Standardization in Industrial internet (IoT) and Condition-Based Maintenance

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1 INTRODUCTION

Industrial internet is a trend which will have a major impact on industry, business, societies and the way we work in the future. Standardization will play an important role in how fast the industrial internet technologies and the general approach will be taken into use; what kind of platforms and ecosystems will there be; who will be the winners in the change; and which domains and businesses will be the first to adopt new paradigm.

Industrial internet and IoT are topical matters at the moment but it is difficult to find an up-to-date study about the current state of the standardization related to them. This paper will give an overview on Industrial internet and IoT related standards and standardization. Also unofficial industry standards and their potential development and impacts are studied. The relevant standardization organizations are reviewed as well as emerging standards. The perspective of standardization is from Condition-Based Maintenance (CBM) perspective, although other aspects including wireless communications and networking are included.

Specific questions to be answered are: What are the most relevant standardization organizations and standards related to Industrial internet and IoT; Which standards are relevant in CBM; What is the current state and the future development of standardization?

2 INDUSTRIAL INTERNET AND IOT

Here, we use the definition by Industrial Internet Consortium: *"the Industrial internet connects smart machines and devices and people at work, leading to better decision making through advanced analytics that result in transformational business outcomes".* Industrial internet comprehends the non-consumer side of IoT and applies "internet thinking" in industrial settings. [7]

The concept, Internet of Things (IoT), has arisen to reflect the growing amount of smart and connected products and emphasize the new opportunities they can bring. What makes smart and connected products different is not only the internet but also the changing nature of them. It is their extended capabilities and the data they can produce. [16]

The IoT represents a vision where the internet stretches to the real world comprising physical items and every-day objects that are connected to the virtual world. Objects can physically act as access points to internet services and they can be controlled and monitored remotely. [12]

The most vital strength of the IoT vision is the extensive impact it will have on several sectors of daily life, see Figure 1. From private users' point of view, the consequences of IoT will be noticeable in domestic and working fields. From business users' perspective, the most visible effects will be in the fields such as, industrial manufacturing and automation, process management and business, logistics and intelligent transportation of goods and people. [1]

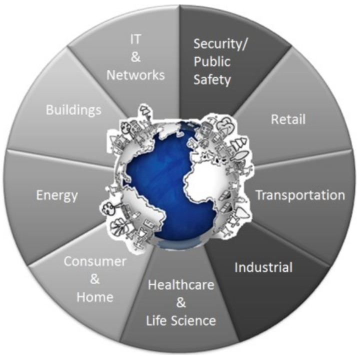

Figure 1. IoT – World of connected devices [13]

3 INDUSTRIAL INTERNET AND IOT STANDARDIZATION

Standards can bring benefits for technology, economy and society. They also have an effect to sustainability as they provide ways on the management of processes and the use of technologies influencing environmental, social, and economic aspects. Standards provide benefits in following respects: reliability and safety, support of legislation and government policies, interoperability, business benefits, and consumer choice. [17] [5]

Standards play an important role when developing the IoT and they are essential for allowing all players an equivalent access and use. Standards development and coordination will contribute effective development of IoT applications, devices, infrastructures and services. In today's network world, global standards are more relevant than local agreements. The IoT standardization is complex as it can include a variety of different standards, such as architecture standards, application requirements standards, communication protocol standards, information processing standards, data standards, identification standards, security standards, and public service platform standards. [3]

It is essential to have common standards for building a successful IoT ecosystem. Many evolving applications use their own standards and major standards are still under development. For example, Ubiquitous ID and EPC Global are two different and non-compatible ways for identifying items. Different technologies are typically committed to a single application and existing solutions are fragmented. Diverse standards and technical solutions will slow down the global development of the IoT. [4]

By creating commonly accepted standards, developers and users can implement IoT applications and services that can be deployed on large scale. At the same time, development and maintenance costs can be saved in the long run. Standardization can also speed up the spread of IoT technology and innovations. [19]

3.1 Standardization organizations

Standardization work of IoT is multidimensional and relatively complex. The aim of any technology-oriented standardization work is to provide specifications that address concerns like accomplishing interoperability between interconnected devices in a field with several suppliers and actors. Standards are developed for different industries and there is a variety of standardization organizations and bodies, both official SDOs (Standards Development Organizations) and special standards specifications developing interest groups, consortiums and alliances. [6] [2]

The amount of international and national standardization organizations is large, but the most relevant official standardization organizations for Industrial internet and IoT are ETSI, ISO, IEC and ITU. Besides these official bodies a number of unofficial alliances and forums play an important role. These include AllSeen Alliance, GS1/EPC Global, HART Communication Foundation, IEEE, IETF, IPSO, ISA, MIMOSA, OIC, OMA, Thread Group and many others.

