A communication model for interlinking national tsunami early warning systems

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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). A main objective of the UNESCO Intergovernmental Oceanographic Commission (IOC) Tsunami Programme is the integration of National Tsunami Warning Centres (NTWC) to ensure information exchange during tsunami events. This will lead to ocean-wide tsunami early warning systems-of-systems covering the four IOC Intergovernmental Coordination Groups (ICG) regions (see Fig. 1).

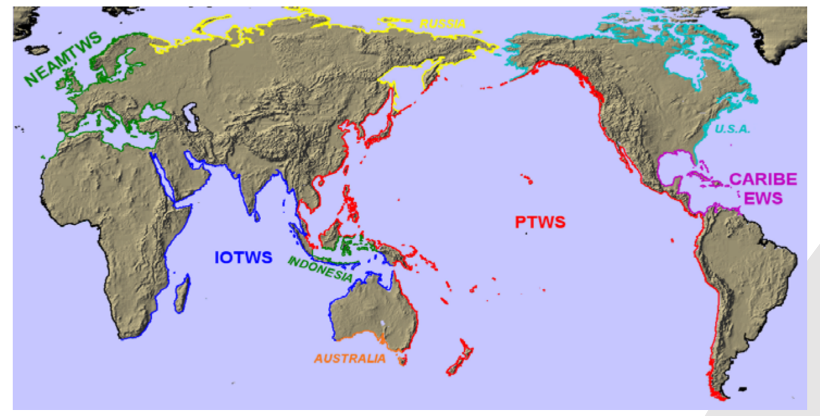


Fig. 1. IOC Intergovernmental Coordination Groups for Pacific Ocean (PTWS), Indian Ocean (IOTWS), Caribbean Sea (CARIBEWS) and North East Atlantic and Mediterranean Sea (NEAMTWS)

Challenge

The current IOC implementation guidelines (UNESCO 2008) does not provide solutions or recommendations for a an automated, programmatic machine to machine communication of complex data structures in critical situations. However, 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. Therefore the challenge was to develop a communication model based on well established standards of the emergency management domain and the ESS domain that serve all needs of the IOC communities.

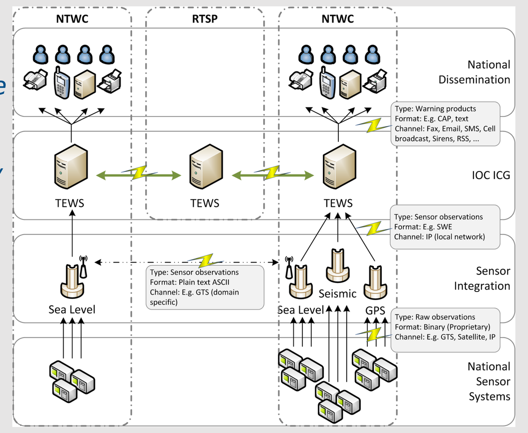


Fig. 2. The layered architecture of TEWS and the coupling of NTWC and RTSP. So far sensor systems use their specific networks for the exchange of sensor measurements. On the IOC/ ICG level communication is relying on web frontends and GTS but missing an adequate model. Our solution addresses the green arrows to introduce a standardized communication model on the TEWS level.

Requirements

A checklist for developing early warning systems has been developed by the United Nations International Strategy for Disaster Reduction (UN/ ISDR 2006). Even though 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 interviews and questionnaires (http:// goo.gl/byZuN) were performed to collect the missing answers (Lendholt et al. 2012).

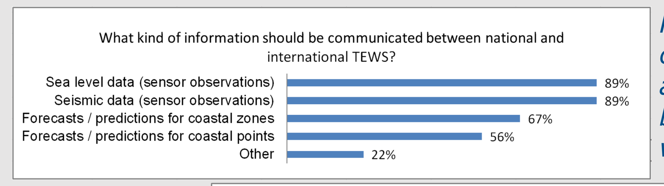


Fig. 3a. Both, sensor observations and forecasts, are expected to be exchanged between interlinked early warning systems.

