

Supporting Internet of Things Activities on Innovation Ecosystems

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1. EXECUTIVE SUMMARY

Publishable summary

The report provides an overview of IoT platforms followed by a systematic analysis and concise description of the platforms and their features. The purpose is to analyse the IoT platforms both commercial and open source, while mapping the IoT use cases and applications around the platforms and presenting the factors that are relevant for the adoption of the platform. The analysis offers a comprehensive looking at all aspects of platform activity, from elements like communication capabilities, to the availability and quality of documentation, the ease of use of APIs, SDK environments and the use of innovation support events such as pit stops or hackathons to engage with platform adopters and potential platform adopters.

The remaining report is structured in seven chapters covering an overview of IoT platforms, their mapping into the IoT layered architecture, the description of the main functional components of IoT platforms, the IoT service model and the functional components of IoT platforms presented in Chapter 3. Chapter 4 offers an overview of the global IoT platform market starting by presenting the evolution of the market and the specific elements in different regional markets and concluding with a summary of market trends. The framework for analysis, the assessment methodology and the market reflections on leading platforms are described in Chapter 5. An overview and description of different types of platforms and their features are presented in Chapter 6 with the identification of three broad categories: commercial platforms of global industry players, SME/start-up, open source platforms and an additional group that includes the OneM2M compliant platforms. The commercial IoT platforms have evolved from the platforms developed in different sectors and are classified under four main categories: device, communication/connectivity, cloud and industry centric platforms. Chapter 7 offers an overview of the IoT platforms used by the IoT ecosystems that are created by the IoT-EPI projects, summarising the architectural mapping, IoT applications targeted by the IoT-EPI projects and a discussion on common challenges. The analysis in this report has looked on different technological and consumer/business/industrial approaches on the IoT platforms. These are addressing the heterogeneous sensing and actuating technologies, data ownership, security and privacy, data processing, data sharing capabilities, the existence of a community of developers/users and the support to application developers, the creation of an IoT ecosystem, and the availability of dedicated IoT marketplaces.

IoT platforms enable enterprises to monitor and control IoT endpoints, build applications to meet digital business requirements, and will be an essential element in the development of a digital single market. In the new digital economy, IoT platform ecosystems are the foundation for new value creation and the driver for developing new IoT applications. This requires architecting and developing IoT platforms that addresses the new technologies for communication, control, management and security of endpoints in the IoT to form a coherent architecture. The IoT Platform market represents a new dynamic segment that emerged few years ago, and as in any new markets, the landscape is complex and changing very rapidly. IoT Platforms are key for the development of scalable IoT applications and services that connect the physical, digital and virtual worlds between things, systems and people.

Non-publishable information

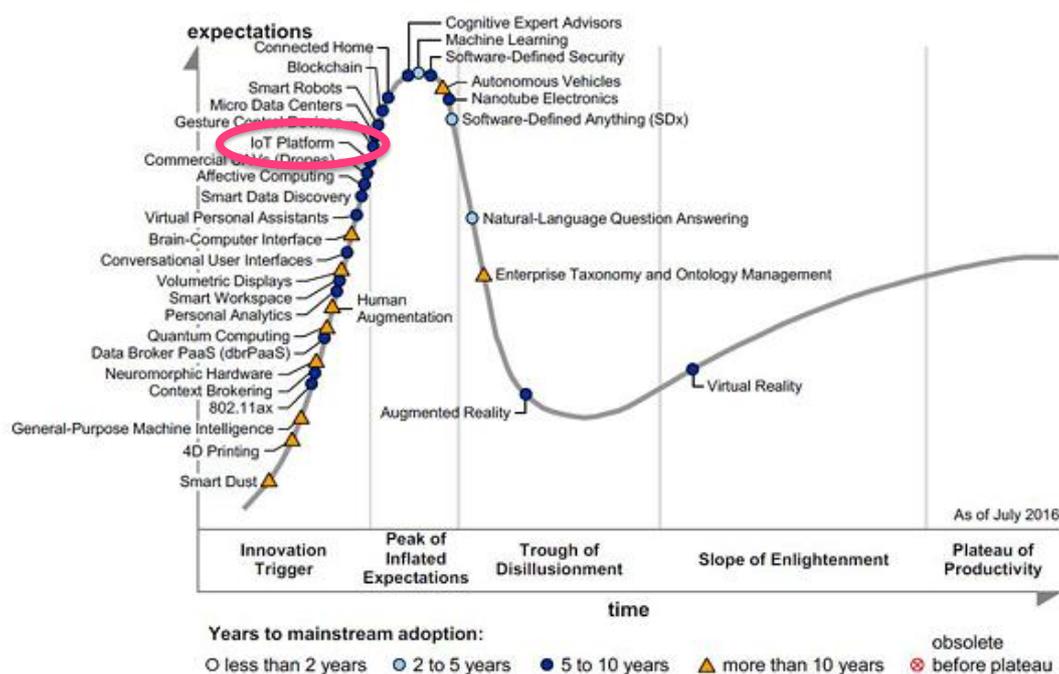
None.

2. INTRODUCTION

The IoT market has started to move towards action and companies are realizing that building end-to-end IoT systems from scratch is a tedious task and a big risk with many business cases still shaky and not clearly validated. With so much re-inventing the wheel happening at the same time in different organizations, the market has responded by generating a wave of companies that deliver out-of-the box solutions that encapsulate major parts of an end-to-end IoT system in repeatable and replicable building blocks that can be used in different vertical of the market. These solutions are known as IoT platforms.

IoT platforms enable companies to bring IoT solutions more rapidly to the market by cutting development time and expenses for IoT systems. By paying per use or for fixed licensing terms, the risk of failed investment is minimized.

As a result, IoT platforms have grown significantly in popularity, which the recent Gartner Hype Cycle shows (see Figure 1). However, the hype has led to a situation that can be described as a modern day IoT Babylon with more than 360 platforms on the market, as a leading IoT market research firm has recently found.



Source: Gartner (July 2016)

Figure 1: Gartner Hype Cycle 2016. IoT platforms are on the rise.

In this context, the European Commission has funded the creation of seven European IoT platform ecosystem, which form together the European IoT platform initiative.

The goal of these projects is to overcome the increasing market fragmentations by delivering solutions for IoT platform interoperability and demonstrating the benefit of the resulting interoperability in different real world pilots. The ambition that the projects have set is to develop these platforms into successful and thriving innovation ecosystems.

In this report, we aim to capture the current IoT platform landscape and provide the European research and innovation community and policy makers with some orientation in this fast-paced market.

2.1 Purpose and structure of the report

The report aims to unveil features and characteristics of the current IoT platforms market and describe in more detail the context in which the IoT-EPI projects are operating. More specifically, it aims to deliver the following insights about the broader market:

- How does the global IoT market look like in terms of IoT platform providers?
- Which platforms are currently perceived as leading on the market?
- What makes them more successful than others?
- What features do they offer?
- What protocols do they use and will be important ones to inter-operate in future with?
- How do they build successful ecosystems in terms of partnerships and developers?

The report also takes a closer look at the IoT-EPI project, in order to understand the underlying platforms of choice and how they align with the overall market.

This deliverable is organised in three main parts. The first part analyses the current companies offering IoT platforms on the market. It examines the geographic spread of IoT platform providers and classifies them according to company types, industrial segments covered, and at complementary technologies developed to support their platform offerings.

The second part provides a deep analysis of IoT platforms that we have identified as market leading, by combining and synthesizing a set of different sources. The list of platforms has been selected based on academic, business, and journalistic expert views on the current market. We adopted a cross-integrated set of sources for covering a wide as well as focused range of platforms.

The third part examines in more details the IoT platform activities of the IoT-EPI projects and contrast them to the current market situation. The report concludes with concrete recommendations for the research and innovation community as well as policy makers of how to navigate the fragmented IoT platform landscape.

2.2 Target audience

This deliverable is aimed to provide information to different stakeholders of the European IoT ecosystem. It focuses specially on following target groups: IoT European Platform Initiative projects, the European Commission, and more generally at companies and end-users that want to use IoT platforms.

The content of this deliverable is meant to provide the IoT EPI projects with a summary of the current market situation and potentials, in order to adapt and improve their own current and/or future works to the present IoT platform market. Namely, this document should support the different IoT EPI members to clarify and improve their strengths and reshape their strategy in response to the current market. Hence, the EPI members could adopt this document as a resource to reflect upon about what project actions could make their platforms more successful.

The document is also expected to meet the interest of the European Commission by providing a picture of the current situation of the IoT platform market. By describing current patterns and trends, existing gaps, and market strengths and failures, it aims to provide food thoughts for new areas where funding interventions may be desired.

Finally, we think the deliverable can provide some guidance to companies and businesses who require more orientation on the currently highly fragmented IoT platform market. In particular section 6 may be useful, where we perform a deep dive into more than popular 25 IoT platforms and their features, business model and ecosystem activities. It is important to note that this is not an exhaustive and extensive benchmarking exercise but merely a survey of currently popular IoT platforms on the market.

3. AN OVERVIEW OF IOT PLATFORMS

An IoT Platform can be defined as an intelligent layer that connects the things to the network and abstract applications from the things with the goal to enable the development of services.

The IoT platforms achieve a number of main objectives such as flexibility (being able to deploy things in different contexts), usability (being able to make the user experience easy) and productivity (enabling service creation in order to improve efficiency, but also enabling new service development).

An IoT platform facilitates communication, data flow, device management, and the functionality of applications. The goal is to build IoT applications within an IoT platform framework. The IoT platform allows applications to connect machines, devices, applications, and people to data and control centres.

The functionality of IoT platforms covers the digital value chain of an end-to-end IoT system, from sensors/actuators, hardware to connectivity, cloud and applications as illustrated in Figure 2. Different types of platforms have emerged.



Figure 2: IoT Platforms covering the data value chain

IoT platforms' functionalities covers the digital value chain from sensors/actuators, hardware to connectivity, cloud and applications.

Hardware connectivity platforms are used for connecting the edge devices and processing the data outside the datacentre (edge computing/fog computing), and program the devices to make decisions on the fly. The key benefits are security, interoperability, scalability and manageability by using advanced data management and analytics from sensor to datacentre.

IoT software platforms include the integration of heterogeneous sensors/actuators, various communication protocols abstract all those complexities and present developers with simple APIs to communicate with any sensor over any network.

The IoT platforms also assist with data ingestion, storage, and analytics, so developers can focus on building applications and services, which is where the real value lies in IoT.

Cloud based IoT platforms are offered by cloud providers to support developers to build IoT solutions on their clouds. Infrastructure as a Service (IaaS) providers and Platform as a Service (PaaS) providers have solutions for IoT developers covering different application areas.

PaaS solutions, abstract the underlying network, compute, and storage infrastructure, have focus on mobile and big data functionality, while moving to abstract edge devices (sensors/actuators) and adding features for data ingestion/processing and analytics services.

The functions offered for the IoT consumer/business/industrial platforms are presented in Figure 3.

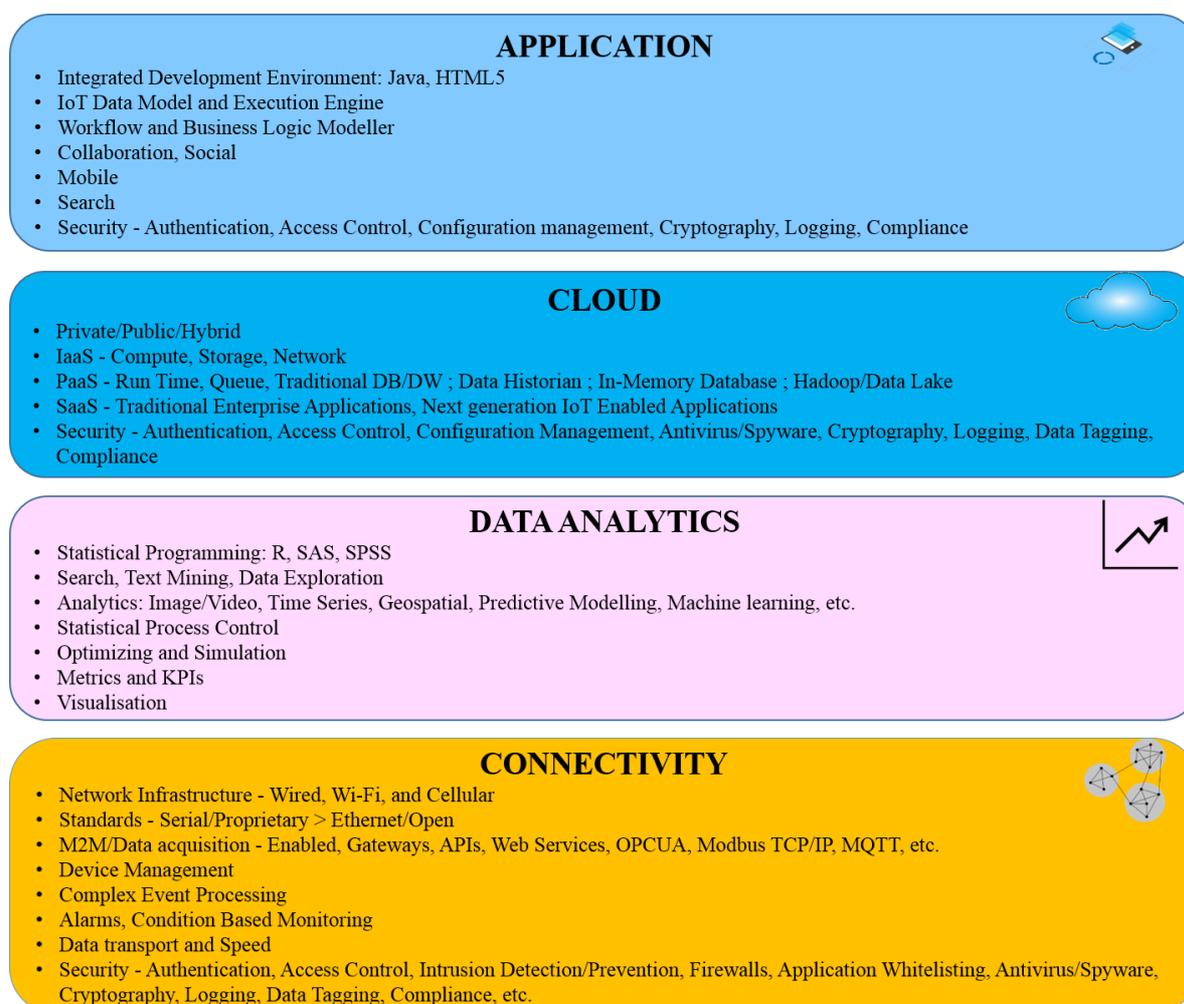


Figure 3: Implementation elements in the main areas covered by IoT platforms

The IoT Platforms provide a framework for categorizing the technology capabilities that are necessary to deliver connected things, operations, assets, and the enterprises.

- The four main blocks of capabilities presented in Figure 3 are: Connectivity that includes the hardware and software to network within the factory and the enterprise, standards for integrating machines, clouds, applications and the technology for managing devices, transferring data, and triggering events;
- Data analytics: including the use of a set of statistical and optimization tools to refine, monitor, and analyse structured and unstructured data for enabling different services;
- Cloud that integrate various types of cloud technologies across the enterprise to implement computing and storage capabilities (i.e. at the edge, within the factory, at the enterprise, or outside the firewall);
- Application area that integrates the tools for creating new mashup software applications that leverage the areas of the IoT platform.

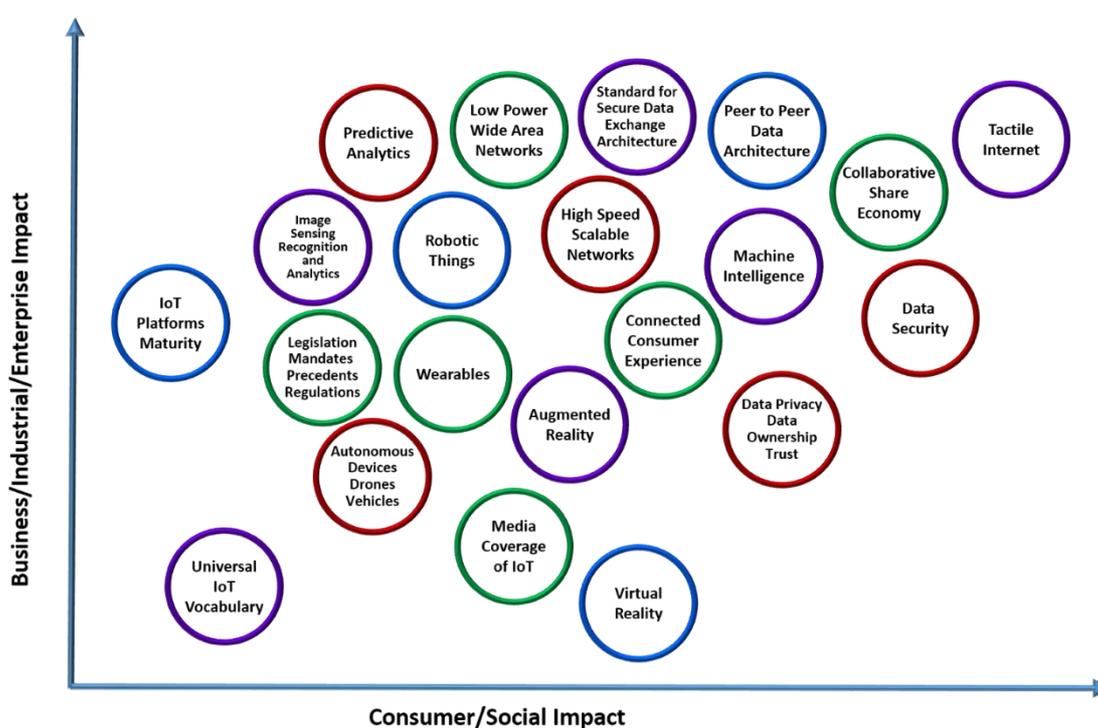


Figure 4: IoT platforms impact in IoT consumer, business and industrial markets

IoT platforms maturity has a high relevance for the business and industrial IoT markets where the requirements are high, while for consumer markets the impact is relatively low as presented in Figure 4 (impact of various technologies on the future IoT consumer/business/industrial markets).

3.1 IoT Layered architecture

The approach to define the functional elements of the IoT platforms in this section uses the eight layers IoT architecture presented in Figure 5 [1]. The IoT platforms used by developed and used by the IERC covers these layers and functional modules in different ways. The description of the elements and modules covered by the IoT platforms is presented in Figure 6.

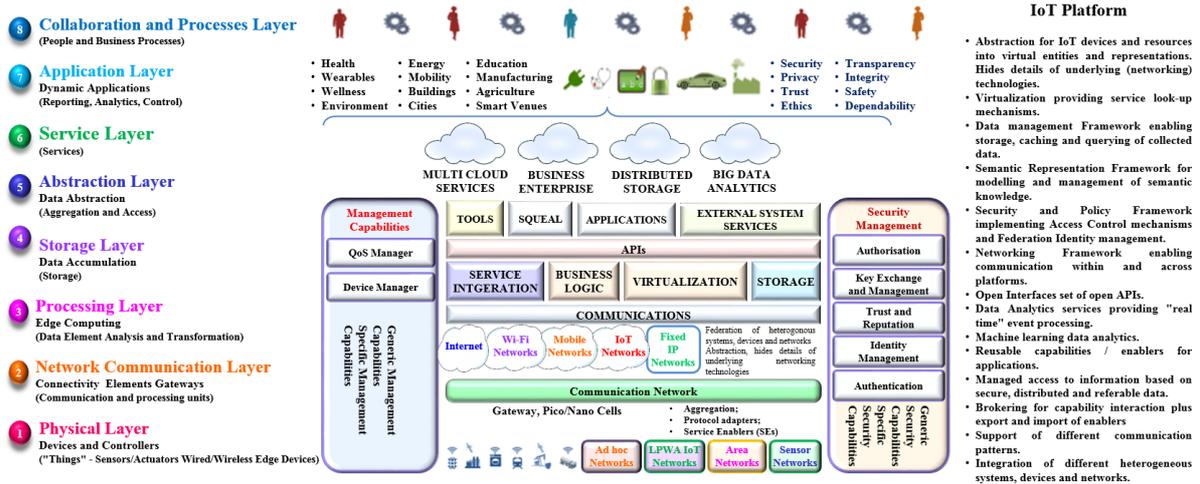


Figure 5: Eight layers IoT architecture

IoT platforms (i.e. software platforms, cloud platforms, and hardware connectivity platforms) are addressing and handling the complex data and events integration, protocol translations, and connectivity issues, in order that the developer focuses on the IoT application and business requirements.

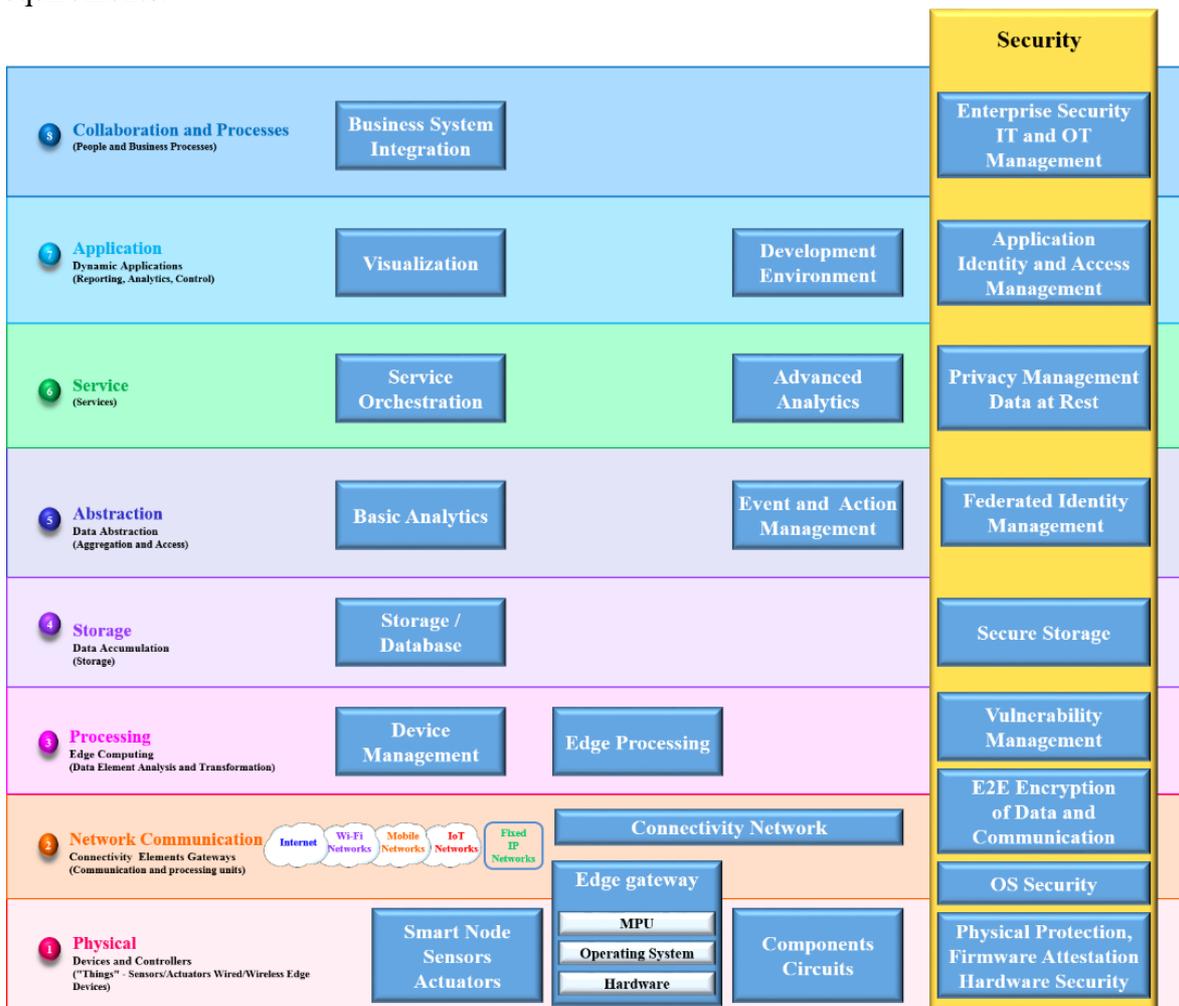


Figure 6: IoT platforms components across the IoT architectural layers

The platforms providers create IoT ecosystems that involves close partnerships with stakeholders that use their technology.

The table below defines the important components in the various layers of the IoT architecture that supports the analysis of the features of different IoT platforms making the comparison of various solutions easier.

Table 1: Mapping the IoT Platforms components to eight layers IoT architecture

IoT Architectural Layer	Components	Definitions
Collaboration	Business system integration	Enables integration with existing enterprise and other external systems
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards
	Development environment	Provide integrated development environment to simplify development of apps
Service	Service orchestration	Supports mashup of different data streams, analytics and service components
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed
Abstraction	Event and action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics
Storage	Storage/Database	Cloud based storage and database capabilities (not including on premise solutions)
Processing	Device management	Enables remote maintenance, interaction and management capabilities of devices at the edge
	Edge analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity
	Edge gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform
Physical Layer	Operating system	Offers low-level system SW managing HW, SW and runs applications
	Modules and drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level

IoT platforms address the components in the IoT layered architecture approach and cover the following elements [1]:

- Abstraction – abstracting physical IoT devices and resources into virtual entities and representations, enabling interoperability through uniform access to heterogeneous

devices and resources over multiple communication protocols such as MQTT, Restful, etc.

- Virtualization – providing service look-up mechanisms that bridge physical network boundaries and offer a set of consumable services.
- Data management Framework – enabling storage, caching and querying of collected data as well as data fusion and event management, while considering scalability aspects.
- Semantic Representation Framework – for modelling and management of semantic knowledge
- Security and Policy Framework – implementing Access Control mechanisms and Federation Identity management responsible for authentication and authorization policies and for enabling federation among several IoT platforms respectively.
- Networking Framework – enabling communication within and across platforms, providing means for self-management (configuration, healing and optimization) through cognitive algorithms.
- Open Interfaces – set of open APIs (possibly cloud-based) to support IoT applications, and ease platform extension by enabling easy interaction and quick development of tools on top of the platform.
- Data Analytics services – providing "real time" event processing, a self-service rule engine to allow users to define simple and complex rules, and querying, reporting and data visualization capabilities.
- Machine learning data analytics – a set of complex machine learning algorithms, for providing real-time decision capabilities.
- Development tools and standardized toolkits – for fast development of (possibly cloud-based) IoT applications that can be integrated by different companies.

Developments of IoT platforms involves an entire ecosystem of stakeholders covering the whole value chain of the IoT that together coordinate and deliver the functionalities and the services required by the various supported IoT applications.

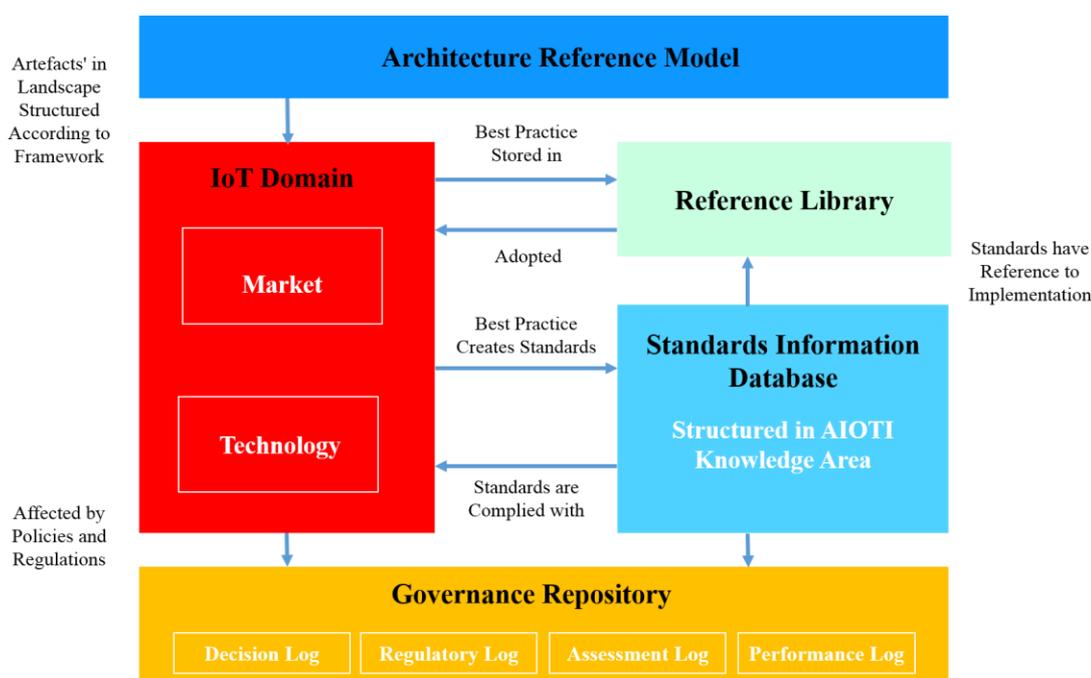


Figure 7: The IoT Enterprise Framework.

