The Internet of Things: Toward a Better-connected World?

George Weir

george.weir@strath.ac.uk

University of Strathclyde Glasgow

IARIA ComputationWorld 2026

Far-background

- 1970s**:** ICL mainframe computer
- Early 1980s: DEC PDP11 mainframe
- Late 1980s: VAX 1100 then Sun Workstations
- 1980s:
  - Vint Cerf
  - Richard Stallman
  - Doug Englebart
  - Tim Berners Lee

Dr George Weir

Background and foreground

- **My research background:**
  - Human Computer Interaction, AI, Internet of Things, Cloud Security, Cybercrime, Digital Forensics

Dr George Weir

- **My foreground**:
  - Computer and Information Sciences
  - Criminology
  - Local Government

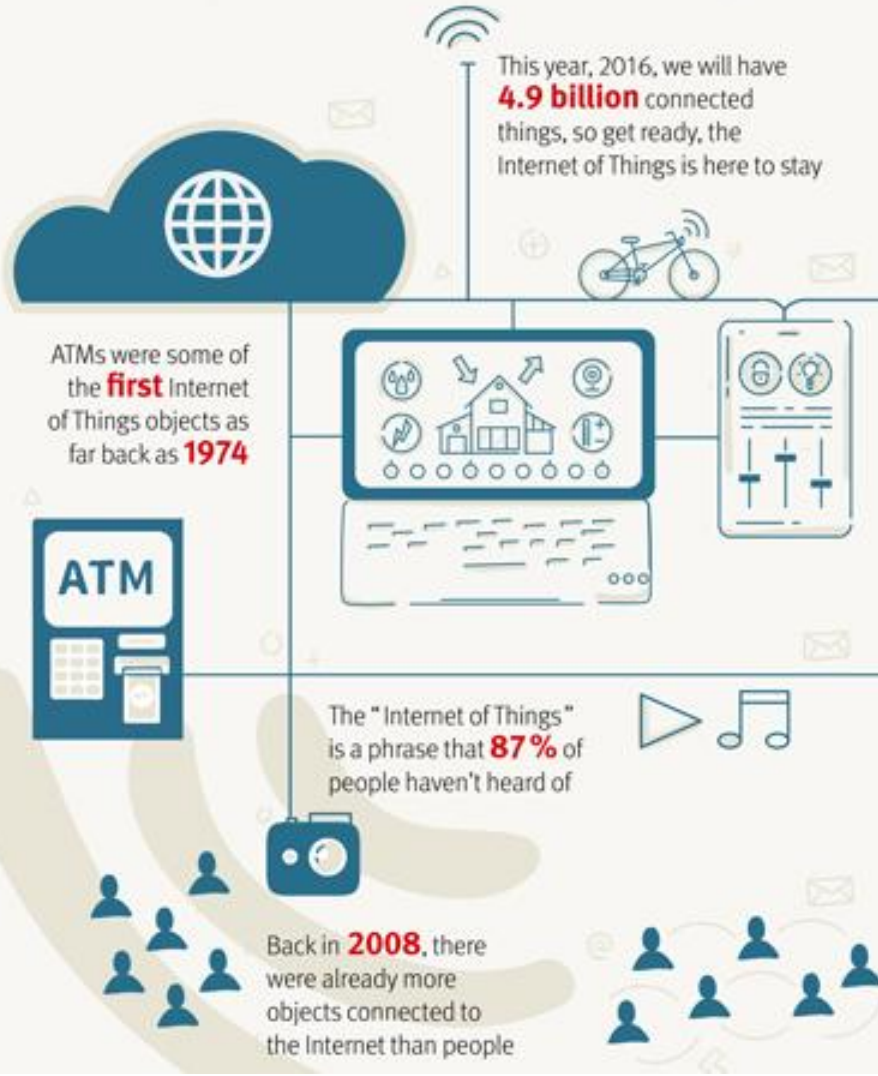
University of Strathclyde Glasgow

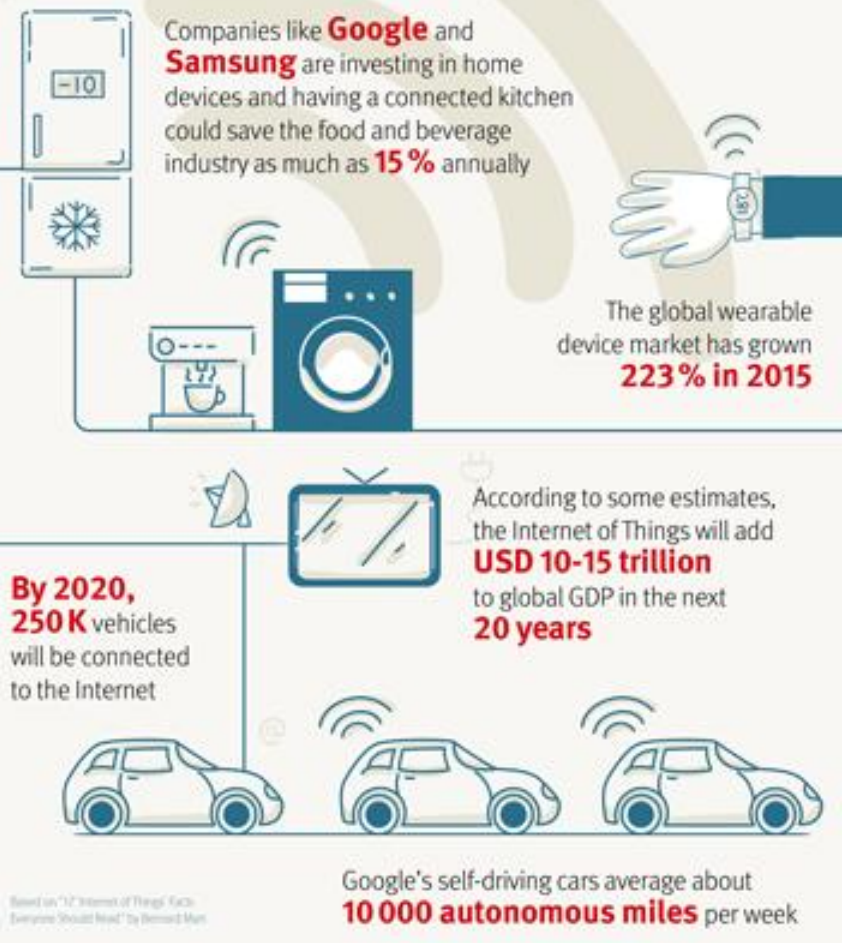
SFU SIMON FRASER UNIVERSITY
SCHOOL OF CRIMINOLOGY

south AYRSHIRE COUNCIL
Comhairle Siorrachd Àir a Deas
Making a Difference Every Day

