The trend towards the Internet of Things: what does it help in Disaster and Risk Management?

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Abstract – According to the Gartners’ hype cycle 2014, the emerging Internet of Things (IoT) has just reached the top of public awareness and expectations. However, looking beyond its use as a buzzword and the high expectations, there is a clear technological trend that will affect the amount and type of information that is available in Risk and Disaster Management. The seamless interconnection of devices to the Internet, being sensors of all types ranging from in-situ measurement devices, sensors on smart phones up to hyper-spectral cameras mounted on satellites, offers an enormous potential for the improvement in recognizing and assessing risks, for the targeted launch of preventive measures such as improved quality, preciseness and personalization of early warnings. The same is true for decision support in disaster management. However, to exploit this potential, there is an urgent need to improve interoperability.

This paper argues for an open, standardized approach of sensor-based global information management based upon international standards. It provides an overview about the relevant initiatives (e.g. GEOSS, European Research Cluster on the Internet of Things IERC) and standardization bodies (e.g. ISO, OGC) and their architectural approaches for the IoT. Furthermore, it presents highlights and results of relevant projects, e.g. EO2HEAVEN in the domains of environment and health, TRIDEC for better decision support in tsunami early warning systems, and OpenIoT for an open source IoT software platform. The paper concludes with an assessment of the current user requirements and technological trends as well as a discussion of the next steps to be taken in order to exploit the IoT potential for the benefit of risk and disaster management improvement, however, also having in mind cyber security concerns.

Keywords – Internet of Things, standards, early warning, sensors, Open IoT, disaster and risk management

1. The Emerging Internet of Things

“Your phone as quake detector” – this headline on the cover page of an ACM journal of July 2014 and the related article (Faulkner, Matthew et al (2014) boils the Internet of Things down to its essence. Sensor-equipped consumer devices coupled to the Internet, combined with professional seismic measurement devices and other observation sensors paved the way towards community sense and response (CSR) systems with unprecedented scale and detail. Wächter and Uslander (2014) described the significant role of Information and Communication Technology (ICT) for the development of warning systems for geological disasters. As illustrated in Fig. 1, they map functions and characteristics of tsunami warning systems (TWS) to computing and communication capabilities of underlying ICT infrastructures. The increasing use of the Internet in the last decades already enabled the transition from far-field TWS to near-field TWS with reaction times of minutes instead of hours. While the upstream from sensor systems (see Fig. 1) benefits from the integration of physical and virtual seismic sensor networks with earth observations of sea levels, being in-situ or remotely from space, the downstream to target groups makes heavy use of Internet-based services such as electronic mail, Web portals in addition to TV and radio casting.

We have now entered the era of ubiquitous computing relying upon the ubiquitous availability of Internet access, services and computing power as documented in figure 2.

This emerging Internet of Things (IoT) is more than a buzzword. Although having recently reached the peak of public awareness and expectations in 2014 and, hence, just entering the phase of disillusion (see Fig. 3), there is a clear longstanding technological trend that will affect the amount and type of information that is available in Disaster and Risk Management. The seamless interconnection
of devices to the Internet, being sensors of all types ranging from in-situ measurement devices, sensors on smartphones up to hyper-spectral cameras mounted on satellites, offers an enormous potential for the improvement in recognizing and assessing risks, for the targeted launch of preventive measures e.g. improved quality, preciseness and personalization of early warnings. The same is true for the decision support in disaster management.

Sensors of various types are indispensable tools in order to feed early warning systems with data about environmental phenomena and the features of interest that are relevant to assess given geo-hazards. Environmental sensing is getting ubiquitous as sensing capabilities are increasingly embedded in various types of objects, ranging from mobile phones, objects of daily use up to dedicated sensor platforms such as buoys or unmanned aircraft vehicles. Things are getting smart in the sense that sophisticated data processing and communication capabilities will be directly embedded into the sensors. These capabilities may be exploited in two ways: firstly, sensors with wireless communication and self-description capabilities may connect on local level with other sensors to form ad-hoc sensor networks. Secondly, sensor tasking may be used to request the execution of a “monitoring task” on the sensor level with configurable notification policies towards interested consumers, e.g. notification only when thresholds have been exceeded. CSR systems have to be integrated into systems-of-systems, not dedicated to a single region or task, but acting as service and information providers to other systems. However, to exploit this potential, there is an urgent need to improve interoperability.

