INCORPOARATION OF GEOSENSOR NETWORKS INTO INTERNET OF THINGS FOR ENVIRONMENTAL MONITORING

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ABSTRACT:

Thanks to the recent advances of miniaturization and the falling costs for sensors and also communication technologies, Internet specially, the number of internet-connected things growth tremendously. Moreover, geosensors with capability of generating high spatial and temporal resolution data, measuring a vast diversity of environmental data and automated operations provide powerful abilities to environmental monitoring tasks. Geosensor nodes are intuitively heterogeneous in terms of the hardware capabilities and communication protocols to take part in the Internet of Things scenarios. Therefore, ensuring interoperability is an important step. With this respect, the focus of this paper is particularly on incorporation of geosensor networks into Internet of things through an architecture for monitoring real-time environmental data with use of OGC Sensor Web Enablement standards. This approach and its applicability is discussed in the context of an air pollution monitoring scenario.

1. INTRODUCTION

The most critical information sources of evaluating, preventing, and reducing harmful effects of environment on human health and other species are environmental data. Effective environmental monitoring is essential to move from reactive to proactive manner in decision making. The environment is heterogeneous and changes dynamically in space and time. So, its monitoring requires a high temporal and spatial resolution.

During the last decade, phenomenal growth in Internet and in situ sensing technologies have influenced the field of geosciences significantly. Tremendous development in manufacture of battery-powered low-cost miniaturized sensors and in wireless digital communication have provided significant novel capabilities for several observation and management tasks (Duckham, 2012).

GeoSensor Networks (GSNs) are "specialized applications of Wireless Sensor Networks (WSNs) technology in geographic space that detect, monitor, and track environmental phenomena and processes" (Nittel, 2009). Opportunities provided by key features of GSNs including capability of generating high spatial and temporal resolution data, measuring a vast diversity of environmental data and automated operations, can improve the quality timeliness of environmental monitoring (Duckham, 2012). Considering these features, GSNs have been an important part of technologies involving sensor networks, and also many emerging concepts, in particular Internet of Things (IoT). Internet of things is "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols" (Yang, Yang, & Plotnick, 2013).

Moreover, growing development technology in the fields of communications, capturing and computing data has provided new capabilities in many applications such as environmental monitoring tasks. Geosensor nodes are intuitively heterogeneous in terms of the hardware capabilities and communication protocols to take part in IoT scenarios. Therefore, ensuring interoperability is an important step to integrate various devices together. Additionally, environmental problems have a global nature. Efficient understanding and monitoring of environment requires integration data from heterogeneous data sources from several organizations and agencies all around the world. In other words, an open, scalable, flexible and sustainable infrastructure is needed. Considering this challenges, Open Geospatial Consortium (OGC) has built a framework of open standards for exploiting Web-connected sensors and sensor systems of all types. With this respect the main purpose of this study is to discuss that how the geosensor networks incorporate into the Internet of Things in order to improve environmental monitoring tasks.

The remainder of this paper is organized as follows: an overview of the concept of IoT, foundational technologies for it will be presented in Section 2. Section 3 will explore layer architecture of IoT for monitoring real-time environmental data with use of SWE. Its applicability is discussed in the context of an air pollution monitoring scenario in section 4, and Section 5 concludes this paper.

2. BACKGROUND

2.1 Internet of Things

The simplest concept of Internet of Things rise from the *Internet* as a storage and communication infrastructure, *Things* and *a connection in between* (Uckelmann, Harrison, & Michahelles, 2011). Internet of Things could be defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. In this context, *Things* refers to real world object, human beings, virtual data, intelligent software agents or any other real or

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virtual participating actors (Yang et al., 2013). Haller (Haller, 2010) defines *Things* as "entities of interest" such as rooms, buildings and things in the environment like rivers and glaciers.

There is no a clear definition of the term "Internet of Things" in the scientific and relevant industrial community thus far. One of its definitions is " Internet of Things links uniquely identifiable things to their virtual representations in the Internet containing or linking to additional information on their identity, status, location or any other business, social or privately relevant information" Ubiquitous/pervasive computing, communication technology, embedded device, Internet of People, Internet protocol are some example fields of research that overlap partially with Internet of things (Uckelmann et al., 2011).

Because of being Internet-based and accessing wide area network, the IoT is not restricted to any physical boundary. Additionally, its real-time characteristic provides not only an effective solution for global problems such as environmental monitoring, but also a framework for international cooperation e. g. Global Earth Observation System of Systems (GEOSS) and form smart Earth (Li, Yao, Shao, & Wang, 2014).

Implementation of the IoT paradigm into the real world requires several technologies on both data acquisition and networking levels. Most used technologies on data acquisition level are sensor networks, radio frequency identification (RFID), and two-dimensional code equipment. Bluetooth, wireless local area network (WLAN), and the Internet are solutions for networking issues. Sensor networks have a big role in most of IoT applications, but heterogeneity in each networks in terms of the hardware capabilities and communication protocols entails using standards e. g. IEEE 802.15.4 and 6LowPAN.(Tan & Koo, 2014). In this context, OGC has developed Sensor Web Enablement initiative (SWE) standards which provide extensive support for GSNs usage in IoT implementations XML-based encodings and service interfaces for discovering, accessing and exchanging any kind of sensor data (Tamayo, Granell, & Huerta, 2012).