The STF 505 has defined an Enterprise IoT Framework, in order to put a global structure on the framework used for the analysis of the SDO landscape.

Such a framework has to deal not just with the technology, but also with other relevant areas to be taken into consideration such as stakeholder views, the regulatory aspects (e.g. for a city). All of these together make up an enterprise view [2].

The reports of the Alliance for Internet of Things Innovation (AIOTI) working group WG03 point out that part of the complexity of IoT comes from its intention to support a number of different applications covering a wide array of disciplines that are not all part of the ICT domain. An overview of all these elements can be overwhelming without a structural view. The STF 505 approach is to view the IoT framework as an Enterprise Architecture (in line with the TOGAF model for Enterprise Architecture) [2].

The main elements of this framework shown in Figure 7 are the following:

- An Architecture Reference Model which consists of an IoT architecture integrating all components that make up an IoT system;
- An IoT domain which holds the view of what makes up an IoT system;
- A Standards Information Database which is the main object of study of the IoT standards landscaping, aiming to hold all relevant standards that can be used;
- A Reference Library which holds any re-useable information that can be used across the IoT large scale pilots;
- A Governance Repository that houses all policies, regulations that applies to any large-scale pilots.

3.2 Functional components of IoT platforms

This section presents a brief overview of IoT platforms functions. In order to better relate to the need for such functionality, we initially introduce a service model that is common across various IoT services and applications. We then discuss platform functionalities in more detail.

3.2.1 Typical IoT service model

Most IoT applications and services have a common underlying service pattern, which can be characterised by six distinct activities. These activities are Acquire, Analyse, Action and Achieve, Assess and Adopt, which we describe as the *6A service* pattern. The 6A service pattern is depicted in Figure 8 in more detail.

Each IoT application or service has a desired goal or impact in the real world it aims to *achieve*. Examples are maintaining an adequate level of comfort and user experience in a home environment, providing optimised utilisation of energy or water resources in a utilities context, providing an optimised end-to-end supply chain or the minimisation of congestion and maximisation of throughput in a transport scenario.

In order to achieve their objectives, IoT applications and services can trigger a set of *actions* that influence real world processes underlying them. These could be notifications and visualisations to users to trigger further actions or encourage longer-term behaviour change. Actions could also be triggered without the human in the loop by re-routing delivery of packets in a logistics process, adjusting the behaviour or features of objects or machines, by changing the environment through actuators, such as adjusting temperature in building or opening or

closing windows or gates. *Actions* require the right decision making processes to be in place, which are encoded in some of knowledge base such as rules or more complex algorithms.

Making the right actions requires the right information for decision-making processes to be in place. In IoT systems this decision making processes rely mainly on real world information that is *acquired* through IoT nodes providing one or multiple modes of sensing capabilities. In some circumstances, IoT systems also utilise soft-sensing capabilities to acquire real world information. The latter refers crowd-sourcing information from human users by prompting them to input perceived qualities about their environment or real world processes.

In some cases, it may be sufficient to implement actions directly based on acquired real world information. However often more information processing is needed to *analyse* the acquired real world data and make it more suitable for (autonomous) decision-making. Data cleansing, fusion, augmentation and analytics are important elements to extract actionable insights from the captured real world information.

During the service design cycle and during operation, one needs to *assess* whether the desired goals and impacts are reach and whether these are still appropriate targets to have. Necessary changes may lead to a recalibration of the different other aforementioned steps.

An IoT system requires upgrades as new technology building blocks become available. New technologies are then *adopted* which can be any of the following: software, hardware, communication components or algorithms.

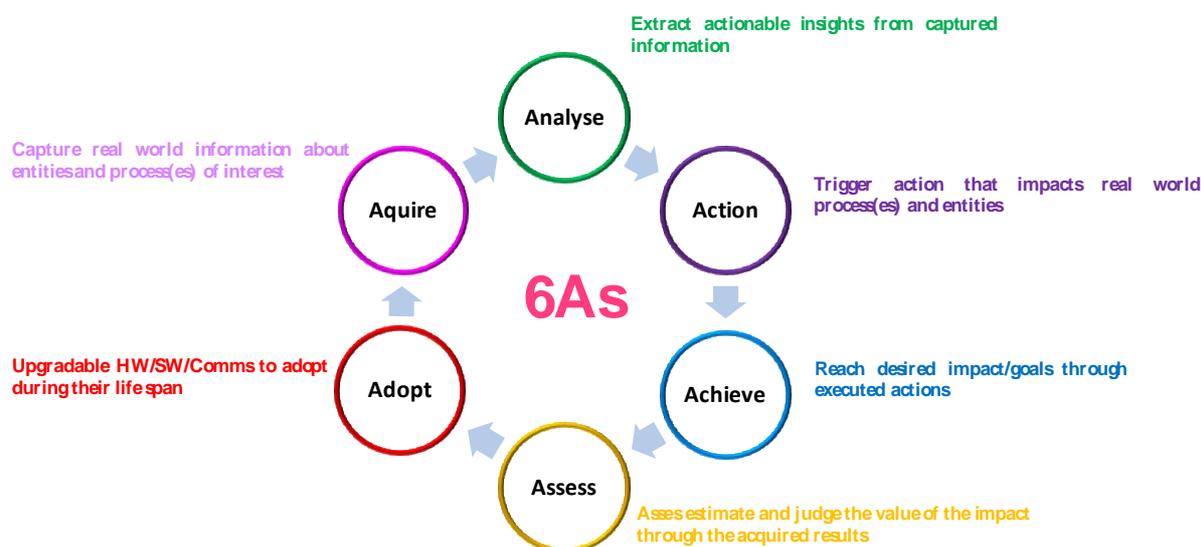


Figure 8: 6A service pattern for IoT applications and services.

3.2.2 Functional components of IoT platforms

The goal of IoT platforms is to simplify the development of IoT applications and services and their operation by providing a set of out of the box functionality that is typically needed for their realisation. Rather than developing required system components from scratch for an end-to-end IoT systems, developers and service providers are able to build upon a set proven building blocks, significantly shortening the development cycle and time to market. As these building blocks are common and repeatable across a variety of IoT applications and services, it contributes to the economies of scale, thus reducing the overall costs for the delivery of an

IoT enabled solutions. The latter is essential to make many dreamed up IoT service scenarios commercially viable.

IoT platforms can offer a diverse set of functional components, which contribute towards the realisation of IoT service pattern described in the previous section. Figure 9 shows a functional stack that covers all relevant service features that IoT platforms may offer.

Broadly speaking, IoT platforms can be described as a form of IoT middleware, which sits between IoT devices located at the edge of the network (assumed to be at the bottom of the stack) and IoT applications and services that build on top of it. Consequently, the bottom of the stack encompasses IoT device centric features while the upper layers of the stack provide value added features for applications development and service enablement. In the middle are functions that support better management and exploitation IoT data.

Connectivity and normalisation deals with the ingestion of IoT data from and the efficient dispatching of commands to heterogeneous IoT devices. Heterogeneity refers to the diversity of communication protocols that IoT devices are utilised, varying data formats and representations as well as device hardware capabilities. IoT platforms often offer a southbound API for device to platform communication, which supports a few common web based protocols and standards. In order to ease integration with these APIs, platform vendors or device vendors may make agents and libraries available (as software module or device firmware) that ensure constant connectivity and harmonized data formats.

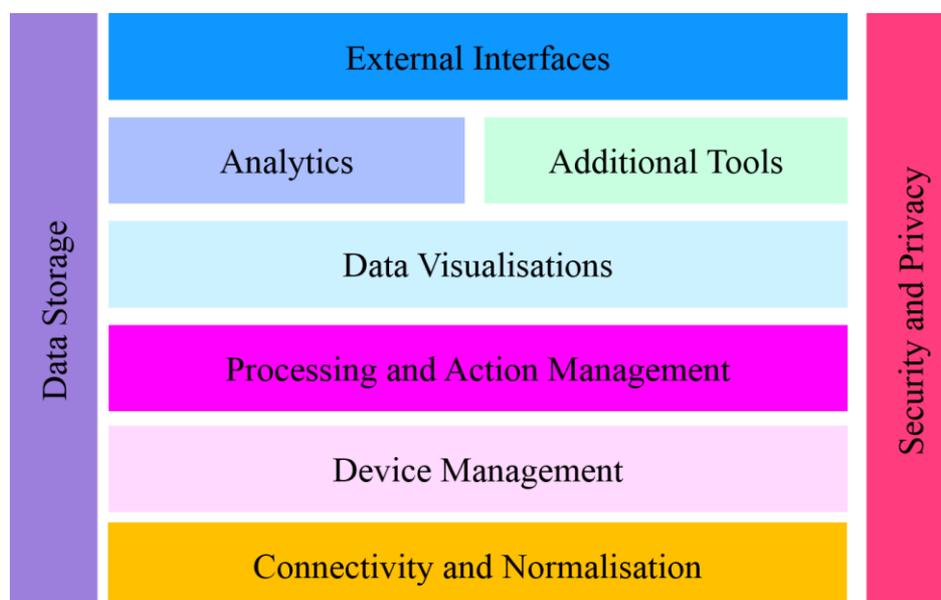


Figure 9: Functional components of IoT platforms.

Device management ensures that IoT devices are properly working with the IoT platform and are up to date with latest firmware or software versions. Functions offered by IoT platforms is typically device discovery/registration, device directory services with capability descriptions, device status monitoring as well as tools for the remote update of on device software.

Processing and action management are functions that operate on top of received IoT data streams from the different IoT devices. They enable simple mapping of low-level sensor events

to higher-level events through simple logical constructs or rules and link these to new events or action commands towards IoT devices or end-users. Often this component features a rules editor and a rules engine. The former allows users to define simple rules that combine data feeds from IoT devices with conditions and corresponding actions. The latter executes these rules and triggers corresponding actions.

Data storage is a core service of most IoT platforms. It captures data originating from IoT devices for on line or off line processing and other state information that may be relevant about the devices. There are different data store architecture out there, which depend on the primary data processing use cases. This could be NOSQL like big data stores or time series databases. Most of them make use of cloud storage technologies to achieve scalability.

Data visualisation components allow users to explore IoT data, in order to verify correctness of incoming data streams, find interesting correlations and build dashboards that provide feedback to end-users based on a diverse set of KPIs that are underpinning decision making enabled by the IoT service. Typically, data visualisation are in the form of out-of-the box displays and widgets providing 2D or 3D views of different kinds and selection options for the different IoT data sets. Data visualisations are useful tools both for the IoT application developer during production time and for the end user of the IoT application during runtime.

The *analytics* component is a collection of tools that allows insights from data to be extracted and more complex data processing to be performed. This includes toolboxes of more generic data mining or machine learning techniques over to more specialised algorithms for a specific application domain. The can be off line techniques operating over data bases of historic data or allow online stream processing across incoming data streams. Some of the platforms offer the ability for third parties to plug in analytics components.

Additional tools represent a miscellaneous category that captures tools for the management of the overall platform such as user management and dev ops tools or tools for application development and orchestration. Other tools are apps or interfaces for mobile devices such as Android or IOS to enable interaction with the IoT platform.

External interfaces represent APIs for the development of applications and services on top of the system functions. It also includes tools or wrappers to plug into other enterprise backend systems.

4. AN OVERVIEW OF THE GLOBAL IOT PLATFORM MARKET

The IoT platform market boomed in 2013 driving business opportunities for potentially 25 billion things connected to the Internet in less than five years from today [IoT-Analytics 2016]. Moreover, the growth of number of connected things and services is impacting and stimulating business worldwide [Gartner 2015]¹.

Imagining a world with more than 25 billion connected things is a fascinating exercise. More than a fascinating, it is a relevant exercise for the fact that the connection of billions of things will impact and affect innovation, business, and social life. However, analysing and understanding the IoT platform market is a complex issue since it includes multiple segments of industry and different technologies in many different countries.

This section aims to provide an overview of this vibrant fast-paced market. Our analysis considers the currently most extensive IoT database, a collection of 360+ IoT platform providers assembled organised by IoT Analytics, a market research firm that focuses on IoT². Our analysis highlights similarities and differences among countries, companies, technologies, and industrial sectors. We consider both the global evolution of the IoT platform market as a whole and zoom into European landscape to gain a finer grained picture on the local market development.

We organize the section as follow: first, we describe the evolution and the access of companies to the global IoT market; second, we analyse the industrial segments covered by the companies; third, we examine the technological domain of the IoT platforms. We conclude by summarizing the overall IoT platforms market state.

4.1 The evolution of the IoT platform market

In this section, we describe the general traits of the IoT market: the evolution in time and its current shape in Europe and in other regions across the world. We first focus on the evolutionary aspect of the IoT scenario in order to understand the roots of one of the features of the so called “*the third industrial revolution*” (Rifkin, 2014). The IoT has been described as one of the elements that are driving our society towards a new industrial revolution.

This statement is highly relevant to understand that one of the core building blocks of the Internet of Things, the IoT platform, is the engine of a powerful machine that is changing productive dynamics. Hence, understanding the way that the market of IoT platforms grows may help institutions and tech-industry to stimulate future innovation.

The IoT market evolved and advanced over the last ten years and will continue to expand in the years to come. Figure 10 provides insights into the evolution of the IoT platform market. Information related to launching IoT platforms tells us that a small number of IoT platforms have been emerging since late 2000 and that this market experienced a significant boost during the last few years. In fact, as Figure 1 highlights, 70% of platforms in the worldwide scenario are operating only since 2013.

¹Gartner Says 6.4 Billion Connected "Things" Will Be in Use in 2016, Up 30 Percent From 2015
<http://www.gartner.com/newsroom/id/3165317>

²<https://iot-analytics.com/current-state-of-iot-platforms-2016/>

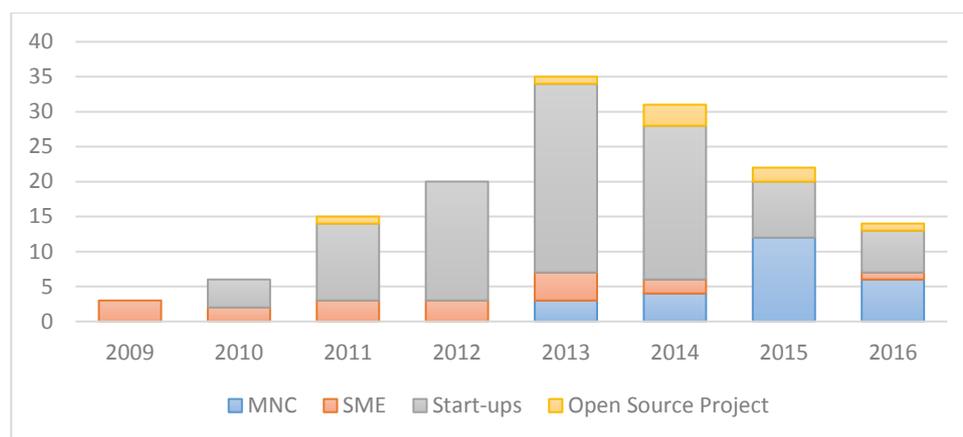


Figure 10- Worldwide focus on the number of IoT platforms launched on the market per year
[Source IoT Analytics]

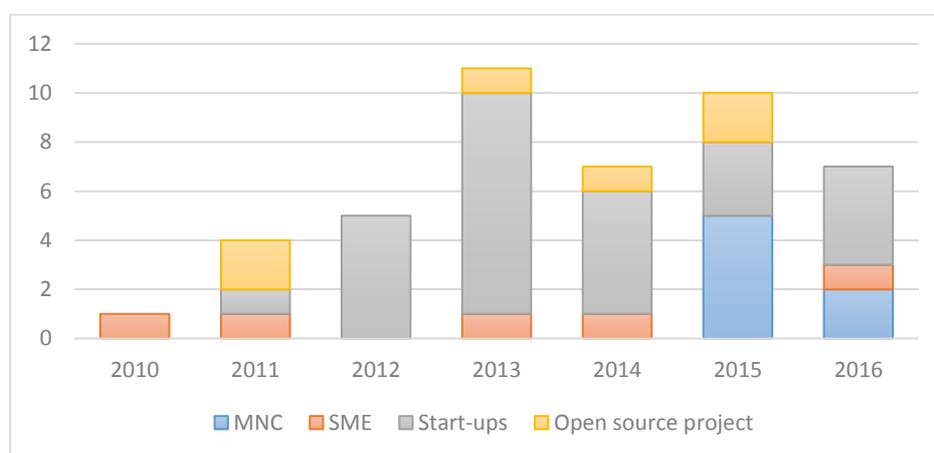


Figure 11 - European focus on the number of IoT platforms launched on the market per year
[Source IoT Analytics]

Besides, as Figure 1 and Figure 2 highlight, 2013 marked the year of the biggest growth of the IoT platforms both for the Worldwide and European market. While the growth of the global market was initially dominated by US players, the evolution of the market in the last three years led to a rebalancing of the situation. The global market saw more international competition emerging, reducing the global number of US based IoT platform providers from 60% before 2013 to about 50%.

Moreover, as we can observe from Figure 1 and Figure 2, the market growth has been mainly dominated by a start-ups and less so some SMEs. After early successes, a gold rush led to the creation of many IoT platform start-ups that seem to push the industry growth at the moment. The recent two years saw many multi-national players responding to it by entering the playing field with own IoT platform offerings or through acquisitions of existing players.

The interesting aspect of observing the evolution in time of the IoT platforms is how the access to the market can influence the evolution of the industry itself. Based on data in our hands and conscious of the differences between the number of start-ups and the number of SMEs and MNC, we can notice that the wave of IoT platforms launched on the market described an interesting trend in respect to the type of company that launch a new platform and overall, how

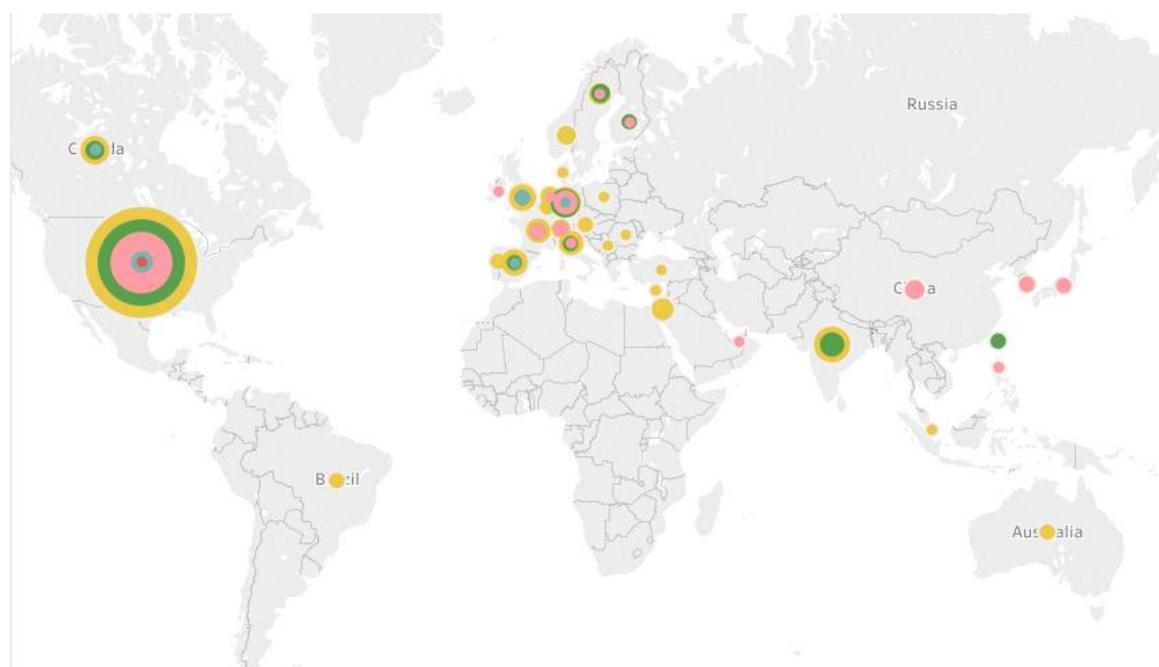
the market is getting established through a balanced combination between young and established companies.

While in 2009 the most relevant companies in the IoT platform markets were SMEs, the percentage in the following years decreased until 2013 when IoT began to face a higher level of industrial interest (see Figure 1). The European regions followed a similar trend, which is comparable, the worldwide scenario (see Figure 1 and Figure 2). In addition, in the European context during the establishing period of the IoT platforms market, Open Source Project are also playing their game. The 50% of the Open Source Project are described by IoT Analytics as European based rather than be based in specific countries.

The evolution and the establishment of the IoT platforms market is based on the common play among established companies, and lively and flexible start-ups. While the growing curve finds – for the moment – its peak in 2013 the following years are showing the establishment of the IoT platforms market.

4.2 Regional markers of IoT market

While the previous section introduced the evolution of the IoT market, this section focuses on regional analogies and differences.



Map based on Longitude (generated) and Latitude (generated). Color shows details about Company type. Size shows sum of Number of Records. Details are shown for Location Country. The view is filtered on Exclusions (Company type, Location Country) and Company type. The Exclusions (Company type, Location Country) filter keeps 67 members. The Company type filter excludes 0.

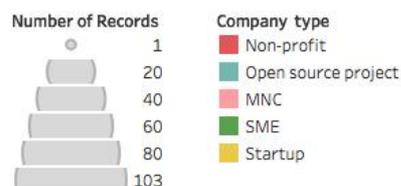


Figure 12 - Global distribution of different type of companies

Figure 12 represents the current distribution of the different types of companies all over the world, while Figure 13 focuses on the European scenario. Looking at the market as a whole

and regionally is helping us to understand how the market is shaped and how we can support the innovation by comparing these areas.

As introduced in the previous subsection, the IoT platform market has been led by American companies, predominately based in California. However, the market extended and included other regions, including European and Asian countries. Figure 12 highlights that US and European market have the most diverse ecosystem in terms of different company types. Other regions such as Australia, Brazil, Canada, India, Israel, Korea, Philippines, Singapore, Taiwan, and United Arab Emirates, are increasingly taking part in the IoT market. However, differently from these countries, China, Korea, Japan, Philippines, and United Arab Emirates IoT market are dominated by multinational companies, which include more than 10 thousand employees and/or are publicly listed ones.

The European IoT market is based on a quite lively and differentiated industrial scenario as different types of companies characterize the IoT platforms landscape (see Figure 13). It is interesting to observe the diverse type of companies that constellate the European scene. The European region reveals a noteworthy combination between Start-ups and established companies that are determining the continuity of the IoT platform market.

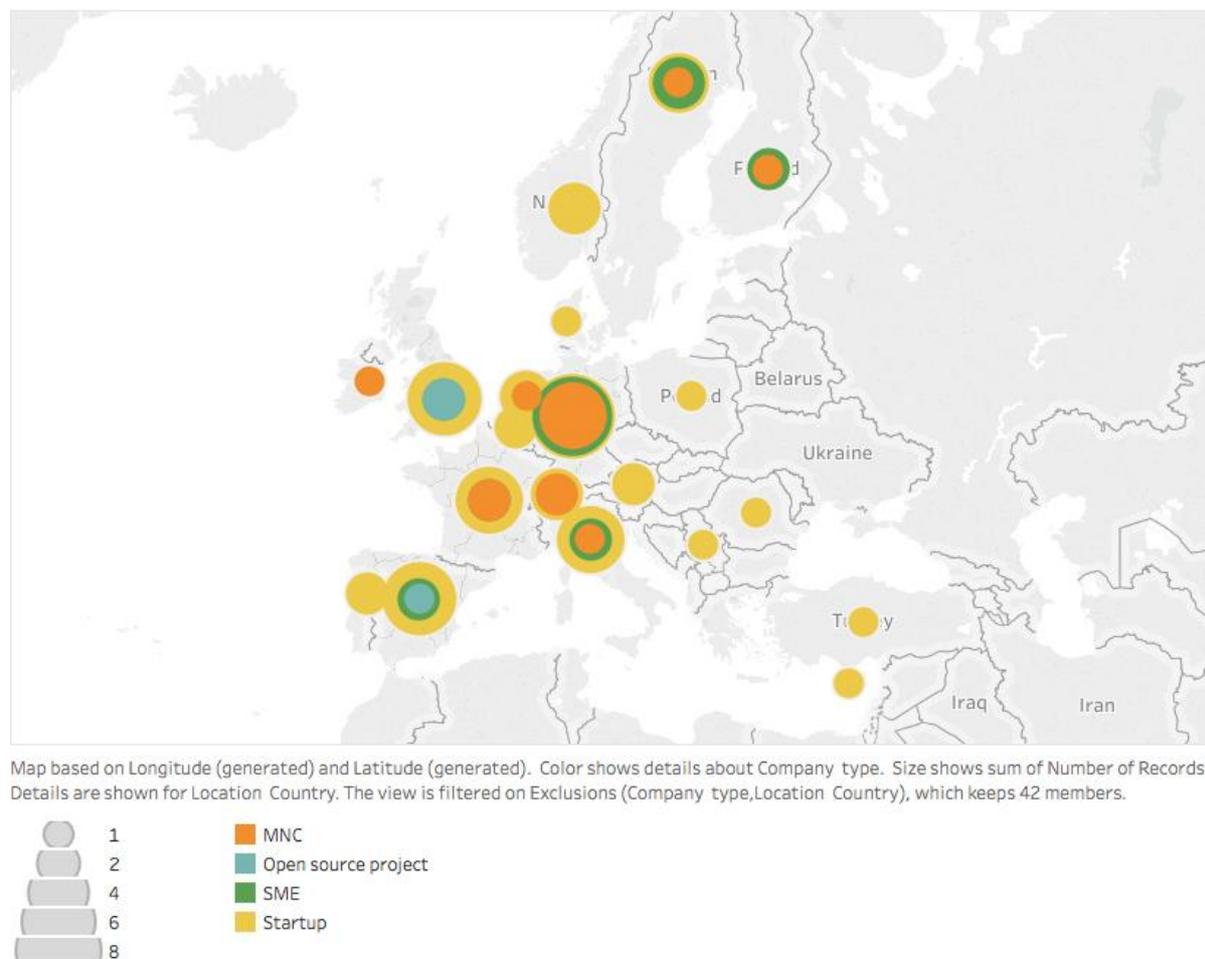


Figure 13 - European distribution of different type of companies

The European situation is comparable to the US when it comes to start-ups, as they constitute the majority of companies that develop IoT platforms. In terms of EU countries, Spain,

Germany, Italy, France, UK, and Switzerland boast the highest number of companies providing an IoT platform. As the graph illustrates, the IoT market in these countries relies on an ecosystem that combines Start-ups, SMEs, Multinational companies, and Open Source projects (see Figure 4). IoT Analytics data reveals Germany is the most active region, where 32% of European based IoT platforms are developed. In Germany, the 38% of the companies that develop IoT platforms are start-ups, 33% are SME, and 24% are multinational companies. Additionally, the IoT German market has produced successful Open Source Projects such as OpenHab.

Following the German trend, two Open Source Projects are based in the UK. However, the British IoT platforms market is mainly formed by Start-ups and SMEs, and lacks large multinational corporations. A similar, structure of the IoT platforms market can be observed in Spain. In contrast, the French, Italian, and Swedish markets are based on a combination of Multinational companies and SMEs that run alongside Start-ups.