The Internet of Things
a very short story

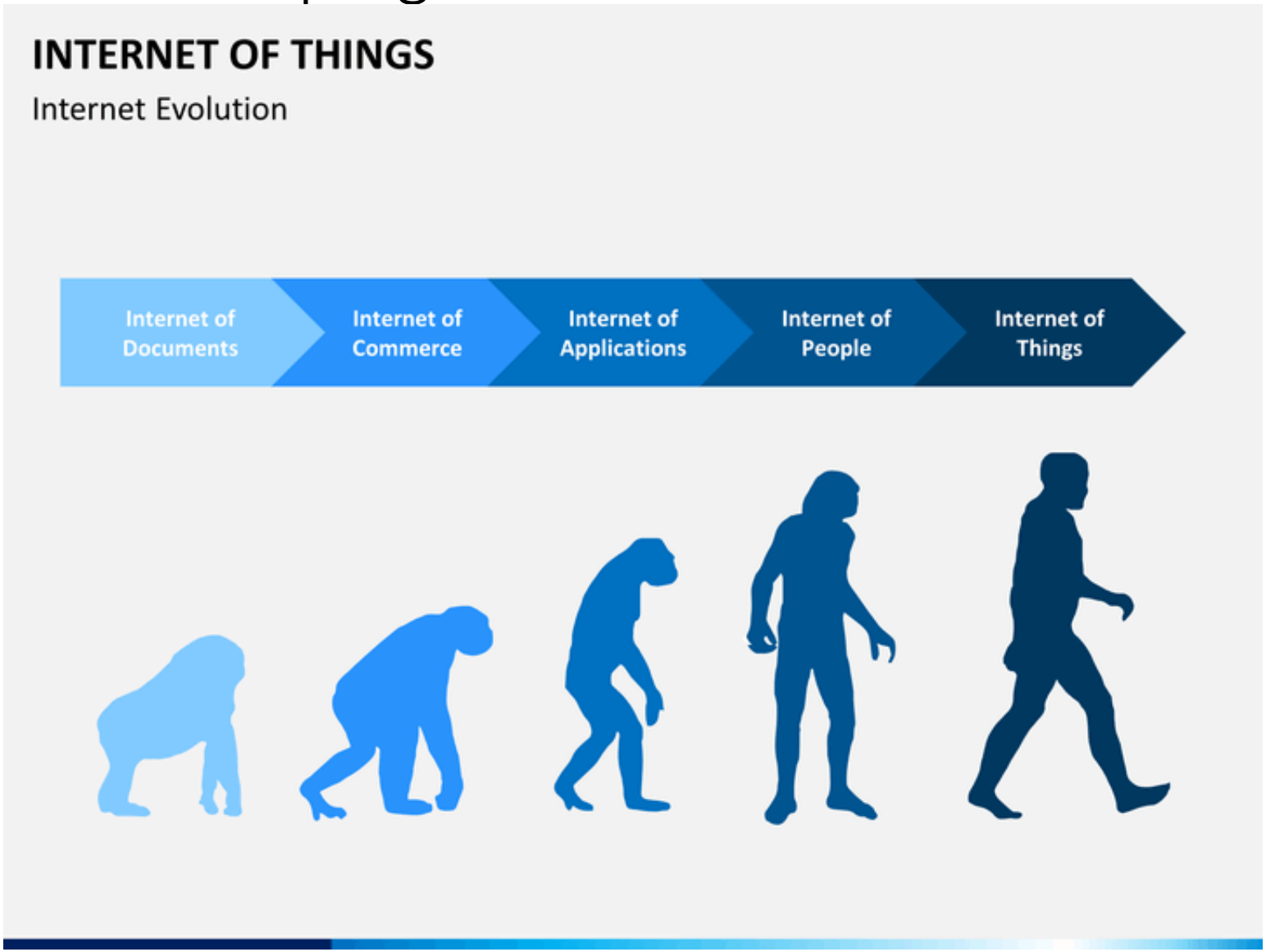
The Internet of Things is the network of physical devices, vehicles, buildings and so on embedded with electronics, software, sensors and network connectivity that enable these objects to collect and transmit data via the Internet.

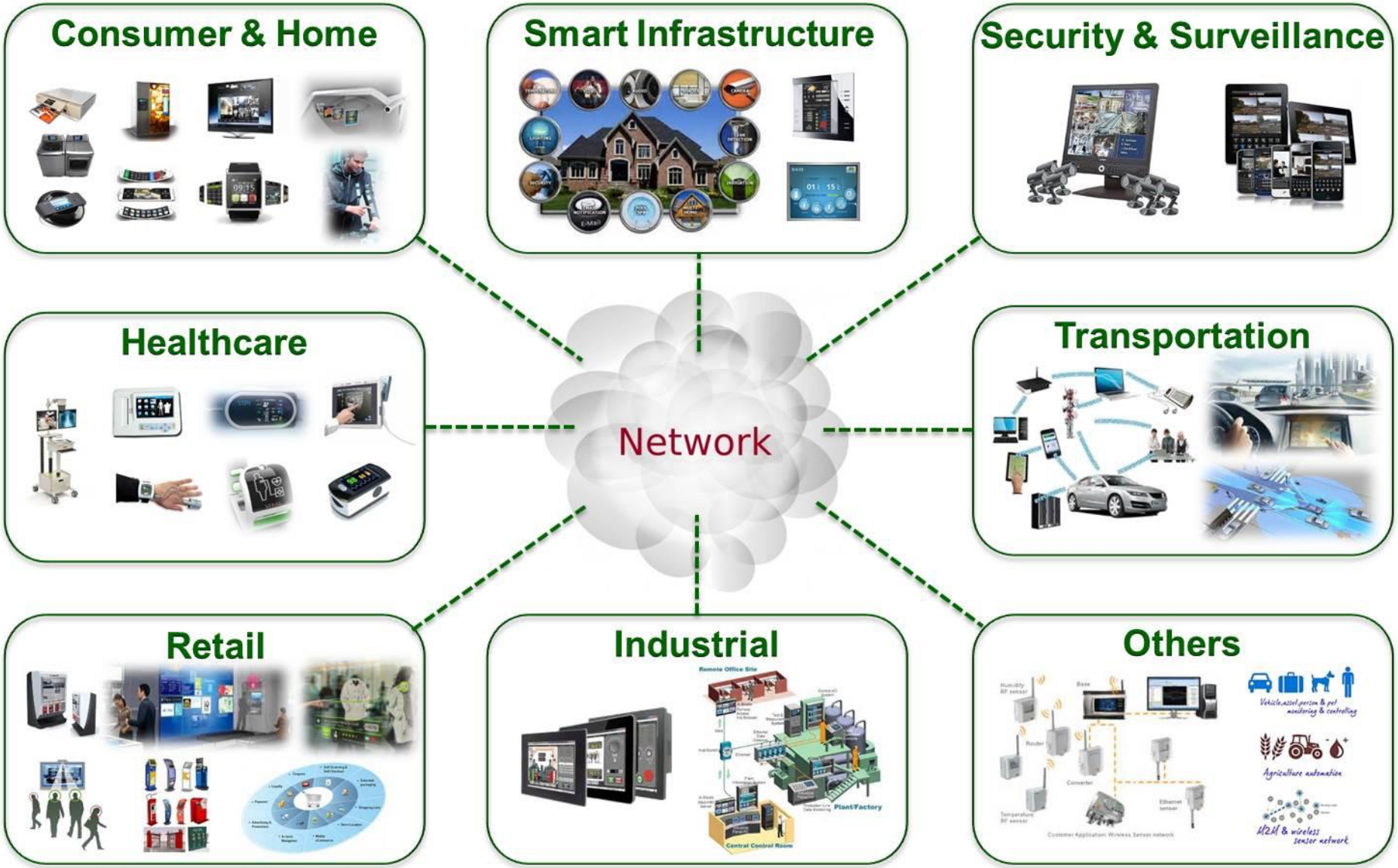




iso.org

A natural progression?



