Models for Innovative IoT Ecosystems

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ABSTRACT
The Internet of Things is a concept and a paradigm with various visions and multidisciplinary activities. The present paper first gives shortly a background on the evolution of the Internet of Things. The trends which drives the evolution of the business perspectives to the Internet of Things are presented. As well, it discusses the two classes of Internet of Things business models that have emerged – the vertical and horizontal one. Furthermore, the paper gives an overview of different approaches for horizontal integration of Internet of Things ecosystems as the one of Intel, Amazon, Google, Microsoft, IBM, etc. In conclusion, the business model development is outlined and it is pointed out that the horizontal integration is the one that will most probably thrive in the near future.

CCS Concepts
• General and reference~General conference proceedings • General and reference~Empirical studies • Computer systems organization~Embedded and cyber-physical systems • Computer systems organization~Distributed architectures • Software and its engineering~Cloud computing • Software and its engineering~Distributed systems organizing principles

Keyword
Internet of Things; Ecosystem; Horizontal Business Models; Vertical Integration

1. INTRODUCTION
The Internet of Things (IoT) is rapidly evolving, but there is a need to understand challenges in obtaining horizontal and vertical application balance and the key fundamentals required to attain the expected 50 billion connected devices in 2020.
The IoT creates an intelligent, invisible network fabric that can be sensed, controlled and programmed. IoT-enabled products employ embedded technology that allows them to communicate with each other or the Internet [1].
IoT is a concept and a paradigm with different visions, and multidisciplinary activities. IoT considers pervasive presence in the environment of a variety of things, which through wireless connections are able to interact with each other create new services.
Recently IoT has evolved to a multidisciplinary domain where devices, Internet technology, and people create a complete ecosystem for business innovation, reusability, interoperability, including security and privacy matters [2].
IoT ecosystems offer solutions comprising of large heterogeneous systems of systems beyond an IoT platform and solve important technical challenges in the different industrial verticals. This requires a new approach to value creation and the monetization of end-users value [3].
The IoT describes the interconnection of objects or "things" forvarious purposes including identification, communication, sensing, and data collection. "Things" range from mobile devices to general household objects embedded with capabilities for sensing or communication through the use of technologies such as Radio Frequency Identification (RFID). The IoT represents the future of computing and communications, and its development relies on dynamic technical innovation in fields such as RFID, sensor technologies, smart things, nanotechnology and miniaturization [3].
IoT is concerned with building up a platform that allows to process information, communicate data, analyze context collaboratively by individuals, organizations and businesses.
Both the industrial and consumer scenarios are important, but the deployment is not simplified since they are different vertical systems [1].
The evolution of business perspectives to the IoT is driven by two underlying trends:

- The change of focus from viewing the IoT primarily as a technology platform to viewing it as a business ecosystem;
- The shift from focusing on the business model of a firm to designing ecosystem business models.

An ecosystem business model is a business model composed of value pillars anchored in ecosystems and focuses on both the firm's method as well as any part of the ecosystem's method of creating and capturing value [4].
This conceptual study is organized as follows. After the brief introduction into the topic, a background is presented regarding vertical and horizontal business models related to the IoT. Second, the major platforms for IoT are presented like the one of Intel, Google, Amazon, Microsoft and IBM. Third, the impact of those platforms on the business models and future business model development is discussed in the Conclusion..

2. VERTICAL AND HORIZONTAL BUSINESS MODELS FOR IOT
Two different models of IoT have emerged, one is vertical and the other horizontal. Apple is a great example of the success of the vertical approach, not only for its end to end considerations, but

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for revising the whole model of personal computing – a good mix of granular and abstract problem solving.

2.1 Vertical Business Model for IoT

In the vertical business model, the IoT device, the gateway (if used), and the Cloud-based service are all provided and controlled by the one and the same company. This approach has the advantage for the end-user that there are no compatibility issues to deal with among the various elements, and a single point of contact to deal with if anything goes wrong. The disadvantages are that the end-user is entirely dependent on the vendor for improvements, enhancements, or upgrades to the offering.

Vertical business models can also result in users needing several different systems to achieve a spectrum of tasks, each with its own gateway and cloud operations. In a smart home, for instance, it is easy to end up with separate providers for security, HVAC, and appliance systems. This complicates system management for the end-user.

It is still common that IoT applications are built as vertical silos with the purpose of supporting only one specific application for one kind of things or devices. This approach will cause a lot of troubles when different kind of things, sensors or other devices are being added or when the business model evolves [5].

Most of the first IoT offerings to come to market follow this vertical model. That is not surprising, given that there is yet little infrastructure in place to support a horizontal business however, this is changing [1].

2.2 Horizontal Business Model for IoT

The motivation behind a horizontal model is to foster rapid growth and innovation in the industry by allowing multiple providers to work with a common framework. The idea is that by making the gateway and cloud resources something that can be assumed to be in place and with open functionality, innovators can concentrate their efforts on creating devices and services.

