Internet of Things: vision, recent commercial hype, and research challenges

University of Cyprus

NET works R esearch Laboratory

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Workshop on Internet of Things (IoT) and Wireless Sensor Networks (WSN), 5 March 2015, CSIR, Pretoria, SA

1

- https://www.youtube.com/watch?v=tcUvg9jcfG8

- https://www.youtube.com/watch?v=sgMG7zRrcPk

- https://www.youtube.com/watch?v=0hz_UUdTDUA

- https://www.youtube.com/watch?v=QSIPNhOiMoE

Talk summary on IoTs

- **What is the IoTs, and what is its vision**

- Application spectrum and industry forecasts

- Where are we today?

- Industry "hype" and commercial announcements by key players in the marker

- Research challenges

- Accompanying measures and activities

- Realising the IoTs (one supporting approach is the Web of Things)

- Concluding remarks and discussion

ONE VIEW: BIG BUSINESS

50,000,000,000
BY 2020, THE NUMBER OF INTERNET-CONNECTED THINGS WILL REACH OR EXCEED 50 BILLION

IN 2015
223%
THE GLOBAL MARKET FOR WEARABLE DEVICES

27,000,000,000
M2M
MACHINE-TO-MACHINE CONNECTIONS
BY 2024

[IoT] WILL ADD
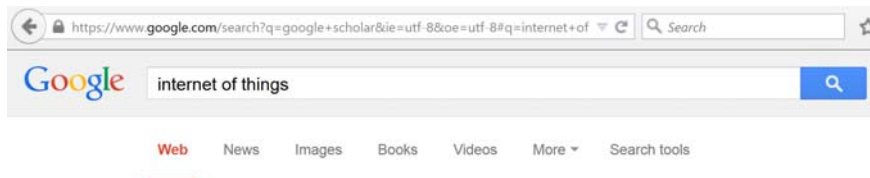**$15 TRILLION**
TO GLOBAL GDP
IN THE NEXT 20 YEARS

CONNECTED THINGS

BY **2020** — 250,000,000
VEHICLES WILL BE CONNECTED TO THE INTERNET

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Google search on the IoTs

789 million hits!!!!

The internet hits are
about 5 billion!!!

http://www.forbes.com/sites/ciocentral/2016/09/13/why-the-consumer-internet-of-things-is-stalling/#12d343712b69

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Indicative recent activities

- **IBM Opens Watson IoT Global Headquarters in EU** M2M MAGAZINE+ | December 17, 2015

- **IBM to invest $3 billion to establish a new IoT unit**

  M2M MAGAZINE+ | March 31, 2015

- **Cisco to establish a IoT Innovation Center in Spain**

  M2M MAGAZINE+ | July 25, 2014

- **Etisalat to launch Internet of Things (IoT) platform**

  – M2M MAGAZINE+ | July 14, 2015

  Abu Dhabi, July 11, 2015: Etisalat Group , the leading telecommunications operator in Middle East, Africa and Asia, is to launch the region's first Internet of Things (IoT) application development and device management platform. Etisalat will be working with Oberthur Technologies (OT) and ThingWorx, a PTC Business, both global industry leaders in the field of IoT solutions, to build and manage the platform as Etisalat 's partners.

- **SAMSUNG launches ARTIK IoT Platform & Chips**

  – M2M MAGAZINE+ | May 15, 2015

- **UK Gov backs £24 Million IoT Research Hub**

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Indicative recent activities by Telecom operators

- **Orange deploys network for Internet of Things (IoT) M2M MAGAZINE+ | September 22, 2015**
    - Orange is now broadening its connectivity offer and preparing for the future of the IoT. With this network based on LoRa technology, it is especially useful for connecting sensors in Smart Cities. The LoRa network will be operational from the first quarter of 2016 and progressively deployed nationwide
    - http://www.machinetomachinemagazine.com/2015/09/22/orange-deploys-network-for-internet-of-things-iot/?utm_source=M2M+MAGAZINE&utm_campaign=f303142127-M2M_NEWSLETTER_M2M3_31_2015&utm_medium=email&utm_term=0_93f5c0834f-f303142127-44713641&ct=t%28RSS_EMAIL_CAMPAIGN%29

- **BT trials new network tech for 'Internet of Things'**

- **Swisscom tests network for the Internet of Things**

- **IBM and ARM Collaborate on Internet of Things (IoT)**

- **HP announces Internet of Things (IoT) Platform**

- **IDC: Internet of Things to Transform Manufacturing**

SmartThings – Samsung IoTs

SmartThings Smart Home Starter Kit

by SmartThings

★★★★☆ ▾   167 customer reviews

| 43 answered questions

Price: **$199.00**

In Stock.

Ships from and sold by Amazon.com. Gift-wrap available.

