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IoT Business Models Framework

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Summary					
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DoW	The IoT business models as presented in this tasks cover the identification and analysis of the logic of an IoT ecosystem (form by several companies), or an individual company, the way it operates and how it creates value for its stakeholders. The task presents a conceptual framework for the business model which is a reflection of the IoT ecosystem's/company's realized strategy. In this context, the IoT business models reproduce the content, structure, governance of technology and business transactions designed to create value through the exploitation of IoT business opportunities through applications. A special focus is laid on the view from technology providers as there is very good access to respective ecosystems/ players. The task studies first current business models and provide taxonomy, indicating, which ones can be improved or enabled by IoT technologies. The base of the study is the existing literature on business models as well as input from several WGs of AIOTI; then, though searching available information; different approaches are classified and identify which business model "family" seems more suitable for a specific product and market, according to the past experience.				
Comments					

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1. EXECUTIVE SUMMARY

1.1 Publishable summary

The challenge for Internet of Things (IoT) stakeholders and the IoT ecosystem is to create value for individuals or businesses.

The value differs for different stakeholders; individuals can perceive value as something that is “improving” their life or bring them new experiences; businesses, perceive value by ROI (return on investment), that is translated in saving company money, directly, either by lowering costs, or indirectly, by improving efficiency of existing resources, etc.

The involvement of many stakeholders in the IoT digital value chain can create rather complicated business models necessary for many IoT applications that in short term limit the impact of IoT technologies and applications.

IoT brings challenges to the stakeholders in the IoT ecosystem on identifying horizontal needs and opportunities, the management challenge related to internal organizational goals (i.e., matching technology and to the objectives of business developers), and the ways to overcome the market maturity issues for new IoT technologies.

The IoT business models concepts and framework as presented in this document cover the identification and analysis of the logic of an IoT ecosystem (form by several companies), or an individual company, the way it operates and how it creates value for its stakeholders.

The document discusses the conceptual framework for the business model which is a reflection of the IoT ecosystem's/company’s realized strategy. In this context, the IoT business models reproduce the content, structure, governance of technology and business transactions designed so as to create value through the exploitation of IoT business opportunities through applications. A special focus is laid on the view from technology providers as there is very good access to respective ecosystems/players.

The document presents first current business models and provide taxonomy, indicating which ones can be improved or enabled by IoT technologies. The base of the study is existing literature on business models as well as input from several Working Groups (WGs) of The Alliance for Internet of Things Innovation (AIOTI). Through searching available literature and information from IoT technologies, applications and solutions providers, different approaches are presented and the identification of business model “family” that seems more suitable for a specific product and market is done, according to the past experience.

1.2 Non-publishable information

None.

2. INTRODUCTION

Digital innovations are a key enabler for meeting the objectives of many of our societal challenges from sustainable health systems to the improvement of resource and energy efficiency as addressed in Commission policies like the Energy Union and the Circular Economy.
The internet, the web and recent developments in virtual and augmented reality continue to reshape the production and business models of all creative industries.

This additional value creation from digital innovations occurs in [1]:

- **Products:** Driven by the development of the Internet of Things, the further integration of ICT in all types of products and artefacts offers a wide range of opportunities for the growth of new industries including start-ups and is transforming all sectors of the economy. This includes developments of markets like the connected car, wearables or smart home appliances.
- **Processes:** the further spread of automation in production and the full integration of simulation and data analytics in processes and supply chains are bringing substantial gains in productivity and resource efficiency over the full cycle from product design to lifecycle management.
- **Business models**: by re-shuffling the value chains and blurring boundaries between products and services. Smart connected products come with services and customers adopt changing behaviour e.g. on "ownership", co-creation and sharing (the apps economy). The impact of adding services to the product portfolio of manufacturing companies has been shown to increase profitability by up to 5.3% and employment by up to 30% [2].

The IoT developments have major implications for business model innovation and the use of existing frameworks and streamlining established business models cannot address the challenges pose by new products, services and IoT ecosystems related to value co-creation and value capture.

Value co-creation, involves performing activities together with other partners in the IoT ecosystem that increase the value of a company’s offering and encourage end-users’ willingness to pay. In the hyper-connected society, products and services are connected with other products, leading to new analytics and new services for more effective forecasting, process optimization, and customer service experiences and the new IoT business models are about creating experiences of value. In this context, the IoT value chains and value networks are important parts of the IoT business model that defines how the service is delivered. IoT ecosystems have very complex value chains because they impact and influence a large number of processes over the IoT architectural layers shown in Figure 13. The increase revenue potential offered by complex multidisciplinary and technological heterogeneous IoT applications requires that IoT stakeholders need to work together to deliver on the promise of IoT.

2.1 Purpose and target group

This document establishes a first analysis of current IoT business models to build a framework and specifies afterwards a taxonomy for IoT enabled technologies.

[1] Digitising European Industry Reaping the full benefits of a Digital Single Market, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, COM(2016) 180 final, 19.04.2016

[2] M. Crozet, and E. Milet, Should everybody be in services? CEPII working paper 2015

The framework is used as a basis to structure and organise the existing literature on the topic business models and serves as a basis to initiate the dialogue with the Internet of Things European Platforms Initiative (IoT-EPI) Research and Innovation Action (RIA) projects on concrete material to be discussed and updated in a dynamic matter during the UNIFY-IoT project life time.

The business model framework is used for the discussion with IoT-EPI RIA projects related to value co-creation and to the market viability of business endeavours enabled by IoT platforms.

It is a first step in the UNIFY-IoT project developments, followed by workshops, trainings and in-depth analysis of companies and institutes in the ecosystem of UNIFY-IoT partners, which lead in the end to a policy recommendation for the European Commission based on the feedback from different stakeholders.

2.2 Contribution

SINTEF is the task leader. SINTEF coordinates the task activities and addresses the creation of IoT business models framework based on the close cooperation and coordination with the H2020 RIAs addressing the IoT ecosystems around different IoT platforms for smart connected objects. The framework captures the challenges of building IoT ecosystem business models considering the heterogeneity of smart node devices at the edge, network technologies, multiple standardisation initiatives, the immaturity of innovation, and the unstructured ecosystems. The activities are aiming to identify tools or KPIs for ecosystem business models evaluation where the elements such as value design and value co-creation are included in IoT ecosystems development.

DIGICAT added input on the IoT business models that it is aware of in the UK and Ireland.
ISMB will support the definition of the Business Models Framework with particular attention to value constellation of stakeholders.

SISAX-M addressed business models from companies in Silicon Saxony and Germany that arose from new technologies in the field of IoT, e.g. by Metioronics, Silistra, ZigPos or Dresden Elektronik.

HIT worked on the Business Models Taxonomy, helping in definition of families and analysing current models to identify the most suitable ones.

3. IoT Business Models Framework

3.1 IoT Business models

The IoT is bridging the physical, digital, cyber and virtual worlds and requires sound information processing capabilities for the “digital shadows” of these real things. IoT applications are gradually moving from vertical, single purpose solutions to multi-purpose and collaborative applications interacting across industry verticals, organizations and people, which represents one of the essential paradigms of the digital economy. Many of those applications still have to be identified, while involvement of end users in this innovation is crucial. IoT technologies are key enablers of the Digital Single Market[3] (DSM), which will have a potentially significant impact on the creation of jobs and growth, along with providing opportunities for IoT stakeholders in deploying and commercializing IoT technologies and applications within European and global markets [9].

In IoT applications, physical objects have features of digital cyber and virtual technology and they can sense/actuate, be programmable, addressed and communicate with other objects or/and humans. Combining digital, cyber and virtual technology with physical objects requires collaborations and cooperation between partners from different industrial sectors and domains.

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 and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things to create new applications/services and reach common goals. In the last few years IoT has evolved from being simply a concept built around communication protocols and devices to a multidisciplinary domain where devices, Internet technology, and people (via data and semantics) converge to create a complete ecosystem for business innovation, reusability, interoperability, that includes solving the security, privacy and trust implications [9].

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 and across verticals. This requires a new approach around value creation and capture, the monetization of end-users value as presented in Figure 1[4].

IoT’s disruptive nature requires the assessment of the requirements for the future deployment across the digital value chain in various industries and in many application areas considering even better exchange of data, the use of standardized interfaces, interoperability, security, privacy, safety, trust that will generate transparency, and more integration in all areas of the Internet (consumer/business/industrial).

IoT will generate even more data that needs to be processed and analysed, and the IoT applications will require new business models and product-service combinations to address and tackle the challenges in the DSM.

The challenge for IoT stakeholders and the IoT ecosystem is to create value for individuals or businesses. The value differs for different stakeholders: individuals can perceive value as

[3] http://ec.europa.eu/priorities/digital-single-market_en
[4] Smart Design - http://smartdesignworldwide.com/

something is "improving" their life or bring them new experiences; businesses, perceive value by ROI (return on investment), that is translated in saving company money, directly, either by lowering costs, or indirectly, by improving efficiency of existing resources, etc.

Monetising in the hyper-connected society is not limited to physical product and services, and other revenue streams are possible after the initial product sale, including value-added services, product experience, subscriptions, and apps, which in the new digital economy can exceed the initial purchase price.

THE INTERNET OF THINGS REQUIRES A MINDSET SHIFT
Because you'll create and capture value differently.

		TRADITIONAL PRODUCT MINDSET	INTERNET OF THINGS MINDSET
VALUE CREATION	Customer needs	Solve for existing needs and lifestyle in a reactive manner	Address real-time and emergent needs in a predictive manner
	Offering	Stand alone product that becomes obsolete over time	Product refreshes through over-the-air updates and has synergy value
	Role of data	Single point data is used for future product requirements	Information convergence creates the experience for current products and enables services
VALUE CAPTURE	Path to profit	Sell the next product or device	Enable recurring revenue
	Control points	Potentially includes commodity advantages, IP ownership, & brand	Adds personalization and context; network effects between products
	Capability development	Leverage core competencies, existing resources & processes	Understand how other ecosystem partners make money

SOURCE SMART DESIGN HBR.ORG

Figure 1: IoT mindset shift

The involvement of many stakeholders in the IoT digital value chain can create rather complicated business models necessary for many IoT applications that in short term limit the impact of IoT technologies and applications.

A business model is the plan implemented by a company to generate revenue and make a profit from operations. The model includes the components and functions of the business, as well as the revenues it generates and the expenses it incurs [11].

The business model it is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams [20].
The evolution of business perspectives to the IoT is driven by two underlying trends [12]:

- The change of focus from viewing the IoT primarily as a technology platform to viewing it as a business ecosystem; and
- 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 of creating and capturing value as well as any part of the ecosystem's method of creating and capturing value [12].

IoT brings challenges to the stakeholders in the IoT ecosystem on identifying horizontal needs and opportunities, the management challenge related to internal organizational goals (i.e., matching technology and to the objectives of business developers), and the ways to overcome the market maturity issues for new IoT technology.

In order to defining the business models, there is a need to address the IoT challenges for adoption. In this context, the challenges that are focusing on platform, developer community, business ecosystem for the formation of IoT-based ecosystem business models come in addition to the challenges identified in [12]:

- **Diversity of things** - that refers to the challenge in designing business models for the IoT due to a multitude of heterogeneity of connected things and devices without commonly accepted or emerging standards. The diversity of things is challenging as well for the ways the things are connected with other things, businesses, and consumers/end-users. In this realm, a continuum of possible business models is increasing. IoT is bridging the physical, digital, cyber and virtual things that are becoming available in different formats. These different formats of things are elements that have a specific purpose, comprise a series of data, and can perform actions. They integrate with other applications and physical things, and may require specific business logics.
- **Immaturity of innovation** - that refers to multitude of emerging technologies, components, devices and IoT platforms. The IoT products and services are not yet mature; many are not standardized or modularized for large-scale usage and the features such as "plug and play" are missing as prerequisites for the emerging market. Connecting IoT solutions together enables developers to experiment and create products and services for various IoT ecosystems, and learn from market experiences when designing business models. It is argued [18] that big-bang disruption, which is enabled by new digital platforms, as those used in IoT applications, does not follow the technology adoption lifecycle that recognizes five types of adopters of innovation, including innovators, early adopters, early majority, late majority, and laggards. The new IoT products/services/experiences are perfected with a few trial users and then are embraced quickly by the vast majority of the market. It is expected that the innovation is mature enough for customers to adopt it rapidly.
- **Unstructured ecosystems** - refers to the fact that the existing IoT ecosystems lack defined underlying structures, governance, stakeholder roles, value-creating logics and lack of appropriated or required stakeholders in the emerging ecosystem. New business models demand creating new relationships in new industrial sectors, extending existing relationships and penetrating new sectors. The complexity of an ecosystem is related to the number of participants and IoT is still not mature. Many stakeholders (i.e. device suppliers, suppliers of software infrastructure, suppliers of hosted solutions or smart services, IoT operators, value-added service providers, full service integrators, data collectors/analysers, (open source) user community, IoT platforms providers, etc.) are pushing the business model innovation development. In this context, the focus is on the generation and capture of value in the ecosystems and the unstructured IoT ecosystems result in the need for IoT-specific business model frameworks that support, construct and analyse the ecosystem and business model choices and articulate this integrated value for the stakeholders.

There is no common opinion as to which components make up a business model. The conceptualization used in [14] consists of four dimensions: the Who, the What, the How, and the Why as presented in Figure 2.

Figure 2: Business model definition – the magic triangle [14]

The four dimensions provide an illustration of the business model architecture in the following manner [14]:

- Who: address the issue that every business model serves a certain customer group and identify the definition of the target customer as one central dimension in designing a new business model.
- What: describes what is offered to the target customer, or what the customer values. This is related to customer value proposition or the value proposition that can be defined as a holistic view of a company’s offer of products and services that are of value to the customer.
- How: refers to the build and distribute of the value proposition using company's processes and activities. The processes and activities, together with the relevant resources, capabilities and their orchestration in the focal company’s internal value chain form these dimension within the design of a new business model.
- Value: explains why the business model is financially viable; thus it relates to the revenue model. This unifies aspects like the cost structure and the applied revenue mechanisms, and points to the elementary question of any firm, namely how to generate value.

Table 1 shows the business model framework for IoT applications presented in [21]. The table shows the building blocks that constitute an IoT business model (key partners, key activities, key resources, value propositions, customer relationships, channels, customer segments, cost structure, and revenue streams) and the possible types for each building block.

The framework lacks the detailed approach for specific building blocks or industry sectors has a relatively low number of observations and results cannot be generalized to dissimilar cultures and economies.

Table 1: Business model framework for IoT applications [21]

<table>
<tr>
<td rowspan="2">Key partners
Hardware producers
Software developers
Other suppliers Data interpretation
Launching customers.
Distributors
Logistics
Service partners</td>
<td>Key activities
Customer development
Product development
Implementation; Service
Marketing; Sales Platform development Software development Partner management Logistics</td>
<td rowspan="2" colspan="2">Value propositions
Newness Performance
Customization
"Getting the job done"
Design
Brand/status Price
Cost reduction
Risk reduction Accessibility
Convenience/usability</td>
<td>Customer relationships
Personal assistance
Dedicated assistance
Self-service
Automated service
Communities
Co-creation</td>
<td rowspan="2" colspan="2">Customer segments
Mass market
Niche market
Segmented
Diversified
Multi-sided platforms</td>
</tr>
<tr>
<td>Key resources
Physical resources
Intellectual property
Employee capabilities
Financial resources
Software
Relations</td>
<td>Channels
Sales force
Web sales
Own stores
Partner stores
Wholesaler</td>
</tr>
<tr>
<td colspan="3">Cost structure
Product development cost
IT cost
Personnel cost
Hardware/production cost
Logistics cost
Marketing & sales cost</td>
<td colspan="4">Revenue streams
Asset sale
Usage fee
Subscription fees
Lending/renting/leasing
Licensing
Brokerage fees
Advertising
Start-up fees
Installation fees</td>
</tr>
</table>

The principles presented above can be applied to the IoT business models by answering the four questions and identifying the target customer, the value proposition towards the customer, the value chain behind the creation of this value, and the revenue model that captures the value. The business model allows for a holistic view of the business by combining factors located both inside and outside the firm.

Value creation in IoT can be classified into layers related to manufacturing (manufactures provide the sensors/actuators, gateways, software, communication infrastructure, platforms, tools, etc.), supporting (collecting data, which is utilized in the value creation processes) and value creation (uses IoT as a co-creative factor).

The approach of the IERC is to use a more detailed architecture on eight levels for IoT as shown in Figure 13. The stakeholders are participating into one or more layers and create new own business model based on their role in the IoT ecosystem.

