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The Internet of Things is hardly about technology

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Abstract. Most definitions of the Internet of Things (IoT) take a technology perspective, referring to connected devices exchanging data with each other and with higher levels, establishing autonomously operating systems. From a business perspective, IoT can be regarded as a business transformation, driving commoditization or even threatening conventional businesses, providing opportunities for product and process improvements and opening perspectives for services business or entirely new businesses based on data acquired by IoT. While the development of the Internet of Things resembles in many aspects the characteristics of for example semiconductor and IT platforms, there are some essential differences, mainly in scale and scope, that make the kickstart of a successful IoT more complex. This paper addresses key elements of a successful deployment of IoT and also key roles for IT professionals in IoT.

Keywords: Internet of Things, IoT, Platforms, Open Innovation, Ecosystems, Digitization.

1 Introduction

Most definitions of the Internet of Things (IoT) take a technology perspective, referring to connected devices exchanging data with each other and with higher levels, establishing autonomously operating systems. Such definition easily fits in with other technological developments that are driving the digitisation of our world. Sensing, ubiquitous communication networks, information systems, data analytics, artificial intelligence, robotics, edge and cloud computing are all linked to the development of IoT, either as an enabler or leveraging IoT for new applications.

From a business perspective, IoT can be regarded as a business transformation, driving commoditization or even threatening conventional businesses, providing opportunities for product and process improvements and opening perspectives for services business or entirely new businesses based on data acquired by IoT. New economic powers and regions will emerge, others will lose relevance.

There is no doubt that IoT will be a driver of socio-economic change like the industrial revolution was. Our society will increasingly be run by autonomous systems, self-learning robots will assist people not only in manufacturing, but also in their daily life. Resource management (energy, food, water) will be based on IoT, combining data from numerous sensors and actuators and systems in the field, providing real time insight and steering optimized flows. Curative healthcare will be replaced by a continuum with

preventive monitoring, highly automated treatments and home care. Systems of systems will autonomously run operations in energy, mobility, cities, buildings, industry...

Jobs will disappear while other jobs are created. Education will change to life-long learning while new creative fulfilment of free time will be required. And since the speed of change is fast, people will feel uncertain, distrusting new technologies.

Don't worry about the definition of IoT. IoT is all of it and it is about time that we take an integral, holistic approach while 'separating concerns' to make it work for all.

2 A short history of the future: enabling platforms

Already in the 80-ies have we seen the need for such 'separation of concerns' approach in the electronics industry, although predominantly in the technology area. Socio economic considerations were lagging, as usual.

In the 80-ies the electronics industry was predominantly analog and the design, manufacturing & application required (scarce) deep and wide knowledge. Chip application engineers, designers and technologists were very much from the same origin and closely working together.

But once IC technology was mastered, one could massively apply transistors as switches and a digital technology platform was established. While one breed of engineers worried about making a good transistor switch and replicating them hundred thousand times without flaw, a new generation of engineers that never had seen a transistor was enabled with tools to create complex computing circuits with those large numbers of transistors, not requiring deep transistor and technology knowledge but using instead simulation models ('digital twins'). Separation of concerns.

This created a whole new framework of knowledge and associated professions, but it also bifurcated IC business in fab and fabless companies, all enabled by digital technology platforms.

This bifurcation has repeated several times, all driven by the same principle of establishing a platform that enabled the development of new knowledge, professions and business on it, separating concerns from the layers below.

Integrated Circuit Designers started using standard building blocks and those building blocks were combined in standard IC's such as, microprocessors, microcontrollers and communication chips. Again establishing a digital platform enabling a new breed of engineers to run away with them building programmable computers, communication networks and automation and control systems.

Those systems needed standard SW operating systems and standard application software packages in order to have them deployed massively and a new platform layer, this time in SW was established, based on the same economy of scale as Moore's Law driving the bottom of the pyramid. Large software stacks have high creation and maintenance cost and therefore application toolsets enabled a new breed of SW application engineers to deploy and configure those standard software packages in many domains. This role is largely filled in by many small and medium enterprises.