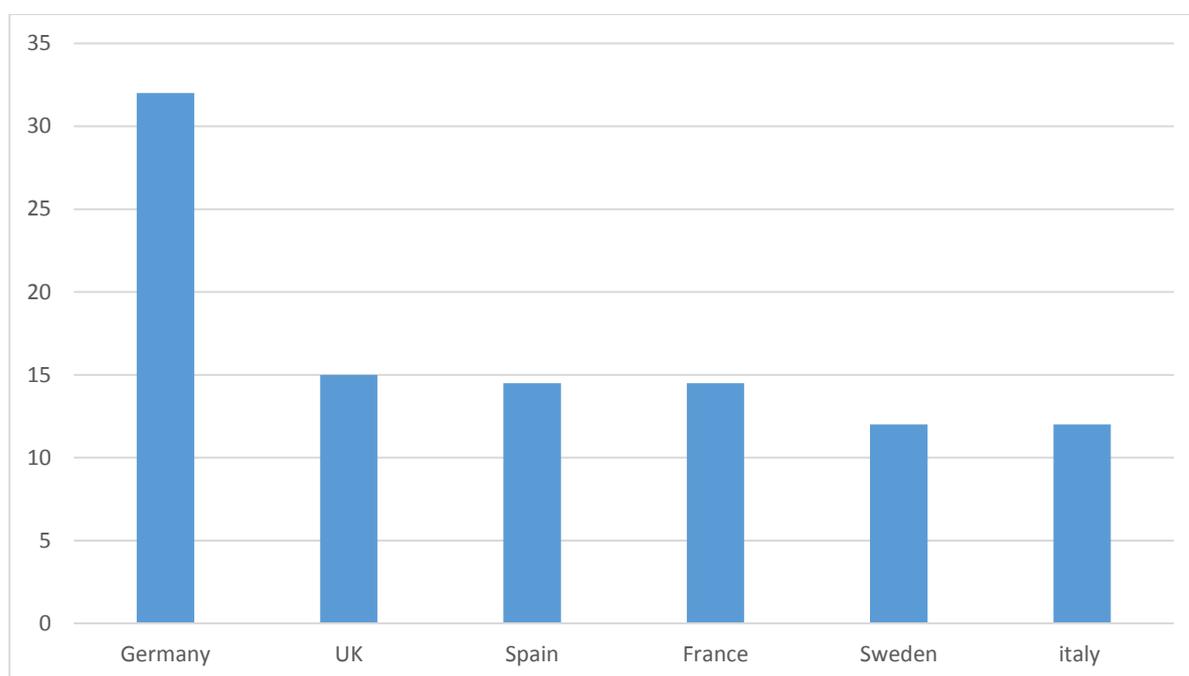


Figure 14 - Number of active IoT platforms [IoT Analytics source]

4.3 Segments in the IoT market

As well the type of companies shapes the IoT platforms market, the industrial segments covered by IoT companies are inspiring the market. The IoT Analytics data set partitions the segments into to high level grouping namely Business to Business (B2B) and Business to Consumer (B2C). The B2C products include segments such as Health, Home, Lifestyle, and Mobility; the B2B products include a larger variety of segments such as Energy, Health, Mobility, Manufacturing/Industrial, Public sector and services, Retail, Smart City, and Supply Chain.

Additionally, the research firm includes two broader sectors: the “Generally all” category aims to include companies that do not specialize in sectors but build IoT platforms for all different segments; whilst, “Generally business” includes companies that only sell B2B products. The data represented in Figure 15 and Figure 16 describe the segments covered by different

companies. While the 34% of the platforms exclusively cover Generally all segments and the 15% of platforms cover “Generally business” segments, the remaining companies develop IoT platforms that cover simultaneously multiple segments.

The data in our hands reveal a higher interest towards B2B and generally all segments. In fact, as can be observed in Figure 15, the proportion IoT platform targeting B2B and generally all segments on the market is considerable higher than the proportion of the B2C segments that include applications for consumers related to health, lifestyle, and mobility. Overall, the worldwide and European trends describe an increased focus on B2B applications with a predominance for Manufacture and industry, Mobility, and Smart cities. Other similarities among the global and the European market include the Business-to-Consumer sectors with particular regard to the Smart Home.

Differently from the worldwide market, the European industry reveal additional interest on B2B Supply Chain and B2B energy sector.

Worldwide Focus on the IoT segments covered in the current IoT industry

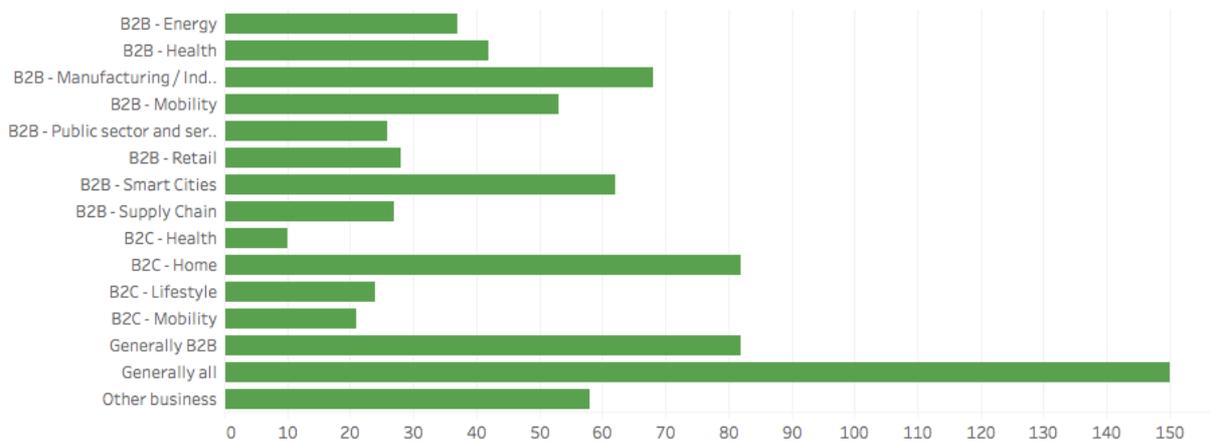


Figure 15 Global description of number of IoT platform for the different segment – each platform can cover different segments, with the exclusion of Generally all.

European Focus on the IoT segments covered in the current IoT industry

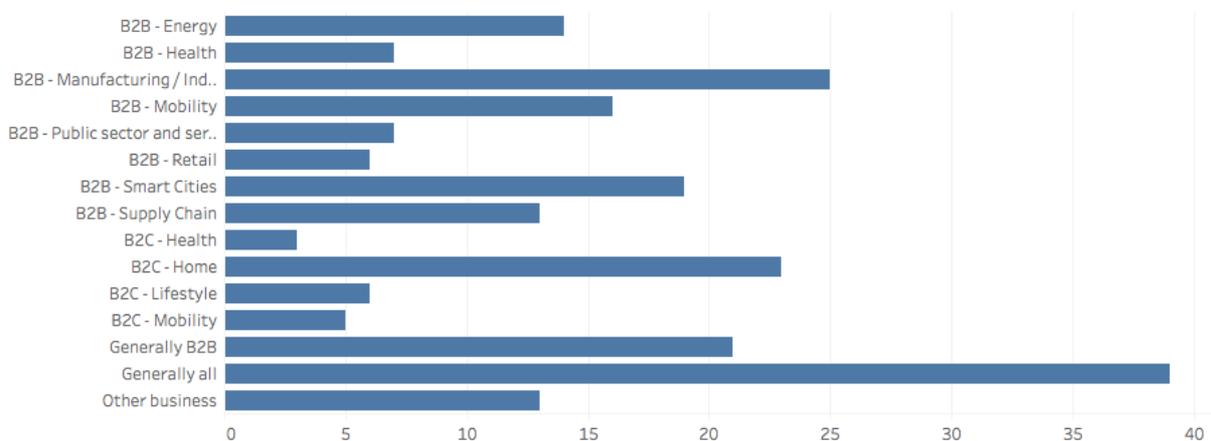


Figure 16 - European description of number of IoT platform for the different segment – each platform can cover different segments, with the exclusion of Generally all.

Quite noteworthy is the comparison among the B2B and B2C segments. The mobility segments in B2B and B2C is denoting the possibility for the market for more growth, which could be potentially enhanced by a combination of these two sectors.

The observation of these two graphs highlights current trends and industries related to different segments of the IoT market. They provide a first step for further reflections on how we can enhance and stimulate the European IoT market in the future.

In order to have a more comprehensive picture of the current IoT market, the following subsection describes which kind of additional technologies the IoT platform industry is currently focusing on.

4.4 Technologies alongside IoT platforms

In this subsection we take into account the technologies that companies develop and provide alongside IoT platforms. The 45% of the companies active in the IoT market are focusing only in developing IoT platforms. However the remaining 55% offer alongside their IoT platforms other related IoT technologies. The majority of these offer one or two additional technologies and rare cases even more than four.

Among the additional technologies provided by the companies, IoT Analytics identifies a list of ten supporting technologies:

- | | | |
|----------------------------------|----------------------------|----------------------------|
| 1. Processors and semiconductors | 4. Operating systems | 9. Analytics |
| 2. Sensors | 5. Developer tools | 10. Database |
| 3. Communication hardware | 6. Complete devices | 11. Other technology tools |
| | 7. Other hardware | |
| | 8. Communication protocols | |

As we observed in the previous subsection, the IoT market is complex in terms of interdependencies. The analysis of the IoT platforms market in connection with the different segments helps define which are the opportunity for Europe to catch up the global picture and to enhance the IoT market. In order to understand the current performances in the development of technologies we look at the worldwide and European scenario of additional technologies to the IoT platforms production.

Worldwide Focus: Technologies that complete and enhance the production of IoT platforms

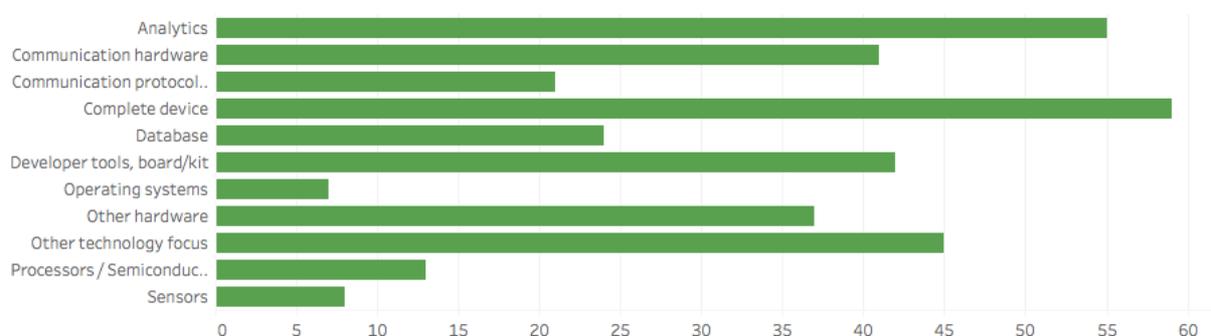


Figure 17 Global description of technologies that complete and enhance the production of IoT platforms.

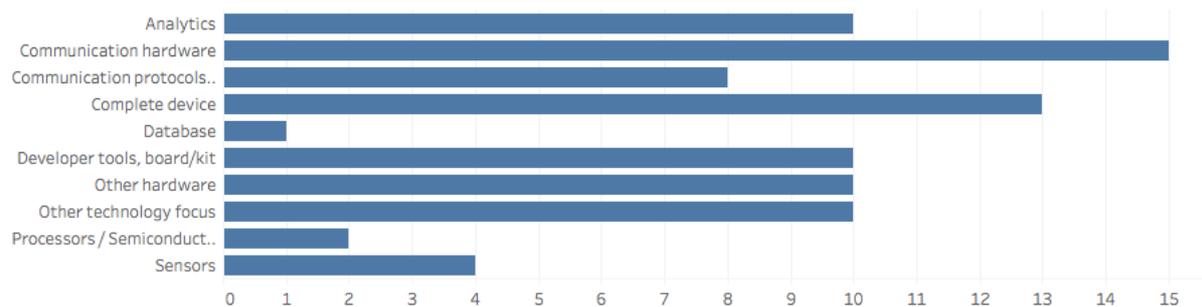


Figure 18 European description of technologies that complete and enhance the production of IoT platforms.

Comparing both graphs, we can observe a strong gap in the European market related to database technologies that support the IoT platforms. However, the European market is stronger communication protocols than the worldwide scenario.

The two graphs are useful because they provide handy evidences for understanding differences and analogies among Worldwide and European technology interests and trends. Moreover, the comparison between the two graphs describes how the European region – where about one third of the worldwide IoT platforms come from – is focusing on some technologies instead of others. For instance, the European scenario is fairly more active into the production of *communication hardware* and *communication protocols* than the Worldwide scenario, which is stronger than the European one in *analytics* and *database* technologies. Different trends can be observed focusing on *processors/semiconductors* and *sensors*. While the Worldwide scenario is more productive in terms of *processors/semiconductors* technologies, the European landscape is more involved in the industry of *sensors*.

Differences and analogies among Worldwide and European market are useful for building understanding on which directions the market could have room for improvement. The following subsection runs through the main observations discussed in this section focusing on highlighting the potential opportunities of the IoT platform market.

4.5 Summary of market trends

This section discussed the current global and European landscape related to the IoT platforms market. First, we reviewed the evolution of market focusing on the number of platforms developed and the type of company that is providing them. We observed that the 70% of the platforms around the world are operating since 2013. The IoT platform market was initially led by SMEs, and burst into life with a large number of start-ups. After peaking in 2013, larger companies followed suit and are now in the pole position to go after customers. These trends were observable nearly across all different regions. There were several interesting trends worth highlighting when examining the overall picture:

- Today nearly 60% of all IoT platform companies come from the north America, the majority from US with a bit from Canada, Europe has the second largest amount but is less than half of US.
- Start-ups currently account for the majority of IoT platform companies on the global market, with 55% percent, followed by SMEs 26%, MNCs 16% and remaining open source.
- The percentage of start-ups is similar across all regions, with US having a lower percentage of start-ups, but a higher than average percentage of SMEs

- Asia boasts a much higher than average percentage of MNC on the market
- Open source is only popular in US and Europe, with Europe having a 4 times higher percentage of open source project than US.
- In Europe Germany is leading the pack accounting for a third of the EU companies, UK, Spain and France follow suite with less than half of the number of Germany respectively
- Germany has a very high percentage of MNCs with about a quarter of companies. At the other end of the extreme is the UK where with no MNC and mainly SMEs and startups, the other countries lie between the two.

Interesting observations can be drawn also when examining sectors that the IoT platform companies are services. Sector agnostic platforms currently dominate both the global and the European picture. However, there is also a large more sector specific offering:

- In in the B2C segments, - smart home is the most dominant application sector, followed by lifestyle and mobility. Health is still early stage and has large potential for scaling. This trend is shared both globally and in Europe.
- Similar trend for the B2B segment in Europe is aligned with the global trend, with top 3 being Manufacturing, smart city and mobility.
- The Manufacturing sector offering is proportionally stronger developed in Europe so is the one for the Energy sector.

Finally, there is an increasing number of IoT platform companies that offer complementary technologies along side their IoT platform offering. In fact, these are more than half of the IoT platform providers globally. There are however variations in what these technologies are. The main difference between the global and European providers are:

- Globally the emphasis of providers lies more on data base technologies and analytics, whereas in Europe there is a stronger emphasis on communications technologies both protocols and hardware.
- The global trend shows more emphasis on processors and semiconductors, while in Europe there is a strong hold for sensor technology.

5. FRAMEWORK FOR IOT PLATFORM ANALYSIS

The number of IoT platform offerings on the market has exploded in recent years as presented in Chapter 4. While it is impossible to analyse all of the 360+ existing IoT platforms in a single document, the merit of discussing all of them is also questionable. Instead, we try to focus our analysis on representative examples of IoT platforms on the market, mainly focusing on the leading contenders. In the following, we briefly present the objectives of our analysis and the methodology we used for selecting IoT platforms to be considered for it. Following this methodology, we determine a set of leading IoT platforms that we will consider for further in-depth analysis in section 6. We also reflect on how the leading platforms relate to the overall market trends analysed in Chapter 4.

5.1 Goals of analysis

An important dimension for UNIFY-IoT is the ability for IoT platforms to act as true ecosystems that facilitate value co-creation with multiple stakeholders along the IoT value chain and the ability to enable diverse IoT business models to satisfy the growing market demand. We believe that platforms with an open ecosystem dimension will be those who are most likely to succeed on the market place in the long run.

The analysis of IoT platforms aims to reveal important insights for to the IoT-EPI projects to create more successful IoT innovation ecosystems on an increasingly crowded IoT market. It also aims to help policy makers such as the EU or national funding agencies to identify priorities for future funding. Lastly it aims to also provide end-users of IoT platforms with orientation on an confusing market place and useful considerations for the selection of IoT platforms for their applications and services.

The analysis will try to find answers to the following questions:

- Which platforms are currently perceived as leading on the market and are likely to succeed in the long run?
- What makes them more successful than others?
- What features do they offer?
- What protocols do they use and will be important ones to inter-operate in future with?
- How do they build successful ecosystems in terms of partnerships and developers?
- What are important technology gaps current not covered by available IoT platforms on market?

5.2 Assessment methodology

A successful IoT platform is the result of a complex reiteration of creating value (conceiving and developing a software) and of retaining the created value by developing “tools, libraries, and platforms” (VisionMobile). Therefore, developing a useful and consequently successful platform is a combination of dynamisms that embrace and accommodate software for managing things and people, while triggering a massive network effect (Lutwak, 2013). In fact, Todd Lutwak describes a platform as “*chaotic, emotional, and even rebellious*”³ expression of developers and programmers. Hence, an IoT platform needs to root in the environment, engage, and increment together with partnerships, and current and potential users.

³ Sources: Managing Platforms is a Human Art (21 October 2013) <http://allthingsd.com/20131021/managing-platforms-is-a-human-art/> last visit: 5th September 2016

From an ideal point of view, we could measure the success of IoT platforms depending (1) on the percentage of market share; (2) on the community of developers who create the value and develop “tools, libraries, and platforms”; (3) on the revenue; (4) the number of projects supported; and (5) the different kinds of applications sustained.

Such data is very difficult to obtain in a fast moving market, as it requires a detailed analysis of business-sensitive information of company activities on a market with more than 360 IoT platform providers. In a highly competitive and hyped up market, companies are inclined to distort reality to support marketing and sales activities. The number of customers, ongoing projects, active developer community and sales are likely to remain inside of company walls. Detailed data can be only obtained from honest interviews and surveys conducted with company insiders.

IoT platforms could be also compared on technical merits such as:

- Useful features they provide at different technical layers,
- Depth of the IoT device ecosystem they support,
- Customer service effectiveness and efficiency and
- Whether their offering represents fair value for money.

Despite the recent advance setting up and operating IoT platforms is still a resource intensive task and most users may only be able to try out a handful of platforms before making a choice for an IoT project. For this reasons, there is a lack of real performance benchmarks or comprehensive IoT platform reviews on the market.

Nevertheless, there are a variety of data sources available today that can provide more in-depth insights about IoT platforms and the existing IoT developer ecosystems.

More specifically we will focus on the following resources in our analysis:

- **Industry analyst reports:** Industry analyst companies that specialise on the IoT data platform market and IoT developer ecosystems. They have invested various years of establishing in-depth insights from direct company engagements to build up a reliable knowledge base.
- **Academic literature:** There is a small body of work emerging at scientific conferences that discusses merits of different IoT platforms on the market.
- **Online communities and resources:** This are usually fora and portals closer to IoT developers that gather information and rankings of popular IoT platforms through online surveys.
- **Survey conducted among the EU research community:** UnifyIoT conducted a survey on IoT platform use among IoT-EPI project partners and members of the IERC cluster
- **IERC cluster book:** The last IERC cluster book highlighted in a survey important IoT platforms on the market.

Our analysis will identify the IoT platforms referred to as leading by the different independent sources and establish a popularity based ranking to highlight a larger set of platforms to be considered for further detailed analysis.

Appendix A in Section 10 provides a detailed analysis of the various resources used and what IoT platforms they reference as important ones. The appendix also includes a list of standards based IoT platforms, more specifically platforms based on the OneM2M standard.

5.3 Identified leading IoT platform

In this section, we present a set of platform that have identified as leading in accordance to an analysis performed by the different resources outlined in section 5.2. In order to provide a balanced analysis in section 6, we consider platforms across different IoT platform industries and vendor types. We also distinguish between commercial and open source platforms.

For the selection, we draw upon the relevancy analysis in section 10.1.5 and select the platforms with most references within the determined industry sector and vendor categories.

It is important to note that our selection is not based on clear scientific market evidence or benchmarking data as this information is not available to us and very difficult to obtain without significant effort beyond the available project resources.

We believe however that the platforms are very representative of the current market trend due to the cross analysis of various different resources and provide good examples for the in-depth discussion in section 6.

We include into our selection commercial platform both from larger vendors which are currently predominately referenced but also platforms from SME and startups as well as open source that we consider as leading.

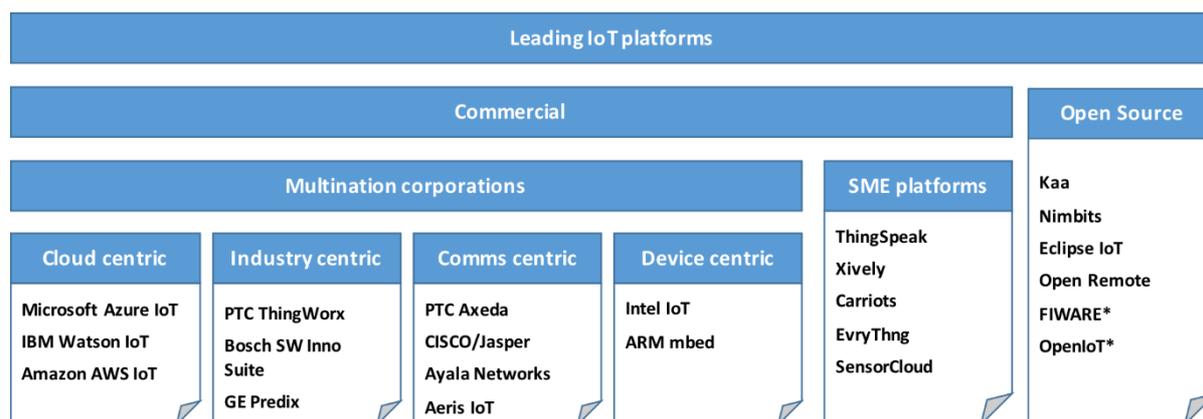


Figure 19: Selection of 23 leading IoT platforms for a more in-depth analysis.

It should be noted that both FIWARE and OpenIoT have been added to the list as they have been the most dominantly platforms cited by the European research community. Interestingly these platforms were not referenced by the analysed international list of resources.

In addition, several OneM2M standards based platforms were selected based on perceived popularity in the user community:

- OpenMTC⁴
- Eclipse OneM2M⁵
- InterDigital OneMPOWER⁶

⁴ <http://www.open-mtc.org/>

⁵ <http://www.eclipse.org/om2m/>

⁶ <http://www.interdigital.com/iot/>

5.4 Market reflections on leading platforms

In this sub-section, we briefly relate the platforms that we selected determined as leading ones to the overall global platform landscape examined in section 4. Our goal is to understand whether the successful platforms resemble similar geographies, company types, sector focus and complementary technologies or whether a different pattern is more prevalent.

For this analysis, we adopt the similar pathway used for analysing the global and the European platforms market: first, we look at the type of companies that develop the platforms; second, we describe which segments of the industries the IoT platforms cover; finally, we examine which technologies companies are developing in addition to the IoT platforms. The overall picture of geographical distribution of the IoT platforms leading companies broadly mirrors the tendencies of overall global trend analysed in the previous section, however with some striking characteristics.

US based IoT platform providers account for the majority of leading platforms in our selection; however, its proportion increases from 60 to 75%. Proportionally European platform are still in second place but a lower percentage of platforms is considered leading, with only 22% percent coming from Europe as opposed to 28%. The other remaining leading platform providers are from Canada. This means that the Asian and South African market are not yet in a position to compete globally.

The geographical distribution of the companies that develop the most relevant platforms for the IoT market are fairly similar to the one pictured by Figure 12. Compared to Figure 20 we can observe that the distribution of the different kind of companies is mirroring the broad worldwide condition for what concern the most influencing countries.

A strong difference can be observed in the much larger ratio of MNCs compared to Start-ups in the USA. While in US larger businesses take a more prominent role, the situation is less biased in the US where landscape of leading platform providers corresponds roughly with the overall distribution. Here start-up based platforms play a more prominent role.

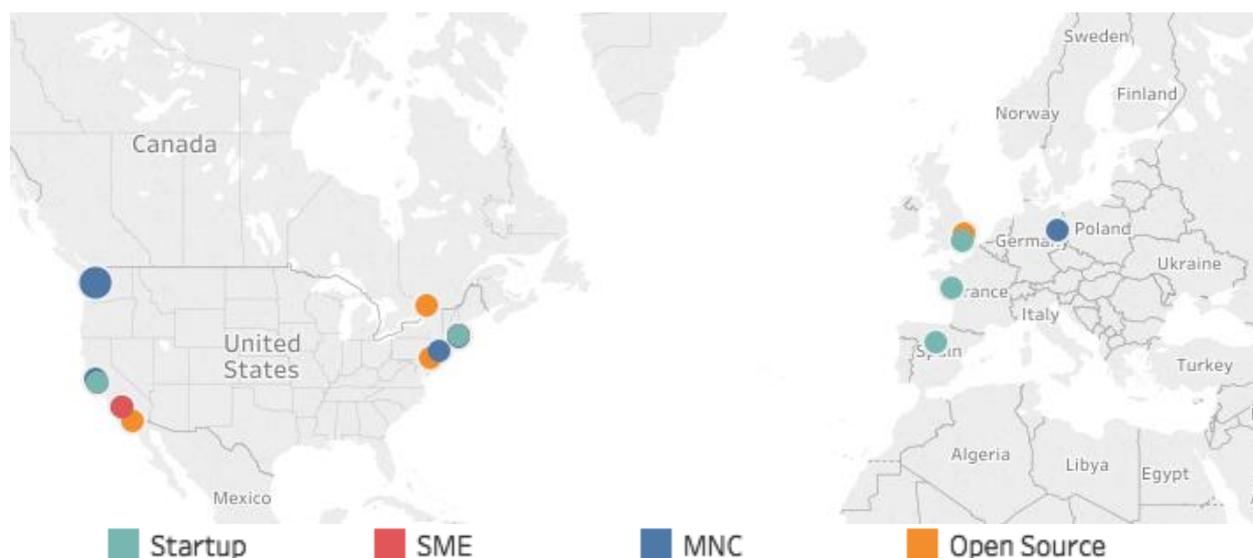


Figure 20 – Geographical distribution and type of the companies producing the most influential and relevant platforms of the IoT market

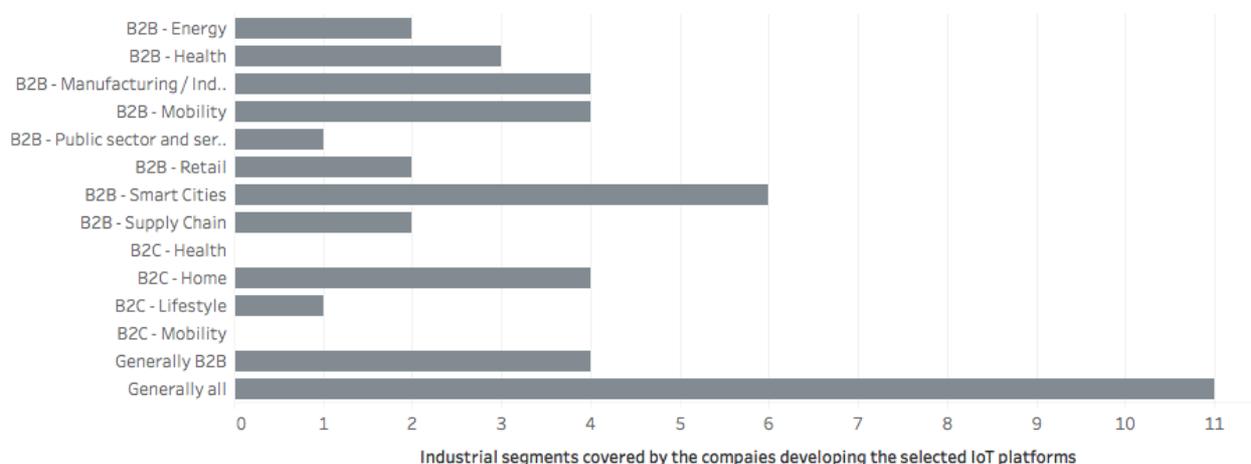
In line with the overall IoT platform landscape, the influence of the European market is maintained also by the leading roles of France, Germany, Spain, and UK for the IoT market. Moreover, distributed projects among European countries foster and encourage a sort of contemporary example of Marshallian districts.