- Collaboration and Processes Layer - people and business processes, transformation decisions based on things apps and knowledge
- Application Layer - dynamic applications, reporting, analytics, control built using things processed "smart" data
- Service Layer – services, multi cloud services, analytics, mining, machine learning.
- Abstraction Layer - data abstraction - aggregation and access
- Storage Layer - data ingestion accumulation and storage
- Processing Layer - edge computing, data element analysis and transformation, analytics, mining, machine learning. pervasive and autonomic services are provided through ubiquitous machines in both “autonomic” and “smart” way
- Network Communication Layer - connectivity elements, gateways, communication and processing units, wireless technologies, and wireless sensor networks body area networks, local area networks, cellular and 3/4/5G, LPWAN, etc. for delivering the information

- Physical Layer - devices and controllers, "things", sensors/actuators wired/wireless edge devices, object sensing and information gathering

The eight IoT architectural layers show that IoT applications need to address heterogeneous technologies and complex issues such as the connectivity with a variety of edge devices, protocols, while connectivity has to be guaranteed taken into account for latency, disconnects, and retries.

The IoT business models framework need to address the why (IoT value proposition), who (IoT stakeholder) and what (IoT architecture layer) as presented in Figure 3.

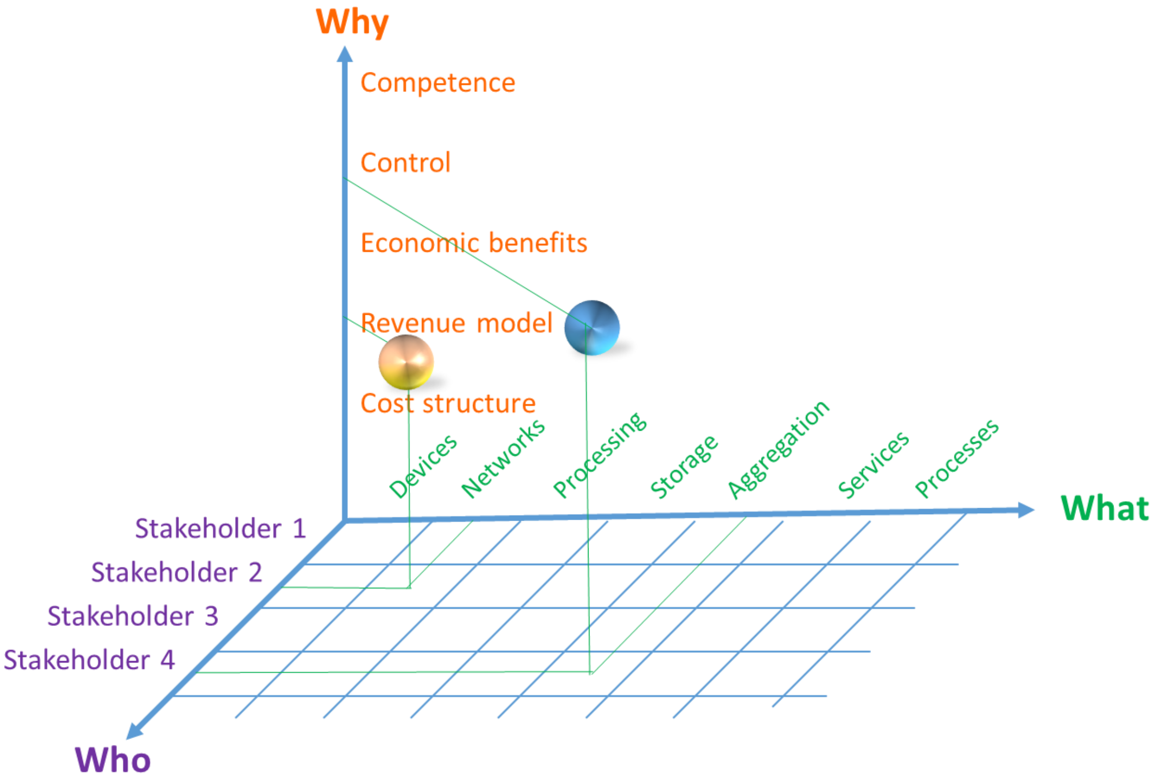

Figure 3: Prototype artefact of the business model type for IoT, (adapted from [22])

The application logic may need to run on the edge devices with limited amount of storage and compute power on sensors/actuators edge devices. Validating the device's identity, access rights and securing the data requires end-to-end solutions that integrates a variety of hardware and software with different standards and unique APIs, which make difficult to a large variety of technologies, each with its own unique interface.

The stakeholders involved in IoT applications can participate into more than one layer, and create the business model appropriate for the IoT ecosystem in which they are involved, by using a business model framework that connects different IoT business models with the underlying ecosystems (closed, open, company centric/private, networked, etc.) and the type of customers (business, industrial, consumers, etc.).

In this context, IoT platforms (i.e. software platforms, cloud platforms, and hardware connectivity platforms) try to address and handle the complex integrations, protocol translations, and connectivity issues, so the developer can focus on the IoT application and business requirements. The platforms providers create IoT ecosystems that involves close partnerships with stakeholders that use their technology.

Following the IoT layered architecture approach, IoT platforms should include the following elements [17]:

- Abstraction Layer – 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 Layer – 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.

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. ARM and Intel offer such IoT platforms [24][25].

As an example to illustrate the previous statement, ARM'mbed helps developers integrate with various chipsets, sensors, and other hardware platforms (i.e. Arduino, Raspberry pi, etc.)[24].

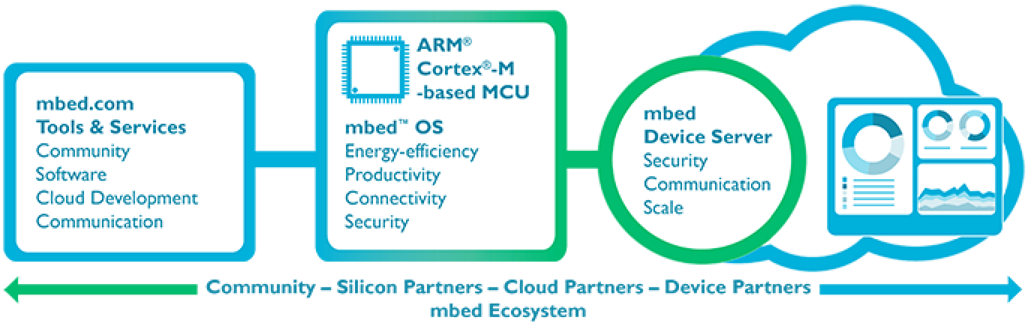

Figure 4: ARM mbed IoT device platform [24]

The Intel® IoT platform [25] 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.

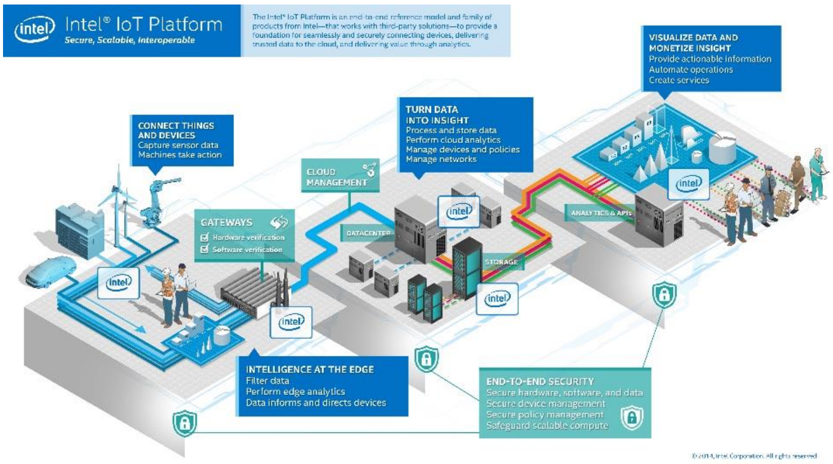

Figure 5: Intel® IoT platform [23]

IoT software platforms are offered by companies such as Bright Wolf [26], ThingWorx [27], Jasper [30], Ayla Networks [28], 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.

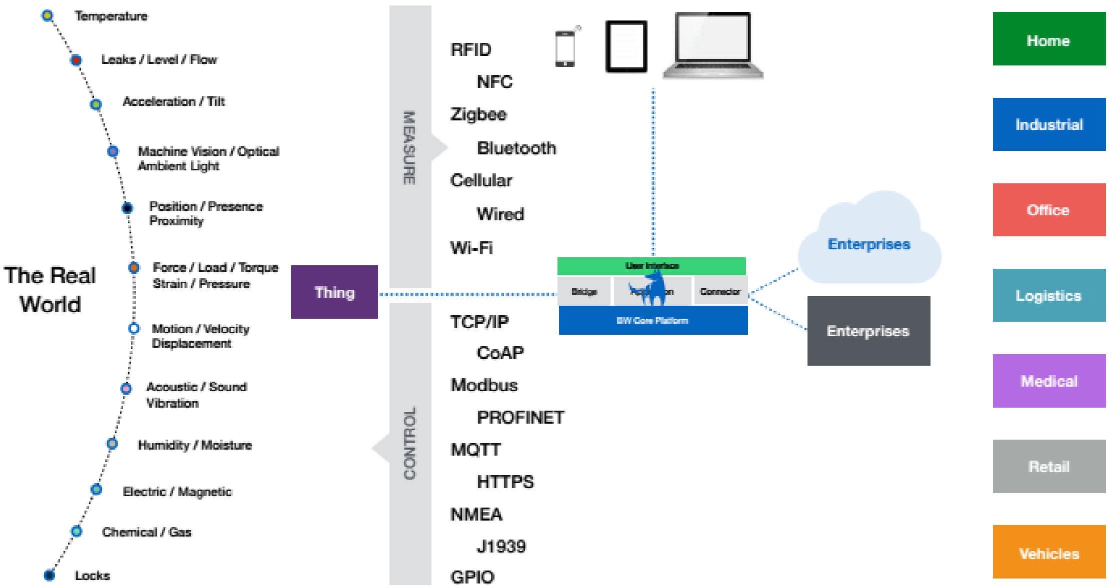

Figure 6: IoT software platform [26]

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. The approach is presented in Figure 7 [35].

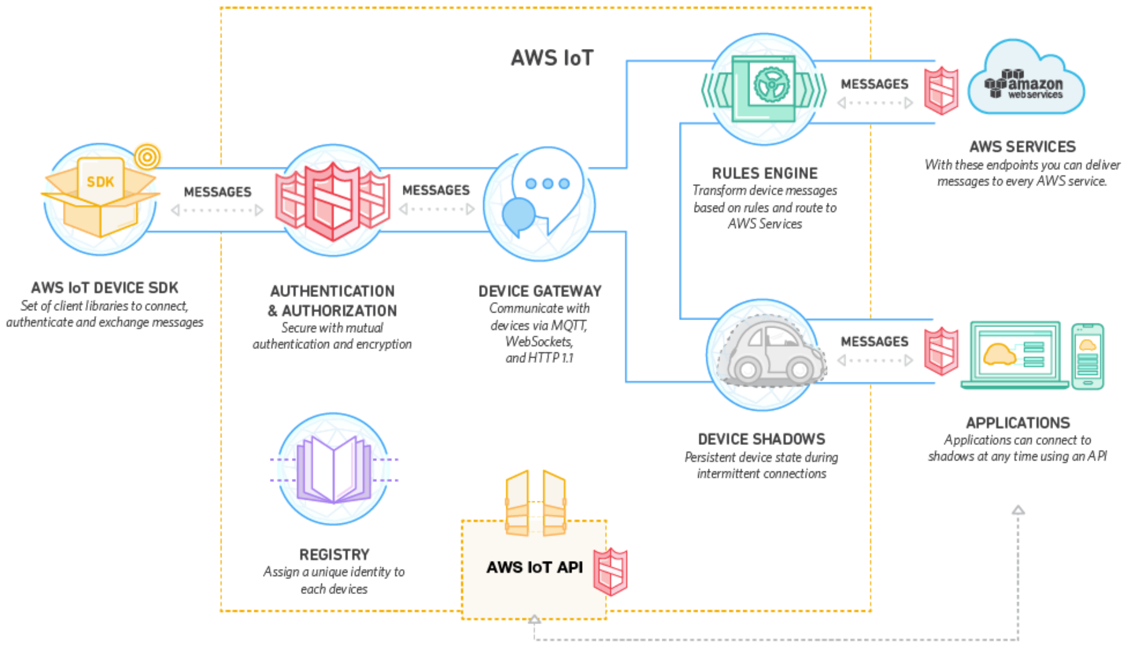

Figure 7: Amazon Web Services (AWS) platform

Google provides a suite of managed services that support the IoT developers to build IoT applications [34].

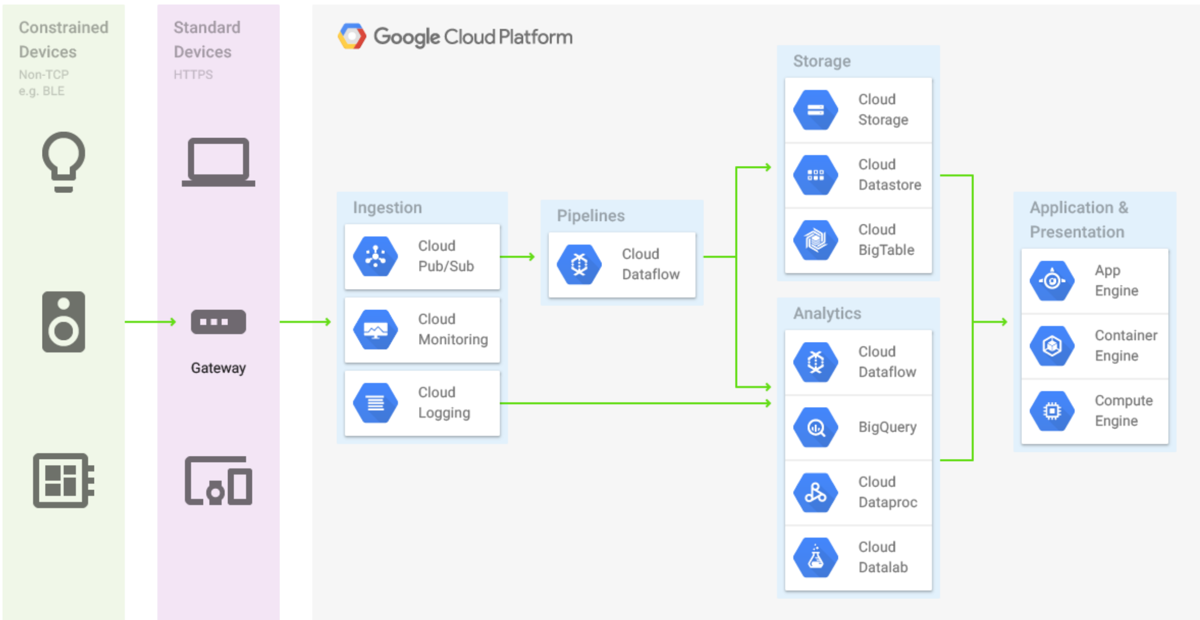

Figure 8: Google IoT platform approach

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

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 allows 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. Block chain technology is used to assure the mechanism to enable the IoT distributed model and the block chain platform, 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, construct and configuration are closely interrelated to the IoT-based business and technology ecosystem set-up.

IoT disrupts consumer and industrial products and services markets and serve as a significant growth driver for semiconductor, networking equipment, and service providers end markets globally.

It is expected that the IoT business models are developed as result of a series of vertical market solutions that witness growth at various rates over the next decade or more, all of which aggregates to 15-30% of annual growth for the concept in totality.

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 9).

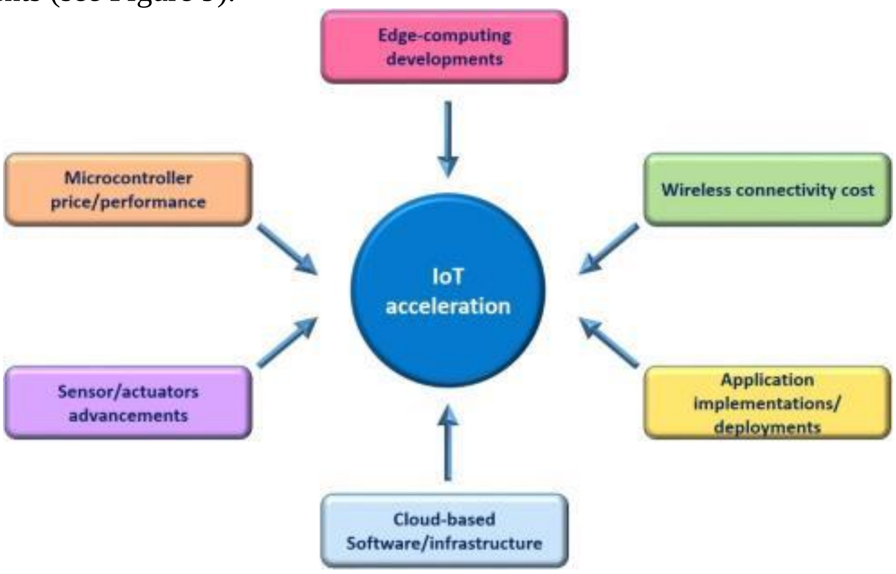

Figure 9: Drivers of IoT growth – Why now? (Adapted from [16])

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 categories as presented in Table 2. 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 [16]. The technical and business perspective of IoT paradigm is illustrated in Figure 10.

