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The Internet of Things – Why Now & What's Next?

This article is based on a Webinar originally presented in July 2015 and available from the IEEE Internet of Things (IoT) portal at URL - http://j.mp/PC_IoTWebinar

Introduction

The technology to connect 'things' to the Internet has existed for more than 20 years, so if we take a look back at recent history we might well be tempted to ask the question why now? In this webinar we examine the origins of the Internet of Things, answer the question "Why Now?", and look forward to the next wave of disruptive technologies that will be coming to a device near you in the next few years.

Peter Corcoran originally worked on connecting Home Network devices to the Internet in the mid-1990's and gave a tutorial on this topic to delegates at the IEEE International Conference on Consumer Electronics (ICCE) back in 2002. With two decades of experience in connecting things to the Internet he is uniquely qualified to answer the questions of "Why Now?" and "What's Next?"

A Short History of the Internet of Things

The term “Internet of Things” (IoT) was first documented by British visionary, Kevin Ashton, in 1999. He used the phrase to describe a system where the Internet connects to the ‘real world’ via an ubiquitous network of data sensors.

Of course the use of this term has grown somewhat beyond the original intention and today it means many things to many people. But to get back to the root of it all we should also consider the “Internet” itself in order to understand the full context of the IoT.

The Beginnings of the Internet

The origins of the Internet go back to the Arpanet in the late 1960’s. By 1970 there were five permanent nodes on the Arpanet at several of the largest US. Learning from these early days the researchers realized they needed to build a robust data protocol that could recover from transmission errors.

In 1974 Vint Cerf introduced TCP/IP but it was a decade later before it was broadly adopted across the network and the real growth could start. In 1984 the c.1,000 active network nodes on the early “Internet” switched over to adopt TCP/IP for their core data transmission and networking protocol. And since then the network has continued to grow unabated.

There are two key things to remember about the Internet: (i) the “Internet” is not the Web; you can think of the Web as a GUI for the display & publishing of data carried by the Internet but the underlying data transports, in particular TCP/IP, are what have allowed the Internet to scale; (ii) the “Internet” was designed to military specifications as a ‘battlefield’ protocol; it is designed to be able to adapt to unreliable channels and to recover from data loss.

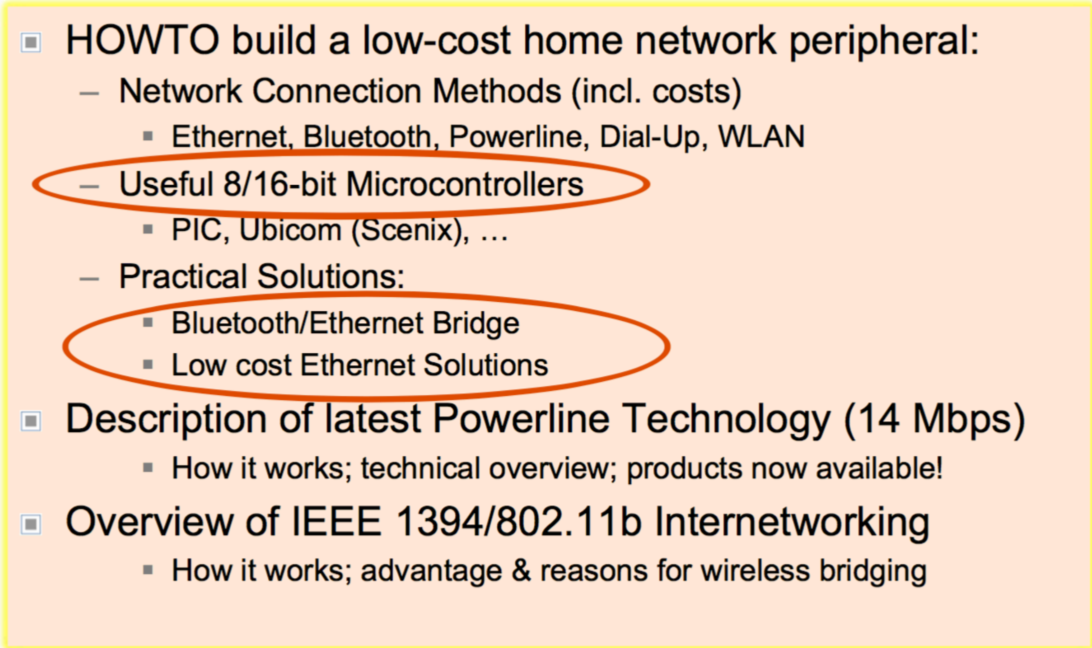
This last point has allowed the “Internet” to grow consistently over the last 4-5 decades and the introduction of mobile devices has further driven this demand. In fact you could say that today a computer is pretty useless without Internet connectivity and that underlying connectivity is provided by TCP/IP.