Further, by working on a common framework, those devices and services can more easily share information and resources.

To foster this horizontal model, many companies are starting to roll out Cloud platforms and gateway hardware that allow multiple users.

The horizontal approach makes innovation easier and allows rapid proliferation of new applications and businesses, but it needs to gain considerable traction before it can pay off on its promises. The vertical model will be dominant for the next few years as the horizontal business models build the installed base they will need.

Preparing the lowest layers of technology for the horizontal nature of the IoT requires manufacturers to deliver on the most fundamental challenges, including:

• **Connectivity:** The challenge is getting the connectivity standards to talk to one another with one common worldwide data currency.

• **Power management:** The challenge is making it easy to add power management to these devices and equipment. Wireless charging will incorporate connectivity with charge management.

• **Security:** With the amount of data being sent within the IoT, security is a must. Built-in hardware security and use of existing connectivity security protocols is essential to secure the IoT. Another challenge is simply educating consumers to use the security that is integrated into their devices.

• **Complexity:** Ease of design and development is essential to get more things connected especially when typical RF programming is complex. Additionally, the average consumer needs to be able to set-up and use their devices without a technical background.

• **Rapid evolution:** The challenge facing the industry is the unknown: unknown devices, unknown applications, unknown use cases. Given this, there needs to be flexibility in all facets of development. A wide variety of wired and wireless connectivity technologies are needed to meet the various needs of the market. Last, a wide selection of sensors, mixed-signal and power-management technologies are required to provide the user interface to the IoT and energy-friendly designs [1].

3. PLATFORMS FOR INTERNET OF THINGS (IoT)

3.1 The Intel® IoT Platform

The Intel® IoT platform [6] provides an end-to-end platform for connecting unconnected devices, allowing data from billions of devices, sensors, and databases to be securely gathered, exchanged, stored, and analysed across multiple industries.

The key benefits are security, interoperability, scalability and manageability by using advanced data management and analytics from sensor to datacenter.

IoT software platforms are offered by companies such as Bright Wolf [7], ThingWorx [8], Jasper [9], Ayla Networks [10], that 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. In addition, these 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.

3.2 The Google IoT Platform

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.

Large companies like Google, Amazon, IBM, Microsoft, SAP, etc. offer such solutions. Amazon Web Services (AWS) provide a robust suite of services to help stream and orchestrate IoT data flows.

Search giant Google is taking the IoT very seriously. They claim that “Cloud Platform is the best place to build IoT initiatives, taking advantage of Google’s heritage of web-scale processing, analytics, and machine intelligence”. Google provides a suite of managed services that support the IoT developers to build IoT applications [11].

A business model framework is used by each stakeholder as a tool that helps developing its business models, by providing an overview of the value chain components for the different solutions provided by the IoT stakeholders.

Google has its own IoT operating system based on Android and “Google grade” security.

Pricing on Google Cloud is done on a per-minute basis and they have a price comparison tool to show you how much you’ll save.

3.3 The Amazon IoT Platform

Amazon’s IoT platform 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.

Amazon's business model is based on pay-as-you-go pricing model and is independent on 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 eco-system.

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 eco-system.

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.

3.4 Microsoft Azure IoT Hub

Azure IoT Hub 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 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.

Azure IoT Hub is made 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 of 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.

3.5 IBM Watson IoT Platform

The Watson IoT platform 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 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 dash boards and alerts. See Table 1 for comparison between the IoT platforms of Amazon, Microsoft and IBM.

Table 1. Comparison of the main IoT platform vendors: Amazon, Microsoft and IBM

IoT Platform Vendors or Companies	Description
Amazon	Amazon Web Services (AWS) from Amazon is device SDK and secure device based gateway. It helps connect different types of sensors from various application profiles with the cloud.
Microsoft	Azure IoT suite, this IoT platform incorporates previous Azure stream analytics which helps in processing large amount of data.
IBM	Product name IBM Watson helps in device management, secure communication, realtime data exchange and data storage.

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.

The platform 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.. In addition, IBM is upselling additional capacity for data storage and data traffic for higher user demands.

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

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.

The different business models depend on the centralised/decentralised models offered by the IoT platforms and the dynamic registration and de-registration of edge devices in an IoT topology. IoT PaaS are associated with cloud architectures in which a central hub provides the backend services to edge devices. The key centralised capabilities of an IoT platform include event processing, enterprise system integration, device discovery, device management, event notifications and real time analytics. The decentralised models offered by the IoT platforms allow the autonomous communication between edge devices in an IoT topology without the need of a central hub with the capabilities such as peer-to-peer messaging, decentralised auditing, decentralised file sharing. Blockchain technology is used to assure the mechanism to enable the IoT distributed model and the block chain platform, and it provides the building blocks to enable edge devices in a distributed topology to exchange data and perform tasks in a trusted and verifiable way.