Table 2: Layers of the IoT value chain [16]

Product	Description
Radios	Chips that provide connectivity based on various radio protocols.
Sensors	Chips that can measure various environmental/electrical variables.
Microcontrollers	Processors/Storage that allow low-cost intelligence on a chip.
Modules	Combine radios, sensors, microcontrollers in a single package.
Platform software	Software that activates, monitors, analyses device network.
Application software	Presents information in usable/analysable format for end user.
Device	Integrates modules with app software into a usable form factor.
Airtime	Use of licensed or unlicensed spectrum for communications.
Service	Deploying/Managing/Supporting IoT solution.

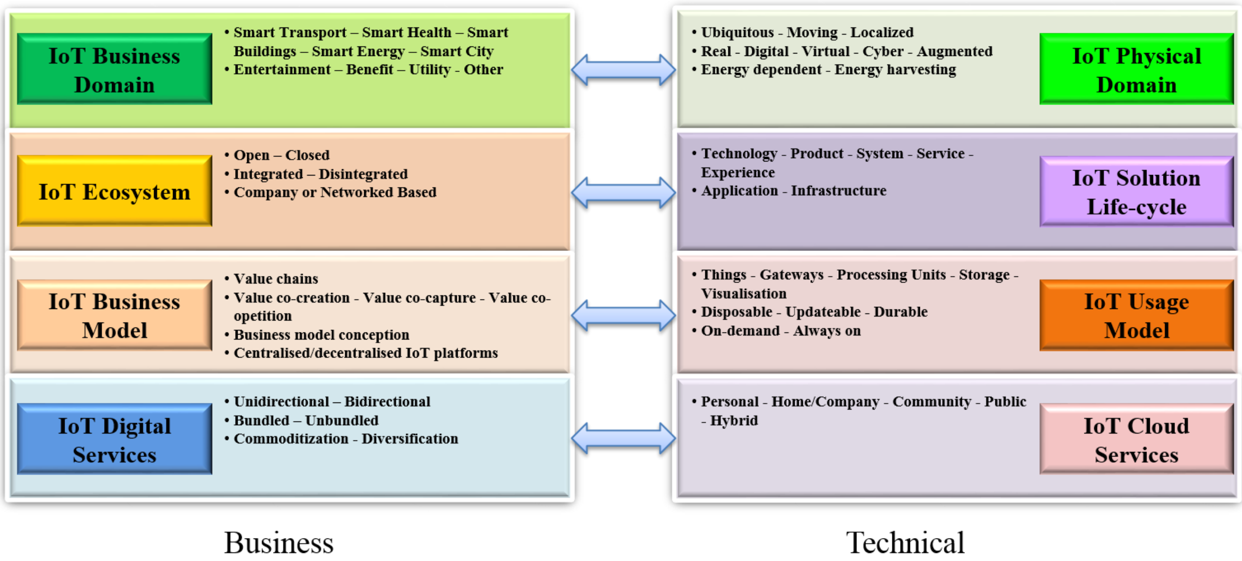

Figure 10: IoT Multi facet perspective

The IoT environment is evolving including the creation and development of IoT ecosystems where the stakeholders are cooperating in the digital value chains across the IoT architectural layers. This requires the development of a flexible and dynamic IoT business models framework, which reflects the complexity and heterogeneity of IoT value chain/value networks and their stakeholders in the IoT ecosystem, over the different stages of the IoT ecosystem development. The IoT business models framework is based on IoT value chains/value networks across the different IoT architectural layers. This considers that the IoT stakeholders are incorporating the various IoT business models in their business strategy.

3.2 IoT Business models developments and future research

The work in [1] provides a broad and multifaceted review of the received literature on business models in which the authors examine the business model concept through multiple subject-matter lenses. The review reveals that scholars do not agree on what a business model is and that the literature is developing largely in silos, according to the phenomena of interest of the respective researchers. The authors found emerging common themes among scholars of business models as following:

- The business model is emerging as a new unit of analysis;
- The business models emphasize a system-level, holistic approach to explaining how firms "do business";
- Firm activities play an important role in the various conceptualizations of business models that have been proposed;
- The business models seek to explain how value is created, not just how it is captured.

These emerging themes could serve as catalysts for a more unified study of business models. The burgeoning literature on business models is young and quite dispersed. It is just starting to make inroads to the top management journals. The conceptual base is still thin, but our review of the literature suggests two ways to advance the study of business models. First, employing concepts that are more precise would allow other researchers to better understand what the business model in the respective study is meant to denote (and what it is not).

The review suggests at least three concepts that might warrant distinct consideration:

- e-business model archetypes,
- Business model as activity system,
- Business model as cost/revenue architecture.

These distinct concepts could all be fruitfully investigated - individually, as well as in relation to each other - under the umbrella theme of the business model. The study shows that four important themes are forming, primarily around the notions of the business model as a new unit of analysis, offering a systemic perspective on how to "do business," encompassing boundary-spanning activities (performed by a focal firm or others), and focusing on value creation as well as on value capture. These themes are interconnecting and mutually reinforcing. This all suggests that the field is moving toward conceptual consolidation, which we believe is necessary to pave the way for more cumulative research on business models.

3.3 Business model innovation by Industry 4.0

Innovation capacity and speed in implementation are core competencies that our society in the future needs to ensure prosperity, because it creates real and sustainable values. The theme Industry 4.0 and its potential deals equally with the related industry, research and consulting [4]. The intelligent networking and interaction of mechanical engineering, electrical engineering and information technology allows completely new optimization opportunities such as the increase in productivity of entire value chains. Here there are already numerous reactions in individual companies, large current research initiatives across all participating industry sectors as well as many events about the application potential of industry 4.0 philosophy. On the other hand, opportunities for radical innovations in the business models also open up. Companies can offer their products under the conditions of industry 4.0 in a new way, or generate additional customer benefits by value-added services across the product lifecycle. Even some industry structures can be levered by the digitization of products and its own operations, such as happened with bookstores, in the music industry and telecommunications.

The Industry 4.0 study [4] examines the impact, risks and opportunities precisely in this little considered development in the mechanical and plant engineering. The study gives information by providing options for the traditional mechanical and plant engineering that show how to remain economically successful based by supporting, networking and digitalization business models, even in times of Industry 4.0.

3.4 Building the hyper-connected society

IoT represents the convergence of advances in miniaturization, wireless connectivity, increased data storage capacity and data analytics. Intelligent edge devices detect and measure changes in environmental parameters and are necessary to turn billions of objects into “smart data” generating “things” that can report on their status, and interact with other “things” and their environment. Universal connectivity and data access provides opportunities to monetise data sharing schemes for mobile network operators and other connectivity players.

IoT supports private and public-sector organizations to manage assets, optimize performance, and develop new business models, allowing a leap in productivity while reshaping the value chain, by changing product design, marketing, manufacturing, and after sale service and by creating the need for new activities such as product data analytics and security. This will drive yet another wave of value chain based productivity improvement. The new market developments allow having access to product usage data that decrease their reliance on the provider for advice and support. In this context, compared with ownership models, “product as a service” business models or product-sharing services can increase buyers’ power by reducing the cost of switching to a new provider. New business models are enabled by smart, connected products and create a substitute for product ownership. Product-as-a-service business models, for example, allow users to have full access to a product but pay only for the amount of product they use. A variation of product-as-a-service is the shared-usage model [17].

These address the IoT developments in the hyper-connected society and the main element is that IoT technologies and applications are considered as pivotal in enabling the digital single market, through new products and services. The IoT, big data, cloud computing and their related business models will be the three important drivers of the digital economy, and in this context it is fundamental for a fully functional single market in Europe to address aspects of ownership, access, privacy and data flow – the new production factor.

New generations of networks, IoT and cloud computing are also vectors of industrial strategy. The IoT stakeholders are creating a new ecosystem that cuts across vertical areas, in convergence between the physical and digital words. It combines connectivity, data generation, processing and analytics, with actuation and new interfaces, resulting in new products and services based on platforms and software and apps.

In the new business environment, new, regulated business models will also be necessary – the raw data that are generated may contain information that is valuable to third parties and companies may therefore wish to make a charge for sharing them. Innovative business models like this will also require legal safeguards (predominantly in the shape of contracts) in order to ensure that the value added created is shared out fairly, e.g. through the use of dynamic pricing models.

3.5 St. Gallen Business Model Navigator

A useful tool in working with IoT business models is provided by the St. Gallen Business Model Navigator™ [15], that transforms the main concept – creating business model ideas by utilizing the power of recombination The methodology uses three steps to address a new business model:

- Initiation – describing the current business model, its value logic, and its interactions with the outside world in order to get into the logic of business model thinking and to build a common understanding of why the current business model will need an overhaul, which factors endanger exploited due to the current way of doing business.
- Ideation – moving into new directions by re-combining existing concepts is a tool to break out of the box and generate ideas for new business models. The navigator includes 55 patterns of successful business models into a set of pattern cards that each contains the essential information that is needed to understand the concept behind the pattern: a title, a description of the general logic, and a concrete example of a company implementing the pattern in its business model.
- Integration – completing the development and promising ideas gradually elaborated into full-blown business models that describe all four dimensions - Who-What-How-Value? – and also consider stakeholders, new partners, and consequences for the market.

A set of checklists and tools, such as the value network methodology, are available. The methodology developed structures the process of innovation of a company's business model and can be applied to developing IoT business models under the proposed IoT business models framework.

3.6 Discussion

Given the disruptive nature of the IoT, current approaches when developing a business model should be adapted accordingly under a dynamic flexible IoT business models framework as suggested before. The most important chance in this regard is convergence of value chains to value networks on the context of IoT ecosystems.

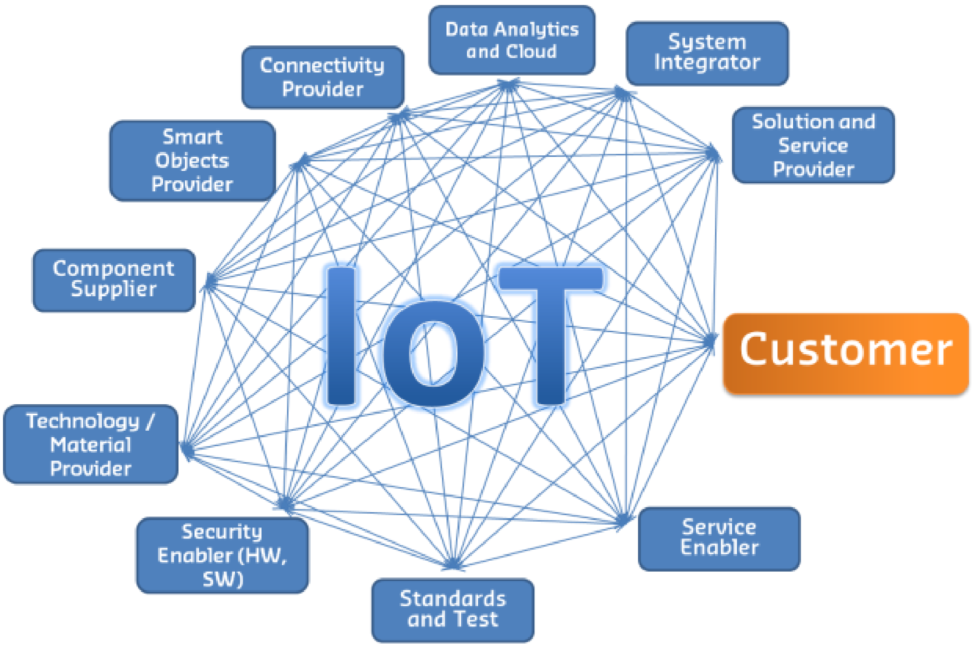

Figure 11: IoT network

When designing the business model, a company should always have a look not only on its nearer environment (direct suppliers, clients, etc.) but rather on the entire ecosystem of the product or service in order to be able to identify additional value propositions and possibly also revenue streams within the system – in other words, new business model combinations.

Any combination from the patterns proposed in might work in this regard. Nevertheless, it is important that a win-win-situation appear if the boundaries of the company are being considered.

4. Business Models Combinations

The Business Model Combination, is a mixture of different business models used in [15] and implemented applied for the analysis of the different hybrid business models used by IoT stakeholders

In this chapter it was used the same reference for naming the business models as it is easily understandable and clearly structured. The combination name is chosen from well-known companies, so that everyone will recognise or guess what kind of business this combination represents.

That leads us to different families, which we suggest as a basic in finding a business model (or several) for IoT enabled technologies. We choose five different formations linked to companies out of the hard and software branch as well as service provider to be as similar as possible for IoT technologies.

4.1 “AMAZON” combination

The Amazon or Amazon Store Combination consists of eight different business models, which work best in accordance with each other. Well known from Amazon is its use and interplay of affiliates, product placement including recommendations and ratings as well as offering traditional products partially and electronically, e.g. music.

Table 3: "AMAZON" combination [15]

Name of business model	Description
AFFILIATION	The idea of the underlying pattern is to use a third party for the supply of customers. The remuneration of the third party, called Affiliates, is done per placement of a new customer or proportionately to basis of successfully completed transactions. Companies can use this pattern to achieve a wider mass of potential customers without significant investigations in its own sales or marketing structure.
CASH MASHINE	According to the Cash Machine concept, the customer pays up-front for the products sold before the company has to cover the associated expenses. This results in increased liquidity that can be used to amortise debts or fund investments in other areas.
E-COMMERCE	Traditional products or services are delivered through online channels only, thus removing costs associated with running a physical branch infrastructure. Customers benefit from greater availability and convenience, while the company is able to integrate its sales and distribution with other internal processes.
LEVERAGE CUSTOMER DATA	The centre of this pattern is collecting customer information to use these for generating a profit. Opportunities for commercialization offer, for example, through direct sales of data to a third party or by the company's own use, e.g. to improve the effectiveness of advertising.

LONG TAIL	Instead of concentrating on blockbuster products, the main income is generated by a part which consists of a "long tail" of niche products. Individually, these products are not requested in great amounts, nor allow they high margins. However, when a high number of them in sufficient large quantities are available, may these small profits show a lucrative sum.
MAKE MORE OF IT	Expertise and other available resources of a company to be used not only for the production of its own products but also be provided for other companies in form of an external service. The aim is to multiply skills outside the Core business.
USER DESIGNED	In this pattern, the customer is both the manufacturer and the consumer. Thus, the company function is limited to supporting its customers in their undertakings and so benefits from their creativity. The customer benefits from the opportunity to realise entrepreneurial ideas without having to establish the necessary infrastructure. Revenue is then generated by the actual sales.
TWO SIDED MARKET	A Two-sided Marked facilitates interactions between multiple interdependent groups of customers. The value of the platform increases as more groups or individual members of each group use it. The two sides frequently come from disparate groups, for example businesses on the one hand and private interest groups on the other.

The *e-commerce* retailer Amazon has the largest online shop formed by the range of the original books available on consumer electronics products, textiles, medical and cosmetic products and digital goods has been extended. Here are the original experience, processes and distribution channels of the book trade to the new product categories been extended. For the purpose of *Leverage Customer Data* patterns are the customer data used in Amazon as a lucrative resource to customers based on individual purchase recommendations to impulse purchases to entice. Through the business model pattern *Two - Sided Market* Amazon also offers merchants to sell their products through the trading platform, and expanded its case relevant customer segments [9]. To raise a business like Amazon (Store) will take a long time to implement. It has been built step by step and therefore we not recommend it for Start-Ups or family companies.

4.2 “IKEA” combination

IKEA is well known from the private sector, i.e. the end user for its individual fulfilment in the composition of the goods. Beyond its three business models, the most prominent in this Combination is the wide variety of the products which enables to build an overall picture in the result – a so called one-stop shop.

Table 4: "IKEA" combination [15]

Name of business model	Description
CROSS SELLING	In this model, services or products from an outside business are added to the offerings, thus leveraging existing key skills and resources. In retail especially, companies can easily provide additional products and offerings that are not linked to their main focus. In this way more potential customer needs can be satisfied and additional revenue

	generated with relatively few changes to the existing infrastructure and assets.
EXPERIENCE SELLING	The value of a product or service is increased by an additional customer experience offered with it. This opens the door to higher customer demand and a commensurate increase in the prices changed. The customer experience needs to be adapted accordingly, for example by appropriate promotion or additional shop fittings.
SELF-SERVICE	Part of the value creation of the service or product is transferred to the customer in exchange for a lower price. This is particularly suited for process steps that add relatively little perceived value for the customer, but in fact incur high costs. Customers benefit from efficiency and time savings. Efficiency may even be increased, as in some cases the customer is able to execute a value-adding step more quickly and in a more target-oriented manner than the company.