Time Travel & Connecting Things in 2002

In the introduction it was mentioned that the capability to connect things has been available for at least 2 decades. Back in 2002 I organized a tutorial session on exactly this topic.

As there were 7 separate presentations I can’t cover the entire contents here, but it is interesting to look back at some of what we thought were the key enabling technologies at that time. Figure 1 shows a slide from this tutorial.

You’ll note in 2002 that ‘things’ were based on 16-bit, or even 8-bit microcontrollers. Yes, it really was possible to squeeze a (limited) TCP/IP stack into these devices! In fact a full presentation at this tutorial was devoted to comparison of different approaches to implementing a low-resource TCP/IP stack.



The second point to note is that Ethernet was viewed as the most practical approach for consumer devices. For wireless we considered a Bluetooth to Ethernet bridge. This focus was based on the cost factors shown in Figure 2. Note the cost of a hardware Ethernet was low enough to be considered for mass-market products and Bluetooth was almost cheap enough to be considered. Wifi was far too expensive being 10’s of USD even in high-volumes.

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Common Home Networking Technologies – Unit Costs (2002)

Network Type	Speed	Wiring Needs	Production Cost	End-User Cost
Bluetooth	< 1 Mbps	None	<$8	$75-$100
Ethernet	10/100 Mbps	Category 5 UTP	$2-$15	$25-$50
Phone-line	10 Mbps	existing phone	$20-$30	$45-$75
Power-line (Intelogis)	50-350 Kbps	existing electrical	$15	$25
Power-line (Intellon)	14 Mbps	existing electrical	$25	$100
Wireless Ethernet (SWAP)	1-2 Mbps	None	$25	$70-$200
Wireless Ethernet (Wi-Fi)	11 Mbps	None	$30-$45	$100-$300

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Now it's a useful point to ask why IoT didn't happen in 2002? The Internet was available as were the embedded systems, the TCP/IP client stacks and suitable low-cost connectivity technologies.

So why didn't the pieces fit together? It is clear that simply connecting "Things" to the network doesn't necessarily add enough value to create sustainable business models – if it did then IoT would have happened back in 2002.

To find an answer we'll have to ask what is different now.

But first lets re-activate our time machine and go even further into the mists of past time.

Time Travel & Connecting Things in 1996

Back now to the mid-1990's, in fact to a time pre-dating Kevin Aston coining the phrase "Internet of Things", where a geeky university lecturer and his students were working on powerline networking and playing around with early versions of the Linux operating system.

They came up with the idea to connect devices on a CEBus powerline network with the Internet [1], [2]. But what to do once you connect devices and you are a CE person? Well you'll want to be able to access, control and show the state of those devices and, if you think about it a bit you'll need to provide a graphical user interface [3]. After all, if you can't get access to controla thing, it doesn't really count as a CE system.

Another key aspect of gluing such local networks to the wide-area Internet is that individual network objects have a local state and this has to be synchronized with an external state of the network that is exposed as a control interface. This requires a separate virtual data structure, known as a 'metadevice', to provide a memory of the individual device state [4]. Conveniently, this data structure can also be mapped onto a user interface that is readily accessed through a Web browser [3], [5]. And a 'metadevice' can inherently act as an agglomerator for multiple devices.

