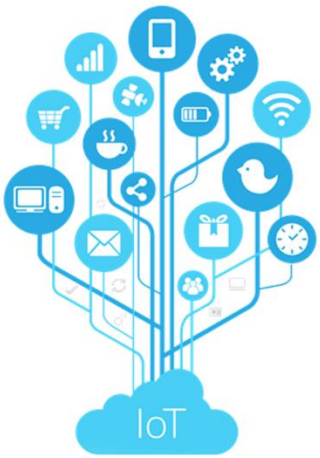
The role-based IoT Ecosystem model

WHITEPAPER
2020



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Executive Summary

The Internet-of-Things (IoT) Ecosystem is a network of organizations developing and adopting IoT products and services through both competition and cooperation. Each actor in the ecosystem affects and is affected by the others, creating a constantly evolving relationship in which each entity must be flexible and adaptable in order to succeed, as in a biological ecosystem.

To deliver maximum value when creating specific IoT products and services it is necessary for each actor to specialize in their field of expertise and to contribute with this specialized knowledge to the other actors in the ecosystem collaboration

As more product manufacturers IoT enable their products, they become part of the ecosystem and potentially become suppliers of more components available to the ecosystem. Thus, enabling the ecosystem to evolve with new and more IoT products and services.

To enable actors engaged with IoT to understand and leverage the IoT Ecosystem, the role-based IoT Ecosystem model is presented in the present document. This can be used by stakeholders to analyse their own role(s) in the Ecosystem and identify which partners for collaboration and creating alliances.

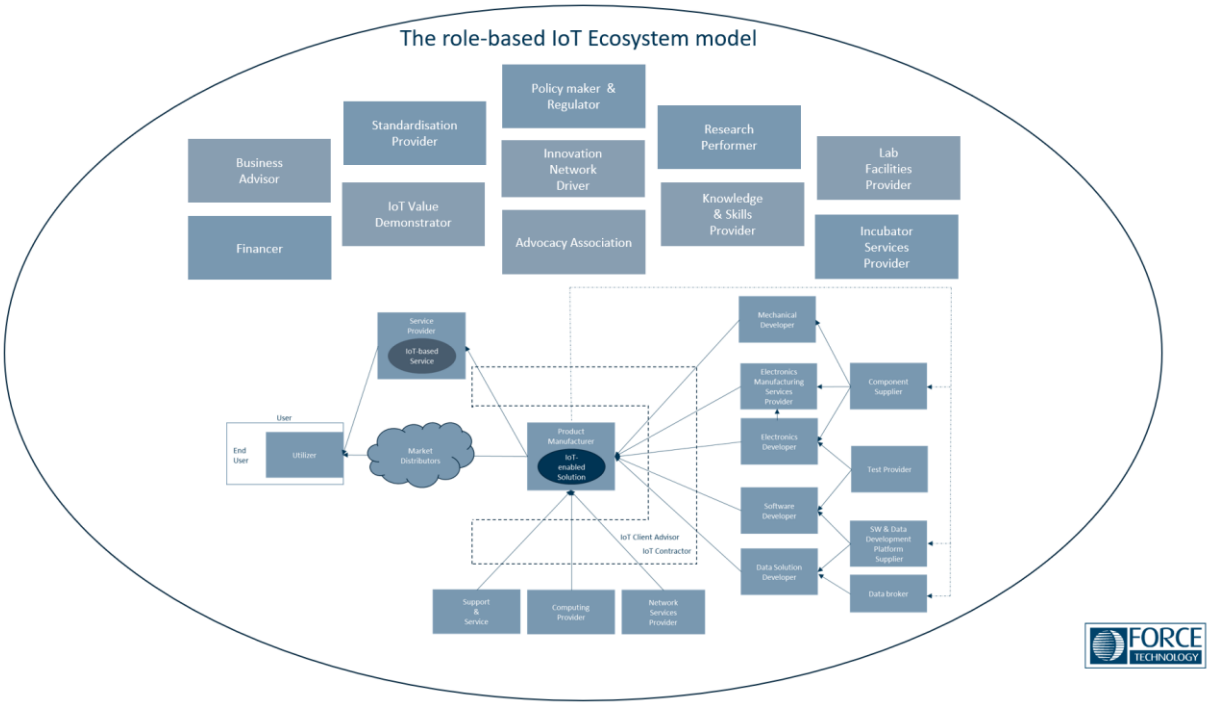

Figure 1 the role-based IoT Ecosystem model

The model is specifically beneficial for IoT client advisors and IoT contractors as an analysis model for clarifying requirements to the roles of actors engaged in Ecosystem based IoT development.

Lastly, the model can be used by organisations that want to develop, operate or adopt IoT solutions but can also be used by organisations that are performing activities into advancing IoT from a societal perspective, to analyse the roles that the actions needs to target and interact with.

Introduction

As the Internet-of-things (IoT) is maturing the solutions becomes more and more widespread, operational, specialised and technical. As with any other industry, this results in a need for an ecosystem of organisations collaborating and competing to advance the focus of the ecosystem.

To illustrate the point, the maturing IoT Ecosystem can be compared to the ecosystem revolved around the automotive industry. First of all, there is an agreement and public consensus about what a car is, that it has a chassis, an engine, a steering wheel, a brake, and so on. This is partly based on cars being similar, i.e. standards, and on many years of public exposure to "the car". Secondly it requires a vast network of sub-suppliers of automotive components that are specialised in each of their products, this can be tyres, metal for the chassis, paint for the car, electronic sub-assemblies, etc. Thirdly, it requires a societal infrastructure such as roads, petrol stations, electrical chargers, legislation, and so on. All of these are provided by actors taking specialised roles. The automotive industry is dependent on all the roles being filled and therefore each must be performed by multiple actors, such that if one actor fails, another can take its place and perform the role better.

In 1886 the first patent was issued for a car 14 years later series production began and in the 1950s there were approximately 40 million cars in the world – to today's society which has been transformed by the car.

