Internet of Things: Services and Applications Categorization

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Abstract—**In this paper we attempt to categorize the services provided by the Internet of Things (IoT) in order to help application developers build upon a base service. First we introduce the four main categories of services, and then follow by providing a number of examples of each of the service categories so as to provide an example of how each type of service might be implemented, and how it can be used to build an IoT application.**

I. Introduction

The Internet can be described as a ubiquitous infrastructure that has evolved from being a technology for connecting people and places to a technology connecting things. The future is the Internet of Things (IoT), which aims to unify everything in our world under a common infrastructure, giving us not only control of the things around us, but also keeping us informed of the state of the things around us.

One of the main problems with IoT is that it is so vast and such a broad concept that there is no proposed, uniform architecture. In order for the idea of IoT to work, it must consist of an assortment of sensor, network, communications and computing technologies, amongst others. But when you start putting together different types of technologies, the problem of interoperability arises. One proposed solution is to adopt the standards of the services-oriented architecture (SOA) deployed in business software systems [1]. Another takes a similar approach, suggesting the integration of Web Services into sensor network with the use of IoT optimized gateways, which would bridge the gap between the network and the terminal [2]. In general, it may be beneficial to incorporate a number of the technologies of IoT with the use of services that can act as the bridge between each of these technologies and the applications that developers wish to implement in IoT. This paper breaks down four main categories of services according to technical features, as proposed and described by [3]. In categorizing IoT services, we aim to provide application developers a starting point, giving them something to build upon so that they know the types of services that are available. This will allow them to focus more on the application instead of designing the services and architectures required to support their IoT application.

II. Types of Services

There are an exceptional number of applications that can make use of the Internet of Things, from home and office automation to production line and retail product tracking. The number of applications is endless. For each application, a particular IoT service can be applied in order to optimize application development and speed up application implementation. Note that the categorizations that follow come from [3].

A. Identity-Related Services

Identity-related services can be divided into two categories, active and passive, and can serve either individuals or enterprise, which can lead to a number of different kinds of applications.

The general identity-related service consists of two major components: (1) the things, all of which are equipped with some kind of identification identifier, such as an RFID tag; and (2) the read device(s), which read the identity of the thing based on its label, in this case reading the information encoded into the RFID tag. The read device would then make a request to the name resolution server to access more detailed information about that particular device.

Active identity-related services are services that broadcast information, and are usually associated with having constant power, or at least under battery power. Passive identity-related services are services that have no power source and require some external device or mechanism in order to pass on its identity. For example, an active RFID tag is battery powered and can transmit signals once an external source has been identified. A passive RFID tag, on the other hand, has no batteries, and requires an external electromagnetic field in order to initiate a signal transmission. In general, active identity services can transmit or actively send their information to another device, whereas passive services must be read from.

B. Information Aggregation Services

Information aggregation services refer to the process of acquiring data from various sensors, processing the data, and transmitting and reporting that data via IoT to the application. These types of services can be thought of, more or less, as one way: information is collected and sent via the network to the application for processing.

Information aggregation services do not have to implement a single type of communication channel in order to work together. With the use of access gateways, an information aggregation service could make use of different types of sensors and network devices and share their data via a common service to the application. For example, an application could make use of RFID tags to be aware of the identity of some devices, while also using a ZigBee network to collect data from sensors, then use a gateway device to relay this information to the application under the same service, say a Web Service such as JSON or XML. Not only would this allow a developer of an application to incorporate a number of different technologies into the application, but it could also allow the application to access various IT and enterprise services that may already be in place.