Some more specific examples are given in several later papers where methods to combine multiple user interfaces into a single metadevice are explored [6]–[9]. One nice aspect of this approach is that different control devices can update the state of a metadevice independently as control messages are sent over TCP/IP. No more fighting over the remote control, as any device that is TCP/IP enabled can be the remote control!

But I digress a bit. It is clear that the enabling technology for IoT existed not only in 2002, but in fact 6-7 years earlier it was also available and arguably in a more capable, functional and scalable form than many of today's IoT solutions. So if the technology existed and there has been no new disruptive breakthrough then we arrive at the same question - why IoT didn't become a commercially successful technology before now?

Why Now? What is Different?

Here we start to get to the nub of matters – the world wasn't ready for IoT in the 1990's or in the early 2000's, so what has changed in the meantime? If you know me you may already know that I've been a bit of an IoT skeptic in recent years, but now I begin to see some things that are changing my views.

To get a better understanding and context lets recap what we know hasn't changed a lot:

The Internet is still pretty much the same; it got bigger and more technologies have been layered on top of TCP/IP and its little brother, UDP. We have a lot of support now for audio and video traffic which shows that the capacity and capability of the infrastructure has increased, but there have not been any radical changes – just a constant growth of nodes and data traffic.

Embedded devices haven't changed radically either. Yes, we have moved to 32 bit systems and most embedded devices can easily support a sophisticated OS, but the underlying connection is still via a TCP/IP stack which was available nearly 20 years ago for 8/16 bit devices.

Connectivity technologies have improved but not radically. Yes, we can now have more sophisticated Wifi connections for less than 5 USD, but you could have achieved a wireless link in 2002 using Bluetooth and an Ethernet bridge. But there isn't anything disruptive here that would argue that IoT will become a commercial success today.

So what is different? Because, if IoT is to be successful in 2016 there should be something new and disruptive to add to the mix or history will be doomed to repeat the failures of the past!

A First Difference – Cloud Computing

I've written elsewhere about the synergies between CE and 'the Cloud' [10]–[14]. Interestingly this is another computing concept that has its origins back in the 1960's but only became a reality in the last decade. Today, there is no doubt that 'the Cloud' is now a part of most of your daily activities.

Most of us have at least one 'cloud mail' account – I have 7 separate accounts on Gmail, each with its own purpose – a different face on my complex work & personal life(s). Many of us also make use of file sharing services such as Dropbox, iCloud, Google Drive – and there are quite a few others. In fact large corporations are fighting hard to host your data because this ensures they can keep you as a customer – well, you do need your 'data' these days, don't you!

And did I mention photos & video? We are now the main generators of content for "the Cloud" [10]. And video and images are the main drivers of storage & infrastructure.

In fact, I said earlier that computers aren't much use these days without a network connection; in the last 5 years it seems that we are seeing a new phenomenon – the data itself is leaving the computer and moving to the network!

And if you've started using 'the Cloud' in any serious way you'll quickly realize that it is quite empowering to have all of your data available in one place and from any device. So once you start using these services more and more of your day-to-day data tends to get sucked up into Cyberspace.

A Second Difference – Mobile Devices & Data Networks

The iPhone was only launched in 2007. Think about that for a moment. It is less than a decade ago, and the first iPhone wasn't actually that great if we reflect back on this technology. But it started something amazing!

