

Internet of Things Interoperability

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Executive Summary

With the expected exponential, if not tetraponential, growth of the Internet of Things (IoT), estimated to exceed 50 billion by 2020, interoperability among these devices—with a myriad of hardware architectures, operating systems, software, middleware, firmware, and connectivity protocols—will be crucial. This paper discusses current state of the art in the IoT interoperability and briefly delves into what the future might bring.

1. Introduction

The IoT includes a wide variety of devices in diverse fields comprising billions of items (Figure 1); however, just connecting them is not sufficient. The real value lies in the potential of providing ability to find, access, manage, and (inter)connect things. The web is one place to exploit and tools like http, JSON, and RESTful web services will help. This is often called a *Web of Things* (WoT). How do we actually extract value from a WoT? Enter *IoT Hubs*.

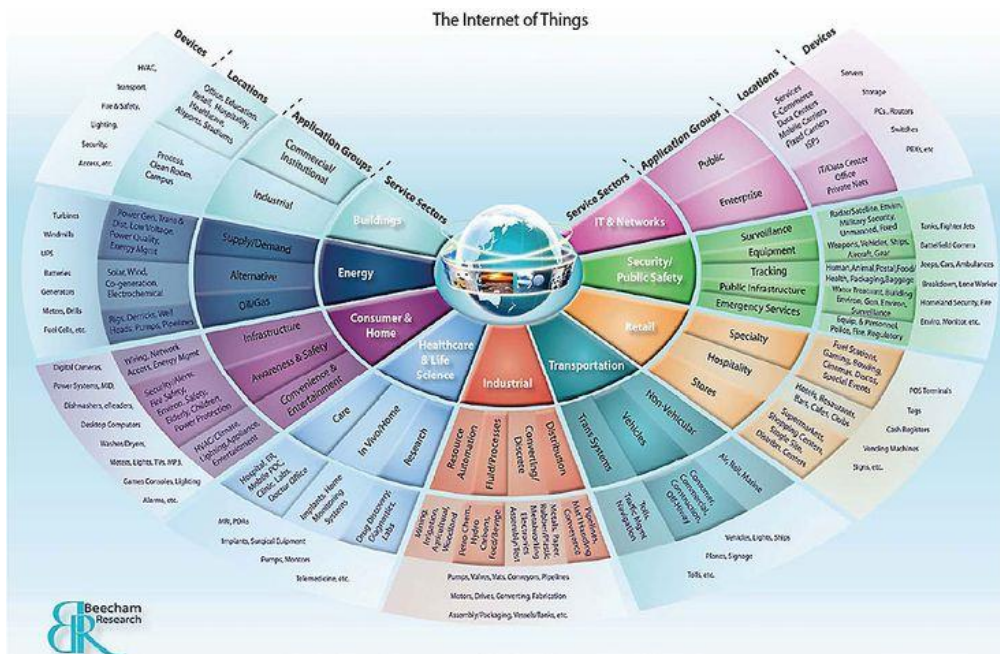


Figure 1. [Internet of Things](#)

2. IoT Hubs

An IoT hub interconnects various existing IoT systems and the IoT Hub API exposes both data and control features to third parties. Similar to the familiar hub-and-spoke architecture or an enterprise service bus (ESB), we could construct these IoT Hubs. The hubs could be general-purpose or product-specific that aggregate representation of things and their metadata, as proposed by Blackstock and Lea (Figure 2)¹. If they are product hubs, we could create hundreds of industry-specific hubs, creating islands of hubs. But this will present interoperability problems, unless standards are established. Figure 3 shows a smattering of vendor-specific, proprietary hubs and this is by no means exhaustive. How

¹ ["IoT Interoperability: A Hub Based Approach,"](#) Michael Blackstock and Rodger Lea, October 2014.



many of these hubs will thrive or just survive in the long run is anybody's guess. Another 'hub' worth mentioning is Amazon's [AWS IoT](#). This, again, is proprietary.

There are also quite a few open-source IoT middleware solutions that could be extended as IoT hubs. These include [EveryAware](#), [LinkSmart](#) (formerly Hydra), [OpenIoT](#), [The Thing System](#), [ThingSpeak](#), and [Thing Broker](#). Mineraud and Tarkoma provide an excellent review, albeit brief, of these products.² Berlin-based [Connctd](#) claims "to interoperate all kinds of devices, appliances, and internet services. With our revolutionary connection framework, we can guarantee a "works with..." promise across all connected devices and services." As we've discussed [before](#), while Industrial IoT will take off, there is still a lot of skepticism in Consumer IoT. For instance, Google purchased Revolv two years ago, following its purchase of Nest, but [discontinued](#) the product on May 15. In other words, as of May 15, 2016, your Revolv hub and app stopped working and Revolv owners were left holding the bag!