While this development has disrupted businesses, it has created enormous economic value overall. It has been a strong driver of 'Moore's Law' in the sense that it created the economic justification for the technological advancements in IC technology and on higher levels in SW. Without platformisation, the market would not have developed and Moore's Law and SW growth would have been stagnating because of lacking returns.

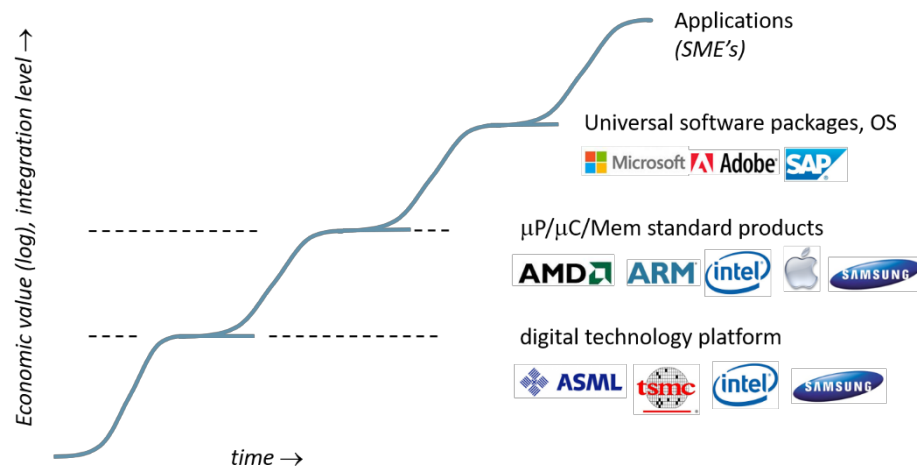


Fig. 1. Schematic representation of technology platforms developed over time in the IC/ICT domain enabling higher integration layers and economic value. Some key players on various levels are illustrated (non-exhaustive)

Figure 1 expresses this stacking of platforms over time, while the overall value exponentially grows with each layer. This is also reflected in the number of jobs that is anticipated in the software industry vs. the hardware industry, being orders of magnitude larger. Particularly in the SW application industry have many smaller companies developed that are configuring and customizing implementations of standard software packages such as ERP systems and databases. This being the case, the economic value is still enabled by the hardware industry.

The rapid development of digital platforms has posed a dilemma for many companies active as they had to decide on their position in this developing value chain. IC manufacturers had to consider focusing on technology or design (separating concerns), or both. Generic SW companies (ERP, OS, DB) had to decide whether to support all its implementations or focus on one of the two. And life is very different above and below:

- Very different perspectives;
- Very different lifecycles;
- Very different competencies required;
- Very different economics (business control points).

But the choice that companies had was enabled by a ‘common interface’ in terms of language, protocols, simulation models... ‘digital twins’, creating a strong interdependency.

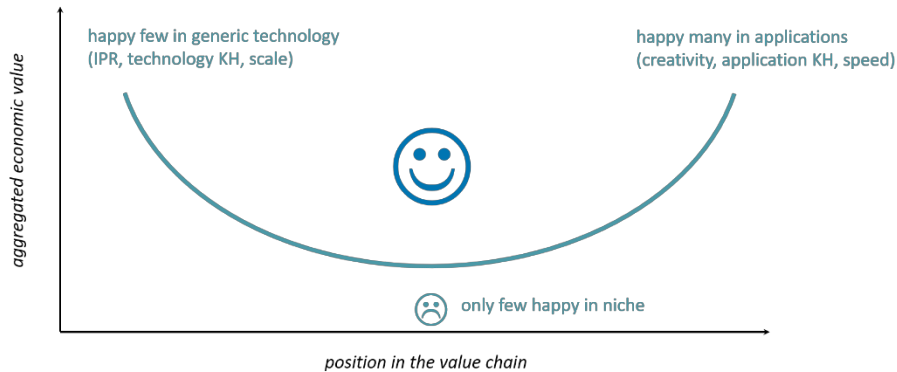


Fig. 2. The smile curve, picking your place in the value chain. In general the economic model on the left side is fueled by high volume, high investments and on the right side by lower volume, high diversity. The number of players on the left side is substantially lower than on the right side, leaving room only for niche players with customized technology in the center.