The Swedish furniture company, has been established in 1943 by Ingvar Kamprad, has succeeded in creating the term "IKEA-effect" by Michael Norton to the customer. The behavioural economics call therefore the fact that a higher appreciation is met with hand assembled items as already finished bulk products. The many additional products and services that IKEA offers to furniture, such as the Swedish food in the restaurant, make feel the customer the experience of the Swedish lifestyle. *Experience Selling* enables to operate IKEA in *cross-selling*, when additional to the furniture the customer be aroused and more satisfied in buying needs, such as the large supply of flowers or pictures [9]. It is very easy to build an IKEA Combination because all three models refer to and complete each other. This Combination serves its customers very comfortable and offers a subjective well-being.

4.3 “DELL” combination

Overall five business models describe the DELL Combination. DELL Company is predestined for hardware components, which are available directly by the producer as well as the service for this. With these five models the Combination focus on the entire value chain.

Table 5: "DELL" combination [15]

Name of business model	Description
CASH MASHINE	According to the Cash Machine concept, the customer pays up-front for the products sold before the company has to cover the associated expenses. This results in increased liquidity that can be used to amortise debts or fund investments in other areas.
DIRECT SELLING	Direct selling refers to a scenario whereby a company’s products are not sold through an intermediary but are available directly from the manufacturer or service provider. In this way, the company avoids the retail margin or any additional costs associated with the middleman. These savings can be passed on to the customer. The pattern helps to establish a uniform distribution model and the direct contact enhances customer relationships.
E-COMMERCE	Traditional products or services are delivered through online channels only, thus removing costs associated with running a physical branch infrastructure. Customers benefit from greater availability and

	convenience, while the company is able to integrate its sales and distribution with other internal processes.
FROM PUSH TO PULL	This pattern describes the strategy of a company to decentralise and thus add flexibility to the company's processes in order to be more customer-focused. To respond rapidly and flexibly to new customer needs, any part of the value chain – including production or even research and development – may be affected.
MASS CUSTOMISATION	Customising products through mass production once seemed to be an impossible endeavour, but this has now changed with the development of modular products and production systems that enable efficient individualisation of products. As a result, individual customer needs can be met under mass production conditions and at competitive prices [15].

One of the first companies which use the developments out of mass customization for the launch of an innovative business model, was the PC manufacturer Dell. In comparison to its competitors, in whom the PCs are purchased only preconfigured, Dell gave customers the chance to assemble their computer according to their own needs. With this type of business model succeeded Dell to establish at the top of the PC industry in the early 1990s [9]. In IoT business it is also recommended to sell or offer the products as interoperable as possible. The most benefit is in connectivity to other hard- and software, which enables new variety of, own products. Besides, the combination of the patterns above gives a good mixture to handle IoT technologies.

4.4 "GOOGLE" combination

In the Google combination are at least five business model patterns included. We choose Google as it is the company that works best with customer data. Also in raising every kind of data and analyse them is the biggest value of such a combination of business model.

Table 6: "GOOGLE" combination [15]

Name of business model	Description
AUCTION	The idea of this pattern is to sell a product or service to the highest bidder. The final price will be determined when a certain end time is reached or a higher offer is not made. This allows the company to skim, the highest willingness to pay by the customer. The client benefits from the possibility of influence on the price of a product.
HIDDEN REVENUE	The logic that the income of the business depends on the users is abandoned. Instead, the main source of revenue comes from a third party, who cross-finances whatever free or low-priced offering attracts the users. A very common application of this model is financing though advertisements: the customers so attracted are of value to the advertisers, who then fund the offering. This concept facilitates the concept of separation of revenue and customer.
LEVERAGE CUSTOMER DATA	The center of this pattern is collecting customer information to use these for generating a profit. Opportunities for commercialization offer, for example, through direct sales of data to a third party or by the company's own use, e.g. to improve the effectiveness of advertising.

PAY PER USE	In this model, the actual usage of a service or product is metered, that is to say, the customer pays on the basis of what is effectively consumed. In this way the company attracts customers who wish to benefit from the additional flexibility, which might be priced higher.
TWO SIDED MARKET	A Two-sided Marked facilitates interactions between multiple interdependent groups of customers. The value of the platform increases as more groups or individual members of each group use it. The two sides frequently come from disparate groups, for example businesses on the one hand and private interest groups on the other.

The Internet giant Google offers customers several benefits, under inclusion the search engine, personal calendar and e -mail services, card applications and evaluation systems and thereby generates valuable customer information. The company succeeded to build a broad customer base, to a part of users as well as on the part of advertisers. The client data can Google use for effective personalized advertising. By offering personalized pay-per-click advertising through AdSense Google succeeded extremely in the revenue model innovation. The advertisers pay only when users actually click on their ad, thereby the wastage can be minimized. Google generated by advertising revenue more than 90 percent of the annual Billion turnover [9].The usage of IoT technologies raises a lot of data, big data and personal data. Therefore, this combination is fully in line with possible business models in IoT business but with the care and attention in privacy and security.

4.5 “CARSHARING” combination - sharing economy

Sharing Industry or Economy is the most modern business model for end users because of ethically and monetary reasons. For the automotive sector and all other things, there is a combination of three-business model to make it a representative sharing business, in this case Car sharing.

Table 7: "CARSHARING" combination [15]

Name of business model	Description
PAY PER USE	In this model, the actual usage of a service or product is metered, that is to say, the customer pays on the basis of what is effectively consumed. In this way the company attracts customers who wish to benefit from the additional flexibility, which might be priced higher.
RENT INSTEAD OF BUY	Here, instead of buying a product, the customer rents it. This reduces the capital typically needed to gain access to the product. The company itself benefits from higher profits on each product, as it is paid for the duration of the rental period. Both parties benefit from greater efficiency in product utilisation, given that time of non-usage, which unnecessarily ties capital down, is reduced.
SELF-SERVICE	Part of the value creation of the service or product is transferred to the customer in exchange for a lower price. This is particularly suited for process steps that add relatively little perceived value for the customer, but in fact incur high costs. Customers benefit from efficiency and time savings. Efficiency may even be increased, as in some cases the customer is able to execute a value-adding step more quickly and in a more target-oriented manner than the company.

An example of another application of fractionalized ownership offer Car-Sharing or other sharing-business concepts. When Car Sharing share - as the name of the concept already implies - multiple owners a car, so this can be used sensible economically. The roots of the car sharing go back to the SEFAGE (Swiss cooperative self-drive), which was founded in 1948 by several individuals in Zurich.

The first commercial use of the car-sharing concept is here generally attributed to the Swiss cooperative company Mobility CarSharing that arose in 1997 by the merger of companies AutoTeilet Cooperative (ATG) and ShareCom. The company counts with now more than 100 000 customers to the most successful car-sharing providers.

Another example of the fractionalized ownership patterns is the company écurie25 founded in 2005, which specializes in fractional ownership of luxury bodies. The business model of écurie25 is very similar to NetJets, so can the customer here acquire shares in a car, which they appropriate use the entitle week [15].
This business models are mostly used for things, which can be transferred to IoT technologies in hardware. It is also possible to have a shared software / service (e.g. streaming of movies) with the difficulty in protection of copyright and to keep the legal frame of the business.

4.6 Taxonomy of business models combinations

Taxonomy by its general definition is a system for naming and organizing things, especially plants and animals, into groups that share similar qualities. For the IoT technologies, we define a taxonomy, which illustrates the identified business model combinations and its overlap.

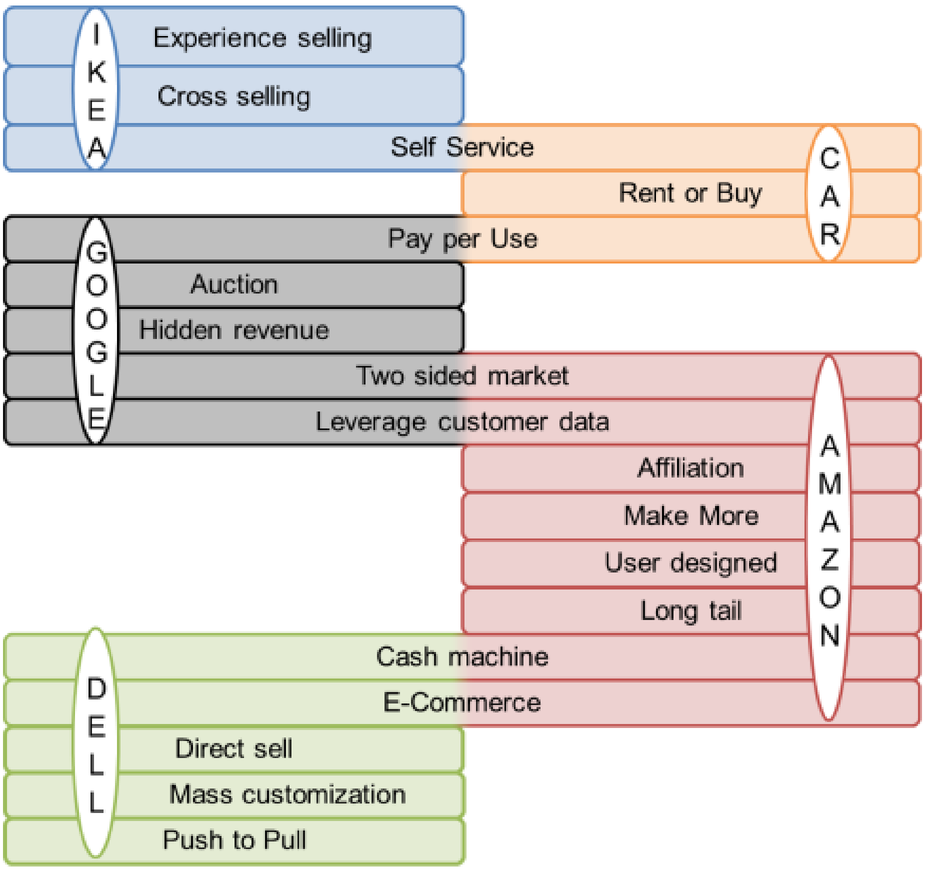

Figure 12: Taxonomy of business model combinations

4.7 Evaluation of business models families

Two main families of business models that can be of interest for the results of the IoT-EPI RIA projects are described below.

4.7.1 Product based business models

Product-based business models are about selling a tangible product. This is the most common business model, in which an asset is acquired by the buyer for a given price, and become its property.

Among this family, though, there are differences: for instance, the so-called *"razor-and-blades"* business model, based on the very well-known razor brand, consist in selling a product for a very low price (the razor), with no margin (if not negative ones) and then sell the necessary accessories (the blades) for a very high price with a consequent high margin. This business model is followed by many printer models (particularly, the home ones), where the printer is relatively cheap while the ink is much more expensive.

Table 8: Product based business models

Name	Description	Pros	Cons
Razor and Blades	Based on the fact that the asset will need consumables to work. The asset is sold with little, if no margin, while the consumables have a very high margin. Besides Gillette, printers and video consoles use this scheme.	Easy to attract new customers for low entry price, steady income due to consumables	Risk of having third party supplies undercutting prices of consumables
Inverting Razor and Blades	This is the opposite of the above business model. The asset is very expensive, and brings a very high margin, while all consumables are for free (or at cost price). Apple is an example: very expensive hardware bound with free software (and unlimited free updates).	TCO generally lower as OPEX is very low	Steep entry barrier
Subscription model	The asset can be used by the buyer for a specific amount of time, for a fee. It can also be a single asset rented to several customers, (server, for instance). When the subscription ends, the asset is returned to the seller. Leasing schemes belong to this family.	Easy to understand and sell, as subscription can usually be flexible and adapted to customers	Subscription may have a fixed duration (1 year, for instance); the user does not own the asset.
Third Party Revenue	In this scheme, the customer (or user) does not pay a fee for the use of an asset. The costs associated are sustained by a third party entity (usually, advertisement). Another possibility is that the data generated by the user can be used by the provider (or owner of the asset) and then sold to third parties; this can be	The user does not have to pay for the asset	It may need large scale numbers to be profitable; volatility of third parties can cause issues to owner.

	particularly interesting for IoT devices that generates high volumes of data.		
Product-as-a-service	In this scheme, the subscriber pays a fee each time he uses the asset. Therefore, the owner of the asset has to maximise the use of it in order to maximise profit, rather than the number of units sold.	Optimised use of assets resulting in higher margins for the owner and lower costs for the user.	Forecasts need to be very precise for optimizing asset quantities and logistics.

4.7.2 Service based business models

Service-based business models are about providing a service to a customer, therefore focusing on skills and know-how rather than on the product itself.

This is the case, for instance, of Open Software like Linux, where distributions like Ubuntu or Fedora are free, and Canonical and Red Hat are providing services for enterprises.

Table 9: Service based business models

Name	Description	Pros	Cons
Licencing	With this scheme, the owner of the Intellectual Property gives the right of developing an asset to third parties, under a fee (which can be linked to the units sold or flat).	The owner of the IP may be able to increase revenues significantly without having many risks	Third parties may do “mission creep” schemes.
Support	The asset is given free to any user; revenues are based on support provided to users, or additional services linked to the asset.	Very low entry barrier, as product is free.	Need to price the support carefully, as only revenue source (too low -> no margin, too high -> no interest as high TCO for the user).

5. Business Models Approaches across IoT Architectural Layers

The approach to define business model families in the IoT in this chapter uses the IoT architecture layers presented on Figure 13. The IoT business models varies according to the different layers. Different categories of IoT business models can be identified that serve different levels of maturity for IoT adoption. Each business model plays a cohesive and integrated role in an IoT stakeholder organization's overall IoT strategy.

Every company that is active in the field of IoT can be assigned to at least one of the layers of the IoT reference model. Therefore, leading companies and respective strategies are described for each of the eight layers [17].

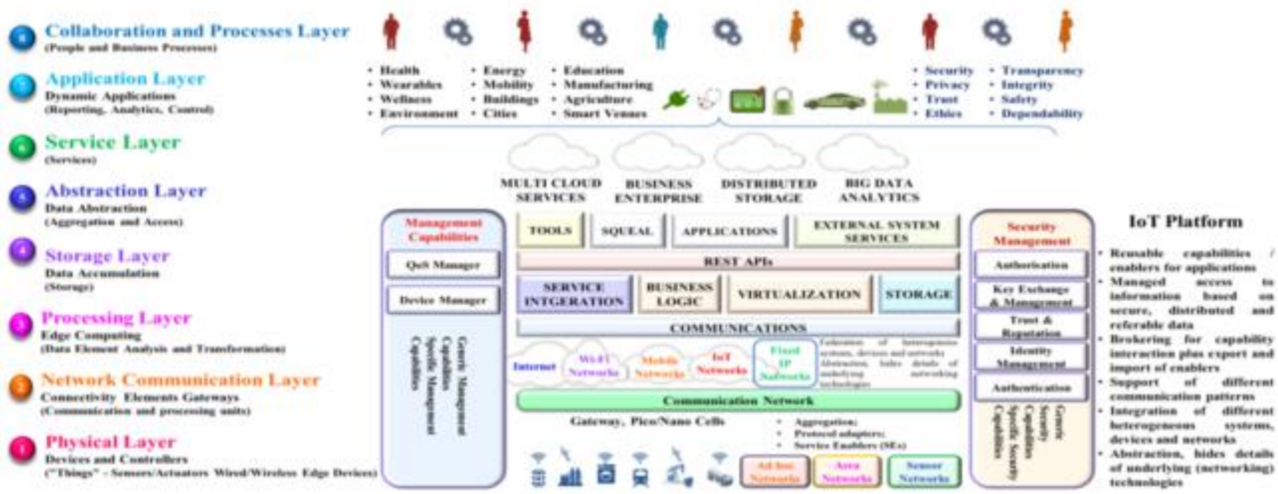

Figure 13: Eight-layer architecture for IoT

5.1 Physical layer

The basis for all IoT technologies is the hardware, e.g. without the infrastructure (e.g. datacentres, servers, etc.) there is no cloud service. The physical layer is the first option to design IoT systems "from the ground", e.g. by integrating relevant functions already on chip level, thereby building entire systems (SOC = system on chip). Advantages of this approach are usually a high level of security and reliability. On the other hand, this approach offers only a limited amount of flexibility with regard to the use cases.

5.1.1 Infineon Technologies

Infineon Technologies AG is a world leader in semiconductor solutions.[5] In general, over the last years, Infineon developed from a pure technology provider into a component/system provider, which holds true also for their competitors and therefore is a typical development in this layer.

The driving force behind this development is the intensified talk to end costumers (such as BMW in case of the automotive division of Infineon) to better understand their needs and to develop new products pull-based (customer demand) rather than push-based (purely technology driven). As an effect, e.g. Infineon built a complete radar system instead of only delivering components.