Open IoT and Fiware are characterized by partners' participation and actions distributed across Europe. The two projects are active across countries from Greece to Ireland, and from Latvia to Spain. In fact, even though the partners are officially defined, the community of developers is expanding independently by the formal boundaries and simply spread by following the evolution of the platforms.

Some differences between the analysis of the bulk of relevant IoT platforms and the general observations provided earlier in this document concern the segment of the industries covered.

As immediately evident from Figure 21, the companies that produce the current most relevant platforms in the IoT market are not focused on *Health* and *Mobility*. However, by taking a closer look at the activities of the companies that cover *Generally all* segments we can identify an increasing interest for B2C *Health* and *Mobility* segments as well.

The trend of the core of the IoT market is roughly resembling the worldwide trend: the *Smart City* segment is currently the most relevant sector, followed by *Manufacturing*, *B2B Health*, and *Smart home*. In contrast, lack of sector coverage of the leading platforms is also evident for B2C *Lifestyle* segment and *Public sector and services*.



B2B - Energy, B2B - Health, B2B - Manufacturing / Industrial, B2B - Mobility, B2B - Public sector and services, B2B - Retail, B2B - Smart Cities, B2B - Supply Chain, B2C - Health, B2C - Home, B2C - Lifestyle, B2C - Mobility, Generally all and Generally B2B.

Figure 21 - Industrial segments covered by the most relevant IoT platforms

A third group of information useful for describing IoT landscape characteristics is related to the technologies that gravitate around the IoT platforms. As can be understood among the descriptions of the selected platforms we can consider technologies that are developed for complementing an existing IoT platform and of technologies that stimulate the design of an IoT platform. As we can notice from Figure 22 the interest of the selected IoT companies on developing technologies in addition to the platforms is quite diversified and is not strictly following the global trend described in Figure 17.

The first evident information is related to the lack of companies interested in enriching IoT platforms with Communication protocols. However, little interest is shown also for *Processors/Semiconductors*, *Sensors*, *Hardware* in general, and *Complete device*.

Technologies that complete and enhance the production of IoT platforms

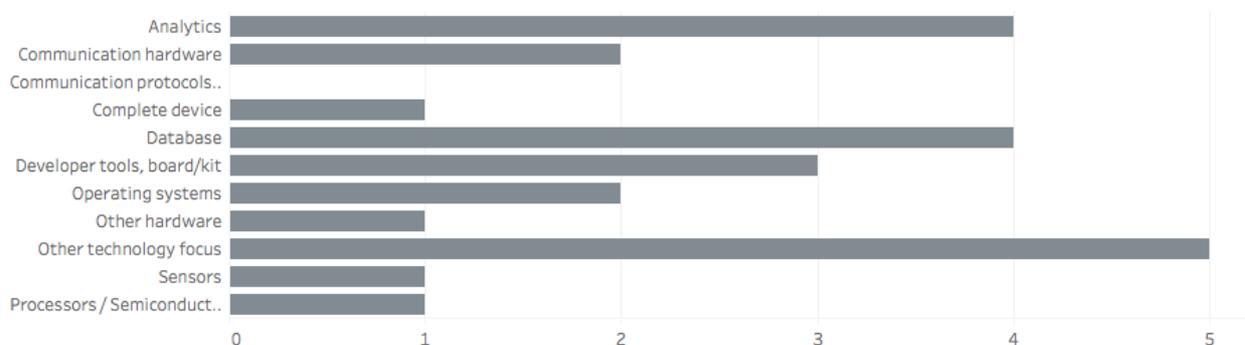


Figure 22 – Additional technologies that are completing and enhancing the IoT platform

In contrast, established IoT platforms market focus more on technologies such as analytics technology, development tools, and broadly speaking complementary technologies that are not specifically related to the IoT.

Comparing Figure 22 with Figure 17 and Figure 18 is helping us to understand how the market is shaped, how it is growing and where it might move in the future. For instance, various EU IoT platform companies focus on providing *communication* solutions. However, the global trend is rather different and *Communication protocols* seems not to be relevant for making IoT platforms globally succeed.

A slightly different situation is related to the segments covered by the IoT market. In fact, the curves of interests among the different analysis are almost overlapping. For instance, little interest is reserved for B2C segments with the exception for the segment of the *Smart Home*.

Given the current technology trend, it seems that International companies are better positioned than European companies, as they are focusing on key areas of differentiation such as analytics and data bases instead of communications and hardware ecosystems.

6. IoT PLATFORM DEEP DIVE

This section provides a more in depth analysis of the leading IoT platforms on the market. Our goal of the deep dive is to gain a better understanding of these platforms and identify patterns that can be indicative for their success. More specifically, we examine the following dimensions for each of the platforms: *functional features* of these platforms *supported IoT protocols*, *pricing and business models* as well as *ecosystem activities* of these platforms. The discussions are based on platforms identified and selected in section 5.4.

The IoT platforms are grouped in three broad categories, commercial platforms of global leading industry players, SME/start-up, open source platforms with an additional section on OneM2M compliant platforms. The section is concluded with a discussion of main findings.

6.1 Global industry players IoT platforms

6.1.1 Cloud centric IoT platforms

Layer	Components	Definitions			
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	V	V	V
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards	V	V	V
	Development Environment	Provide integrated development environment to simplify development of apps	V		V
Service	Service orchestration	Supports mashup of different data streams, analytics and service components	V		V
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed	V	V	V
Abstraction	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	V	V	V
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	V	V	V
Storage	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	V	V	V
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	V	V	V
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.	V		V
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity			
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform			
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications	V		
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	V	V	V
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level			

6.1.1.1 Microsoft Azure IoT

Technical overview

Azure IoT Hub⁷ is a fully managed service integrated into Microsoft Azure's cloud offering, that enables reliable and secure bidirectional communications between millions of IoT devices and a solution back end. The Azure IoT Hub provides reliable device-to-cloud and cloud-to-device messaging, secure communications using per-device security credentials and access control. It offers extensive monitoring for device connectivity and device identity management events and includes device libraries for the most popular languages and platforms. It also provides an IoT gateway SDK for the development processing and application logic at the edge.

The Microsoft Azure IoT platform is composed of core platform services and application-level components to facilitate the processing needs across three major areas of a typical IoT solution. This includes 1) device connectivity, 2) data processing, analytics, and management and 3) presentation and business connectivity.

Devices can be connected directly or indirectly via a gateway, and both may implement edge intelligence with different levels of processing capabilities. A cloud gateway provides endpoints for device connectivity and facilitates bidirectional communication with the backend system. The back end comprises multiple components to provide device registration and discovery, data collection, transformation, and analytics, as well as business logic and visualizations. The business integration and presentation layer is responsible for the integration of the IoT environment into the business processes of an enterprise.

IoT Protocols and APIs

The Microsoft Azure Hub support a broad range of connectivity options to integrate IoT devices. Device can be connected directly or indirectly via so-called field gateways.

The main integration point towards the devices provides is the Azure IoT hub, which offers support:

- AMQP 1.0 with optional WebSocket support,
- MQTT 3.1.17,
- and native HTTP 1.1 over TLS protocols

The Azure IoT device SDK can be used to simplify the development of IoT clients that can connect to the Azure IoT hub via the options above.

More constraint devices require a field gateway implementation to translate from protocols such as COAP, OMA LWM2M, OPC, Bluetooth or Zigbee.

Business model

Azure IoT Hub is madPe available in three editions. There is a **free edition** for developers to get started with a limited number of message supported per day (8k) and up to 500 devices. There are also **two paid for usage bundles** for medium and heavy use which have no device limitations and offer larger message sizes and total numbers of messages per day. Depending on the usage needs a user may purchase one or more of any these bundle options.

The Azure IoT hub also makes further direct sales from support plans for the platform use, depending on the level of customer support needed. Its business model is also based on **cross-selling of services** from the Azure family such as storage services or stream analytics and machine learning services.

⁷ <https://azure.microsoft.com/en-gb/services/iot-hub/>

Community engagement and partnership

Microsoft is able to rely on a wide partner network that spans IoT device partners, gateway partners, network and communication partners, system integrators and independent software vendors. This way Microsoft is able to enable a full end-to-end IoT solution, which utilizes the Azure IoT hub and Azure cloud platform.

Microsoft realizes that selling an IoT platform alone is not enough and requires stronger partnerships. In order to foster a pipeline of suitable partners, Microsoft has set up an IoT Red Carpet program. It is worldwide initiative in which Microsoft carefully selects partners from each country to be the "go to" partners for the new Azure IoT based solutions. IoT Partners are selected based on multiple criteria such as expertise, ability to execute, capacity to achieve targets, market and client base, and proven track record of influenced revenue. Microsoft actively engages with these companies and offers sales and marketing support for their solutions.

In order to engage a developer community Microsoft organizes developer conferences and IoT and Data Platform Day Workshops around the world. It provides an extensive developer portal with blogs, videos and tutorials. Microsoft also offers IoT starter kits from different vendors ready to order on the website, in order to make it easier for developers to get started.



6.1.1.2 Amazon AWS IoT platform

Technical overview

Amazon's IoT platform⁸ offering consists of cloud-hosted functionality that allows different IoT devices to be securely connected to the cloud and to enable bi-direction message exchange between these. More specifically, it provides a web based communication stack, a device registry and a rules engine to perform message transformation and routing towards AWS services, such as storage (S3), stream processing (Kinesis) or Amazon Machine Learning services. Applications can also communicate directly with IoT devices through REST APIs. Additionally, device generated information can be accessed via so called "device shadows" which cache past device state in the platform, to shield applications from intermitted network connectivity that devices may experience. Amazon also provides a device side SDK with common programming languages for easy integration of devices with the IoT platform.

The core services of the Amazon's IoT platform consist of an MQTT broker that receives messages from IoT devices. Communication between devices and broker are protected using X509 certificates. The platform maintains so-called thing shadows, which are respective state variables of IoT devices and a registry of valid IoT devices on the platform. A rules engine allows actions to be defined based on messages received. The rules engine connects the core services with the other services of the AWS ecosystem.

IoT Protocols and APIs

The API of the message broker for Amazon AWS is supports two communication options:

- MQTT 3.1.1

⁸ <https://aws.amazon.com/iot/>

- HTTP / REST API
- MQTT over Websockets

Business model

Amazon's business model is based on **pay-as-you-go pricing model** and is independent of the number of connected IoT devices. Prices are based on the number of messages published to AWS IoT (Publishing Cost), and the number of messages delivered by AWS IoT to devices or applications (Delivery Cost). Delivery to other AWS services is free of charge, however the AWS service use itself demands additional cost, depending on the use. This offers Amazon with **additional cross-selling opportunities**, as customers would not only require IoT connectivity and message routing but also often need persistent data storage or data analytics services.

In order to attract developers, Amazon **offers a free trial period of 12 months**, which includes 250k messages per month. Should a developer exceed either of the limits, Amazon can upsell the service to switch to the pay-as-you-go pricing model. At this stage the developer is already likely to have invested considerable development effort and "locked-in" into the Amazon ecosystem.

Amazon's unique position as a market place for electronics and other goods allows the company also to profit from additional sales of IoT devices and products that a developer may require for the realisation of an end-to-end IoT solution. Likewise it may act as a market place for selling IoT products that may have been enabled on top of the AWS IoT platform ecosystem. This means that apart from the **direct revenue stream** generated by the use of the IoT platform and other AWS services, Amazon also has the opportunity to gain **indirect revenue streams as a result from trade** of IoT products and devices on its market place. Through an increasing successful utilisation of the IoT platform, Amazon is also able to boost the trade on its market place.

Community engagement and partnership

In order to simplify the development, Amazon provides an extensive developer guide for its AWS IoT offering. It offers a range of IoT devices to be connected, ranging from a simple AWS IoT button over to different AWS IoT starter kits. In terms of community events, Amazon organises also various developer conferences, some of them with an IoT track and developer days road show with IoT hackathons/hack days.

Amazon has also established a separate partner programme for IoT hardware, which provide the starter kits that can be used out of the box for the Amazon AWS IoT platform. Partners get preferential access to developer conferences and hackathons and marketing support. Beyond Amazon provides a more generic AWS Partner Program.



856k followers
Amazon AWS



166k likes
Amazon
AWS



197K followers
Amazon AWS



14.2k
followers
Amazon AWS

6.1.1.3 IBM Watson IoT platform

Technical Overview

The Watson IoT platform⁹ is based on top of Bluemix, IBM's cloud and service offering. In order to connect IoT devices with applications, it provides a connectivity and device

⁹ <http://www.ibm.com/internet-of-things/>

management platform. Furthermore, IBM's IoT platform also offers data management services for storage and transformation, analytics services as well as a risk management services that allows the creation of dashboards and alerts.

The connection layer of the Watson IoT platform allows IoT devices to either directly connect to the Watson IoT platform or through gateway devices. It also provides a device management protocol to manage attached devices. For the latter case, the devices should implement a device management agent.

The analytics offering is composed of boards and cards, which allow visualisation of data set values from one or more devices for a quick overview and understanding of the device data. Analytics rules allow the specification of conditions that trigger actions.

Cloud rules allow triggering rules for devices that are connected directly to Watson IoT Platform in the cloud. Edge rules allow trigger rules for devices that are connected to edge analytics enabled gateways.

Application development can be done via client APIs in different languages. They can make use of IBM Bluemix capabilities including Node-RED editor. Through Bluemix various IBM Watson analytics services are available to the app developer.

The Watson IoT platform also support block chain integration, which allows the development of smart contracts that are driven by IoT data.

IoT Protocols and APIs

Communication between device and platform is handled by

- MQTT 3.1 and 3.1.1 API with token based authentication
- HTTP REST API (beta)

The device management protocol is based on MQTT.

It provides client libraries for devices/gateways in C++,C#, Embedded C, Java, mbed C++, NodeJS, Node-RED, Python.

Business model

IBM's business model is based on a tiered pricing model which depends on the number of IoT devices that a user aims to connect to the IoT platform.

There is a free 30-day trial period that allows a developer to connect up to 20 devices with 100MB of free traffic and 1GB of free data storage. Developers can also choose to purchase bronze, silver and gold packages which vary in the number of supported devices that are included in the package and additional device costs should the limited of the package be exceeded. In addition, IBM is upselling additional capacity for data storage and data traffic for higher user demands.

IBM is also cross-selling additional Watson analytics services that may be useful for an IoT developer, which include real time IoT insights, context mapping or driver behaviour analytics.

Community engagement and partnership

IBM offers a developerWorks, a developer portal with articles, tutorials and training, tools and example code as well as a community platform with open source projects. The community platforms offers forums, blogs etc.

IBM also actively engages with the developer community by organizing IoT hackdays and developer workshops across different parts of the world. It also organizes events at different IoT solutions and open source conferences and organizes virtual conferences such as the Grand Slam.

IBM also features 33 different partners, which range from silicon and sensor partners, gateway partners, device, cloud and network partners. They see partners playing various roles alongside IBM across the IoT value chain within the IBM partner ecosystem.

To lower the barriers of service access, IBM also offers financing support for different business using their services.



56.9k followers

IBM IoT



3.8k+ likes

IBM IoT



7.3K followers

IBM IoT



610 followers

IBM IoT

6.1.2 Industry centric IoT platforms

The consumer IoT applications are successful in niche markets and the business case for the Industrial IoT has rapidly evolved in the last few years. IoT connectivity extends to machines, sensors, devices and processes in the industrial sectors, and business outcomes produce increased manufacturing efficiencies, better resource utilization, and transformed support models that are driving adoption. In this context, the development of Industrial IoT platforms is driven by large manufacturing companies.

Layer	Components	Definitions	ThingWorx	Bosch IoT Suite	GE
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	✓	✓	✓
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards	✓	✓	✓
	Development Environment	Provide integrated development environment to simplify development of apps		✓	
Service	Service orchestration	Supports mashup of different data streams, analytics and service components	✓	✓	✓
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed	✓	✓	✓
Abstraction	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	✓	✓	✓
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	✓	✓	✓
Storage	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	✓	✓	✓
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	✓	✓	✓
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.	✓		✓
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity			✓
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform		✓	
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications			
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	✓	✓	✓
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level			

6.1.2.1 PTC ThingWorx

Technical overview

ThingWorx¹⁰ facilitates the streamlined creation of end-to-end smart applications for agriculture, cities, grid, water, building and telematics. Traditional industries are transformed and equipped with modern-day connectivity and smarter solutions through connected devices

¹⁰ <http://www.thingworx.com/>

that provide comprehensive data collection and analysis for data-driven decision-making. ThingWorx reduces the time, cost and risks of building M2M and IoT applications. Users can build comprehensive mobile interfaces with zero coding, take advantage of ThingWorx Composer for application modelling, as well as real-time dashboards and collaborative workspaces - all with the scalability to support millions of devices. The model framework allows seamless integration with other technologies, including augmented reality (Vuforia Studio Enterprise) and industrial connectivity (Kepware Technologies).

Key Features:

- Model-based design with ThingWorx Composer
- SQUEAL (Search, Query, Analysis) for search-based intelligence
- Complete design, runtime and intelligence environment
- Create real-time dashboards and collaborative workspaces
- Create mobile interfaces without coding
- Event-driven execution engine
- 3-dimensional storage
- Supports scale requirements for millions of devices
- Supports 3rd-party device clouds, direct network connections and more

IoT Protocols and APIs

PTC announced ThingWorx Open Platform Strategy in April 2016, which integrates ThingWorx with leading public Device clouds.

- ThingWorx platform API 7.1.0
- REST API
- AlwaysOn™ protocol (Next generation ThingWorx patented protocol)
- Edge and connectivity products:
 - Edge MicroServer (XMPP and WSEMS)
 - Connection Server
 - SDKs (Java, NET, iOS, C)

Business model

ThingWorx was established in 2010 and acquired by PTC. The key to understanding the business model is to view it from PTC's perspective¹¹. PTC supplies software and service solutions to manufacturing organizations, which supply high asset-value and business-critical items of equipment, to help them create and service their products. PTC provides software and services based on sophisticated software tools, which are used to manage application (ALM), product (PLM) and service (SLM) life-cycles and supply-chains. Increasingly, PTC's manufacturing customers are looking to manage their devices remotely. The PTC business model features are: Installed customer base and software solutions integrated into key customer work-flow, which results in long term relationships (barriers to switching vendor). The PTC revenue model: Software licenses, software support services, and implementation services.

Through ThingWorx marketplace, you get access to their partner's products and services that have been certified with PTC's IoT Technology platforms, to build and run your ThingWorx based IoT applications. All components listed on the marketplace are customized, tested and guaranteed to work with the ThingWorx platform.

¹¹ <http://www.more-with-mobile.com/2014/03/ptc-thingworx-dual-aggregation-business.html>

Community engagement and partnership

In order to lower the barrier of IoT platform use for developers, ThingsWorx offers a comprehensive developer portal with access to platform documentation and quick start guides. This includes also ready to go examples to connect a raspberry pi to the ThingsWorx platform. ThingWorx also offers a community site for developers with with blogs, videos and public Q&A forum for peer-support. Besides, ThingsWorx offers a comprehensive range of resources from case studies, videos, white papers, webinars and ebooks. It also offers physical developer fora and online events to reach out to developers.

ThingWorx claims to work with over 28.000 customers to deliver smart and connected products. In order to do this successfully, ThingWorx relies on a strong partner network. Therefore, ThingWorx offers a variety of different engagement programmes with different ecosystem stakeholders. They span partner companies such as business systems and analytics, communication service providers, providers of edge communication & embedded devices, solution providers and system Integrators.

ThingWorx has also a dedicated academic programme, offering the ThingsWorx application enablement platform to Universities and access to educational content to ease the integration of it into university curricula, including content on Udacity.



9k followers



n/a



7.8k followers



n/a

6.1.2.2 Bosch IoT Platform

Technical overview

The Bosch Software Innovations Suite ¹² is modular for advanced flexibility, enabling device management, business process management, and business rules management for the IoT. It integrates seamlessly with existing IT infrastructures for streamlined connectivity and enhanced data analytics. The Bosch Software Innovations Suite is powering the IoT by connecting the four key elements of the ecosystem; people/users, things, enterprises and partners.

Bosch is focusing on application layer by offering the IoT Cloud and IoT Suite platforms. IoT Cloud offer a scalable cloud infrastructure based on Cloud Foundry, which makes it fast and easy for IoT developers to build, test, deploy, and scale their applications. This infrastructure serves as the foundation for the Platform as a Service (PaaS) offering, which helps IoT developers create and deliver IoT solutions. The platform ensures data protection using the latest protective mechanisms. The cloud design helps the users to accelerate IoT projects, improve time-to-market for new IoT solutions, profit from integrated security mechanisms, and lower complexity and costs in the IoT projects.

Three levels of cloud infrastructures are available on the Bosch IoT Cloud:

- Infrastructure as a Service (IaaS): The layer serves as technical foundation for IoT applications and provides the necessary resources to maintain the overlying Platform and Software as a Service layers.
- Platform as a Service (PaaS): The layer comprises the ready-to-use cloud services of the Bosch IoT Suite, which are tailor-made for common requirements in IoT scenarios. In addition, base services, such as database services, runtimes, an e-mailing service,

¹² <https://www.bosch-si.com/products/bosch-iot-suite/iot-platform/benefits.html>

etc., can be directly used. The PaaS offering provides developers the tools they need to create cloud native scalable applications.

- Software as a Service (SaaS): The layer represents the broad range of IoT solutions offered to customers. Due to the cloud design of these solutions, customers do not have to consider the technical infrastructure or – in most cases – application installation and updates.

Bosch IoT Suite services enable the fast development of IoT applications that allows the connecting of different devices reliably. The main elements are:

- Bosch IoT Hub: Messaging backbone for device related communication as attach point for various protocol connectors
- Bosch IoT Remote Manager: Administration of device functions like network connection, configuration, monitoring, etc.
- Bosch IoT Things: Managing assets, reading data from assets, controlling assets, etc.
- Bosch IoT Integrations: Integration with third party services and systems
- Bosch IoT Rollouts: Manages large-scale rollouts of device software or firmware updates, both wired and over the air.
- Bosch IoT Permissions: User management, role based access control, and multitenancy for IoT applications.

Key Features:

- Modular system
- Quick, easy integration with IT systems
- Process, rule and device management
- Proven technology
- Improve existing projects
- Initiate new business models
- Deployed in 600+ international projects

IoT Protocols and APIs

The Bosch IoT Hub; messaging backbone for device related communication as attach point for various protocol connectors.

- Hub Integration, custom connector
- Bosch IoT OMA-DM connector
- Bosch IoT LWM2M connector
- Bosch IoT TR-069 connector
- Bosch IoT mBS connector

Business model

IoT business models are different from traditional ones and there is a move from conventional, linear value streams to value creation within a network of stakeholders; this requires new ways of visualizing value streams within the ecosystem. When defining business models, the focus is shifting from the company level to the ecosystem level so that all stakeholders streamline their efforts to maximize benefits for target groups.

Bosch is focusing on application layer by offering the IoT Cloud and IoT Suite platforms that are suited to deliver the key components for implementing various IoT applications that are connecting users, business partners, devices, machines, and enterprise systems with each other.

The IoT platforms are a key factor for making the IoT happen by bringing value-adding IoT solutions in Industry 4.0, energy, mobility, smart home, and smart city to life. The Bosch Software Innovations Suite is modular for advanced flexibility, enabling device management, business process management, and business rules management for the IoT. It integrates seamlessly with existing IT infrastructures for streamlined connectivity and enhanced data analytics. The Bosch Software Innovations Suite is powering the IoT by connecting the four key elements of the ecosystem: people (users), things, enterprises and partners.

In a study entitled “I4.0/IoT Vendor Benchmark 2016 – Germany,” the Experton Group rated the Bosch IoT Suite as “Leading.” The analyst group emphasizes that the offering comprises an attractive range of products and services, and that Bosch Software Innovations holds a particularly strong market position and competitive standing.

Community engagement and partnership

Bosch Software Innovations (SI) takes a quiet different approach to ThingWorx in engaging with the eco-system. It does not have a developer programme nor does it provide openly access to platform APIs or training material.

Bosch focuses on working together with a set of partners to deliver end-to-end solutions around their platform. This includes strategic partners, global partners, solution partners, silicon partners, technology partners and OEM partners.

Bosch customers span utility companies, manufacturing, retail and logistics, telecom and other sectors.



6.1.2.3 GE Predix

Technical overview

Predix¹³ data services provide rapid access to data and timely analytics while minimizing storage and compute costs. It offers a secure, multi-tenancy model that includes network-level data isolation and encrypted key-management capabilities. It also supports the ability to plug in analytic engines and languages to interact and process the data. There are four key components:

- Connection to the source: Connections are established with GE and non-GE machine sensors, controllers, gateways, enterprise databases, historians, flat files, and cloud-based applications.
- Data ingestion: Data is ingested from the source in real time, and by bulk upload.
- Workflow tools allow the user to identify specific sources and to create default data flows for all—or specific—data sets and data types, including unstructured, semi-structured, and structured. These tools speed the design, testing, and generation of code, making it easier to manage and monitor simple, onetime projects to complex, ongoing data synchronization projects.
- Pipeline processing: The ingestion pipeline can efficiently ingest massive amounts of data from millions of assets. However, data can arrive in different formats, and come from multiple sources, all of which make running predictive analytics difficult. Pipeline

¹³ GE

processing allows the data to be converted to the correct format so that predictive analysis and data modelling can be done in real time. The pipeline policy framework provides governance and cataloguing services, allowing users to perform data cleansing, increase data quality, data enrichment (for example, merging with location or weather data), data tagging, and real-time data processing.

- Data management: Data needs to be stored in the appropriate data store, whether it be time series for machine sensor data, Binary Large Object (BLOB) (for example, MRI images), or an RDBMS. This allows use of the data for both operational and analytical purposes. It also provides data blending capabilities, where users can deploy tools to extract value from these data sources to find patterns and process complex events (i.e., look for a combination of certain types of events to create a higher-level business event).

IoT Protocols and APIs

Different APIs are available such as Predix Time Series API that offering sensor data management, distribution, and storage, Predix Traffic Planning API offering metadata obtained from lighting sensors along public roadways, Predix Asset Data REST API that create and store instanced asset models for machine types and returns data in JSON format. The platform offers MQTT Support. There are three types of edge connectivity options that Predix Machine provides:

- Machine gateway (M2M) - Many assets already support connectivity through industrial protocols such as OPC-UA or ModBus. The Machine gateway component is an extensible plugin framework that enables out-of-the-box connectivity to assets based on the most common industrial protocols.
- Cloud gateway (M2DC) - The cloud gateway component connects Predix Machine to the Predix Cloud. There are several protocols that are supported, most commonly HTTPS or WebSockets.
- Mobile gateway (M2H) - In addition to connecting to the machines and to the cloud, the mobile gateway component enables people (humans) to bypass the cloud and establish a direct connection to an asset. This capability is especially important for maintenance scenarios. When service technicians are deployed to maintain or repair machines, they can connect directly to the machine to understand its operating conditions or perform troubleshooting. In certain industrial environments, where connectivity can be challenging, the ability to bypass the cloud and create this direct connection to the machine is key.

