-DE as envelope for addressing purposes atop of SWE and CAP. It is a lightweight container and allows arbitrary xml fragments as payload. It provides requested addressing functionalities, e.g. to identify message sender and recipient. It also provides elements to announce the message / payload type without checking the payload itself. Our intention is to establish a direct, i.e. programmatically, communication between remote TEWS. In such a setup it is important to exchange technical status messages (TSM), e.g. to communicate operational availability. For these messages a third message type was introduced which does not require any payload since all information can be directly encoded in EDXL-DE key value elements.

Name	SMB	WACB	TSM
Type	Sensor Observations	Bulletins	Status messages
Envelope	OASIS EDXL-DE (XML)		
Payload	OGC SWE (XML)	OASIS CAP (XML)	[n/a]
Message sender	NTWCs providing data, RTSPs forwarding/gateway	RTSPs providing bulletins	NTWCs, RTSPs
Message recipient	NTWCs, RTSPs	NTWCs receiving bulletins	NTWCs, RTSPs

Table 1. Overview C2C Interlink message types.

The next table specifies the application of EDXL-DE. Examples in third column are fictitious. Note: bold font indicates a mandatory element, * indicates that multiple instances are allowed; see specification (OASIS, 2006).

Sub element	**C2C Interlink meaning**	**Example values**
distributionID	Identifier of the C2C message. ID includes the senderID to improve tracing	urn:org:dews-online:c2c:NC:TH:1
senderID	TEWS ID, example for National Centre Thailand	urn:org:dews_online:centre:NC:TH
dateTimeSent	Always UTC	2011-08-01T16:49:00
distributionStatus	For SMB and WACB either “Actual” or during exercise “Exercise”. For TSM always “System”	Actual
distributionType	For SMB and WACB either “Report” or “Update”. For TSM always “Update”.	Update
combinedConfidentiality	Default value applies (may change in future)	UNCLASSIFIED AND NOT SENSITIVE
Language	Always “EN” for English	EN
senderRole *	Not used since the senderID will identify whether the message is sent by NTWC or RTSP	
recipientRole *	Not used (may change in future)	
Keyword	This element stores key value pairs. It is used to specify the message type. The expected value is one of the following: {TSM, WACB, SMB}	<keyword> <valueListUrn> http://www.dews-online.org/urn/c2c </valueListUrn> <value>WACB</value> </ keyword >
distributionReference *	Not used (may change in future)	
explicitAddress *	Not used (may change in future)	
targetArea *	Not used since area referencing is done in payload	
contentObject	WACB: one content Object for each attached CAP payload. SMB: one contentObject for each attached SWE payload. TSM: not used.	

Table 2. Child elements of EDXLDistribution (root element) and their usage in the C2C Interlink Protocol

Usage of explicitAddress is currently not foreseen. On message reception each recipient automatically decides whether the message is of interest or not depending on the senderID in combination with the message type. If RTSP/WAC generates country specific WACBs this may change in future versions. The payload fragments (either CAP or SWE) are stored within an xmlContent element inside a contentObject element. Multiple SMBs or WACBs can be stored in one C2C interlink message having multiple contentObject. However, mixing up SMB and WACB payload is not foreseen. Figure 6 illustrates the EDXL-DE header of a WACB. Due to limited space the CAP payload cannot be shown in full detail.

```
<EDXLDistribution xmlns='urn:oasis:names:tc:…'>
<distributionID>urn:org:dews_online:WAC.IO:CAP6_1</distributionID>
  <senderID>urn:org:dews_online:WAC.IO</senderID>
  <dateTimeSent>2011-03-10T17:50:28.202+00:00</dateTimeSent>
  <distributionStatus>Actual</distributionStatus>
  <distributionType>Report</distributionType>
  <keyword>
    <valueListUrn>http://www.dews-online.org/urn/c2c</valueListUrn>
    <value>WACB</value>
  </keyword>
  <contentObject>
    <contentDescription>CAP message generated by DEWS WAC.IO</…>
    <incidentID>urn:org:dews_online:WAC.IO:6</incidentID>
    <incidentDescription>Tsunami Warning</incidentDescription>
    <xmlContent>
      <embeddedXMLContent>
        <alert xmlns='urn:oasis:names:tc:emergency:cap:1.1' xmlns:xsi='…'>
    <!-- CAP payload with Tsunami bulletin embedded here-->
        </alert>
      </embeddedXMLContent>
```


