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<th><strong>Title</strong></th>
<th>The Internet of Things: why now, and what's next?</th>
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<td><strong>Author(s)</strong></td>
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The Internet of Things;  
Why Now? & What’s Next?

Peter Corcoran, Statutory Lecturer at NUI Galway,  
Editor-in-Chief IEEE Consumer Electronics Magazine,  
Fellow IEEE and Board Member IEEE CE Society  
Distinguished Lecturer IEEE Consumer Electronics Society
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?"
Who am I?

- Professional Volunteer (Electronic & ICT Engineer)
  - Member Board of Governors, IEEE Consumer Electronics Society
  - Editor-in-Chief, IEEE Consumer Electronics Magazine

- Day Job(s):
  - University vice-Dean (2005-2012) & Statutory Lecturer
    - Entrepreneur, Inventor & Technologist
  - Industry Consultant
Where am I?

- E-Mail:
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  - cesmagazine@ieee.org
  - pcor00@gmail.com

- Google Scholar (search ‘Peter Corcoran’)

- LinkedIn:
  - http://www.linkedin.com/in/cregg

- Twitter & Facebook
  - I don’t use these very much …
Today’s Talk

1. A short History of the ‘Internet of Things’?
2. Why Now? What is Different … ?
   – 2.1 What is the Cloud?
   – 2.2 Mobile Data & Smartphones (the first ‘Things’)
3. What is Next?
   – 3.1 The IoT Today – Predictions & Examples
   – 3.2 Scary Stories - where the “Internet” & “Things” are Heading …
     – Privacy, CyberSecurity and Protecting our Digital Lives
     – Energy Consumption
1. A SHORT HISTORY OF THE ‘INTERNET OF THINGS’?
Kevin Ashton coined "Internet of Things" phrase to describe a system where the Internet is connected to the physical world via ubiquitous sensors.

The term “Internet of Things” was first documented by British visionary, Kevin Ashton, in 1999.
The Internet of Things isn’t New … ?

Let's start with a history of the Internet …
Brief History of the Internet

- 1968 - DARPA (Defense Advanced Research Projects Agency) contracts with BBN (Bolt, Beranek & Newman) to create ARPAnet
- 1970 - First five nodes:
  - UCLA
  - Stanford
  - UC Santa Barbara
  - U of Utah, and
  - BBN
- 1974 - TCP specification by Vint Cerf
- 1984 - On January 1, the Internet with its 1000 hosts converts en masse to using TCP/IP for its messaging
The ‘Internet’ is NOT the ‘Web’ …
Note that Vint Cerf & Tim Berners-Lee agree on this!
Concept: TCP/IP Protocol Stack
TCP/IP is a Military Technology – designed to operate in uncertain environments with built-in redundancy & robustness …
Being Robust, Reliable & Scalable it naturally grew in size:

Growth of Internet Hosts *

No. of Hosts

Time Period

IEEE Consumer Electronics Society
So what is the Internet?
A LAYERED NETWORK OF NETWORKS

We are on the periphery of this Infrastructure …
Do you recognize any of the above?

GLUED TOGETHER BY A SUITE OF TCP/IP PROTOCOLS
The 1\textsuperscript{nd} main point for today!

- Computers aren’t much use any more without the network ....
- .... And the network is TCP/IP
So what are these “Things” that I keep hearing about and what do they have to do with the Internet … ?
Three Things …

… Which can connect to the Internet?
Back in 2002 I gave a Tutorial to the IEEE International conference on Consumer Electronics (ICCE):

Let take a look …
Time Machine Activated …
Setting co-ordinates …
Actuating …

DESTINATION TIMEZONE ACHIEVED …
Agenda (2002)

- HOWTO build a low-cost home network peripheral:
  - Network Connection Methods (incl. costs)
    - Ethernet, Bluetooth, Powerline, Dial-Up, WLAN
  - Useful 8/16-bit Microcontrollers
    - PIC, Ubicom (Scenix), …
  - Practical Solutions:
    - Bluetooth/Ethernet Bridge
    - Low cost Ethernet Solutions

- Description of latest Powerline Technology (14 Mbps)
  - How it works; technical overview; products now available!