The term IoT was coined in 1999 and in 2015 there were more than 15 billion IoT devices in the world, and it is impossible to predict how large an impact IoT will have 50 years from now – but will have similar transformation to the world as the car.

The IoT ecosystem is already forming, but we need a terminology and model to understand the roles.

The Basics of IoT solutions

An IoT-enabled Solution is a physical thing which has been enriched with electronic components and is connected to a network to provide digital control and operations of the thing. The combination of electronics and connectivity also allows the thing to digitally interact with other digital solutions and humans. An IoT-enabled Solution it also referred to as an IoT Solution.

The electronic components are typically sensors used to collect data form the surroundings or the internals of thing, actuators to control the thing, data storage to hold embedded software as well as data and a microprocessor to process the embedded software. The electronic components need a battery or another source of power for operations. This is illustrated in *Figure 2*.

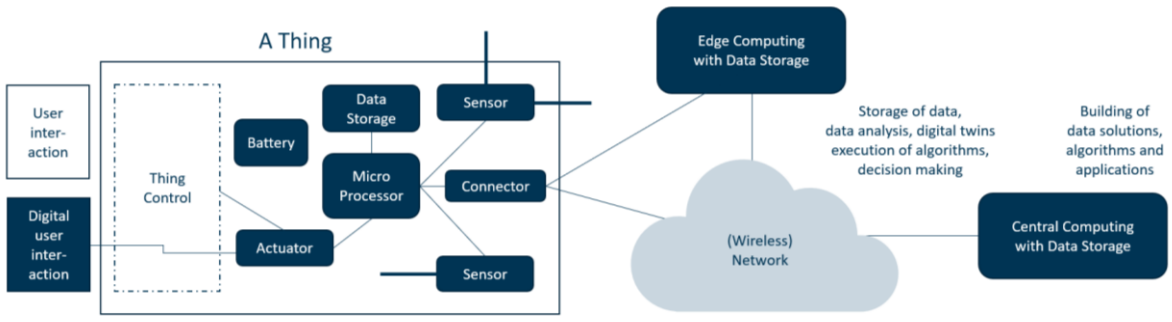

Figure 2 An IoT-enabled solution

To further broaden the application possibilities of the IoT-enabled Solution, it may be part of a larger solution interacting with other software or data solutions. This is also illustrated in *Figure 2*.

A more formal definition of an IoT enabled Solution is:

> *An IoT enabled product is a physical thing, which has a uniquely identifiable representation through the internet protocol. Through sensing and actuation it enables new services and applications bridging the physical and virtual worlds.*

IoT-enabled Solutions can also exist in physically closed networks. However, since many of these closed networks are also using the internet protocol for cheaper and simpler infrastructure in the closed networks, the definition does not require a global internet connection. This is particularly important to be able to use IoT technology in industrial IoT. Very often an IoT-enabled thing is referred to as a "Smart Thing". This is illustrated in *Figure 3*.

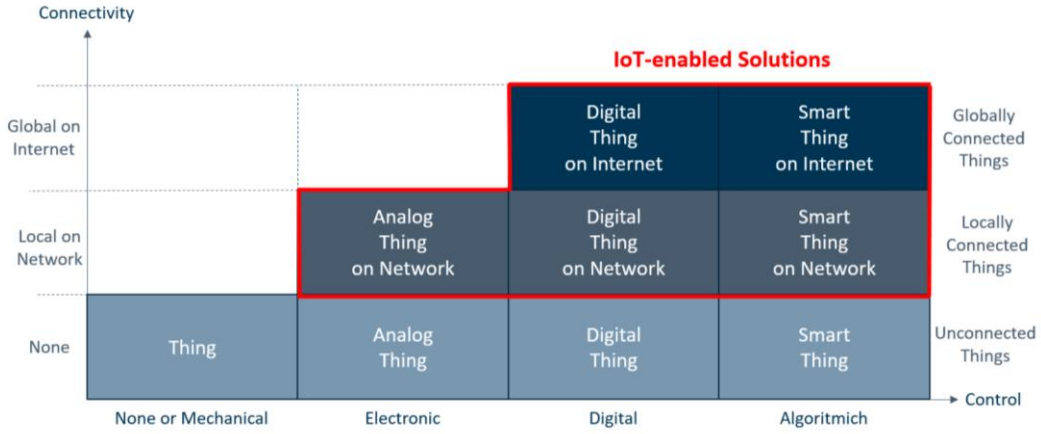

Figure 3 IoT-enabled solutions mapped by level of connectivity and control

An IoT-based Service is a service taking advantage of the possibilities provided by an IoT-enabled Solution to digitally monitor, control, optimise and automate environments and systems in which the IoT-enabled Solution is placed and operating. It is essential to make this differentiation to be able to clarify that the role of using IoT-enabled solutions for traditional services already offered is different from the role of developing and IoT enabled solution. The potential services leveraging IoT are multiple and are shown in *Figure 4*.

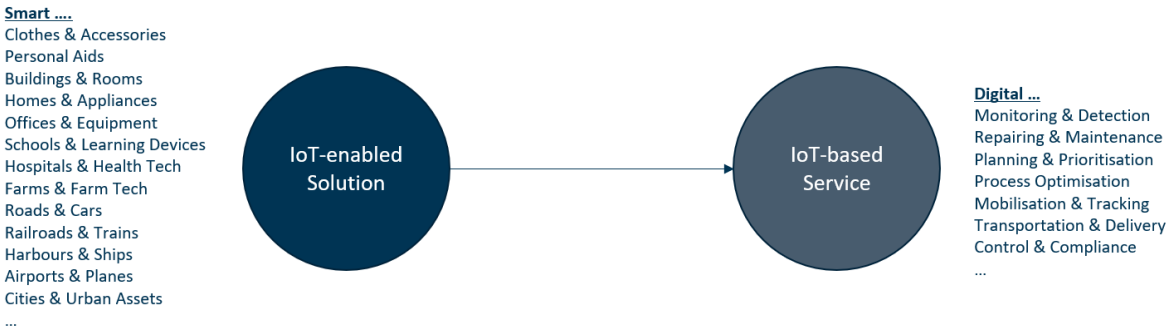

Figure 4 IoT-based services

Overview of the IoT Ecosystem

Definition of the IoT ecosystem

The IoT Ecosystem is a network of organizations developing and adopting IoT products and services through both competition and cooperation. Each actor in the ecosystem affects and is affected by the others, creating a constantly evolving relationship in which each entity must be flexible and adaptable in order to succeed, as in a biological ecosystem.