Business model

Predix (IoT PaaS) supports the development of apps that connect people with industrial machines through analytics and data for better business outcomes. Business model applications areas are Industrial Internet of Things, aviation, healthcare, energy and transportation. Predix Cloud is focusing on providing a platform for developers to “unlock an industrial app economy that delivers more value to machines, fleets and factories”. This means supporting collaboration between a community of developers, providing the technology to build and deploy apps in a secure environment.

The business model includes partnerships between software developers and big data platform providers. IoT business models place greater emphasis on services produced by an ecosystem of technologists that are collaborating to find the best possible, industry-wide solution rather than serving competing interests.

Community engagement and partnership

GE offers a developer portal which contains platform documentation, developer guides with example codes and training material in the form of both online and offline classes. It offers an edge starter kit based on the Intel Edison that directly connects to the predix cloud services. It offers different developer tools and SDKs, as well as podcasts, videos and blog content.

GE also offers dedicated Predix developer training classes as well certification for developers.

GE has a global and regional partner network, consisting mainly of large vendors, operators and consulting firms.

In order to engage with customers, GE Digital has set up a several foundaries across the world that bring together GE experts, technology demonstrations in collaborative work spaces, where customers can co-create MVPs around GE Predix to solve problems in their business. GE also offers a series of events and webinars for potential customers.



24k followers

GE Digital



N/A



59k followers

GE Digital



N/A

6.1.3 Communication centric IoT platforms

Layer	Components	Definitions	Axeda	aeris	CISCO Jasper	Ayla Networks
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	V			
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards	V	V	V	V
	Development Environment	Provide integrated development environment to simplify development of apps	V			
Service	Service orchestration	Supports mashup of different data streams, analytics and service components	V	V		
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed				V
Abstraction	Event & action management	Simple rules engine to allow mapping of low level sensors to high level events and actions	V	V	V	V
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	V	V	V	V
Storage	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	V	V	V	V
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	V	V	V	V
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.				
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity			V	V
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform				
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications				
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	V		V	V
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level				

6.1.3.1 PTC Axeda

Technical overview

Axeda¹⁴ provides a cloud-based platform for managing connected products and machines and implementing IoT and M2M applications. The platform is used to transform machine data into valuable insights, build and run applications and integrate machine data with other applications and systems to optimize business processes. Axeda’s platform encompasses the area of developing and deploying applications and integrating M2M learning into business processes, from preventative data security measures all the way to device provisioning and configuration. The "Machine Cloud" service include:

- Axeda Connect (IoT connectivity middleware): Cloud based communication software that enables you to connect machines and devices to the cloud and then process, transform, organize and store machine and sensor data.

¹⁴ <http://www.ptc.com/axeda>

- Axeda Build (IoT application enablement platform): Cloud based tools that simplify development and enables you to implement IoT applications. Capabilities include data management, a scripting engine, an integration framework, SDKs and web services for accessing data and application services in the Axeda machine cloud.
- Axeda Manage (connected machine management applications): Cloud-based web applications that enable you to remotely monitor, manage, service, and control wired and wireless connected products and assets. Capabilities include remote access, security management, software distribution and configuration management.

Key Features:

- Application services, integration framework and data management
- Integrate machine data into mission-critical applications
- Open API; REST and SOAP services
- Two-way, cloud-to-cloud communications
- Least cost routing
- Intelligent secure agents for internet, cellular and satellite
- Embedded agent toolkits
- Asset tracking and monitoring
- Alerts and notifications
- Device provisioning and configuration

IoT Protocols and APIs

Axeda Machine Cloud Service includes IoT/M2M connectivity services, software agents, toolkits enabling connectivity between devices or assets and the Axeda Platform that supports:

- Adaptive Machine Messaging Protocol (AMMP) is a simple, byte-efficient, lightweight messaging protocol to facilitate machine-to-machine communications and to build IoT connectivity into your product. Using a RESTful API, AMMP leverages HTTPS and JSON as the means for sending and receiving M2M-related messages between an edge device and the Axeda Machine Cloud.
- MQTT

Business model

Axeda provides an advanced cloud based service and software for managing connected products and machines. Provide remote service and analyse usage to improve performance.

Machine-to-machine business processes to enhance service, billing, sales, inventory management, and product development.

Community engagement and partnership

Like ThingsWorx, Axeda is owned by PTC. It represents one of PTC's product offering. However unlike ThingWorx, which has a separate developer community, but relies on PTC's partner network and ThingWorx developer zone.



26.1k followers
PTC



8k likes
PTC



82.8k followers
PTC



n/a

6.1.3.2 Aeris IoT

Technical overview

Aeris ¹⁵ is an end-to-end M2M and IoT service provider. The M2M IoT solutions are built from the ground up for machines only, but they exist to service the users who own and operate those devices. Aeris offers a complete set of IoT platforms and connectivity technologies in the industry, including LTE, GSM, and CDMA for 2G and 3G.

The Aeris platform is scalable and consists of various technology layers that are modular so you can select only what you need and incorporate your own connectivity technology or carrier/operator of your choice. It is a cloud based infrastructure-as-a-service (M2M IaaS) with the application enablement platform (AerCloud) on the top of the technology stack. Other parts are the connectivity management platform (AerPort), IoT and M2M core network (AerCore), Billing and rating engine (Aer/OSS), IoT and M2M analytics (AerVoyance), and Cellular connectivity services (AerConnect). They also offering an online marketplace to develop, launch, and manage innovative IoT solutions that require cellular connectivity,

IoT Protocols and APIs

The AerCloud platform supports the connection of IoT device by different means. It is agnostic to the connectivity technology and supports the following protocols across its connectivity API:

- RESTful API based on HTTP
- MQTT
- CoAP

The platform can also support custom protocols through web adapters.

Business model

The Aeris GSP M2M service delivery platform is a cloud based Platform-as-a-Service (PaaS) offering your M2M business model succeed by directly addressing three key challenges facing mobile network operators: Expanding the addressable M2M Opportunities, Increasing average revenue per connection, and Driving service delivery costs out of M2M services, with small upfront investment. Suggested business application areas are: Network based data management services, application enablement (Data management services); User and operator portal to manage acts, users, SIMs, devices, alert rate plans, and roaming (Connectivity enablement portal); Machine optimized, service delivery core (Advanced core services); and Charging and billing systems for flexible M2M business models and operational requirements (Charging and billing).

Community engagement and partnership

Aeris does not directly offer its platform to developers and therefore has no API documentation or a developer portal.

Aeris main customers are operators and larger enterprises in telematics and connected car, healthcare and utilities.

Aeris has a select partner network that includes one design partner, various hardware partners and channel partners.

¹⁵ <http://www.aeris.com/>

Aeris offers an extensive set of resources such as white papers, case studies, ebooks etc to attract the interest of potential customers.



14.7k followers



285 likes



8.5k followers



303 followers

6.1.3.3 CISCO/Jasper

Technical overview

Jasper¹⁶ provides features to launch, manage and monetize connected devices and IoT applications. The configurable Jasper Control Board Platform is customizable to suit specific operational needs, business models and requirements across industries and across different geographical locations. Jasper serves IoT needs such as connected cars and enterprise mobility, offering network visibility across devices and real-time monitoring for precise control and deeper insights to drive decision-making.

Jasper is used by some of the world's largest corporations to launch, manage and monetize connected devices and IoT applications. The highly-configurable Jasper Control Board Platform is customizable to suit specific operational needs, business models and requirements across all industries and around the world. Jasper serves IoT needs such as connected cars and enterprise mobility, offering full network visibility across all devices and real-time monitoring for precise control and deeper insights to drive decision-making.

Key Features:

- Automate and control devices
- Analyse behaviour patterns and performance
- Real-time monitoring
- Configure rules for segmentation and scoring
- Set up offers, campaigns and programs
- Define service alerts and campaign events
- Maintain full network visibility
- Automate activation processes
- Real-time issue identification and troubleshooting
- Integrates with existing IT infrastructure

IoT Protocols and APIs

Jasper operates its own M2M connectivity management services and provides customers with a global SIM card that integrates into its platform. No information on protocols and APIs is provided.

Business model

Cisco Jasper control center optimizes and automates every stage of your IoT service lifecycle, enabling you to get the most out of your devices, networks and applications. They offering for businesses: Accelerated time-to-market, easily and rapidly scale your IoT services across the globe; Provided automated, real-time visibility and control over all of your networked devices and services; and Ensured higher service reliability with real-time intelligence and monitoring of changing network conditions. Typical business model applications areas are: Connected

¹⁶ <http://www.jasper.com/>

cars, Transport and logistics, Mobile enterprises, Industrial equipment, Retail and payment solutions, and Security and home automation.

Jasper charges customers for every connected device – this includes M2M connectivity services as well the platform services.

Community engagement and partnership

Cisco Jasper does not directly offer their platform to developers and therefore has no API documentation or a developer portal. Instead, Jasper partners with major IoT cloud platform companies such as IBM, Microsoft, SAP and ThingWorx to provide services on top that go beyond IoT device and service lifecycle management.

A key element of Jasper’s business is to provide global M2M connectivity based SIMs with its platform offering. Therefore Jasper partners with more than 25 operator groups globally.

Jasper claims to have over 6k customers.



6.1.3.4 Ayala Networks

Technical overview

Ayala¹⁷ offers a set of solutions that enables manufactures to connect their consumer devices and products to the Internet. Its offering consists of a cloud based Agile IoT platform to connect different devices. Ayala AMAP is a mobile application platform to enable consumer interfaces to devices via popular mobile phone platforms such as Android and Iphone. Ayala Insights is a collection of services that provide business intelligence and analytics capabilities.

The Ayla Cloud Service is the heart of our Agile IoT Platform. The Ayla Cloud offers a full suite of operational support services to better manage and control a connected deployment as well as provides assess to a number of different business intelligence and analytics services to produce intelligent insights and automated operations.

The platform implementation follows a SOA paradigm and the services include device services, such as templates, notification, time and location, image service, and over-the-air updates and user services, including security (Authentication/ Authorization/Accounting, role-based access control, etc.) triggers and alerts, OEM dashboard, and developer websites. It also offers application services such as rules engine, third-party integrations, and custom rules support.

Ayala’s Insights involve data and analytics services, such as logging and metrics, statistics, reports and data discovery and ETL (extract/transform/load data) functionality.

Ayla thus offers a ‘black box’ solution that enables OEMs to create very efficient product development pipelines for similar kinds of connected products. It provides device manufacturer with embedded agents to be pre-loaded into the communication chips that are designed directly into the product, providing all of the code needed for connectivity to the Ayala Cloud service.

¹⁷ <https://www.aylanetworks.com/>

Business model

Ayala Networks seems to focus mainly on manufactures of devices for homes and buildings. This includes HVAC vendors and other vendors who have products that can fall under the smart home and smart office category. Unlike the bigger cloud vendors, Ayala Networks does not provide transparent pricing options. It offers a more bespoke service, working closely together with their customers to simplify the integration of their smart products into the Ayala IoT platform.

IoT Protocols and APIs

Ayala does not openly provide API documentations nor does it mention specific protocols used for the integration of devices into its platform. This seems to be in line with its strategy to support mainly manufactures with a pre-integrated and closed out of the box solution that can be dropped into a manufactures product.

Community engagement and partnership

Ayala does not seem to have strategic partnerships with other vendors, apart from Renesas who provides their dev kit, but has a strong industrial customer base, mainly focused around the smart home market such HVAC vendors, smart fans, home alarm such as gas/smoke alarms, and home security systems, smart lightning, smart locks. Examples of important customers are Fujitsu, United Technologies, Changhong, Hunter, TCL and Dimplex.

In order to make it simpler for developers to get started on the Ayala Network IoT platform, Ayala offers an IoT design kit that comes preloaded with software to directly connected to the cloud platform. This reduces the barriers to their technology by enabling an out of the box experience for the user.

Ayala offers free webinars on IoT opportunities for device / appliance manufacturers positioning their IoT product offering on the market. They also started to provide a series of hands-on tutorials around the IoT platform in different US cities.



1.1k followers



6. + likes



2269 followers



n/a

6.1.4 Device centric

Layer	Components	Definitions	intel	ARM [®] mbed
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	✓	
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards	✓	
	Development Environment	Provide integrated development environment to simplify development of apps	✓	✓
Service	Service orchestration	Supports mashup of different data streams, analytics and service components		
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed		
Abstraction	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	✓	
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	✓	
Storage	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	✓	
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	✓	✓
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.		✓
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity	✓	✓
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform	✓	✓
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications	✓	✓
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	✓	✓
	MPU /MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level	✓	✓

6.1.4.1 INTEL

Technical overview

The Intel[®] IoT Platform¹⁸ is an end-to-end reference model and family of products from Intel and the industry that provides a foundation for seamlessly and securely connecting devices,

¹⁸ <http://www.intel.com/content/www/us/en/internet-of-things>

delivering trusted data to the cloud, and delivering value through analytics. The platform is one of several services by Intel that heavily pushes into the IoT, e.g. by Intel Open Labs or the Galileo developer kit.

Together with the platform, there are two system architecture specifications for unconnected and already connected devices.

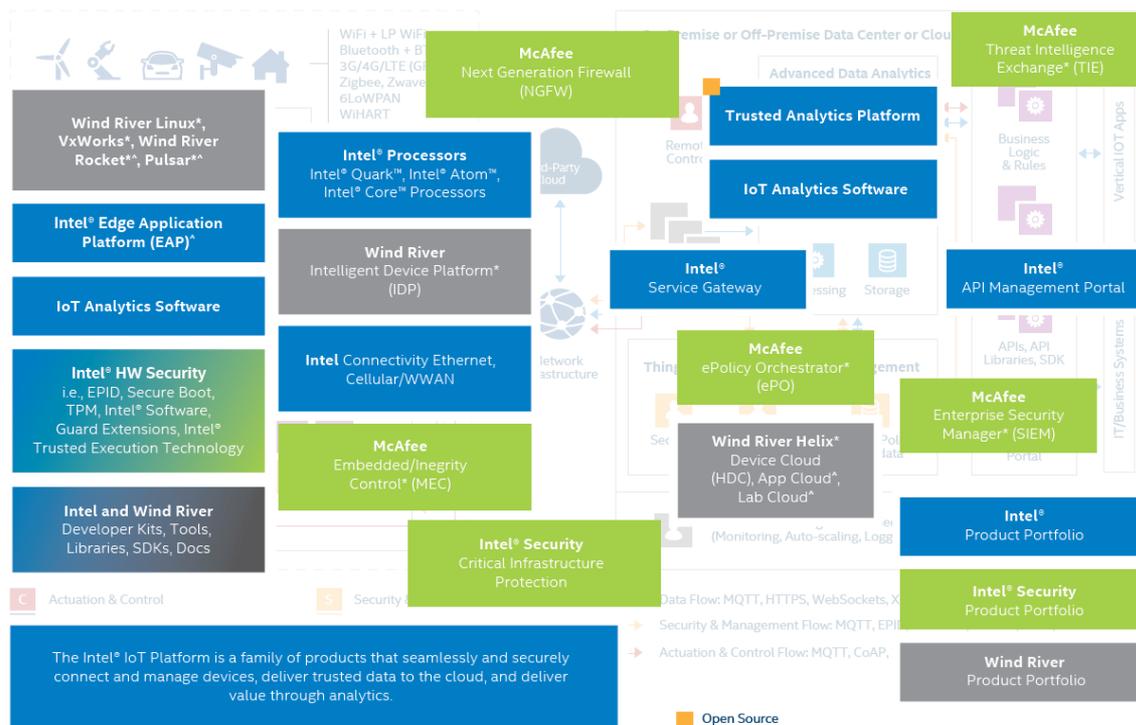


Abbildung 1 Building blocks for INTEL's IoT reference architecture (source: Intel IoT Platform White paper):

IoT Protocols and APIs

The Wind River Intelligent Device Platform XT offers a customizable middleware development environment that provides several APIs, namely:

- Open JDK
- Lua VM
- SQLite and
- OSGi

and supports

- ZigBee
- Bluetooth
- WWAN
- VPN
- MQTT and
- Cloud Connector

¹⁹ <http://www.intel.eu/content/www/eu/en/internet-of-things/iot-platform-solution-brief.html>

with regard to connectivity.

Business model

Launching the spring of 2016, the Intel® IoT Platform Marketplace hosts Intel® IoT Platform Technology software, hardware and peripherals for sale to the public.

With regard to the software, Intel uses a freemium model, offering the Wind River Intelligent Device Platform XT for free together with a (limited) version of McAfee Embedded Control Essential as “Intel IoT Gateway Software Suite.

<https://shopiotmarketplace.com/iot/index.html#/details>

Community engagement and partnership



89,6k followers
(Intel IoT)



44.3k+ like
(Intel IoT)s



788K
followers Intel)



1.2 Mio
followers
(Intel)

Intel actively promotes a community building around IoT capacities and solutions, called the IoT solutions alliance. “Collaboration across the Intel ecosystem brings together the range of expertise and abilities required to create the IoT value chain. The chain begins with components, starting with ingredients, such as processors, modules, operating systems, and security software. Original design manufacturers (ODMs) use these to build boards that end up in things delivered by original equipment manufacturers (OEMS).²⁰

Systems integrators turn these things into industry-specific solutions with application and data analytics software. Network services connect things and cloud services, which take advantage of that analytics and application software to turn raw data into useful information.”

6.1.4.2 ARM mbed

Technical overview

The ARM mbed²¹ IoT Device Platform provides the operating system, cloud services, tools and developer ecosystem to make the creation and deployment of commercial, standards-based IoT solutions possible at scale, according to its own website.

The ARM mbed IoT Device Platform is made up of two key sets of products: device software and cloud based device management services. The part/platform to be analysed in the framework of this analysis is the mbed Device Connector, which provides the following features:

- Based on open industry standard protocols including CoAP/HTTP, TLS/TCP, DTLS/UDP and OMA LWM2M, enabling energy efficient data communication and device management.
- Includes strong end-to-end trust and security using open security standards.
- Works with REST APIs, making it easy to integrate with any system.
- Offers full integration of the developer console and web tools with mbed.com; there is no need to move to a different development environment after deployment.

²⁰ <http://www.intel.eu/content/www/eu/en/internet-of-things/ecosystem.html>

²¹ <https://www.mbed.com/en/platform/>

- Provides an example web application, accelerating proof of concept projects.

ARM mbed is compatible with its embedded operating system mbed OS²² which is designed specifically for IoT. It is built to offer bandwidth efficient connectivity for even the most constrained IoT devices and provides access to the ARM mbed IoT device ecosystem.

IoT Protocols and APIs

Secured end-to-end with DTLS, Uses CoAP/HTTP, TLS/TCP, DTLS/UDP and OMALWM2M, enabling energy efficient data communication and device management, Rest APIs to integrate with existing systems

Business model

The device connector is offered as freemium model, i.t. provided at no cost to IoT developers with a limitation to 100 devices, 10,000 events per hours and two API keys. mbed supports transition to commercial deployments with either on-premises infrastructure or as a service.

Community engagement and partnership



On LinkedIn is a separate group installed called “mbed” with 960 members. The mbed community allows contribution and collaboration between ARM, over 50 partners, and hundreds of thousands of individual developers all over the world. ARM mbed provide a partner portal on its website.

Many of the components and projects have been contributed by the community. The forum and Q&A provide developers with community support, alongside GitHub for technical input.

They divide their partners into three groups: cloud partners, ecosystem partners and silicon partners.

²² <https://www.mbed.com/en/platform/mbed-os/>

6.2 SME/Startup platforms

Layer	Components	Definitions	xively <small>by LogMein</small>	ThingSpeak	carriots	EVERYTHING IoT	SensorCloud <small>Powered by QMC-Security</small>
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	V			V	
Application	Visualization	Presents device data in rich visuals and/or interactive dashboards	V	V	V	V	V
	Development Environment	Provide integrated development environment to simplify development of apps		V	V		V
Service	Service orchestration	Supports mashup of different data streams, analytics and service components	V		V	V	
	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed		V			V
Abstraction	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	V	V	V	V	V
	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	V	V	V	V	V
Storage	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	V	V	V	V	V
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	V		V	V	
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.					
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity					
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform				V	V
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications					
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	V	V	V	V	V
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level					

6.2.1 ThingsSpeak Technical overview

ThingSpeak²³ is an Open Data Platform for the Internet of Things, it connects sensors to the web and the web to things. This open source platform was released by ioBridge in 2010 for creating “*sensor logging applications, location tracking application, and social network of things with status updates*”²⁴. Additionally, collected and stored data can be processed and visualized such as “*timescaling, averaging, median, summing, and rounding*”¹ by using

²³ <https://thingspeak.com>

²⁴ Description from the git repository page related to ThingSpeak codes and sources <https://github.com/iobridge/thingspeak>

Matlab²⁵. Each ThingSpeak Channel supports up to eight numeric and/or alphanumeric fields of data in JSON, XML, and CSV formats. ThingSpeak is a community based platform that works with different data providers and devices: Arduino and Particle Photon and Core, Raspberry Pi, Electric Imp, Twitter and Twilio.

The objective of ThingsSpeak is to make easy the connection between sensors and the web, as well making the collection, analysis and visualization easy to be adopted for different use and integrated by different devices.

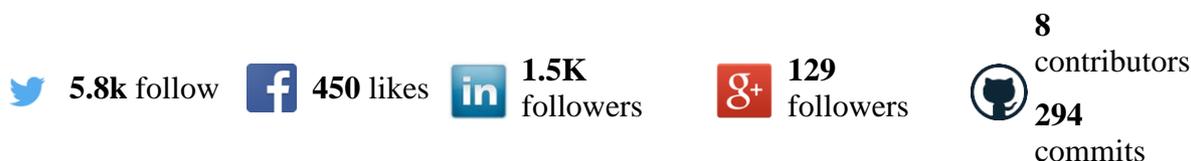
IoT Protocols and APIs

ThingsSpeak API allows to store and retrieve data from things using HTTP over the Internet or via a Local Area Network

Business model

ThingSpeak is featured into the IoT existing system to tap MathWorks products. Thus, ThingSpeak is a free to use platform that integrate MathWorks operations.

Community engagement and partnership



ThingSpeak encourages and stimulates the community by participating to both formal and informal events such as conferences and meet-up. Additionally, the official blog is updated with activities and events that are relevant for the ThingSpeak community. Moreover, the recognized connection with MathWorks includes a further professional networking layer that engage with the community with blog-posts and documentations.

6.2.2 Xively

Technical overview

Xively²⁶ is one of the longest serving IoT middleware platforms on the market. It started its life as a community based platform for sharing sensor data streams known as Pachube and Cosm, before being sold to LogMein, which turned it into a commercial enterprise platform. Xively provides a technology stack for a connected product solution, including messaging, cloud-based APIs, SDKs, integrations, and a management app for the connected product environment. It is designed to accelerate the creation of connected product value, provide operational efficiencies for IT and the business, and help companies integrate their connected products with business systems.

The goal of Xively is to enable easy creations of IoT enabled apps on top of connected devices, allow the integration of devices into existing systems and ultimately enable integrated service platforms. Core of Xively is an IoT platform offering different services such as device identity management, MQTT based messaging bus, time series data storage and event logging. It provides C-based client libraries for connecting devices as well as SDKs for Android and IOS

²⁵ Please, for further information on Matlab for ThingSpeak look at: <http://uk.mathworks.com/hardware-support/thingspeak.html>

²⁶ <https://xively.com/>

based devices. It offers a web based management application for connected devices and provides a well-defined blue prints for creating products and associated work flows. Xively also support basic device management such as firmware updates for IoT devices and integrates with the Salesforce Service cloud.

IoT Protocols and APIs

Xively is a web based platform making use of the normal web stack for integration of data feeds from IoT devices. The Xively IoT APU offers two options for connecting IoT devices:

- HTTP REST API, using HTTPS based authentication
- MQTT with TLS1.2+ for encryption

Business model

Xively operates a direct business model which is based on reoccurring customer revenue for the use of the platform. It uses a Freemium model in order to attract customers, by offering a free subscription than enables access to its APIs. It allows data storage for one month and offers reduced collection, management, and filtering data options. While the API access is not restricted the number of IoT devices to be connected is limited to 25.

Xively also offers month-to-month and annual subscription for its services, which provide full access to platform features. The commercial use of the platform allows customers to open up and share data depending on personal requirements. Data can be managed and stored following a preferred solution that include a mix of cloud and local storage. More information on pricing is not directly available.

Community engagement and partnership



92.4k followers



6.5k+ likes



1.5K followers



281 followers

Xively promotes and participates to networking events as well sponsors hackathons in the core IoT cities such as London, San Francisco, and Boston. While Xively is already established and well known in the community network, the organization behind keeps up the engagement through frequent blog-posts. Xively has well documented API for developers.

Xively has also a wider partner ecosystem to fill in gaps in their current offering, in order to provide an E2E IoT experience for their customers. This includes:

- Chip vendors (Qualcomm, Texas Instruments)
- Business and technology consulting (Cognizant, Cardinal Peak, GlobalLogic)
- Data visualisation and analytics (Splunk, Solidworks)
- CRM (Salesforce)

6.2.3 Carriots

Technical overview

Carriots²⁷ is Platform as a Service (PaaS) for integrating customers' application with "external IT systems through" a development environment, open API and web services.

Carriots is designed for collecting and store data from different devices. Moreover, Carriots provides a software development kit for building application to deploy and scale projects from prototype to full-scaled projects.

²⁷ <https://www.carriots.com>

Carriots aggregates, and stream data by using MQTT, cURL, hURL, to Carriots REST API. The platform supports the control and maintenance of devices Device control and maintenance is enabled. Finally, IoT application are developed by using Java Carriots SDK and coding in Carriots Control Panel web application.

The objective of Carriots is to facilitate and support IoT projects and applications towards its own cloud.

IoT Protocols and APIs

Carriots is a cloud platform that connects devices to collect data and develop applications from them. To collect data, Carriots uses:

- HTTP RESTful API to push and pull XML or JSON encoded data.
- NoSQL Big Data Base for storing the data
- Carriots aggregates, and stream data by using MQTT, cURL, hURL, to Carriots REST API.

Business model

Freemium: A basic version is available for free with service limitation: up to 2 devices and, limited number of API key. Other versions of subscriptions depend on the minimum number of devices connected, API Key, stream and API and SDK Http strategy, and service support and legal agreement.

Community engagement and partnership

Carriots is part of a lively network of partners that include hardware and software companies. Moreover, Carriots participates to national (Spain, since Carriots is a Spanish based company) and international events such as conferences and one day events that take into account various area of the IoT world

 2.3k followers

 74 likes

 224 followers

 14 followers

6.2.4 Evrythng

Technical overview

Evrythng²⁸ is a platform that connects smart products to the web providing real-time web based application. By using an OAuth protocol to connect external applications and products, Evrythng “collects, manages and applies real-time data from smart products and smart packaging to drive IoT applications”²⁹. This platform works with multiple kind of connectivity technologies from smart tags to chips that have digitally identified by Active Digital Identity (ADI). Evrything adopt an OAuth protocol for connecting external applications to products.

Moreover, and we can even set the threshold condition trigger an action send a text alert message.

²⁸ <https://evrythng.com>

²⁹ This description can be found here: <https://evrythng.com/platform/>

Thnghub, the Evrythng local cloud gateway software that solves connectivity issues among different communication protocols. Thnghub turns any device into “*hubs running a software gateway application that’s in lockstep with the full IoT cloud platform, allowing the same functionality both locally and remotely*”³⁰.

The objective of Evrythng is to support companies on developing market-leading products, making easy the digitization and connection of products to the Web.

IoT Protocols and APIs

Evrythng is a web platform that allows the development of external applications. Evrythng provide RESTful API toolkits. Calls and permissions are based on the request of query parameters, URL, and HTTP verb. Moreover, the platform supports MQTT, COAP, and web sockets as communication protocols.

Business model

As the company itself writes in its own website, Everything provides ready-to-hand solutions transforming the business model to software services.

Community engagement and partnership

Evrythng has offices in the core innovative cities: London, New York, and San Francisco where they organize hackathons and other kind of events. Moreover, Everything is participating in different international events and activities such as summit and conferences.

