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# Selecting Network Protocols for Internet of Things Based Upon Innovation and Knowledge Management

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**Abstract**

Network connectivity is believed to be the backbone for Internet of Things and it plays a very dynamic role on how Internet of Things applications are designed. In the current scenario there is a wide range of different standard network protocols available including Bluetooth and Bluetooth LE, 6LoWPAN, 3GPP, LTE, IEEE 802.15.4, to ZigBee, etc. and they help to define how the devices, or the physical objects communicate with each other and to the cloud or to the gateway device. Further, there are lots of drivers for selecting the most suitable wireless protocol, at one end there is technological push to invent innovative solutions and on the other side there appear customer demands for enhancing the Internet of Things applications. The aim of this paper is to propose a rich network design space based upon the innovation and knowledge management techniques which will help the users to select the desired wireless protocol from the different available technologies to fulfill their Internet of Things application requirements. The design is divided into three-dimension space and all the standard protocol options can be studied or realized based along these three axes – battery life, duty cycle and device to gateway distance. The result of the paper is an innovating design with very interesting combinations of network protocols that will provide different options for the designers to select the desired technology based upon the requirements of their Internet of Things application.

## Background

Internet of Things can be defined as a network of smart devices or objects which either have sensors (embedded or external mounter) or built-in wireless connectivity, actuators, and any other mechanism that can collect and transfer the information to the network in cloud [1-4]. McKinsey Global Institute estimates by the year 2025 the potential economic impact of Internet of Things on the global economy might be as high as USD 6.2 trillion [5]. Major multinational companies like ABI evaluates that there would be 450 million Internet of Things connected cars, GE claims the GDP could reach USD 10 to 15 trillion and Cisco expects a higher GDP growth to USD trillion by the year 2035 [4-6].

One of the prime technological drivers or the backbone for Internet of Things is wireless communication and networks [7,8]. The network connectivity for Internet of Things enabled devices and objects are a very recent and innovating field for the developers and the engineers. This creates lot of interest and confusion at the same time on how to develop and design Internet of Things network technology. Lessons learned from the past, is that there is immense knowledge and great understanding on how to design, manufacture and troubleshoot the network technologies for the devices like the computers, servers, smartphones, etc. These network protocols are very standard, and developers are now working on innovating ideas to evolve these technologies for Internet of Things networks. These new patterns and trends provides new insights when compared to the data from the knowledge management cycle and eventually it is saved as a new knowledge data. The Knowledge management is a continuous and real time knowledge updating process [7].

In today's world, Internet of Things connectivity has numerous wireless protocols that are available in the market [6]. Figure 1 above, gives a flavor of the Internet of Things connectivity soup. This builds lot a misperception among the standards committee left alone the confusion for the corporation or the end customer to choose which technology will survive the longest. There is no one answer here, as some of these protocols are excellent technologies and can provide high performance and others can provide great user interfaces [2]. To make the decision even more difficult there are also many diverse commercial products or recent standard proposals out in the development or with the research review committee.

## Methods

The authors of the paper used innovation and knowledge management techniques for the purpose to make the organizations become more innovative, agile and adaptive. The goal is for the developers, companies, users, and customers to select the best network protocols which will work on their different Internet of Things devices and at the same time make them truly digitalized. Using the domain knowledge about the standard network technologies, we created operational processes which is driven by innovational and scrum methodologies and it helps to collect, analyze and share the information across all the Internet of Things networks or ecosystem. Sensors and embedded technology enables the real time data flow through the wireless networks and creates of new real time knowledge on regular bases and increases the knowledge management database. Further, it provides lot of opportunities for innovation by better understanding the different available knowledge platforms [7].

The method proposed for selecting the Internet of Things wireless protocol is divided in to three key dimensional axes as shown in the Figure 2 below. On the x-axis is the battery life, the y-axis is the duty cycle of the data rate of the device and the last dimension which is on the z-axis is the device to gateway distance or the range. The proposed network design space can handle diverse complex protocols and

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**Figure 1:** Internet of Things connectivity soup (Caganova et al. [2]).