Figure 6. EDXL-DE envelope of WACB disseminated by Wide Area Centre Indian Ocean (WAC.IO)

3.2 Reference Implementation

Using XML for envelope and payload enables a great flexibility regarding implementation and selection of the communication channel. However, even the presented model foresees an asynchronous communication, the usage of a strong coupling with minimum delay better fits to the machine2machine approach. Therefore relying on email was not an option. Instead the reference implementation was built on a message oriented middleware (MOM) infrastructure. Apache Active MQ (http://activemq.apache.org) was chosen as message broker. Within the DEWS/TRIDEC reference architecture, the Command and Control User Interface (CCUI) glues together the upstream information flow (incoming sensor observations) and the downstream warning dissemination. Following the concepts of a hub and spoke architecture, the C2C message handling was embedded as new plug-in also at the CCUI.

3.3 Validation

Validation took place in a virtual test environment. Several test scenarios based on real sensor events were performed. In addition, DEWS has been installed for evaluation and testing purposes in a closed and secure testing environment at the Badan Meteorologi, Klimatologi dan Geofisika (BMKG), the Indonesian tsunami early warning center in Jakarta. There, one scenario was demonstrated as live-demo in the presence of BMKG experts. This scenario is briefly described here. It comprises of two DEWS national centers (Thailand and Indonesia) as NTWCs and one DEWS WAC as RTSP. Both NCs are connected to virtual sensor systems reflecting real world setups. Simulated sensor measurements are replayed in real-time by a so-called Scenario Player. NCs forward incoming sensor measurements as SMBs to the WAC. These measurements are displayed in situation map (e.g. earthquake measurement) and depicted as mareograms (ocean level measurement). They are used to trigger an ocean-wide wave propagation simulation that again can be used for risk assessment of the official IOTWS coastal forecast zones (see Figure 7, top right). Based on this classification the operator releases semi-automatically a WACB. Semi-automatically means that the message generation process is completely automated but the CCUI will not release the message without human confirmation. On incoming WACB the NC operators are informed via notification about new bulletins. On mouse click they activate the generation of communicated forecast zones. As shown in Figure 7 (bottom left) only the zones corresponding to that country are generated. The national operator can use this information for situation evaluation and re-dissemination of the warning message to national recipients such as local warning systems, rescue services, etc. (see Lendholt and Hammitzsch, 2011). Both CCUIs in Figure 7 include flags in the status bar indicating the status of external EWS. The shown WAC (top right) is currently configured to be connected with Thailand (TH), Indonesia (ID) and Sri Lanka (SL). The last one is highlighted in red since it was not running during this scenario. At a national CCUI (bottom left) only status of the connected WAC is indicated.

