Internet of Things (IoT)

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MAXIMIZING VALUE FROM PREDICTIVE ANALYTICS AND BIG DATA

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Introduction

The term Internet of Things (IoT) was first invented by Kevin Ashton in 1999. In the Internet of Things (IoT) era, many of the objects that surround us will be on the network. Radio Frequency Identification (RFID) and sensor network technologies will rise to meet this new challenge, in which information and communication systems are invisibly implanted in the environment around us.

Smart connectivity and context-aware computation using network resources is an integral part of Internet of Things (IoT). With the growth of Wi-Fi and 4G-LTE wireless Internet access, the evolution towards ubiquitous information and communication networks is clearly understood. However, for the Internet of Things (IoT) vision to successfully emerge, the computing model will need to go beyond traditional mobile computing scenarios that use smart phones and portables, and develop into connecting everyday existing objects and implanting intelligence into our environment. For technology to disappear from the awareness of the user, the Internet of Things (IoT) claims: (1) a shared understanding of the situation of its users and their appliances, (2) software architectures and pervasive communication networks to process and communicate the contextual information to where it is related, and (3) the analytics tools in the Internet of Things that target for autonomous and smart behavior. With these three elementary grounds in place, smart connectivity and context-aware computation can be established successfully.

With time Internet of Things (IoT) has been more comprehensive covering a broad range of applications like healthcare, utilities, transport. A radical development of the current Internet into a network of interconnected objects that not only collects information from the environment (sensing) and interacts with the physical world (actuation/command/control), but also utilizes existing Internet standards to provide services for information transfer, analytics, applications, and communications. The presence of devices enabled by open wireless technology such as Bluetooth, radio frequency identification (RFID), Wi-Fi, and telephonic data services as well as embedded sensor and actuator nodes, Internet of Things (IoT) has stepped out of its infant stage and is on the verge of transforming the current static Internet into a fully integrated Future Internet. This led to the interconnection between people at an exceptional scale and pace. The next revolution will be the interconnection between objects to create a smart environment. A schematic diagram which shows the interconnection of objects is depicted in the below Fig. 1, where the application domains are selected based on the scale of the impact of the data generated.

