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ENVIRONMENTAL MONITORING SYSTEMS USING INTERNET OF THINGS – STANDARDS AND PROTOCOLS

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ABSTRACT: The Internet of Things (IoT) consist of smart connected devices in homes, businesses and cities that has the ability communicate over an Internet without human-to-human or human-to-computer involvement. IoT communication standards and platforms has a high potential for a wide range of applications in different domains. Collecting the data by a large number of sensors, is a challenging task because of many open issues. Effective collection and distribution are crucial for classes of smart city services such as environmental monitoring, public security, transportation, and other. Unfortunately there are many connection gaps between the raw sensor data and the information context that are needed by high-level services and applications. Utilization of some Semantic Web standards provide better integration of sensor with applications, but still is far from being solved. Therefore, we have analyzed selected standards, protocols, and architectures and have suggested some enhancements into "common semantics" model.

KEY WORDS: IoT, Internet of Things, environmental monitoring, semantic IoT, smart city

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Introduction

Internet of Things is a platform where every day devices surrounding us become smarter, every day collecting the data and processing becomes intelligent, and every day communication becomes more useful for people. The Internet of Things (IoT) has been defined in Recommendation ITU-T Y.2060 (ITU-T Study, 2015) as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies". While the Internet of Things is still evolving, its effects have already stared in making incredible changes in many areas as a universal solution media for providing services in completely different ways. Gartner (Rivera, Rob, 2014) reported that 25 billion devices will be connected to the internet by 2020 and those connections will facilitate the used data to analyze, preplan, manage, and make intelligent decisions autonomously. The US National Intelligence Council (NIC) has embarked IoT as one of the six ''Disruptive Civil Technologies" (Council National Intelligence, 2008). In this context, we can see that service several sectors, such as: smart city, e-health, e-governance, transportation, e-education, retail, agriculture, process automation, industrial manufacturing, logistics and business management etc., are already getting benefited from various forms of IoT paradigm and technology.

First wave of IoT systems in smart city domain emphasized on connecting sensor using lightweight protocols such as CoAP and XMPP (old fashioned publish/subscribe communication model). The Smart-Object devices with domain specific smart automatic rules are rapidly replacing first wave of IoT devices (Kortuem et al., 2010). Although these devices do not utilize semantic technologies (Park et al., 2014), they provide higher-level of sensor-to-application communication than just plain transfer of raw sensor data.

Sensor data representation formats used in a sensor networks is various, and most of them cannot understand the value's meaning in other systems. Therefore, values and information from the systems must be prepared, shared and provided additional metadata information for other applications. The second challenge is develop knowledge discovery techniques and services for big smart city data storing, transfer and provide useful analytics.

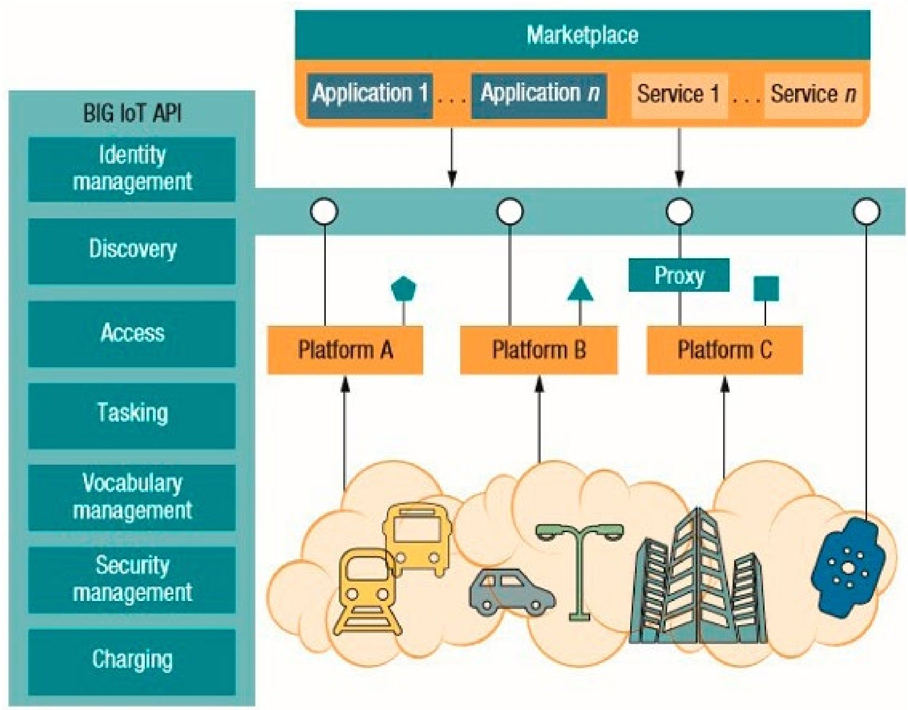

Figure 1. A model of a basic Internet of Things (IoT) ecosystem architecture

Source: (Bröring, et al. 2017), https://www.infoq.com/articles/enabling-iot-platform-interoperability [15-10-2017].