- Overview of IEEE 1394/802.11b Internetworking
  - How it works; advantage & reasons for wireless bridging

<table>
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<tr>
<th>Network Type</th>
<th>Speed</th>
<th>Wiring Needs</th>
<th>Production Cost</th>
<th>End-User Cost</th>
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<tbody>
<tr>
<td>Bluetooth</td>
<td>&lt; 1 Mbps</td>
<td>None</td>
<td>&lt;$8</td>
<td>$75-$100</td>
</tr>
<tr>
<td>Ethernet</td>
<td>10/100 Mbps</td>
<td>Category 5 UTP</td>
<td>$2-$15</td>
<td>$25-$50</td>
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<tr>
<td>Phone-line</td>
<td>10 Mbps</td>
<td>existing phone</td>
<td>$20-$30</td>
<td>$45-$75</td>
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<tr>
<td>Power-line (Intelogis)</td>
<td>50-350 Kbps</td>
<td>existing electrical</td>
<td>$15</td>
<td>$25</td>
</tr>
<tr>
<td>Power-line (Intellon)</td>
<td>14 Mbps</td>
<td>existing electrical</td>
<td>$25</td>
<td>$100</td>
</tr>
<tr>
<td>Wireless Ethernet (SWAP)</td>
<td>1-2 Mbps</td>
<td>None</td>
<td>$25</td>
<td>$70-$200</td>
</tr>
<tr>
<td>Wireless Ethernet (Wi-Fi)</td>
<td>11 Mbps</td>
<td>None</td>
<td>$30-$45</td>
<td>$100-$300</td>
</tr>
</tbody>
</table>
In this Presentation we are going to take a look at how to choose a TCP/IP stack in practice.

To do this we will consider and compare a number of available commercial solutions:

- **uP Specific Solutions** – Microchip PIC, Ubicom IP2022
- **Open Software Solutions** – uIP is a “free” micro-TCP/IP stack
- **Hardware Solutions** – Seiko iReady is a TCP/IP LSI chip
- **Enhanced Solutions** – NodEM TCP/IP from Yippee Inc

Important aspects of a stack are:

- ROM (program) and RAM (memory) usage
- Stack-type:
  - blocking or non-blocking;
  - single or multi-tasking
- Modularity – how easy is it to customize to end-user requirements
- Portability – how well does it work on different hardware
Why didn’t IoT Happen in 2002?

- We had the ‘Internet’ …
- We had the Embedded Systems …
- … and the TCP/IP stacks…
- … and the ‘connectivity’ technologies …

- Why didn’t the pieces fit together … ?
The 2\textsuperscript{nd} main point for today!

- Connecting “Things” to the network doesn’t necessarily add enough value to create sustainable business models ....

- .... something is still missing???
Time Machine Activated …
Setting co-ordinates …
Actuating …

DESTINATION TIMEZONE ACHIEVED …

Fig 2: Overview of the Software and Hardware components which make up the Gateway.
Peter M. Corcoran, and Joe Desbonnet; "Browser-style interfaces to a home automation network." Consumer Electronics, IEEE Transactions on 43.4 (1997): 1063-1069.
What an ‘object infrastructure’ looks like – nearly 20 years ago! ("Browser Style Interfaces to a Home Automation Network")

Fig. 4 An Enhanced Device Browser can provide very detailed access to the CAL Object Structure of Appliances connected to a Home Automation Network.
And on a Workstation Terminal ...

... each window links to a device!

(LATER IN THE YEAR)

1997

Fig. 8 The Device Browser described in 3.3 is shown with two single-context HiPlets, A Keypad and a Display.
The 3\textsuperscript{nd} main point for today!

– The technical capabilities to implement quite sophisticated “Things” were available in 1990’s …

– The technology has been commoditized since then, but no ‘rocket science’ disruption …
2. WHY NOW ... ?
WHAT IS DIFFERENT ... ?
The Internet is growing even faster …
… in turn this has driven associated infrastructure.
2.1 WHAT IS ‘THE CLOUD’?

Key infrastructure such as … “The Cloud”!
Almost all the modern-day characteristics of cloud computing were thoroughly explored in Douglas Parkhill's 1966 book, *The Challenge of the Computer Utility*. Parkhill was the first to draw a comparison to the electricity industry and the use of public, private, government and community forms, elastic provisioning and the illusion of infinite supply.

The first scholarly use of the term cloud computing was in a 1997 lecture by Ramnath Chellappa. He defined the term cloud as a computing paradigm where “... the boundaries of computing will be determined by economic rationale rather than technical limits”.