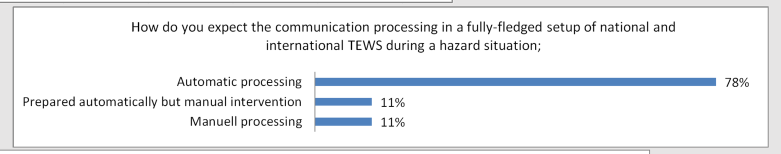


Fig. 3b. Automatic data processing is expected.

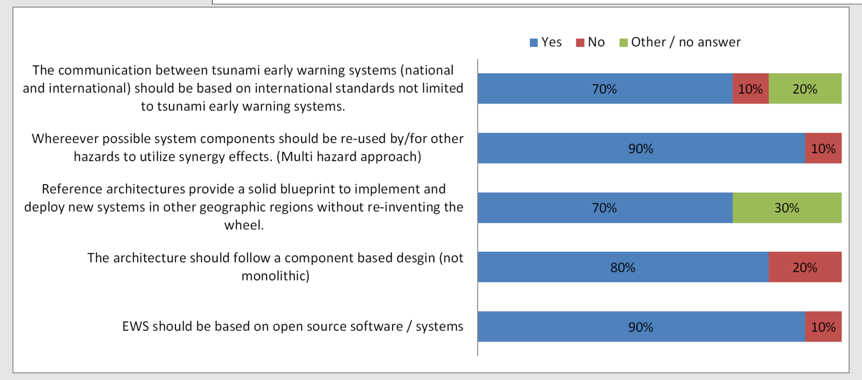


Fig. 3c. A set of questions addressing architectural aspects reveals that a component based architecture that relies on international standards and open source is preferred that should not be bounded to a certain geographic area nor a specific hazard.

Coastal Forecast Zones

To ensure interoperability between RTSPs and NTWCs of the Indian Ocean, the ICG/IOTWS introduced coastal forecast zones (CFZ). They serve as standardized spatial reference schema used in IOC bulletins to communicate tsunami arrival times and wave heights.

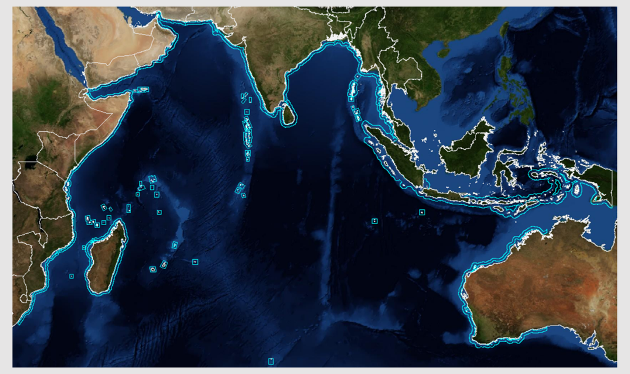


Fig. 4. Official ICG/ IOTWS Coastal Forecast Zones

(v5.1: 569 zones around the Indian Ocean)

The Model

Based on review and survey results the communication model was designed with these constraints: the protocol must be based on approved standards; must focus on a simple, robust and easily extendable solution; must rely on open source products; must be based on XML instead of plain text formats.

The Centre to Centre (C2C) communication:
- relies on a messaging infrastructure
- specifies three different types of payload (see Table 1):
  - sensor observations encoded in OGC SWE (Sensor Web Enablement)
  - IOC bulletins encoded in OASIS CAP (Common Alerting Protocol)
  - Technical status messages
- uses OASIS EDXL-DE as message envelope

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

OGC: Open Geospatial Consortium
OASIS: Organization for the Advancement of Structured Information Standards
EDXL-DE: Emergency Data Exchange Language - Distribution Element

Table 1. Message types and encoding standards.

Reference Implementation

Apache Axis is used as message oriented middleware (MOM). The C2C message handling was embedded in the Command and Control User Interface (CCUI) that serves as central application towards the operator in the DEWS/TRIDEC reference architecture.