2.2 Sensor Web Enablement

Sensor Web Enablement (SWE) initiative is a suite of standards which make interoperable usage of sensor resources operational in a standardized way. This infrastructure enables discovery, access, tasking, as well as eventing and alerting within the Sensor Web. Therefore, Sensor Web acts as an infrastructure for sensor resources as same as WWW for general information sources which allowing users to easily share their information resources in a well-defined way (Bröring et al., 2011). So, SWE can be considered as an effective solution to the IoT scenarios involving geosensor networks.

The SWE interface model is composed of standards that specify the interfaces of the different Sensor web services. These are Sensor Observation Service (SOS), Sensor Event Service (SES), Sensor Planning Service (SPS), and Web Notification Service (WNS). Observations & Measurements (O&M), Sensor Model Language (SensorML), Transducer Markup Language (TML) are SWE information model which define data models primarily for the encoding of sensor observations and sensor metadata. For more details, the reader may refer to (Bröring et al., 2011).

3. IOT ARCHITECTURE

The remarkable increase in the numbers of Internet-connected devices being deployed implies that eventually trillions of things will be on the Internet. Therefore, there is a crucial need for an adequate architecture that permits easy connectivity, control, communications, and useful applications (Stankovic, 2014). The basic IoT model is a 3-layer architecture consisting of the Application, Network, and Perception Layers (Figure 1). At perception layer (also called the sensing layer or the edge technology layer) the information is obtained from the physical world. So, it can be regarded as the hardware or physical layer. The data is transferred in the network layer. In fact, this layer is responsible for connecting the perception layer and the application layer. Finally, the application layer provides services or applications to integrate or analyse the information received from the other two layers. There is another layers architecture for IoT which adds two additional layers to three-layer architecture as illustrated in Figure 1. In five-layer architecture, the access gateway layer together with network layer, manage the communications in the IoT environment and transmit messages between the objects and systems. The middleware layer is usually used to provide a more flexible association interface between the hardware and applications (Tsai, Lai, & Vasilakos, 2014).

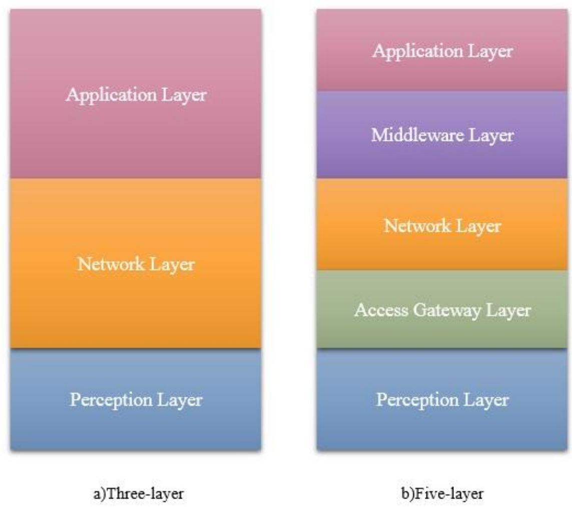

Figure 1. The IoT architecture

Bröring et al. (2011), described a sensor web layer stack that identified four classes on their positions within this stack (Figure 2). These classes' borders are drawn fuzzy, because their functionalities might overlap and some middleware approaches offer functionalities belonging to multiple classes.

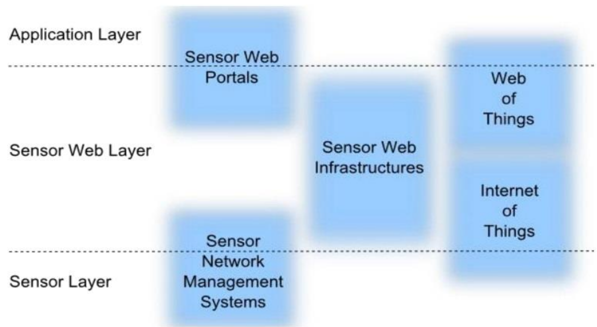

Figure 2. Sensor web layer stack and IoT position in it (Bröring et al., 2011)

Sensor network management systems focus on wireless sensor networks (WSNs) specially, and research areas such as routing protocols, optimization of in-network communication, and the localization of sensors within a network. This class is in the

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service of sensor network management functionality. Sensor web infrastructures provide access to sensor resources on the web and make sensors available from application layer by building up sensor web infrastructures. In this class, some relevant approaches use SWE standards to make interoperable access to sensors. Sensor web portals make sensor resources accessible on the application level and make it feasible for users to upload and share sensor data with several formats like numeric data (e.g., temperature measurements), audio and video data (e.g., Web cameras). Web of things is a growth of the Internet of Things. It leverages existing Web protocols as a common language for real objects to interact with each other.