This item ships to **Larnaca, Cyprus**. Learn more

- Secure your home for a fraction of the cost of a traditional home security system
- Stay connected to family members by getting notifications when people, pets, and cars come and go
- Get immediate alerts if doors or windows open unexpectedly
- Secure dangerous, off-limit, or valuable areas of your home
- Be notified if movement is detected at home while you're away or asleep

Roll over image to zoom in

Samsung to Acquire SmartThings, Open IoT Platform

Samsung announced that it has entered into an agreement to acquire SmartThings, the leading open platform for the smart home and the consumer Internet of Things. SmartThings supports an open and growing ecosystem of developers, who are producing new types of connected devices and unique apps in the cloud that change how everyday objects work. With Samsung's resources and support, SmartThings will be able to expand its platform and become available for even more partners and devices.

"As an open, standards-agnostic platform for the Internet of Things, our vision has always been to innovate, build, and make the world smarter, together,"

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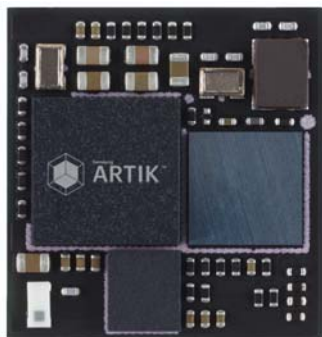
ARTIK 1 has the world's smallest form factor (12mm x 12mm) in its class. Aimed especially at power-sensitive devices, ARTIK 1 provides weeks of use on a single charge. Its hardware includes a 9-axis motion sensor with gyroscope, accelerometer and magnetometer, as well as Bluetooth low energy connectivity. With a feature set tailored for wearables and IoT end nodes, ARTIK 1 is a mobile workhorse.
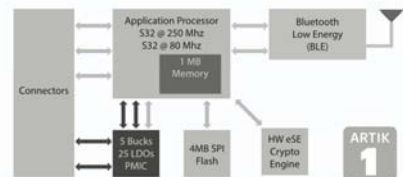
ARTIK 5 uses Samsung's next-generation ePoP (package-on-package) technology to offer a broad cross-section of devices and applications the best combination of computing power and storage capacity at its size. ARTIK 5 offers a balance between performance and power consumption that is unique in the industry. Integrating ARM processors, best-in-class security features and a range of wireless connectivity options, ARTIK 5 delivers not only the essentials, but a new standard for IoT applications.
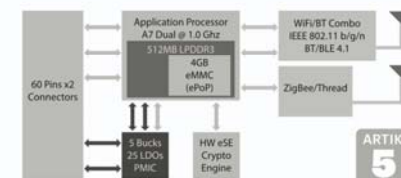
ARTIK 10 is designed for a new class of IoT device capability. It is ideal for applications with higher local performance and storage requirements, or demanding video encoding and playback needs. ARTIK 10 integrates rich wireless connectivity with built-in advanced security capabilities. Leveraging the same high-volume, high-performance processor and semiconductor expertise found in Samsung's flagship mobile phones, ARTIK 10 delivers the kind of performance and integration that, up until now, has not been available in the diverse IoT market.

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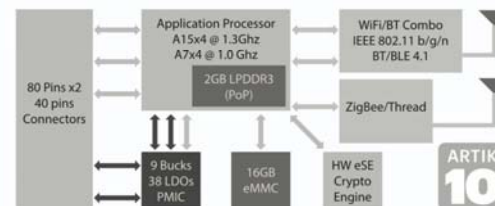
Eight questions you should be asking about the internet of things

- **How will the IoT change our daily lives**, what impact will it have on sustainability and what shouldn't be connected?

- Marc Ambasna-Jones answers the big questions
  - What effect will the internet of things (IoT) have on our daily lives?
  - What shouldn't be connected and why?
  - Will IoT actually work over the internet or will it have its own dedicated wide area network?
  - What will happen in terms of jobs losses and skills as IoT makes devices and robots more intelligent?
  - Will it impact sustainability?
  - What happens to big data and privacy?
  - will there not always be criminals looking to gain access to data stores for monetary gain?
  - What difference can governments make to ensuring IoT will be safe and secure, and is there a serious potential threat to governments and states?

Internet of Things (IoTs)

What exactly is the

Postscapes collaborated with Harbor Research on an infographic to tell a more complete story about the Internet of Things.

"**From our perspective, this story is not just about people communicating with people or machines communicating with machines.** Smart, connected systems **are a technological and economic phenomenon of unprecedented scale, encompassing potentially billions if not trillions of nodes -- an** Internet of infinite interactions and values**..."**
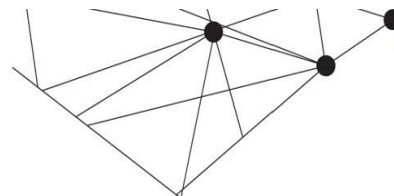
"INTERNET? of THINGS"?