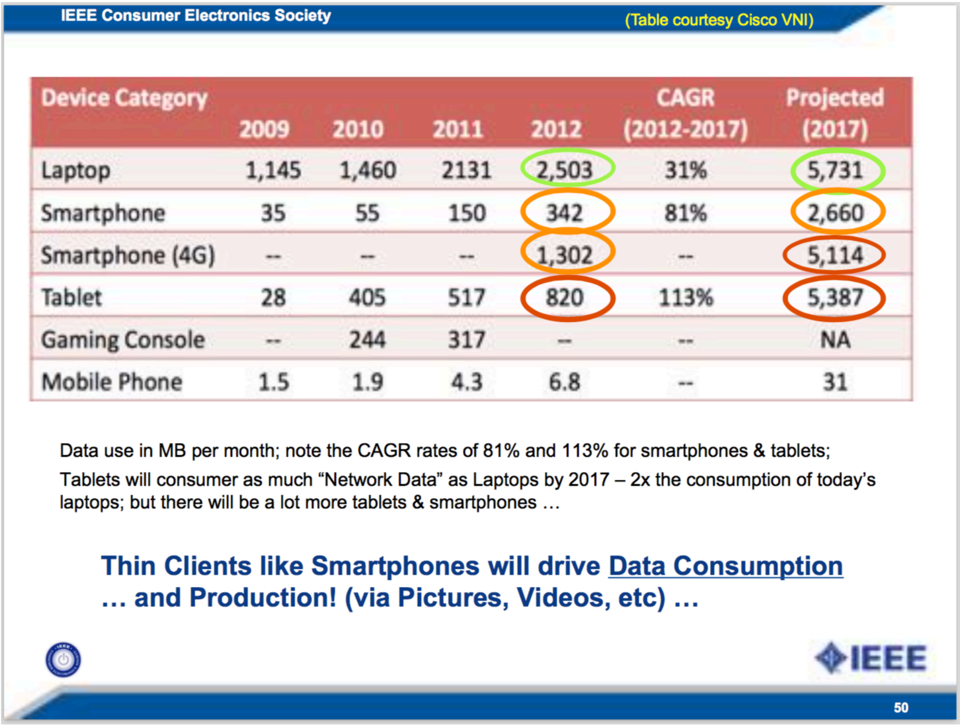
Now consider life without your smartphone? No wonder that more smartphones have been manufactured than there are people on the planet!

Smartphones have changed all of our lives in very significant ways. They combine multiple functions into one device providing a phone, a camera, a video recorder, an alarm clock, a personal music player, a calendar & personal organizer, a map & travel planner, a messaging/paging system, a TV remote control, and so on. In fact there isn't much that you can't do with today's smartphone and the manufacturers are working on fixing that!

And you always have it with you, don't you! No doubt that smartphones are a disruptive technology!

So in Figure 3 we show a table with the data transfers per month from a range of devices. The table is a couple of years old [15] but it captures the spirit of data growth on the Internet.

If you look at the 2012 numbers in Figure 3 you see that a laptop was generating about 2.5 GB of network data; by 2017 it was predicted to be generating nearly 6 GB. But the real story lies with the 4G smartphones and tablets both of which will be over the 5 GB threshold by 2017. Now the real story is that there were only 0.6 billion laptops in 2012 and market growth is low. In contrast there will be of the order of 2B active tablets by 2017 and likely 4-5 billion smartphones.



Device Category	2009	2010	2011	2012	CAGR (2012-2017)	Projected (2017)
Laptop	1,145	1,460	2131	2,503	31%	5,731
Smartphone	35	55	150	342	81%	2,660
Smartphone (4G)	--	--	--	1,302	--	5,114
Tablet	28	405	517	820	113%	5,387
Gaming Console	--	244	317	--	--	NA
Mobile Phone	1.5	1.9	4.3	6.8	--	31

Data use in MB per month; note the CAGR rates of 81% and 113% for smartphones & tablets; Tablets will consumer as much "Network Data" as Laptops by 2017 – 2x the consumption of today's laptops; but there will be a lot more tablets & smartphones …

Thin Clients like Smartphones will drive Data Consumption … and Production! (via Pictures, Videos, etc) …

So what is the conclusion from this? Well there will be continuing exponential growth of network data for the next few years, as the user becomes the main source of 'added-value' data.

Summary: What is Different ... from 1997 or 2002?