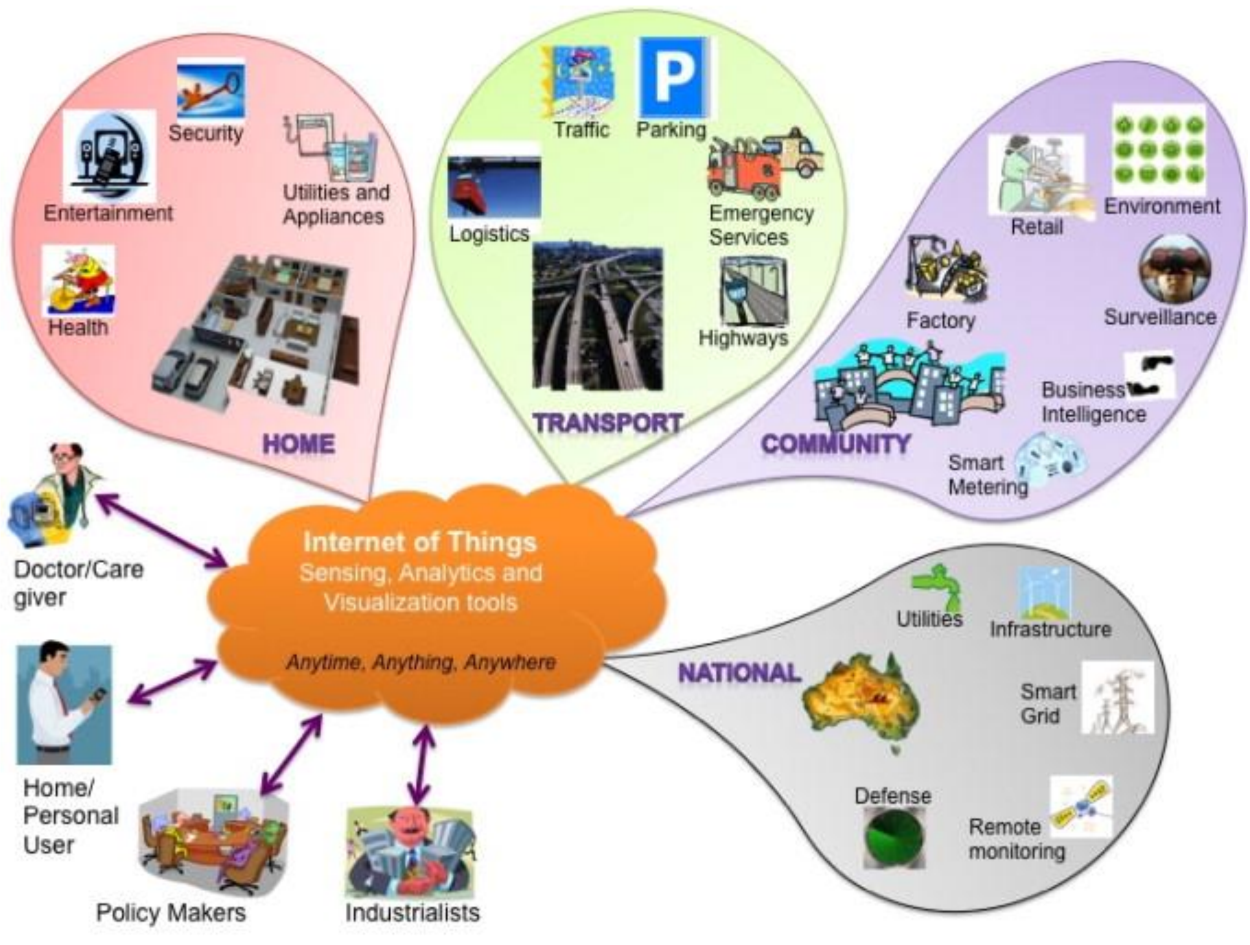

Fig. 1.
Internet of Things schematic showing the end users and application areas based on data.

Definition of IoT

As defined by Atzori, Internet of Things (IoT) can be recognized in three paradigms—internet-oriented (middleware), things oriented (sensors) and semantic-oriented (knowledge). The RFID group describes the Internet of Things as – The worldwide network of interconnected objects uniquely addressable based on standard communication protocols. According to Cluster of European research projects on the Internet of Things –'Things' are active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention. According to Forrester, a smart environment – Uses information and communications technologies to make the critical infrastructure components and services of a city's administration, education, healthcare, public safety, real estate, transportation and utilities more aware, interactive and efficient.

IoT Elements

There are three IoT elements which facilitates seamless ubiquitous computing: (a) Hardware—made up of sensors, actuators and embedded communication hardware (b) Middleware—on demand storage and computing tools for data analytics and (c) Presentation—easy to understand visualization and interpretation tools which can be extensively accessed on different platforms and which can be designed for different applications. Few technologies are discussed below which make up the three elements stated above.

Radio Frequency Identification (RFID):

RFID technology is a major advancement in the embedded communication paradigm which facilitates design of microchips for wireless data communication. These help in the automatic recognition of anything these are attached to acting as an electronic barcode The passive RFID tags are not battery powered and these use the power of the reader's inquiry signal to communicate the ID to the RFID reader. This has led to many applications particularly in retail and supply chain management. The applications can be found in transportation and access control applications as well. The passive tags are used in many bank cards and road toll tags which are among the first global deployments. Active RFID readers have their own battery supply and can detect the communication. Of all the various applications, the main application of active RFID tags is in port containers for monitoring cargo.