Most of the current IoT services (figure 1) require IoT applications (BIG IoT API) to have knowledge of IoT middleware (communication software) and sensors or sensor networks for accessing IoT resources. Heterogeneous IoT middleware are not easy to be accessed by different applications since each IoT gateways has no open and standardized Application Programming Interface (APIs). Various organizations such as the OpenIoT Alliance, AllSeen Alliance, and IPSO Alliance are working on standardization of „Internet of Everything" communication protocols to provide interoperability between various solutions.

Although the utilization of many standards provide better integration of semantic knowledge with ICT (Information and Communications Technology) systems, the interoperability challenges on IoT is not solved and more advanced semantic IoT architecture is required to provide higher level of interoperability between connected IoT systems.

An overview of literature

The Internet of Things has evolved very fast in recent years and sometimes the term IoT refers, erroneously, only to device and the way connected devices called „things". However there are more than just devices, even for devices with advanced systems and high computing power such as smartphones.

The main characteristics and functions of the layers (IoT Stack) rely on the capacities of an IoT system to provide functions, protocols and operations across those layers (Serrano, Soldatos 2015). From the physical level protocols (device) where raw data are collected, to a layer with a well-defined APIs (protocols) and protocol-driven information system that enabling services at a business level. The IoT Stack for service delivery models and interoperability for the Internet of Things is shown in figure 2.

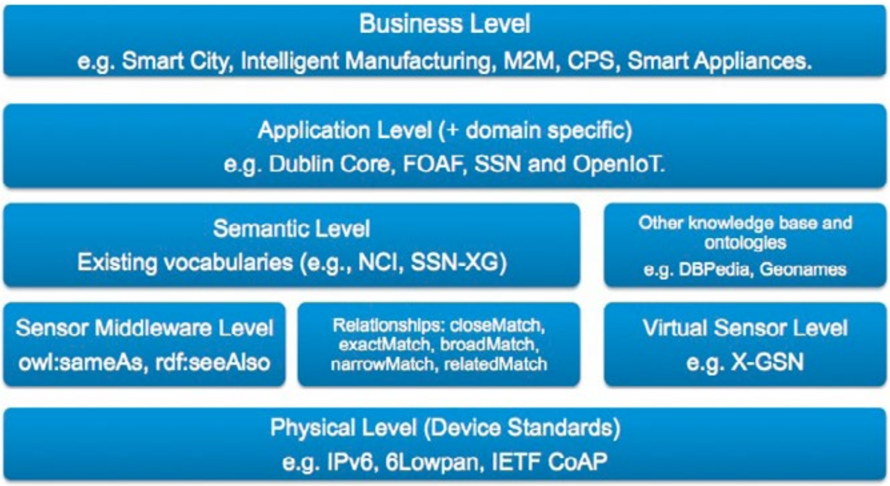

Figure 2. IoT stack for service delivery and interoperability: protocols and standards

Source: (Serrano, Soldatos 2015), https://iot.ieee.org/conferences-events/wf-iot-2014-videos/26-newsletter/september-2015.html [15-10-2017].

Functional design and implementation of a complete Wireless Sensor Network (WSN) platform can be used for many purposes, e.g. monitoring of long-term environmental changing based IoT applications (Lazarescu, 2013).

The OpenIoT Architecture

The integration of multiple IoT systems demand to have interoperability platforms able to communicate between all the IoT solutions. One of them is OpenIoT. OpenIoT was incepted in 2010 with the main goal of converging sensor data systems using cloud computing infrastructures with IoT. OpenIoT focuses on the IoT Data Stream management (Serrano et al., 2013) shown in figure 3. OpenIoT is a design concept that implemented sensor platform of the IoT Stack.