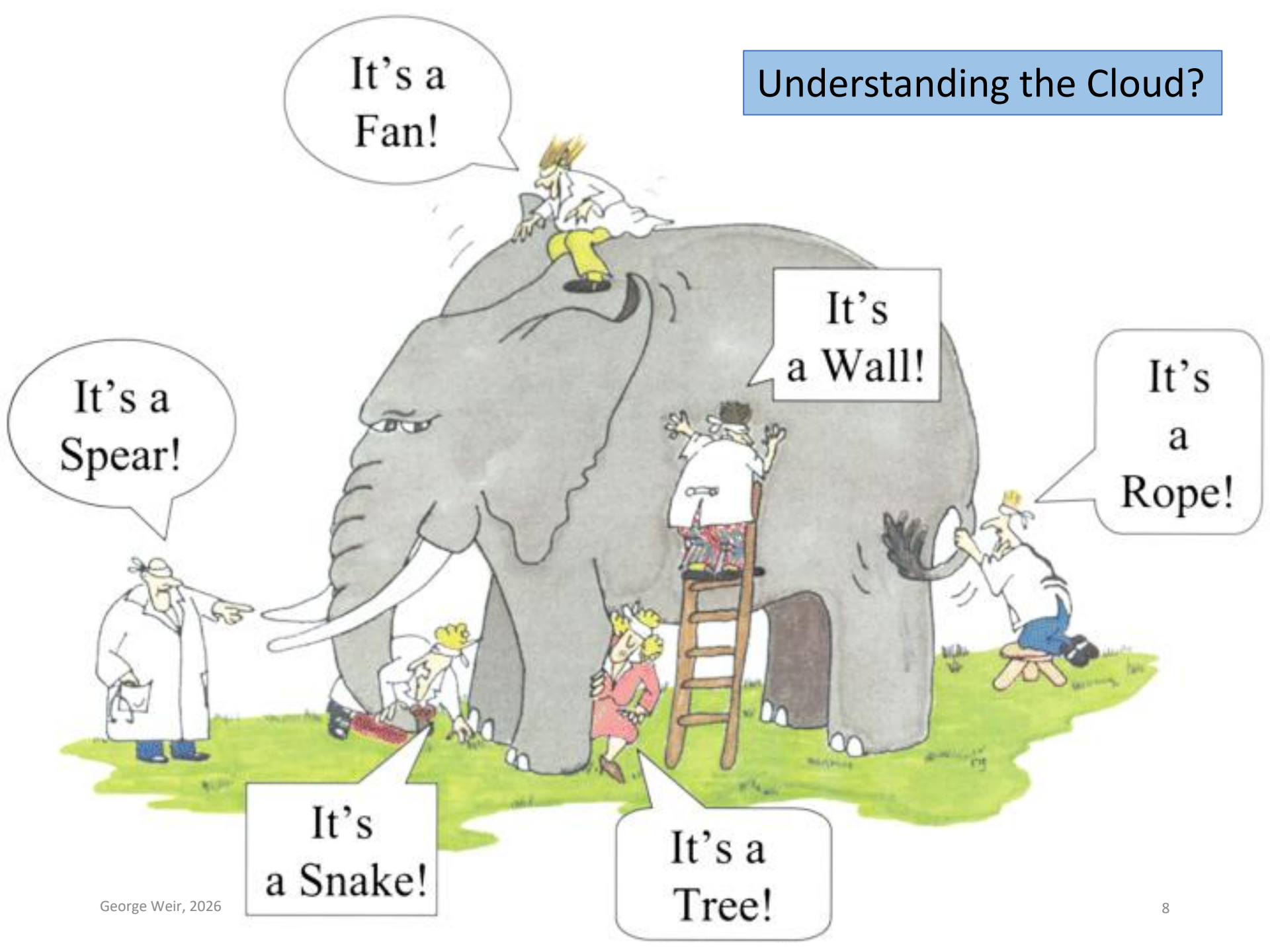


IoT and Cloud

- Cloud is seen as an enabling technology

ti.com

Understanding the Cloud?



INTERNET OF THINGS LANDSCAPE

Platforms & Enablement (Horizontals)

Connectivity: IFTTT, Sympli, ioBridge, ARRAYENT, electric imp, haystack, sensinode, ThingWorx, NODE, EVRYTHNG, bugswarm

Open Source Platforms: sense, spark, Nimbits, ThingSpeak

Software Platforms: sense, SmartThings, Withings, NINJABLOCKS, xively, TWINE, OSITO, zonoff

Sensor Networks: MESHSYSTEMS, SAFECAST

Enabling Networks: FreedomPop, Open Garden, SocialSign.in, SIGFOX

Corporates: IBM, GE, LG, CISCO, Honeywell

Applications (Verticals)

Quantified Self

Wearable Computing: GLASS, Pebble

Fitness: FUEL, amiigo, Withings, fitbit, JAWBONE

Health: BASIS, LUMOback, HAPIfork, wahoo FITNESS, NuMetrex, Signal

Family: REST, Lively, Good Night Lamp, Withings, EVADO FILIP

Lifestyle

Leisure: blossom, ICA kitchen, Thimble, remee, iGrill, HEXBRIGHT, sobi

Pets: gibi, FITBARK

Toys: sifteo, MakieLab, KAROTZ, greenGOOSE

Music: glar

Gardening: BITPONICS, plantlink, Koubachi

Home Improv.: Radiator Labs, netatmo

Connected Home

Home Automation: SmartThings, stickNFIND, NINJABLOCKS, revolv, Ubi, NODE, lapka, electric imp, Wovyn

Energy Efficiency: knut, nest, wemo, tado°, LIFX, ecobee, belkin echo, micasaverde

Security: Kwikset, ALARM.COM, BOSCH, CANARY, Lockitron, HomeMonitor, iSmartAlarm

Industries

Retail: Nomi, euclid, placemeter

Healthcare: ViSi MOBILE, AdhereTech, AliveCor, TELCARE, intelligentM

Automotive: mojio, Dashlabs, SYNC, OpenXC, entune

Smart Buildings: APOGEE, Johnson Controls, Schneider Electric

Industrial Internet

Robotics: KIVA Systems, ROMOTIVE, Double Robotics, Airware, inuro robotics, RoboteX, MOMENTUM MACHINES, 3D Robotics

Greentech: BigBelly SOLAR, Axeda, enlighted, GRIDMOBILITY

3D Printing: 3DSYSTEMS, MezzoMill, Stratasys, formlabs, shapeways, MakerBot INDUSTRIES, RepRap

New Interfaces

NeuroSky, sphero, EQUISO, emotivo, gestigon, PrimeSense, Interaxon, LEAP

Building Blocks

Connection Protocols: neul, ZigBee, macheen, RFID, NFC, Wi Fi, Bluetooth, M-Bus, MQTT, 2G 3G 4G