[5] http://www.infineon.com/cms/en/about-infineon/company/

They established these use cases in IoT under consideration of security as illustrated in Figure 14.

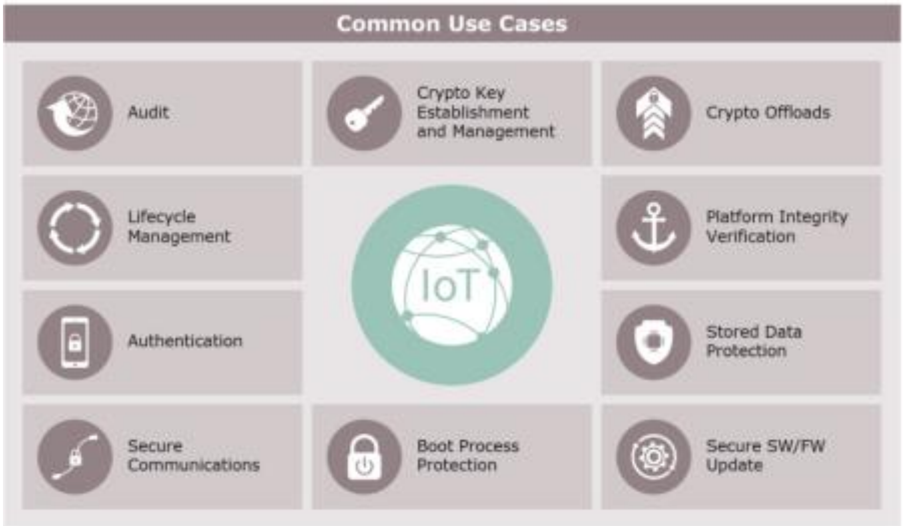

Figure 14: IoT use cases Infineon Technologies

Furthermore, Infineon has developed a broad range of easy-to-deploy semiconductor technologies to counter growing security threats in the IoT. These solutions enable system and device manufacturers as well as service providers to capitalize on growth opportunities by integrating the right level of security without compromising on the user experience. Complemented by software and supporting services, these hardware-based products create an anchor of trust for security implementations, supporting device integrity checks, authentication and secure key management.

The success of smart homes, connected vehicles and Industry 4.0 factories hinges on confidence in robust, easy-to-use and fail-safe security capabilities. The greater the volume of sensitive data to be transferred over the IoT, the greater the risk of data and identity theft, device manipulation, data falsification, IP theft and even server/network manipulation.[6]

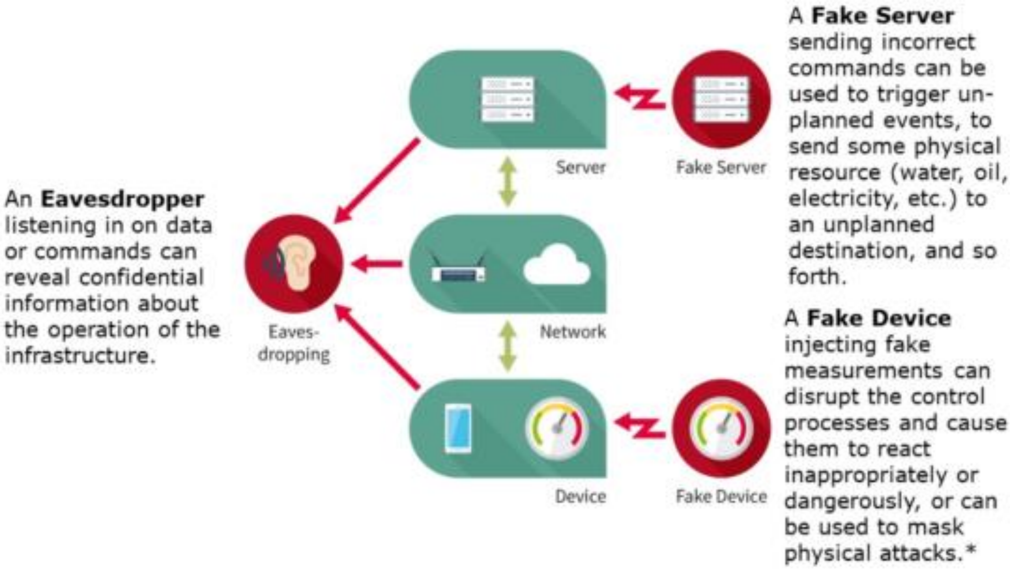

Figure 15: Security matters Infineon Technologies

[6] http://www.infineon.com/cms/en/applications/chip-card-security/internet-of-things-security/

5.1.2 STMicroelectronics

STMicroelectronics is a global leading electronics and semiconductor manufacturer. It is commonly called ST, and it is Europe's largest semiconductor chipmaker based on revenue. [7]

Sales and Marketing organization is made up of four regional Sales organizations addressing all types of business models and supporting all types of customer (direct sales, distribution, on-line).

ST is embracing the FOSS business model (Leveraging Free & Open Source Software) wherever applicable, mainly on open Linux or Android platforms. These are suitable for running application software downloaded by the end-user, or proposed by operators. They create the need for a substantial amount of software components to be developed, customized or ported.[8]

Figure 16: Supply chain ST Microelectronics[9]

ST's product portfolio contains a wide range of products able to support wireless and wired connectivity as well as communication and networking infrastructures.[10]

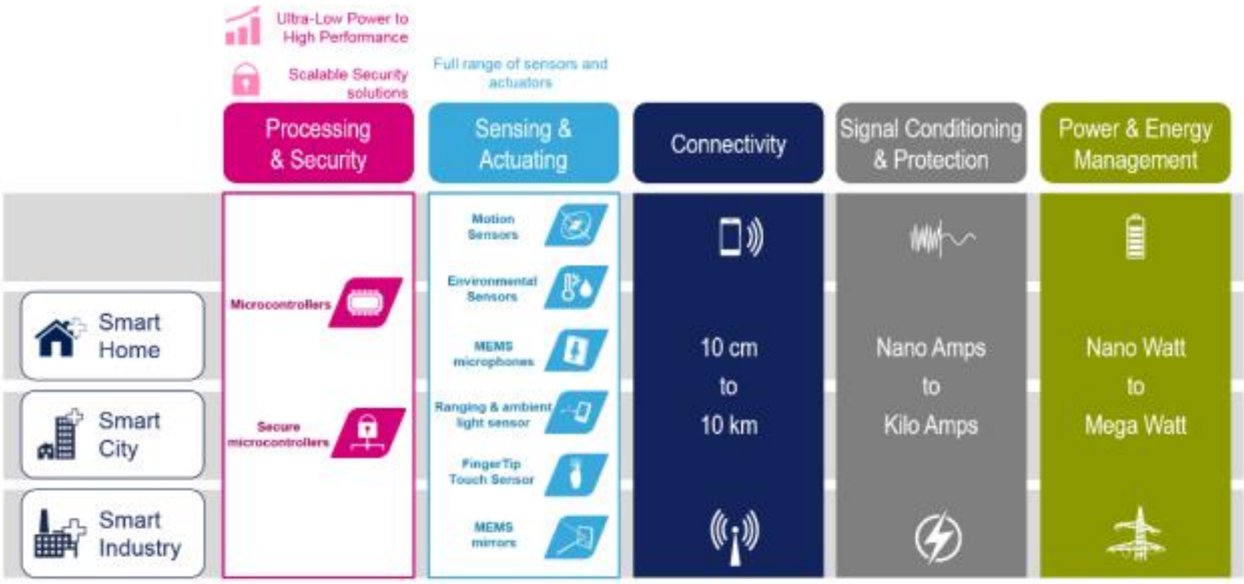

Figure 17: IoT products ST Microelectronics[11]

[7] https://en.wikipedia.org/wiki/STMicroelectronics
[8] http://www.st.com/content/st_com/en/about/customer-satifaction/five-areas-of-excellence/business-excellence.html
[9] http://www.st.com/content/st_com/en/about/customer-satifaction/five-areas-of-excellence/supply-chain.html
[10] http://www.st.com/content/st_com/en/support/resources/iot-products.html
[11] http://www.st.com/content/st_com/en/about/customer-satifaction/five-areas-of-excellence/supply-chain.html

5.1.3 NXP Semiconductors

NXP Semiconductors Dresden AG develops complete system solutions (ICs, reference designs, software and support tools) for wireless communication. These are based on a powerful and configurable architecture that is optimized for multi-protocol applications. [12]

The Security and Connectivity Business Unit of NXP is the world leader for secure connections and smart solutions that are used to protect transactions and identities of people and equipment. In banking and credit cards, identity documents, in electronic ticketing, access control applications or smart metering systems, the contact-based and contactless chip specialist encrypt personal data and prevent tampering. The MIFARE technology from NXP optimized in 650 cities worldwide ticketing systems in public transport, and invented by Sony and NXP Near Field Communication (NFC) technology in 2011 a standard feature for smart phones and tablets.

Since NXP also manufactures chips for reader infrastructure, the company can offer complete solutions and ensuring that as credit cards or NFC phones everywhere can interact with POS terminals in the world without any problems. [13]

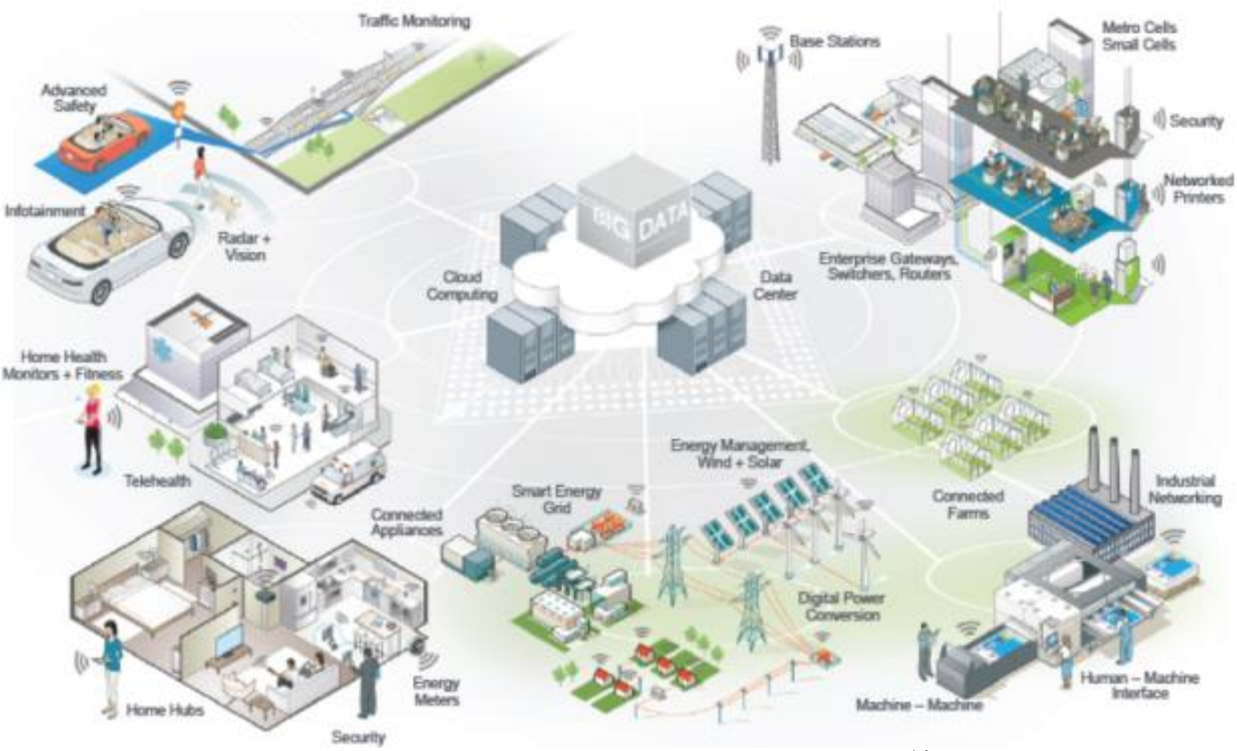

Figure 18: IoT products NXP Semiconductors[14]

From the end node to the cloud, you can see in Figure 18, NXP provides an unrivalled portfolio for supporting the incredible growth of smart, connected solutions including microcontrollers and microprocessors, security, connectivity, analogue and sensors, and RF. Everything you need for IoT. [15]

[12] http://www.silicon-saxony.de/nc/en/members/mitglieder-foerderer-detail-information/member/sisaxmembers/show/nxp-semiconductors-germany-gmbh/

[13] http://www.nxp.com/about/worldwide-locations/nxp-in-deutschland/security-and-connectivity:SECURITY-AND-CONNECTIVITY

[14] http://www.st.com/content/st_com/en/about/customer-satifaction/five-areas-of-excellence/supply-chain.html

[15] http://www.nxp.com/applications/solutions-for-the-iot-and-adas/smart-connected-solutions-for-the-iot:SMART-CONNECTED-SOLUTIONS?fsrch=1&sr=2&pageNum=1

The companies operating in the physical layer of the IoT architecture face today a fragmented marketplace with many niche products. Most IoT applications do not generate enough sales to justify design of a single chip specifically targeted at them. The fragmentation represents a concern because it limits economies of scale, thus raising production costs. Semiconductor companies may be able to achieve the necessary sales volume by classifying IoT devices into archetypes based on their specifications.

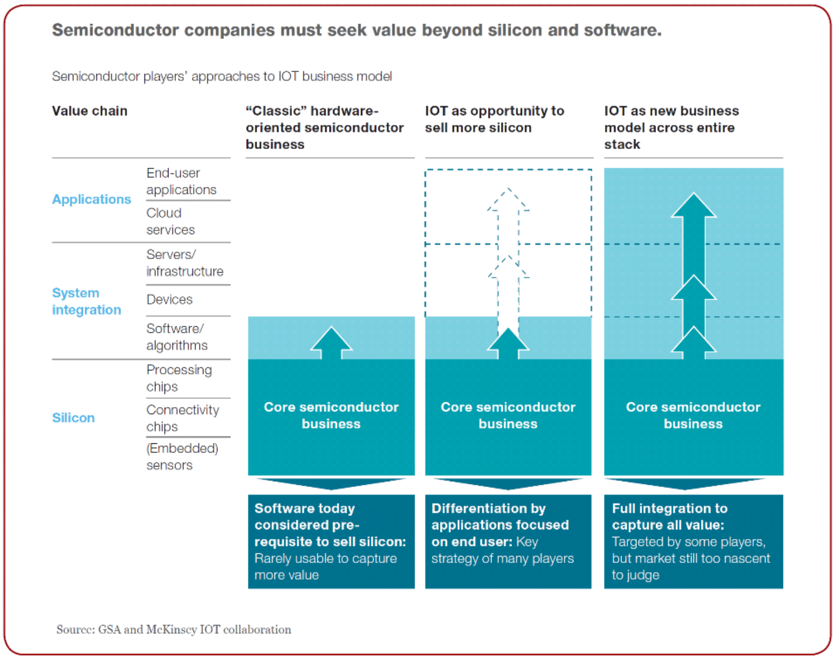

Figure 19: Value beyond silicon and software [10]

The companies can then create a single platform to cover each archetype, which will have more widespread appeal than a chip tailored to a niche application. There is a challenge of extracting more value from each application and semiconductor companies need to deliver complete solutions that cover multiple layers of the technology stack. This requires new innovative IoT business models that brings new revenue opportunities and risks. The opportunities include software, security, systems integration and IoT stakeholders are looking to add value at multiple layers of the technology stack, through software, security, and systems integration as presented in Figure 19 [10][17].

The trend push for the use of IoT platforms that include integration with devices, sensors, communication protocols, big data analytics and machine learning technologies. This development requires new IoT business models and indirectly puts hardware and telecom companies in competition with IoT platform vendors and cloud computing companies like AWS, Google, and Microsoft, as the major IoT stakeholders battle to become the defacto standard IoT platform.

5.2 Network layer

There is no doubt that the opportunities to be reaped by telco operators in the IoT sector are sizable owing to device connections globally forecast to reach billions and touching most, if not all, vertical markets. Telecoms operators are thus at the heart of this change as almost all IoT services rely on networks they provide.

Thanks to this central role of communications in many IoT deployments, how companies create value is often a function of the interaction between sensor technology and the network layer.

Linking new and legacy sensors within an IoT ecosystem often means that companies seeking to realize value from the IoT need to work closely with their communication services providers (CSPs).

As illustrated by Deloitte[16], the IoT value loop begins with creating and communicating information in entirely new contexts: sensor technology enables actions in the world to give rise to data while network links allow to create and communicate, thus liberating data and enabling the rest of the value loop.