2. Sensor-Based Global Information Management

The interoperability between components in one CSR as well as the interaction between different CSR in a systems-of-systems environment is determined by the degree of the standardization of interfaces, data exchange formats and protocols. CRS shall enable an efficient and flexible exchange of information as well as the remote call and eventually reuse of their embedded functional components across system boundaries. Thus, there must be an

<table>
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<tr>
<th>Phase / Era</th>
<th>I - Data processing</th>
<th>II - Microcomputer</th>
<th>III - Internet</th>
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<tr>
<td>Architecture</td>
<td>Limited application of computers</td>
<td>far-field TVS</td>
<td>near-field TVS</td>
<td>networks of TVS, system-of-systems</td>
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<td>Upstream Sensor Systems</td>
<td>Analogue registration, first digital sensor recording</td>
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<td>Decision Support</td>
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<td>Downstream Dissemination</td>
<td>SMS, radio broadcasting</td>
<td>FAX, telephone, TV broadcasting</td>
<td>mail, web portals, TV narrow casting</td>
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</tr>
<tr>
<td>ICT</td>
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<tr>
<td>Communication</td>
<td>Morse telegraphy, Telex, teletype telephones</td>
<td>Proprietary LAN protocols, video with limited bandwidths</td>
<td>Internet protocols, broadcast AM/FM, satellite links</td>
<td>Global IT-standards, GIS/RS, WIS, Open Geospatial Consortium, mobile networks, Future Internet</td>
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<tr>
<td>Standards</td>
<td>Programming languages</td>
<td>Proprietary data formats, special protocols e.g. S/DX</td>
<td>Internet protocols, broadcast AM/FM, satellite links</td>
<td>Global IT-standards, GIS/RS, WIS, Open Geospatial Consortium, mobile networks, Future Internet</td>
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Figure 1: Upstream and Downstream in Tsunami Warning Systems (Wächter and Usländer, 2014)
agreement on information models and service interfaces - in the best case based on international standards.

An essential element of such an IoT support is an “open geospatial service platform” (see Fig. 4) which provides seamless access to resources (sensor data, information, services and applications) across organizational, technical, cultural and political borders. “Open” hereby means that service specifications are published and made freely available to interested vendors and users with a view to widespread adoption. Furthermore, an open service platform makes use of existing standards (e.g. International Standardization Organization ISO and the Open Geospatial Consortium OGC) where appropriate and otherwise contributes to the evolution of relevant new standards. There are various international initiatives aiming at mapping such service platforms to the Internet of Things. Two of them shall be mentioned here: GEOSS and the European Research Cluster on the Internet of Things IERC.

2.1. GEOSS

GEOSS is an intergovernmental program, coordinated by the Group on Earth Observations (GEO). GEOSS is a 10-year global program that aims to provide to the broad environmental science and user community decision-support tools and support for the monitoring, analysis and modelling of various environmental phenomena through the integration of existing and future sources of EO information. The GEOSS work plan focuses on nine so-called societal benefit areas, among which are environmental topics but also the topic “reduction and prevention of disasters” (see Fig. 5). Interoperability arrangements ensure that the heterogeneous systems within GEOSS can communicate and operate. Data, information and service providers within GEOSS are guided by technical specifications for collecting, processing, storing and disseminating shared data, metadata and products. Interoperability arrangements in GEOSS are based on open standards, with a preference for formal international standards (Usländer, Coene and Marchetti, 2012).

2.2. European Research Cluster on the Internet of Things IERC

The aim of European Research Cluster on the Internet of Things (IERC) is to address the large potential for IoT-based capabilities in Europe and to coordinate the convergence of ongoing activities. The IERC will facilitate the knowledge sharing at the global level and will encourage and exchange best practice and new business mod-
els that are emerging in different parts of the world. In this way, measures accompanying research and innovation efforts are considered to assess the impact of the Internet of Things at global and industrial level, as well as at the organizational level (see http://www.internet-of-things-research.eu). Two IERC-related research projects are explicitly mentioned: firstly, the IoT-A (IoT Architecture) project, that proposed an architectural reference model together with the definition of an initial set of key building blocks. Secondly, the OpenIoT project aiming at delivering an open source blueprint for large scale self-organizing cloud environments for IoT applications (see below).

