Internet of Things

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Statistics

- Number of people in the world: 7 billion
- Number of PCs: 1.6 billion
- Number of mobile phones: 7.2 billion
- By 2020, number of 'things': 40 billion

What is the IoT?

The Internet of Things (IoT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems [Webopedia]

What is the IoT?

The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices [Wikipedia]

Value of the IoT

Deloitte: Providers in the IoT ecosystem have a largely unexplored opportunity to develop compelling IoT solutions that explore how the ability to collect and analyze disparate data, in real-time and across time, might transform the business.

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Value of the IoT

[Accenture] found that countries could generate up to an estimated US$3.6 trillion in additional value over and above the indication of current trends

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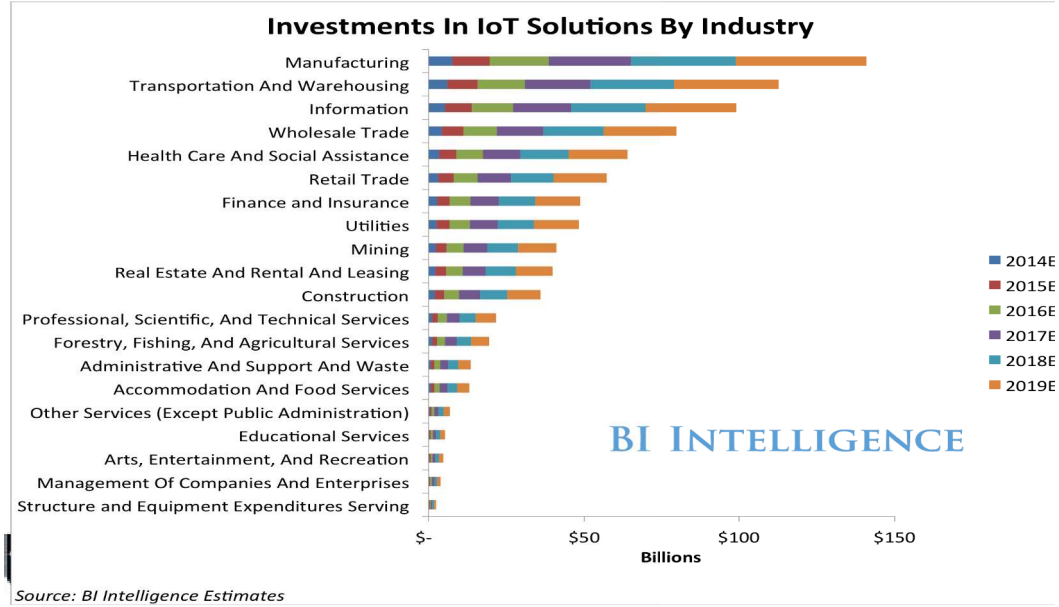
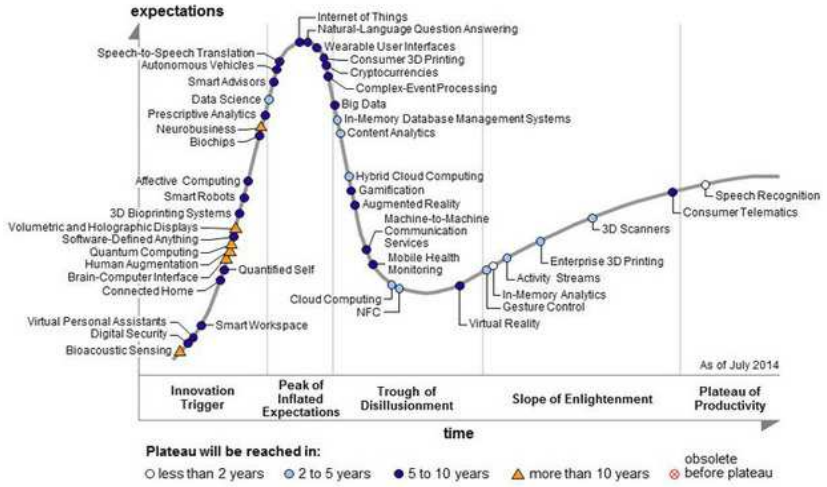
IoT growth areas