The main areas of features of OpenIoT address some needs in principle to:

- guarantee semantic interoperability of various IoT services and sensor data streams;
- maintain the reference model implementation for semantically interoperable IoT;
- enable the delivery of services utility-based – as Sensing as-a-Service.

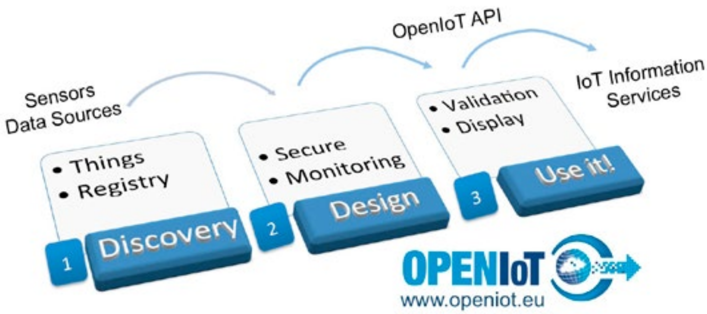

Figure 3. The OpenIoT platform implementing the IoT Stack

Source: (Serrano, Soldatos, 2015), https://iot.ieee.org/conferences-events/wf-iot-2014-videos/26-newsletter/september-2015.html [15-10-2017].

The elements described in the platform „OpenIoT Stack" (Serrano, Soldatos, 2015) are part of a process with relations and interactions for the IoT landscape. The OpenIoT stack (Serrano et al., 2015) has been designed in the context of IoT systems and defines and establishes the relations between the operations and the role that sensors, devices and services can play in the whole IoT systems.

Semantic IoT

Interoperability between messaging protocol in modern IoT applications, multiple application level protocols such as CoAP (Constrained Application Protocol), XMPP (Extensible Messaging and Presence Protocol) and MQTT (Message Queue Telemetry Transport) are proposed by various organizations to become the de facto standards to provide communication interoperability. However, we need special layer, located between physical level sensors and cloud-based services that we call a gateway. A smart IoT gateway framework (additional layer based on standards and protocols) is a software solution that bridges the semantic gaps between the raw sensor data and the information context that is needed by top-level services and applications (Desai, Sheth, Anantharam, 2015).

One of the major initiatives, which utilizing Semantic Web for IoT architecture, includes the OpenIoT project, funded by Europe Unions framework program. The OpenIoT focuses on developing open source software platform for IoT interoperability using linked sensor data, protocols and services (OpenIoT Consortium, 2012). Many providers of IoT hardware and APIs design their own semantic IoT service platform, but most of them provide building blocks that are very similar, e.g. knowledge base, resources management, ontology, semantics process, analytics, broker. On the figure 4 we see sample one of the them.

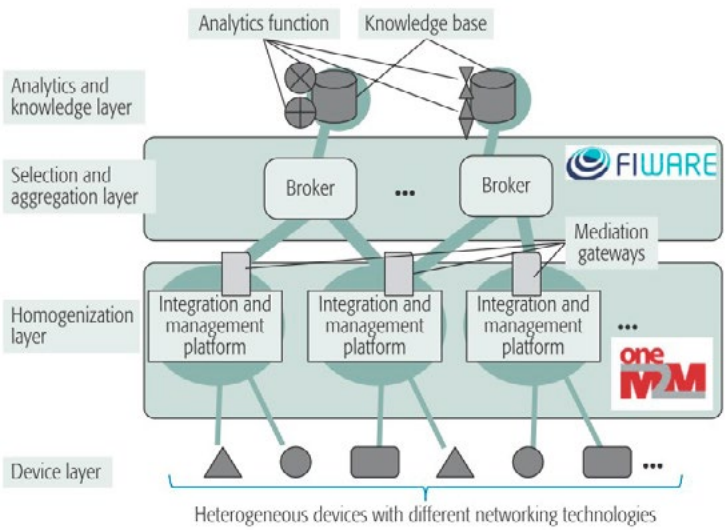

Figure 4. Functional Architecture of Semantic IoT Service Platform. Architecture of IoT Process Automation and its 3 GEs (Generic Enablers)

Source: (FIWARE 2014).

Next Generation Network

The Next Generation Network (NGN) is a packet-based (send data in separate, small blocks) network able to provide telecommunication services and to make use of high Quality-of-Service multiple broadband technologies. In NGN concept, services are independent from underlying transport-related technologies. Another important element is Wireless Sensor and Actuator Networks. WSANs will be used in a broad set of heterogeneous application scenarios leading to a big variety of deployments with completely different communication infrastructures, protocols, data-rates, latencies, etc. For example, in some cases, SANs could be available through a broadband Internet connection or even satellite, while in others they could be accessible through GRPS connectivity.