3. Research Projects

Various research projects in the domain of Disaster and Risk Management rely upon such open geospatial services and IoT paradigms and validate them in real-world scenarios. Here, we present three European projects of the 7th Framework Program: EO2HEAVEN, TRIDEC and OpenIoT.

3.1. EO2HEAVEN

The objective of EO2HEAVEN (Earth Observation and Environmental Modelling for the Mitigation of Health Risks, http://www.eo2heaven.org) is to contribute to a better understanding of the complex relationships between environmental changes and their impact on human health. The main result of the project is the design and development of a Geographical Information System based upon an open and standards-based spatial information infrastructure envisaged as a helpful tool for research of human exposure and early detection of potential health endangerments. For this reason, the project developed models to relate environmental data with exposure and health data. EO2HEAVEN examined different Earth Observation products, especially those resources available free of charge for the research community. In order to study the impact of human activity on health the project took advantage of the availability of this long time-series data combined with its great potential to detect and map environmental variables. For this purpose EO2HEAVEN also worked on the integration of remotely sensed and in-situ environmental measurements. The SII therefore facilitates the set-up of observation and decision support systems that rely upon the correlation and fusion of earth observation, in-situ and human health data.

Throughout the life span of the project the stakeholder requirements from three different case studies (see Fig. 6) have been assessed and the technical solutions proposed by EO2HEAVEN were evaluated through an iterative process, thus ensuring that the solutions can be applied on a wider scale. A first case study was developed in Dresden (Germany) addressing the environment effects on allergies and cardiovascular diseases. A second case study was located in south Durban industrial basin (South Africa) and also dealt with the pollution and respiratory diseases. The third case study was conducted in Uganda and investigated the impact of climatic variables on the outbreak of cholera.

![Figure 6: EO2HEAVEN Approach and its Case Studies](image)

3.2. TRIDEC

TRIDEC (Collaborative, Complex and Critical Decision-Support in Evolving Crises, http://www.tridec-online.eu) focuses on the use of new technologies to enable intelligent information management in real time.

The biggest challenge is constructing a communication infrastructure with interoperable services that makes it possible to efficiently find, merge, evaluate, and manage huge amounts of information and data that are growing dynamically, both in terms of number and size. Groups of decision makers located in different places are then able to cooperate in an environment that supports the decision-making process. This allows them to respond to looming natural disasters such as tsunamis at an early stage, and enables them to carry out successfully all phases of complex and critical operations such as deep drilling. The TRIDEC exhibit shows the latest developments in the area of intelligent data processing for crisis management systems. One example of this is an early warning system for maritime disasters resulting from leaks in deep water drilling. Such leaks are common in oil and gas drilling operations, and can potentially cause serious environmental damage. Another example is the tsunami early warning system currently being developed for the Mediterranean and northeast Atlantic. The ways in which these systems work will be shown in live demonstrations and films, and the sensors are on display at the trade show booth. Visitors at the booth will be offered the unique opportunity to make a globe oscillate and to assess the results in a seismological correct manner.

3.3. OpenIoT

OpenIoT (Open Source cloud solution for the Internet of Things, http://openiot.eu/) creates an open source middleware for getting information from sensor clouds, without having to worry about what exact sensors are used. OpenIoT explores efficient ways to use and manage cloud environments for IoT “entities” and resources (such as sensors, actuators and smart devices) and offer-
ing utility-based (i.e. pay-as-you-go) IoT services. OpenIoT will provide instantiations of cloud-based and utility-based sensing services enabling the concept of “Sensing-as-a-Service”, via an adaptive middleware framework for deploying and providing services in cloud environments.

The OpenIoT middleware architecture comprises three main levels: the GSN-X to access and gather sensor-based information from various sources, the LSM (Linked Sensor Middleware) that processes sensor data and answers user and service requests based upon semantic technologies, and the tool level that aims at providing a user-friendly and flexible tool environment to bridge the gap to the end-user. As the OpenIoT platform is available by means of an open source license at GitHub (https://github.com/OpenIoTOrg/openiot), it may be easily used and tailored for Disaster and Risk Management projects around the world. The next step will be to enhance the platform by domain-specific features for various smart ecosystems, such as Smart City, Smart Grids or Smart Agriculture.