To deliver maximum value when creating specific IoT products and services it is necessary for each actor to specialize in their field of expertise and to contribute with this specialized knowledge to the other actors in the ecosystem collaboration

As more product manufacturers IoT enable their products, they become part of the ecosystem and potentially become suppliers of more components available to the ecosystem. Thus, enabling the ecosystem to evolve with new and more IoT products and services.

Modelling the IoT ecosystem

In 2019 a survey was performed with interviews of key stakeholders and actors in the ecosystem and a literature study of scientific material on business ecosystems and IoT ecosystems. Mapping of all the actors did not provide the needed clarity in the model, as it was hard to compare one actor to another, as many had different roles, which were not a 1-to-1 match for categories of actors. Therefore, different segmentations were explored. Finally, the method for analysing and mapping the IoT ecosystem used a focus on roles as entities has were chosen as:

- Many types of actors in the IoT Ecosystem are covering many different roles
- Using roles instead of types of actors helps to keep the complexity down
- It is possible to define distinct roles for each part in the IoT Ecosystem
- The different processes of the IoT Ecosystem work well with the roles

This resulted in: The role-based model of the IoT Ecosystem.

Analysing the IoT Ecosystem, a thing centric approach to IoT was chosen. Therefore, the role a product manufacturer, became the centre of the role-based model. The product manufacturer who are transforming a non-IoT product into an IoT-enabled solution then transforms into an IoT solution owner.

When organizing the roles in the ecosystem, 4 distinct groups of roles appeared in the ecosystem as shown in *Figure 5*.

- IoT development Roles
  Roles that are involved in the technical development of the IoT-enabled solution
- IoT Operations Roles
  Roles that are involved in the technical operation of the IoT-enabled solution
- IoT Usage Roles
  Roles that are using, benefiting, involved in providing access to the IoT-enabled solution
- IoT Governance and support Roles
  Roles that are establishing an IoT ready society by performing IoT Ecosystem supportive non-technical activities

The first three groups are collectively referenced as the primary roles of the IoT ecosystem, as these are directly involved in the technical realisation and user adoption of the IoT solutions.

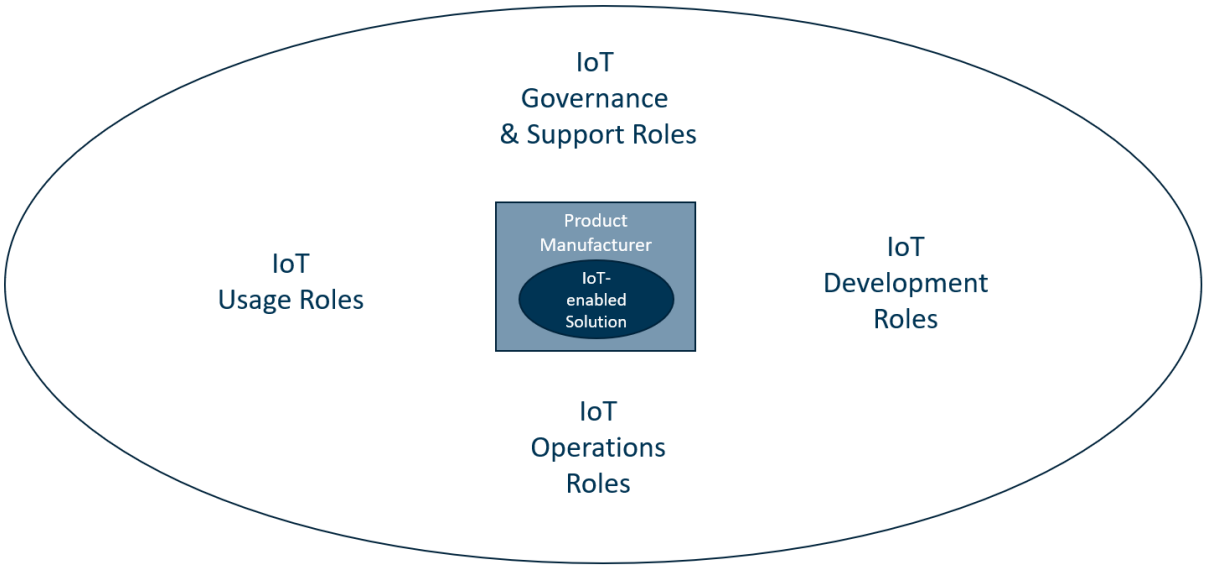

Figure 5 The four groups of roles in the IoT Ecosystem

Primary part of the IoT ecosystem

For simplicity the first mapping of the roles in the ecosystem only contains the first three groups of roles. These are the roles directly involved with the technical realisation and application of the IoT solution and are shown in *Figure 6*. The challenge for the product manufacturer is apparent from the model as they need to understand and coordinate the responsibilities of many different roles.