Wireless Sensor Networks (WSN):

Recent technological progress in low power integrated circuits and wireless communications have resulted in availability of efficient, low cost, low power miniature devices for use in remote sensing applications. The combination of these factors has improved the possibility of using a sensor network consisting of a large number of intelligent sensors, facilitating the collection, processing, analysis and circulation of valuable information, gathered in a variety of environments. Active RFID is nearly equivalent to the lower end WSN nodes with restricted processing capability and storage. The challenges that must be overcome to realize the huge potential of WSNs are substantial in nature. Sensor data are allocated among sensor nodes and transmitted to a distributed or centralized system for analytics.

Addressing schemes:

The potential to exclusively identify 'Things' is critical for the success of IoT. This will not only authorize us to exclusively identify billions of devices but also to manage remote devices through the Internet. The few most critical features of building an unique address are: uniqueness, reliability, persistence and scalability. The current IPv4 may assist to an extent where a group of sensor devices can be identified geographically, but not individually. The Internet mobility attributes in the IPV6 may mitigate some of the device identification problems; however, the heterogeneous nature of wireless nodes, variable data types, concurrent operations and confluence of data from devices aggravates the problem further.

Continuous network functioning to channel the data traffic ubiquitously and steadily is another aspect of IoT. Although, the TCP/IP takes care of this mechanism by routing in a more dependable and efficient manner, from source to destination, the IoT faces a bottleneck at the interface between the gateway and wireless sensor devices. Furthermore, the scalability of the device address of the current network must be viable. The addition of networks and devices must not impede the performance of the network, the functioning of the devices, the dependability of the data over the network or the effective use of the devices from the user interface. To address these issues, the Uniform Resource Name (URN) system is regarded as the fundamental for the development of IoT. URN generates replicas of the resources that can be accessed through the URL. With large amounts of spatial data being collected, it is often quite vital to take advantage of the benefits of metadata for transferring the information from a database to the user through the Internet. IPv6 also gives a very good option to access the resources individually and remotely. Another crucial development in addressing is the development of a lightweight IPv6 that will address home appliances uniquely.

Wireless sensor networks that run on a different stack compared to the Internet, cannot possess IPv6 stack and hence a subnet with a gateway having a URN will be necessary. Therefore, we require a layer for addressing sensor devices by the applicable gateway. At the subnet level, the URN for the sensor devices could be the unique IDs and a lookup table at the gateway to address this device. Each sensor will have a URN (as numbers) for sensors to be addressed by the gateway at the node level. The entire network now forms a web of connectivity from users (high-level) to sensors (low-level) that is addressable (through URN), accessible (through URL) and controllable (through URC).

Data storage and analytics:

One of the most important outcomes of this emerging field is the production of an unusual amount of data. The critical issues are storage, ownership and expiry of the data. Currently the internet consumes up to 5% of the total energy and it is sure to rise even further. Hence, data centers will ensure energy efficiency as well as reliability that run on harvested energy and are centralized. The data have to be stored and used intelligently for smart monitoring and actuation. It is essential to design and develop artificial intelligence algorithms which could be centralized or distributed on the basis of the requirement. Non-linear, temporal machine learning methods based on evolutionary algorithms, genetic algorithms, neural networks, and other artificial intelligence techniques are required to achieve automated decision making. These systems exhibit characteristics such as interoperability, integration and adaptive communications. They also have a modular architecture and are usually very well-suited for IoT applications. Moreover, a centralized infrastructure to aid storage and analytics is required. This forms the IoT middleware layer and there are numerous challenges involved here. As of 2012, Cloud based storage solutions are becoming more popular. In the next few years ahead Cloud based analytics and visualization platforms are forecasted.

Visualization:

Visualization is quite critical for an IoT application as this enables the interaction of the user with the environment. With substantial progress in touch screen technologies, use of smart tablets and phones has become very inherent. For a lay person to fully benefit from the IoT revolution, visualization has to be created. As we move from 2D to 3D screens, more information can be communicated in meaningful ways for consumers. This will also facilitate policy makers to transform data into knowledge, which is crucial in fast decision making. Extraction of meaningful facts from raw data is non-trivial. This encircles event detection and visualization of the raw and modeled data, with information represented according to the requirements of the end-user.