1999 - Salesforce.com pioneered the concept of delivering enterprise applications via a simple website. This made it possible for software firms to deliver applications over the internet.

2002 – 2006: post dot-com bubble, Amazon played a key role by modernizing their data centers to handle the huge surges in network traffic at Xmas. Afterwards the company realized that surplus computing capacity could become a new business for them.
A Corporate Conspiracy … ?
Some Links:

- Cisco – VNI (Visual Networking Index)

- IEEE Cloud Computing
A View Inside ‘The Cloud’
An Occasional Engineer is Seen …
The Cloud now provides key computing infrastructure …

- **Messaging** - cloud-based Mail Services
- **Storage** – virtual storage from all major vendors; prices competitive with personal physical storage!
- **Content & Multimedia** – Photos, Videos, etc
- **In the Background:**
  - **Security Services** to user accounts safe
  - **Tracking & Location Services**
  - **Privacy Services** - enforcement by regulators?
Example #1 – Online E-Mail

Gmail (2004)

- A radical re-thinking of the e-mail service; there were some key user advantages to managing e-mail on a Web server:
  - Access to e-mail from ANY Web browser;
  - No mail client compatibility issues;
  - Management & Admin all “in the cloud”

- Large storage allowance means you don’t have to clean your inbox; Google says you’ll never have to delete any e-mail, EVER!

- Of course Google loves to mine all the data associated with your e-mail!
Example #2 – Online Storage

- Dropbox (2008), Google Drive (2007), iCloud (2011), many others …
  - Software sits on your computer but everything is duplicated at a remote data center;
  - Enables sharing of data between different users;
  - The models facilitates sharing of data between laptop/desktop and mobile devices;
  - You can (almost) forget about data backup as this is part of the ‘service’ …
Example #4 – Online Applications

Youtube (2005)

- User generated video storage; free service!
- Lots of controversy around copyright and related issues, but acquired by Google in 2006 providing 'deep pockets' to resolve teething problems ...
- Continues to grow and build services with a focus around user-video;
- Video is THE underlying growth content driving network infrastructure;
- My kids watch more youtube than regular TV ...
- Many things are best explained in video clip:
  - Minecraft Tutorials; Game Walkthroughs; How-To tutorials for DIY, repair and assembly tasks;
The 4th main point for today!

- Computers aren’t much use any more without the network, and over the last decade ….

- … the data has left the computer and moved to the network as well!
2.2 MOBILE DATA & SMART-PHONES
Why are Thin Client Important?

- Phenomenal Growth rate in Smartphones & Tablets in last few years
- Changing fundamental use patterns of CE-ICT
  - Many consumers now view TV/Movies on ‘small screen’;
  - New Media – youtube, facebook, Netflix, etc …
  - New Services – grocery shopping, games, social networks
- Tablets bring ICT from Desktop into Living Room
- Disruptive Technology!
Data use in MB per month; note the CAGR rates of 81% and 113% for smartphones & tablets;
Tablets will consume as much “Network Data” as Laptops by 2017 – 2x the consumption of today’s
laptops; but there will be a lot more tablets & smartphones …

### Table

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<td>1,145</td>
<td>1,460</td>
<td>2131</td>
<td>2,503</td>
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<tr>
<td>Smartphone</td>
<td>35</td>
<td>55</td>
<td>150</td>
<td>342</td>
<td>81%</td>
<td>2,660</td>
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<td>Smartphone (4G)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,302</td>
<td>--</td>
<td>5,114</td>
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<tr>
<td>Tablet</td>
<td>28</td>
<td>405</td>
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<td>244</td>
<td>317</td>
<td>--</td>
<td>--</td>
<td>NA</td>
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<td>Mobile Phone</td>
<td>1.5</td>
<td>1.9</td>
<td>4.3</td>
<td>6.8</td>
<td>--</td>
<td>31</td>
</tr>
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</table>

**Thin Clients like Smartphones will drive Data Consumption … and Production! (via Pictures, Videos, etc) …**
Growth in Numbers = Big Growth in Data Traffic …

- Today (2012) -
  - c. 600 Million Laptops

- Tomorrow (2017) –
  - c. 2,000 Million tablets (+ c. 1000 Million Laptops)
  - c. 4,000 Million smart-phones (conservative?)