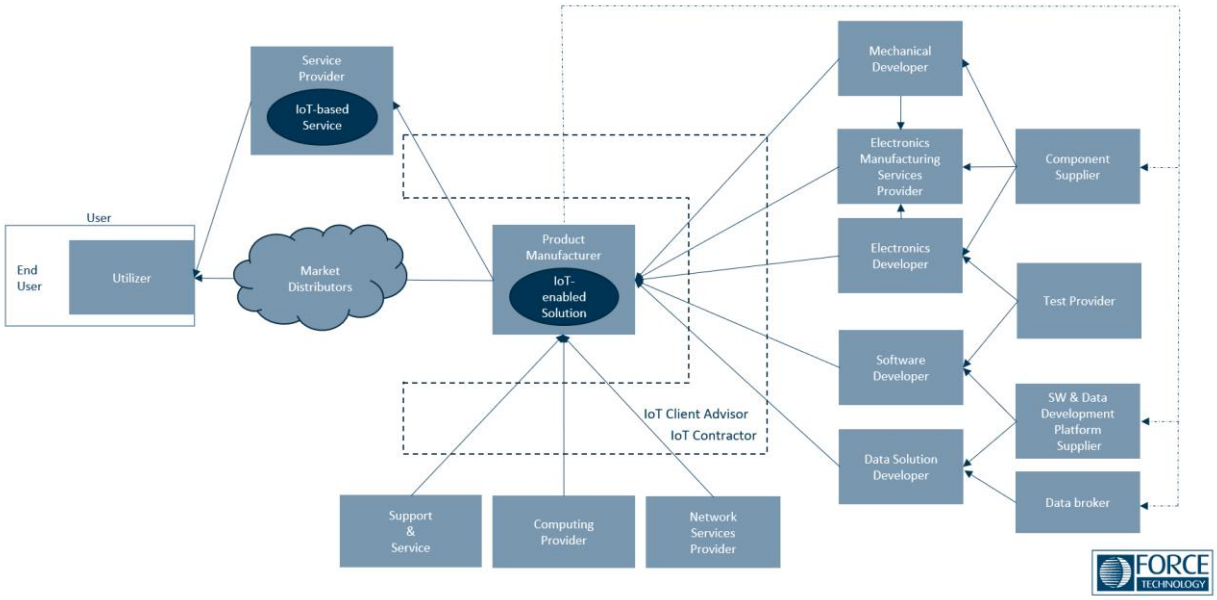

Figure 6 The primary roles of the role-based model of the IoT Ecosystem

For the development these are the Mechanical Developer, Electronics Manufacturing Services Provider, Electronics Developer, Software Developer, and Data Solution Developer, who base their solutions on Component Supplier, Test Provider, Software and Data Development platform Supplier, and Data broker roles. For the operations these are the Network Services provider, Computing Provider, and Support &

Service. For the Usage of the IoT-enabled solution these are the Market Distributors, Service Provider, Utilizers and End Users.

It is therefore also apparent why many Product manufacturers are challenged when creating IoT-enabled solutions as they need to competences to understand, and communicate with the actors performing the roles and manage the development, operations and usage adoption process. Therefore two additional roles are introduced in the model: The IoT client advisor and the IoT contractor – both of which are inspired by the construction industry. Where both roles are used to design, plan, coordinate and manage the construction process as many building owners does not have the needed competences for all of these aspects. And at the same time does not have a comprehensive overview of the contractors and subcontractors suited for the specific building, which may have specific requirements for the masonry, carpentry, electrical installations, etc.

Similarly for IoT, the Product manufacturer, needs an advisor who can aid the process and be their partner in the dialogue with the other roles. In some cases the requirements to the solution is simple, such that the Product Manufacturer can engage directly with an IoT contractor, but this often also requires and analysis of the IoT concept with respect to technical and market requirements.

The IoT Client Advisor may assist in several tasks:

- Process Advisory – designing and planning the whole process or parts of the process
- Project Management – managing the planned process with all its suppliers, stakeholders, deliveries, communication, etc.
- Suppliers Selection – the selection of the right IoT suppliers (e.g. a selection between the actors in the different supplier roles in the ecosystem) for the different parts of the process.
- Orchestration of suppliers – the ongoing orchestration of the cooperation between the selected suppliers
- Architectural Advisory – advising on the right solution architecture of the envisioned IoT Solution
- Orchestration of deliveries – the ongoing orchestration of the different solutions parts to achieve the best possible technical integration
- Handling of an IoT Contractor – assist the Product Manufacturer in the ongoing management and control of the IoT Contractor

The IoT Client Advisor should possess a complete and current overview of the IoT marketplace with the IoT Suppliers including their primary domains and strengths.

The IoT Contractor takes the full responsibility for delivering a specified IoT Solution (or a major part of it) with all its different parts and their integration – contractually and legally – to the Product Manufacturer. Thereby, the IoT Contractor lifts the burden of the Product Manufacturer of having to deal with many part suppliers in its development process. The IoT Contractor is comparable to the "System Integrator" role known from software development.

Governance and support part of the IoT Ecosystem

After understanding the IoT ecosystem directly involved in the development, operations and usage of IoT-enabled solutions, it was apparent that additional roles were engaged with forming the IoT ecosystem. These are more general and essential in establishing an IoT ready society by performing IoT Ecosystem supportive non-technical activities. This includes providing the human resources for the actors engaged with the primary roles of the IoT Ecosystem, providing legislation and standards to be used and complied to by the primary roles, creating papers and inspirational material for the primary roles to adopt IoT, and to create a technical infrastructure of research and lab facilities for IoT. Lastly the governance and support parts are engaged in the financial aspects of IoT. This is both on providing funding for advancements of IoT and creating business models for the IoT solutions – such that the primary roles can fund the activities.