What is the Internet of Things (IoTs)

Smart Systems and the Internet of Things are driven by a combination of:

What is the Internet of Things (IoTs)

Sensors and actuators

giving our world a digital nervous system.
e.g. Location data using GPS sensors. Eyes and ears using cameras and microphones, along with sensory organs that can measure everything from temperature to pressure changes.

Machine Vision / Optical Ambient Light

Position / Presence / Proximity

Acceleration / Tilt

Motion / Velocity / Displacement

Electric / Magnetic

Temperature

Leaks / Levels

Humidity / Moisture

Acoustic / Sound / Vibration

Force / Load / Torque Strain / Pressure

Flow

Chemical / Gas
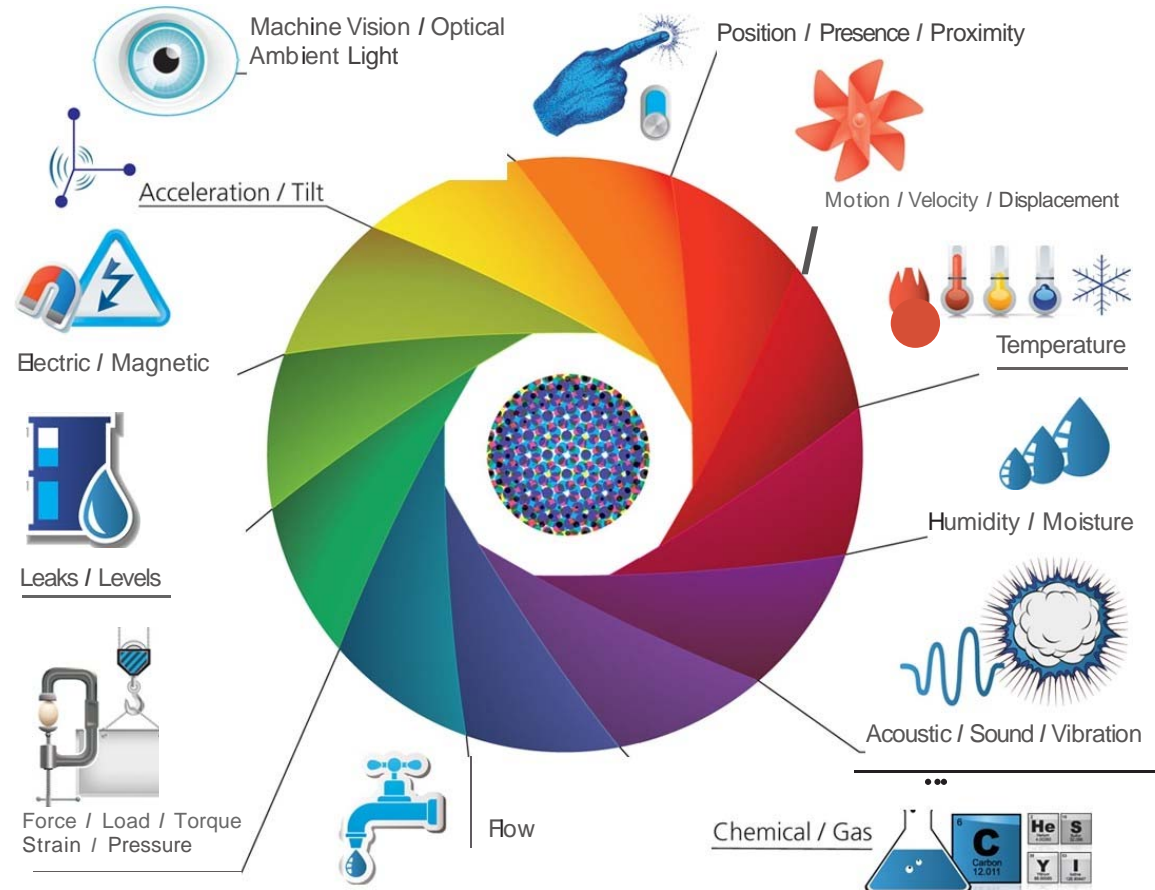
What is the Internet of Things (IoTs)

@ CONNECTIVITY

These inputs are digitized and placed onto networks.

LTE Advanced
Cellular 4G / **LTE**
3G - GPS / GPRS
2G / GSM / EDGE, CDMA, EVDO
WEIGHTLESS
WIMAX
LICENSE-FREE SPECTRUM
DASH 7

InterPlanetary Network

WiFi

BLUETOOTH
Z-WAVE

6LoWPAN
NFC ZIGBEE
ANT
RFID

POWERLINE
ETHERNET
PRINTED

IPv4 IPv6 UDP DTLS RPL Telnet MQTT DDS CoAP XMPP HTTP SOCKETS REST API

WAN
Wide Area Network - 802.20

MAN
Metropolitan Area Network -802.16

LAN
Local Area Network - 802.11

PAN
Personal Area Network - 802.15

What is the Internet of Things (IoTs)

PEOPLE & PROCESSES

These networked inputs can then be combined into bi-directional systems that **integrate data, people, processes and systems for better decision making**.

