

# Interoperability as a Catalyst and Challenge for the Development of Internet of Things

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## Abstract

*Interoperability is the capability of two different devices and networks to communicate with each other for the exchange of important information. Today, smart things and objects are driven by the Internet in which individuals, businesses and government rely on technology and devices to improve daily life, efficiency and increase security. In this context, the Internet-of-Things (IoT) is a communication paradigm which aims to bring forth an invisible and innovative framework to connect a plethora of digital devices with the Internet. Thus, it intends at making the Internet more immersive and pervasive but interoperability between devices from different domains is a major barrier in IoT success. In this paper, we devise a taxonomy to best bring forth interoperability perspective in IoT, highlighted synergies to promote IoT in the context of smart cities and identified that interoperability among different standards and communication technologies is still a significant challenge. The paper also proffers solution to unlock the barrier of interoperability issues for the development of IoT in other to give future research direction.*

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**Keywords:** *Internet-of-Things (IoT), Smart City, Open Source, Interoperability, Protocol, Device.*

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## 1.0 INTRODUCTION

The Internet of Things (IoT) is an emerging technology in a broad range of domain that was first coined by Kevin Ashton in 1999. However, Atzori, (2010) and Gubbi, (2013) defined IoT as the connection of physical things such as objects and places via the Internet. It is a paradigm that defines a technological revolution where physical and virtual things would be connected to other things and to the current internet infrastructure. The benefit of the Internet of Things (IoT) is that it will make businesses more cost efficient, government more productive, and our lives simpler. It is a novel cutting edge technology that proffers to connect a plethora of digital devices endowed with several sensing actuation and computing capabilities with the Internet thus enabling smart city initiatives all over the world. The problem statement is that with the concept of smart cities gaining traction across the globe, there are a number of challenges. There are countless IoT technologies emerging that offer much promise for what can be achieved and by connecting all of these smart devices, systems and sensors together, much of a city infrastructure can be automated to offer seamless communication and services. In other to overcome the biggest challenge being faced now to a global implementation of an integrated citywide IoT network, which is not one of investment, rather one of the interoperability between the various devices and systems in use. Interoperability is the ability for unique devices such as home monitoring system, network devices

and smart phones, to share data and interact with one another. IoT interoperability can be defined as the ability of two systems to communicate and share services with each other (Kiljander et al, 2014). In this paper, our focus is to examine why the interoperability in IoT has emerged as a catalyst and major challenge for the development of the Internet of things IoT and proffer solutions on ways it can be addressed.

## 1.1 BACKGROUND

Lake et al (2012) stated that the IoT connects sensors and devices that record physical observations to applications and services of the Internet. The Internet of things is a combination of spatially distributed smart objects which have sensing capabilities and embedded identification through radio frequency identification (RFID) technology. Specifically, the integration of sensors, RFID tags, and communicating technologies forms the underpinning of IoT. It addresses the traceability, visibility, and controllability of smart objects. Hence, in terms of communication protocols, data formats and technologies, IoT devices are highly heterogeneous and interoperability remains a significant burden to the developers of Internet of Things' systems. Thus due to lack of worldwide acceptable standards, interoperability tools remain limited. Despite efforts to standardize the way IoT hardware is configured to ensure interoperability, problems still exist with some manufacturers not adhering to the guidelines. The issue with the current state of interoperability in IoT is that the market is very fragmented, especially due to incompatibilities between brands, and a common effort is needed to reach common standards for communication. Hence, in this paper we are also creating the awareness and need for synergies because the philosophy of IoT is to create a world in which millions of devices are able to communicate with each other in the best and widest possible way, without technical or commercial limitations, in order to make our lives a little better.

a) **INTERNET OF THINGS:** IoT offers numerous services which are of great interest in the context of smart cities to not only improve the quality of human lives, but also leverage the city administration by reducing the operational costs (Zanella, 2014). Major offerings include waste, water management and smart lighting. For instance, smart IoT modules can be deployed within homes, workplaces and grid stations, for distributing and consuming energy efficiently. In e-healthcare, IoT devices can be positioned on the body of patients for monitoring health parameters such as temperature, pulse rate, sugar level, and provide opportunities for doctors to regularly monitor their patients. Besides, urban IoTs can provide solutions to control traffic congestion through monitoring of traffic intensity either using GPS (Global Positioning System) services in modern vehicles or using wide area networks (WANs).