Applications

Diverse application domains will be affected by the emerging Internet of Things. The applications can be classified based on various attributes such as type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact. The applications are categorized into four application domains: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile. There is a huge crossover in applications and the usage of data between domains. For example, the Personal and Home IoT produces electricity usage data in the house and thereby making it available to the electricity (utility) company which can in turn optimize the supply and demand in the Utility IoT. The internet permits sharing of data between different service providers in a seamless manner and thereafter building multiple business opportunities.

Cloud centric Internet of Things

The vision of IoT is seen from two perspectives— 'Internet' centric and 'Thing' centric. The Internet centric architecture will encompass internet services which is the main focus while data is provided by the objects. In the object centric architecture, the smart objects are the main focus. In order to understand the full potential of cloud computing as well as ubiquitous sensing, a combined framework with a cloud at the center seems to be most feasible. This results in flexibility of dividing associated costs in the most reasonable way and is also highly extensible. Sensing service providers can provide their data with the help of a storage cloud; analytic tool developers can provide their software tools; artificial intelligence experts can provide their data mining and machine learning tools beneficial in transforming information to knowledge and eventually computer graphics designers can provide a range of visualization tools. Cloud computing can offer these services as Infrastructures, Platforms or Software. This is in agreement with the ubiquitous computing vision of Weiser as well as Rogers' human centric approach. Thus the data generated, tools usage and the visualization created fades into the background, tapping the full potential of the Internet of Things in different application domains.

Developing IoT applications with the help of low-level Cloud programming models and interfaces like Thread and MapReduce models is difficult. To overcome this difficulty, an IoT application specific framework for rapid creation of applications and their deployment on Cloud infrastructures is needed. This is accomplished by mapping the recommended framework to Cloud APIs supported by platforms such as Aneka. Therefore, the new IoT application specific framework should be able to provide support for (1) reading data streams either from sensors directly or fetch the data from databases, (2) demonstration of data analysis logic as functions/operators that process data streams on Cloud infrastructures, and (3) if any incidents of interest are identified, outcomes should be transferred to output streams, which are connected to a visualization program. With the help of such a framework, the developer of IoT applications will be able to use the power of Cloud computing without knowing low-level details of creating reliable and scale applications. For the realization of such an environment for IoT applications a model is shown in Fig. 2, thereby reducing the time and cost involved in engineering IoT applications.