Telecom: at&t, verizon, T-Mobile, Virgin mobile, boost mobile

M2M: CROSSBRIDGE, gemalto, Jasper wireless, Numerex, Telit, ERICSSON

Software: amazon web services, hadoop

Mobile: iOS, Parse

Hardware: opengate, ARDUINO, beagleboard.org, spark

Parts /Kits: MAKEY MAKEY, TinkerForge, littleBits, MOSORO, readymate

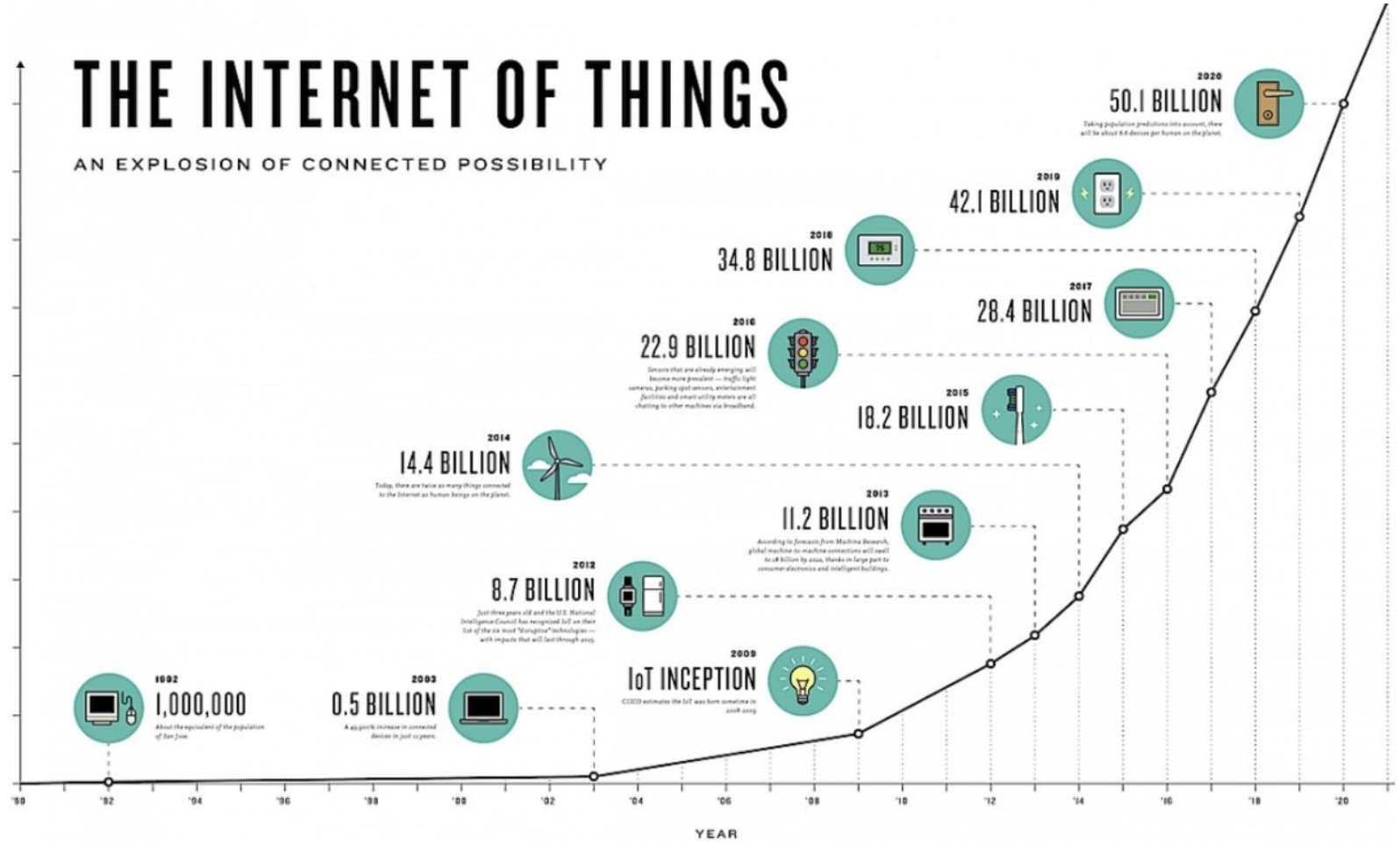
Services: PCH International, DRAGON innovation, makexyz, TN, adafruit, CIRCUIT LAB

Incubators: BOLT, LEMNOS Labs, HAXLR8R, springboard();

Funding: KICKSTARTER, indiegogo

Distribution: Grand St., Anvil

Explosion of Possibilities



Mesh-net.co.uk

Media prediction

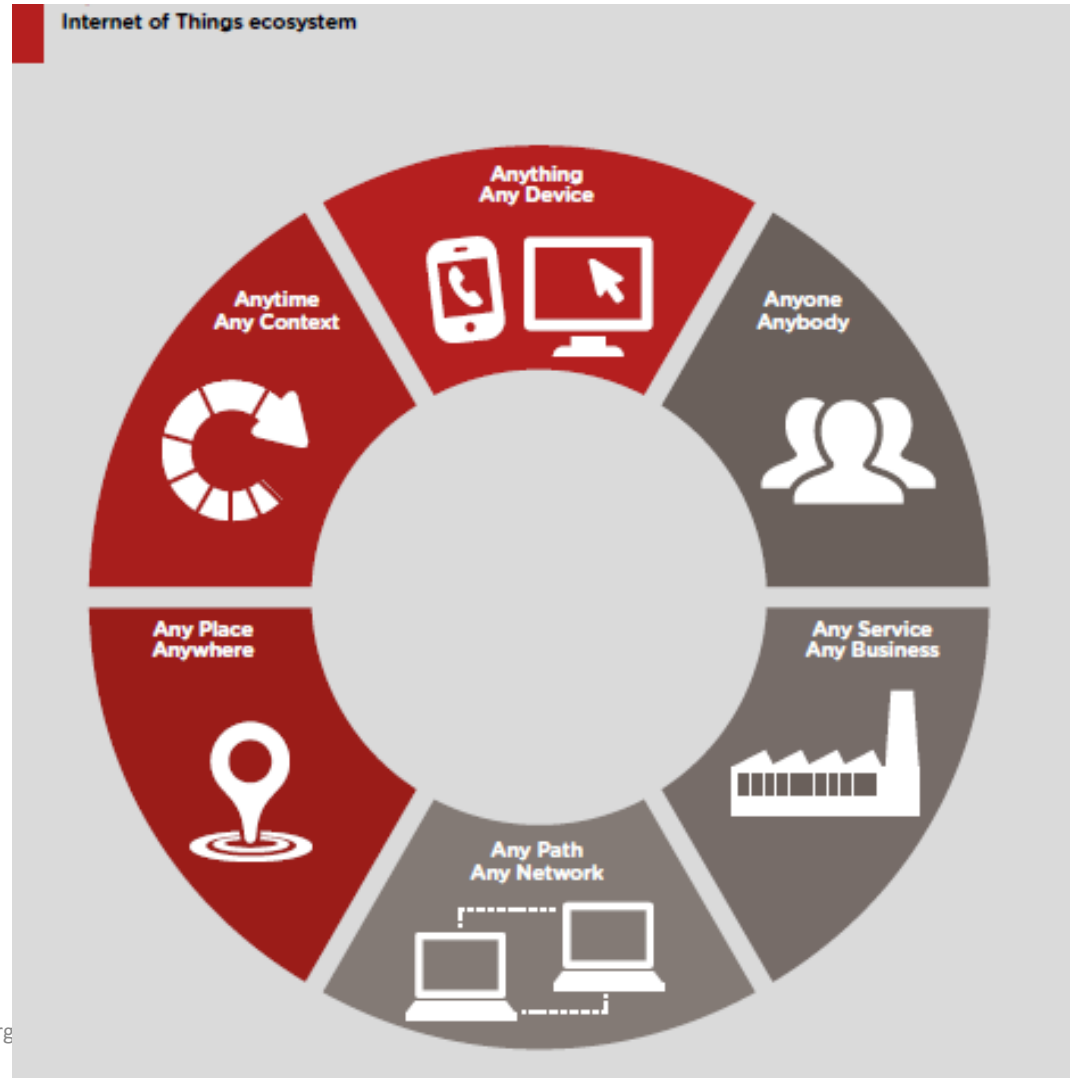
- “A typical home will soon contain a network of gadgets designed to make life easier.” (Sunday Times)