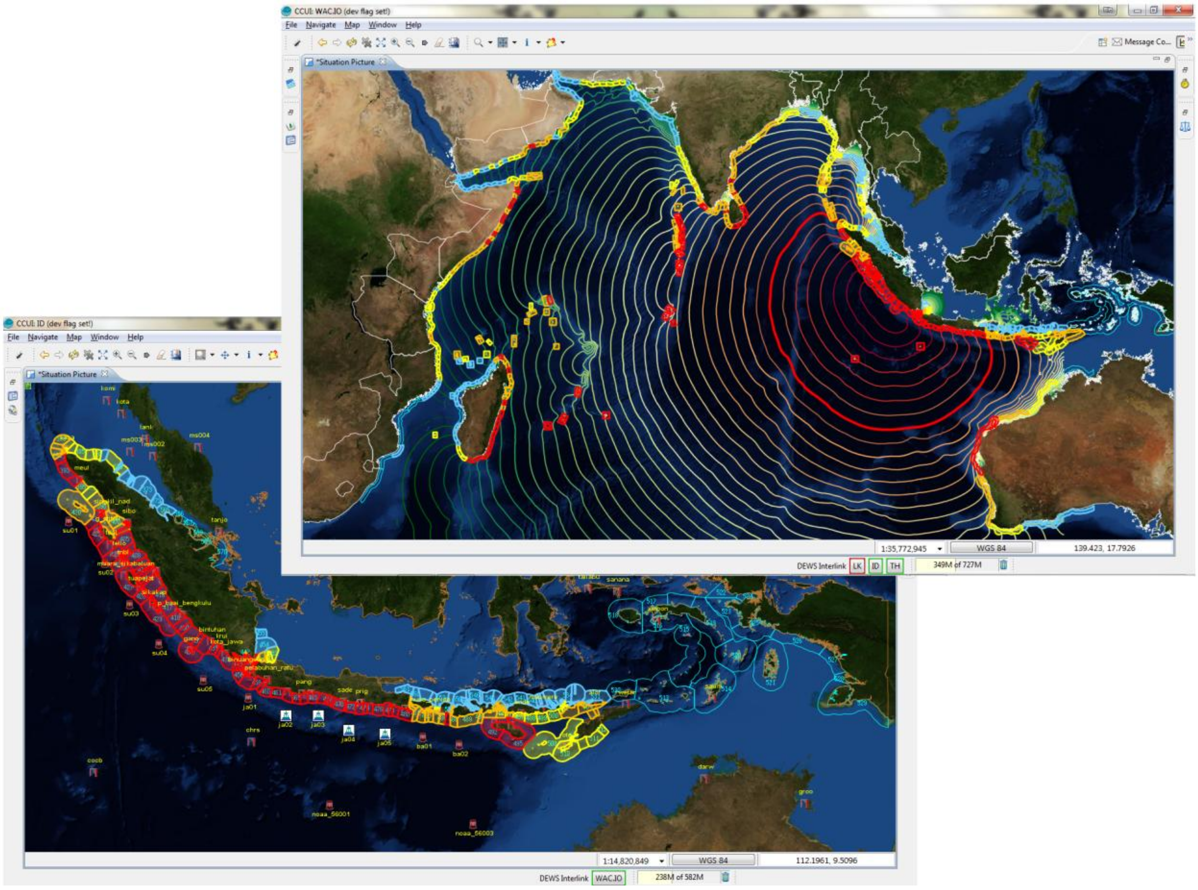

Figure 7. Classified coastal forecast zones based on forecasts generated by WAC (RTSP, top right). WACB sent from WAC to Indonesian NC (NTWC, bottom left) includes affected zones encoded in CAP. Imported as new layer in NC.

4 CONCLUSION AND FUTURE WORK

The communication and data exchange between early warning systems is a new challenge in the upcoming era of system of systems. In this paper we have explored the requirements and preconditions to establish a new communication model that fills the gap identified in the IOC guidelines for setting up a network of national tsunami early warning system. The presented solution is based on well-established standards from OGC and OASIS. In contrast to actual solutions such as usage of GTS the presented communication model splits message format and communication channel and hereby enables a greater applicability. The partition into envelope and different payload types provides again a greater flexibility and expandability regarding future requirements. The chosen standards realize a solution that is not bound to the Tsunami case. No domain specific standard, neither on the sensor level nor on the application level, was chosen. This allows a transfer to other scenarios and fulfills the request of following the multi-hazard-approach, which is a driving force in the development of modular, standards-based interoperable warning systems; as requested by UN/ISDR (2006): “Economies of scale, sustainability and efficiency can be enhanced if systems and operational activities are established […] within a multipurpose framework […]. Multi-hazard early warning systems will also be activated more often than a single-hazard warning system, and therefore should provide better functionality and reliability for dangerous high intensity events, such as tsunamis, that occur infrequently.” However, this transfer will be part of future research.

The reference implementation has been installed for testing purposed at Badan Meteorologi Klimatologi dan Geofisika (BMKG) institute in Jakarta. To promote our proposed solution we are looking forward to establish a test deployment between Thailand and Indonesia in near future. In the context of the TRIDEC project the system is running as national center at the Kandilli Obervatory and Earthquake Research Institute (KOERI) in Istanbul. Both deployments will supply new insights and other requirements that will impact future developments.

5 ACKNOWLEDGMENTS

The work presented here was performed in the context of two European research projects. The Distant Early Warning System (DEWS, www.dews-online.org) project was funded in the 6th Framework Programme (FP) of the European Commission and lasted until May 2010. It aimed for the development of a reference architecture for EWS based on open standards and free and open source software. Application scenario was the development of a TEWS for the Indian Ocean incorporating IOTWS guidelines. The research activities continued in the TRIDEC project (www.tridec-online.eu) funded in the 7th FP. TRIDEC stands for Collaborative, Complex and Critical Decision-Support in Evolving Crisis. It focuses on new technologies for real-time intelligent information management in collaborative, complex critical decision processes in earth management. One of its application scenarios follows up the development of a reference architecture for early warnings systems but with a slight shift from the Service Oriented Architecture (SOA) paradigm to Complex Event Processing (CEP).

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