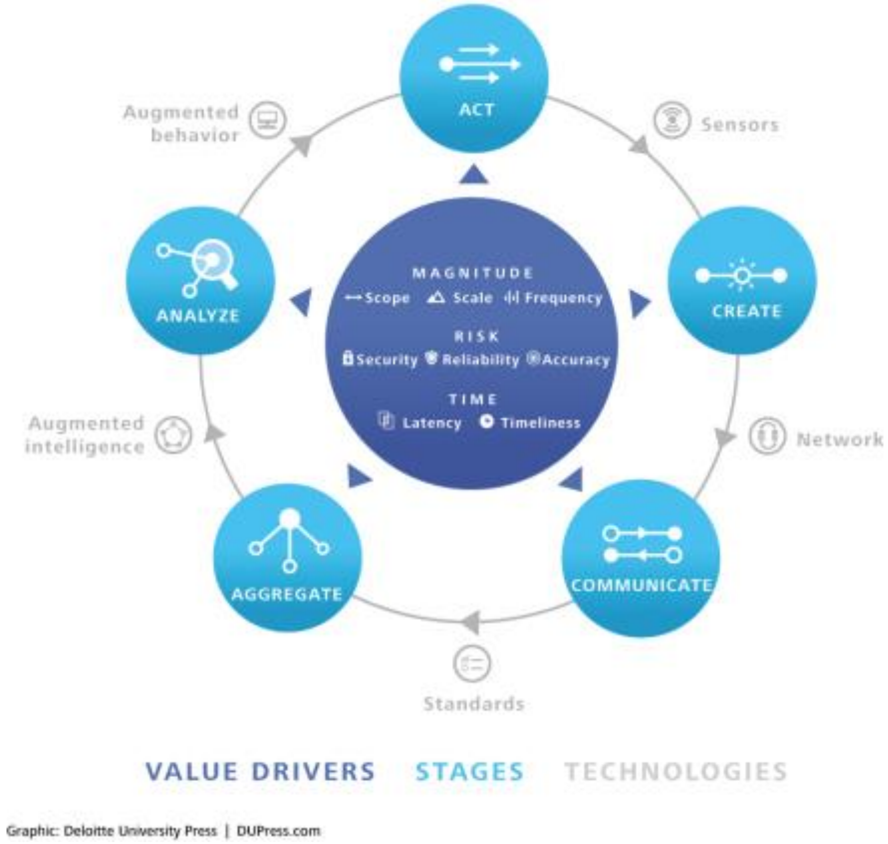

Figure 20: IoT value loop

Although M2M is a bright spot in the rapidly maturing mobile industry – as testified by a thriving connectivity market in which Vodafone continues to lead the pack of players vying for global supremacy in terms of SIM cards, followed by AT&T, Deutsche Telekom and Telefonica (according to Machina Research[17]) – operators seem not able to realize its full potential without strategic partnering and business model shifts.

As put by Ovum[18,] "for telcos there are really two opportunities: to stand back and provide the connectivity for M2M services, or to roll up their sleeves and get involved with the end-to-end provision of solutions". Whilst the former is a smaller opportunity but is much more straightforward for telcos to address, the latter is much bigger, but involves new skills and competencies, and defining new kinds of relationship with system integrators and software development. Along these lines, Ovum argues that market fragmentation and paucity of technological standards could provide the biggest opportunity for telecoms operators in the IoT

[16] http://dupress.com/articles/internet-of-things-iot-in-telecom-industry/

[17] https://machinaresearch.com/news/m2m-csp-benchmarking-report-2015-the-fast-growing-and-increasingly-competitive-m2m-csp-business-sees-continued-global-leadership-from-vodafone-and-att/

[18] http://www.ovum.com/press_releases/ovum-outlines-operators-m2m-opportunities-as-it-forecasts-revenues-will-more-than-treble-over-the-next-five-years/

fast-evolving industry that offers clear opportunity for aggregators able to interconnect the myriad of devices and provide meaningful one-stop-shopping functions on top of them.

This relentless expansion of the chart of services provided by telco operators in the IoT sector, which go well beyond the 'traditional' boundaries of mere M2M connectivity (see figure below), is reinforcing the instrumental role of telcos in ensuring that IoT succeeds, according to Nokia[19].

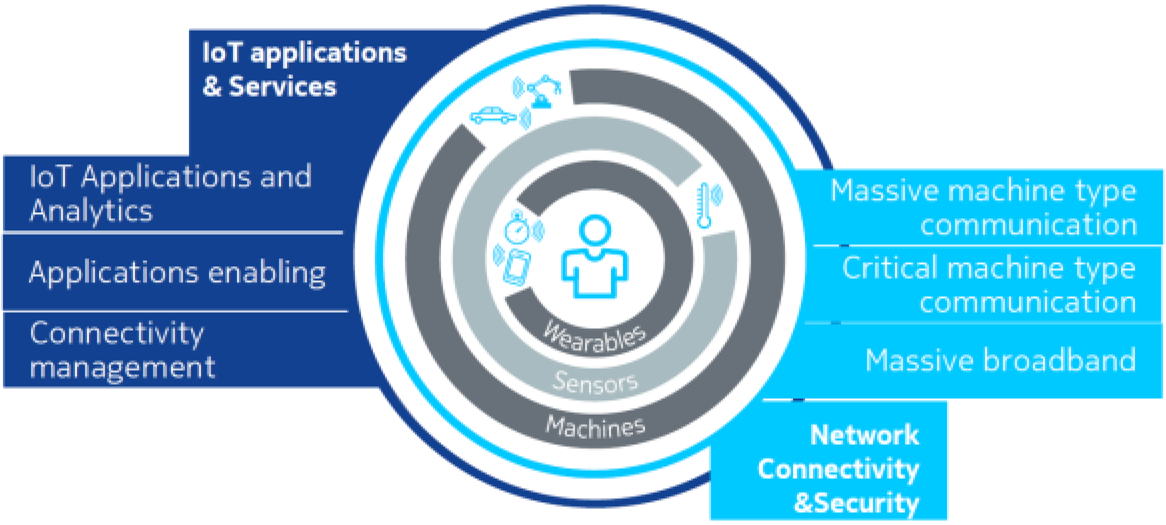

Figure 21: boundaries of connectivity

Case studies that corroborate this trend abound. As reported by Financial Times[20], in 2012 Vodafone decided to invest in platforms for different industries, marking a shift in approach among telecoms companies to providing services beyond simple connectivity. Vodafone made its largest purchase in this area to date with the £115m acquisition of Italy's Cobra Automotive Technologies, a provider of connected car services. The impact is testified by tangible figures: Vodafone has grown its team working on M2M communications from seven people to 1,300 in just five years (2010-2014). And it goes without saying that Vodafone is not alone in the telecom industry in making these investments – others include AT&T and Telefonica – and these companies are also facing competition from technology groups. This is echoed by Martin Garner, analyst at CCS Insight, according to whom "there are good opportunities in M2M for telcos, but they may not be easy, the major M2M deals are often on long sales cycles and are highly competitive".

This step change in terms of strategic positioning (i.e., from connectivity providers to enablers of holistic IoT solutions) has been recently investigated by several authoritative market research firms. Main findings are succinctly discussed in following paragraphs.

A report published by Ericsson[21] portrays the afore-mentioned climax related to the sophistication of services provided by telco operators. Depending on their history, market preconditions and ambitions, network operators can take on different roles: network providers (i.e., communication service providers 'sensu stricto' focused on connectivity) may evolve into service enablers (i.e., providers of horizontal platforms enabling third parties' endeavours), which in turn may make the leap to service creators (i.e., developers of end-to-end, fit-for purpose services).

[19] http://networks.nokia.com/sites/default/files/document/9_let_s_talk_-_internet_of_things_operator_strategies.pdf
[20] https://next.ft.com/content/9588e6ba-4aec-11e4-b1be-00144feab7de
[21] https://www.ericsson.com/br/res/docs/2014/gtwp-op-evolving-operator-roles-aw-print.pdf

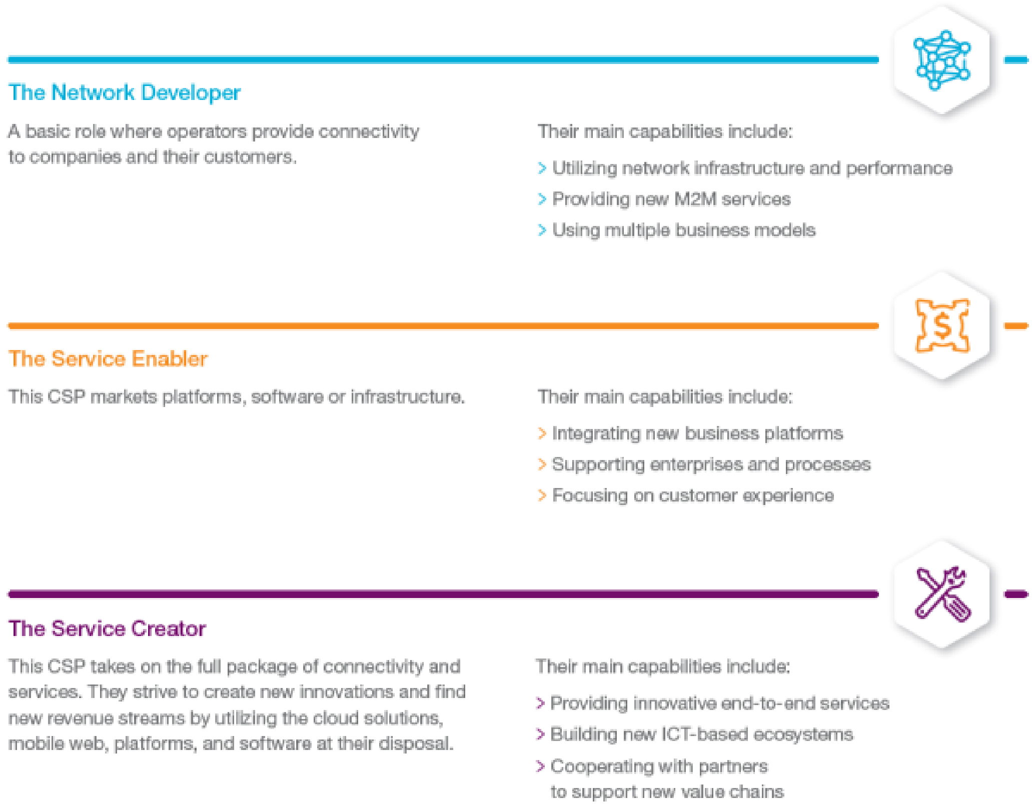

Figure 22: Services provided by telco operators (Source: Ericsson, 2014)

According to Analysis Mason, when it comes to IoT operators' strategies tend to be framed around four evolutionary business model approaches.

In the first approach, an operator puts together a basic cellular connectivity package of pricing and service. This connectivity is sold to other companies that use the operator's SIM card in their device and application. For the operator, these SIMs generate additional revenue for a limited investment, but this model puts the operator in a weak position, as differentiation on connectivity alone is typically small. As a commodity product, pressure on connectivity prices will also be high.

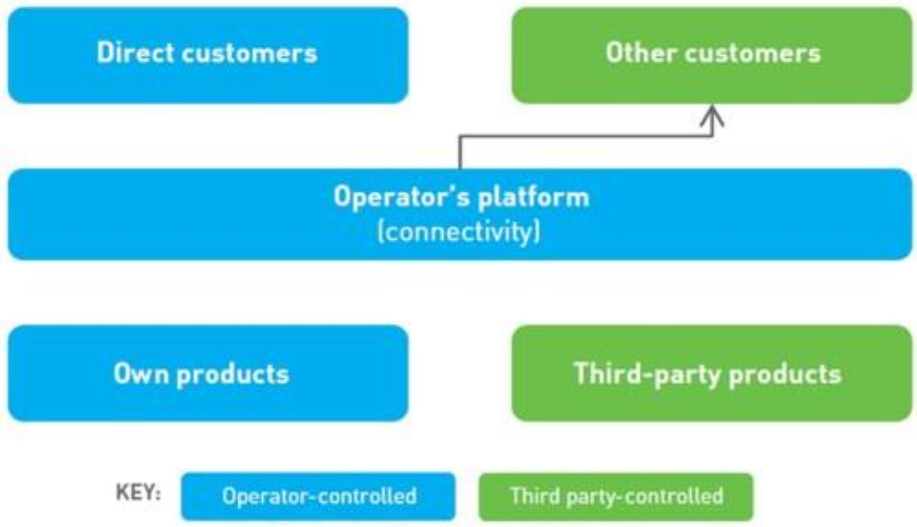

Figure 23: Telecoms operators selling connectivity services only [Source: Analysys Mason, 2015]

To overcome such hurdles, the second approach entails that the operator collaborates with a OEM provider of IoT/M2M solutions (solutions that typically comprise hardware and software), reselling the solution, often under its own brand to its own customers.

This position provides the operator with more benefit than connectivity alone as it is adding value and leveraging other strengths (e.g., ability to bill and support, sales channel), but is heavily reliant on partners and the partnerships themselves can be difficult to develop and to maintain.

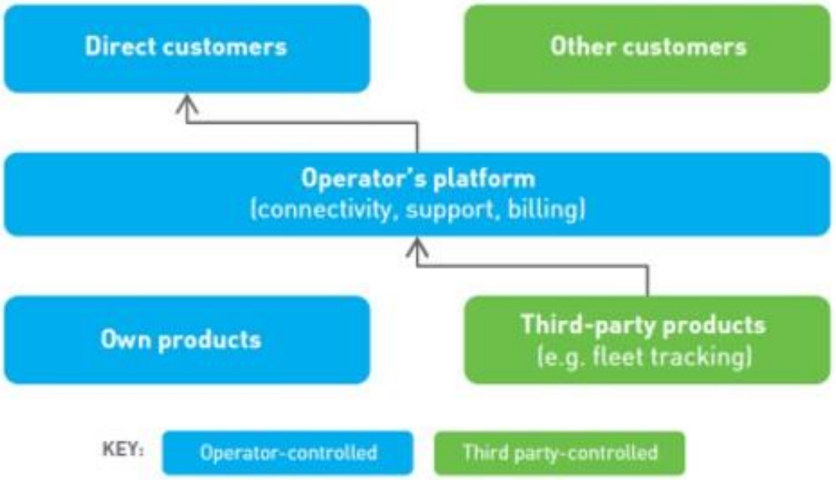

Figure 24: Telecoms operators selling third-party products [Source: Analysys Mason]

In an attempt to avoid an excessive dependence on partnerships, the third evolutionary approach is framed around an operator that sells its own solution in selected vertical markets, either developed internally or gained through acquisition and to control the service end-to-end[22]. In this model, the operator wins a greater share of revenues, which puts it in a stronger position, for example to determine the product roadmap.

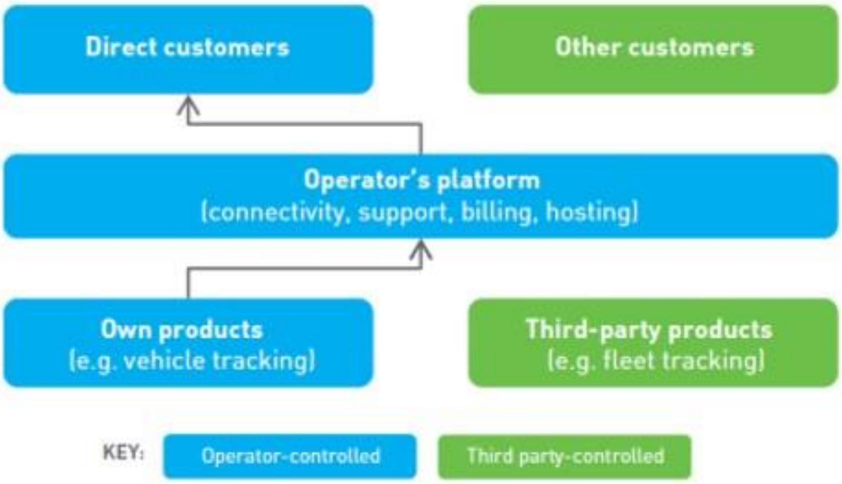

Figure 25: Telecoms operators selling internal products [Source: Analysys Mason, 2015]

However, there are some downsides to this business model approach: the operator needs to pick winners to get success, the product's potential is likely to be limited by the operator's footprint and the operator may not have the internal expertise or vertical market knowledge to develop a

[22] Vodafone and Verizon have followed this approach through acquisition (of Cobra and Hughes Telematics respectively) and a number of operators have also developed small, often bespoke, products internally.

full-fledged solution; furthermore, operators are not always a welcoming environment for the development of products/services as market endeavours that do not see fast growth are often in danger of being withdrawn.

Rather than focusing all of its attention on the end-user vertical markets, an operator could concentrate on what common elements it can provide for multiple vertical markets. These could include traditional operator strengths, such as connectivity, but also reach into different areas, such as hosting, billing, systems integration, professional support and application enablement.

This fourth business model approach does not preclude approaches 2 or 3 as the operator can provide complete solutions to the most attractive targeted vertical markets. This fourth approach, by providing a menu of à la carte services, expands an operator's role where it does not want to provide the complete solution.