Customer Relationship & Support

Analytics & Cloud/API

Upgrades & Configurations

Remote Mortoring / Maintenance

Control &

Automation

Supply Chain Management

Security / Energy

Mobile Devices & Apps

People

Location & Tracking

Financial

Processes

http://postscapes.com/what-exactly-is-the-internet-of-things-infographic
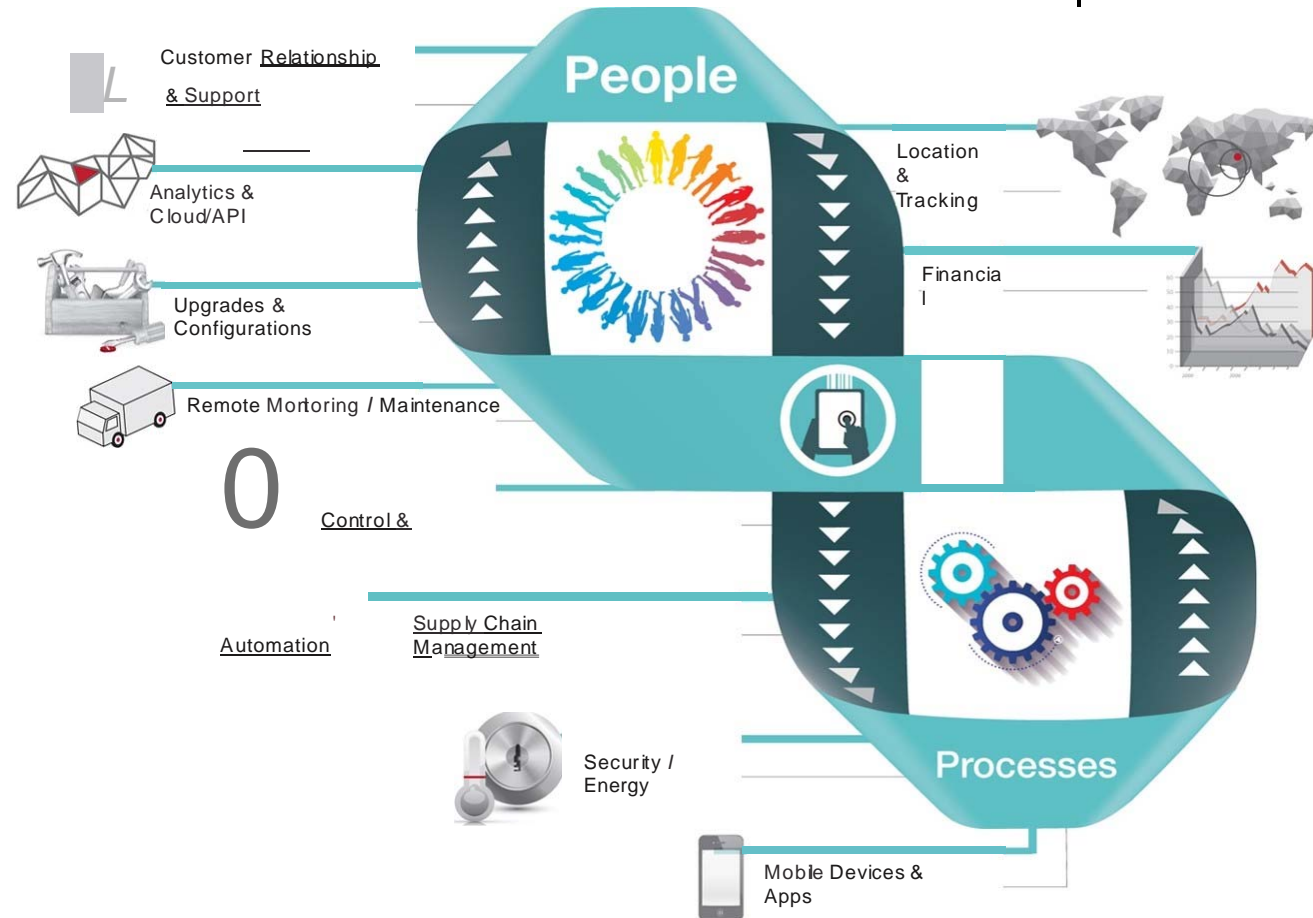
What is the Internet of Things (IoTs)

interactions between sensors + connectivity + people + processes are starting to create new types of smart applications and services

