Engineer's Skills for the Internet of Things (IoT)

An Online Continuing Education Course for Engineers

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1 Preliminary Considerations

A new paradigm has appeared over the past decade or more - the "Internet of Things" (IoT) - enabled by technical developments in the fields of telecommunications, software, micro-mechanics, electronics, and data analysis, among others. Concurrent developments in various pairs of those fields have allowed engineers to cross over traditional discipline boundaries and develop novel products that improve the way things are done: the way we develop products, the way the products serve humans, the way we do business, the way we *predict* situations.

The Internet of Things is defined as "a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with *unique identifiers* and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."[i] Additional vernacular definitions have been offered, such as "where the web and the physical world will meet," Industrial Internet, Smart Home, Smart City, etc.

The first documented device connected to a remote data center was a vending machine in the early 1980s[ii]. It functioned more like a technical toy for a limited audience (read: programmers), as it allowed the software programmers to check the fill status before making the trip to the machine to get a can of soda. This concept has evolved from being a "techie hobby" to serving the rest of the world, and the term “Internet of Things” has been introduced in 1999 by Kevin Ashton at Procter & Gamble in the context of linking RFID devices to the Internet[iii].

Today, the IoT technology has already been adopted by numerous industries. They range from the expected (healthcare, energy, transportation, etc.), to less anticipated (agriculture, building management, etc.)[iv]. Going forward, the future forecasts about the IoT impact are bullish. One estimate states that 127 devices are connected to the internet every second[v], while others have predicted that by the next decade, there will be 21 billion connected "things" in use[vi], with IoT generating more than $11 trillion of economic value[vii]. Additional estimates vary significantly (showing a figure of up to 80 billion devices by next decade[viii]), but the general consensus is that the number of connected devices is considerably increasing. The lion share—covering about 30% of that—is taken by the industrial segment, while consumer domains such as Home, Office, Cars, Retail, etc. cover most of the remaining areas. This will be enabled by estimates of having a quasi-100% population coverage of a low powered wide area network by the middle of the next decade[ix].

The optimistic picture painted above has been somewhat corrected in the past few years, as a response to slower-than-expected growth in IoT projects[x]. However, when considering both trends, this can only mean a necessary adjustment to the reality of a too optimistic forecast, given the domain novelty and the industry's lack of readiness to exploit its benefits.

The industry has already recognized that IoT is nothing less than a literal paradigm shift, as it transforms how products are defined, delivered, and used[xi]. The Engineer, more so than the rest of the industry players, must be ready to support the development of this new paradigm. Old

skills are required in new ways, and new skills need to be developed and put into practice to support this new paradigm. Industry estimates show that by 2030, the workplace technical skills will need to be augmented by social and emotional skills. Those estimates show a demand reduction for the physical and basic cognitive skills (~ -30% of current hrs worked) and increased demand in the higher cognitive skills (+8% of current hrs worked), social/emotional skills (+24% of current hrs worked) and high technical skills (a whopping +55% of current hrs worked)[xii].

Building smart, connected devices that better answer the humans' needs… it is clear that this new paradigm is pushing for new ways of work and requires new skills from Engineers. Complexity, managing big data, and lateral thinking are skills that enable the successful implementation of IoT Projects. How will the Engineers get ready to support this new paradigm?

2 Elements of the IoT

So, what makes the IoT? Is the answer “some devices/a few 'intelligent' devices”? or “some data processing across devices”? or "a network of things that communicate amongst themselves"? or "intelligent things that can process data and react accordingly"? The answer is “all of the above” and even more:

- Things - are devices that perform a function useful to the Customers
- Data - is the information transmitted between the Things, as well as between Things and Cloud
- Network - is the web of connections that allows for communication between Things and Cloud
- Cloud – represents storing and accessing data and programs over the Internet, instead of the local hard drive[xiii]
- Process - is the analysis of the data, together with the back-and-forth transmission of the input and output

Put it another way, IoT is a system of systems that work together to provide meaningful functions for the users and society. The IoT elements are illustrated in the following Figure.