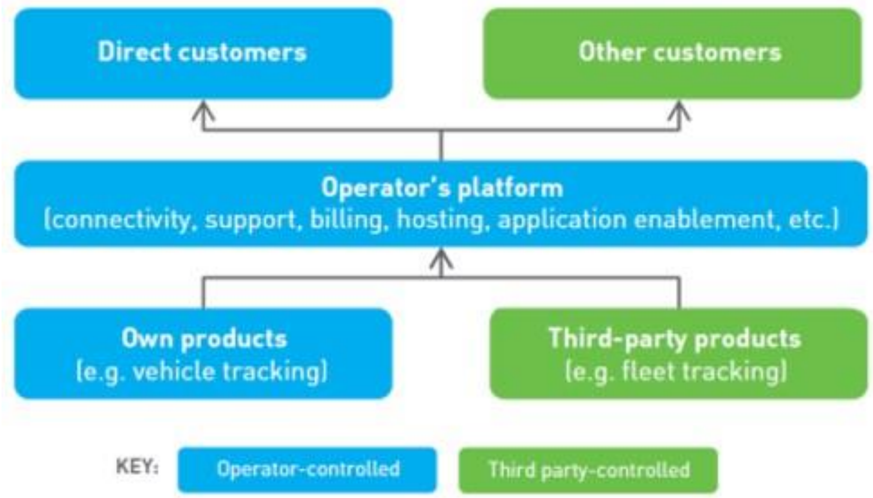

Figure 26: Telecoms operators providing a broad menu of M2M services [Source: Analysys Mason, 2015]

The benefits of this fourth business model for the operator are as follows:

- It does not face an either/or choice. It can provide end-to-end solutions in some verticals (Approach 3) and enabling capabilities in others.
- It gains access to customers that are not interested in an end-to-end solution but want a white-label offering.
- It can build on its scale and strength. The operator can focus on the aspects where scale matters (e.g., hosting) without getting into the detail of specific niche vertical market solutions.
- It moves the focus away from vertical market solutions to common elements. This moves it to areas closer to an operator's traditional strengths.

As pointed out by Analysis Mason, this menu-based business model has already gained traction. Two examples inter alia testify this:

- Deutsche Telekom, through T-Systems, is providing a fleet management system to MAN Trucks. Deutsche Telekom provides the fleet management application, as well as first-line customer support, but the service is sold and branded by MAN. Rather than providing an end-to-end solution, Deutsche Telekom is essentially wholesaling its fleet management solution. This approach gives Deutsche Telekom access to a customer it could not reach if it only targeted direct customers.
- AT&T (American Telephone and Telegraph Company) has an agreement with GE (American General Electric Company) to support the Industrial Internet. The agreement

between the two US companies covered connectivity of multiple types (e.g., mobile, fixed and satellite) and included some hosting. The end user of the GE services may be unaware of AT&T's role but it gives AT&T access to a customer it otherwise could not reach.

To cope with these tectonic changes apropos of business model approaches, mobile operators are experimenting with different structural setups, as clarified by Nokia[23]. Findings elaborated by the Finnish company situate the development of additional value propositions (i.e., offerings that go beyond mere connectivity) along a continuum related to the degree of autonomy in building M2M undertakings.

Figure 27: Business model approaches (Source: Nokia, 2014)

While the business model transition undergone by telco operators has been presented so far as driven by vertical integration – in an attempt to gain stronghold in different stages of the value chain – not to be overlooked is the attempt to exploit horizontal integration in the pursuit of economies of scale and economies of scope.

Figure 28: Vertical opportunity matrix

[23] http://networks.nokia.com/sites/default/files/document/9_let_s_talk_-_internet_of_things_operator_strategies.pdf

Figure 29: Horizontal diversification

As visualized in the 'Vertical Opportunity Matrix' coined by Nokia[24], telco operators may test the waters of diverse sectors to harness nascent business opportunities while leveraging a common portfolio of skills and assets.

A synoptic representation of telco operators already familiar with this approach of horizontal diversification is provided in the following graphics (source: Nokia).

Taking into account the diversified landscape that could be observed, table below shows a three-pronged business model that appears as a common thread running through the telco operators examined on a global scale.

Therefore, the three families of offerings, their underlying rationale and the monetization logic can be considered as framework for characterizing the role of network operators in fostering IoT ecosystems.

Table 10: Three-pronged business model

Type	Connectivity-related offerings	Additional technological IoT offerings	Complementary offerings
Rationale underlying the business line	Core business	Vertical integration (combination in one firm of two or more stages of the value chain normally operated by separate firms) and/or horizontal integration (acquisition of additional business activities that are at the same level of the value chain in multiple industries)	Functional integration
Type of revenue stream	Basic revenue stream	Revenue stream taking the lion's share in terms of 'weight'	Additional revenue stream
Monetization logic	Tariffs charged depending on volume of traffic and number of connections	Recurring fees for accessing IoT functionalities in 'as a service' fashion	Consulting fees on a project basis

To operationalize such a framework, the table below summarizes how five telco players in the spotlight are implemented the three-pronged business model previously outlined.

More specifically, the case history includes: Vodafone[25], Orange[26], Deutsche Telekom[27], Telefonica[28] and AT&T[29].

24 http://networks.nokia.com/sites/default/files/document/9_let_s_talk_-_internet_of_things_operator_strategies.pdf
25 http://www.vodafone.com/business/m2m
26 https://datavenue.orange.com
27 https://m2m.telekom.com
28 https://iot.telefonica.com
29 https://www.business.att.com/enterprise/Portfolio/internet-of-things

Table 11: practical examples for business model in network layer

Player	Connectivity-related offerings	Additional technological IoT offerings	Complementary offerings
Vodafone	M2M communication services	IoT Managed Tablet, Integrated Terminals, Asset Tracking, Energy Data Management, Monitoring and Control, Smart Grid and Metering, Connected Cabinets, Telematics Usage-Based Insurance	Consultancy, solution design and development, implementation services, project management, operational services
Orange	3G/4G connection of IoT sensors based on LoRa technology	DataVenue cloud-enabled package composed by Live Objects (customized service to connect machines and objects to company's IT), Flexible Data (complete and secured service to power up Big Data projects), and Flux Vision (markers to measure the attendance of a specific location or event based on mobility data), LoRa Orange IoT Studio (including fully loaded SDK and network sandbox)	Business model advisory, data science consultancy, communication module integration, start-up support, sourcing and manufacturing on partners' behalf
Deutsche Telekom	Solutions for secure M2M connection of IoT devices (including critical applications), Narrow Band IoT (NB-IoT) and Low Power Wide Area (LPWA) solutions, centralized monitoring via M2M Service Portal	Cloud of Things, myKIDIO, Vending Telemetry, Connected Home & Smart Home, Connected Health solutions (e.g., home care, telematics, mobile tracking)	Business advisory on IoT
Telefonica	IoT Connectivity Hub composed by network connectivity (mobile and fixed) and Managed Connectivity services (control and management of IoT lines and connectivity in real-time and remotely)	Global IoT Device Support Service (hardware-related services related to device support, device management, device portfolio), Smart Business Control (device gateway, data processing and storage, application services), IoT Business Advisor (aggregated information flows from the IoT horizontal	CRM/ERP integration, Telefonica Open Future (program to support entrepreneurial talent worldwide), prototyping support

		platforms), vertical solutions (Smart Mobility, Smart Cities, Smart Retail, Energy Industrial), GSM shield for Arduino	
AT&T	End-to-end M2M connectivity via Global SIM, AT&T Module Library	IoT Device Certification, IoT Starter Kit, AT&T Control Center, M2X Data Service (cloud-based data storage), Flow Designer, pre-packaged solutions for vertical domains (Vehicle Solutions, Asset Management, Smart Cities, Healthcare), AT&T Drive Studio (solutions for the connected car industry)	AT&T Foundry (acceleration of business ideas), professional services (consulting, device lifecycle solutions, application solutions, managed services and support)

5.3 Processing layer

The layer addresses the edge computing, data element analysis and transformation, analytics, mining, machine learning, pervasive considering that autonomic services are provided through ubiquitous machines in both "autonomic" and "smart" way.

The processing layer provides the ability to process and act upon events created by the edge devices and store the data into a database in the storage layer. The processing layer can be closely interlinked with data analytics platform based on a cloud-scalable platform that supports big data technologies such as Apache Hadoop to provide highly scalable map reduce analytics on the data coming from the edge devices. The business model applied by the IoT stakeholders depends on the type of IoT platform provided and on the type of processing required in the cloud or at the edge. Complex event processing can be supported for cloud based solutions to initiate near real-time activities and actions based on data from the edge devices and from the rest of the system.

The requirements for the processing layer are connected to the need for highly scalable, column-based data storage for storing events, map-reduce for long-running batch-oriented processing of data and complex event processing for fast in-memory processing and near real-time reaction and autonomic actions based on the data and activity of devices and the interconnected systems.

Edge computing requires processing at the gateway level and the enterprise applications leverage edge devices data in end-to-end value streams involving edge devices and people within digitized processes.

In this context, the business models have to consider interrelated and distinct complex event processing elements such as on edge devices or at the edge processing of event streams, correlating and processing events within the gateway, correlating, analysing and processing events with the cloud aggregation; and complex event processing within the context of business process management or process involving humans, enterprise applications and edge devices.

The use of cloud aggregation provides opportunities for predictive analytics or real-time correlation of device status involving multiple devices across the ecosystem on the other side the edge computing offers speed and agility of responsiveness in end-to-end value streams and these processes requires the use of different IoT business models and involvement of various IoT stakeholders in the value chain.

5.4 Storage layer/abstraction layer

The IoT stakeholders addressing this layer consider the efficient storage and organization of data and the continuous update of data with new information, as it made available through the capturing and processing channels. Archiving the raw and processed data addresses the offline long-term storage of data that is not needed for the IoT system's real time operations. Centralized storage considers the deployment of storage structures that adapt to the various data types and the frequency of data capture.

Relational database management systems can be used that involves the organization of data into a table schema with predefined interrelationships and metadata for efficient retrieval for later use and processing. Storage technologies such NoSQL key-value stores are used to support big data storage with no reliance on relational schema or strong consistency requirements typical of relational database systems.

For autonomous IoT applications, the storage can be decentralized, and data is kept at the edge or at the objects that generate it and is not sent up the system. This model is increasingly used in conjunctions with the mobile edge computing and fog computing implementations.

In this context, Apache™ Hadoop® is used as scalable storage platform designed to process very large data sets across many computing nodes that operate in parallel. This provides a cost effective storage solution for large data volumes with no format requirements and is used by several IoT solutions and connected to different existing IoT platforms.

Many companies are focusing their business model not only on processing and analytics of data but as well on the storage of data. Companies such as IBM is applying IBM Watson, Apple and Google are experimenting with Apache Hadoop in their back-end systems and Microsoft Azure is providing three additional ways for enterprises to store data on Azure, making the cloud-computing platform supportive of big data analysis.

Azure "data lake" service is storing large amounts of data, and has an option for running "elastic" databases that can store sets of data that vary greatly in size. The Azure Data Lake is designed to interface to Hadoop and other "big data" analysis platforms. This service is useful for IoT-based systems that use large amounts of sensor data. The Data Lake uses Hadoop Distributed File System (HDFS), so Hadoop or other big data analysis systems can deploy it.

The Azure SQL Data Warehouse, offers the possibility to store petabytes of data so it can be easily ingested by data analysis software, such as the company's Power BI tool for data visualization, the Azure Data Factory for data orchestration, or the Azure Machine Learning service. Azure SQL Database service offer for Azure cloud databases to reduce storage costs and prepare for bursts of database activity.

The service can be useful for running public-facing software services, where the amount of database storage needed can fluctuate a lot. Software-as-a-Service (SaaS) offerings must overprovision their databases to accommodate the potential peak demand, and can be costly.

An elastic option allows an organization to pool the available storage space for all of its databases in such a way that if one database rapidly grows, it can pull unused space from other databases.

5.5 Data management and service layer

Data management and data analytics are vital functions in IoT systems where large amounts of sensor generated data and events have to be logged, stored and processed to generate new insights or events on which business decisions can be taken.

Traditional cloud storage and computing providers are well positioned to provide offerings tailored for an IoT platform middleware that sits on top of networks and IoT device streams. It is therefore no surprise to see major cloud players also to move into the IoT market by expanding their existing "infrastructure as a service (IaaS)" eco-systems, with the hope of generating additional revenue stream based on smaller adoptions to these.

As a result, various IoT platforms from these companies have now emerged in the past year, providing full stack solution for ingesting data from IoT devices and linking them to cloud based storage and processing services. These can be considered as platform as a service like (PaaS) offerings. In the following we will give three prominent examples of platforms from major cloud and storage service providers, which offer similar functionality but somewhat vary in the pricing schemes and business models around these. Table 12 provides a summary of the main business models and corresponding revenue streams.

Table 12: Main business models and corresponding revenue streams

Revenue model	Type	Amazon AWS IoT Platform	Microsoft Azure IoT hub	IBM Watson IoT Platform
Direct revenue	**Freemium**	Free trial period of 12 months with monthly message limitations	Free edition non-time limited with restrictions on msg per day and number of devices	free 30-day trial period with device storage and traffic limitation
	Direct revenue	Pay-as-you-go based on number of messages published to platform and delivered from platform	Two different usage bundles without number of device limitation offering larger message sizes and total numbers of messages per day.	Three tiered model that various based on number of connected devices
	Upselling	Pay-as-you go (see above)	More usage bundle combinations based on need	additional capacity for data storage and data traffic
	Cross-selling	Cross selling of AWS services such as data storage or data analytics services	Azure services such as storage services, stream analytics and machine learning services	Watson (analytics) services
Indirect revenue		Indirect revenue streams as a result from trade of IoT products on Amazon market pace		
Other				Financing support for developers

5.5.1 Amazon AWS 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.

5.5.2 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 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.

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 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.

5.5.3 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.

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

5.6 Application layer

5.6.1 Bosch IoT and Cloud platforms

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 [23].

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.

IoT Cloud offer a scalable cloud infrastructure based on Cloud Foundry, which makes it faster and easier 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 ensure 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.

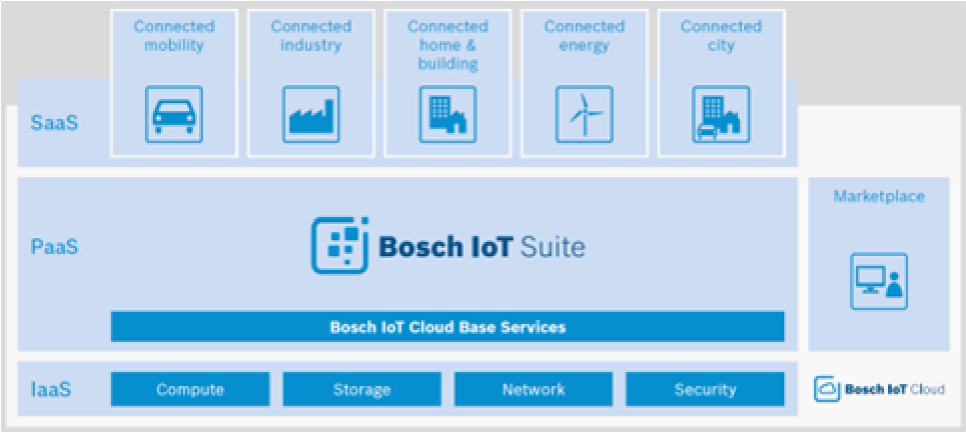

Figure 30: Bosch IoT cloud solution [23]

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, 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.

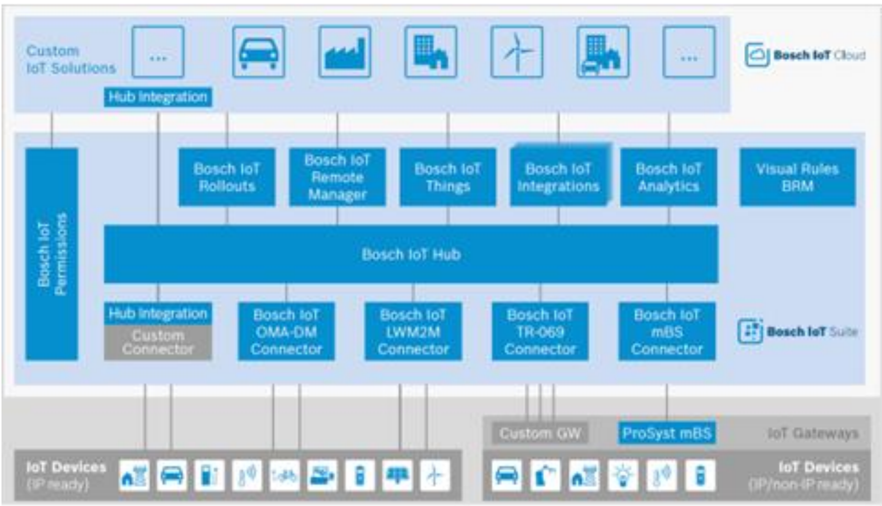

Figure 31: Bosch IoT suite solution [23]

Bosch IoT Suite services enable the fast development of IoT applications that allows the connecting of different devices reliably. The main elements are [23]:

- IoT Hub: Messaging backbone for device related communication as attach point for various protocol connectors

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

Figure 32: Experton Market Insight I4.0/IoT Vendor Benchmark 2016 - Germany IoT platforms [Source: Experton Group, 2015].