Starting with popular connected devices already on the market

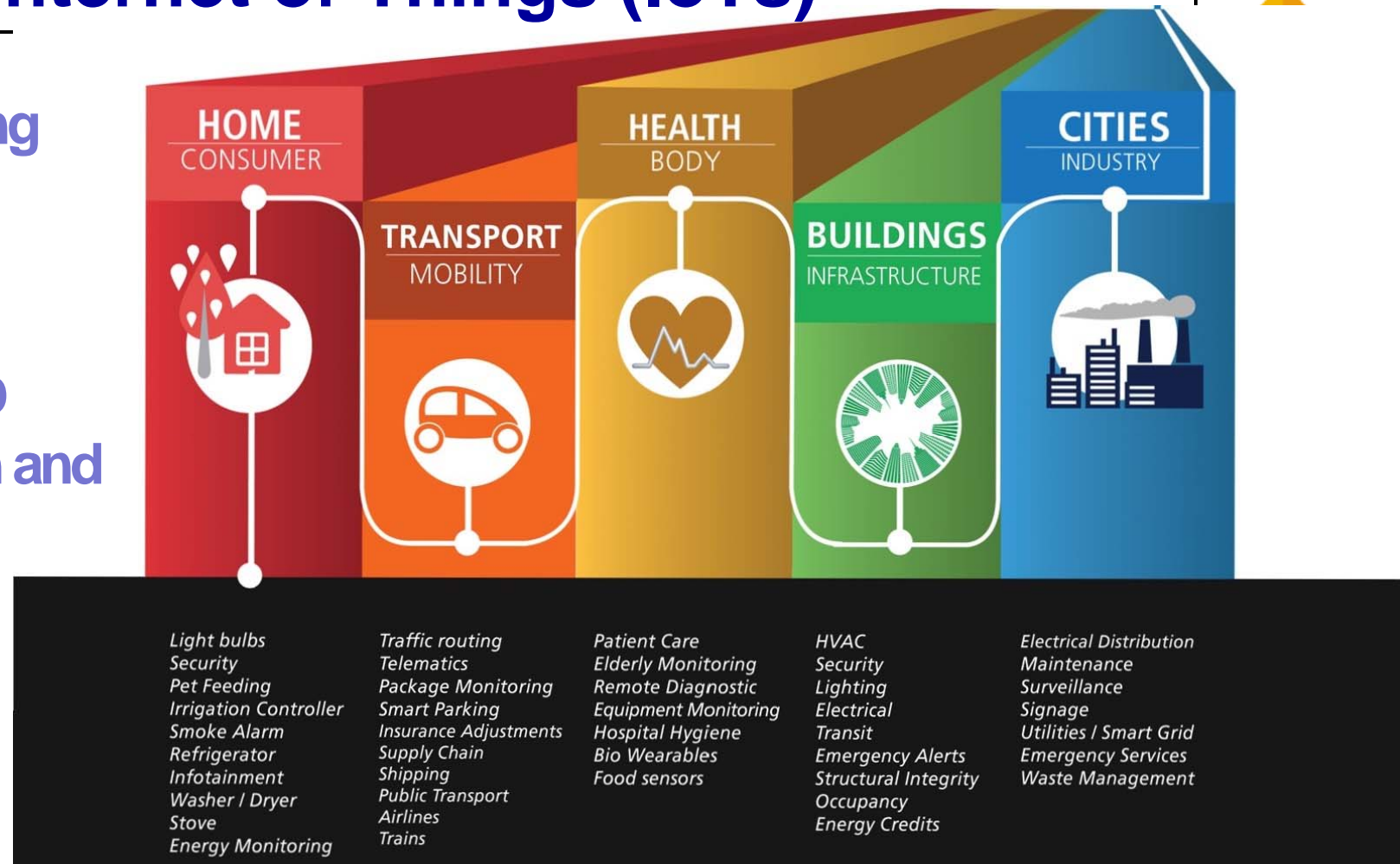| SMART THERMOSTATS	CONNECTED CARS	ACTIVITY TRACKERS	SMART OUTLETS	PARKING SENSORS
nest		BASIS	Belkin, Efergy, etc…	STREETLINE CONNECTING THE REAL WORLD
Save resources and money on your heating bills by adapting to your usage patterns and turning the temperature down when you're away from home.	Tracked and rented using a smartphone. Car2Go also handles billing, parking and insurance automatically.	Continuously capture heart rate patterns, activity levels, calorie expenditure and skin temperature on your wrist 24/7.	Remotely turn any device or appliance on or off. Track a device's energy usage and receive personalized notifications from your smartphone.	Using embedded street sensors, users can identify real-time availability of parking spaces on their phone. City officials can manage and price their resources based on actual use.