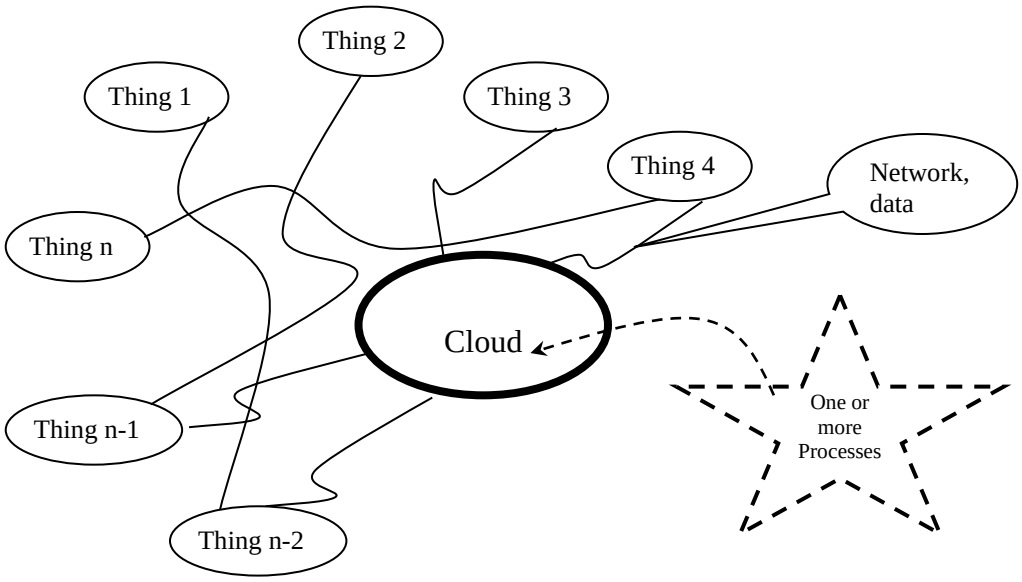

Figure 1: Components of IoT

The IoT has several characteristics:

- it is fully scalable, already enormous and ever-expanding
- it is complex, and its complexity increases as its size increases
- it is very dynamic; constantly changing
- it is heterogeneous, as it runs on a variety of platforms and applications
- network communication requires full security protocols

All IoT elements already existed independently before the public and general industry became interested in the IoT, providing useful service by themselves. However, connecting them in the manner illustrated above adds synergic value to the individual elements, the value of connected IoT elements becomes greater than the sum of its components.

2.1 Things

A "Thing" (or device) can literally be anything that can be connected to any other thing. This can mean not only a physical device but also a being or a piece of application software. The connection relates the Thing's state at a point in time and requires sensors to collect the picture of its status and means to communicate that data. The "Thing," or device, needs to be uniquely identified, and have the ability to interface with other things without human help. At a minimum, it needs to have the following characteristics:

- unique identity
- ability to sense

- ability to communicate

and they need to do the following:

- connect and communicate with other things
- monitor things
- search for things
- manage and control things
- (partial) ability to execute commands

All those elements can only be designed by Engineers who need to employ their (classic or newly developed) skills to answer those needs.

2.2 Data

In a general form, data is defined as "individual facts, statistics, or items of information." While this satisfies every need, this needs to be more specific in the IoT world, so the Engineer can work with it.

In the IoT context, data represents the collection of useful bits of information that is extracted and transmitted by the devices. The devices react to the data they sense, and may even process it before acting on it. However, IoT adds a higher level of usefulness to this (and more complexity), as it allows for data processing in a much l hat considers elements outside a single device. IoT provid tiple inputs (sometimes in the order of millions ew, or all, devices in the network. Thus, better

Data can be in one of otion[xiv]. Data at rest is data stored in a device he internet. It is stored and ready to be used at modified, transformed, or otherwise processed eling between devices or between devices and

2.3 Network, conne

Connectivity is an essent unicate, and enables the expected IoT synergy ks within networks, or across networks. Note may be on isolated networks, thus precluding

Connectivity can be of thr cloud[xv].

- Connectivity of Local Devices