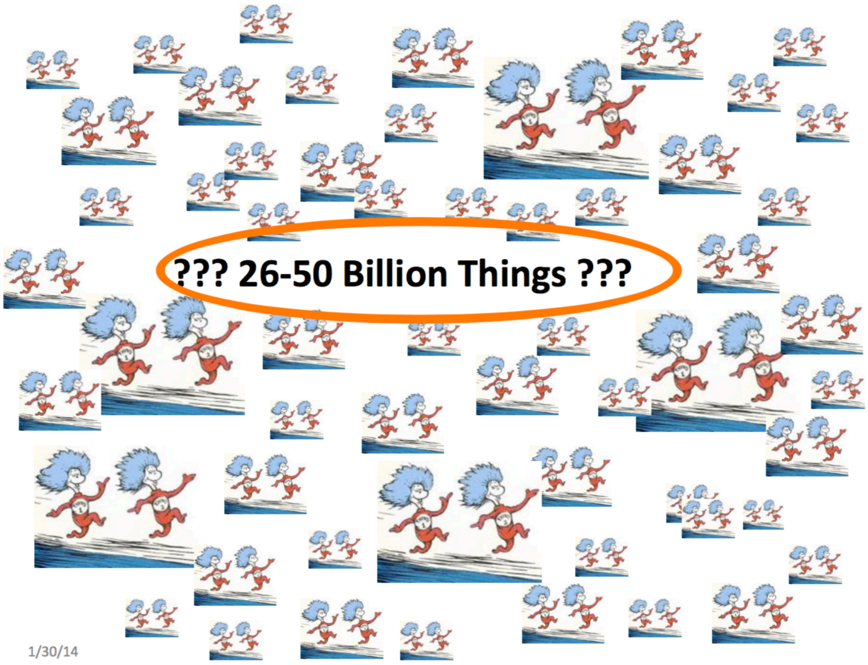
So let sum these up:

- The Cloud has evolved a set of **sophisticated infrastructures** for storage, messaging, security, content & connectivity
- Mobile networks have driven **ubiquitous connectivity**
- Smartphones provide the **user interface** (and a **gateway** for some devices) to access, manage and control our "Things"
- And the Internet means this new infrastructure is accessible everywhere ... truly Ubiquitous!

Predictions, Ubiquity and the Peak of Inflated Expectations

You don't have to go far to find some pretty amazing predictions for the adoption of 'things'; Gartner has predicted 26 billion units by 2020; Cisco has an even higher estimate of 50 billion.

Of course it depends on (i) what you consider to be a "Thing" and (ii) what you consider to be 'connected to the Internet'. If we include devices connected to secondary networks such as Bluetooth, RFID nodes and Home Networks such as Zigbee, 6LoPan and others, well then these estimates start to make some sense. Data can certainly make its way from such secondary networks onto the Internet.



So if you accept these figures consider the potential impact of such a significant growth in network devices and data. We already saw that 3-4 billion smartphones would create a lot of data, but this number of new devices – many of them working 24/7 – will definitely stress today's network infrastructures.

So if IoT does happen it is going to be BIG! Maybe even BIGGER than the smartphone revolution? You can find a lot more examples of different examples of 'things' in the last part of my webinar at: *http://j.mp/PC_IoTWebinar*

Scary Stories, Future Concerns and Key Challenges for 'Things'

Its likely a safe bet to say that the number of 'things' that are connected to the Internet is only going to increase, so whether we see a big step-up in the numbers of connected devices over the next 1-2 years it will surely happen over the next 10-20 years. This leads to some very real concerns that magnify trends that are already developing since the 'smartphone revolution'.

Privacy & CyberSecurity

So when every device is connected and equipped with a wide range of sensing technologies how will be manage and preserve individual privacy? As cameras grow smaller and smaller and wearable technologies become practical how will you know who is recording your meetings and interactions with other persons?

We've seen recent articles in CE Magazine discussing examples including the use of Google Glass to observe and learn user PIN numbers; the NEST thermostat can be hacked and knows when you are, and aren't at home; home security and baby monitor cameras are easily hacked and in many cases they stream open, un-encrypted video data in well known H264/MPEG formats. Anyone with a moderate technical skill level can intercept you home security video and learn if you are home!

Most connected devices are secured with a factory-supplied default username + password. Users rarely change these as they will 'have to remember" a new username and password. So to hack many devices you simply log on as 'admin' and type in 'password'; on other devices these default values are written 'on the box'. So our first major concern is that of privacy and cyber-security – the two are intertwined and properly designed security protocols will support and benefit privacy on a device.