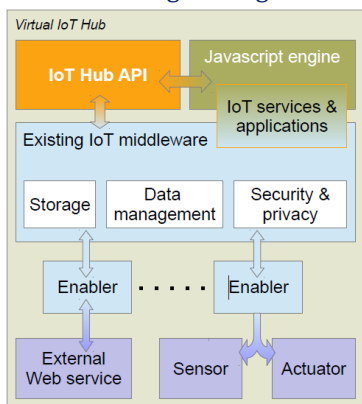


Figure 2. An IoT Hub Architecture³



Figure 3. Vendor-Proprietary Hubs

There are also a few alliances and consortia attempting to establish standards and address interoperability issues. These are listed in Table 1. The beauty of standards is there are so many to choose from! Which of these will dominate and survive in the long run? Those who invest time and money. Remember the Golden Rule: Those who have gold make the rules.

Another organization worth mentioning is the [Hypercat Consortium](#) founded by [Innovate UK](#). Because it was born in the U. K. most of its members are U. K.-based, although there are quite a few U. S. companies, including Accenture, Broadcom, Cisco, IBM, and Symantec.

IoT hubs are fine, but they can't support interoperability among heterogeneous hub platforms. Enter *Meta-hubs*.

² "[Toward interoperability for the Internet of Things with meta-hubs](#)," Julien Mineraud and Sasu Tarkoma, November 25, 2015.

³ *ibid.*



Table 1. IoT Alliances and Consortia (Founding date)

 (December 2013)	 (March 2014)	 (February 2016) (formerly Open Interconnect Consortium) (July 2014)
<ul style="list-style-type: none"> • Major Premier-level Members: Haier, LG Electronics, Panasonic, Qualcomm, Microsoft, Sharp, Silicon Image, Sony and TP-LINK. • Almost 150 members comprising Premier, Community, Ecosystem, and Sponsored 	<ul style="list-style-type: none"> • Founding Members: AT&T, Cisco, GE, IBM, and Intel • 237 members, as of February 2, 2016 	<ul style="list-style-type: none"> • Founding Members: ARRIS, CableLabs, Cisco, Electrolux, GE Digital, Intel, Microsoft, Qualcomm, and Samsung

3. Meta-hubs

Meta-hubs (Figure 4) may be defined as bridging pieces toward interoperability for hub-based middleware systems.⁴ They are a variation of regular IoT hubs with a few differences.

- They do not enable communication between the platform and smart objects, but store information about IoT hubs and the services that they published. This is akin to a [metadatabase](#).
- Meta-hubs include a catalog of applications and services based on the IoT Hub API and can be executed by the JavaScript engine, allowing applications to take advantage of using local feeds while extracting data from remote sources available through the meta-hubs. For example, imagine an aircraft jet engine with blades instrumented with strain gages and temperature sensors. The system can constantly monitor the strain and temperature of each blade and, if any anomalies compared to its neighboring blades are found, it can immediately notify so corrective actions can be taken before a major disaster occurs.

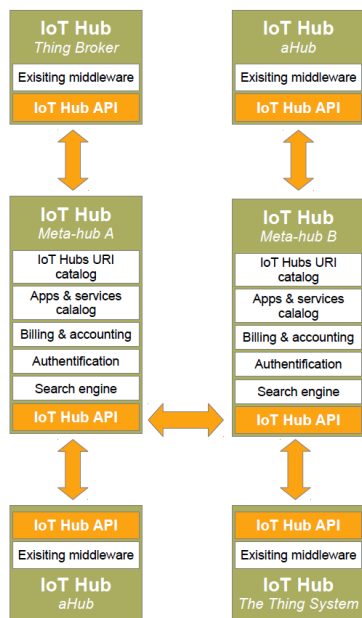


Figure 4. Network of IoT hubs including meta-hubs

⁴ *ibid.*



4. Future

The oft-quoted 2015 McKinsey Global Institute report⁵ on the IoT states “On average, interoperability is necessary to create 40 percent of the potential value that can be generated by the Internet of Things in various settings...Interoperability is required to unlock more than \$4 trillion per year in potential economic impact from IoT use in 2025, out of a total potential impact of \$11.1 trillion across the nine settings that we analyzed.” Although one research firm⁶ questions the dollar forecasts and is equally skeptical about the 20 billion to 50 billion devices forecast, the importance of IoT interoperability cannot be overemphasized.

We hope the various consortia and standards bodies will converge and agree to arrive at a standard that will be universally adopted by IT vendors, carriers, service providers, consumer-device makers, and the public sector alike. The last thing we want to see is UNIX-ification of the IoT. Remember at one time we had over 60 UNIX flavors in the market. Thanks to a [Benevolent Dictator](#), we now have Linux and two vendors—Red Hat and SUSE—[command over 90%](#) of the enterprise Linux market. We need a similar leader—a corporation or a visionary individual—to drive the standards effort. Otherwise, lack of interoperability standards can result in a REAL IIoT—*Inoperable Internet of Things!*

⁵ [“The Internet of Things: Mapping the Value Beyond the Hype,”](#) McKinsey Global Institute, June 2015.

⁶ [“20 Billion connected devices in 2020 is pie in the sky,”](#) Beecham Research Press Release, November 5, 2015.