Government initiatives

The Internet of Things: making the most of the Second Digital Revolution

A report by the UK Government Chief Scientific Adviser

Large-scale Ecosystem



Report perspective: *we should engage quickly with these developments for the welfare of the population and the economic benefit of the country.*

Key ingredients

- Communication
  - Wireless technology
    - Wlan
    - Bluetooth
    - GPRS (GSM)
    - New communication standards
- Integration
  - Local systems talking together and to ‘upper level’ systems
- Data analysis
  - Widely distributed data gathering
  - Centralised synthesis and analysis

Applications

- Home automation
  - Building management systems
- Energy
  - Smart meters
- Healthcare
  - Telehealth: delivery of remote health-related services
- Transport
  - Self-adjusting vehicles
- Agriculture
  - Sensor-based yield management
- Manufacture
  - Industry 4.0

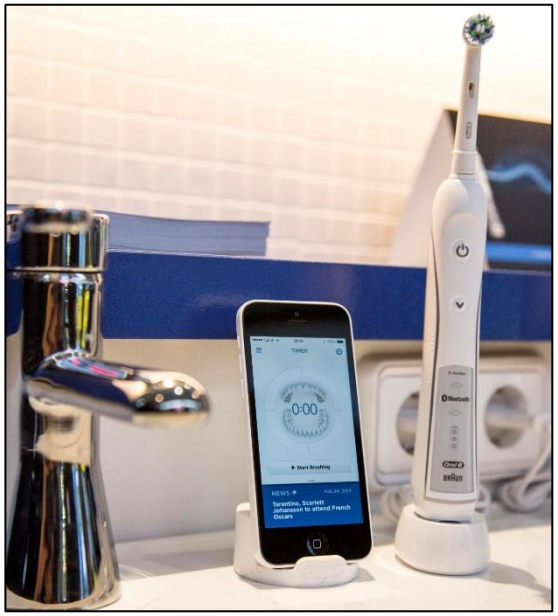
Apps on Your Fridge?

- ‘Upgrade your life with a Wi-Fi enabled refrigerator
- Featuring a brilliant 8’’ touchscreen that puts access to apps at your fingertips
- Check the morning weather, browse the web for recipes, explore your social networks or leave notes for your family—all from the refrigerator door’

Samsung advert

Smart toothbrush

- Bluetooth smartphone interaction
- No internet connection (yet!)



Smart energy meters

- Consumers with smart meters can have an in-home display (IHD) that lets them see how much energy they are using and what it will cost.
- This will let them have more control over their energy use and help them save energy and money.

Wearable technology

- Smart watches with sensors
  - Health and fitness applications
- Smart clothing is predicted to overtake the sale of fitness trackers

The Polo Tech smart shirt by Ralph Lauren, can measure heart rate and respiration connecting to a smartphone via Bluetooth

Wearable technology (2)

- The Polo Tech smart shirt by Ralph Lauren
- Can measure heart rate and respiration, distance travelled and calories burned
- Connects to smartphone or tablet via Bluetooth

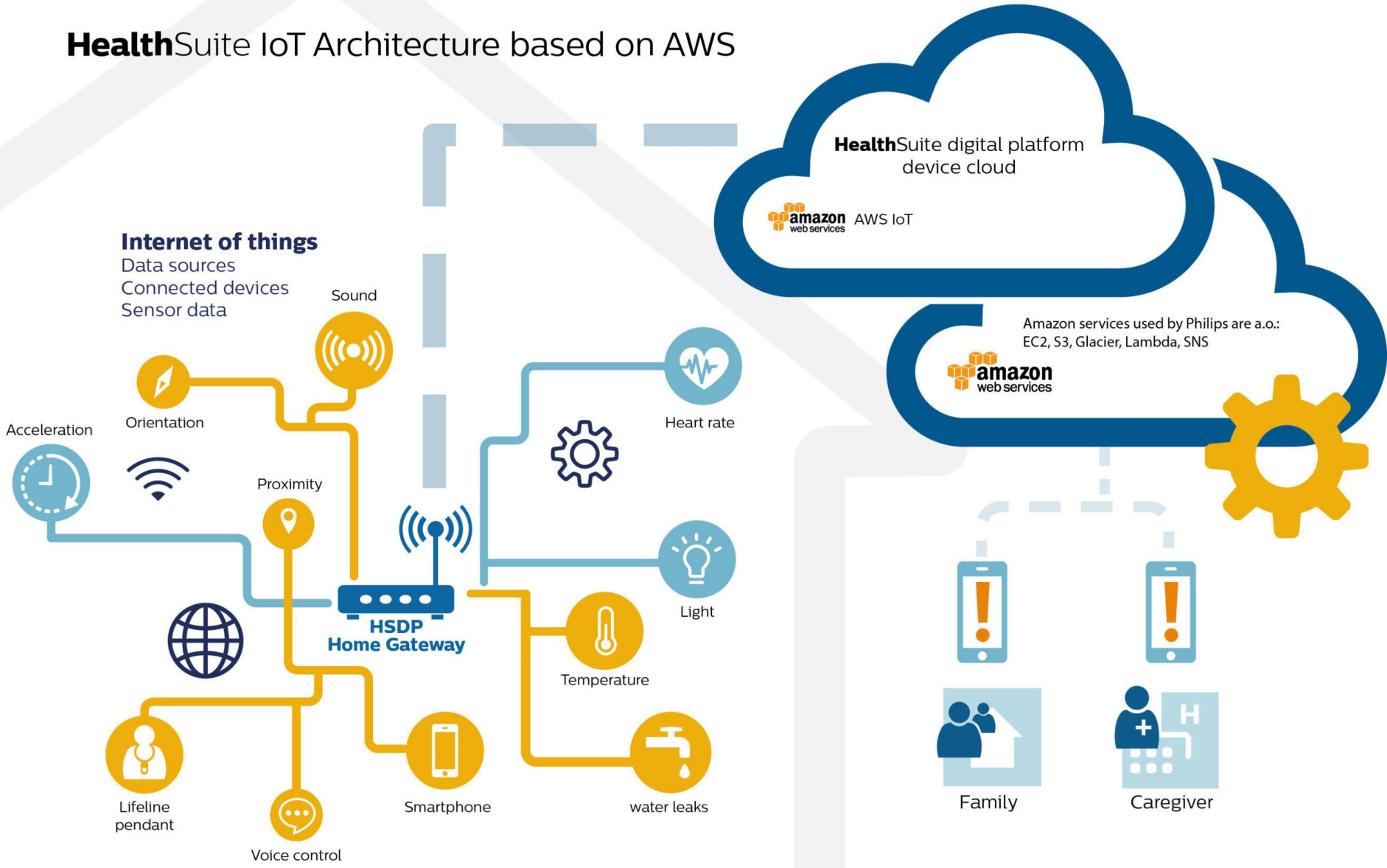
Intelligent Transport Systems

- **Smart E67 (Estonia/Latvia):** European project involving smart road weather stations and improved traffic management along a key transport route
- **I-24 Smart Corridor (US):** Implemented to reduce congestion and improve safety through advanced monitoring and active management

Cooperative ITS Corridor

- Cameras every 100 metres
- Wi-Fi antennas every 500 metres
  - Short-range ‘car to road’ communication
- Measuring exact position of vehicles 10 times per second
  - within 1 metre accuracy
- Improved flow management
  - claims to address the ‘braking shockwave’ problem