b) **INTEROPERABILITY:** Interoperability is the capability of two different devices and networks to communicate with each other for the exchange of important information. Smart cities include IoT devices from a diverse range of domains, e.g., smart metering, e-healthcare, logistics, monitoring, and intelligent transport. In a smart city, interoperability plays a vital role to provide connectivity among devices operating with different communication technologies. For example, smart metering uses wide local area network (WLAN) technologies as the under laying communication protocols while the intelligent transportation systems mainly utilize dedicated short-range communication (DSRC) and mobile technologies for communication. According to World Economic Forum Report (2015), interoperability between devices from different domains is a major barrier in IoT success due to lack of universal standards.

c) **SMART CITY:** A smart city is a complex ecosystem characterized by the intensive use of Information and communication Technology (ICT), aiming at making the cities more attractive, more sustainable and a unique place for innovation and entrepreneurship (Gubbi et al, 2013). The major stakeholders include application developers, service providers, citizens, government and public service providers, research community, and platform developers. Furthermore, the smart city cycle consists of numerous ICT technologies, development platforms, maintenance and sustainability, Apps for evolving citizens, and technical, social as well as economic key performance indicators (KPIs). Consequently, IoT systems will play a fundamental role in the deployment of large scale heterogeneous infrastructures.

## 2.0 RELATED LITERATURE

The fundamental for realizing the vision of a global IoT is interoperability. The importance of interoperability cannot be over emphasized, like mentioned earlier, Internet of things (IoT) is a future vision through which physical and digital objects can be interlinked and intercommunicated to provide some domain specific services to drive smart cities. Research efforts have been made to integrate IoT with smart city environments. Nathalie et al (2012) proposed a perspective of interoperability of smart cities in which IoT devices were considered service providers mimicking cloud based services. The proposal offered a higher level of abstraction to deploy innovative ubiquitous applications by eliminating the barriers between physical IoT devices and logical (cloud service providers) worlds. In contrast, Zanella et al (2014) presented a comprehensive survey of the architectures, protocols and enabling technologies for a web-service based IoT framework in the Padova smart city project.

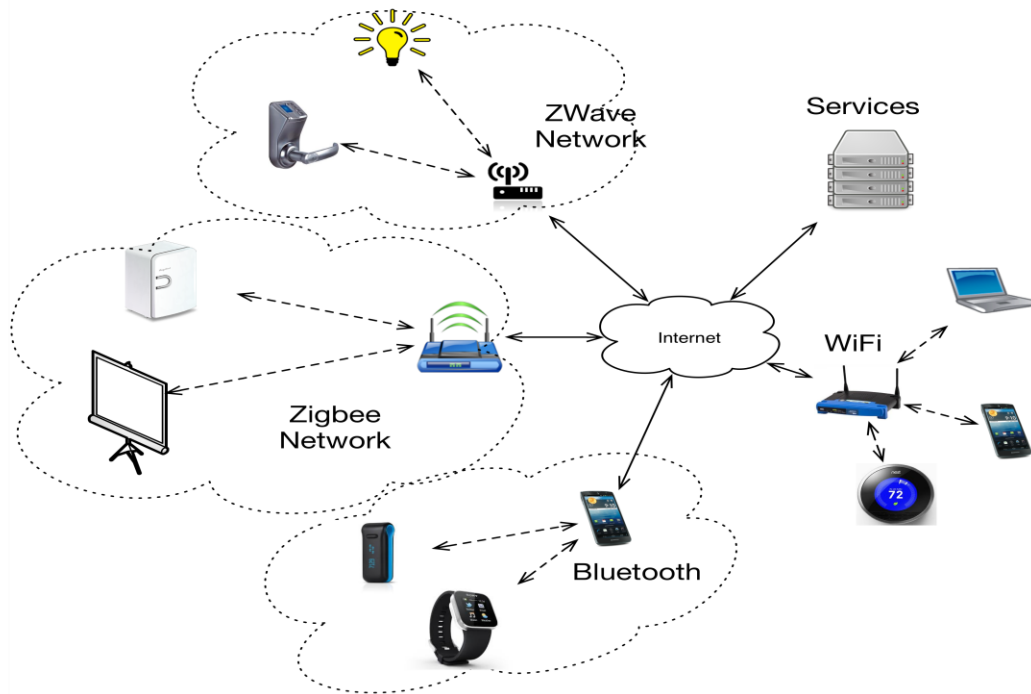
In another perspective to offer IoT convergence, interoperability and acceptance of numerous ICT technologies for realizing smart cities, Ganchev et al (2014) proposed a generic top down smart city architecture in which service providers play a role of central information unit that is connected to a set of IoT based services.