Research methods

Semantic subsystem is not enough to create truly "intelligent" services. Such services combine input events (triggers) and real-time IoT information with other data sources from mobile devices and social networks. In order to integrate many various heterogeneous systems, semantic reasoning as well as knowledge processing is needed to correctly link and map different data, as well as to provide semantic searches.

Most interesting research areas in bridging this gap and make services more useful for ordinary mobile phone or smartwatch users. There are many study on designing advanced semantic gateway that makes uses of services available in easy way. For instance, if someone would want to know the current temperature and air humidity of a shopping mall, office building or other public place. The request can be handled by special services, but not probing directly the devices or set of sensors. The conversion from the high level concept of „temperature of a location" to low level of device „data from sensor X" has to be translated in the system level.

To provide services that the knowledge of Internet of Things can be used by high level as a named services, semantic and ontology has been considered as a key technology. And the last thing is geofencing. Geofencing is a critical set of concepts for the IoT. It's the basic technologies to start using the IoT services depends on our location or stop devices from working outside of our secured environments. For IoT systems, an ontology can provide high-level abstraction for device metadata to enable semantic-oriented presentation of the environment and to provide interoperability of the sensors, systems and applications.

Results of the research

Syntactic and semantic interoperability have already been widely addressed in literature, but areas of environmental monitoring systems are mentioned as a one of many areas of application. Most of the existing work has focused in ontology design (Wang et al., 2012) (Nambi et al., 2014). The authors present the concept of a Smart Entity and Control Entity that is used for ontology alignment and match-making. This enables automation of deployment of IoT applications in heterogeneous environments.

Work of the authors (Ganzha et al., 2017) aims at the design and implementation of an open framework and associated methodology to provide interoperability among heterogeneous IoT platforms, across a software stack (devices, network, middleware, application services, data and semantics). They focus on the data and semantics layer. Specifically, the role of ontologies and semantic data processing.

The paper (Ruta et al., 2017) proposes a SWoT framework in Wireless Sensor Networks (WSNs) enabling cooperative discovery of sensors and actuators. A extension of the CoAP protocol makes possible to use semantic matchmaking via nonstandard reasoning to better characterize the resource discovery.

Advanced architecture with special gateway was proposed in (Desai, Sheth and Anantharam, 2015). The paper proposes a gateway and Semantic Web enabled IoT architecture to provide interoperability between systems, which utilizes established communication and data standards. The Semantic Gateway as Service (SGS) allows translation between messaging protocols via a multi-protocol proxy architecture.

Interesting cross-sectional analysis we can find in (Kovacs et al., 2016). Paper presents many standards, protocols and techniques as a elements of Global IoT services (GIoTS) that are combining locally available IoT resources with cloud-based services. The authors explain a system architecture for achieving world-wide semantic.

More technical technological approach we have in (Park et al., 2014). The paper focuses on how technologies contributes to improving interoperability between IoT devices, and making easily use of them. The proposed technology platform provides semantic-based IoT services, and semantic interoperability of devices.

Authors (Gyrard, Serrano, 2015) share their vision of Semantic Web of Things applied to smart cities. They highlight main research challenges and propose way to applied the semantic IoT engine to smart cities. The proposed semantic engine is applied to three use cases, existing solutions: Machine-to-

Machine Measurement (M3) framework, FIESTA-IOT EU project and VITAL EU project.

Semantic IoT Standarization

Key standardization efforts that have sought to establish sensor data models for sensors to be accessible and controllable via the Internet (Web Services and HTTP) include:

- OGC Sensor Web Enablement (SWE): The SWE efforts established by the Open Geospatial Consortium include following important specifications: Observation & Measurement (O&M), Sensor Model Language (SensorML) and Sensor Observation Service (SOS) (Botts et al., 2008);
- Semantic Sensor Network (SSN) ontology: The SSN ontology, developed by W3C provides a standard for modelling sensor devices, sensor platforms, knowledge of the environment and observations (Atkinson et al., 2017), (Compton et al., 2012);
- Semantic Sensor Observation Service (SemSOS): The Semantic Web enabled implementation of SOS. SemSOS implementing a semantic reasoning service acting on the knowledge base (Henson et al., 2009). SemSOS is the principal component of Semantic Sensor Web (Sheth, Henson, Sahoo, 2008).

