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**The Internet of Things - Concept and Problem Statement**  
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## Abstract

This document explains the concept of the Internet of Things (IoT) and several features of the IoT. In addition, this document specifies problems considering technical issues for the IoT. Based on this, this document discusses architectural implications in order to solve problems.

## Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC-2119](#).

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## **1. Introduction**

The Internet of Things (IoT) [1-3] is a novel paradigm that is becoming popular with research and industries. The basic idea is that IoT will connect objects around us to provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, smart phones make it possible to materialize IoT which interact and co-operate each other to make the service better and accessible anytime, from anywhere.

There are so many applications that are possible because of IoT. For individual users, IoT brings useful applications like home automation, security, automated devices monitoring and management of daily tasks. For professionals, automated applications provide useful contextual information all the time to help on their works and decision making. Industries with sensors and actuators operations can be rapid, efficient and more economic. Managers who need to keep eye on many things can automate tasks connection digital and physical objects together. Every sectors energy, computing, management, security, transportation are going to be benefitted with this new paradigm. Development of several technologies made it possible to achieve the vision of the IoT. Identification technology such as RFID allows each object to represent uniquely by having unique identifier. Identity reader can read any time the object allows real time identification and tracking. Wireless sensor technology allows objects to provide real time environmental condition and context. Smart technologies allow objects to become more intelligent which can think and communicate. Nanotechnologies are helping to reduce the size of the chip incorporating more processing power and communication capabilities in a very small chip.

This document explains the concept of the IoT and several features of the IoT. In addition, this document specifies problems considering technical issues for the IoT. This document also contains architectural considerations in order to solve problems with feasible technological solutions.

## **2. Concept of IoT**

- o Definition of the "IoT"

The "Internet of Things (IoT)" refers to the networked interconnection of everyday objects. An "IoT" means "a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols" [5].

o Definition and scope of "thing"

In the IoT, "thing" is object of the physical world (physical thing) or of the information world (virtual thing), which is capable of being identified and integrated into the communication networks [6]. The "thing" should be identified at least by one unique way of identification for the capability of addressing and communicating with each other and verifying their identities.

o Visions of IoT and goals for new architecture/framework

In terms of standardization, a new paradigm of IoT implies many visions depending on expertise of standardization bodies. Commonly we focus on the deployment of a new generation of networked objects with communication, sensory and action capabilities for numerous applications with a vision "from simple connected objects as sensor networks to more complex and smarter communicated objects as in the envisioned IoT" [7]. In the IETF/IRTF perspective, one of our visions is to provide global interoperability via IP for making heterogeneous/constraint objects very smart.

We are investigating a new architectural framework to support scalability and interoperability for IoT as a research item. The goals for this are to identify several problems of existing protocols and find possible solutions for solving these problems.

### **3. Features of the IoT**

#### **3.1. Overall aspects**

The IoT has the following features: order(s) of magnitude bigger than the Internet, no computers or humans at endpoint, inherently mobile, disconnected, unattended.



### **3.2. Applications/services aspects**

There are many use cases among various stakeholders in IoT environment. Each device/machine can be used for multiple applications/services with different characteristics.

### **3.3. Networking aspects**

It is required to provide a common communications technology that supports all applications/services as well as heterogeneous networking interfaces.

### **3.4. Link/physical layer aspects**

There are various types of networking interfaces which have different coverage and data rates. These environments have the characteristics of low power and lossy networks like Bluetooth, IEEE 802.15.4 (6LoWPAN, ZigBee), NFC etc.

### **3.5. Smart/connected objects aspects**

Smart/connected objects are heterogeneous with different sizes, mobility, power, connectivity and protocols. A physical object interacts with several entities, performs various functionalities and generates data that might be used by other entities. Usually resources of these objects are limited.

### **3.6. Smart environment aspects**

Smart environment which consists of networks of federated sensors and actuators can be extended from homes/offices to buildings/cities. From residential home, end-to-end large scale services such as smart cities can be considered.

## **4. Problems**

### **4.1. Identifier for objects and services**

There are various kinds of identifier with different identification codes according to objects and their services. Current identification schemes for objects are also different from their purposes.

Technical considerations:

- o Identification (new naming space, globally unique ID)



With the huge evolved communication objects, the hierarchical identification schemes are required. The aggregation feature of IPv6 address is one of example.

According to the classification of "Things", the different identification schemes are required. That is, the information such as books, medicine and clothes may not require the global identification because revocation lists are required. It means some objects will be destroyed.

#### **4.2. Object naming**

Current Internet just identifies the specific server which contents are stored. As the end points of current Internet are hosts, individual content in a server cannot be identified in the network.

Technical considerations:

- o Object naming services

The name service of Internet such as DNS (Domain Name System) [[RFC1034](#)] has already been one of the most important infrastructures of the Internet nowadays. For example, DNS is an indispensable system of the Internet used for translating the "human-friendly" host names of computers on a TCP/IP network into their corresponding "machine-friendly" IP addresses. In general, DNS also stores other types of information, such as the list of mail servers that accept email for a given Internet domain. By providing a worldwide, distributed name service, DNS is an essential component of the functionality of the Internet.