 5k followers

 514 likes

 3.4k followers

 36 followers

6.2.5 SensorCloud

Technical overview

SensorCloud³¹ is a platform for storing, visualizing, remote managing, and analysing data. The platform was designed in the first place to support long-term deployments of MicroStrain wireless sensors. However, SensorCloud platform evolved and is currently supporting “*any web-connected third party device, sensor, or sensor networks through a simple OpenData API*”³².

SensorCloud includes features such as MathEngine, FastGraph, and LiveConnect. MathEngine provides tools for processing and analyzing data that, when applicable, will create an output channel through FastGraph viewer. LiveConnect instead is a tool that allows interacting with WSDA gateway³³ and remote sensors.

Since 2011 this platform provide secure cloud services built on top of Amazon Web Services. Moreover, all data are private and can be shared with other authorized users.

³⁰ Please, for further information look here: <https://evrythng.com/thnghub-evrythngs-unique-local-cloud-gateway/>

³¹ <https://sensorcloud.com>

³² Information related to the connection between MicroStrain and SensorCloud can be found here: <https://www.microstrain.com>

³³ WSDA gateways enable coordination and schedule communication between remote sensor nodes. Further information can be found here: <http://www.microstrain.com/wireless/gateways>

IoT Protocols and APIs

SensorCloud uses cloud computing platform. It provides RESTful API allowing any device and application to upload data to the platform by using standard HTTP request commands.

Finally, the SensorCloud SDK combines source code for Python, Java, C# and models of the clArc language. SensorCloud SDK generates service framework based on clADL, MDL, and TDL models.

Business model

Freemium: A basic version is available for free. Limits for the free version and extensions for advanced versions include data storage parameters, number of transactions, and custom alerts.

Community engagement and partnership

SensorCloud is part of the broad community of LORD MicroStrain Sensing Systems that develops different kind of sensors and software for a diversify range of uses.

 **723** follow  **151** likes  **696** follow  **36** follow  **6** contributors
111 commits

6.3 Open source platforms

Layer	Components	Definitions	 KAA	 Nimbits	 eclipse smarthome	 OpenRemote	 FIWARE	 OPENIoT
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems						
	Application	Visualization			✓	✓	✓	✓
Service	Development Environment	Provide integrated development environment to simplify development of apps				✓	✓	
	Service orchestration	Supports mashup of different data streams, analytics and service components					✓	✓
Abstraction	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed					✓	
	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	✓	✓	✓	✓	✓	✓
Storage	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	✓	✓	✓	✓	✓	✓
	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	✓	✓	✓	✓	✓	✓
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	✓		✓	✓	✓	
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.	✓		✓		✓	
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity						
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform						
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications						
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	✓		✓	✓		✓
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level						

6.3.1 Kaa Technical overview

The Kaa project³⁴ is an open source IoT middleware platform that can be used for building end-to-end IoT solutions, connected applications, and smart products for different IoT application domains. Kaa aims to speed up IoT product development, allowing IoT service and solutions providers to concentrate on maximizing their product’s unique value to the consumer.

Kaa enables data management for connected objects and back-end infrastructure by providing the server and endpoint SDK components in Java, C and C++. It handles connectivity from

³⁴ <http://www.kaaproject.org/>

devices to the backend and supports a range of commercial IoT hardware platforms. It abstracts network connection such as WiFi, Ethernet, Zigbee, MQTT, CoAP, XMPP, TCP, to simplify the creation of applications that communicate with devices even over intermittent data connections. It provides a scalable data processing backend that supports different open source big data processing systems. Kaa also provides a topic based message delivery system for participating device and service side end-points. It also provides simple end-point management functionality to organise participating end-points into groups and allow end-points to expose data parameters as profiles that the server side can control. This way messages can be addressed and filtered to a subset of end-points or their software behaviour can be modified.

Business model

Kaa is an open source project initiated by Cybervision, a software company based in US and Ukraine. The use of the platform is free and hosting of the platform components are left to the end user. The business model of Cybervision is based on providing commercial services around the Kaa platform that make it easier for third parties to build IoT systems enabled by Kaa. This includes professional consultancy services for projects, software engineering and production support around Kaa platform.

IoT Protocols and APIs

Kaa mainly focuses on scalable data collection and event processing from different device end-points and making these conveniently available to multiple applications. The platform API is mainly RESTful, providing a diverse set of client libraries to connect internet connected IoT devices. The implementations include client SDKs for Java, C, C++ and Objective C. In order to deal with non-IP devices such as Bluetooth or Zigbee, Kaa assumes IoT gateways connecting these devices, built upon the SDKs.

Community engagement and partnership

CyberVision, the company behind Kaa, has a partnership program that aims to engage stakeholders such as IoT vendor, M2M connectivity provider, chip manufacturer, data analytics software vendor, hardware manufacturer or system integrator around the open source platform. The partnership aims at integrated the Kaa platform into the partners product and to enhance its market appeal and functionality. So far no partners are listed on the website.

The Kaa platform code is hosted on github with an active developer community of about 15-20 core developers, providing continues contributions since Oct 2014. Kaa offers good portfolio of support mechanisms to customers/end-users of the platform with project website, developer guides, API documentations, developer forum and regular webinars. The project participates in various tradeshows and conference events as well as meetups and is about to organise 2 hackathons with the community. Kaa webinar can be found on you tube, the project has also a linked and twitter profile.

Kaa claims to have more than 100+ community projects, although no direct reference to these are provided. In order to facilitate integration of different IoT device platforms providing libraries Intel Edison, beaglebone, RaspberryPi, econais, LeafLabs, TI CC3200 and ESP8266.

In terms of operating systems, Kaa support Android, IOS, Linux, Ubuntu Snappy and QNX.



5k followers



n/a



300 followers



n/a

6.3.2 Nimbits

Technical overview

Nimbits³⁵ is an open source data historian server built on cloud computing architecture that provides connectivity between devices using data points. The platform is used for developing hardware and software solutions that can connect to the cloud or to each other, logging and retrieving large amounts of data from physical devices, triggering events or alerts, or initiating complex analysis. Nimbits is a platform for connecting people, sensor and software to the cloud with one another. It is based upon data logging and rule technology. It resolves the complexity associated with Edge Computing in IoT by facilitating a platform which is built upon embedded system locally and then filtering noise, running rule engine and then pushing data that are very important on the cloud. It first records and then processes geo informatics and time stamped data and then produces rule from that information. Here rules can alerts, push notification, statistics any calculation. Nimbits Public Cloud is an instance of Nimbits server.

IoT Protocols and APIs

It is a PaaS that can be downloaded on a Raspberry Pi, Web Server, Amazon EC2, or Google App Engine. Nimbits is build provided for Google App Engine and Linux Systems Compatible with most J2EE servers (Apache Tomcat, Jetty Server).

A public version of Nimbits is available on app.nimbits.com, all of the functionality on the public server can on the developer personal App Engine account.

The API is HTTP/RESTful using json+hal.

Business model

It is available an open source version of Nimbits Server for download.

Licensed under the Apache License, Version 2.0; you may not use the platform except in compliance with the License.

All of the functionality can be customized for specific needs

Community engagement and partnership

Nimbits is an open source effort by mainly one author. There are no significant community engagement activities, nevertheless it has sparked an interested user base in the IoT community.



n/a



n/a



n/a



n/a



1 contributor

964 commits

91 star gazers

6.3.3 Eclipse IoT/ smart home

Technical overview

Eclipse Smart Home³⁶ (ESH) is a software running in the home. It contains the major code and data structures that are needed in a home automation server. ESH is developed within the Eclipse Java community. ESH bases on Java CGI and runs on such capable java implementations. One of such is OpenHAB where ESH actually is derived from.

³⁵ <http://bsautner.github.io/com.nimbits/>

³⁶ <http://www.eclipse.org/smarthome/>

It has a strong focus on heterogeneous environments, i.e. solutions that deal with the integration of different protocols or standards. Its purpose is to provide a uniform access to devices and information and to facilitate different kinds of interactions with them. Main features include a powerful Xtext/Xbase-based rule engine, declarative user interface descriptions and an extensible REST API.

Developers can easily build an individual smart home solution by adding their own extensions to this framework - the result can be deployed on embedded devices, which can run a JVM such as a Raspberry Pi. The full stack is pure Java/OSGi and is built on top of Equinox, EMF and Jetty.

The initial contribution to this project comes from the open Home Automation Bus (openHAB), which provides a huge list of free extensions, which allow to easily integrate systems like **KNX, Philips Hue, Z-Wave, EnOcean, DMX, Plugwise, Homematic or Sonos**.

IoT Protocols and APIs

The Eclipse SmartHome project is a software framework for building smart home solutions with integration of different protocols (enOcean, KNX, MODbus) or standards.

Its purpose is 1) to provide a uniform access to devices and information and 2) to facilitate different kinds of interactions with them.

The Eclipse SmartHome is used as a basis of the [openHAB](#) and [QIVICON](#) by Deutsche Telecom.

Business model

ESH is open source.

More than 2000 tools, applications, projects, etc. available on Eclipse marketplace under different type of license (commercial, non-commercial, free, open source, GPL, etc.)

Community engagement and partnership

The code base of the project is utilised by 6 different companies to offer open source platforms or commercial ones.

It offers tutorials for software developers to get started provides demos to get up and running quickly. It offers an online documentation and discussion fora and issue trackers for the developer community.

It also provides information for HW/device manufactures to create binding for the ESH platform for the integration of their devices.



2.1k followers



n/a



n/a



n/a



82 contributors

2.5k commits

362 Star gazers

6.3.4 OpenRemote (HIT)

Technical overview

OpenRemote³⁷ is software integration platform for residential and commercial building automation. OpenRemote platform is automation protocol agnostic, operates on off-the-shelf hardware and is freely available under an Open Source license. OpenRemote's architecture enables fully autonomous and user-independent intelligent buildings. End-user control interfaces are available for iOS and Android devices, and for devices with modern web browsers. User interface design, installation management and configuration can be handled remotely with OpenRemote cloud-based design tools.

IoT Protocols and APIs

HTTP, Z-wave, serial, KNX, EnOcean, R-Net,

Business model

Open Source license

The software is available to consumers for free. OpenRemote is currently focused on building a sustainable business, which it believes it can achieve by licensing its software to the makers of connected devices. OpenRemote also sees a moneymaking opportunity beyond the home in providing its software to cities, which are becoming increasingly interested in using technology for everything from communicating with citizens to monitoring traffic. Last year, OpenRemote conducted a small test in Eindhoven, in hopes of using automation and crowdsourcing to monitor a city. This included people tracking with cameras, sound-level tracking, social-media monitoring, and an app that people in the area could use to rate what the atmosphere was like. The company is currently working on a larger-scale project in Eindhoven, Kil says. “If you put four walls around a city, it’s a big room, if you know what I mean,” he says.

Community engagement and partnership

Open Remote has a developer reference and tutorial. It offers an extensive documentation and provides instruction for protocol and device integration. OpenRemote also offers a user forum, user reference and user tutorials to get started. Open remote has a set of partners across 10 countries that provide support in realising projects with the platform.

 588 followers

 1.7k likes

 264 followers

 12



3 contributors

199 commits

18 Star gazers

6.3.5 FIWARE

Technical overview

FIWARE³⁸ is an open platform, which provides a set of tools for different functionalities, is an innovation ecosystem for the creation of new applications and Internet services.

The platform provides enhanced OpenStack-based Cloud capabilities and a set of tools and libraries known as Generic Enablers (GEs) with public and open-source specifications and interfaces. These FIWARE GEs are distributed in different technical chapters and provide

³⁷ <http://www.openremote.org/display/HOME/Home>

³⁸ <https://www.fiware.org/>

different capacities. For example, the Internet of Things chapter provides tools to connect sensors and other devices; while the applications' chapter offers powerful business intelligence tools and for the development of interfaces; or as the chapter for Advanced Interfaces allows implementing functionalities related to virtual reality, augmented reality or 3D.

FIWARE Lab is the experimentation environment where technology providers, solution developers and their stakeholders and data providers (cities) can identify problems, design and build solutions on the platform and experiment with them.

Another pillar of the FIWARE architecture is context management. FIWARE provides a mechanism to generate, collect, publish or query massive context information and use it for applications to react to their context. This is a complex process, as this information may come from different sources: systems, mobile apps' users, sensor networks, etc. It is our Context Broker, through a REST implementation of API OMA NGSI, which allows to shape and access it, whatever the source is.

The use and management from data coming from "Things" (i.e. sensors, actuators and other devices) is also a complex process, as there are many different protocols in the IoT sphere, but FIWARE provides a set of GEs allowing to access the relevant information through only one API (NGSI). It not only allows to read this sensor information, but also to act on some elements. Therefore, Context Broker is an essential part of the architecture to collect data, analyse them on real time, consult archives and their analysis, as well as to publish them as open data. On the other hand, other functionalities such as business intelligence, web interfaces and advanced interfaces allow the creation of very powerful applications and solutions.

IoT Protocols and APIs

FI-WARE offers a catalogue of 'generic enablers', each driven by open, standard APIs, aimed at helping developers, and government information and data architects, to remove the complexity involved in trying to integrate a variety of systems

Regarding the RESTful APIs:

- Each HTTP request in a FI-WARE RESTful API may require the inclusion of specific authentication credentials.
- The specific implementation of a the API implemented by a given Generic Enabler (GE) may support multiple authentication schemes (OAuth, Basic Auth, Token) to be determined by the specific provider that implements the GE.
- Resource representation is transmitted between client and server by using HTTP 1.1 protocol, as defined by IETF RFC-2616.
- FI-WARE RESTful APIs may support XML or JSON as representation format for request and response parameters.

Business model

FIWARE is the technological core of the Future Internet Public-Private Partnership (FI-PPP), a European programme for Internet innovation aimed at accelerating the development and adoption of Future Internet technologies in Europe, advancing the European market for smart infrastructures and increasing the effectiveness of business processes through the Internet.

Consequently, this industry-driven endeavour has been developed and expanded thanks to a joint funding that combined the European Commission's institutional funding with private investments undertaken by European industrial players. The financial contribution of FIWARE

partners is illustrated in the figure below (source: European Commission), which considers the three stages of FIWARE development in the timeframe 2011-2016.

	Cost	EU Funding	%	Participants' contribution	Partners	Unique Partners
Phase 1	€ 138,789,915	€ 88,481,890	64%	€ 50,308,025	278	214
Phase 2	€ 111,527,403	€ 78,165,000	70%	€ 33,362,403	168	148
Phase 3	€ 148,585,901	€ 129,999,208	87%	€ 18,586,693	176	148
Total	€ 398,903,219	€ 296,646,098	74%	€ 102,257,121	622	398

Due to this funding scheme, FIWARE sustainability over time – once the EU funding is over – depends on a governance model centred around the FIWARE Foundation. The foundation – i.e., the legal independent body providing shared resources to help achieve the FIWARE mission by empowering, promoting, augmenting, protecting, and validating FIWARE technologies and supporting the community around, including users, developers and the entire ecosystem – will be launched soon and will operate on a membership basis by offering various packages, namely: Platinum Members, Gold Members, Associate Members (e.g., non-profit, public research institutions) and Individual Members. Therefore, members – Atos, Engineering, Orange and Telefónica and the other members that will follow – will directly contribute to the survival of the FIWARE open platform: the incentive for these players – as it happens for other open source endeavours (e.g., Linux kernel development) – is not to act as charity but rather to gain competitiveness in their markets through the establishment of ‘complementary assets’ to their core business.

Community engagement and partnership

From the very beginning, FIWARE was built thanks to the joint efforts of different actors; and now, FIWARE is going a step further in the creation of a community to gather web entrepreneurs, mentors, investors, students, academia, industry and public sector innovators to keep progressing.

FIWARE endeavours focus on three different projects to:

- Expand the reach of FIWARE at a global level through the FIWARE Mundus, a worldwide expansion of FIWARE into Latin America, North America, Africa, and Asia.
- Setting new innovation hubs around the world, through the FIWARE Innovation hubs, a European network of business hubs working together for an easy implementation of FIWARE technologies in businesses.
- Create a European environment of innovative business hubs, through FIWARE Accelerators providing 80M funding for the most talented teams and business proposals building upon FIWARE technology.
-



9.74k followers



5.3k+ likes



2.4K followers



- followers

6.3.6 OpenIoT

Technical overview

OpenIoT³⁹ is a generic middleware platform for Internet-of-Things applications, which allows to link together Internet-connected devices and semantic Web services via a friendly user interface, working either in Cloud Computing environments or with a local server.

This platform is available as a Virtual Development Kit, providing a complete cloud solution for the Internet of Things which allows users to easily get it up and running, to get information from sensor clouds and connect this information with Web services without worrying about exactly what different sensors are being used.

OpenIoT open source platform for the IoT includes unique functionalities such as the capability to compose (dynamically and on-demand) non-trivial IoT services, following a cloud/utility based paradigm.

OpenIoT is a joint effort of prominent open source contributors towards enabling a new range of open large scale intelligent IoT (Internet-of- things) applications according to a utility cloud computing delivery model. OpenIoT has developed a blueprint middleware infrastructure for implementing/integrating Internet-of-Things solutions. The OpenIoT infrastructure provide the means for:

- Collecting and processing data from virtually any sensor in the world, including physical devices, sensor processing algorithms, social media processing algorithms and more. Note that in OpenIoT the term sensor refers to any components that can provide observations. OpenIoT facilitates the integration of the above sensors with only minimal effort (i.e. few man-days effort) for implementing an appropriate access driver.
- Semantically annotating sensor data, according to the W3C Semantic Sensor Networks (SSN) specifications.
- Streaming the data of the various sensors to a cloud computing infrastructure.
- Dynamically discovering/querying sensors and their data.
- Composing and delivering IoT services that comprise data from multiple sensors.
- Visualizing IoT data, based on appropriate mashups (charts, graphs, maps etc.)
- Optimizing resources within the OpenIoT middleware and cloud-computing infrastructure.

OpenIoT combine and enhance results from leading edge middleware projects, such as the Global Sensor Networks (GSN) and the Linked Sensor Middleware (LSM) projects.

IoT Protocols and APIs

OpenIoT offers open, standard APIs

Business model

OpenIoT – as project funded by the European Commission – is not characterized by a specific business model for the consortium as a whole. In fact, the project aim is to set foundations for exploitation roadmaps pursued by single partners or aggregation thereof.

³⁹ <http://www.openiot.eu/>

The sustainability of project results – including the IoT platform – passes through maintenance and evolution actions performed by partners or third parties (e.g., adopters) potentially called upon.

Community engagement and partnership

OpenIoT is the outcome of an EU project with the same name. It is part of the EU open platforms repository and used as a basis for various EU projects. In order to engage with the community a foundation has been planned. However, it seems that it has never been realised.

The current documentation and community support is available at the git hub repository. Some documentation and papers are available on the project website.



13 contributors

662 commits

243 Star gazers

6.4 OneM2M based platforms (ETSI)

This section provides a deep dive into four popular standards based IoT platforms, which follow the recent OneM2M standard. The platforms are not yet widely deployed, but their importance is likely expected to increase in future, in particular in the context of mobile network operators who increasingly are shifting their business models away from connectivity to services. The table below outlines the capabilities and functionality these platforms provide within an end-to-end IoT system.

Layer	Components	Definitions	Eclipse OM2M™	One MPOWER™	CDOT	Open MTC
Collaboration	Business System Integration	Enables integration with existing enterprise and other external systems	✓	✓		
	Visualization	Presents device data in rich visuals and/or interactive dashboards	✓	✓		
Application	Development Environment	Provide integrated development environment to simplify development of apps		✓	✓	
	Service orchestration	Supports mashup of different data streams, analytics and service components	✓	✓	✓	
Service	Advanced analytics	Allows insights from data to be extracted and more complex data processing to be performed	✓	✓	✓	
	Event & action management	Simple rules engine to allow mapping of low level sensor events to high level events and actions	✓	✓	✓	✓
Abstraction	Basic analytics	Provides basic data normalization, reformatting, cleansing and simple statistics	✓	✓	✓	✓
	Storage/ Database	Cloud based storage and database capabilities (not including on premise solutions)	✓	✓	✓	✓
Processing	Device management	Enables remote maintenance, interaction & management capabilities of devices at the edge	✓	✓	✓	✓
	Edge Analytics	Capabilities to perform processing of IoT data at devices at edge as opposed to cloud.	✓	✓	✓	✓
Network	Connectivity Network/ Modules	Offers connectivity networks/HW modules enabling air interface connectivity				
	Edge Gateway (HW based)	Offers IoT gateway devices to bridge connectivity from IoT nodes into the cloud based platform				
Physical Layer	Operating system	Offers low-level system SW managing HW, SW & runs applications				
	Modules & Drivers	Offers adaptable modules, drivers, source libraries that reduce development & testing time	✓	✓		
	MPU / MCU	Offers multi-purpose programmable electronic devices at microprocessor/microcontroller level				

6.4.1 Eclipse OM2M™ / Sensinov IoT™

Technical overview

Eclipse OM2M™⁴⁰ is an open source project managed by LAAS-CNRS™ and Sensinov™⁴¹ at the Eclipse foundation. It offers a horizontal IoT service platform based on oneM2M™ standard for cross-domain interoperability easing mass-scale deployment in various domains such as smart cities, factories of the future, health care, and connected cars. The platform helps expanding businesses and services independently of the underlying technologies. The architecture is modular, designed on top of a protocol-independent kernel, running on top of an OSGi run-time and highly extensible via plugins. The interface is based on a lightweight RESTful API for seamless interaction with applications, services, and devices supporting multiple communication bindings and content formats.

The platform is ready for deployment in heterogeneous nodes including servers, gateways, and small sensors from the most powerful to the most constrained environments Each node exposes to registered applications a set of service capabilities comprising common service functions, communication protocol bindings, device interworking, management, and security, with additional support for advanced features such as flexible containers and Smart Home Device Template (SDT). Data storage and retrieval service relies on a flexible persistence layer supporting embedded and server databases, in-memory mode, SQL and NoSQL models (MySQL, MongoDB, etc.). Device configuration, feature enablement, software upgrade, provisioning, and fault management using lightweight device management protocols. Integration of vendor-specific devices or assets via interworking proxies in order to quickly bring together a complete IoT system.

IoT Protocols and APIs

Supported IoT protocols include:

- HTTP
- CoAP
- WebSocket
- 6LowPan
- BLE
- Zwave
- Zigbee
- EnOcean
- Hue
- LWM2M

Business model

Sensinov™ offers IoT solutions and products based on standards, open API and open source developed on on top of Eclipse OM2M. Sensinov™ intends to become a fast-growing IoT business targeting devices, gateways and cloud applications for mass-scale IoT deployment. Initially targeted markets are Smart Cities (buildings, water, energy, transport, integration, and mobility) and Service Providers and Operators (platform, associated services and applications). Fully customized and turnkey solution with flexible deployment solution (Platform as a Service (PaaS), Commercial and private clouds).

⁴⁰ <http://www.om2m.org>

⁴¹ <http://www.sensinov.com>

Community engagement and partnership

Sensinov™ and LAAS-CNRS™ are highly involved in open source activities at the Eclipse foundation and promote Eclipse OM2M project through various events, presentations, white papers, webinars, and hackathons. They are aiming to have solid partnerships worldwide and win-win engagements that make mutual business sense, while remaining focused on our vision. Their goal is to work in regional and strategic partnerships with industry leaders who share a similar vision and believe in the value of IoT.

6.4.2 InterDigital oneMPOWER™

Technical overview

InterDigital's Internet of Things (IoT) platform⁴², oneMPOWER™ powered by wot.io™, is a horizontal solution that integrates and manages connected devices and data feeds across industries and diverse communication networks. Its comprehensive suite of service-layer tools spans data, device, connectivity, security, and transaction management. oneMPOWER™ conforms to the global oneM2M™ standard for the IoT. As an open standard, oneM2M™-compliant solutions lower the risk of vendor and technology lock-in while future-proofing investments to capitalize on future IoT innovations. Some of the organic platform functionality includes data management, multiple transport binding protocols, OMA LWM2M device management, event management, charging, and various security features that include access controls, authentication and encryption, and multi-tenancy. The platform itself consists of server software, gateway software to manage and secure IoT-edge devices, flexible software development kits (SDKs), advanced visual development and test tools, and enhanced cloud hosting capabilities that provide access to a wide range of data services powered by wot.io™.

wot.io™ is a revolutionary operating environment that acts as a fabric between data acquisition systems, data services and applications. Its distributed flexible architecture enables cloud and on-premise deployments, features rich adaptor and partner frameworks, and offers an extensible data processing pipeline to integrate anything from connectivity and security to various data services. It also facilitates aggregation and transformation of varied, disparate or legacy data sources into unified systems to support anything from industry specific applications to advanced data marketplaces.

In two complementary smart city applications, oneTRANSPORT and Smart Routing, oneMPOWER™ powered by wot.io™ is being used to demonstrate the world's first open and scalable IoT platform enabling multi-region, multi-modal and multi-system transport integration across geographies in the United Kingdom. Working with 14 other public-private partners, this pre-procurement commercial deployment targets an initial population of 9 million people. This real-world solution is driven by dynamic business models which are supported by a brokerage structure based on an open marketplace for data and data services.

IoT Protocols and APIs

InterDigital's IoT platform supports a broad range of architectures for connecting IoT devices and various data sources. Supported transport layer protocols include:

- HTTP, CoAP and MQTT and their respective security mechanism such as TLS/DTLS (based on oneM2M™ standard)
- wot.io™ further supports adapters to protocols including WebSocket, AMQP, and others.

⁴² <http://www.interdigital.com/iot>

InterDigital's IoT platform is agnostic to devices and gateways and their underlying hardware, operating systems or connectivity technologies. InterDigital offers a Java-based SDK with RESTful APIs for its IoT platform and other types of SDKs (e.g. Android, iOS) to reduce adoption time (e.g. oneTRANSPORT).

Business model

InterDigital's strategy is to provide its IoT technologies through best-in-breed system integrators, aggregators and service providers across industries that include Smart Buildings and Smart Cities, Transportation, Industrial, and Enterprise. InterDigital enables customers and partners to create managed IoT service offerings and data exchanges, thus unlocking the true data value. InterDigital does this through both software licensing and platform hosting. InterDigital also engages in strategic partnerships such as Convida Wireless, its joint venture with Sony. InterDigital offers Developer Portals for oneMPOWER™ and wot.io™ for free evaluations to its partners, customers and other developer communities.

Community engagement and partnership

InterDigital has offices in North America, Europe and Asia where it actively promotes its solutions through various events, presentations, white papers, blogs, and hackathons. InterDigital has developed – and is continuing to extend – a broad range of co-operations and partnerships. It has forged relationships with many third-party data services spanning analytics, business intelligence, reporting, monitoring, and beyond to complement its IoT portfolio. It also has relationships with device manufacturers, connectivity providers, and systems integrators. Finally, InterDigital has strong ties with various industry associations that include oneM2M™, the Industrial Internet Consortium (IIC), and works closely with universities, and start-up accelerator and incubator communities.

6.4.3 C-DOT

Technical overview

The Centre for Development of Telematics (C-DOT) ⁴³is the Telecom Technology development centre of the Government of India. C-DOT has developed oneM2M specifications based Common Service layer Platform named C-DOT's Common Service Platform (CCSP).

C-DOT's Common Service Platform (CCSP), is a Software based Platform, which provides a horizontal service layer for the applications of various domains. CCSP is based on oneM2M specifications. The CCSP provides services like registration, security, data management and repository, group management, discovery, subscription and notification to the applications through the standardized interfaces as defined in oneM2M.

The CCSP solution set comprises of

- CCSP for the field domain nodes : M2M Device and the M2M Gateway i.e ASN- Application Service Node and MN – Middle Node
- CCSP for the Infrastructure domain node - Infrastructure Node (IN).

To enable the application developer, CCSP also provides the Java based SDK (Software Development Kit). It also supports Visual Resource tree viewer tool.

C-DOT shall be opening up its CCSP for offering services to the partners' applications.

⁴³ <http://www.cdote.in>

C-DOT is also playing a significant role in defining the standards for the M2M communication in India, primarily focusing on oneM2M standards.