Environmental monitoring

Environment monitoring is key for multiple applications and requires that devices used in acquiring environment data to be scattered over a wide area. Monitoring is quite complex and challenging process, but with recent advances of dedicated protocols, standards and semantic models in many areas there is a good premise for automating almost each activity in monitoring of any system, process, and environment.

Publication (Cocioaba, Tudose, 2017) describe a system which integrates the two networks' main capabilities (Wi-Fi and IEEE 802.15.4 Networks) by monitoring data in a heterogeneous Wireless Sensor Network. Nodes can transmit sensor data over the Internet to other devices, server applications or cloud based solutions, making the whole process of environmental monitoring accessible.

Work of the authors of the paper (Tovarnitchi, 2017) shows the main questions identified while trying to design architecture for an OpenSmartWorld environment monitoring system, e.g. what kind of system should have and what technologies and standards should be used in order to support required functionalities.

Table 1. Research areas of environmental monitoring systems based on ideas of IoT

	Areas of research			
Proposed solution	sensors and devices	sementic/ ontology	gateway layer	Internet/cloud
Cocioaba and Tudose 2017	High	Low	High	High
Tovarnitchi 2017	Low	Low	High	High
Mois, Folea and Sanislav 2017	High	Low	Low	Low
Andrés 2016	High	Low	Medium	Low
Boubrima, Bechkit and Rivano 2017	Low	Medium	Low	Low

Source: author's own work based on publications research.

Authors (Mois, Folea, Sanislav, 2017) presents three different IoT-based wireless sensors for environmental and ambient monitoring: one employing HTTP, one using Bluetooth Smart. All of the presented systems provide the possibility of probing remote sensors and visualizing data from every device with an Internet connection.

This work (Andrés, 2016) presents a new development model for wireless community networks. This model is based on the use of the monitoring of air quality and environmental variables in order to reward less polluted areas. The CleanWiFi network constantly monitors the air for pollutant gases, and uses the same data for public WiFi service, displaying information about the quality of the air to the user.

In this paper (Boubrima, Bechkit, Rivano, 2017) authors focus on an alternative or complementary approach, with a network of low cost and autonomic wireless sensors. Their main contribution is to design stochastic model of nature of pollution.

Dedicated IoT Platform

The benefit of developing dedicated IoT platforms (figure 5) is that it is relatively easy to maintain IoT applications in one domain. System has a limited selection of different types of IoT devices and operations. For service providers, it is easy to manage the devices and data of the selected domain specific applications. Unfortunately, in this case, users need special applications or web site for each dedicated systems.