However, in IoT, one vital issue is interoperability among smart objects that is the ability to interconnect and communicate different vendors' systems to form a cost effective and easy to implement network. But there are still challenges because the IoT ecosystem needs interoperability to create a seamless configurability of the various devices or sensors or products to connect and collaborate with each other. Gazis et al (2015), give a short overview of the challenges of IoT including semantic, technical interoperability and smart things. Although several studies exist on IoT and smart cities, convergence of these two areas grants further academic efforts for flourishing of IoT-based smart cities.

## 3.0 THE METHODOLOGIES OF IOT INTEROPERABILITY

The use of common information models and techniques for IoT interoperability exists. For instance, in an IoT sensor network communication or IoT system is designed using one of the popular low level standard technology like Zigbee, Bluetooth Mesh, Z-wave, WiFi, etc for devices to collaborate with each other. This has made multiple devices bound to different protocol/technology over a period. One of the current IoT challenge is to add a new device in an existing network that

is having a different communication protocol to collaborate compared to the existing device network. The power constrained sink node is a technique to connect the physical world objects which require efficient networking protocols (Pratikkumar et al 2015). The IoT domain is scattered between various low power networking protocols (ZigBee, ZWave, and Bluetooth), traditional networking protocols (Ethernet, WiFi) and even hardwired connections. Figure 1 shows IoT low power networking protocols with traditional devices associated with them.



*Fig 1, An Exemplify IoT Network Architecture*

*Source: Adopted from Pratikkumar et al, (2015). Semantic Gateway as a Service Architecture for IoT Interoperability.*

From the Figure 1, these protocols are designed for domain specific applications with distinctive features. Solving interoperability issue at this level requires standardization at the hardware level.

Other methods of interoperability of the devices can also be examined from the aspect of:

- a) *Semantic Interoperability*: this is concerns with the human interpretation of the contents.
- b) *Syntactical Interoperability*: here the messages transmitted by communication protocols need to have a well-defined syntax and data formats (like XML extensible markup language).
- c) *Technical Interoperability*: hardware/software components, systems and platforms that enable common machine-to-machine communication. This is mainly on protocols and the infrastructure needed for the protocols to operate.

Current interoperability methodologies are multiple, for instance, different types of connectivity protocols and devices; multiple interoperability standards like OneM2M; multiple group creating the interoperable service platform for IoT. There are also some developing interoperability solutions by adopting standards and open-source development with the objective to improve IoT standardization.

### 3.1 IOT INTEROPERABILITY TAXONOMY

Issues of interoperability can be seen from different perspectives due to heterogeneity. In physical world there are many types of heterogeneities. For instance, people speak languages not similar but they still communicate with each other through a translator or using common language. Similarly, diverse elements comprising IoT (communication devices, applications and services) should seamlessly cooperate and communicate with each to realize the full potential of IoT ecosystem. The classification of interoperability in IoT is devised from different perspectives to: device interoperability, network interoperability, syntactical interoperability, semantic interoperability, and platform interoperability as shown in Figure 2.