Source: BI Intelligence Estimates

Gartner hype-cycle



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Previous peaks

- 2006: Web 2.0 and Folksonomies
- 2009: Cloud computing and ebook readers
- 2012: Wireless power and BYOD

Components of the IoT

- Sensors and actuators to collect data and perform actions
- Network connection from these to the (inter)net
- Processing engines to interpret the data and generate actions

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Example: parking systems

- Melbourne city council has embedded sensors below each parking spot
- The sensor measures the time you park, rather than the time you feed the meter
- More friendly systems will point you to empty parking spaces

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Tracking personal activity

Body sensors include

- Heart monitors
- Walking meters
- Blood pressure meters
- Checking on your baby remotely

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Aged care

- Prevention or detection of falls
- Detection of health anomalies (heart attack, etc)
- Medication management

Environmental monitoring

- Pollution monitoring
- Radiation monitoring
- Monitoring bridge/building structures
- Earthquake monitors

Wine growing

- By adding moisture sensors to each row of plants, a watering system can give customised delivery to each plant

E-textiles

- E-textiles are fabrics that enable digital components (including small computers), and electronics to be embedded in them
- These computers may be used for fashion effects or as part of the IoT

Types of sensors

- Acoustic
- Chemical
- Electrical
- Moisture
- Radiation
- Pressure
- Force
- Heat
- Proximity
- Location
- Velocity
- Acceleration

Some actuators

- Motors
- Heaters and coolers
- Lights
- Electrical switches/relays
- Signals
- Vibrators
- Communications

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Converters

- Analogue to digital
- Digital to analogue

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Device descriptors

- W3C had the Semantic Sensor Network project – dead?
- OIC (Open Interconnect Consortium) has descriptions of ~100 devices
- OGC (Open Geospatial Consortium) has Sensor Web Enablement targetted to geolocation properties
- IPSO (IP for Smart Objects) defines ~20 objects for IoT
- Descriptions are incomplete

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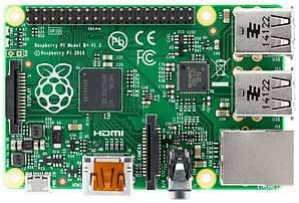
Arduino microcontroller

- Designed as a simple controller
- for sensors and actuators
- Cost A$40
- Has I²C serial bus, RS232, digital I/O pins, analog inputs
- Uses “shields” to extend functionality such as ethernet, wireless, motors, datalogging, ...

Raspberry Pi

- System on a Chip designed for school children
- Cost £25-35
- Has sold over 6 million
- Opened up a new market
- Has 256Mb–1Gb RAM,
- Ethernet, HDMI, USB, now WiFi and BT
- Runs Linux or (1Gb) Windows 10



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Systems on a chip

- CubieBoard

- BeagleBone

- PandaBoard

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Freescale i.MX6 SoCs

- Available in 14x14mm and 9x9mm BGA packages
- Designed for automotive instrument clusters and infotainment systems, as well as medical equipment, industrial HMI, digital signage, and media streaming applications

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Millimetre CPUs

- The Michigan Micro Mote is a computer only 1mm^3
- Realisation of Smart Dust idea from 1992

Communications

Current protocols

Internet

- IPv4
- IPv6
- TCP
- UDP

Wired

- 1-wire, 2-wire

Wireless

- WiFi
- Bluetooth
- Zigbee
- Z-wave

Powerline

- X10, LonTalk

Wireless protocols for IoT

- Bluetooth low energy
- 6LoWPAN (IPv6 over low power PAN)
- Zigbee
- Z-Wave

Networking topologies

- Internet
- Mesh networks
  - Gateway nodes
  - Simple sensors
  - Router nodes

Middleware

Once the data is into the internet, standard middleware tools can be used to manage it

- HTTP, CoAP
- REST, XML
- Javascript
- PHP, Java servlets, ...