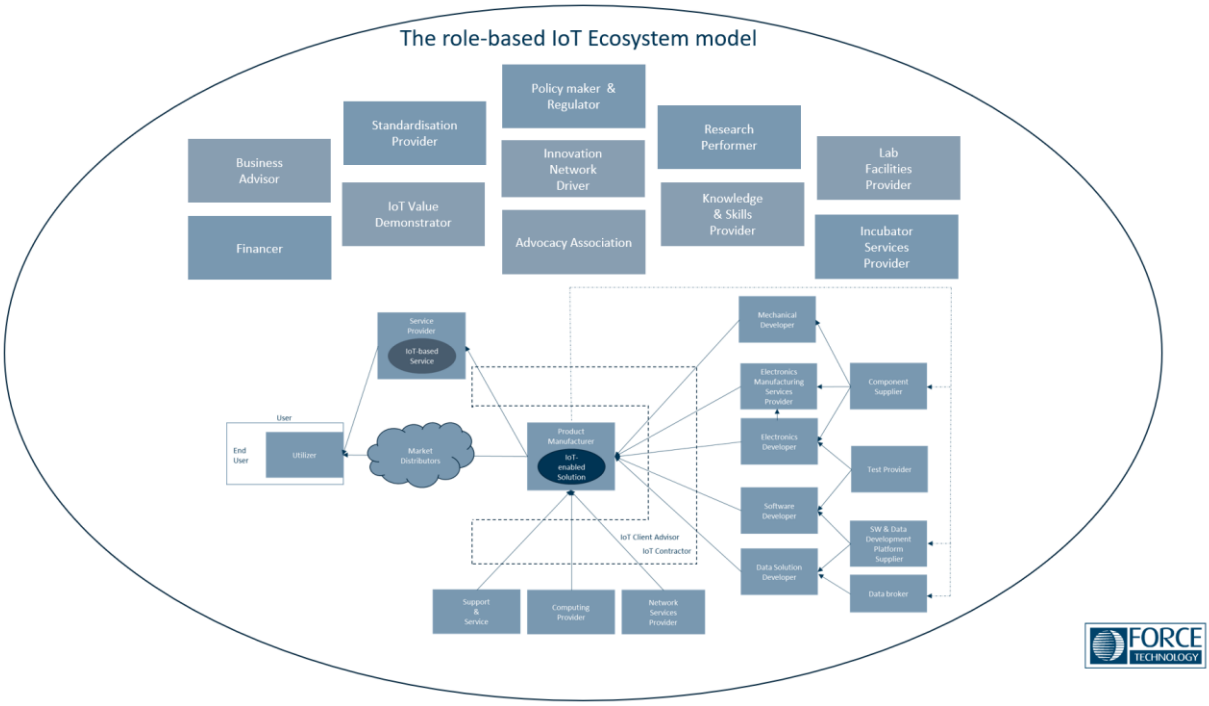

Figure 7 The complete IoT ecosystem

Application domains and the role-based Ecosystem model

The role-based Ecosystem model is generic across the various application domains – which often have ecosystems of their own. When considering specific actors their technical knowledge within the domain and insights into the operational models of the domain, should be taken into account also. The application domains can be segmented into:

- Agriculture Production
- Apparel, Footwear and Accessories
- Banking, Insurance & Fintech
- Cities, Traffic, Infrastructure and Urban Assets
- Construction and Building Materials
- Education, Schools, Labs & Research
- Events, Venues, Travel & Entertainment
- Environment, Climate and Recycling
- Healthcare and Personal Aids
- Home and Appliances
- Manufacturing - Food and Life Science
- Manufacturing - Machinery, High Tech & Medico
- Manufacturing - Process & Chemicals
- Police, Rescue, Security and Defence
- Property and Facilities
- Retail
- Transportation, Logistics & Wholesale
- Utilities, Energy, Oil and Gas

The roles in the Ecosystem – part 1: The primary roles

In this section we describe the roles of the first three groups of the IoT Ecosystem

Product Manufacturer

The manufacturer of the physical product which is being IoT-enabled. Is also referred to as the "Product Owner" or the "IoT Solution Owner".

The role of Product Manufacturer can be performed by well-established companies with existing non IoT-enabled products on the market – or start-ups trying to enter the market with new products being born as IoT-enabled.

The Product Manufacturer may start an IoT enablement as part of the product development process – or maybe based on a request from a User.

The Product Manufacturer may possess some of the capabilities needed to IoT-enable his product but will need to source the rest of the capabilities form the IoT Ecosystem.

The Product Manufacturer will seek to own the IP for the IoT-enabled solution to protects his business.

Mechanical Developer

The Mechanical Developer role is responsible for the mechanical parts of the IoT-enabled solution. This includes actuators related to the IoT-enabled solution, but also encapsulation and protection of the electronics against environmental conditions where the solution must be used.

The Mechanical developer is also responsible for ensuring the industrial design of the devices such that they are easy to use, ergonomic, and appealing to the end clients.

The Mechanical Developer role is also responsible for considering any needed or beneficial modifications required to the existing machines which are integrated with the IoT-enabled solution.

Electronics Developer

The Electronics Developer has the responsibility to develop the electronic hardware and firmware for the IoT-enabled product. This can either be as components integrated in the physical product, or as a device that senses and/or actuates the desirable properties of the physical product.

The Electronics Developer must interact with the Component Supplier role to select optimal hardware components such as microchips, sensors, actuators, communication modules, power supplies, casings, etc.

Through design, the Electronics Developer combines the components, writes firmware code, and encapsulate the design to an IoT enabled product which can be placed on the market.

The Electronics Development Provider must interact with the Test provider to clarify environmental and regulatory and interoperability requirements to the resulting IoT-enabled product and ensure that the tests are performed for documentation of compliance.

The Electronics Development Provider must consider maintainability during operation of the IoT-enabled products such as functionality for upgrade firmware and ensure patching for cybersecurity.

Electronics Manufacturing Services Provider

The Electronics Manufacturing Services (EMS) Provider role is responsible for manufacturing the hardware used for the IoT enabled products. The role coordinates with the component suppliers to ensure the supply chain in delivery of the IoT enabled product or devices that enable the manufacturers product.

The EMS also has the role of supporting the Electronics Development provider in design for manufacturing. i.e. to ensure that the devices can be mass manufactured cheaply, efficient and with maximum yield.

The EMS is also responsible to perform the Factory acceptance test before the devices are shipped from the factory.

Lastly the EMS also has a special responsibility with respect to IoT. As an IoT enabled product must be uniquely identifiable it has to be given a unique identification number, and this will typically be done on the production line of the EMS.

Component Supplier

A Component Supplier is the supplier of electronic, mechatronic and/or mechanic components and/or modules.

The Component supplier must collaborate closely with the electronics developer and the mechanical developer to find the right components for the IoT-enabled solution.