What is the Internet of Things (IoTs)

and quickly advancing TO DIVERSE APPLICATIONS

or even COMPOUND APPLICATION within and across industries

HOME CONSUMER

TRANSPORT MOBILITY

HEALTH BODY

BUILDINGS INFRASTRUCTURE

CITIES INDUSTRY

Light bulbs	Traffic routing	Patient Care	HVAC	Electrical Distribution
Security	Telematics	Elderly Monitoring	Security	Maintenance
Pet Feeding	Package Monitoring	Remote Diagnostic	Lighting	Surveillance
Irrigation Controller	Smart Parking	Equipment Monitoring	Electrical	Signage
Smoke Alarm	Insurance Adjustments	Hospital Hygiene	Transit	Utilities / Smart Grid
Refrigerator	Supply Chain	Bio Wearables	Emergency Alerts	Emergency Services
Infotainment	Shipping	Food sensors	Structural Integrity	Waste Management
Washer / Dryer	Public Transport		Occupancy	
Stove	Airlines		Energy Credits	
Energy Monitoring	Trains			

http://postscapes.com/what-exactly-is-the-internet-of-things-infographic

Talk summary on IoTs

- What is the IoTs, and what is its vision
- **Application spectrum and industry forecasts**
- Where are we today?
- Industry "hype" and commercial announcements by key players in the marker
- Research challenges
- Accompanying measures and activities
- Realising the IoTs (one supporting approach is the Web of Things)
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Applications of the IoTs

- **numerous and diverse**, permeating into practically all areas of every-day life of individuals, enterprises, and society as a whole

- span **numerous applications domains**: smart energy, smart health, smart buildings and city, smart transport, and smart industry

- span across **many industries**, e.g. device manufacturers, communication manufacturers and providers, cloud and servers, application developers, etc…

- **many enabling technologies** must **converge** to enable IoT applications

- also, touch upon **many other issues** (not necessarily technical) , e.g. privacy, safety, integrity, transparency, anonymity, etc…

IoTs Market appraisal

2014: nearly **2 billion connected devices** will be shipped

This number will grow to nearly **8 billion connected devices** for the year **2020**
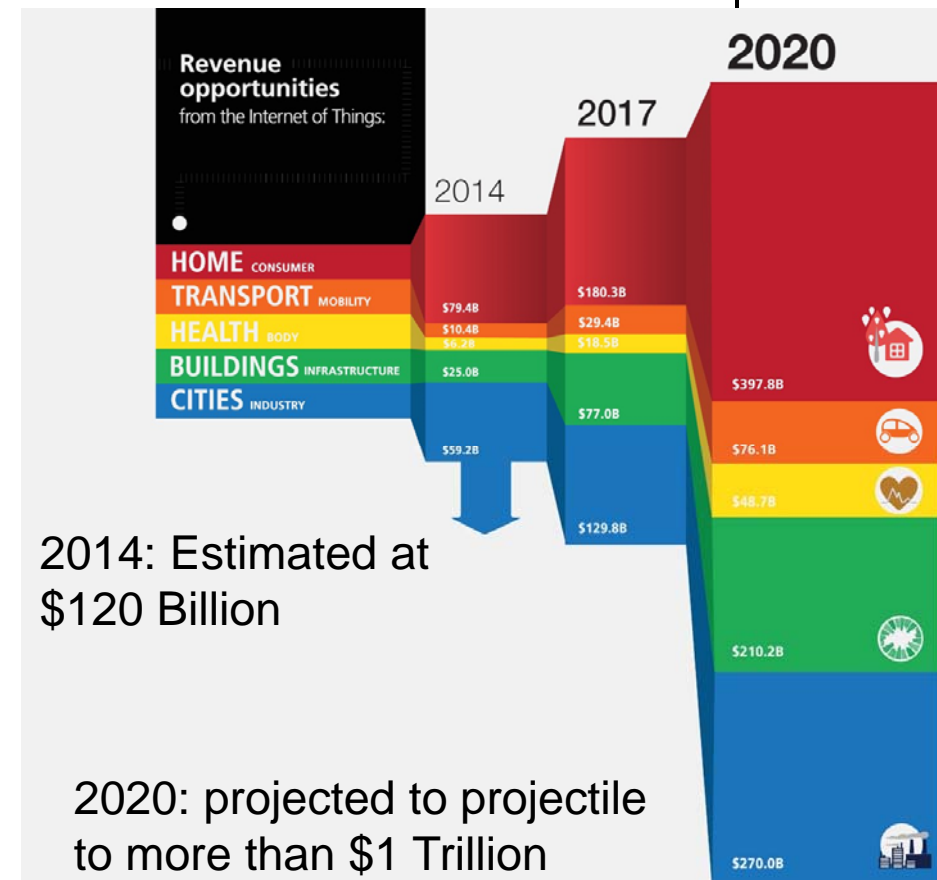
By the year 2020
Gartner estimates IoT product and service suppliers generate incremental revenue exceeding $300 billion.
IDC forecasts **worldwide market for IoT solutions** will grow from $1.9 trillion in 2013 to **$7.1 trillion**.
Cisco increasing to **$19 trillion** its forecast for the economic value created by the "Internet of Everything".