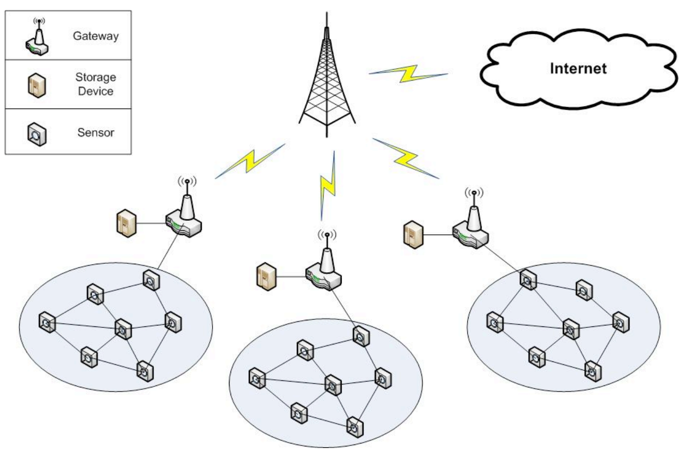

Figure 1: Aggregate Network diagram with sensor network and access gateways

C. *Collaborative-Aware Services*

Collaborative aware services are services that use aggregated data to make decisions, and based on those decisions perform an action. As IoT takes shape, it should bring about the development of complicated services that make use of all of the data that can be retrieved from the extensive network of sensors. This will require not only being able to retrieve information, but to relay back responses to the collected information to perform actions. These services will thus require "terminal-to-terminal" as well as "terminal-to-person" communication. By providing collaborative aware services, the IoT infrastructure naturally requires greater reliability and speed, and will require the terminals to either have more processing power or be linked with some other device that does.

D. *Ubiquitous Services*

Ubiquitous services are the epitome of the Internet of Things. A ubiquitous service would not only be a collaborative aware service, but it would be a collaborative aware service for everyone, everything, at all times. In order for IoT to reach the level of providing ubiquitous services, it would have to overcome the barrier of protocol distinctions amongst technologies and unify every aspect of the network. There is no particular system architecture for the Internet of Things, but there have been numerous papers written about the use of Web Services or REST (representational state transfer) APIs (application programming interfaces) to unite loosely coupled things on the Internet under a single application so that they can be reused and shared. IPv6 is also a protocol that could greatly benefit the increase in ubiquitous services. Reference [4] proposes such an architecture that, if implemented, would be considered a ubiquitous service.

III. Applications of IoT Services

Moving past what each of the categories means, the following subsections provide examples of each type of service in an attempt to offer developers a starting point when developing their own application. The idea is to provide a series of examples for each service type that use a common technologies so as to provide a basic framework to build an application upon a specific type of service.

A. *Identity-Related Services*

Identity-related services are the most simple, yet maybe one of the most important, services to be provided to an application of the Internet of Things. Applying an identity-related service to an application provides the developer with vital information about every device, or every *thing*, in their application.

The most prominent technology used in identity-related services is RFID. RFID is a technology that enables data to be transmitted by a tiny portable device, called a tag, which is read by an RFID reader and is processed according to the needs of that particular application. RFID provides an upgrade from the traditional form of device identification: barcode scanning. RFID is more versatile because it does not require line of sight transmission, and, in the case of active RFID tags, can transmit its data as opposed to simply just being read by a reader device.

Most IoT applications that are aimed at providing an identity-related service make use of RFID technology. As described in [5], the RFID tag stores an identification code unique to that device. The RFID reader reads that code, and looks up the device in the RFID server, which then returns the detail information require by the application.

Production and shipping are two common applications that would benefit greatly from the use of an identity service. Another application that uses an identity-related service describes a model that can solve the information asymmetry problem in supply chain management and supply chain information transmission [6].

Every IoT application will either be based on, or at least incorporate some instance of, an identity-related service. This is because for the IoT to incorporate everything in the physical world to the digital world, the application will need to be able to identify all of the devices that are connected.

B. *Information Aggregation Services*

Information aggregation services incorporate identity related services, along with other components such as Wireless Sensor Networks (WSNs), and access gateways to collect information and forward it to the application for processing. The information aggregation service is just responsible for providing the application with all of the information that is collected, and potentially processed along the way, from the terminals of the system (sensors, RFID tags, etc). In this regard, the WSN can be a powerful tool for collecting and communicating data between terminals and the platform (host of application), as long as the platform is within range of the WSN. But this would not be an IoT application on its own; an IoT application would consist of multiple WSNs all configured to work together to provide information about the world around them. The link between these networks is an access gateway. The general structure of this network is shown in Figure 2 below. Each access gateway in the IoT network will have access to the database server, thus every device would be connected and information from the entire network aggregated at the database server.