Volume of data

- An individual sensor might produce a few bytes of data per minute
- 30 billion of these will produce 15 petabytes per year

Small data volumes

- Small data volumes such as sensors in a house can be handled by devices such as the Raspberry Pi
- Data is usually transferred using protocols such as REST by JSON data over HTTP to a web server
- Results and control are managed through Web pages

Medium volumes

- Larger volumes of data will require more substantive processing
- R as a statistical language is gaining popularity
- Python with the NumPy package is used extensively

Issues of very large volumes

David Roe:

- It tends to arrive as a steady stream and at a steady pace, although it can arrive in batches like test logs that can be processed and passed on straight away
- It comes in very large quantities and accumulates very fast
- The real value can only be uncovered using analytics
- It is rarely used for production purposes
- It is deleted very quickly, unless it is needed for compliance reasons

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Managing very large volumes

- Distributed systems are needed for very large volumes
- Map-Reduce is a common technique
- Hadoop is a major map-reduce processing engine
- NoSQL is an alternative to standard d/b

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Programming languages

- Microcontrollers: C, Assembly, Forth, Basic
- Microprocessors: C, Java, Python, C#, C++, …
- Web: Javascript, PHP, Java, …
- Big data: R, Python, Java

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Programming languages

- Mobile agent languages - see Leppänen
- ELIoT is designed for the IoT

```
Temperature_on_sensor ->
      ask "sensor.corp.net",
            { temperature }
writeln "Temperature is ", temperature_on_sensor
```


Operating systems

- TinyOS (from SmartDust) 1kB RAM
- RIOT 1.5kB RAM
- Contiki 2kB RAM
- Huawei LiteOS 10kB RAM
- Samsung RTOS ?RAM

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Data processing sites

- ThingSpeak is an open source data repository and processing site
- OpenIoT is being built, includes annotating sensor data according to the W3C Semantic Sensor Networks (SSN) specifications.
- Amazon allow you to spin up as many virtual machines as needed
- CKAN is another open source data repository and processing site

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Home automation

- Home automation systems attempt to bring the IoT into the home
- They manage thermostats, lighting systems, security systems, watering systems, ...

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Samsung

- Samsung have committed to having 90% of products will be “IoT devices” by 2017 and 100% by 2020
- Samsung currently uses SmartThings
- SmartThings supply a hub that talks multiple protocols: Zigbee, Z-Wave, IP
- Samsung is committed to “open” solutions

Apple

- Apple uses a system HomeKit integrated into IoS 8
- This is an Apple proprietary system

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Google and Nest

- Google acquired Nest, a maker of “smart” thermostats, smoke detectors, etc
- All Nest devices talk to the Nest servers, so that it maintains a model of your house accessible from anywhere
- The API is proprietary

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Open source systems

- OpenHAB
- Home Assistant
- Many others: OpenRemote, Freedomotic, Open Home Automation, ...

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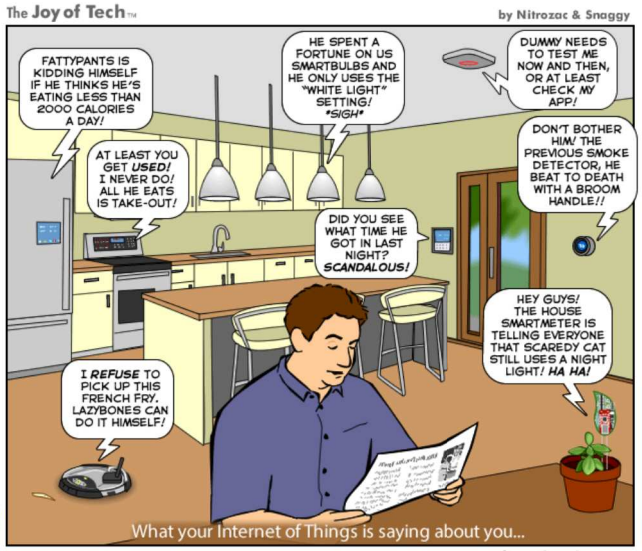
Allseen Alliance

• Art Lancaster: "The AllSeen Alliance believes that consumers should have control over [their] devices and their data"

•Members include: LG, Sharp, Haier, Panasonic, Sony, Electrolux and Sears. Other members include Silicon Image, Cisco, TP-Link, Canary, Two Bulls, doubleTwist, FON, Harman, HTC, LIFX, Liteon, Muzzley, Sproutling, Microsoft and Wilocity [Wikipedia]

Solution looking for a problem?