New forecasts regarding the IoT opportunity, with
GE estimating "Industrial Internet" potential to add $10 to **$15 trillion** to global GDP over next 20 years

Revenue opportunities from the Internet of Things:

	2014	2017
HOME CONSUMER	$79.4B	$180.3B
TRANSPORT MOBILITY	$10.4B	$29.4B
HEALTH BODY	$6.2B	$18.5B
BUILDINGS INFRASTRUCTURE	$25.0B	$77.0B
CITIES INDUSTRY	$59.2B	$129.8B

2020: $397.8B, $76.1B, $48.7B, $210.2B, $270.0B

2014: Estimated at $120 Billion

2020: projected to projectile to more than $1 Trillion

http://postscapes.com/what-exactly-is-the-internet-of-things-infographic

Gil Press: http://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/

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IoTs: where are we today?

- *"As IoT is gathering its momentum, the number of initiatives around the world taken by research organizations, industries, standardization bodies, and governments to bring IoT to a mass market, is significant."**
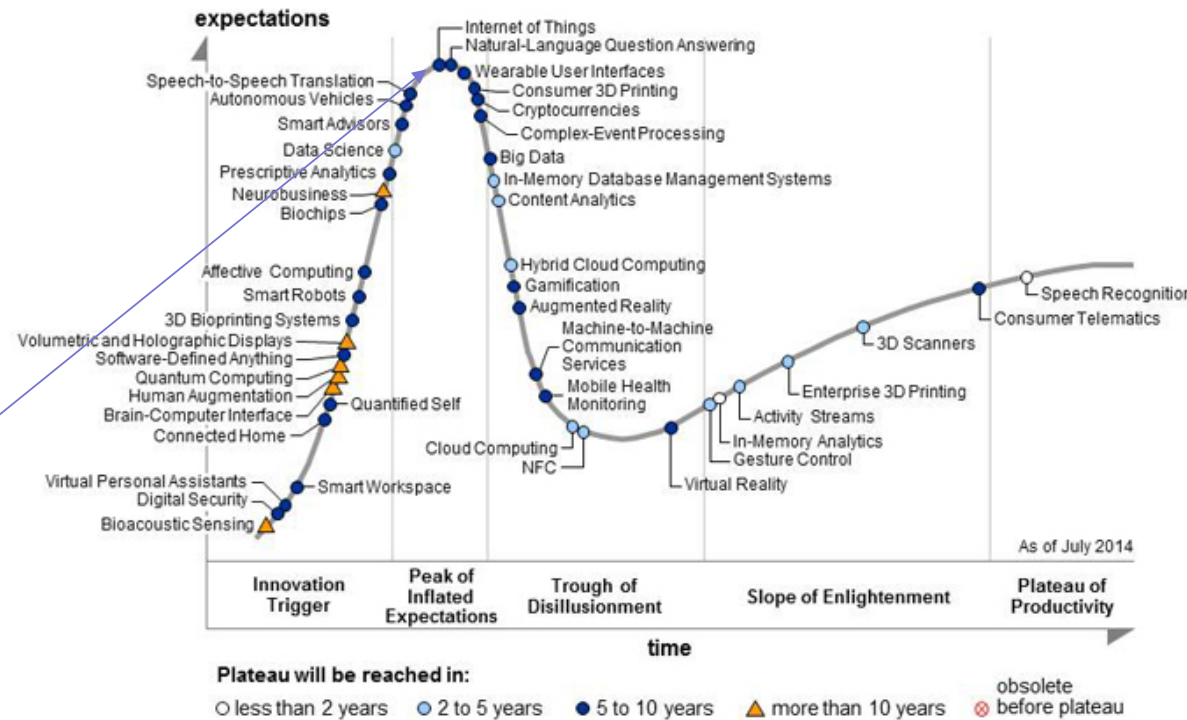
  * Eleonora Borgia, The Internet of Things vision: Key features, applications and open issues, Review Article, Computer Communications, Volume 54, 1 December 2014, Pages 1-31

- *But, is this enough?*

- *Have we reached an IoTs world, as a ubiquitous service as the Internet is today?*

- *Or at least do we have the necessary foundations to build the IoTs (soon)?*

IoTs State of play

- So, where are we?
  - have we reached the inflection point toward uptake in a grand fashion?

- Forbes - Internet of Things By The Numbers: Market Estimates And Forecasts
  - according to Gartner, the Internet of Things is the most hyped "emerging technology" today, and
  - the Internet of Things, "is becoming a vibrant part of our, our customers' and our partners' business and landscape."
  - <u>plateau will be reached in 5-10 years!!</u>

http://www.gartner.com/technology/research/hype-cycles/

http://www.forbes.com/sites/gilpress/2014/08/18/its-official-the-internet-of-things-takes-over-big-data-as-the-most-hyped-technology/

IoTs State of play

- **however, at the moment**
  - very fuzzy (at least from a research observer's point of view)
  - is there a lot of noise or are there concrete wide-scale deployments (home, city, infrastructure, e.g. smart grid,…), going beyond the pilots?