HealthSuite IoT Architecture based on AWS



prnewswire.com

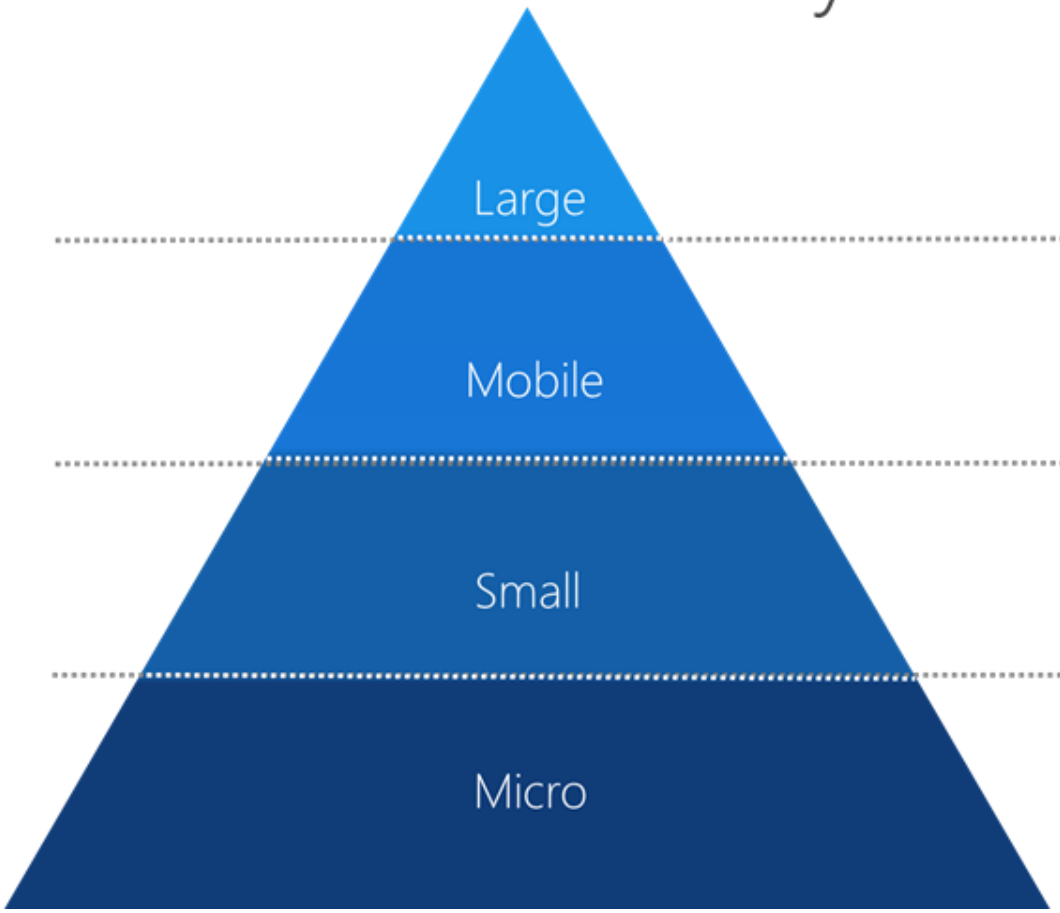
Health applications

- Mainly monitoring and data capture
- Some remote access to consultations

Ecosystem requirements

- Varieties of device
- Networking models
- Communication models

IoT Device Taxonomy



POS terminal, ATM, MRI
x86, PC-like, apps
Embedded Industry 8.1, Standard

Industry handheld, POS tablet
ARM and x86, shell experience, apps
Embedded Handheld 8.1

Gateways, wearables, panels, cars
ARM and x86, diverse hardware, no shell
Embedded Compact, Auto

Controllers, fixed-use, sensors, actuators
ARM, constrained hardware, headless
.NET Micro Framework

Varieties of device

- Three varieties of ‘device’
  - Inert (with location markers)
  - Data gathering and relay
    - Sensor-based with data transfer
  - Decision making
    - Action based upon detected conditions

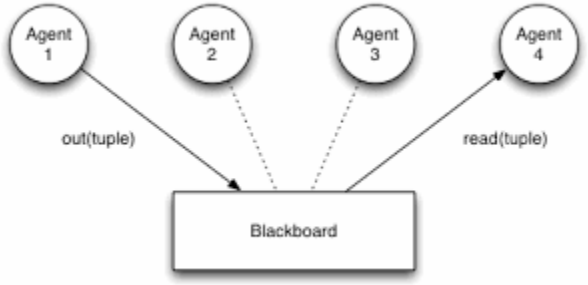
Networking models

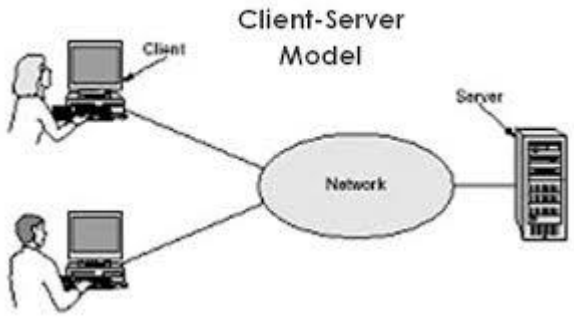
- Networking models
  - Mobile device to local network
    - As we have presently
  - Close proximity, ad hoc networking
    - Device to device
    - Peer to peer
- These models can interact

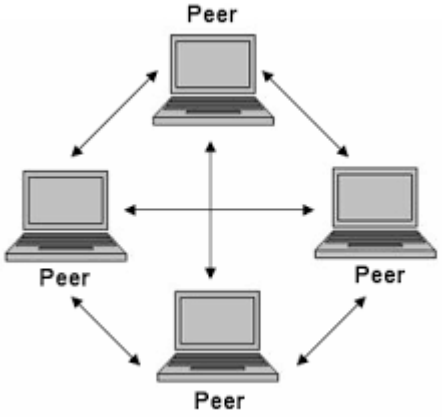
Communication models

- Main communication models
  - Blackboard
  - Client-server
  - Peer to peer

  - And combinations thereof (e.g., cloud-based)







Home ecosystem

- Devices register presence and status with central management system
- Domestic sensor network
  - tracks and monitors internal systems, devices and other ‘objects’
    - including people
- Extended to ‘inert’ objects
  - e.g. through RFID tags
    - no more lost items

Home ecosystem (2)

- Domestic objects outside the home can also be tracked/monitored
  - Children
  - Pets
  - Vehicles
  - Mobile phones, …
- Smart inventory, commercial and domestic
- Regulated service reports
  - Ease of data production for insurance
  - Home reports when selling property