Similarly, object name service will also be one of essential and key elements in the IoT, which can be used for translating the "thing-friendly" names of object which maybe belong to heterogeneous name spaces (e.g. EPC, uCode, and any other self-defined code) on different networks (e.g. TCP/IP network, constrained network) into their corresponding "machine-friendly" addresses or other related information of another TCP/IP or constrained network. The object of IoT based on a TCP/IP or constrained network can easily communicate with other object on the same or any other network with the name of the object by object name service, without considering whether the address of the targeted object has been changed or not.



To fulfill the aforementioned objective, object naming service based on the IoT needs to be researched. The compatibility of heterogeneous name spaces and the efficiency for the constrained network of this kind of service are supposed to be the most important issues to be studied in future.

#### **4.3. Security/privacy/authority**

The loss of security and privacy in communications and services, with personal data is becoming available and unwanted communication becoming rampant.

The overall problem is further aggravated by the diversification of the Internet with new types of devices and heterogeneous networks. The user is confronted with a wide range of methods and devices with which to access the digital world, and it can no longer be assumed that a single, independent access per device will suffice, nor that the user will actually own all these devices.

Using identities as representations of entities of all kinds as the end points of communications, the handling of the privacy of data in the network and the infrastructure is key issues to solve problems associated with the diversifying of the Internet towards an IoT, and to be reachable in the digital world [8].

Technical considerations:

- o ID-management for objects (security, authentication, privacy)

Basically each object should not be able to authenticate during the short time because the hundreds of objects may request the approval at the same time. Therefore, group authentication and authorization methods are required.

- o Trustworthy networking

Confidentiality, authenticity and trustworthiness of communication partners need to be maintained. Users need to give objects limited service access not allowing them to communicate in uncontrolled manner.



#### **4.4. Presence (of people; of devices)**

Key challenging issue is to develop a mechanism which accepts, stores and distributes presence information with the relationship between people and devices.

Technical considerations:

- o Awareness of presence

#### **4.5. Geographic location (self-identification of location)**

For IoT applications/services, we need to know the physical location of objects and the location of information from objects. Problems are how to identify location information related to objects with autonomic way.

Technical considerations:

- o Awareness of location

#### **4.6. Discovery/search**

Every object can be a source of information. Information from object should be stored and discovered through searching in order to use it by persons. For this, semantic and context information can be used.

Technical considerations:

- o Tools for information modeling of objects

Characterizing of objects using semantic and ontology technologies are required. Suitable services for objects must be automatically identified. As users want to know objects information and their availability all the time, it requires appropriate semantic means of describing their functionalities.

#### **4.7. Tracking and mobility support of mobile object**

To support the routing and mobility protocols, the IoT networks have structural characteristics. That is, the mobility support models are

required. Some objects move independently. Others will move as the one of group. Therefore, according the moving feature, the different tracking methods are required. It is important to provide ubiquitous and seamless communication among objects while tracking the location of objects.

Technical considerations:

- o Location-based mobility support for mobile objects

#### **4.8. Data processing /computing**

For supporting various applications in the IoT environment, information should be able to transfer among objects operating under varied perspectives without humans.

Technical considerations:

- o Information model (data store, retrieval, transfer, etc.)

According the Information model, the functionality of data processing should be distinguished.

- o Policy/preferences

#### **4.9. Heterogeneous networking environment (IP and non-IP, etc.)**

Objects have different communication, information and processing capabilities. Each object would also be subjected to very different conditions such as power energy availability and communication bandwidth requirement. Networking interfaces of objects are heterogeneous in terms of coverage, data rate, etc. For communicating among objects, both IP and non-IP interfaces should be supported for providing interoperability among heterogeneous interfaces.

Technical considerations:

- o Interworking model with proxy (gateway)

Each gateway should support the multiple interfaces, which are evolved in different heterogeneous networks.

- o Interoperability

In order to facilitate communication and cooperation common practices and standards are required. Interoperability solution should be maintained to provide seamless interaction among them. Service description, publishing, and discovery mechanisms should be interoperable otherwise the IoT will be converted into islands of heterogeneous object network.

o Device adaptation

Each connected objects should be able to adapt the situation where it is now. When a person with smart phone enters home, it should adapt communication mechanism, addressing and localized environment. When it reaches in office environment it should adapt with new situation where the mechanisms available in home can be different. Adaption in many senses should be maintained.

#### **4.10. Global connectivity (IP-based)**

Each object should support the end-to-end communications. And also outside-initiated services may be supported into the inner network. For global interoperability, IP is considered for communicating smart objects.

Technical considerations:

o IPv6 protocol

To solve scalability regarding addressing, object-to-object communication needs huge number of IP addresses in order to uniquely identify each objects. As a scalable solution, IPv6 can be used which can accommodate as many things as required to include in the IoT. Using IPv6 with abundant address spaces, globally unique connectivity can be provided without additional processing.

#### **4.11. Scalability**

All of objects are highly distributed with ubiquity features (e.g., any where, any time). Scalable solutions are necessary in the distributed networking environment.