The Component Supplier often have a large supply chain, commissioning other component suppliers and/or Product Manufactures components/modules/products.

The component supplier role deals only with "off the self" product – the Product Manufacturer role handles any custom-made components/modules/products.

Test Provider

The Test Provider role is responsible for defining which tests are necessary for the IoT enabled product in the intended use case and intended markets, and for performing the testing. The test provider should support the Electronics Development Provider with the test requirements as early as possible in the development.

The test can contain multiple test types such as: Regulatory testing for market approval, robustness and reliability testing, penetration testing for cyber security, software tests, and functional testing

Testing can be performed with various physical environmental factors such as: Vibration, humidity, dust, water, shock & bump, electromagnetics, electrical safety and use patterns

Testing can be performed with various virtual environmental factors such as: Throughput, portability, interoperability, integrity, Network security, units, module, and functional testing.

Software Developer

A software development provider offers dedicated software development through a group of professionals with specific experience and skills that suit the product manufacturers demands on the base of his infrastructure, service definitions and hosting choices.

The software developer is therefore responsible for adapting the existing IoT platform software to the specific need of the solutions.

The software development provider role is primarily on the edge, server, and cloud sides of the IoT product development team.

Data Solution Developer

The Data Solution Developer is responsible for developing the Data Solution part of the IoT Solution by taking the data created by the other parts of the IoT solution and using these for specific purposes. These purposes may be control of the IoT Solutions itself, creating or supporting a service made possible by the IoT Solution or supporting/making business decisions based on the data.

The Data Solution Developer will typically use a platform with a given toolset for the development work.

The Data Solution Developer may also need to include other data sources in the Data Solution part than only the data provided by the IoT Solution itself. In this case, the Data Solution Developer will use on or more Data Brokers to obtain the necessary data to make the solution work.

Data Broker

The role of the Data Broker is to supply additional data sources and data to the Data Solution Developer to make the data solution part of the IoT Solution fulfils its objective.

The Product Manufacturer may take this role to supply its own data to supplement the solution, but it can also be other companies and institutions who takes this role.

In Denmark, this role may often be taken by public institutions delivering free public data (dansk: ”de frikøbte offentlige data”). This could be institutions like: Agency for Data Supply and Efficiency (dansk: ”Styrelsen for Dataforsyning og Effektivitet”), Danish Geodata Agency (dansk: ”Geodatastyrelsen”) and Danish Institute for Meterology (dansk: ”Dansk Meterologisk Institut”).

SW and Data Development Platform Provider

A software and data development platform is a group of technologies that are used as a base upon which other applications, processes or technologies can be developed. These can be very generic and basic (like an operating system on which software applications can be run) or specifically tailored to provide functionality to a certain type of applications (like the Microsoft Azure IoT Hub).

While software platforms are focused on driving an application, collecting data and presenting it the user or through API’s to other applications, Data platforms are focused on data manipulation and analysis (like data warehouse, BI platforms etc).

Computing Provider

The role of the Computing Provider is to provide the IT set-up, e.g. computing power, data storage and basic software) necessary to run and operate the IoT Solution and its parts. So the Software parts and the Data Solution parts of the IoT Solution will run on the IT setup provided by the Computing Provider.

The computing provision can consist of several parts such as a central part and a distributed part close to the other IoT Solution parts.

Often this role will either be taken the Product Manufacturer self or by a third-party computing provider such as a professional IT sourcing provider or a cloud computing provider. So the Computing parts setup can be provided on premise at the Product Manufacturer, on shore, at the IT outsourcing company (on premise, on shore, near shore or off shore) or provided as a cloud service (IaaS or PaaS). When delivered as PaaS, it can be combined with the SW and Data Solution Platform.

Network Services Provider

The Network services provider is responsible for providing the connectivity to the IoT enabled products, when they are in operation. The network services provider role is often external and based on infrastructure investments, if the communication is though cellular, fiber, or Low Power wide area technologies over a large area such as a country.

For short range wireless technologies and internal networks, the network services provider role is often embedded in the product manufacturers organisation or the utilizers organization.

Support & Service Provider

When a non IoT-enabled product is turned into an IoT-enabled product, it is also turned into a digital solution which requires a different kind of support. An IoT Solution will typically require a kind hotline or 1. level support which can be reached by phone or online. Also, the 2. line support may different in terms of

online problem diagnostics, software updates, etc. The role of the Support and Service Provider is to perform 1. and next level support for the IoT Solution.

Typically, a well-established Product Manufacturer will already have a traditional support and service setup targeting for example mechanical incidents. In this case, this setup may be extended, and the role can be performed by the Product Manufacturer himself. But the role can also be outsourced to be performed by a dedicated third-party support end service organisation or by the third-part Computing Provider or the Network Services Provider.

Market Distributors

A Market Distributor is a channel used by the Product Manufacturer to reach its Users (Customers) with its IoT-enabled Product. This will typically be retailers for IoT consumer products, distributors and resellers for Business to Business (B2B) IoT products – or a combination of those. But also more sophisticated Market Distributors such as installers, facility managers, construction companies, etc.

For B2B IoT Solutions, the Product Manufacturer himself may take the role of Market Distributor. But for consumer IoT Solutions and large scale B2B IoT Solutions, the Product Manufacturer will typically use third-parties for this role. And if the IoT Solution requires advanced installation or enablement, specific service providers may be required to perform the role.

User

The User role is the one who uses and/or operates the IoT enabled product or service. The User role is split into two: The End User and the Utilizer:

- **The End User**: Is the one who directly use and/or operates the IoT enabled product or service.
  An example can be a citizen who use an IoT enabled trash bin.
- **The Utilizer** role puts the IoT enabled product or service into use.
  The Utilizer can either purchase off the shelf products / services or request new products / services from the Product Manufacturer.
  An example can be a municipality ordering IoT enabled trash bins

Service Provider

The Service Provider is using the capabilities provided by an IoT-enabled Solution to offer new services or improved services to the Users. The same actor may take on both the role as Product Manufacturer and Service Provider, but the roles may also be split between different actors.