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.

5.6.2 SIListra Systems GmbH

Hardware and software growing together in embedded systems like made of Silistra. Their slogan “Building safe systems despite unreliable hardware” points out the importance of security again as described in the company examples in 5.1 Physical layer.

Therefore, they developed the Software Coded Processing technology, which goal is the industry-wide protection of life and property through the detection of execution errors in embedded systems. [30]

Different technologies, e.g. Software Coded Processing are to enable applications to detect execution errors (such as bit-flips in memory or CPU). To achieve this goal a transformer tool generates a Coded Program form an original program. The Coded Program (see graphics below) behaves just like the original program. It consumes input data and produces output data. [31]

[30] http://www.silistra-systems.com/
[31] http://www.silistra-systems.com/tech.html

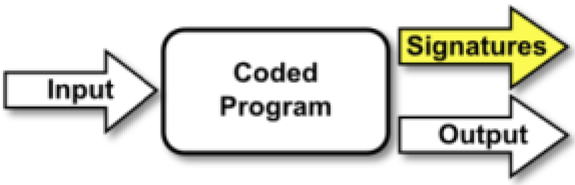

Figure 33: Software coded processing by SIListra

The advantages are that redundancy can be reduced. To detect one execution error only one channel is sufficient (and not two like in traditional approaches). Arithmetic Codes, shown in Figure 34, are the basis that they use to transform the original program into a Coded Program and to pre-calculate the Signatures.

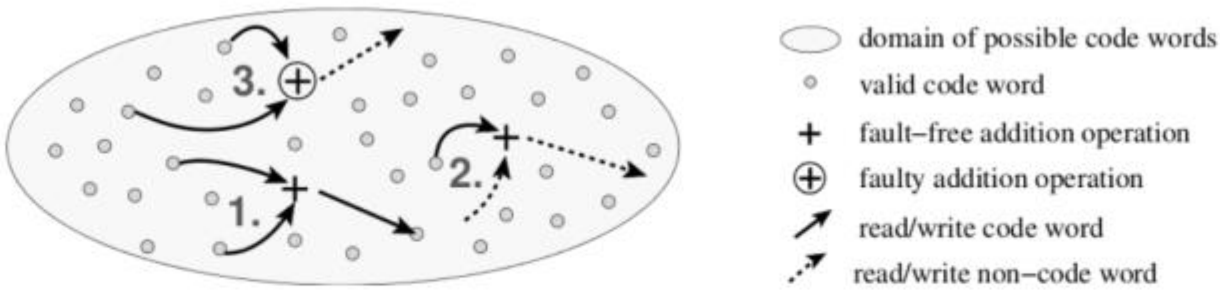

Figure 34: Arithmetic codes SIListra

5.6.3 Dresden Elektronik

Dresden elektronik acts on the market as competent partner for development of complex electronic devices and volume production. From the very first idea to the finished product, they assist the customers to solve individual tasks.

Figure 35: Service of Dresden elektronik

They promote their products and services with a kind of certification "100% Made in Germany" which can be adapted by other companies as well as it is a hidden quality note. The complete system solutions offer the customer to profit thereof with a considerably reduced time-to-market and top-quality marketable products.[32]

The key is to seek an intense contact to the customers to become the desired partner through optimal quotation management, material purchasing, manufacturing, on-time delivery and after sales service. The high quality standards on the products and proceedings act like the all-embracing link.[33]

Overall, the unique selling point of Dresden elektronik is the obsolence management because the high level of innovative capacity in the electronics industry unfortunately causes assemblies to become obsolete. Manufacturers modify their components and discontinue their assemblies. When stockpiling or special procurement no longer helps, they are able to assist in searching for other types of replacement parts or switch revisions.[34]

5.7 Impact of IoT platforms on business models

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[35].

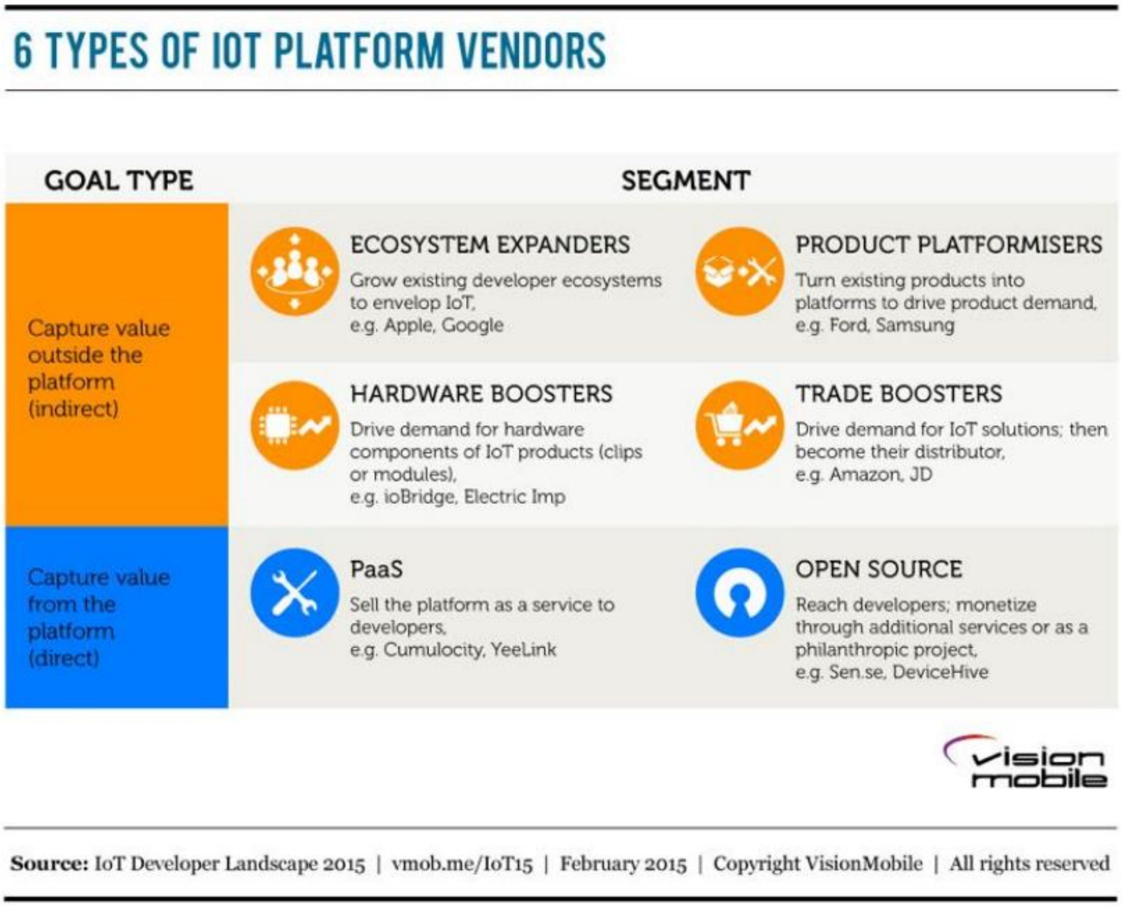

Figure 36: Overview of types of IoT platform vendors.

[32] https://www.dresden-elektronik.de/ingenieurtechnik/company/?L=1
[33] https://www.dresden-elektronik.de/ingenieurtechnik/service/?L=1
[34] https://www.dresden-elektronik.de/index.php?id=908&L=1
[35] https://iot-analytics.com/product/iot-platforms-white-paper/

With over 360 companies[36] now offering IoT platforms on the market today, there is a strong belief that IoT platforms are a viable business with substantial revenue growth opportunities.

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 this confusing landscape, Vision Mobile has identified six types of IoT platform vendors that differ in how they capture value from their IoT platform offerings and their underlying strategic objectives. Figure 36 depicts these categories, which can be broadly grouped into vendors that directly capture value from the IoT platforms and those who utilise IoT platforms to grow revenue indirectly related to these.

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.

The indirect business model assumes value to be captured outside the IoT platform. The IoT platform acts as a catalyst and driver for existing or new revenue streams. *Eco-system expanders* are moving from existing developer eco-systems into the IoT space. They have a significant advantage as they are not starting their eco-system from scratch but are able to leverage an already pre-existing developer base to quickly grow an attractive eco-system around the platform.

The *product platformisers* are companies that turn their existing high value products/assets into IoT platforms and to open these up to developers to generate new richer service experiences for their existing customer base. *Hardware boosters* are companies that generate their main revenue stream from selling IoT related hardware. They use IoT platforms to drive the demand for IoT hardware. *Trade boosters* are companies that provide market places for consumer products and IT solutions. Their interest in engaging in IoT platforms is to drive the demand for IoT solutions and take a cut in their distribution.

It is important to note that the above is an initial taxonomy in order to better characterise the business models in the immature and quickly evolving IoT platform landscape. The UnifyIoT project will analyse the emerging platform landscape together with the IoT-EPI in the coming months and share more learnings on business models around IoT platforms an upcoming *Report on IoT Platform Activities (D3.3)*.

[36] https://iot-analytics.com/product/list-of-360-iot-platform-companies/

6. IoT Business Models – Outlook and Future Developments

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 such as "sensor as a service". Successful companies will consider more then only one business model and will have to look for a holistic model with regard to all IoT architectural layers in order to capture the maximum value.

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.

In particular, connected devices open opportunities by turning the IoT stakeholders from passive participants in the value chain/value networks to parts in the value creation and co-creation. Not only quick and customized responses to user behaviour, but also data analytics and respective services by leveraging the communication between the objects will open the door for success of IoT companies.

Though the IoT business models are intermingling today, all major IoT stakeholders have operated within established business models that reflected the distinctive competencies at the core of each group. The advent of IoT applications is pushing the boarders between these legacy business models and all the existing emergent players and start-ups as well as the larger IT, software/hardware and network stakeholders will have to re-think their strategies.

In this context, there is a need for addressing a conceptual framework for the business model which is a reflection of the IoT ecosystem's/company's realized strategy. IoT business models need to reproduce the content, structure, governance of technology and business transactions designed so as to create value through the exploitation of IoT business opportunities through applications. A special focus is laid on the view from technology providers as there is very good access to respective ecosystems/players.

The IoT business models framework can use the experience and the examples from other domains, but given the disruptive nature of the IoT, current approaches when developing a business model should be adapted accordingly under a dynamic flexible IoT business models framework based on the IoT value chains/value networks across the different IoT architectural layers. This approach considers that the IoT stakeholders are incorporating the various IoT business models in their business strategy. The most important chance in this regard is convergence of value chains to value networks in the context of IoT ecosystems.

7. REFERENCES

[1] M. E. Porter, Competitive Strategy: Techniques for Analyzing Industries and Competitors, ISBN-13: 978-0684841489, Free Press, 1st Edition, 1998.

[2] C. Zott, R. Amit and L. Massa, The Business Model: Recent Developments and Future Research, Journal of Management, 2011, online at DOI: 10.1177/0149206311406265

[3] D. Schallmo Kompendium Geschäftsmodell-Innovation, 2014

[4] FH IPA Geschaeftsmodell Industrie 4.0 Studie Wieselhuber, 2015

[5] E. Fleisch, M. Weinberger and F. Wortmann, Business Models and the Internet of Things, Bosch IoT Lab White Paper, 2014, online at http://www.iot-lab.ch/wp-content/uploads/2014/11/EN_Bosch-Lab-White-Paper-GM-im-IOT-1_3.pdf

[6] D. Bilgeri, et. al., The IoT Business Model Builder – White paper of the Bosch IoT Lab in collaboration with Bosch Software Innovations GmbH, 2015, online at http://www.iot-lab.ch/wp-content/uploads/2015/10/Whitepaper_IoT-Business-Model-Builder.pdf

[7] Vodafone M2M barometer report 2015

[8] IoT Business Model, EUROTECH, online at http://www.eurotech.com/en/products/IoT+Business+Model

[9] O. Vermesan and P. Friess (Eds.). Digitising the Industry - Internet of Things Connecting the Physical, Digital and Virtual Worlds, ISBN: 978-87-93379-82-4, River Publishers, Gistrup, 2016.

[10] McKinsey & Company and the Global Semiconductor Alliance (GSA), May 2015. The Internet of Things: Opportunities and challenges for semiconductor companies, online at http://www.gsaglobal.org/wp-content/uploads/2015/05/1.-GSA-McK_Report-IoT_Text_Executive-Summary.pdf

[11] Business Model, Investopedia, 2014, online at http://www.investopedia.com/terms/b/businessmodel.asp

[12] M. Westerlund, S. Leminen, and M. Rajahonka. Designing Business Models for the Internet of Things. Technology Innovation Management Review, 4, pp. 5-14, 2014.

[13] S. Turber, J.V. Brocke, O. Gassmann, and E. Flesich. Designing Business Models in the Era of Internet of Things. 9th International Conference, DESRIST 2014, Miami, 22-24 May 2014, pp. 17-31, online at http://dx.doi.org/10.1007/978-3-319-06701-8_2

[14] O. Gassmann, K. Frankenberger, and M. Csik. Revolutionizing the Business Model. In O. Gassmann, and F. Schweitzer, (Eds.), Management of the Fuzzy Front End of Innovation, Springer, New York, pp. 89-98, 2014. http://dx.doi.org/10.1007/978-3-319-01056-4_7

[15] O. Gassmann, K. Frankenberger, and M. Csik. The St. Gasllen Business Model Navigator, online at http://www.bmilab.com/fileadmin/images/home/The_St.Gallen_Business_Model_Navigator.pdf

[16] R. James. The Internet of Things: A study in Hype, Reality, Disruption, and Growth. Raymond James US Research, Technology & Communications, Industry Report, 2014, online at http://www.vidyo.com/wp-content/uploads/The-Internet-of-Things-A-Study-in-Hype-Reality-Disruption-and-Growt....pdf

[17] O. Vermesan and P. Friess (Eds.). Building the Hyperconnected Society- IoT Research and Innovation Value Chains, Ecosystems and Markets, ISBN: 978-87-93237-99-5, River 5ublishers, Gistrup, 2016.

[18] L. Downes and P.F. Nunes. Big-Bang Disruption. Harvard Business Review, 91(3), pp. 44-56, 2013, online at https://hbr.org/2013/03/big-bang-disruption/

[19] J.P., Espada, O.S., Martínez, B.C.P., García-Bustelo and J.M.C. Lovelle. Virtual Objects on the Internet of Things. International Journal of Artificial Intelligence and Interactive Multimedia, 1(4), pp. 24-30, 2011, online at http://dx.doi.org/10.9781/ijimai.2011.144

[20] A. Osterwalder, Y. Pigneur and C. L. Tucci, Clarifying business models: origins, present, and future of the concept. *Communications of the Association for Information Systems*, *16*(1), pp. 1, 2005.

[21] R.M. Dijkmana, B. Sprenkelsa, T. Peetersa and A. Janssenb, Business models for the Internet of Things, *International Journal of Information Management* 35, pp. 672–678, 2015.

[22] S. Turber and C. Smiela. A business model type for the Internet of Things. *Twenty Second European Conference on Information Systems, Tel Aviv 2014.*

[23] Bosch IoT Suite, online at https://www.bosch-si.com/products/bosch-iot-suite/benefits.html.
[24] ARM, online at http://www.arm.com/markets/internet-of-things-iot.php
[25] Intel, online at http://www.intel.com/content/www/us/en/internet-of-things/iot-platform.html
[26] Bright Wolf, online at http://www.bright-wolf.com/pages/platform.html
[27] ThingWorx, online at http://www.thingworx.com/
[28] Ayla Networks, online at http://www.aylanetworks.com/platform/aylas-iot-cloud-fabric
[29] Xively, online at https://xively.com/
[30] Jasper, online at http://www.jasper.com/
[31] SAP Internet of Things Solutions, online at http://go.sap.com/solution/internet-of-things.html
[32] IBM Bluemix, online at https://console.ng.bluemix.net/
[33] Microsoft Azure IoT platform, online at https://www.microsoft.com/en-us/cloud-platform/internet-of-things-azure-iot-suite
[34] Google Cloud Platform online at https://cloud.google.com/solutions/iot-overview and https://cloud.google.com/solutions/iot/
[35] Amazon Web Services platform, online at https://aws.amazon.com/