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Privacy

• With increasingly personal and realtime data, privacy is even more at threat
• “Privacy? Get over it” Scott McNealy, Sun Microsystems
• For a current example, see http://www.abc.net.au/technology/articles/2015/02/19/4183553.htm

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Security

• Basically, stuffed
• A device costing 50c will have no maintainers, no upgrades, no fixes
• Schneier: ‘It’s going to come crashing down’
• With IPv6 everything will be visible

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Scale of vulnerabilities

- Mark Pesce: "*33 billion connected devices means 33 billion attack surfaces*, each with their own exploits, zero day attacks, weaknesses and vulnerabilities"

- Galen Gruman "wait until [hackers] can access building boilers and turn them into bombs, disable our door locks, open our garage doors, turn on sprinkler systems in data centers, and set self-driving cars to crash or simply stay put."

- Chris Grifin: "In November last year, a Russian website streamed feeds from 73,000 unsecured webcams in 256 countries"

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SCADA

- SCADA (Supervisory control and data acquisition)
- SCADA systems are used to control and monitor physical processes, examples of which are transmission of electricity, transportation of gas and oil in pipelines, water distribution, traffic lights, … [Wikipedia]
- SCADA was neither designed with security in mind, nor with networking
- Attacks include Stuxnet in Iran

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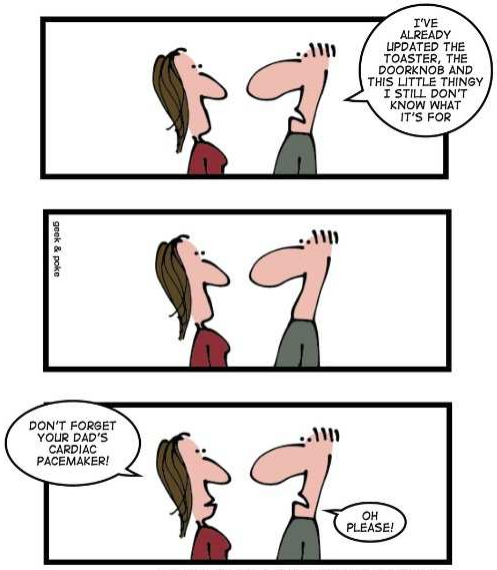
Non-solutions



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Solutions?

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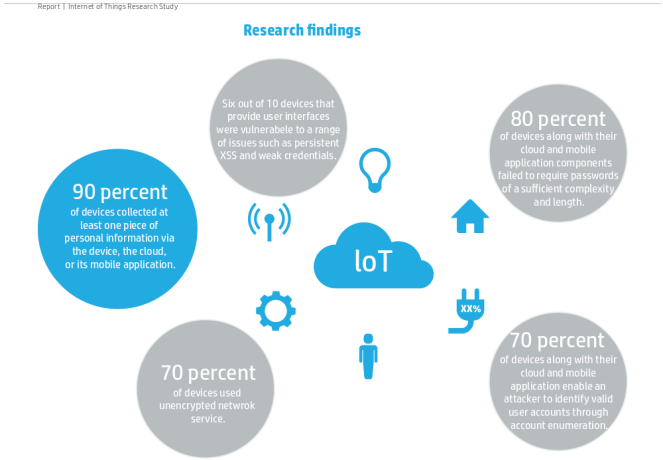
HP Fortify project



VPNs?

- Only a few devices will need to see all of the internet
- Can VPNs be used to group and hide sets of devices?
- VPNs are heavyweight (all encryption systems are), so use power
- Within a VPN there is total trust
- Laptops etc are additionally protected by uid/passwords
- Devices won't have that additional level and may be physically vulnerable

Underwriters laboratory?

Dark Reading: “An Underwriters Laboratories-type safety certification could serve as a basic model for driving Internet of Things product security, according to the White House's national cyber security coordinator.”