CCSP opens up as a service between the data collection/acquisition and the data consumer applications. The horizontal service layer enables faster application development and deployment. With the oneM2M architecture, it provides great openness and hierarchy for the deployment of the solution. Further, based on oneM2M, CCSP opens up interoperability between devices and applications.

IoT Protocols and APIs

CCSP supports the HTTP and CoAP transport layer protocols. The security at the transport layer is achieved through the TLS.

It also supports the XML as well as the JSON formats.

CCSP is agnostic to the underlying hardware, operating systems or connectivity technologies. It is based on the CRUD-N operations and RESFUL APIs.

It also supports a framework for writing the application in the standards way, thus reducing the time for understanding the specifications and adopting them.

Business model

C-DOT offers CCSP on commercial licensing based model. Also partnership through transfer of technology based model is available.

Community engagement and partnership

C-DOT has offices in Delhi and Bangalore. C-DOT has been participating in various conferences and exhibitions, where it is actively promoting its CCSP. C-DOT also has been giving presentations in various Government of India forums for moving in M2M in a standardized way.

6.4.4 OpenMTC

Technical Overview

The OpenMTC platform⁴⁴ is a prototype implementation of an M2M middleware aiming to provide a standard-compliant platform for M2M services. Our customers and research partners use the OpenMTC platform to interconnect various sensors and actuators from different vertical domains with a cloud-enabled, open platform, which aggregates collected data, forwards data to the application and mediates instructions to end devices for event-based control.

The OpenMTC solution has been designed to act as a horizontal convergence layer in terms of a Machine-to-Machine (M2M) middleware for machine type communication supporting multiple vertical domains. Those domains are usually the classic M2M verticals (market segments) such as transport and logistics, utilities, automotive, eHealth, etc. which can be deployed independently or as part of a common platform.

OpenMTC mainly consist of two common M2M capability layers, a front-end in the field domain and a back-end, cloud-based platform in the infrastructure domain. Those layers follow the oneM2M standards in oneM2M-TS-0001 and oneM2M-TS-0004 and the ETSI Technical

⁴⁴ <http://www.open-mtc.org/>

Committee M2M in TS 102.921 and TS 102.690. The OpenMTC gateway runs on different hardware platforms like Android, Arduino and Raspberry Pi.

IoT Protocols and APIs

OpenMTC supports different protocols and various local access technologies through Interworking Proxies that mediates between the specific technology and the OpenMTC API. A selection of supported technologies ZigBee (Xbee-based), FS20, Bluetooth, WiFi, 4G. Both front-end and back-end nodes support common service capabilities that can be used by the applications through open interfaces. The front-end and back-end nodes are able to use different transport protocols: HTTP, CoAP, and MQTT.

Business Model

OpenMTC is a M2M system for R&D purposes, designed to provide horizontal convergence layers supporting multiple vertical application domains, such as transport and logistics, utilities, automotive, e-health, etc. We enable our clients and partners to customize general and specific network and service conditions. OpenMTC toolkit accelerates the time required for testbed establishment and customization.

Community engagement and partnership

There are different stakeholder groups that OpenMTC is engaging with:

- Research Institutions & Universities
 - o R&D on real M2M network
 - o Innovating new concept and algorithms
 - o Applications Developers
 - o Validating M2M applications
 - o End-to-End M2M connectivity
- Manufacturers
 - o Validate their products end-to-end
 - o Looking for the missing pieces
 - o Operators
 - o Be prepared for M2M/IoT mass fixed & devices
 - o Validate and evaluate M2M services

6.5 Summary of key market trends

Different types of IoT platforms have emerged in the last past years as they developed from the platforms that specific stakeholders or industrial sectors have promoted. In the following, we briefly highlight key observations from the analysis of the leading platforms in this section.

Platform eco-system constellations

There is a range of commercial IoT platforms on the market. They can be grouped into four categories: device centric communication/connectivity centric IoT platforms, industry centric IoT platforms and cloud centric IoT platforms. In some segments, also non-commercial open source platforms are emerging and gaining in importance.

The device centric IoT platforms are developed as hardware-specific software platforms pushed by companies that commercialize IoT device components and have built a software backend that is referred to as an IoT platform. These backends are often reference implementations to ease the development of end-to-end IoT solutions, which are made available as starting points to other eco-system partners.

The connectivity IoT platforms address the connectivity of connected IoT devices via communication networks. The starting points are often traditional M2M platforms for connectivity and device management, and then these are evolving into platforms that provide support for the management of the full IoT service life cycle. Connectivity based platforms primarily focus on providing out of the box solutions for device/product manufacturers, which they can drop into their existing products to make them connected. Recent development provide analytics tailored for extracting the business insights about the performance of connected devices.

The cloud centric IoT platforms are offerings from larger cloud providers, which aim to extend their cloud business into the IoT. They offer different solutions with for example Infrastructure-as-a-service IaaS back ends that provide hosting space and processing power for applications and services. The back ends used to be optimized for other applications have been updated and integrated into IoT platforms offerings from large companies.

The industrial centric IoT platforms are the platforms designed to address the challenges of industrial IoT and integrates extensive features compared with the IoT consumer and business solutions (i.e. strong integrated IT and OT end-to-end security framework).

Multi-national co-operations (MNCs) currently dominate the picture, in particular in the space of cloud centric, industry-centric platforms and device centric IoT platforms. As the IoT platforms landscape is developing very fast with companies applying different strategies and business models such as sectorial approach that starts with the connectivity layer and is extending to expand to a platform features from the bottom-up.

Large companies use the top-down approach that they have a portfolio of software platform or cloud services and build extension to address the specific requirements for IoT applications. The development is starting from the analytics and cloud part and developing out the IoT platform features from the top-down. In the industrial sector, there are different strategies with companies developing their own industrial IoT platform or using a partnership approach by building alliances to offer the full industrial IoT platform suite. A different approach is developing or extending the IoT platforms offers through targeted acquisitions and/or strategic mergers. Another strategy used by several companies is to use the tactical/strategic investments throughout the IoT ecosystem developed around their IoT platforms and technologies.

Open source platforms are predominately emerging in consumer IoT space, such as the home automation sector or are outcomes of collaborative IoT research initiatives. The main driver is the cumbersome integration of an increasingly diverse set of end devices and protocols – making it costly for proprietary platform providers.

The platforms surveyed in this section have promising features and their relevance is increasing. The use of the open source IoT platforms are expected to enable faster integration of new IoT solutions across various application domains and across competitors in the value chain and help accelerating the adoption of a IoT platform software technology from bottom-up with the active involvement of SMEs and start-ups.

A recent example is the announcement⁴⁵ of Bosch and GE to open source various of their platform building blocks to quicker move towards an interoperable industrial IoT environment.

⁴⁵ <http://www.pcworld.com/article/3124749/ge-bosch-and-open-source-could-bring-more-iot-tools.html>

By sacrificing revenue streams that they currently gain from proprietary components, the companies believe the resulting environment will lead to significant growth and business opportunities on top of converged IoT platforms.

Functional coverage of IoT platform

The surveyed IoT platforms cover a broad range of functionalities of the end-to-end stack. Most common functions across IoT platform are data storage, device management and simple processing and action management as well as some basic analytics support from the data. Visualization support is also an essential feature offered by the leading platforms.

Our analysis found that IoT platforms of larger companies cover more functionality across the end-to-end IoT stack. They generally provide better support for enterprise system integration and support for more advanced analytics. Commercial platforms of smaller players lack advanced analytics and edge analytics capabilities. This is an important observation, as most value in the IoT will be captured in the insights extraction and business layer integration. Thus, larger companies seem to have an edge compared to smaller companies with respect to future market demands.

Nearly all platform offer ready-made libraries and in some cases firmware to allow the integration of popular IoT device platforms into their platform. These are often bundled with a starter kit towards end-users. Offering out of the box experience for at least one or more devices is important for successful platforms as it lowers the barriers for developers.

Device centric platforms provide more optimised HW/SW stacks. They collaborate with other commercial IoT platforms such as cloud and industrial platform players to enable them to provide more optimised end-to-end solutions.

Commonly used IoT protocols

Most of the IoT platforms are providing information about the openness of the platforms, the availability of a Representational State Transfer (REST) API, as well as data access control and service discovery mechanisms, which suggest that IoT services will become like web services and IoT service mashups and data analytics will be key integrators for the future of IoT technologies. HTTPS stack with REST APIs is the most common protocol stack for the integration of IoT edge devices, followed by MQTT. Other more prominent protocols supported by the platforms are OMA LWM2M and COAP.

Connectivity centric platforms show typically provide a large support for common Internet based IoT protocols. Industry centric platforms shows a larger diversity in more specialised proprietary protocols, while consumer oriented platform in the smart home space generally support more short range protocols out of the box.

Ecosystem activities

Many leading IoT platform providers realize that their platforms are only as good as the applications and services their platforms enable on the global market. As the requirements across different sectors and even between different businesses within a sector are very diverse, there is a need for many applications and services to satisfy the market needs.

The mobile phone market has shown the increased benefits of the app economy, which offers opportunities of a long tail of many smaller businesses to create value across platform eco-

system. In these ecosystems, creative developers play an important role in order to stimulate innovation and market growth.

Therefore, many of the successful IoT platform providers open their platforms to external developers and provide an extensive set of support measures to engage them and lower barriers for innovation. This starts from providing well-documented platform APIs over to full-blown developer portals with training, tutorial and example codes, developer fora and community platforms for peer-support. This is often complemented by webinars and physical events such as developer road shows, hackathons, workshops and in some cases full blown developer conferences.

Another important observation is that current successful IoT platforms on the market have realized that the current IoT play is an eco-system play they cannot walk alone and that they are only as strong as their alliance are. As such, the many of the IoT platform vendors have forged partnerships along the entire IoT value chain in order to compete successfully in the delivery of end-to-end solutions. Some IoT vendors such as Microsoft go even as far as offering marketing and sales support for their partners to enable a more successful business development on the market.

7. IoT EPI PLATFORM PROJECTS

IoT platforms are being shaped by varying entry strategies of different companies trying to capitalise on the IoT potential. Start-ups, hardware, middleware software, networking equipment manufacturers, enterprise software and mobility management companies are all competing to become the market leaders providing the best IoT platforms.

This section provides an initial analysis of the IoT EPI projects. More specifically, it looks at the IoT platforms these projects are based on and the IoT applications they focus on. The information has been obtained from multiple sources: 1) surveys that have been distributed by the IoT EPI projects; 2) interactions with the projects as part of the IoT EPI task forces and information from the study if existing documents that are available from these projects. The section concludes with a discussion on common trends of these projects and market strategic observations.

7.1 IoT platforms utilised in the IoT EPI projects

7.1.1 Existing platforms utilised by the IoT EPI projects

The following section captures the different platforms the IoT-EPI projects are utilizing in their project. The purpose is to capture the current state of play and to get a feel for the diversity and overlap of IoT platforms across the seven emerging ecosystems. Our analysis briefly captures the name, whether the platform is commercial or not and a brief description of its main purpose.

AGILE		
IoT platform	Nature of platform	Brief description
Resin.io	Commercial	Device management platform for Linux based IoT devices. It makes it simple to deploy, update, and maintain code running on remote devices.
Eclipse IoT	Open source	Eclipse smart home, an IoT platform for smart home environments and Eclipse Kura an OSGI based framework for IoT gateways.
NodeRED	Open source	Tool for wiring together hardware devices, APIs and online services in new and interesting way. Visual IoT service enablement platform developed by IBM.

BigIoT		
IoT platform	Nature of platform	Brief description
Smart Data Platform	Open source	Smart Data Platform (SDP) is a self-service platform enabling application development based on Internet of Things and Big Data. SDP is based on project Yucca which allows for interconnecting applications, social networks, systems and distributed objects and collecting data and information, by processing and analysing them to develop end-to-end solutions
Smart City Platform	Commercial, Bosch	Considering solutions for Smart Cities, the requirements differ from those known for classical enterprise applications. In fact, Smart City installations are composed of many different

		solutions individually customized for the city, but with a common need w.r.t. operation, data sharing and security. The Smart City platform (SCP) targets to connect the silos in the Smart City, i.e., governance, mobility, energy, environment, industry life, tourism, etc. Bosch SCP offers tools and methods to develop, operate and maintain such systems without sacrificing data security and privacy.
Wubby Platform	Commercial, Econais	Wubby is an ecosystem of software components and services for rapid development of everyday objects. Everyday objects are physical objects embedded with electronics, software, sensors and network connectivity to collect and exchange data.
OpenIoT Platform	Open Source	OpenIoT is a sensor middleware platform that eases the collection of data from heterogeneous sensors, while ensuring their semantic annotations. It enables semantic interoperability in the cloud and provides IoT app development tools.
Traffic Information Centre Platform	Commercial, VMZ	The TIC mobility platform provided by VMZ is a data and service platform that has been developed to provide comprehensive information on all mobility options available in Berlin. The platform includes real-time data from the traffic information center, mobility operators and infrastructure providers and provides a multimodal routing platform using the modal router offered by third parties.
Bitcarrier/Sensefield/FastPrk	Commercial, World Sensing	Worldsensing provides a unique traffic management portfolio for Smart Cities that includes Bitcarrier, a real-time intelligent traffic management and information solution designed for both road and urban environments. Fastprk provides an intelligent parking system and Sensefields provides an innovative system for detecting and monitoring vehicles and traffic flow.
BEZIRK Platform	Open Source	Bezirk is a peer-to-peer IoT middleware for both communication and service execution on local devices following the service-oriented paradigm. Bezirk is developed with a view to facilitate asynchronous interactions between the different components of an application with respect to distribution across different devices in a network.

BioTope		
IoT platform	Nature of platform	Brief description
O-MI/O-DF Reference Implementation	Open source	Implementation of O-MI and O-DF standards for the IoT that makes it easy to set up standard-based IoT node instances. Mainly used for “sandbox” installations but can be scaled up for “industry-level” purposes.
DIALOG	Open source	IoT Middleware originally developed by Aalto in 2001, which has been further developed and used in numerous research projects as well as industrial pilots.
NodeRED	Open source	Tool for wiring together hardware devices, APIs and online services in new and interesting way. Visual IoT service enablement platform developed by IBM.

Warp 10	Open source	Platform for storage, management and analysis of IoT data, especially for Geo Time Series.
FIWARE	Open source	FIWARE is a middleware platform for the development and global deployment of applications for Future Internet. It is an outcome of a large investment of the EU into large-scale research programme involving network vendors and operators.
Open IoT	Open source	OpenIoT is a sensor middleware platform that eases the collection of data from heterogeneous sensors, while ensuring their semantic annotations. It enables semantic interoperability in the cloud and provides IoT app development tools.
Mist	Closed-source	Software stack for distributed, secure IoT deployments of ControlThings.
eAir web	Closed-source	Cloud service for remote use and management of Enervent Air Handling units.
Other	Open/Closed source	Numerous platforms such as BMW's platform, several Smart Parking platforms in Helsinki, OpenDataSoft's platform. Estimated over 10 different platforms used now or in the future.

InterIoT		
IoT platform	Nature of platform	Brief description
SEAMS	Proprietary, EU project	Smart, Energy-Efficient and Adaptive Management Platform (SEAMS) is a state-of-the art prototype-monitoring tool developed and implemented within the framework of the European project SEA TERMINALS at Noatum Container Terminal Valencia. The SEAMS platform prototype is capable of monitoring the machines and equipment that are being used at a Port Container Terminal.
I3WSN	Academic platform	Industrial Intelligent Wireless Sensor Networks for indoor environments, platform developed by Universitat Politècnica de Valencia
e-Care Tilab Platform	Proprietary	Mobile Health Platform developed by TI, and connecting IoT devices used to monitor patients and the cloud
Unical BodyCloud	Open source	BodyCloud is an open platform for the integration of BSNs with a Cloud Platform-as-a-Service (PaaS) infrastructure and it's currently based on Google App Engine.
NodeRED	Open source	Tool for wiring together hardware devices, APIs and online services in new and interesting way. We will use it in the AS2AS interoperability framework
OpenIoT	Open source	OpenIoT is a sensor middleware platform that eases the collection of data from heterogeneous sensors, while ensuring their semantic annotations. It enables semantic interoperability in the cloud and provides IoT app development tools.
FIWARE	Open source	FIWARE is a middleware platform for the development and global deployment of applications for Future Internet. It is an outcome of a large investment of the EU into large-scale research programme involving network vendors and operators.

UniversAAL	Open Source	UniversAAL is an IoT platform developed in the framework of an FP7 project and applied currently in different AAL, eHealth and AHA environments.
Eclipse OM2M	Open Source	Open source project based on OneM2M started by LAAS-CNRS and currently under Eclipse umbrella
Microsoft Azure IoT Suite	Proprietary Microsoft	Provides an easy to configure back-end for IoT deployments. It provides data collection, in-motion analysis, storage and visualization. Complete REST API and provides strong security mechanisms. Domain agnostics, provides no models for data.
Amazon AWS IoT	Proprietary Amazon	AWS module specially intended to IoT systems. It enables a straightforward access to Amazon Cloud thanks to a easy to use management interface and a REST API to control the status of the things connected. Once data is sent to the AWS IoT, then it can be used the huge ecosystem of AWS cloud solutions. This platform is completely domain agnostic and provides a strong security protection.

TagItSmart

IoT platform	Nature of platform	Brief description
SocIoTal	Open source	Community IoT platform with privacy aware data sharing. Developed by the FP7 SOCIATAL project.
FIWARE	Open Source	FIWARE is a middleware platform for the development and global deployment of applications for Future Internet. It is an outcome of a large investment of the EU into large-scale research programme involving many network vendors and operators.
Evrythng	Commercial	IoT Smart product platforms. The platform collects, manages and applies real-time data from smart products and smart packaging to drive IoT applications.
RunMyProcess	Commercial	Build device independent, connected applications with strong business process integration; Deploy systems at global scale; Run secure, reliable and scalable operations. Thousands of pre-built connectors to quickly integrate IoT-enabled devices, cloud services, and social media with on premise enterprise applications and systems.
Microsoft Azure	Commercial	Full cloud based platform with IoT specific components to support connection of devices to the cloud, analyse, store and visualize captured data. Can be combined with advanced data analytics, machine learning and other components.

symbioTe

IoT platform	Nature of platform	Brief description
OpenIoT	Open source	OpenIoT is a sensor middleware platform that eases the collection of data from heterogeneous sensors, while ensuring their semantic annotations. It enables semantic interoperability in the cloud and provides IoT app development tools.

Symphony	Commercial, Nextworks	Networks platform for the integration of home and building control systems. Symphony can monitor, supervise and control many different building systems, devices, controllers and networks available from third-party suppliers. It is a service-oriented middleware, able to integrate several functional subsystems into a unified IP based platform.
Mobility Back-end as a Service (MoBaaS)	Commercial, Ubiwhere	System integration platform to wrap around different city data sources. Application enablement environment geared towards smart city apps focusing on transport and mobility aspects of cities.
nAssist	Commercial, Sensing and Control Systems S.L.	A software platform designed and conceived to allow agile, continuous management of data in the fields of energy efficiency, security and automation. Cloud-based communication software that enables clients to easily and intelligently connect machines and devices to the cloud and then process, transform, organize and store machine and sensor data.
Navigo Digitale IoT platform	Commercial, Navigo	A vertical IoT platform created to manage digital assets pertaining to harbours used for boating and yachting. Its focus is to provide services to the harbour's activities (B2B) and to its end-users (B2C).
KIOLA	Commercial, AIT	A mobile health data collection and online therapy management system. It integrates different sensor devices on the client side and provides backend interfaces for health management systems.

Vicinity		
IoT platform	Nature of platform	Brief description
LinkSmart	Open source	IoT middleware originally developed in the Hydra project. It allows developers to incorporate heterogeneous physical devices into their applications through easy-to-use web services for controlling any device.
IoTivity	Open Source	IoTivity is an open source software framework enabling seamless device-to-device connectivity to address the emerging needs of the Internet of Things.

7.1.2 Architectural mapping

The IoT platforms adoption is driven by several factors such as economics that add cloud services and the development of partner ecosystems. In this context, device manufacturers provide built in solutions and models with the IoT SDKs to provide ease of use that allows the use of multiple portals and applications to get the IoT platforms and devices fully configured. The relationship with the service providers is increasingly important with the integration within the IoT suite the various offerings from service providers.

The development in the area of standardisation is accelerating in the area of device discovery and ability for heterogeneous devices to communicate and interoperate. Standards are key to

enabling interoperability, driving down costs and stimulating growth. However, standards processes are complex, take a long time to evolve and be adopted, and will still take some time to have mature, stable standards dominating, so suppliers and buyers are having to over-invest in multiple standards.

In this complex environment, the IoT-EPI projects are developing interoperability solutions that are addressing different layers in the IoT architecture and offer mechanisms for providing interoperability between different IoT platforms addressing various use cases and applications.

In the following paragraphs, we briefly discuss the mapping of the IoT architecture layers to the activities and solutions provided by the IoT-EPI projects.

AGILE builds a modular hardware and software gateway for the IoT focusing on the physical, network communication, processing, storage and application layers. The AGILE software modules are addressing functions such as device management, communication networks like area and sensor networks and solution for distributed storage. The project considers all the modules needed to provide a robust security management solution.

bIoT provides a platform that enables stakeholders to easily create new IoT systems and to rapidly harness available information using advanced Systems-of-Systems (SoS) capabilities for Connected Smart Objects by providing standardised open APIs to enable interoperability. The project address all eight layers of the IoT architecture and validates the interoperability solutions in a cross-domain environment.

Big-IoT develops a generic, unified Web API for smart object platforms implemented by overall 8 smart object platforms. The project focusses on the upper layers of the IoT architecture addressing the security management, APIs, service integration, external system services, applications multi cloud services and business enterprise.

INTER-IoT project addresses an open cross-layer framework, an associated methodology and tools to enable voluntary interoperability among heterogeneous IoT platforms by focusing on six layers of the IoT architecture with modules covering the QoS and device management, service integration, external system services, storage and virtualisation. The project consider all network communication layer and the full security management suite.

symbIoTe is providing an abstraction layer for a unified view on various IoT platforms and sensing/actuating resources. In the Application Domain, a high-level API for managing virtual IoT environments is offered to support cross-platform discovery and management of resources, data acquisition and actuation as well as resource optimization. The project focusses on seven layers of the IoT architecture from physical to application layer and considering the full security management suite.

TagItSmart! offers a set of tools and enabling technologies integrated into a platform with open interfaces enabling users across the value chain. The project address seven layers of the IoT architecture working on modules for security management, business logic, service integration, storage, APIs, big data analytics and business enterprise.

The **VICINITY** project focuses on a platform and ecosystem that provides “interoperability as a service” for infrastructures in the IoT and addresses the five upper layer of the IoT

architecture. The work considers the service integration, business logic, virtualisation, storage, APIs, tools, external system services, applications, data analytics and cloud services.

7.1.3 IoT applications targeted by the IoT EPI projects

In order to have an overview of the IoT applications domains targeted by the IoT-EPI projects, it is important to understand the focus of the projects in terms of core business and value proposition. During the IoT-EPI Common Workshop held in Valencia, a mapping of IoT-EPI RIAs was presented by various Task Forces, emphasizing differences in terms of core business as well as in relation to target users served by project value propositions. Four main areas of interest were identified, namely:

- Integration of devices
- Creation of platforms
- Interoperable Devices
- Autonomous Reasoning

Work carried out in the different IoT-EPI task forces examined both the interest areas of the project in terms technological level and the application domains in which pilot developments are foreseen.

Table 2 shows the mapping and the overlap of IoT-EPI projects from the perspective of the different technological levels their work is touching upon. Mostly, projects are focused on interoperability at the platform level, although some developments are expected both at device and gateway (network) level.

Table 2. IoT-EPI overlapping at different technological levels

Technological level	Related IoT-EPI Projects	Targeted application
Platform/Application Level	BIG Io	Service and Application Marketplace
	bIoTopeT	Service co-creation and interoperability communication
	Inter-IoT	Platform interoperability
	symbIoTe	Discovery and sharing of resources / Platform Internetworking
	TagItSmart!	Service Composition
	VICINITY	Cross-platform interoperability and added value
Gateway Level	AGILE	Device and Data Management and IoT applications
	symbIoTe	
	VICINITY	
Device Level	AGILE	Device development
	TagItSmart!	

The work in the task forces also examined the application domains, in which projects are expected to perform a deployment or pilot activity. The goal was amongst others to identify opportunities for joint application pilots. The following application domains were key target of the IoT-EPI projects:

- Environment/Energy monitoring and recycling
- Livestock Monitoring
- Mass market, PLM, Smart Retail, Product Monitoring
- Port/Vessel Monitoring (logistics)
- Smart City
- Smart Healthcare and quantified self
- Smart Mobility

The Figure 23 visualizes the mapping of the identified application domains and the different projects. In the following, we briefly discuss the intended pilots for each of the projects.

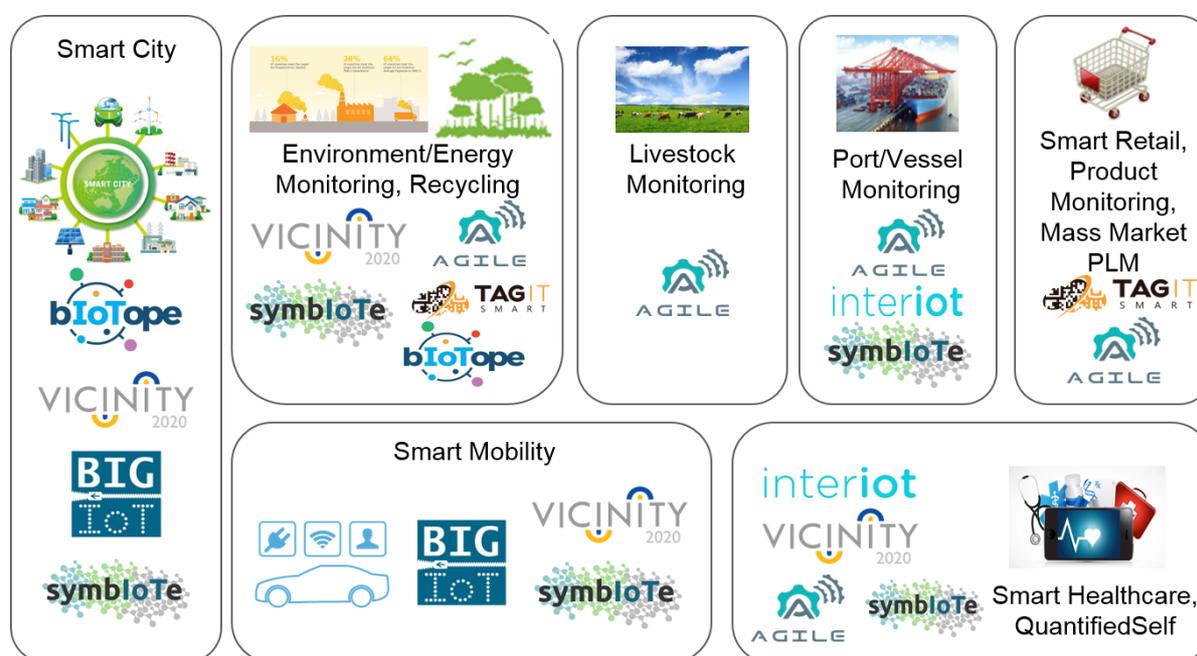


Figure 23. Overlapping applications domains and pilots foreseen by the IoT-EPI projects

AGILE builds a modular hardware and software gateway for the Internet of Things. With five pilots in *QuantifiedSelf*, *open air monitoring using drones* and *smart retail*, AGILE will demonstrate easy adaptation, use and prototyping in different IoT domains. All AGILE software modules will be delivered as 100% Open Source, with the majority of them becoming part of a new Eclipse Foundation IoT Project.

Big-IoT aims to develop a generic, unified Web API for smart object platforms, called the BIG IoT API. The BIG IoT API will be implemented by overall 8 smart object platforms. Following an evolutionary and agile approach, the developed technologies will be concurrently demonstrated in three regional pilots involving partners with strong relation to public authorities. Under a common theme of *'smart mobility and smart road infrastructure'*, various use cases within the pilots will validate the developed technologies.

bIoTope lays the foundation for creating open innovation ecosystems by providing a platform that enables companies to easily create new IoT systems and to rapidly harness available information using advanced Systems-of-Systems (SoS) capabilities for Connected Smart Objects by providing standardised open APIs to enable interoperability. A dozen *smart city pilots* will be deployed in three distinct European cities/regions, distinguishing between domain specific pilots and cross-domain smart city pilots.