Energy Issues

There are going to be many different types of 'things' but we can be sure of one aspect of each type of 'thing' – they will all use energy.

The amount will vary, but the reality is that devices must either be connected to a fixed power line or incorporate a battery. The former implies a fixed installation and potentially a new wired power infrastructure will be needed to match the requirements of these ‘things’; the latter implies another device that will need to have its battery charged or changed on a regular basis.

But the energy use of the ‘things’ themselves is only part of this equation – to accommodate a growing number of IoT devices the existing wireless infrastructure will have to expand, and as most of these devices will use wireless connectivity for convenience it is the wireless communications infrastructure that has to grow, and potentially grow quite rapidly. And it is this same infrastructure that is the main driver of global electricity consumption [15].

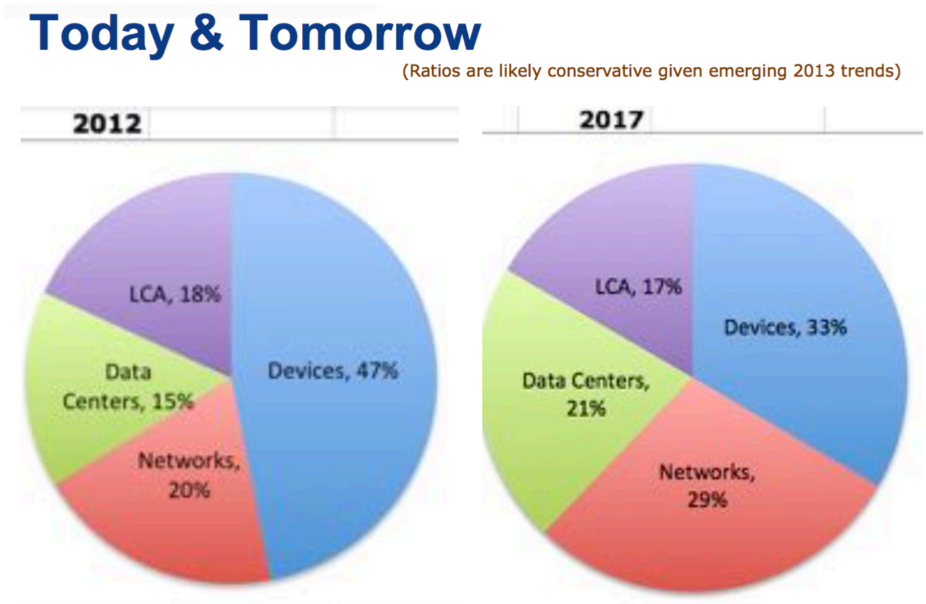


Figure 5 shows how the balance between operational energy usage, networks and data centers will change under the influence of smartphone & tablet growth up to 2017.

Note how network energy increases from 20% to nearly 30% over a few short years. If the activity of 3-4 billion smartphones can cause such a shift then 50 billion ‘things’ is going to impact energy consumption of the network infrastructure by a similar or larger measure so we could be moving towards the era where 50+% of energy is due to the network!

Remember that many ‘things’ will run 24/7 and consume energy continuously. Even if the devices themselves are quite low power they need a communications infrastructure that is not so low-power and in many cases a cloud data service that also can use significant amounts of energy.

Concluding Thoughts

As a long-term IoT skeptic – at least since the early 2000’s - I recently agreed to give a Webinar on this topic. As a consequence I had to examine and re-think many of my arguments based on the last 2 decades that I spent “waiting for the IoT”. In this article I’ve explained how I came to a modified view on the Internet of Things.

Yes, it might just actually be starting to happen, driven by a combination of improved “Cloud” infrastructure, the smartphone revolution and recent improvements in mobile data networks. There are still multiple barriers and challenges in the short term but, after all, that is what engineers live for and there isn’t anything that can’t be resolved given the state of todays embedded systems and networking technologies.

However there are two key societal challenges – privacy/security and energy consumption. These are often lost in the current ‘excitement’ that surround IoT but ultimately these will prove to be the key challenges that determine the long-term sustainability of the Internet of Things.

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