4. Added Value for the Post 2015 Framework for Disaster Risk Reduction

The Hyogo Framework for Action 2005–2015 expresses the strong need to develop and strengthen early warning systems that are people-centered as one of the priorities for action. As shown by the example of tsunami warning systems in Wächter and Usländer (2014), this goal has been widely addressed using state-of-the art Internet technology. Now the next step is to exploit the potential of the emerging Internet of Things that puts the capabilities of Internet-connected objects together with the capabilities of humans into the foreground.

5. Recommendations

Having in mind the ongoing international initiatives as described in section 2 as well as the experience made by prototypical IoT applications in various research projects as explained in section 3, the following recommendations are derived.

5.1. Research

Research activities shall be continued on the design, development and provision of an open, scalable, dependable and secure information and communication (ICT) infrastructure aiming at supporting all phases of disaster risk management. Such an ICT infrastructure should encompass sensors and actuators of all kinds, data processing and data mining capabilities as a service, tailored and user role-specific multi-lingual information display, flexible and easy-to-use decision support and as well as capabilities to downstream information to all those concerned in a reliable fashion. Furthermore, it should

- rely upon open ICT standards, e.g., according to standards of ISO and/or the Open Geospatial Consortium (OGC)
- have a defined service level,
- have tailored applications with easy-to-use, intuitive user interfaces,
- work also (probably in limited fashion) in crisis situations,
- be self-configurable, self-repairing and self-adapting,
- be open to all stakeholders,
- obey data privacy and security regulations, e.g., according to the OECD fair information principles.

5.2. Education and Training

People shall be educated and trained how to use their mobile devices to assess risks, support early warning of disasters, behave in crisis situations and support efficient damage assessment.

5.3. Implementation and Training

The above mentioned ICT infrastructure shall be implemented step-by-step as a global system-of-national systems in a coordinated, multi-organizational (UN, WHO, WMO,...) endeavor as a profiled interoperable application of the Internet of Things and Services. Civil-military cooperation shall be made possible in order to enable military forces to help in crisis situations in an efficient and coordinated manner. The use of such an infrastructure shall be trained on a regular basis, also taking into account partial failure of the infrastructure in time and space.

5.4. Policy Dialogue

The design and implementation of an interoperable ICT infrastructure for disaster risk reduction requires a coordinated and harmonized approach of various global, regional and local stakeholders. Beyond the technical obstacles of syntactical and semantic interoperability of risk and crisis management applications, there is a need for agreement on policy level – the common conviction and willingness to set-up and maintain such an infrastructure despite of different interests and cultures. Only a continuous policy dialogue can achieve this, encompassing both civil and military organizations.

6. Conclusions

The examples show that there is a huge potential in applying the next step of the Internet – the Internet of Things – to challenges of Disaster and Risk Management. Community sensing and response (CSR) will be the next functional and architectural level of such systems, assuming that the problem of interoperability will be solved, and corresponding standards will be agreed upon. The OpenIoT open source platform (http://openiot.eu) may be used as both an experimental and operational platform.

Furthermore, the architecture of risk and crisis management applications is a design artefact that results from a dialogue between experts in thematic domains such as flooding, diseases or tsunamis, and information technology experts (Usländer et al., 2010). As in traditional soft-
ware engineering it is a dialogue between those who express their requirements in terms of which information and functions they need, with which level of quality and dependability, and those who know about the capabilities and constraints of software systems and architectural styles. Today, service-oriented architecture is used more and more for the design of such applications. Hence, the architecture should reuse as much as possible standard services and existing capabilities of IoT infrastructures to get a cost-effective solution.

However, a powerful ICT infrastructure such as the Internet of Things can only solve part of the problem of early warning, or in general disaster and risk management. The human factor still remains important, too. Coppola (2011) stresses that "Early warning mechanisms must include public education, accurate risk perception, a communications system to relay the message, and an emergency management system to adequately coordinate the response". Public safety from environmental dangers is one of the five key elements in Environmental Security that has to be considered “within and across national borders” (Landholm, ed.), 1998). According to Coppola (2011) there is a need for further action and the inclusion, training and education of end-users of various disciplines (e.g., geo-scientists, citizens, emergency organizations, environmental and security agencies) including their cultural context and risk perception in order to really exploit the potential of early warning systems and their underlying ICT capabilities.

References


Citation