An example of split roles occurs when a municipality (User/Utilizer) purchases new IoT-enabled waste containers from a Product Manufacturer thereby allowing disposal companies (Service Providers) to offer new enhanced waste disposal services. An example of combined roles occurs when a Product Manufacturer uses an IoT-enablement of its machinery to offer a new service for predictive maintenance on the machinery.

The term "Servitization" is normally used when an existing Product Manufacturer is expanding his business model from being product-based to also be services-based.

IoT Client Advisor

The IoT Client Advisor (dansk: "IoT Bygherrerådgiver") is engaged by a Product Manufacturer (or a User/Utilizer) to assist in the development process from an IoT business idea to a market ready IoT Solution. The IoT Client Advisor can assist in parts of the process or in the whole process from start to end. During the process, the IoT Client Advisor may assist in several tasks:

- Process Advisory – designing and planning the whole process or parts of the process
- Project Management – managing the planned process with all its suppliers, stakeholders, deliveries, communication, etc.

- Suppliers Selection – the selection of the right IoT suppliers (e.g. a selection between the actors in the different supplier roles in the ecosystem) for the different parts of the process.
- Orchestration of suppliers – the ongoing orchestration of the cooperation between the selected suppliers
- Architectural Advisory – advising on the right solution architecture of the envisioned IoT Solution
- Orchestration of deliveries – the ongoing orchestration of the different solutions parts to achieve the best possible technical integration
- Handling of an IoT Contractor – assist the Product Manufacturer in the ongoing management and control of the IoT Contractor

The IoT Client Advisor should possess a complete and current overview of the IoT marketplace with the IoT Suppliers including their primary domains and strengths.

IoT Contractor

The IoT Contractor (dansk: "IoT Totalleverandør") takes the full responsibility for delivering a specified IoT Solution (or a major part of it) with all its different parts and their integration – contractually and legally – to the Product Manufacturer. Thereby, the IoT Contractor lifts the burden of the Product Manufacturer of having to deal with many part suppliers in its development process.

A supplier actor in the IoT Ecosystem performing one of the basic roles as Electronics Developer, Software Developer or Network Services Provider may also choose to take on the role as IoT Contractor.

Taking on the role as IoT Contractor, an entity will also choose to take on many of the tasks otherwise performed by the IoT Client Advisor as part of the full delivery contract such as: project management, architecting, orchestration, integration, etc.

The IoT Contractor is comparable to the "System Integrator" role known from software development.

Alliances in the Ecosystem

An Alliance is a cooperation between two or more actors in the IoT Ecosystem – typically mastering and pursuing different roles in the IoT Ecosystem. In accordance with their roles, each actor is specialized in delivering a specific part of an IoT Solution. Therefore, an Alliance will be able to gather several parts of an IoT Solution together and to deliver them in a more coherent and consistent way.

An Alliance can be:

- A Permanent Alliance where the actors have an on-going cooperation which they continuously try to promote to potential customers
- A Project-based Alliance where the actors enter into a one-off cooperation targeting a certain project at a potential customer

An Actor can be part of several – both Permanent and Project-based – Alliances at the same time. This is controlled by the commercial conditions agreed by the Actors in their Alliances

The roles in the Ecosystem – part 2: Governance and support roles

In this section the roles for the governance and support group of the ecosystem is described.

Business advisor

The business advisor is responsible for creating business plans for IoT and advise on how to get funding for the development through collaboration with the financer. This can either be through public innovation funding, private equity, internal investments etc.

As with many other roles it is important to remember that the roles can be covered both internally from the product manufacturer, the alliances or an external organisation.

The Business advisor should know about the typical value propositions for IoT related to Product Value for customer such as: Efficiency, Compliance, Sustainability, Customer Relation, Service Value for customer, Servitization of business, Profitability, and Health & Safety.

The business advisor is also a navigator in the application domains for IoT found in section 0.

Standardisation provider

The standardisation provider is responsible for facilitating the access and development of standards for IoT. This can be divided into multiple organisation types.

- **International standard development Organisations** (SDOs) that develop standards based on international and industry consensus in some cases for compliance against regulatory requirements. This can be organisations such as: ISO, ITU, IEC, IEEE, CEN/CENLEC, and ETSI
- **National standardisation bodies** (NBs), that facilitates national access to standards and translations to the national language. They also facilitate that national experts can participate in the work performed in the SDOs
- **Organisations providing experts** to the SDOs through the NBs. This can be universities, Research and technology organisations and private companies seeking insight and influence on the international standards

Policy maker & regulator

The policy maker and regulators are responsible for creating market regulation and support structures to ensure proper widescale deployment of IoT.

For the regulators this can be national authorities or can be union authorities.

For the policy makers these are the politicians creating laws and support programs for IoT

Advocacy Associations

Advocacy associations are involved in the adoption and development of IoT with a consideration for the member companies in their association. This can be industry manufacturing products, associations for installers, technology developers, associations for farming, associations for retail, etc.

The Advocacy associations are responsible for collecting their members interest and describing how they can leverage the potential within IoT

Research performer

Research performers are researching within topics related to IoT. This can be technical research, organisational research, business model research, and research for implications in the society, such as increased productivity or the green transition.

The research performers are typically Research and technology organisations or universities.

Lab facilities provider

Lab facilities providers provide an infrastructure for testing IoT solutions. These fall within two categories: controlled lab environments and living labs

The controlled lab environments have, and provide, access to test facilities such as radio anechoic chambers, climate-controlled chambers, cybersecurity test facilities, software test facilities, and other labs where investments typically are too large for the individual companies.

The living lab providers facilitate and operate living labs, where developers can test their solutions in a realistic environment. The second aspect is to provide access for IoT Users to explore the possibilities of IoT solutions by seeing all the tested products and solutions in action.