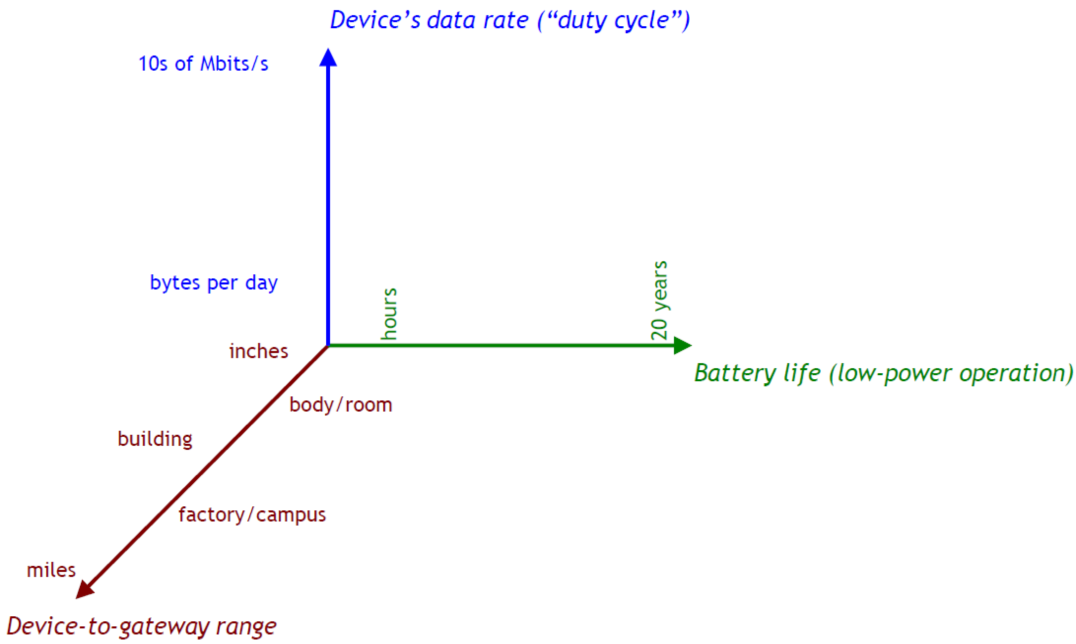


**Figure 2:** Three-dimensional network design space (Balakrishnan [1]).

simplify them in to a workable network design. This helps to compare different networks on a same chart and depending upon the application the designer can opt for the preferred solution.

The first dimension is the battery life and it really depends upon the operation of the technology. As shown in the graph above, on the left side there are powered devices which are not a concern as they are attached to the power source [1]. So far in Internet of Things scenario, the devices and sensors are attached to a power source, so the battery life is not that a big issue. Whereas on the other side of the graph, we have systems or devices which needs to run for 20 years or so, for example the sensors which are placed in a field to monitor the environment conditions like temperate, moisture, etc. Further, there is lot of other things in between like gateways, servers and other auxiliary systems which also needs to be considered. The achievement will be to build a system which can provide high battery life and sustain these time frames.

The y-axis is the data rate or the duty cycle of the devices. This means how much data are communicated between the devices and the servers (cloud network), between the devices and gateways or other peripheral devices [2]. The data is calculated by bytes per day of information exchange, on the lower part of the axes it could be few bytes per day per device and on the other extreme it could be gigabytes of data per day per device. Examples includes sending pressure rating of a device which is few bytes per day, however sending images or videos can be in gigabytes per day.

The third axis is the range of communication between the device and the gateway. The range varies a lot with distance. It could be few