- TV Panels are also becoming “connected”:
  - Smart TV
  - Add-on connectivity: Boxee, Apple-TV, many others …
The 5th main point for today!

- Exponential Growth as ... the user becomes the Main Source of added-value Data!
3. WHAT COMES NEXT?

The “Things” are coming …
3.1 THE INTERNET OF THINGS TODAY – SOME PREDICTIONS
What is Different … from 1997 or 2002?

- 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!
How Ubiquitous?

Gartner: “IoT Installed Base Will Grow to **26 Billion Units** By 2020.” *That number is likely too low.*

- Every mobile
- Every auto
- Every door
- Every room
- Every part, on every parts list
- Wearables cheaper than water
“Thing” connected to the internet

During 2008, the number of things connected to the internet exceeded the number of people on earth.

By 2020 there will be 50 billion.

Sources: Cisco IBSG, Jim Cicconi, AT&T, Steve Leibson, Computer History Museum, CNN, University of Michigan, Fraunhofer

Image Courtesy: CISCO
26-50 Billion Things
The 6\textsuperscript{th} main point for today!

Hang onto your Hat!
We saw 3-4 Billion Smartphones would create a lot of DATA, but ...

IoT is going to be a LOT \textbf{BIGGER}!
3.1 INTERNET OF THINGS TODAY? – SOME EXAMPLES
1. RFID – *Identification* for Things
One Application of IoT/RFID

Scenario: shopping!

1. When entering the doors, scanners will identify the tags on her clothing.

2. When shopping in the market, the goods will introduce themselves.

3. When moving the goods, the reader will tell the staff to put a new one.

4. When paying for the goods, the microchip of the credit card will communicate with checkout reader.
IEEE Consumer Electronics Magazine

April Issue

Protect Yourself from RFID

Fend off frightening tracking tech.

By Katherine Albrecht and Liz McIntyre

A CREEPY NEW SPYING TECHNOLOGY CALLED RADIO-FREQUENCY IDENTIFICATION (RFID) is starting to show up on products you buy at stores like Walmart, and it could be used to track your every move. RFID uses tiny microchips hooked up to miniature antennas to track items a from a distance. This chip and antenna combination is called an RFID tag. Each tag contains an ID number that uniquely identifies the item to which it is attached. It is like a Social Security number for things. RFID tags are tracked by RFID reading devices. These readers gather information from the tags via radio waves, similar to the radio waves that allow you to listen to your favorite FM radio station. RFID radio waves, like FM radio waves, travel invisibly through solid objects such as purses, backpacks, wallets, and shopping bags.

HOW DO RFID SYSTEMS KEEP TRACK OF ITEMS?

RFID readers collect and process information from matching RFID tags whenever they are in reading range. Since each tag contains a unique ID number and is associated with a specific item, it is possible to link items to specific customers at checkout. This makes it possible to track customers using tagged items, like shoes, as a proxy. There are some preliminary plans to watch the tags at all times, long after purchase and anywhere in the world, through a developing infrastructure known as the Internet of Things.

RFID tags are easy to hide. They can be sandwiched in price labels, hidden within the soles of shoes, printed on boxes, and even woven right into fabric and clothing labels [1]. Right now, you might have one in a store loyalty card or credit card and not know it! Most RFID tags get their power from the reader device, so they do not need batteries. With no parts to wear out, they can beam tracking information to RFID readers indefinitely. The readers can also be hidden, and we have seen plans to embed them in floors, doorways, ceiling tiles, and store...
2. Machine-to-Machine (M2)
M2M #1 – The SmartGrid

SMART GRID
A vision for the future—a network of integrated microgrids that can monitor and heal itself.

- Smart appliances: Can shut off in response to frequency fluctuations.
- Demand management: Use can be shifted to off-peak times to save money.
- Solar panels:
- Offices:
- Processors: Execute special protection schemes in microseconds.
- Storage: Energy generated at off-peak times could be stored in batteries for later use.
- Generators: Energy from small generators and solar panels can reduce overall demand on the grid.
- Sensors: Detect fluctuations and disturbances, and can signal for areas to be isolated.
- Wind farm:
- Central power plant:
- Isolated microgrid:
- Disturbance in the grid:
M2M #2 – Smart Factories
M2M #3- Smart Cities
3. Smart-TV & Home Networks
Home Nets #1

Networked lighting can improve your home environment and reduce energy costs …
Home Nets #2 – Home Security

- A Wireless camera that runs up to 4 months on a battery pack;
- Smart – runs in low power mode until some motion is detected;
- Cloud storage so a burglar can’t destroy your image data – a significant advantage of cloud!
Home Nets #2 - Meet Mother
(The scary side of Internet of Things!)
The ‘motion measuring’ gateway with a marketing mission …
... and the Motion Cookies ...