Financer

The financers are responsible to provide financial funding for the development of the IoT solutions. This can be:

- Internal funding providers in the organisation developing the IoT solutions
- Public funding programmes for the innovation within IoT
- Private investors to invest in SMEs and start-up's for acceleration of their market introduction and innovation
- banks willing to provide loans to companies investing in IoT

It is important that the financers are in close collaboration with the business developers as the financer typically make decisions based on the business cases provided by the business developers.

As with many other roles it is important to remember that the roles can be covered both internally from the product manufacturer, the alliances or an external organisation.

Innovation network driver

The innovation networks have the purpose to facilitate collaboration and knowledge sharing between the actors and therefore play an essential role in inspiring the alliances to emerge. They are typically in close collaboration with the research performers and the IoT evangelists

The innovation networks play a specific role within IoT. These are typically focused on one or more of the specific application domains listed in section 0

IoT Value demonstrator

The IoT value demonstrator is a specific role that other actors can take to publicly demonstrate the value of IoT. This should be based on business cases and value propositions that document the advantages in adopting or developing IoT.

The value demonstrators typically have IoT evangelists employed for public speaking that can inspire and engage the public within IoT. These can advocate for the adoption of IoT and inspire the other potential actors to become part of the IoT ecosystem.

Knowledge and Skills provider

The Knowledge and skills provider is responsible for providing education about IoT. It can be focused on technology, business models or innovation, and can be both for basic, or continuing, education for professionals seeking more expertise within IoT.

The knowledge and skills providers are also producing reports and whitepapers that helps the professionals navigate the IoT landscape to provide overview and guidance in implementation and technology choices for IoT.

Incubator services provider

The incubators facilitate shared offices, support facilities, and typically access to funding such that start-ups can be part of a larger community within technology development and innovation. These can be focused on specific IoT activities, be domain specific or can be a broader combination of both. Typically, the incubators are linked to accelerator programs that helps the start-up's grow to viable businesses.

Conclusion

The Internet-of-Things (IoT) Ecosystem is a network of organizations developing and adopting IoT products and services through both competition and cooperation. Each actor in the ecosystem affects and is affected by the others, creating a constantly evolving relationship in which each entity must be flexible and adaptable in order to succeed, as in a biological ecosystem.

To deliver maximum value when creating specific IoT products and services it is necessary for each actor to specialize in their field of expertise and to contribute with this specialized knowledge to the other actors in the ecosystem collaboration

As more product manufacturers IoT enable their products, they become part of the ecosystem and potentially become suppliers of more components available to the ecosystem. Thus, enabling the ecosystem to evolve with new and more IoT products and services.

To enable actors engaged with IoT to understand and leverage the IoT Ecosystem, the role-based IoT Ecosystem model is presented in the present document. This can be used by stakeholders to analyse their own role(s) in the Ecosystem and identify which partners for collaboration and creating alliances.

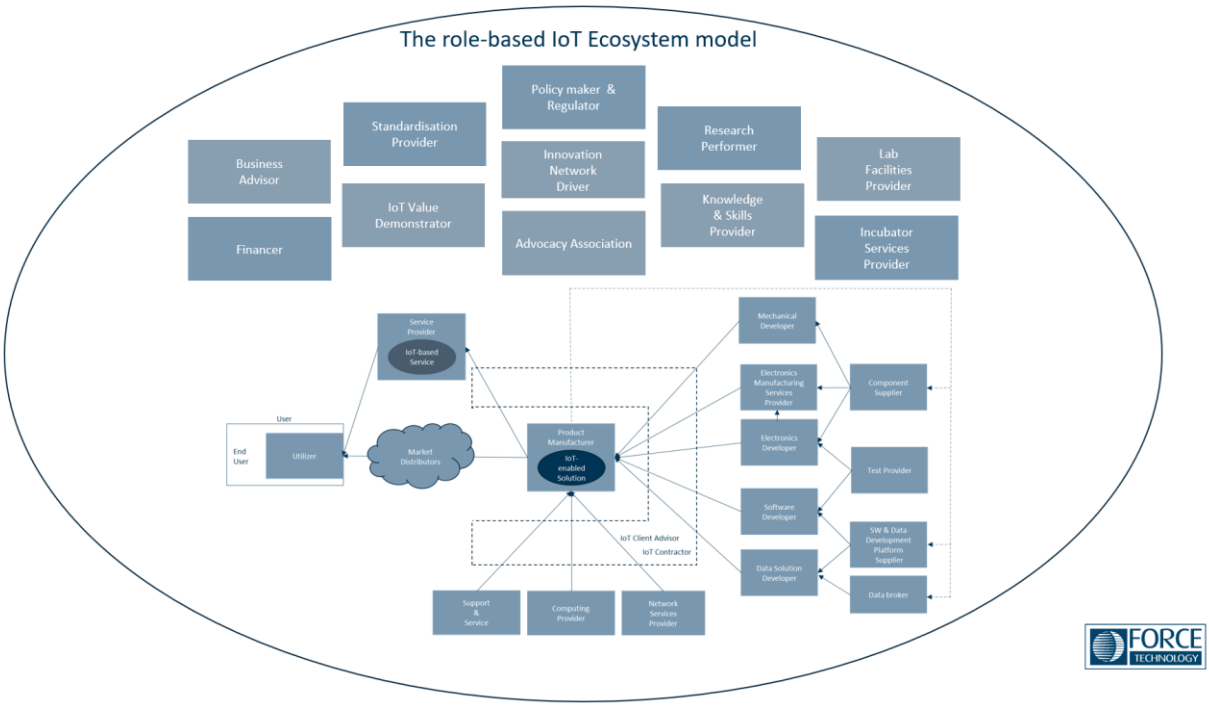

Figure 8 the role-based IoT Ecosystem model

The model is specifically beneficial for IoT client advisors and IoT contractors as an analysis model for clarifying requirements to the roles of actors engaged in Ecosystem based IoT development.

Lastly, the model can be used by organisations that want to develop, operate or adopt IoT solutions but can also be used by organisations that are performing activities into advancing IoT from a societal perspective, to analyse the roles that the actions needs to target and interact with.