Already in the 90's was the so-called ‘smile curve’ introduced to express the dilemma of positioning oneself in the value chain. The vertical axis reflects the economic value that a company may create and the horizontal axis the (upward) movement in the value chain. As stated earlier, the total value of all companies is substantially larger on the right hand side but this value is created by many more application companies. There is only room for fewer players on the left hand side where the rules of the game are in general scale and high investments. The center reflects that you can't be both and there is only room for niche players with relatively low impact. That does not imply that representatives of the same (vertically integrated) conglomerates can show up on the left and the right... They can, but within those companies they will be very different animals requiring dedicated management and business controls.

3 The Internet of Things: some things are repeats of history

Like the stacked platform picture that one can draw for the IT technology and applications ecosystem, one can create such picture the Internet of Things (fig. 3). Clearly the IC technology stack is deeply embedded in the first layer of this IoT ecosystem, creating intelligent devices that are able to communicate. They represent (embedded) systems on their own.

Fig. 3 does not aim to depict a standard way of looking at the IoT but one could recognize a few layers of the OSI model in it. The main thing is that it represents a very

strong way of ‘separating concerns’ as the various layers have so much specialism in technology, business models, competencies and culture that one could regard it as different worlds that somehow are intimately dependent on each other.

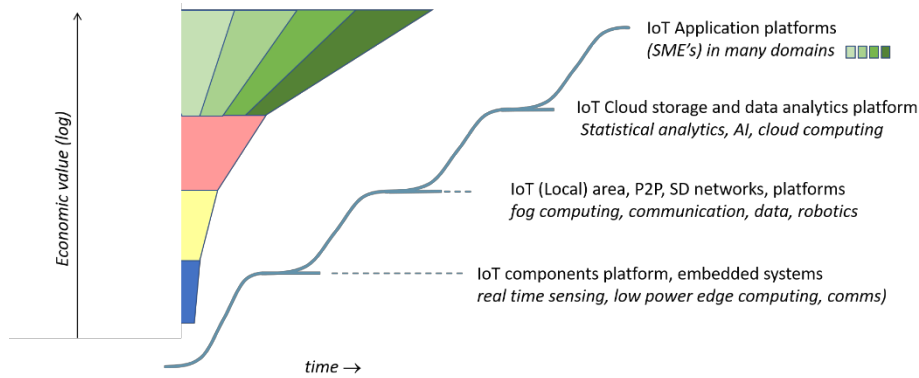


Fig. 3. Schematic representation of some key platform layers in the development of Internet of Things. The economic justification of enabling (lower) layers comes from many applications in various domains, each requiring expert knowledge

The picture also represents different architectural choices when it comes to data processing, that can be executed in end-nodes of the IoT (edge computing), in intermediate nodes, often representing local area networks and servers (fog computing) and central information processing often in the cloud. Hybrid forms are the most likely candidates for a solid implementation of IoT as the non-functional characteristics of centralized and decentralized systems are very different. We will go a bit deeper in this in the next sections.

The higher one gets in this picture, and the higher up in the value chain, the more diversification is taking place and knowledge of the application domain becomes essential. While this was already the case in IT for e.g. bookkeeping, for CAD, for control systems, it is taken to an extreme in IoT. IoT will be much more pervasive in society and one cannot create meaningful IoT applications without a solid understanding of the socio economic impact of it. This is where technology push ends.

Only by enabling an ecosystem that is deeply involved in applications in real life can a scale be created to justify the investments in the underlying layers such as communication networks and software systems. The key question is whether we are on track to create such ecosystem.