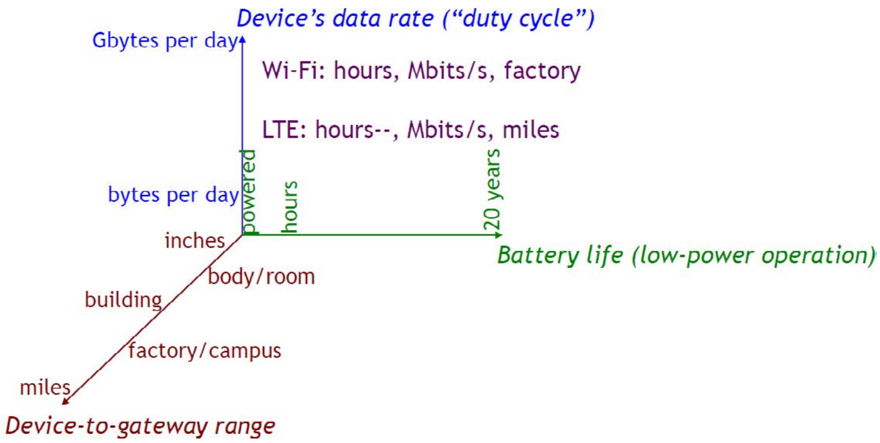


**Figure 3:** Three-dimensional design space for Wi-Fi and cellular technologies.

inches, paying at a cash counter using your smartphone or a room area network, where the devices needs to communicate within a building. Then there are far field communications which require kilometers long connectivity, for example – the device is placed in a forest which is measuring the environment conditions and the gateway is somewhere outside of the forest in a control room [1]. It is also important to note once the information reaches the gateway, we can run software to mediate and translate the data to the servers.

## Results

Using the knowledge acquired from the internet technology (IT) in the field of network connectivity there are so many protocols from Bluetooth smart, IEEE 802.15.4, 4G, LTE, Wi-Fi, etc. which does the same function of communicating the data from the devices to the servers [2]. Internet of Things can use the expertise in the wireless and the cellular network to build the backbone which implies to the Wi-Fi and the cellular technology (2G, 3G, 4G and the LTE). Both these technologies are widely available, can support high bandwidth, and there are already applications which are build around these technologies in Internet of Things. Comparing these technologies against the three-dimension design space provides the following results (Figure 3):

Wi-Fi uses megabits per second of peak data rate therefore it can run up to gigabytes of data per day. However, its battery life is for few hours only, further the technology ranges from the device to gateway fits to the mid-range communication which is typically within a campus or a building or a factory.

Like Wi-Fi, Cellular technology like 4G or LTE can get gigabytes of data per day. However, the date comes with a cost which is very expensive as compared to Wi-Fi when run over a long period. The battery life is also lesser that Wi-Fi and the range distance would come under the large field communication up to kilometers or miles of connectivity.

This provides very exciting combinations of regions when these protocols are placed in the three-axis design space. Furthermore, when comparing diverse standards against the design space, there was very interesting observations and results which arose like the three axes are not independent of each other, therefore for a given standard or a protocol it might run 100 kilobytes of data cycle per day and the batteries life might last for three years however if you run the same standard for gigabytes of data cycle per day, then the battery might only last for four to five days.

## Conclusion

In summary, there are many Internet of Things network protocols which are available in the market today. Using the experience and the knowledge gained with the innovated network topologies from Internet Technology (IT) it was comprehended that the developers cannot underestimate the effect of bundling technologies into popular devices. For instance, some protocols like Wi-Fi, Bluetooth Classic and Bluetooth Low Energy (BLE) did not prevail initially for couple of years and recently they became very popular. So, it helps to realize that the adaption rate of the technology can be spread throughout all the applications and it changes the whole economics. Further, technologies evolve fast especially with the network designs, so placing them on the three-dimensional rich design space helps to compare different protocols to best fit the customer requirements or end applications.

Considering the three-dimensional network design space, the different axes are not independent of each other and it clearly defines that there are many order of magnitude or ranges to fit the technology. So, in principle to look at the network connectivity, there is no single Internet of Things system or protocol which can scan around the entire range of these three dimensions. Therefore, there are two conclusions to be considered. First is to select any given or preferred technology or standard and place it on three axes model and see if it fits the requirements of the application or customer demand. Other conclusion is to think proactively awhile designing or deploying the Internet of Thing application and placing the requirements on three-dimension model and see what all standards or protocol meets the criteria and then select the best networking technology for the application. For the future development, selecting the protocol which could get embedded in to the common used devices like laptops, smartphone or other wearable devices will be the crucial factor as it will allow the companies and users to lot of options for integration.

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