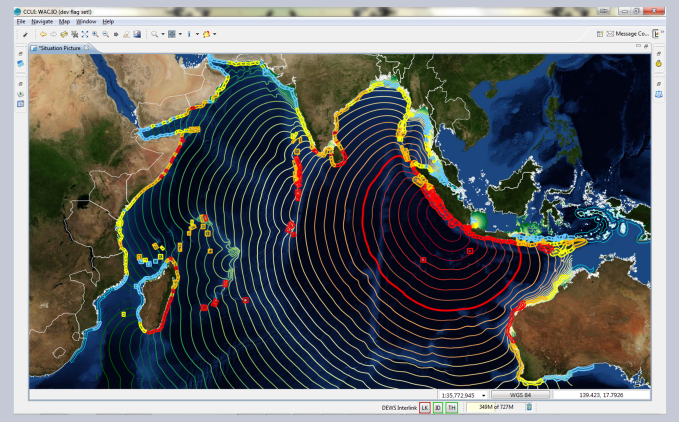
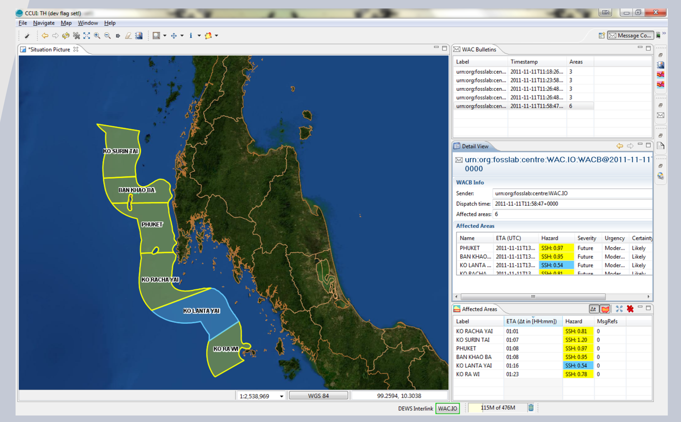
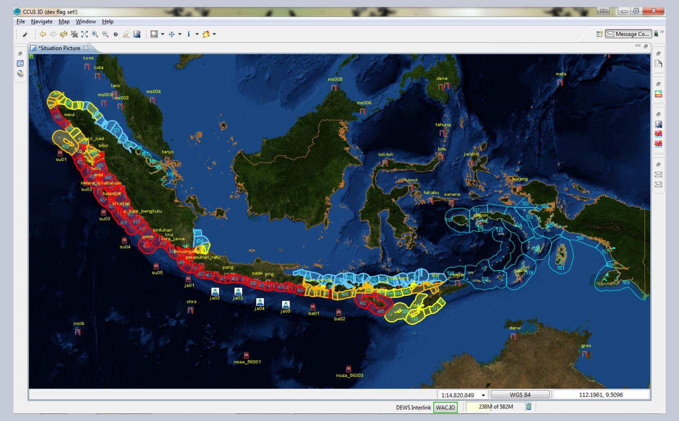


Fig. 5a. (right) WAC CCUI with simulation based wave propagation and classified CFZs for the Indian Ocean.
Fig. 5b. (bottom left) CCUI for national centre Thailand. The received bulletin contains only Thai CFZs.
Fig. 5c. (bottom right) CCUI for national centre Indonesia highlighting all affected Indonesian CFZs.





Workflow

Fig. 6a. Exemplary setup: Three national earl warning centres are connected to a Wide Area Centre (WAC), which corresponds to a Regional Tsunami Watch Provider (RTSP) or Regional Tsunami Service Provider (RTSP), both IOC terminology.

Fig. 6b. Earthquake occurs close to Bandah Aceh in the Indian Ocean.

Fig. 6c. Earthquake is detected by Indonesian early warning system.

Fig. 6d. Indonesian disseminates local/national tsunami warnings based on sensor measurements and tsunami simulations/forecasts.

Fig. 6e. Indonesian forwards its sensor measurements (seismic data, buoy and tide gauge observations) to the Wide Area Centre.

Fig. 6f. Based on received sensor measurements the WAC runs ocean wide simulations. The results are used to disseminate official IOC warning bulletins towards connected national centres.

Fig. 6g. National early warning centres disseminate local/national tsunami warnings based on official IOC bulletins.

Conclusion

The communication and data exchange between early warning systems is a new challenge in the upcoming era of system of systems. 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 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).

References

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Acknowledgements

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