4 The Internet of Things: some things are different

While the development of the Internet of Things resembles in many aspects the characteristics of the semiconductor and IT platforms as discussed in section 2, there are some essential differences, mainly in scale and scope, that make the kickstart of a successful IoT more complex.

First of all has the investment scale gone up, for example in communication infrastructures. While the investment in 2G communication networks could be justified by just mobile phone traffic and 3G networks by increased data use on smart phones, future networks will be based on serving trillions of IoT devices in many different application domains with different requirements that all have to be developed.

But the same holds for platform developments in e.g. smart mobility or smart cities. They will require large investments that can only be earned back with many different application use cases. There is no single use case anymore that justifies the investment. This brings a higher level of uncertainty, that has to be countered by a strongly orchestrated approach for which we see 3 variants in today's world:

- Orchestration by governments;
- Orchestration by powerful (vertically integrated) companies;
- By collaborative platforms and ecosystems.

Secondly, IoT technology requirements differ from general Internet requirements that all require dedicated developments. Some of the most obvious ones are:

- Very low standby and communication power consumption in devices;
- Flexible bandwidth allocation (from very low to high);
- Very low cost per node serving extremely large numbers of nodes;
- Flexible and programmable communication layers (P2P, local, central);
- Extremely low latency for several applications;
- Extremely high reliability and resilience for several applications;
- Strong security and privacy requirements;
- ... several other non-functional elements such as sustainability.

Serving some of these requirements will require fundamental changes in the architecture of next generation internet.

Thirdly, the higher one gets in the value chain, the wider the scope that needs to be orchestrated/managed and deep involvement of application domain specialist beyond technology will be crucial for IoT, more than it was for ICT development:

- A very wide range of application domains such as Smart Cities, Homes / Living, Healthcare, Farming, Energy, Mobility, Water Management, Industry... and more to come;
- Many technologies in HW, SW, Communications, Systems Engineering, Robotics, Sensing, Data Analytics, Hypercomputing, User Experience... and all non-functional requirements such as security and privacy;
- Legal and liability aspects;
- Socio-economic and human aspects;
- Education and training;
- Use case development.

The overall orchestration in scope, complexity and uncertainty of all these elements and the establishment of platforms that allow a 'separation of concerns' is probably the largest challenge for the development Internet of Things in Europe, more than the individual developments in technologies.

5 Key elements for a successful deployment of IoT

The key issue with IoT is not technology, but the fact that

*applications and platforms are insufficiently established...
because supporting platforms are insufficiently established...
because their justification by applications is insufficiently established*

This is depicted in figure 4 and figure 5. Figure 4 represents the idealized stack of ‘smile curves’ of players in the components and IoT devices domain, the networks domain, the data domain and the application domain. As stated before, this is not necessarily the only way of breaking down the IoT value chain, but it illustrates the matter. The value is increasing exponentially along the chain and within each domain, one has to pick a position, require a high degree of focus and specialization.

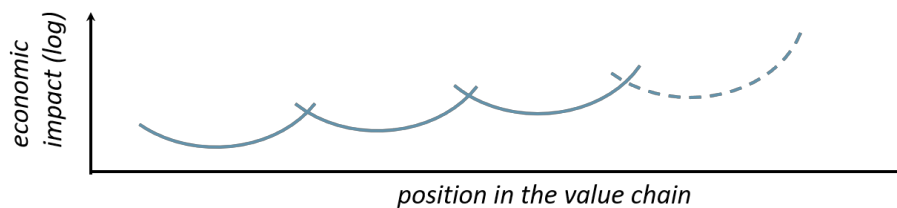


Fig. 4. The idealized stack of smile curves for an IoT value chain. Common interfaces and well connected platforms establish a high economic impact

This ‘ideal’ situation is emerging in ecosystems driven by government in China or by very strong platform companies in US. Note that the left hand part of the value chain does not require strong orchestration as industry platforms have very much established itself, but the challenge starts already at next generation communication networks.

