Internet of Things (IoT)

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INTRODUCTION

The term "Internet of Things" (IoT) refers to a worldwide network of uniquely identifiable interconnected objects that can seamlessly interoperate using communication protocols like Radio Frequency Identification (RFID), Bluetooth, Near Field Communication (NFC), barcodes, as well as embedded sensors and actuator nodes. The goal of IoT is that all daily life objects equipped with unique identifiers (having specific identities and virtual personalities) can be linked to the Internet and therefore can be managed as well as connect, communicate and interoperate with each other. The IoT applications are vast, covering numerous everyday fields and activities. Nonetheless, the full realization of the concept of IoT still faces many challenges. Throughout this article we discuss the background, the main characteristics as well as the various architectural, design and protocol issues of IoT, keeping in mind that objects are fundamentally resource constrained devices, which need to meet specific Quality of Service (QoS) and security requirements.

BACKGROUND

The concept of "Internet of Things (IoT)" was first mentioned in 1999 in the Auto-ID Center, when Kevin Ashton and his colleagues envisioned *"a world in which all electronic devices are networked and every object, whether it is physical or electronic, is electronically tagged with information pertinent to that object."* (Sarma et al., 2000). The first IoT application came to life in 2003, when Auto-ID Center launched its initial EPC (Electronic Product Code) network for automatically identifying and tracing the flow of goods in supply chains.

Since then, the Internet has experienced an immense growth, from a few connected hosts to billions of interconnected devices, sharing and running numerous applications. Today, the number of objects/things connected to the Internet exceeds the number of the connected people. By the year 2020, this number is expected to reach 24 billion devices, as depicted in Figure 1.

The next step of the IoT vision is to interconnect people and objects over the Internet from "any-time, any-place" for "any-one" into "any-time, any-place" for "any-thing," thus, creating a "smart" environment, leading ultimately to a more convenient way of life for everyone.

KEY TECHNOLOGIES

The realization of the IoT vision depends mostly on the development and integration of its key applied technologies, as well as their implementation and acceptance on a society level. The four (4) key technologies of IoT can be organized into RFID, sensor technologies, smart technologies and nanotechnology (Zhang & Zhu, 2011).

RFID

The Radio Frequency Identification (RFID) technology connects objects over-the-air by the use of electromagnetic induction for the purpose of wireless automatic identification. A RFID system consists of the tag, the reader and the back-end computer system. The tag has a unique Identifier (ID) and an antenna for transmitting radio waves in the surrounding area. In this way, every tagged object can be uniquely identified. RFID tags can be passive or active, depending on whether the tag

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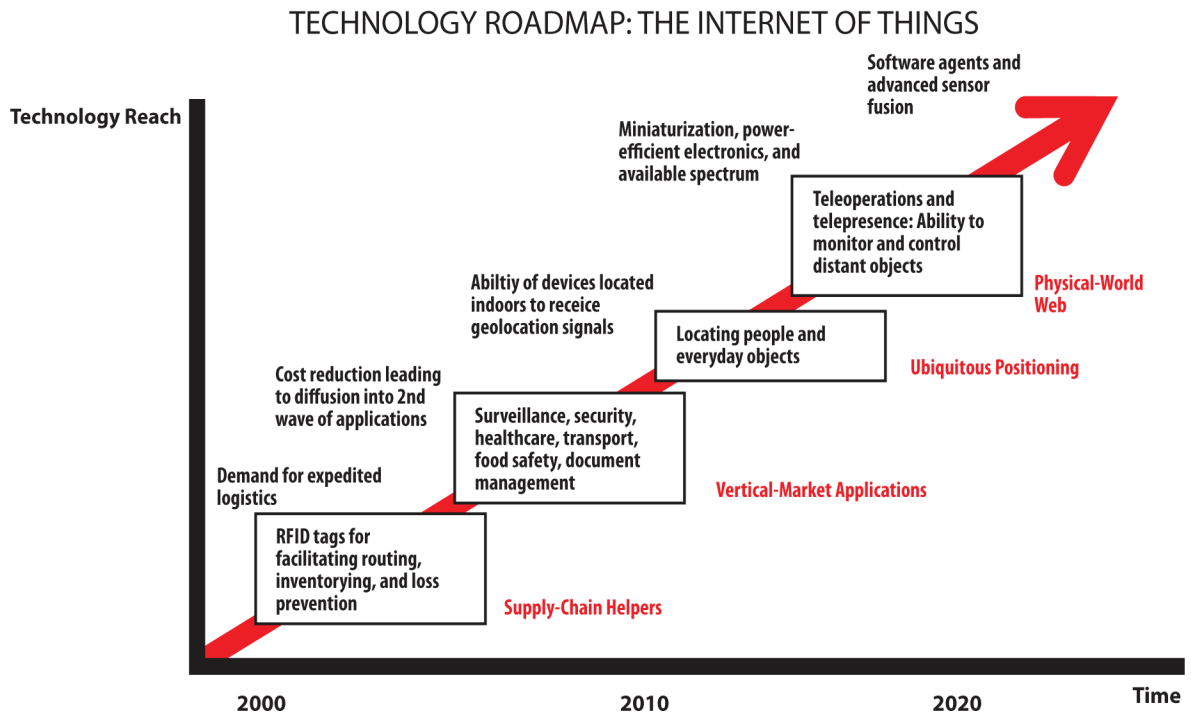
Figure 1. Internet of things technology roadmap (SRI Consulting Business Intelligence, 2008)



has a power supply on-board (Welbourne et al., 2009) (Kosmatos et al., 2011).

Sensor Network

Wireless Sensor Networks (WSNs) provide a reliable and efficient solution that covers specific communication needs. These networks consist of a large number of sensors installed in the "things," allowing them to sense the environment. After the collection of data, they can transmit them to the base stations, where based on their analysis, the appropriate actions can be decided and implemented (Gazis et al., 2012).

Smart Technology

The success of IoT depends greatly on the ability to make objects "smart" by applying appropriate technologies, i.e. artificial intelligence, machine-human interaction, intelligent signal processing. The objects communicate with each other and with the users, and even taking automated decisions based on the feedback/readings received from the system and the sensors, respectively.

Nanotechnology

Nanotechnology (smaller microchips) is also essential for the system's optimum functionality. By making "things" very small (almost tiny), sensors can be easier installed inside every object, providing improved connection and interaction between them as well as with the system itself. Moreover, their reduced size helps in effectively reducing the power consumption of the system, which is one of the major IoT challenges, since the objects are usually operated with batteries.

RESEARCH PROJECTS

Several research projects focus on the emerging Internet of Things, aspiring to contribute to the development and faster spread of the IoT vision. In the following paragraphs, three of the more well-known IoT projects are briefly described.

- **SENSEI** (Integrating the Physical with the Digital World of the Network of the Future)