In this context, the IoT business models are evolving and in terms of lifecycle, cooperation and configuration are closely interrelated to the IoT-based business and technology ecosystem set-up. It is expected that the IoT business models would be developed as a result of a series of vertical market solutions that witness growth at various rates over the next decade or more.

The IoT acceleration will be influence by factors such as sensors/actuators advancements, microcontroller processing units price/performance ratio, wireless connectivity cost, edge-computing developments, Cloud-based software infrastructure and application implementations and deployments (see Figure 1).

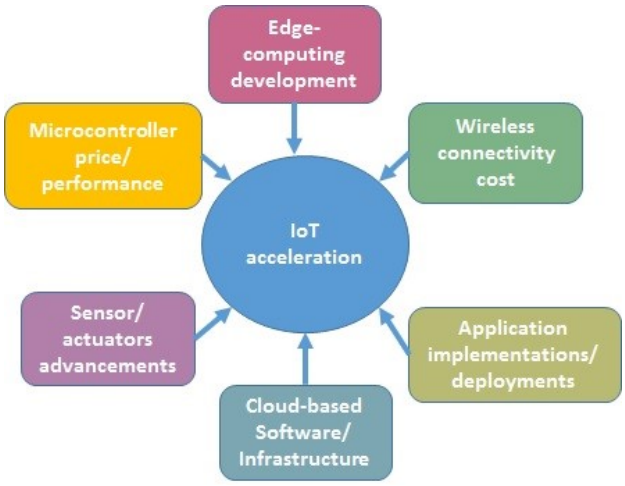

Figure 1. Drivers of IoT growth [12]

The business model parameters focus is different as the service content increases in the digital value chain for IoT markets. Elements such as value proposition, revenue mechanism, value chain, target market, value network, and competitive strategy are added in network-centric view in IoT business model. The various layers of the IoT value chain are divided in different distinct product or service. Radios/communications chips provide the underlying connectivity, sensors provide much of the data gathering, microcontrollers provide the processing of that data, modules combine the radio, sensor and microcontroller combine it with storage and make it "insertable" into a device. Platform software provides the underlying management and billing capabilities of an IoT network, while application software presents all the information gathered in a usable and analysable format for end users. The underlying communication infrastructure provides the means of transporting the data while a service infrastructure needs to be created for the tasks of designing, installing, monitoring and servicing the IoT deployment. The IoT stakeholders compete at one layer of this value chain, while many create solutions from multiple layers and functionally compete in a more vertically integrated fashion [12].

3.6 Impact of IoT Platforms on Business Models

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. Cloud based IoT platforms are offered by the 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 [13].

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. The platforms providers create IoT ecosystems that involves close partnerships with stakeholders that use their technology. 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 [13].

In order to accelerate the time to market for IoT projects, products and services, many companies resort to utilising pre-built IoT platforms and customise these to their deployment context, instead of developing an alternative in-house platform [14].

Many of the platforms differ in the offered functionality – some are more focused on communications and devices, while others focus more on data management services, some target requirements of specific verticals while others claim to be generic for any application domain, some are open source while others are based on proprietary technology stacks.

This large diversity together with the immaturity of the current IoT platforms market, makes it difficult to clearly identify business models that IoT platform vendors can successfully adapt, both in terms of capturing value from their own propositions and together with their wider stakeholder eco-system.

As an initial attempt in characterising the confusing landscape, direct value can be captured from Platform as a Service (PaaS) offering, where mainly proprietary platforms are offered as white label solutions to developers/service providers or sold on a pay-per-use basis to their customers as part of an end-to-end IoT solution. In contrast the Open Source model relies on companies to offer the software underlying an IoT platform as a free asset to the developer community, with the goal to lower the barriers of access and easier reach developers. The revenues in the latter model are typically based on specialist consultancy and system integration activities carried out around the free asset, with the goal to customise it quickly to the diverse demands of different customers.

4. CONCLUSION

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. The requirements across different sectors and between different businesses within a sector are very diverse so, there is a need for many applications and services to satisfy the market needs. 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.

Another important observation is that current successful IoT platforms on the market have realized that the current IoT play is an ecosystem play so that, they are as strong as their alliance are. That is why many of the IoT platform vendors have strengthen the partnerships along the entire IoT value chain in order to remain successful in the various end-to-end solutions [13].

When designing the business model, a company should always have a look not only on the direct suppliers, clients, etc., but also

on the entire ecosystem of the product or service in order to be able to identify additional value propositions and revenue within the system, i.e. new business model combinations. [3]

Many of the existing business models can be applied also for new products and services within the IoT. However, the IoT also creates opportunities for new business models.

Key for successful new IoT businesses will be the alignment of embedded systems technologies, intelligent device communications, network services, IoT infrastructure and application services by integrating the advances in nanoelectronics, cyber-physical systems, and communications with software services, apps, and APIs combined with business models disruption.

There is no best IoT cloud platform, and ultimately it will depend on the specific needs of the business. At the moment Amazon is the most established in this field, but could be expensive.

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