However, a more realistic picture today which holds for Europe is depicted in figure 5. Not being driven by a central government powers or by large platform players, there is a lack of established data and application platforms, orchestrated and managed standard interfaces and in essence a lack of common goals. Even though individual expertise and goals of companies may differ, they require a common goal in IoT platform developments to be successful for their individual successes. Without such platforms, their individual value creation will become obstructed.

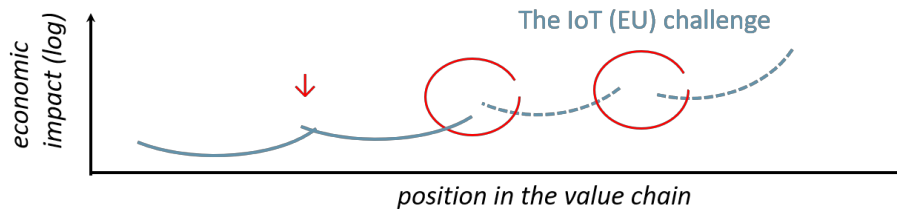


Fig. 5. A representation of today's ecosystem in EU Internet of Things, with data and application platforms and their orchestrated interfaces lacking, making the application value creation speculative and also reducing the economic value of lower layers

Not having a central governmental power for orchestration, nor extremely powerful platform companies established in Europe, the question to companies in this ecosystem is therefore very much: *Do you bet on your monopolistic do-it-yourself power or on your collaborative power for IoT?*

The only alternative way forward in establishing the required ecosystem seems to be the creation of *collaboration platforms*, uniting individual players around the common interest. The establishment of such platforms in Europe first of all assumes a sense of urgency in European industry that no single company/organisation can manage the whole stack on its own related to:

- Investments required and need to focus for economy of scale
- Knowledge and competency scope required for different parts
- Culture required for different parts

and a willingness to work together in an open innovation ecosystem that:

- Separates concerns ('mind your own business') building on strengths;
- Shares the common elements that don't differentiate the one company from the other (protocols, standard functions, infrastructures, architectures);
- Creates a large degree of interoperability.

Such ecosystem, although much more difficult to establish than alternatives that work under singular top-down control, can even prove to be more stable and attractive in the longer term because of:

- Involvement of a wider group of stakeholders, leading to higher acceptance and trust by society and governments;
- Better attention to non-functional aspects of IoT, in particular security, privacy, portability, resilience, flexibility;
- Faster development of use-cases, particularly when SME's and creatives gain access to these platforms. Their applications can greatly contribute to the justification of platforms whereas the creation and maintenance of platforms generally requires the skills and scale of larger companies.

And so, the key issue with IoT development in Europe is not technology, but a lack of:

- Collaboration between industrial players;
- Collaboration across functional silos;
- Understanding that economic justification of IoT infrastructures comes from multiple use cases in multiple domains, requiring an integrated approach.

It is not just the creation of platforms that needs a justification from many use cases in many domains, but very much the maintenance of such platforms, requiring a 24/7/365 high performance in the operational management of cities, homes, healthcare, energy, mobility etc.

Since the economic justification for any platform comes from *collectives* of applications, another key element in the deployment of IoT to the selection of those applications or use cases. This comes with a great deal of uncertainty that can only be managed by applying large scale experimentation in real scale environments. The mindset for the linked development of platforms and applications should therefore be:

Many applications will fail, get used to it!
Several applications will be successful, count on it!

Unlike technology development that usually takes place in laboratories, the development of uses cases takes needs to take place in cities, homes, healthcare ecosystems etc., involving:

- A real world environment
- Early involvement of end-users and key stakeholders beyond technology
- Expectation management (including non-functional aspects)
- The notion that early failure on any aspect is valuable learning

Governments have an important role to play in facilitating such real-world experimentation, e.g. by using innovative procurement procedures instead of traditional buying of upfront specified solutions against lowest cost.