4. ENIRONMENTAL MONITORING APPLICATION

There are many applications in which geosensor networks incorporate into IoT, and perhaps many that are not yet imagined. Here a small application subset is examined for environmental monitoring, in particular air pollutions.

Because the geosensors are equipped with various environmental sensing capabilities, e. g. temperature, pressure, humidity, wind speed, wind direction as well as hazardous pollutants such as COx, NOx, PMx, SO2, geosensor networks are well-suited to environmental monitoring. Geosensor networks with capability of absolute or relative positioning as well as gathering real-time and precise data with high spatial and temporal resolution, have a great potential to provide geospatial information for end users.

For example, sensor nodes can be scattered across an environment and constantly collect data about air pollutant gases and other relevant information to determine cold and hotspots and predict their trends for the next hours. This information opens up new ability for decision makers to have a safe interaction with the environment. In case of air pollution, they can keep air pollutant concentrations at a healthy level which is suitable for human health and also the environment. Urban transportation and industrial activity are the main cause of the air pollution in metropolitans and big cities. Besides, some natural conditions such as topography, inversion temperature, humidity and wind intensify air pollutant concentrations. So, providing appropriate information of this cases at right time, right place and right precision plays an important role to control air pollution and also environmental monitoring.

Individual nodes would lead to greater environmental monitoring opportunities. We can detect various environmental events by using this kind of widespread continuous data acquisition. By precise analyses, gathered data would help predict (storms, earthquakes) and alert (unexpected accidents). Integration of a network with Internet of things, would lead an access from anywhere in the world to this environmental data. So, remote access to global data may lead to greater and real-time weather monitoring applications. For example, modern cars can monitor air and road temperature using built-in sensors. Nowadays, mobile phones have GPS sensor, accelerometer and compass that can record audio and video from environment by in-built microphone and video cameras. Miniaturized pressure sensors, dual-microphone solutions for ambient noise cancellation, and more specialised air quality sensors are new developments in mobile phones.

Low cost of these devices makes them suitable for environmental monitoring. In comparison to art environmental monitoring systems, they have not high quality at measuring and can just play a complement role for them, especially at providing new spatially localised environmental observations.

Real-time or near real-time access to data generated by any kind of geosensor networks such as air quality monitoring stations, smartphones, traffic lights, cameras, biosensors or even satellite images via Internet and integrated with GIS prepares a system of systems for control and monitor environment, urban transportation, health and industrial activities. This system transit human interactions with his surroundings into a smart phase. It also can be considered for solving global issues as GEOSS.

5. CONCLUSION

This paper gives an overview on the Internet of Things concept as well as its common architecture. The IoT requires devices to obtain technology from the physical world and turn them into data. Sensors are general devices that accomplish this mission. IoT devices are intuitively heterogeneous in terms of the hardware capabilities and communication protocols. Therefore, ensuring interoperability is an important step to integrate various devices together. To bridge this gap, OGC developes Sensor Web Enablement (SWE) initiative which is a framework of open standards enabling interoperable usage of Web-connected sensor resources by enabling their discovery, access, tasking, as well as eventing and alerting .The ability of things to communicate opens up a wide variety of applications. In this study, application of IoT for environmental monitoring, in particular air pollution, are proposed.

REFERENCES

Bröring, A., Echterhoff, J., Jirka, S., Simonis, I., Everding, T., Stasch, C., . . . Lemmens, R. (2011). New generation sensor web enablement. *Sensors, 11*(3), 2652-2699.

Duckham, M. (2012). *Decentralized spatial computing: foundations of geosensor networks*: Springer Science & Business Media.

Haller, S. (2010). The things in the internet of things. *Poster at the (IoT 2010). Tokyo, Japan, November, 5*, 26.

Li, D., Yao, Y., Shao, Z., & Wang, L. (2014). From digital earth to smart earth. *Chinese Science Bulletin, 59*(8), 722-733.

Nittel, S. (2009). A survey of geosensor networks: Advances in dynamic environmental monitoring. *Sensors, 9*(7), 5664-5678.

Stankovic, J. (2014). Research directions for the internet of things. *Internet of Things Journal, IEEE, 1*(1), 3-9.

Tamayo, A., Granell, C., & Huerta, J. (2012). Using SWE standards for ubiquitous environmental sensing: a performance analysis. *Sensors, 12*(9), 12026-12051.

Tan, J., & Koo, S. G. (2014). *A Survey of Technologies in Internet of Things.* Paper presented at the Distributed Computing in Sensor Systems (DCOSS), 2014 IEEE International Conference on.

Tsai, C.-W., Lai, C.-F., & Vasilakos, A. V. (2014). Future Internet of Things: open issues and challenges. *Wireless Networks, 20*(8), 2201-2217.

Uckelmann, D., Harrison, M., & Michahelles, F. (2011). An architectural approach towards the future internet of things *Architecting the internet of things* (pp. 1-24): Springer.

Yang, L., Yang, S.-H., & Plotnick, L. (2013). How the internet of things technology enhances emergency response operations. *Technological Forecasting and Social Change, 80*(9), 1854-1867.