Technical considerations:





- o ID/LOC separation

In IETF LISP, Shim6 and Other WG, ID/LOC separation methods have been developing. For more scalable and robust network, ID/LOC separation features are required.

#### **4.12. Autonomics (self-configuring, intelligence for control)**

For self-configuration, a problem is how a device needs to establish its connection automatically with a plug and play manner. In addition, for intelligent control, a problem is how a device can understand a message for control (e.g., command).

Technical considerations:

- o Remote control and management/maintenance of objects

Solutions for remote control and management without human intervention are required to support various kinds of intelligent applications/services using smart objects.

For example, IPv6 auto-configuration and multi-homing features are useful for the autonomics. The scope-based IPv6 addressing features are easily applied for self-configuration such as smart building and smart grid.

#### **4.13. Constraint objects**

Like the Full-function device (FFD) and Reduced Function Devices (RFD) in sensor network, the objects of IoT should be classified in viewpoint of functionalities.

For constraint objects which do not have enough power, memory, computing, to develop lightweight protocols for minimizing energy consumption is essential. However, these protocols do not have enough capabilities compared to conventional protocol which is running on always-on devices with enough power.

Technical considerations:

- o Coordination among constraint objects

Through the collaboration of objects with full functionalities, required capabilities can be provided to constraint objects.

- o Energy efficient protocol for constraint objects

Energy efficient communication mechanisms are essential. Active and sleep mode operation can be a possible solution.

#### **4.14. Web Services**

Each object may be identified through the web services. It means that the object should be identified by the URL/URL. For web of objects, it is required to invent technologies for leveraging real-world object exposed using Web on the Representational State Transfer (REST) interface.

Technical considerations:

- o Light-weight Web protocols

#### **4.15. Various volumes of data traffic**

Depending on application and use cases there is variance in data volume. In a scenario where there is brief collaboration among objects data volume will be less. However, in case where there are large number of objects and interact among very frequently there are large volume of data.

Technical considerations:

- o Efficient processing of data traffic with different granularities

How to handle various volumes of data traffic is one of the important challenges. From network perspective it is difficult to handle bulk amount of data if objects produce huge bytes of data regularly or irregularly. In addition, if the number of object in a network significantly increases, it also causes traffic congestion. Solution can be periodic communication between objects or some data compression, aggregation and optimization techniques.

## **5. Architectural implications**

This document has explained the concept of the IoT and several features of the IoT. In addition, this document has specified problems considering technical issues for the IoT.

Based on this, it is required to find possible solutions for each problem. It would be a good starting point to consider a new architectural framework in order to solve problems. Thus, various issues on the architecture for IoT are discussed in this section.

### **5.1. Vertical vs. Horizontal**

From technical problems for IoT, the current standards should require extension of the architectural principles of both vertical (from link/physical to service/application) and horizontal (one object(user) to other object(user) through local networks as well as global Internet infrastructure) perspectives.

In the vertical aspect, more studies should require in networking capabilities for control and operation of various services over complicated stacks of different layer technologies. In horizontal aspects, further enhancements of user-centric communication capabilities should take into account the complex user situations including various devices connected to home networks and various access technologies which support convergence. These capabilities are necessary to support the ubiquitous networking to provide seamlessly interconnection between humans and objects for Any Services, Any Time, Any Where, Any Devices and Any Networks.

### **5.2. Architectural considerations in the service perspective**

In the service perspective, a target goal of architecture design is to support various applications using a common communication infrastructure. For this, service oriented architecture, open service platform and overly networks are considered.

- o Service oriented architecture

Objects are becoming smarter with the continual augmentation of communication and computing capabilities. Service Oriented Architecture (SOA) based programming, which was initially used for complex, and rather static business data sharing can now be used for small objects [9]. Objects can offer their functionalities using the Simple Object Access Protocol (SOAP) or the REST Application Programming Interface (API) based approaches [10]. This allows objects to interact dynamically. Devices that provide their functionality as a web service can be used by other entities such as business applications or even other devices.

- o Open service platform

Open service platform is required for promoting integrated and interoperable IoT services while easily interworking with existing service platform based on open standards.

- o Overlay networks (Service overlay)

For deployment of abstract services, logical networks on top of a physical infrastructure are created. These networks have an overlay topology that logically interconnects all the participating nodes/objects in the physical network.

### **5.3. Common infrastructure in the networking perspective**

In the networking perspective, common infrastructure should provide scalable, interoperable solutions to support abundant of communicating nodes/objects.

- o New concepts of networking

For stimulating interactions among connected objects with efficient way, new concepts of networking are also required. We need to investigate feasibility of those technologies. The followings are some examples:

- User-centric networking
- Data-centric networking
- Content(Information)-centric networking

- o Interoperable end-to-end model



TBD

o Integrating of smart objects

Common infrastructure for IoT should provide functionalities for integrating of smart objects.

## **6. Security Considerations**

TBD

## **7. IANA Considerations**

This document has no actions for IANA.

## **8. References**

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TBD

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