3.2 Architectures

The diversity of IoT application areas has resulted into different requirements for IoT systems. The requirements differ significantly because of the heterogeneity of the domains. This has resulted into a variety of different IoT architectures with diverse set of components and functionalities, as well as varied terminologies. This, in turn, has led to limited interoperability between different systems and has complicated the development of the complete domain. Reference architectures are appropriate tools for addressing these issues and ensuring common understanding. Many IoT related projects, e.g. ETSI M2M, FI-WARE, IoT-A and IoT6, have specified their own versions of architecture based on different aspects depending on the scope of the project. [10]

3.3 Platforms

Software platforms have been attracting wide publicity in the IoT field and there are many platform providers competing in the market. Indeed, the software platform competition may become as conclusive as in the mobile communications business, where Google Android and Apple seem to have all but divided the market between them. There are several strong players in the platform competition such as Accenture, Axeda, IBM, Microsoft (Azure) and ThingWorx. However, it is not necessarily in the interest of the customer companies to have few platforms with rather closed interfaces on the market, instead their interest is to have open interfaces and lot of competition among platform providers.

3.4 Communications

Considering IoT applications there will likely be a combination of traditional networking approaches. On communications level several standards can be identified (Figure 2), including:

- **Power Line Communications (PLC),**
- **LAN (and WLAN)** via Ethernet (IEEE 802.3) or Wi-Fi (IEEE 802.11),

- **Bluetooth Low Energy (Bluetooth Smart),**
- **IEEE 802.15.4** including ZigBee and its recent derivatives ZigBee IP and ZigBee RF4CE, WirelessHART, ISA100.11a;
- **6LoWPAN** (IPv6 over Low power Wireless Personal Area Networks),
- **CoAP** (Constrained Application Protocol) and
- **REST** which is a simplification of the ubiquitous HTTP and hence allows for simple integration between them. [6]

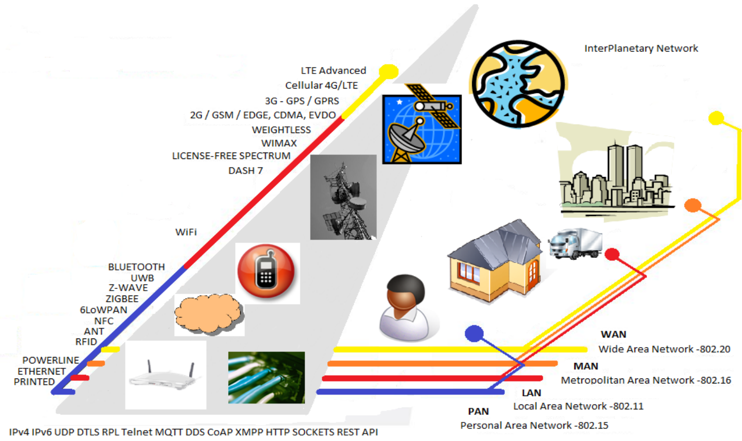

Figure 2. Communications standards [13]

4 CONDITION-BASED MAINTENANCE (CBM)

Condition-Based Maintenance (CBM) is a maintenance strategy that is based on the actual condition of the asset to choose what kind of maintenance needs to be done. In CBM the maintenance is done when particular indicators show signs of decreasing performance and upcoming failure. Condition data is collected with internal sensors either continuously or at certain intervals. Industrial internet and the technology improvements today are enabling better performing of CMB. Wireless connectivity, lower cost sensors and big data processing tools make it easier and cheaper to gather, store and analyze the performance data and monitor the equipment health. [18] [11]

Well performed asset management has become an expected normal practice in mature organizations. Asset management has roots as a named discipline in several industry sectors. Practices in asset management have developed from various sources, converging to increasing international consensus and formal standards, such as [18] [14]:

- **PAS 55,** specification for the optimal management of physical assets, aligns with the requirements of ISO 9001, ISO 14001 and OHSAS 18000,
- **IEC 62264** (enterprise-control system integration) based on ANSI/ISA S95,
- **ISO 15745** (industrial automation application integration framework),
- **MIMOSA** (Machinery Information Management Open System Alliance) - IEEE 1232,
- **ISO 13374** (condition monitoring and diagnostics of machines),
- **EN/IEC 60204** - 1 (safety of machinery),

- **OPC UA** specifications address the challenges in security and data modelling in service-oriented architectures in manufacturing systems. OPC is an interoperability standard for the reliable and secure exchange of data in the industrial automation space and in other industries [15],
- **ISO 15926** "Industrial automation systems and integration – Integration of life-cycle data for process plants including oil and gas production facilities [8],
- **ISO 10303** "Industrial automation systems and integration – Product data representation and exchange", also known as "STEP", is a standard for computer-interpretable representation and exchange of product manufacturing information [9].

5 DISCUSSION AND CONCLUSIONS

As the number of connected devices is rising and different products will be linked together in ways they might not have been done ever before, there certainly is a need for common standards and solutions. Our conclusion is that the standards on IoT and Industrial internet are just emerging.

At today's IoT field the products are targeted to specific vertical application domains, such as machinery or automotive, or to the horizontal consumer market, such as home automation and consumer electronics. The solutions are based on different co-existing protocols, platforms and interfaces, either proprietary or standard. Many emerging applications use their own standards and major standards are still developing. Existing solutions are fragmental and diverse technologies are dedicated to a single application.

Figure 3. shows an illustration of the current state and future development of Industrial internet and IoT standards in different layers. Part of the standards will be official, part de facto, agreed by alliances or forums or dictated by companies in decisive roles. This latter case is probably most likely in the area of software platforms in which there are many alternative designs available. Most likely there will be a few platforms that will become de facto standards and that form the dominant design.

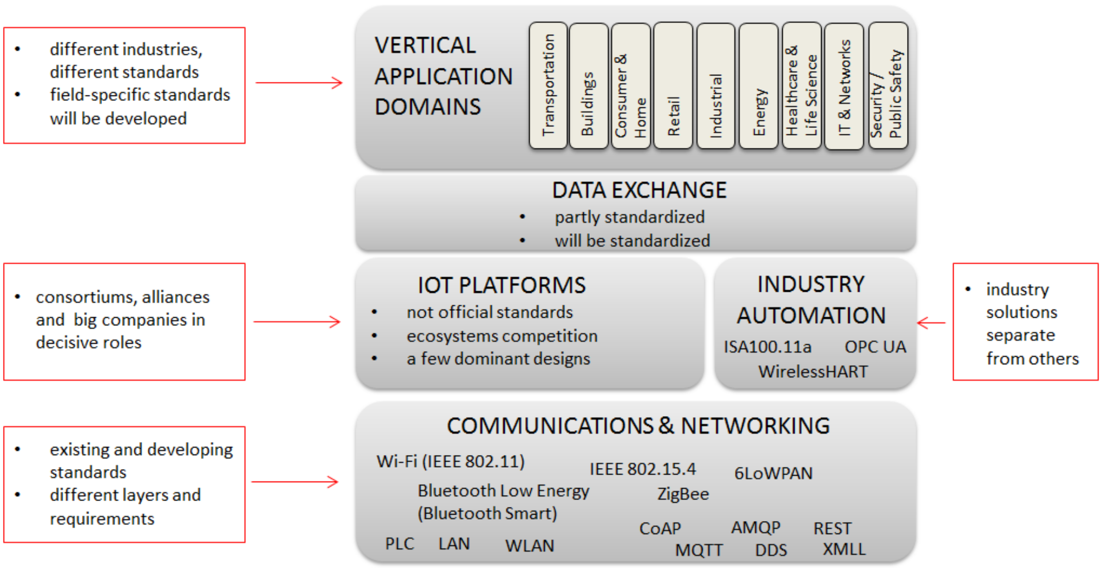

Figure 3. Standards in Industrial internet and IoT [13]

The strongest and most widely used standards will be on the lower levels of communication and application stack, i.e. in communications and networking, since there the benefits, e.g. interoperability are obvious and pressing while the advantages of proprietary solutions are small.

When considering the upper levels at "the stack" including data and semantic interoperability, software platforms and data-analysis, domain specific standards and even proprietary solutions will be more widespread because of both technical and business reasons.

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