RASP?

- RASP (Runtime Application Self Protection) is a category of security mechanisms proposed by Gartner
- “Modern security fails to test and protect all apps. Therefore, apps must be capable of security self-testing, self-diagnostics and self-protection. It should be a CISO top priority”
- Waratek applies this to the JVM in a containerised sandbox

Instruction sets

- ARM cpus can run in two modes: secure and normal
- Intel's Software Guard Extensions extend the instruction set to enforce data security
- Priceton University's Bastion system gives h/w protection to software hypervisors

Secure SoCs

The Freescale i.MX6 UltraLite has

- Secure boot
- Hardware cryptographic cipher engines
- Random number generator
- Tamper detection
- “enabling hardware-verified peripheral and memory access requests for secure isolation and prevention of tainted system resources”
- Uses ARM trusted environment

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Secure Memory

Flash memory has its own processing power:

- Google announced Vault – a secure microSD with ARM chip
- Go-Trust claim they got there first
- GlobalPlatform have a secure specification for Java card multi-application processing

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Programming languages

- Newer programming languages are safer than old ones – no pointers, better type checking, etc
- Some are designed for systems programming:
  - Go
  - Rust

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Operating systems

- Most O/S's are large and insecure
- There are many micro-O/S'es at < 10k
- Redox is a micro-kernel O/S written in Rust
- The NICTA seL4 microkernel has been
  - Proven to be functionally correct
  - Proven to be secure for access control

Virtualisation – type 2

- Type 2 virtualisation runs a hypervisor on top of an O/S
- Examples include VirtualBox, VMware Player, QEMU

Virtualisation – type 1

- Type 1 virtualisation runs a hypervisor on top of bare metal
- Examples include Xen Server, VMware EXSi, Microsoft Hyper-V

Containers

- Containers discard the O/S from the contained system
- Examples include Docker, Ubuntu LXD

Unikernels

- Unikernels discard the O/S completely
- Examples include Rumprun, Mirage O/S, bare metal apps on RPi

Block chains?

- Block chains are used by Bitcoin to validate transactions: only accepted if a majority of blocks in a chain accept it
- IBM's Adept project is exploring these for IoT, with a majority of devices needing to accept a command as valid

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Security by design

- The only real solution is for every stage of design of an IoT system to mandate security as a design issue
- OWASP (Open Web Application Security Project) includes a Top Ten of security issues to be addressed in design and implementation of IoT

Deductive systems

- Complex systems will require the ability to make judgements and take actions
- With IoT these actions will take place in physical space

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Smart rooms decisions

Bill and Linda are watching a pornography movie when their ten year old son enters the room. What does the smart room do?

Smart car decisions

The smart car is driving along a main road at the speed limit when a child runs out onto the road in front of it. What does the smart car do?

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Universities

- Stanford has started a Secure IoT project
- UNSW has an IoT group
- UTS has an IoT Professor
- Deakin has gained a research group from Swinburne
- And more...

Conferences

- IoT World
- IoT Security Summit
- 6th Int Conf on IoT
- IEEE 3rd World Forum on IoT
- 7th Int Conf on Cyber-physical systems

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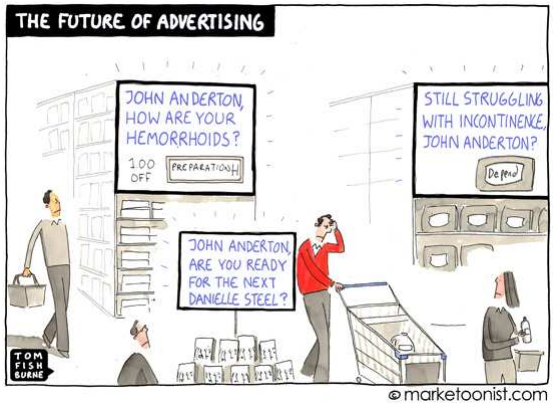
Research issues

- Security
- Interoperability

Conclusion

The IoT is definitely coming, but what kind of future it will build is unknown



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