Motion Cookies are the first essential members of the ever growing Sense Mother family.

They have the power to detect and understand the movements of objects and people. Small and slick, they can be affixed to almost anything.
Silly, but claims to solve problems

Walk
Are you active enough to stay fit? Monitor the number of steps you make, the distances you walk, the calories you burn.

Espresso
How many espresso coffees do you brew? Do you drink too many of them in the evening? Get notified before you run out of capsules.

Teeth
Do you really brush your teeth better than your children? Accept the challenge and see who sets the example.

Door
Monitor the access to your home. Get an alert when unusual activity is detected while you are away.
4. Healthcare & Connected Capabilities
Wearable Technologies?
Too Extreme?
The 7th main point for today!

- “Things” come in many shapes and sizes – and I’m only focusing on consumer “Things” ... there are a lot in Industry too!

- The next step is for **connectivity to be the default** for all Embedded Electronics because it will be ‘built-in’ to the chipsets ...

- So you’ll need to **think connected**, because everything “Electronic” will be ...
3.2 SCARY STORIES & FUTURE CONCERNS
If every “Thing” is connected …

- What about Privacy?
  - Google Glass can detect your passwords & PIN

- Personal Security?
  - NEST smart thermostat can be hacked so people know when you are home – Blackhat 2014

- Home Security Cameras
  - recently a Russian Website put up video access to 1000’s of Chinese home security cameras …
  - default passwords so no hacking!
IEEE Consumer Electronics Magazine

April 2015 Issue –

Welcome to the Age of Sousveillance …
Überveillance, the Web of Things, and People

What is the culmination of all this surveillance?

By M.G. Michael, Katina Michael, and Christine Perakis

HISTORICALLY, TELECOMMUNICATIONS COMPANIES have measured voice and data traffic for reasons related to service dimensioning and engineering management. Today, personalized devices make it possible to understand not only the requirements for the capacity needed in a network but also household and individual usage patterns. This has changed the way that companies now market their products and services and sell directly to individuals. Beyond marketing is the intimate knowledge gathered of why people do things, inferred by patterns of life data and metadata. This is the precise knowledge of customer behaviors, habits, and characteristics.

The Internet of Things (IoT) promises even greater connectedness as individual items begin to come alive on a global network, each with its respective IP address. Big data will soon be able to reveal patterns and trends that were previously in calculable. We will seek even greater levels of scrutiny in the not-too-distant future, heralding in an age of uberveillance. We now know much more about consumers than traditional call holding times and the location of an individual user in a mobile network. Using evidence-based approaches, we can know what consumers are thinking, how they are feeling, and even what they will do next with a high degree of accuracy.

Embedded surveillance devices will likely replace clunky mobile and wearable handsets and bracelets, which will introduce an ability to transcend physical boundaries.

Psst... Your Location Is Showing!

Metadata in digital photos and posts could be revealing more than you realize.

By Katherine Albrecht and Liz McIntyre

A PICTURE MIGHT BE WORTH a thousand words, but someone can also pinpoint your X and Y coordinates on a map—even if you'd prefer otherwise. Just ask Internet security mogul John McAfee, creator of the famous McAfee Virus Scan software. His story illustrates how data embedded in digital photographs can lead to big trouble.

After making millions from the sale of his software company, the eccentric McAfee left the rat race and built a beachfront pleasure palace in Belize. There, the sexagenarian reportedly experimented with drugs, entertained young women, kept noisy dogs, and generally did his own thing.

He admitted his dogs annoyed the community, including his closest neighbor Gregory Faull, who often complained about the constant barking. When Faull was found murdered in 2012, the Belize authorities identified McAfee (whom they considered a gun-toting, drug-laced madman) as a prime suspect.

McAfee fled Belize to avoid arrest, using his fame and press connections to take highly publicized jobs at the police along the way. These tales included an article in the online publication Vice Magazine titled, "We Are with John McAfee Right Now, Suckers" [3]. The story featured a picture of McAfee on the lam at an undisclosed jungle location.
A Cybermodel
for Privacy by Design

Building privacy protection into consumer electronics.