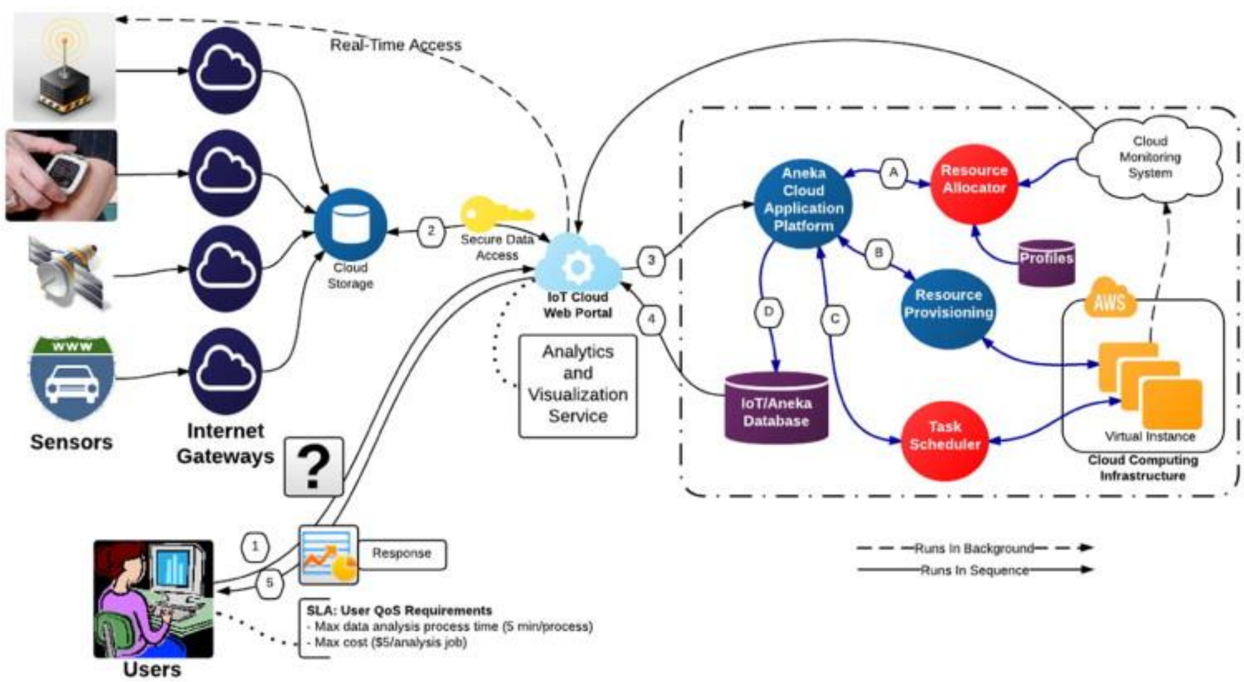

Fig. 2.
A model of end-to-end interaction between various stakeholders in Cloud centric IoT framework.

Open challenges and future directions

The Cloud centric vision holds a flexible and open architecture that is user centric and empowers different players to interact in the IoT framework. It allows interaction in a way suitable for their own needs, rather than the IoT being imposed on them. In this manner, the framework includes provisions to meet different requirements for data ownership, security, privacy, and sharing of information. Some open challenges are discussed based on the IoT elements mentioned earlier. The challenges include IoT specific challenges such as privacy, participatory sensing, data analytics, GIS based visualization and Cloud computing whereas the standard WSN challenges include architecture, energy efficiency, security, protocols, and Quality of Service. The end goal is to have Plug n' Play smart objects which can be installed in any environment which can make use of information and enabling them to fuse with other smart objects around them. In order to accomplish this goal a pivotal role is played by standardization of frequency bands and protocols. Key developments in IoT research in the context of pervasive applications which includes the technology drivers and crucial application outcomes are expected in the next decade.

Summary and conclusions

The propagation of devices with communicating–actuating capabilities is bringing closer the vision of an Internet of Things, where the sensing and actuation capabilities seamlessly merge into the background and new capabilities are created through new information sources. The evolution of the next generation mobile system will rely on the creativity of the users in designing new applications. IoT is an ideal emerging technology to influence this domain by providing new evolving data and the required computational resources for developing revolutionary apps. User-centric cloud based model plays an important role towards approaching this goal through the interaction of private and public clouds. In this way, the requirements of the end-user are brought forward. To meet the diverse and competing needs of different sectors, a framework is proposed which is facilitated by a scalable cloud to provide the capacity to utilize the IoT. The framework permits networking, computation, storage and visualization themes thereby allowing independent growth in every sector but complementing each other in a shared environment. The standardization which is ongoing in each of these themes will not be adversely affected with Cloud at its center. In recommending the new framework associated challenges have been raised ranging from appropriate interpretation and visualization of the huge amount of data. Through to the privacy, security and data management issues that must underpin such a platform in order for it to be genuinely feasible. International initiatives are quite clearly accelerating the progress towards an IoT, furnishing an overall view for the integration and functional elements that can deliver an operational IoT.

Reference

Internet of Things (IoT): A vision, architectural elements, and future directions

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