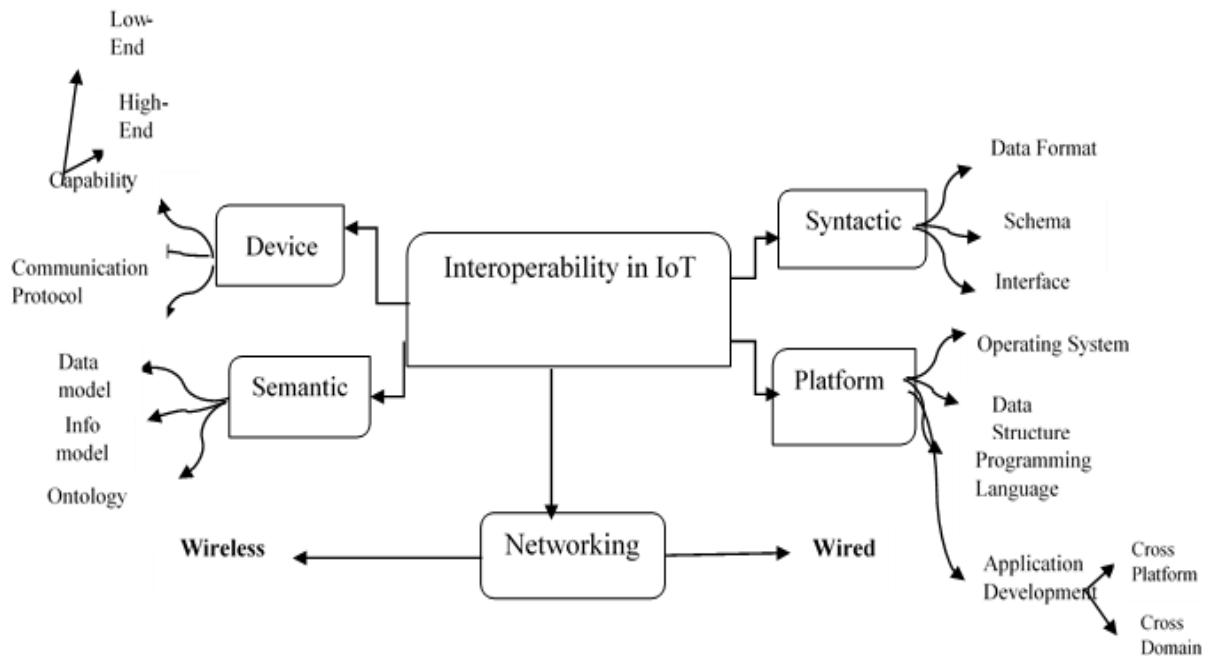


Fig 2, An IoT Interoperability Taxonomy

a) *Device interoperability*: the device called smart objects/things, may consist of *low-end devices* or *high-end devices* or (Hahm et al, 2016). The *low-end IoT devices* are resource-constrained in terms of energy, processing power and communication capabilities than typical hosts such as RFID tags, tiny and low-cost sensors, and actuators, Arduino, and OpenMote to name a few. On the other hand, the *high-end IoT devices* have enough resources and computational capabilities such as Raspberry Pi and smartphones.

*b) Network interoperability:* the networks that IoT devices will be operating on will continue to be heterogeneous, multi-service, multi-vendor and largely distributed. Different from desktop computers, IoT devices generally rely on various short-ranged wireless communication and networking technologies which is rather more intermittent and unreliable (Hahm et al, 2016).

*c) Syntactical interoperability:* this refers to interoperation of the format as well as the data structure used in any exchanged information or service between heterogeneous IoT system entities. The messages transmitted by communication protocols need to have a well-defined syntax and data formats (like XML, etc)

*d) Semantic interoperability:* the W3C defines semantic interoperability as “enabling different agents, services, and applications to exchange information, data and knowledge in a meaningful way, on and off the Web” (W3C, 2019). It concerns with the human interpretation of the contents.

*e) Platform interoperability:* issues in IoT arises due to the availability of diverse operating systems (OSs), programming languages, data structures, architectures and access mechanisms for things and data.

From the forgoing classification, it is justifiable to note that interoperability is a catalyst devices require for operability for the following reasons: so that consumers will not worry if one device will talk with another, so manufacturers have future-proof technology investment, and application developers can imagine and design apps for the largest possible ecosystem of compactible devices.