Particularly the involvement of societal stakeholders in this experimentation is crucial in order to get valuable feedback on implementations but also to gain trust and address critical concerns in society regarding the impact of IoT applications and new technology that could hamper a successful deployment of IoT, even though technology works perfectly. In that sense should experimentation include e.g. legal and social aspects.

Lack of trust is considered the largest inhibitor of IoT deployment and lack of trust is strongly related to the non-functional aspects of IoT such as privacy and security. Trust is perception that cannot always be addressed by technology. Education and involvement of people in the development of IoT is essential and new knowledge and insights will be developed that in the end could pay off for Europe running a human centric socially embedded IoT.

The Internet of Things development is largely a self-fulfilling prophecy creating higher value for all, provided we:

- Create a collaborative platform in many aspects beyond technology
- Involve a wide range of (societal) stakeholder in an early stage
- Are prepared to experiment, fail and learn
- Are prepared to enable higher value creation before re-distributing it

6 Key roles for IT professionals in IoT

From the sections above, one may anticipate also large changes in certain professions, particularly the ones that operate on interfaces of different disciplines or across different domains and in applications. Other, more specialised professions will not fundamentally change even though underlying technologies will evolve.

Professionals at the end of the chain, in applications, will be increasingly confronted with the enormous opportunities of IoT. This is already happening in e.g. Smart Farming, where the new generation of farmers is strongly involved with the latest technologies in sensing, data analytics and automated growing control in e.g. city farming. In many other domains will the traditional craftsmen become users of intelligent systems, robotics and data that will on the one hand replace many of their traditional work and on the other hand enable them to do ground breaking new things. This is a large part of the social transformation.

Many more IT professionals will be required that operate on interfaces, bringing a wide scope of knowledge and experience or able to link with application domain specialist, talking ‘farmers language’ with IoT farmers, ‘transporters language’ with IoT transporters etc. Several universities and colleges have already recognised this need and started educational programs for:

- T-profile Engineers, ‘platformers’ integrating many functional and non-functional aspects of platforms with strong IT components (communications, data, embedded systems). Typically these professionals need strong architecting and platform management skills;
- II-profile Engineers, linking with other disciplines (legal, social) and/or engaging with application domains, requiring non-technical skills and application knowledge.

These profiles are schematically depicted in fig. 6. I-profiles these days form the majority of ICT profiles, focusing on dedicated subjects and specialism in the ICT landscape. But there is a limitation to what a single mind can do in this increasingly complex world of systems of systems. It is unlikely that ‘I can do it all’ and increasingly we need T- and II-profile Engineers integrating vertically and horizontally.

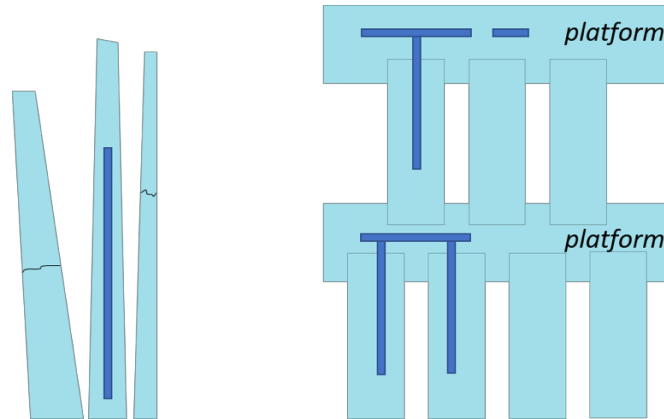


Fig. 6. Schematic representation of competency profiles, applicable to ICT professionals. I-profiles represent ‘do it yourself’ end-to-end professionals from the early days and the many specialist that today operate in a specific expertise field. Increasingly, platform integration profiles (T-shape) and cross-domain integration profiles (Π-shape) are required to build the IoT.