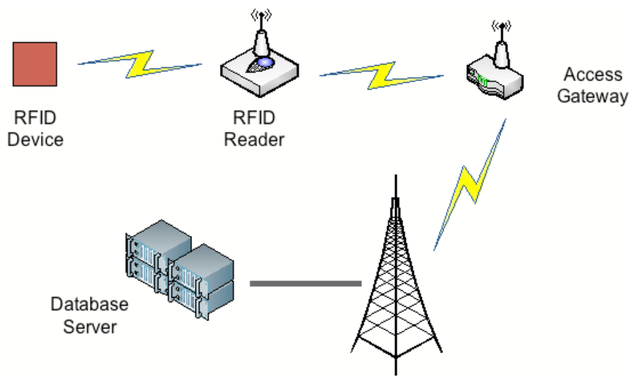

Figure 2: RFID network example

There are a number of applications out there that make use of information aggregation services and access gateways. In [7], the importance of extending the information aggregation service to beyond the WSN is proposed by using a cellular network (CN) to extend the range of the WSN. The idea is that if a terminal is outside of the WSN of interest, it uses CN resources to access that information through the use of an "IoT gateway," which essentially implements both WSN and CN resources.

Information aggregation services are useful in monitoring situations, such as energy monitoring in the house and in the enterprise, or, if the Internet of Things has been realized, monitoring of anything, anywhere. For example, [7] introduces a monitoring and control system for use in an agriculture greenhouse production environment. The system measures and records critical temperature, humidity and soil signals which is then transmitted through the network to the platform for processing. Another application [9] uses a ZigBee WSN to monitor physiological data of patients that automatically generates electronic medical records.

C. *Collaborative-Aware Services*

The key difference between information aggregation services and collaborative-aware services are the use of the data collected to make decisions and perform actions. As mentioned before, the keys to creating a collaborative-aware service are network security, speed, and terminal processing power. Terminals can no longer be just simple sensors that collect information, or if there are simple sensors in the network, there must be separate embedded devices within the network that can make use of the data.

There are fewer applications published in terms of IoT and collaborative-aware services. We can, however, attempt to apply new technologies to a collaborative-aware service. An example of a new technology that will help shape the way the Internet of Things grows is IPv6. IPv6 is a new version of the Internet Protocol (IP) that allows for a significantly greater number of addressable devices to be connected to the Internet. Although the use of IPv6 has had a slow start, it is definitely the Internet protocol of the future due to the lack of available IP addresses. Moving forward, one of the most important factors in IoT becoming reality is being able to address each of the embedded devices in the world, which converting to IPv6 would allow. Reference [10] offers a number of applications for IoT, many of which could be considered collaborative-aware services, or which could at least provide a baseline for such a service. They propose integrating every object into the IP infrastructure using both IPv6 and 6LoWPAN, which is the use of IPv6 over low power wireless personal area networks. They propose a network with three types of nodes, all of which can be reprogrammed to function as any of the three types. The three types essentially are a base station node (IPv6 router), a mobile node (wireless dongle that allows WSN connectivity to a standard laptop) and specialized nodes, which are used for specialized tasks. This becomes a collaborative-aware service because it incorporates terminal-terminal and terminal-person communication, which is accomplished due to the use of the IPv6 protocol.

D. *Ubiquitous Services*

Ubiquitous services are the ultimate goal of the Internet of Things, taking collaborative-aware services to the next level by providing complete access and control of everything around us, whether it be through a computer or a mobile phone or something else.

Ubiquitous services have yet to be realized in the world today, but most research in IoT is ultimately aimed at providing some piece to the puzzle that will ultimately be ubiquitous services. In [4], the authors first talk about why the Internet of Things is so difficult to realize. One of the biggest hurdles for IoT is having a single architecture that allows the many different application layer standards to communicate and interoperate. The authors in [4] proposed an architecture, based on RESTful services, in which a universal API would be created so that everyone who creates devices to be used in the Internet of Things has an architecture to adopt in order to be interoperable with the rest of the world's devices.

IV. CONCLUSION

This paper outlined the four main categories of services of the Internet of Things and attempted to provide some examples of each in order to give the developer of an IoT application a starting point for his application. Many people are using Web Services and access gateways in order to interface with the terminals, while others are moving towards the use of IPv6, which will allow for more devices to be connected directly to the Internet and be IP addressable, as opposed to being a part of some subnetwork that is connected to the Internet through a gateway. Overall, there is still much work to be done in IoT, specifically in finding a way to incorporate all of the services into an omnipresent, omnipotent service aimed at delivering communication anytime, anywhere, for anybody, and for everything.

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