#### 4.0. CHALLENGES INTEROPERABILITY POSES TO IOT

Today, a major challenge is that the disincentive technology giant e.g Apple, IBM, Microsoft, Google etc have to create interoperability in which open standards undermine the competitive advantages they are each trying to create. Each of these companies have the money and plans supporting their individual, equipment, propriety operating systems, and protocols. To build bridges, standard with other systems will lessen their differentiation.

Every day, IoT device is installed in its ecosystem and platform: the smartphone running on the Android operating system cannot interact with the smart access control system powered by iPhone operating system (iOS) without a proprietary gated app developed by the brand, this a challenge. For IoT to flourish, there must be free exchange of information and functionality.

While emerging vendors are working towards full interoperability, this remains a challenge for mass consumerization of IoT. Today, although many things can interact with each other, the reality remains that interoperability in this early phase remains barrier because, resource-intensive and proprietary are largely controlled by vendors. Few tech giants are working together to solve this because it undermines their proprietary assets, namely data and user base.

#### 4.1. SYNERGIES AND INITIATIVE TO UNLOCK IOT BARRIERS

Addressing these challenges is essential to unlocking the full potential of Internet of Things. The academia and industry have emphasized the importance of interoperability in IoT. The industry attempts to address IoT interoperability challenges through standardization. Several efforts have emerged to establish standards by providing interoperability between IoT devices, network services, data format owned by different providers. The European Union has also recently funded several research projects under the H2020 program focusing on the federation of IoT platforms.

Other initiatives to support interoperability in IoT include but not limited to the following:

- a). Industrial Internet Reference Architecture (IIRA), created in 2014 by some of the main operators in the market and focused on industrial IoT applications.
- b). IEEE P2413 – Standard for an Architectural Infrastructure for the Internet of Things, a standardization project aimed at identifying similarities in IoT environments as diverse as intelligent buildings, intelligent transport systems or healthcare.
- c). A European Union EU project, called Iot-A, created to develop architectures that can be applied in different domains.
- d). The open source initiative called IoTivity, with over 300 members, including leading companies in the sector, which is aimed at guiding and promoting cooperation between companies and developers.

It may, however, take a long time before the related standards are fully agreed upon and accepted. To resolve this issue, researchers in both academia and industry have been developing a list of innovative solutions for interoperability and heterogeneity in different IoT systems.

## 5.0. CONCLUSION

The Internet of Things is growing, and interoperability has become an imperative. This paper identified that interoperability is a major challenge to the success of IoT in evolving seamless society. We devised IoT interoperability taxonomy based on different perspectives to: device interoperability, network interoperability, syntactical interoperability, semantic interoperability, and platform interoperability for the understanding of the reader. We noted that common models and techniques for IoT interoperability exist as interoperability is a catalyst devices require for operability. Initiatives to promote IoT and synergies to unlock the IoT barriers are unearth. Specific challenges were identified and to surmount these challenges we conclude that the way forward is a collaborative, standards-based approach in which millions of devices are able to communicate with each other as the future development of IoT will to a large extent depend on improved interoperability.

## 6.0. RECOMMENTATIONS

Regardless of make, model, manufacturer, or industry, there is need of a consolidated common standard that makes devices communicable and operable. Therefore, it is essential for development of intermediate tools called mediators to improve interoperability between IoT devices, in other to

bridge between different specifications, data, standards and middlewares. Leading technology developers and manufacturers should set generally accepted standards.

To unlock this barrier of interoperability, different levels e.g., device, network, communication, application and platform issues should be identified. To address these issues, an intelligent and holistic approach is required to provide connectivity to billions of IoT devices. For instance, standardization of one M2M and FIWARE is a major step in overcoming the interoperability issues with the collaboration of world's largest standardization bodies such as ETSI, 3GPP, and OMA.

To achieve multi-vendor interoperability, open source implementations will play a vital role for sharing information. Open source is software with publically available source code, so anyone can rewrite or adapt the code. Open source has been indispensable to the growth of IoT because when software is written in the same publically available language, it makes it easier to develop devices that interact.

Finally, research efforts should focus on the interoperability perspective such as device, network, syntactical, semantic, cross-platform, cross-domain and interoperability approach of openness, connectivity, application protocols, and security/privacy metrics in addressing interoperability challenges.

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