By Michael H. Davis, Ulrich Lang, and Sid Sheyeh

Does privacy protection matter in consumer electronics (CE)? What is privacy, how is it valued, and where does it sit in your organization today? Chances are, if you do not have a chief privacy officer or data protection officer, your company is lacking in protecting critical data, let alone observing all the laws and statutory regulations dealing with privacy (e.g., audits, compliance, etc.). Managing privacy is crucial, especially considering the key mandated privacy requirements, such as those concerning personally identifiable information (PII), the Health Insurance Portability and Accountability Act (HIPAA), and the payment card industry (PCI). In addition, the privacy definitions and the policy and enforcement effectiveness are themselves varied and complex, and they change depending on where your data reside—i.e., the state, province, and country. For example, the European Union’s (EU’s) data-protection directive [1] is much stricter than the weak U.S. privacy laws. (Note that if you plan to market a global CE product, you should know about the Safe Harbor Framework.)

How does one start to protect critical data and observe the associated privacy requirements with many of the privacy rules and variables themselves in flux? Where common, ubiquitous privacy requirements are lacking, few (if any) implementation-level, definitive privacy specifications exist for developers to build privacy-enhancing technologies (PETs), including CE. Therefore, we collectively need a global privacy framework to design and measure capabilities; we chose the Privacy by Design (PbD) initiative [2] as an existing international effort to support. We developed a cybermodel that enables the PbD seven foundational principles (described in the “PbD Principles” section). The fair information practice principles (FIPPs) [3] are another set of high-level foundational requirements that are widely referenced and integrated in privacy rules and laws, as are the Organization for Economic Cooperation and Development (OECD) privacy principles [4], [5]. Both need to be accounted for in a cybersecurity for PbD (CyP) model. Thus, CyP

IEEE Consumer Electronics Magazine

Jan 2015 Issue –

Welcome to the Age of Sousveillance …
Using OAuth to provide access control for the Internet of Things...
IEEE Consumer Electronics Magazine

July 2015 Issue –

The Dark Side of IoT

Editorial - “I Am Game of Thrones”
About the risks of our digital lives being ‘stolen’ as easily as a certain hit TV-Series …
The 8th main point for today!

- If Everything is connected...
- ... then everything is exposed to cyber-threats; the #1 priority for the Internet of Things will be **Cyber-Security**
- We already see many cloud services and devices begin to use secured point-to-point links and two-step authentication...
What about Energy Usage … ?

Here is some data from a 2013/14 study I worked on with some other researchers …
Emerging Trends in Electricity Consumption for Consumer ICT (2013)

- In 2010 Global Electricity use was 23,192 terawatt-hours (TWh), 6.5% above the 2009 level (International Energy Agency - 2013).
- Approximately 7-10% of this is due to CE-ICT depending on your information source(s).
- Working Paper at:
  - http://vmserver14.nuigalway.ie/xmlui/handle/10379/3563
  - “Emerging Trends in Electricity Consumption for Consumer ICT” – A. Andrae (Huawei) & P. M. Corcoran (Nat. Univ. Ireland Galway)
But 3 additional ways that CE-ICT uses Electricity ….

- Directly from the mains supply (Operational)
- Manufacturing electricity (Embodied Energy)
- Network connection (Core network + Radio Access Network)
- “The Cloud” (Data Centers)
Today & Tomorrow

(Ratios are likely conservative given emerging 2013 trends)
Final Numbers (CE-ICT) from our Study

- The Future is still in our Hands …
Growth in Internet of Things could Significantly Affect these Results

- Study did not take account of predicted IoT Growth Rates …
- IoT Devices will be significant generators of network traffic on a 24/7 basis …

- Wireless data traffic becomes the main driver of energy consumption for most connected devices (modern electronic devices are very efficient in terms of operating energy compared with older computers & TVs) …
The 9th and last point for today!

- Wireless data costs energy and many IoT devices will use wireless access to connect ...
- For modern devices the network energy cost has significant growth rates; it is already more significant than operational power ...
- After Security, the next most important challenge for IoT is Energy use ...
??? 26-50 Billion Things ???

??? Are We Ready ???
Questions

A full version of this presentation (PDF) is available as well; note that it is significantly larger - c. 30MB