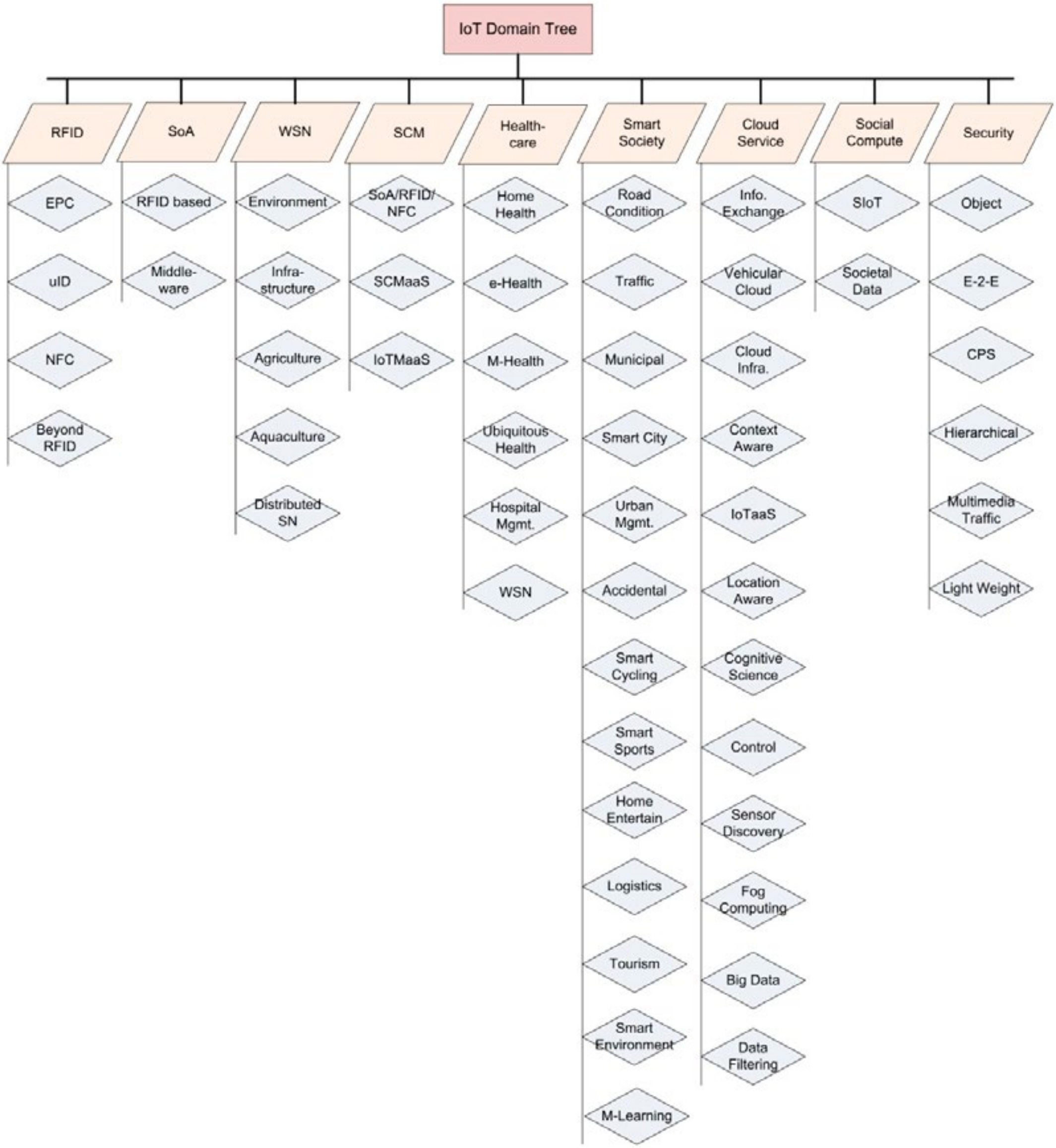

Figure 5. Application domains of IoT cloud platforms, also "Home Entertain", "Logistics", "Tourism", "Smart Environment", "M-Learning", "Fog Computing", and many more

Source: (Ray, 2016).

Universal urban IoTs, in fact, should be design to support the Smart City vision, which aims at exploiting the most advanced technologies to provide useful services for the administration of the city and for the citizens. Users wants mobile application and services in one platform with good user experience, not hundreds of small apps. Unfortunately, in the real world, most of the solution providers wants to build their own platform and standards, even based on W3C guidelines.

W3C Recommendations (Atkinson et al., 2017) provides guidelines to help data providers to design more useful services linked as a part of Smart City platform for citizens. It introduces the concept of cross-domain data such as climatic, occupation, pollution, traffic, activity, etc. Semantic Sensor Network standard can help to build a tools to share dataset with many domain ontologies specific to smart cities.

Conclusions

The Internet of Things is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with sensors, and suitable protocol stacks that will make them becoming an integral part of the Internet and our life. The IoT solutions landscape is full of different and incompatible proposals for the practical realization of IoT systems. Therefore, from a system perspective, the realization of an IoT solutions, together with the required services and devices, still lacks an established standards, frameworks and best practice. Currently, most of the IoT services are provided by different platforms and systems, and each platform often is associated with a certain domains.

Semantic Sensor Network is visualized as the key solution for heterogeneous sensors which enables semantic integration for real time systematic measurement and handling of environmental dynamics to achieve essential solutions or services. SSN follows a horizontal and vertical modularization architecture by including a lightweight but self-contained core ontology. With their different scope are able to support a wide range of applications and use cases, including environmental monitoring.

We suggest that cities authorities should deploy a solution based on W3C standards and their own Smart City IoT guidelines. There are a few good examples where developing standards can help to build widely adopted IoT platform. One of them is Australian Government Linked Data Working Group. Developing Government standards for guidance and establishing technical mechanisms for „Linked Data” implementations will ensure individuals, businesses and organisations can benefit from the opportunities these technologies offer.

The smart city concept received in the last few years a significant research effort and technological development. We believe that one of the possibilities is to solve the problem of interoperability of solutions from different providers is design by W3C Organization a guidelines and implementation of a reference IoT semantic gateway framework.

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