It requires the development and maintenance of technical and non-technical skills to be successful in:

- Solving societal challenges
- Addressing non-functional system aspects crucial for trust
 - Educating and involving society
 - Providing end users with options and personal data ownership
- Managing convergence on application level
 - Internet, IoT, mobile, IIoT, OT, data analytics, systems of systems, SDN
 - Cybersecurity
 - Cloud-, fog-, edge- computing and their distribution
 - Real-time, mission critical SW for specific application domains
 - VR, AR, robotics, digital twins, BIM...
- Interoperability and portability of functions and data
- Designing and deploying distributed Systems Architectures

But this also provides many development opportunities for IT professionals and an increase of jobs.

7 The Alliance for Internet of Things Innovation (AIOTI)

The Alliance for Internet of Things Innovation (www.aioti.eu) was kickstarted in 2015 and formally established in 2017 with the aim to address the cross functional and integration aspects of building a successful IoT. It is a member driven organisation with representatives from industry (large and small), academia and society that:

- Is at the forefront of IoT adoption, able to identify what is required to drive this adoption;
- Strives to break down silos so that the market for IoT can develop;

- Develops IoT ecosystem across vertical silos including start-ups and SMEs;
- Contributes to Large Scale Pilots to foster experimentation, replication and deployment;
- Supports convergence & interoperability of IoT standards;
- Gathers evidence on market obstacles for IoT deployment in a Digital Single Market.

by

- Promoting an integrative approach;
- Leveraging existing initiatives, be the missing link;
- Co-operating with other global regions while European values, including privacy and consumer protection, are maintained.

AIOTI embraces diversity, expressing the different views of interest group along the value chain. AIOTI is leveraging a structure of horizontal working groups, addressing common elements in technology research, ecosystems, standards and policies with an implementation driven approach in vertical working groups. This is depicted in fig. 7.

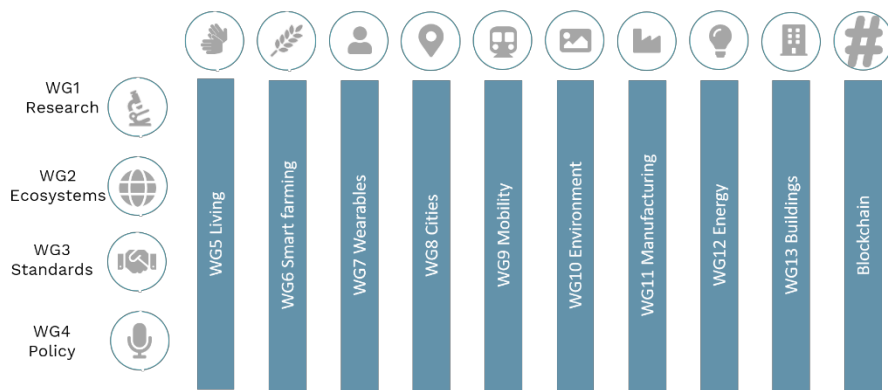


Fig. 7. Working structure of the Alliance for Internet of Things Innovation (2018), combining horizontal and vertical working groups (WG)

8 Conclusions

We have taken an integral perspective on the development of IoT, beyond technology and clearly the Internet of Things holds many *promises*. But just as much as the *promises*, the development of IoT has many *challenges* requiring a new approach involving:

- Creating platforms by a strong collaborative approach beyond technology;
- Socio-economic aspects in a Human Centric IoT;
- The education and involvement of end-users;
- Privacy, security, resilience... and many more non-functional aspects;
- Critical architectural choices;
- Real scale experimentation.

Those elements and technical elements should be addressed in an integrated approach, on the one hand leveraging specialist companies and individuals, separating concerns, but linking them in an overall approach. The Alliance for Internet of Things Innovation promotes and drives such approach.

Interesting and responsible opportunities emerge for IT professionals, playing key roles in architecture and platform integration and in linking application domain specialists and end-users.