Prospects

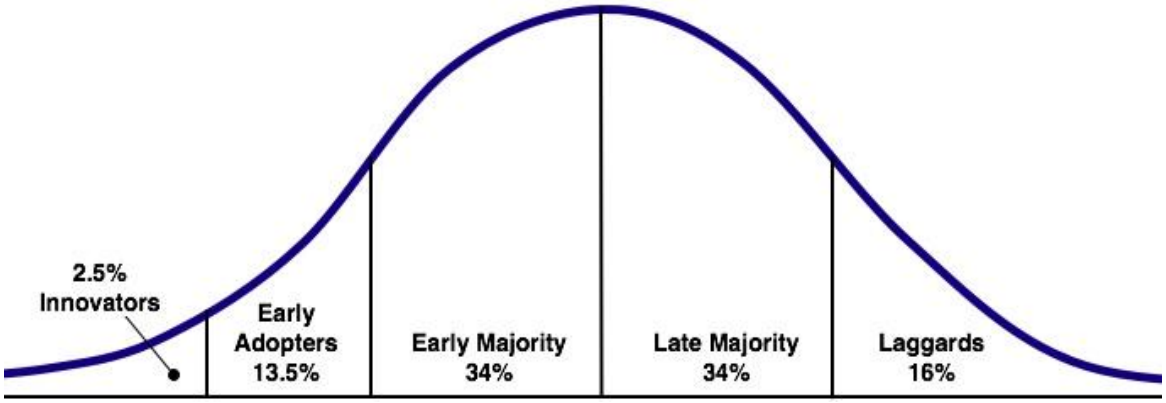
- Highly integrated monitoring and control
  - domestic, district, regional and national
- Device self-monitoring for fault tolerance and timely repair
  - e.g., engine status monitor
- Environment monitoring for smart control
  - e.g., weather forecast affecting thermostat settings
- Significant cost benefits through better insight on system demand
  - e.g., cheaper health service
- Better guarantees of system performance
  - Quality of service enhancements through optimised production

Technology adoption and direction

- One area not prominent in earlier UK government initiatives is manufacturing - sector is represented principally by private enterprise
- Manufacturing has been greatly influenced by developments in IoT
  - A 2023 survey commissioned by Ubisense *reveals that more than three-in-five manufacturers (62%) have embraced IoT technologies in their manufacturing or assembly processes*
  - *over two-in-five manufacturers (43%) are currently leveraging real-time location systems (RTLS); This highlights the increasing importance of precise asset tracking and management within modern manufacturing environments*

Technology adoption

- Historical indications of technology adoption, at the company and individual levels, suggest that adoption is rarely, if ever, a linear process
- Most theories of technology adoption favour a bell curve model of take-up over time
- For example, the Technology Acceptance Model identifies five adoption stages characterised in terms of the individuals responsible for making the adoption decision
- Where are we on IoT adoption?



Major issues

- Usability
- Reliability and robustness
- Availability
- Locus of control
- Privacy
- Integrity and responsibility
- Security

Usability

- Usability is always a concern and may still be an issue in new instances of interactive IoT systems
- IoT adoption may be spurred by the trend toward '*invisible integration*'
  - By means of connectivity and native 'intelligence', domestic and commercial devices may become inherent and unseen, with little requirement for user engagement
  - Aspects of IoT may become invisible in their usual operation
- Progress in voice input/output and conversational systems suggest that we are heading this way
- As a result, IoT technology may add little overhead to usability with connected devices

Reliability and robustness

- With greater dependency on co-operating systems the risks increase
- Greater complexity may result in multiple points of failure
- Assurance of reliability becomes more urgent because the likelihood and potential impact of failure or error is greater
- When complex integrated systems become mission or life critical, the highest levels of robustness in design and reliability in operation is required
- The status of individual devices, inter-linked devices and communication link, will affect the robustness of centralised and de-centralised services
- Reliability is also influenced by capacity and performance level so quality of service may be as critical as device failure

Reliability and robustness (3)

- Mission critical?

"How am I supposed to cook? The Internet is down."

Availability

- Availability is often determined by reliability and robustness
- Contention over available resource means that some services, and some users, will lose out
- Ultimately, benefits and limitations may not be equally spread
- Without equal service provision (and availability) for all, we have a new setting of ‘haves’ and ‘have nots’
- A capitalist approach would suggest differing service options at different costs
- This is one method of living with the inherent limitations of the technology

Availability: services

- How do we spread the benefits?
- We don’t all have the necessary infrastructure
  - High speed broadband
  - Domestic networks
  - Centralised monitoring and control systems
  - New era of ‘haves and have nots’?

Availability: data

- Who gets access to the data?
- At what cost?
- New scope for data brokers?
- New avenues for personalised adverts…
- New product supplements?

Availability: quality of service

- Differing service options at different costs?
- Two tier health service with two access modes:
  - personal contact and on-line
- Latter will initially be cheaper option
- May evolve into more specialised service
  - e.g., advice and input from world leading medics, at a premium cost

Availability: A new digital divide?

- Integrating old and new?
- Accommodating rich and poor?
- New education required?

Locus of control

- IoT has significant scope for data gathering, data consolidation, and data synthesis
- The ownership and use of information on end-user interaction, behaviour and preference can be sensitive issues
- Where does control of such data reside?
  - Presumably, with the owners of the technology
- When interacting with third-party systems, individuals generate data that has value, but that data does not belong to the user
- Neither do users control how ‘their’ information is used
- Unlike the individual who has contributed data, the technology controller is able to materialise this value

Locus of control (2)

Locus of control (3)

- Who is in control?

"Bad news - the scale is threatening to cut off our access to the fridge..."