INTER-IoT project aims at the design, implementation and experimentation of an open cross-layer framework, an associated methodology and tools to enable voluntary interoperability among heterogeneous Internet of Things (IoT) platforms. The INTER-IoT approach will be used case-driven, implemented and tested in three realistic large-scale pilots: (i) *Port of Valencia transportation and logistics* involving heterogeneous platforms with ~400 smart objects (INTER-LogP); (ii) an Italian National Health Center for *m-health* involving ~200 patients, equipped with body sensor networks with wearable sensors and mobile smart devices (INTER-Health); (iii) a *cross domain pilot* involving IoT platforms from different application domains.

symbIoTe aims at evolving the currently fragmented IoT landscape by providing an abstraction layer for a unified view on various IoT platforms and sensing/actuating resources. In the Application Domain, a high-level API for managing virtual IoT environments will be offered to support cross-platform discovery and management of resources, data acquisition and actuation as well as resource optimization. The symbIoTe project will consider five use cases - *Smart Residence, EduCampus, Smart Stadium, Smart Mobility and Ecological Routing* and *Smart Yachting*.

The overall objective of **TagItSmart!** is to create a set of tools and enabling technologies integrated into a platform with open interfaces enabling users across the value chain to fully exploit the power of condition-dependent functional codes to connect mass-market products with the digital world across multiple application sectors.. Five use cases have been identified and will be demonstrated and evaluated at ecosystem trials either at laboratory-scale, at controlled environment: *Digital Product, Lifecycle Management, Brand Protection, Condition Dependent Pricing* and *Home Solutions*.

The **VICINITY** project will build and demonstrate a platform and ecosystem that provides “interoperability as a service” for infrastructures in the Internet of-Things (IoT). There are four use cases: The first use case will be a *smart energy micro-grid* that is enabled by municipal buildings. The second use case will show how to *combine infrastructure from different domains: a Smart Grid ecosystem will be combined with an Assisted Living* use case. The third use case will be *eHealth*, while the final use case will show how a large number of data sources from different domains can be combined in an intelligent parking application.

7.2 Discussion

The analysis of the IoT-EPI project reveals interesting insights into the emerging IoT ecosystems. We will briefly highlight key observations on IoT platform use and application domains and compare those to the current trends on the global market.

The seven-ecosystem projects utilize 35 distinct IoT platforms, which represents nearly 10% of the global IoT platform offerings that we are aware of. The diversity represents the common trend of the global market. There is an intrinsic heterogeneity due to the immature market and

lack of consolidation. This is likely to change in future, where we expect much more convergence to happen as the market matures and unsuccessful platforms go out of business. An astonishing observation is that more than 50% of the platforms that the IoT-EPI projects are utilizing are open source. This is very unlike the trend that we see in on the global market where the market place where the proportion of open source platform is below 5% and the majority dominated by commercial offerings.

Only four IoT platforms are used in more than one of the IoT-EPI projects. The most used being OpenIoT (4), NodeRED (3), FIWARE (3) and Microsoft Azure (2). The remaining 31 platforms are unique to individual projects. This lack of commonness of platforms is interesting.

Another interesting observation is that only six of the 35 platforms selected by the projects are those we have identified as leading in our market analysis conducted in the previous section. The corresponding platforms are Bosch IoT SW Suite, Eclipse IoT, Evrythng, Microsoft Azure IoT, Amazon AWS IoT and Eclipse OneM2M.

Out of the seven projects, two of the projects have more than 10 IoT platforms, whereas two have three or less IoT platforms. These shows there are significant variations across the IoT ecosystem heterogeneity and size, while all projects demand a similar level of funding.

In terms of application sectors, the seven IoT ecosystems cover a broad range of sectors, which is very well representative of the global market. The most popular sector is smart cities, followed by mobility, energy, which seems to follow as well the global sector specific trend of IoT platforms. Interestingly health / personal care has strong interest among the projects, which is currently not as strongly reflected in the global trend of sector specific IoT platforms.

Architectural decisions to define IoT platforms must ensure that the developed solution implements a horizontal approach to overcome the existent vertical fragmentation. From the analysis of the IoT-EPI project approaches results that most of the projects address five to seven layers of the IoT architecture and their focus is providing interoperability solutions to connect existing IoT commercial and open source platforms. The validation is plan to address different use cases across various industrial sectors.

8. SUMMARY AND CONCLUSIONS

IoT platforms are the highest, most generalized layer of intelligence and user interface, that ties together connected devices and web-based services. They collectively define a reference architecture model for the IoT, taking into consideration a wide range of technologies, communication protocols and standards. An IoT platform must allow external users and devices to connect to it, based on a governance model, which is the basis to decide, “Who gets what”. IoT platforms are able to coordinate and manage connectivity issues, and to guarantee the security and privacy of the data exchanged, by a large number of networked devices while overcoming interoperability issues. The use of a pre-defined set of protocols to share certain services, a federation of platforms will allow optimizing the use of the resources, improving service quality and most likely reducing costs. IoT platforms address both technological and semantic interoperability issues among heterogeneous IoT devices and need to minimize the complexity of collecting and processing large amounts of data generated in IoT scenarios. The platforms need to address scalability, security issues and guarantee that the developed solution is built upon commercial or open-source software based on open specifications that allows portability and reduce product development costs, while encouraging creativity and collaboration among the various IoT stakeholders. IoT platforms need to provide solutions to assimilate data from multiple vendors and support open API interfaces across platforms. This requires taking into consideration issues such as openness, participation, accountability, trust, security, privacy, effectiveness, coherence, etc., while offering innovative solutions that enable self-governance, self-management, and context aware scalability [28].

The analysis performed in this report has looked on different technological and consumer/business/industrial approaches on the IoT platforms. These are addressing the heterogeneous sensing and actuating technologies, data ownership, security and privacy, data processing, data sharing capabilities, the existence of a community of developers/users and the support to application developers, the creation of an IoT ecosystem, and the availability of dedicated IoT marketplaces.

IoT platforms enable enterprises to monitor and control IoT endpoints, build applications to meet digital business requirements, and will be an essential element in the development of a digital single market. In the new digital economy, IoT platform ecosystems are the foundation for new value creation and the driver for developing new IoT applications. The IoT platforms need to offer support for service mashups and create ambient user experience with the emergence of ambient intelligence, augmented/virtual reality and tactile Internet.

This requires the architecting and developing IoT platforms that addresses the new technologies for communication, control, management and security of endpoints in the IoT to form a coherent architecture.

Today, the providers of IoT platforms are fragmented and in the near future, there is a need to designing overarching, integrated IoT platforms that bring the devices, networks and endpoints together in the companies' and IoT ecosystems that develop various IoT applications.

In this context, the IoT platforms need to be and act as a complete IoT/IT/OT ecosystem converging the consumer/business/industrial applications by collecting and sharing data broadly within an organization, sectors, and IoT applications. This need to be converted into

an IoT platform strategy, based on open specifications, strong interoperability principle, security and standardization.

The development of possible IoT Platforms as a Service is seen as a strategy that is pushed by several large IoT players.

IoT platforms will have an important impact on autonomous, self-driving vehicles technology and applications, while playing an essential role in the creation of Open Urban Platforms in the cities based on the federation of different IoT platforms together with other types of platforms operating in the cities.

The reason of this trend is based on the increased public interest with mobility as a service when this is convenient, relevant and based on the information shared by various platforms including IoT platforms in the city. The IoT federated platforms will support strengthening the relationships between people, vehicles, and services and enhance utilizing identity relationship frameworks, context centric design principles, and ecosystem interoperability for accelerating the adoption of these technologies.

IoT Platforms are key for the development of scalable IoT applications and services that connect the physical, digital and virtual worlds between things, systems and people.

The IoT Platform market represents a new dynamic segment that emerged few years ago, and as in any new markets, the landscape is complex and changing very rapidly. The immaturity of the current IoT platform market is evident due to the sheer number of providers actively offering solutions. This oversaturation of IoT platforms on the market will lead to consolidation and many platforms going out of business in near future. Increasing standardisation and joint efforts in open source development across major players will see a more aligned landscape emerging. The battle will be fierce and it is the bigger players who currently have the upper hand in this battle in the current climate. Potential customers are hesitant to make today major investments into an IoT platform as tomorrow it may be out of business. A larger vendor has an easier sell than a smaller business as he is likely to stay for some time and has a track record to point to. There may be enough room for SMEs on niche markets; however, the majority of the smaller platform providers will disappear in future. Smaller businesses and start-ups are advised to rather focus on providing disruptive, innovative solutions or value added services around emerging dominant IoT platform ecosystems.

Companies and end-users that want to apply IoT platforms to their operations first should make themselves familiar with existing products for their specific industrial sector. Furthermore, an internal analysis should be made on what are the basic requirements to the platform (end-to-end, open source, etc.), desired feature sets, APIs etc., as well as the envisaged focus of the platform (analytics, mobile, device integration, artificial intelligence, M2M learning, virtual/augmented reality, tactile Internet).

Many of the IoT-EPI project strive to create interoperability solution to enable data access and federation across these platforms. There is a danger that resource may be wasted on making platforms interoperable, which now or near future have no market relevance. That fact that only 6 of the 35 platforms are identified as currently leading ones on the market, requires a new process of evaluating the IoT platforms landscape.

In this context, the focus is developing and deploying IoT technologies and applications using a federation of IoT platforms and a strong IoT ecosystem of integrators, aggregators, service providers, RTOs across various industries. These ecosystems need including industrial, consumer, business stakeholders that enable customers/end-users/stakeholders to create managed services offerings, co-create value (products, services, experiences) based on new business models and exchange data thus unlocking the true data value chain in order to deploy solution for digital single market.

While the overall IoT market is starting to mature, there are various gaps still existing both on technology and business models. One of these gaps is the support for integrated cloud, mobile edge computing and edge analytics solutions in current IoT platforms. As the number of IoT devices grows, it will become increasingly inefficient to extract necessary insights in the cloud. Emerging industrial IoT applications, Tactile Internet and autonomous/robotic systems solutions will require much faster reactivity at the edges of the networks. In order to support these requirements, analytics algorithms will have to operate in a distributed context between edges and cloud with heterogeneous capabilities. Apart from the algorithmic, artificial intelligence and M2M learning advances, this requires much more sophisticated frameworks in place to enable effective synchronisation and adaptability.

Another important gap is the lack of 3rd party market places inside of the current IoT platforms. Despite the increasing focus to capture developer mind share, concrete market place mechanisms to enable revenue share between the providers of the IoT platform and 3rd party app or analytics component developers are not yet existing. This is however a crucial element to spark the success that we know of the app economy in the mobile world.

Only some IoT platforms of bigger players such as Microsoft Azure or IBM Watson / Bluemix provide early indications of such mechanisms, by allowing third party plugin and services to be discovered and utilised. In addition, IBM for provides block chain technologies alongside their IoT platform offering.

The emergence of such market places is only the beginning of leveraging more easily economies of scale. The creation of a single digital market for IoT requires federated market places across currently emerging IoT platform silos. By enabling re-use of assets across different IoT ecosystem boundaries, secondary revenue streams can be generated for IoT infrastructure investments, which will boost the overall IoT market. Open source technology will play an increasing role in fostering common foundations across vendor specific ecosystems. By overcoming proprietary technology choices and giving in on initial market position, more powerful market place can emerge with less barriers and more revenue growth opportunities for all IoT stakeholders involved.

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10. APPENDIX A: RESOURCES FOR IOT PLATFORM ANALYSIS

The Appendix contains a list of resources that have been used to determine currently popular IoT platforms on the market.

10.1 Global IoT platform resources

10.1.1 Industry analyst reports

There are varieties of industry analysts focusing on ICT technology and the hype around IoT has certainly attracted the attention of many of them. A variety of reports have become recently available, focusing on different aspects of the IoT ecosystem, ranging from wireless connectivity over to applications and services.

IoT Analytics

On the IoT platform side, IoT Analytics⁴⁶ appears to have currently the edge. They narrowly focus on the IoT market and own the most extensive IoT platform database currently available. We based our analysis in the previous section on the IoT platform list. However, they provide no direct IoT platform benchmarks. An indicative piece of information is list of the 20 most popular IoT companies. IoT Analytics performed this selection based people's Google searches and twitters for IoT platforms, and which IoT companies appears on newspaper and blog headlines, and how many IoT-focused employees these companies have. While these metrics are quite interesting when referring to established and big company, they become less useful in relation to emerging and niche platforms. Below is a list of the companies who themselves have IoT platforms.

- | | | |
|--------------|------------|----------------------|
| 1. Intel | 6. Samsung | 12. General Electric |
| 2. Microsoft | 7. Apple | 14. Amazon |
| 3. Cisco | 8. SAP | 15. HP |
| 4. Google | 10. Oracle | 16. Arduino |
| 5. IBM | 11. ARM | 19. PTC |

Vision Mobile

In terms of mobile and IoT developer ecosystem, Vision Mobile⁴⁷ seems to be leading resource on the market. Vision Mobile regularly conducts surveys directly with the IoT developer communities. For their most recent report ⁴⁸3,150 developers from 140 countries where consulted. Data collected from this survey provided an understanding on the IoT developer ecosystem. The survey aimed to offer insights on features a programmer is looking for when choosing an IoT platform for developing new IoT service or application. Top element of an IoT developers agenda are (1) fast and easy development (2) low cost and ratio value-cost (3) familiarity with the technology. In another report called IoT megatrends 2016, Vision Mobile reveals the top platforms based on an analysis from the developer community. The listed

⁴⁶ <https://iot-analytics.com/>

⁴⁷ <https://www.visionmobile.com/>

⁴⁸ <https://www.visionmobile.com/blog/2016/02/best-practices-for-a-successful-iot-developer-program>

platforms are succeeding in supporting the creation and preservation of value in different sectors of the IoT landscape.

Smart Home	Industrial IoT	Connected Car
Amazon	Amazon AWS	Apple Car Play
Eclipse Smarthome	Bosch	Android Auto
Google	Eclipse	Carvoyant
Icontrol networks	GE Predix	GM Dash
Insteon	Intel	Mojo
Microsoft	IBM Bluemix	Ford
SmartThings	Oracle	Tencent
	SAP	Vinli
	Salesforce	
	ThingWorx	

In another report, Vision Mobile analyses the IoT open source community. The report lists notable IoT open source platforms and differentiates device centric and cloud centric ones. The table below captures the platforms seen most popular by IoT developers.

Device centric IoT platforms	Cloud centric IoT platforms
Open Hab/Eclipse Smarthome	DeviceHive
Nimbits	DeviceHub
IoT ToolKit	OpenRemote
Chimera IoT platform	ThingsSpeak
	SiteWhere
	Kaa

10.1.2 Online communities and resources

Internet of Things Institute

The IoT Institute is a platform for connecting “professionals in the IoT ecosystem and inspires them by providing real-world, actionable information on the latest IoT trends, analysis, and use-case studies for smart cities, the Industrial IoT, smart buildings and energy, and the innovators creating the IoT infrastructure.”⁴⁹ The IoT institute selected 20 different IoT leaders by asking to end-users from different segments of IoT application. The ranked 20 IoT leader platforms are:

- | | |
|--------------|-----------------------|
| 1. Google | 6. Intel |
| 2. Microsoft | 7. Siemens |
| 3. Cisco | 8. AT&T |
| 4. Amazon | 9. GE |
| 5. IBM | 10. Honeywell/Tridium |

⁴⁹ <http://www.ioti.com/about>

- | | |
|--------------------------------|----------------------|
| 11. Hewlett Packard Enterprise | 16. Johnson Controls |
| 12. Oracle | 17. SAP |
| 13. Rockwell Automation | 18. Verizon |
| 14. Schneider Electric | 19. Deli |
| 15. Texas Instruments | 20. Bosch |

Forbes

Forbes online is the web presence of the American business magazine. For our purpose we surfed Forbes.com and found a useful article that lists the first 100 IoT platforms active in 2015 “Mattermark Lists The Top 100 Internet Of Things Startups For 2015”⁵⁰. Forbes outsourced the research to Mattermark⁵¹. This organization combines “artificial intelligence and data quality analysis to provide insights into over 1 million private companies, over 470,000 with employee data, and over 100,000 funding events”. The list discussed by Forbes is built on indicators such as: web traffic, social traction, and business growth metrics (e.g. employee count over time, funding). However, Forbes focused mainly on start-ups and excluded from its interest established companies and their developed IoT platforms. It is because of this that we included in the Mattermark list also the platforms highlighted in another article “The Platform of Things: The Mega IoT Platforms Land Grab”⁵². Because the list provided by Mattermark included start-ups related to IoT but not exclusively referred to platforms, we matched and combined the IoT Analytics table with the Mattermark one. Thus combining the two spreadsheets and the article related to established companies in IoT we get an ordered list of other 20 platforms.

- | | |
|----------------------|----------------------------|
| 1. Cisco | 11. Stratoscale |
| 2. IBM Watson | 12. IFTTT |
| 3. GE | 13. Kaazing |
| 4. mPrest | 14. Zonoff |
| 5. Microsoft | 15. Ayla Networks |
| 6. Solaris | 16. GreenPeak Technologies |
| 7. Amazon Web Servis | 17. Arrayent |
| 8. Jasper | 18. InnoPath Software |
| 9. SimpliSafe | 19. EVERYTHING |
| 10. Enlighted | 20. Bit Stew Systems |

Postscapes

Postscape is a web platform with the aim “to track the emerging nodes, connection and consolidated layers of the one machine” and to support decision makers and end-users in the complexity of a fragmented market⁵³. This list includes and integrate different platforms filtered by requirements, features, and focus:

- | | |
|------------------|----------------------------|
| 1. Ayla Networks | 3. Autodesk Fusion Connect |
| 2. Artik Cloud | 4. AWS IoT |

⁵⁰ <http://www.forbes.com/sites/louiscolombus/2015/10/25/the-top-100-internet-of-things-startups-of-2015/#4130890255af>

⁵¹ <https://mattermark.com>

⁵² <http://www.forbes.com/sites/sarwantsingh/2016/07/14/the-platform-of-things-the-mega-iot-platforms-land-grab/2/#214592ca6df4>

⁵³ The mission of the portal can be find here: <http://about.postscapes.com>

- | | |
|-------------------------|-----------------|
| 5. GE Predix | 13. Kaa |
| 6. Google Cloud IoT | 14. Macchina.io |
| 7. Microsoft Azure | 15. SiteWhere |
| 8. ThingWorx | 16. ThingSpeak |
| 9. Salesforce IoT Cloud | 17. Temboo |
| 10. Telit | 18. Carriots |
| 11. Xively | 19. Losant |
| 12. Zebra Zatar Cloud | 20. Ubidots |

Internet of Things Wiki

This website is a “free resource for understanding IoT” that provides information related to the IoT panorama. IoTwiki is partnering with a set of other reliable sources: IoT council, Council Global, IoT Tech Expo, IoT world, IoTBD, IDTechEx, and IoTConnect. They identify the Top 10 platforms that are driving the current IoT platform market.

- | | |
|--------------------|------------------------------|
| 1. AWS | 6. Salesforce IoT Cloud |
| 2. Microsoft Azure | 7. Carriots |
| 3. ThingWorx | 8. Oracle |
| 4. IBM Watson | 9. General Electric’s Predix |
| 5. Cisco | 10. Kaa |

10.1.3 Academic sources

#Article 1 Mazhelis, O. and Tyrväinen, P. A Framework for Evaluating Internet-of-Things Platforms: Application Provider Viewpoint. *IEEE World Forum on Internet of Things (WF-IoT)*. 2014

This paper focuses on and describes a series of platforms by analyzing a set of parameters the authors define as relevant for understanding how broadly the platforms cover the “potential needs of the application providers”. For doing so, the authors highlight some features helpful for analyzing platforms: design and implementation – device, Gateway, UI, and Web; operations – fulfillment, assurance, and billing. Thus, based on these different features, authors provide another list of platforms:

- | | |
|--------------------------|----------------|
| 1. Arkessa | 7. OnePlatform |
| 2. Axeda | 8. RealTime.io |
| 3. Etherios Device Cloud | 9. SensorCloud |
| 4. NanoService | 10. TempoDB |
| 5. Nimbits | 11. Thingworx |
| 6. Ninja Blocks | 12. Xively |

#Article 2 Mineraud, J., Mazhelis, O., Su, X., and Tarkoma, S. Contemporary Internet of Things platforms. *arXiv:1501.07438 [cs.OH]*

This report aims to collect and list platforms for a “quick review”. For this report the authors do not provide a reasoning for their selection. However, based on the references they bring, we can assume the list is a combination of previous and not really up-to-date researches.

- | | | |
|----------------|---------------------------|-----------------------|
| 1. Air Vantage | 6. Devicehub.net | 10. Evrything |
| 2. Arkessa | 7. Ericsson IoT-Framework | 11. Exosite |
| 3. Axeda | 8. EveryAware | 12. Fosstrack |
| 4. Carriots | 9. EveryWare | 13. GrooveStreams |
| 5. DeviceCloud | | 14. Hub-of-all-Things |
| | | 15. IFTTT |

- | | | |
|-----------------|----------------------|------------------|
| 16. LinkSmart | 24. RealTime.io | 32. Thing Broker |
| 17. MyRobots | 25. SensiNode | 33. ThingSpeak |
| 18. Niagara | 26. SensorCloud | 34. ThingSquare |
| 19. Nimbits | 27. SkySpark | 35. ThingWorx |
| 20. NinjaBlock | 28. Swarm | 36. Sense Tecnic |
| 21. OpenIoT | 29. TempoDB | WoTki |
| 22. OpenRemote | 30. TerraSwarm | 37. Xively |
| 23. Open.Sen.se | 31. The thing system | |

#Article 3 [3] Sruthi, M. and Kavitha, B. R. A survey on IoT Platform. *International Journal of Scientific and Modern Education (IJSRME)*. 1:1, 2455-5630, 2016

This paper is a state of the art review that bases the analysis of the platforms on (1) the way they integrate to cloud, (2) the supported protocols, (3) Security, (4) Type of the analysis, and (5) the sector of application.

1. Xively
2. Axeda
3. ThingWorx
4. ThingSquare
5. Bugswarm
6. SensorCloud
7. ThingSpeak
8. Everything
9. Everyware Device Cloud
10. Idigi Device Cloud

#Article 4 Zdravković, M., Trajanović, M. Sarraipa, J., Jardim-Gonçalves, R., Lezoche, M., Aubry, A. and Panetto, H. Survey of Internet-of-Things platforms, 6th *International Conference on Information Society and Technology, ICIST 2016*, Feb 2016, Kopaonik, Serbia. 1, pp.216-220.

This paper provides a list of platforms based on a set of key elements for distinguish the platforms: (1) how they support the heterogeneity, (2) the architecture and dependencies, (3) how the platform creates knowledge through data, (4) level of robustness and openness, (5) the level of security, and in relation to security (6) the level of privacy, and (7) the position of humans in controlling/using the platform. Following these parameters, the authors selected and described the following platforms:

1. Arrayent
2. Axeda
3. Bugswarm
4. Carriots
5. Evrything
6. Exosite
7. GrooveStream
8. IFTTT
9. Kaaproject
10. LinkSmart
11. Mbed
12. Nimbits

13. Particle.io
14. Autodesk SeeControl
15. SensorCloud
16. ThingWorx
17. ThingSpeak

10.1.4 IERC cluster book 2015

The IERC cluster book of 2015 had a chapter dedicated to IoT platforms during which most important platforms on the market were discussed. The list was comprehensive and included a set of 20 IoT platforms and OS. The table below summarises the IoT platforms. The numbering does not refer to a ranking but is just used for increased readability.

- | | | |
|------------------------------|--------------------------------|--------------------|
| 1. Axeda | 6. Xively | 11. IBM Watson IoT |
| 2. ThingWorx | 7. ARM mbed | 12. Open Remote |
| 3. SAP IoT Solutions | 8. Intel IoT platform | 13. Arrayent |
| 4. Microsoft Azure IoT Suite | 9. Jasper | 14. Echolon |
| 5. Ayala Networks | 10. Bosch SW Innovations Suite | 15. Sensor Cloud |

10.1.5 Relevancy analysis

In order to determine the relevancy of the different cited IoT platforms in our list of resource, we have examined the number of occurrences of the different platforms within the different resource lists and grouped it according to the resource category. For reasons of overview, we have listed only platforms that have been cited more than once by the analysed list of resources.

Platform	Type	Relevancy count					
	Company	Centricity	Analyst	Online	Academ	IERC	Total
PTC ThingWorx	MNC	Industry	2	3	4	1	9
Microsoft Azure	MNC	Cloud	2	4		1	7
Amazon AWS	MNC	Cloud	2	4			6
IBM Watson IoT	MNC	Cloud	2	3		1	6
PTC Axeda	MNC	Telco			4	1	5
GE	MNC	Industry	1	4			5
Kaa	OS	Cloud	1	3	1		5
ThingsSpeak	Startup	Cloud	1	1	3		5
Xively	SME	Cloud		1	3	1	5
Carriots	Startup	Telco		2	2		4
Cisco	MNC	Telco	1	3			4
EVERYTHING	Startup	Cloud		1	3		4

Google Cloud IoT	MNC	Cloud	2	2			4
Intel	MNC	Device	2	1		1	4
Nimbits	OS	Cloud	1		3		4
Oracle	MNC	Cloud	2	2			4
SensorCloud	SME	Industry			3	1	4
ARM mbed	MNC	Device	1		1	1	3
Arrayent	SME	Industry		1	1	1	3
Ayala Networks	MNC	Telco		2		1	3
Bosch	MNC	Industry	1	1		1	3
IFTTT	SME	App		1	2		3
OpenRemote	OS	Consumer	1		1	1	3
Salesforce IoT Cloud	MNC	Cloud	1	2			3
SAP	MNC	Cloud	1,1			1	3
Arkessa	SME	Telco			2		2
BUGswarm	OS				2		2
Eclipse Smarthome	OS	Consumer	1,1				2
EveryWare Device Cloud	SME	Cloud			2		2
Exosite	Startup	Cloud			2		2
GrooveStreams	Startup	Analytics/ Cloud			2		2
HP	MNC	Cloud	1	1			2
Jasper (now CISCO)	MNC	Telco		1		1	2
LinkSmart	OS	IT/Network			2		2
Ninja Blocks	Startup	Consumer			2		2
RealTime.io	SME	Cloud			2		2
SiteWhere	Startup	Telco	1	1			2
TempoDB	SME	Cloud			2		2
ThingSquare	Startup	Consumer			2		2

10.2 European research community survey

UnifyIoT has conducted a survey among the IoT-EPI projects to understand current platforms of choice within the research community. Several open source solutions have been listed as platforms of choice with an option to also specify additional platforms. A summary of the chosen platform is provided below in the order of popularity based on 35 responses from community members. It should be noted that the responses refer to IoT platform technologies rather to specific implementations thereof, eg. FIWARE, IoT-ARM or HyperCat.

1. OpenIoT
2. FIWARE
3. IoT-ARM (IoT-A)
4. OGC SWE
5. IoTivity
6. Hyper/CAT
7. 5GVIA
8. UDG
9. OpenWSN

10.3 OneM2M based platforms

OneM2M based platforms are M2M platform implementations that follow the OneM2M standard, an increasingly important IoT related standard in the Telecoms sector. As standardisation is still ongoing, there are currently not too many commercially available offerings on the market. Some Telecoms operator chose to implement their own OneM2M platform, which is often an extension of their own service delivery platform to support standards compliant M2M services. Other vendors have their own M2M platform offerings. Some open source implementations are also emerging. Below is a list of the most advanced IoT platforms, which are commercially available or deployed by operators:

- OpenMTC (<http://www.open-mtc.org/>)
- Eclipse OneM2M (<http://www.eclipse.org/om2m/>)
- Interdigital OneMPOWER
- SK Telecom, KT and LG U+ all have certified OneM2M platforms
- HPE Universal IoT platform
- CDOT OneM2M platform, India