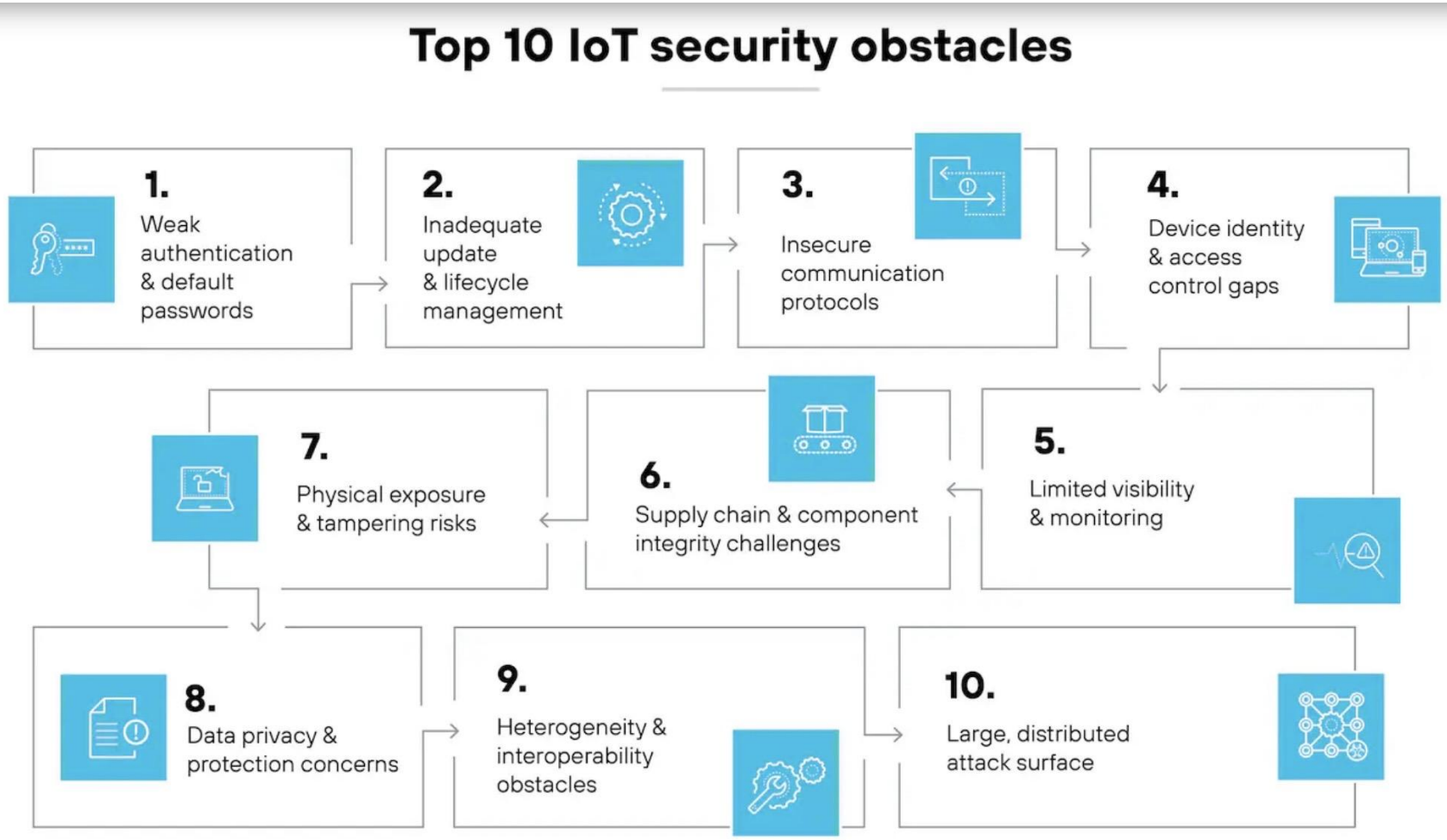
Privacy

- Centralised data collection?
- The rise of ‘big data’ and data analytics
- Who owns the information?
- How can it be used?
  - Timely intervention (e.g., health care)
  - Targeted advertising
  - Product development
- Nowhere to hide?
- Tracking via our portable devices

Integrity and responsibility

- The increased reliance on AI-based automated decision-making may lead to social, legal, and moral challenges
- One is the impact on employment, with AI-based systems able to replace large sections of the workforce
- A second is the absence, for the most part, of explanation facilities tied to automated decision-making
- Open discussion of the legal and social implications is increasing, but answers and resolutions seem absent so far
- Recent attempts to control the scope of AI (through agreement or legislation) seem bound to fail but are worthy of attention in the meantime

Security obstacles

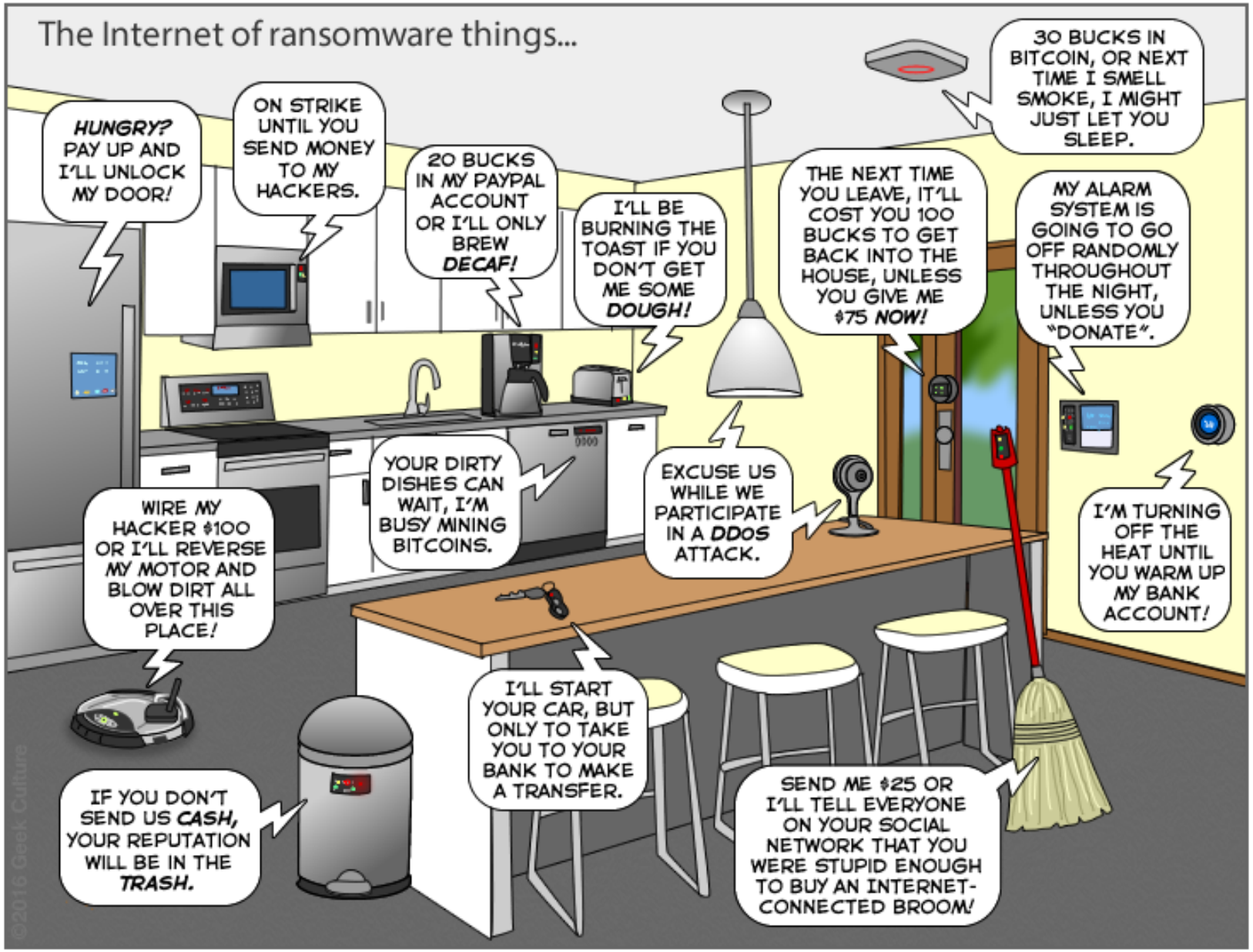


paloaltonetworks.com

Securing IoT is harder than securing traditional IT systems.

Security: Health risks?

- Moving toward implanted devices
- Risk of illicit device access



INTERNET OF THINGS OR INTERNET OF THREATS?

KASPERSKY

What risks does the IoT brings to your life and how do you use new connected devices wisely

USB-dongle for video streaming

Using the vulnerability in USB-dongle, the attacker could show false error messages to the user and urge them to reset their Wi-Fi network password.

Coffee maker

Coffee maker could contain a vulnerability that would expose user's Wi-Fi network credentials.

Baby monitor IP camera

Using credentials to the Wi-Fi network, criminal could exploit multiple vulnerabilities in Baby monitors and spy on its owners.

Home security system

Contact sensors that use magnetic felds could be bypassed by a burglar with a powerful enough magnet.

The future of IoT?

- We are still early in the penetration and acceptance of IoT
- Functionality and scope are likely to expand considerably
- Increasing access to ‘new’ content through AI systems will impact upon conventional means of production
- This will affect employment in the Arts and scientific occupations, including computer programming
- Ethical concerns must rise with increased reliance on AI-based automated decision-making, and inevitably lead to social, legal, and moral challenges

Conclusion (1)

- Should we be happy with IoT prospects or concerned at the threats that may well emerge?
- The optimistic response embraces the positive and, wherever possible, opposes the negative effects of technical innovation
- We must weigh up the benefits in terms of utility and economy, against the drawbacks, often in terms of social inequality and disruption

Conclusion(2)

- Note the difference between the Internet of Things promising '*a better connected world*'
  - in which the interconnections make the world better
- and merely promising '*a better-connected world*'
  - in which, simply, connectivity is enhanced
- We must hope (and strive) for the former but can, at least, expect the latter