- **many initiatives**
  - big player companies have initiatives on play …
  - standards are very active …. and policies starting to exist in many countries
  - many pilot projects, funded research projects …, e.g.
    - European Research Cluster on Internet of Things (IERC). promoting a common vision of the IoT paradigm, facilitating also the knowledge sharing and the secure IoT deployment at world level
    - US ''National Science Foundation's Future Internet Architecture (NSF FIA)'' program
    - China, National Basic Research Program of China'',.''National High Technology Research and Development Program of China'', ''National Natural Science Foundation of China
    - Korea (National Research Foundation of Korea, NRF), Japan (New Generation Network Promotion Forum, NWGN), SA initiative at CSIR and smart city by City Power
    - and many others have initiated IoTs funded projects
  - research is still active … google scholar search shows 16k hits in 2015… lots of pilot projects…

- **but, are we converging toward a ubiquitous IoTs, being widely deployed**

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Recent industry "hype"

- IoTs was one of the **buzzwords at this year's CES in Las Vegas**

- **keynote speakers** from Korean brands LG and Samsung both **talk about IoTs** in their opening addresses
  - Samsung president and chief executive officer, BK Yoon, called for greater openness and collaboration across industries to unlock the infinite possibilities of the Internet of Things
  - LG chief technology officer Dr Skott Ahn explained how the Internet of Things (IoT) is transforming the way consumers live, work and play

Samsung IoTs vision and strategy CES in Las Vegas, 2015

- **Samsung CEO sees big things for Internet of Things**
  - http://www.usatoday.com/story/tech/2015/01/05/ces-las-vegas-samsung-ceo-bk-yoon/20968119/

- LAS VEGAS -- BK Yoon CEO of Samsung Electronics, the $211 billion global giant **put** it **simply**: "**The Internet of Things is "ready to go. " and "Internet of Things is The Next Big Thing**"
  - "It's not science fiction anymore -- it is science fact," Yoon said during the hour-long keynote speech at the Consumer Electronics Show here late Monday. "**I would argue that the age of the Internet of Things has already started**," he said.

- The **era of Internet of Things isn't a distant idea of the future. It has already begun. "**However, it is important that it evolves around our lifestyles and this can only be done by working closely with industry peers and partners, and openness among devices. Samsung believes together, we can unlock the infinite possibilities of IoT".
  - Seamless technology possibilities
  - Samsung devices will be open
  - Security must be embedded in both the hardware and software
  - SmartThings hub interconnects with all Samsung connected devices in an open fashion – runs on android, IoS, etc… services + devices

- **Samsung will invest 100 million for IoTs development**

IoT Has Already Started

100% IoT in 5 years

20 Devices/sec

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http://global.samsungtomorrow.com/events/ces2015-videos/#layerPopup

LG IoTs vision and strategy

- LG's chief technology officer Dr Skott Ahn: "The Internet of Things isn't about just some devices and the apps that control them. It's what connects everything we value with the innovations that are centred around our lives.

- at LG, we're taking an open approach to maximise the value offered to our customers through platforms, connectivity and the overall IoT ecosystem."

- HomeChat and webOS are driving the IoT ecosystem to make consumers' lives more convenient and more productive.

Google IoTs strategy

- Google made waves in 2014 with major acquisitions and investments in the IoT space.

- Google's strategy.

  – According to Ryan Martin of 451 Research, **Google made its investments -- vertically, not horizontally:**

    - $3 billion for smart thermostat maker Nest Labs, began building its robot army, and other strategic acquisitions along the way.

    - So far, Google has focused its capital on four major verticals: wearables, the connected home, automotive (connected cars), and robotics.

  – During CES in Las Vegas Google's Nest announced an additional 15 partners in "Work With Nest," its developer program for third-party devices to Nest's devices

IoTs platforms

Future Internet - FIWARE
Open APIs for Open Minds

The FIWARE Open Platform provides a rather **simple yet powerful set of APIs** that ease the development of Smart Applications in multiple vertical sectors.

The specifications of these APIs are **public and royalty-free**.
Besides, an **open source reference implementation of each of the FIWARE components is publicly available** so that multiple FIWARE providers can emerge faster in the market with a low-cost proposition.

CONTRIBUTE TO FIWARE LAB ECOSYSTEM WITH YOUR OWN IOT!

Dec 04 2014

Blog   Comments Off

The following post was written by *Carlos Ralli Ucendo*. We would like to thank him for his helpfulness and his collaboration.

FIWARE Lab enables you to connect IoT devices in a private environment for your own Apps exploitation, but it also enables you to connect and share them publicly available for any other developer interested. This article focuses on the later approach, although it might work well as a learning exercise for the other goal.

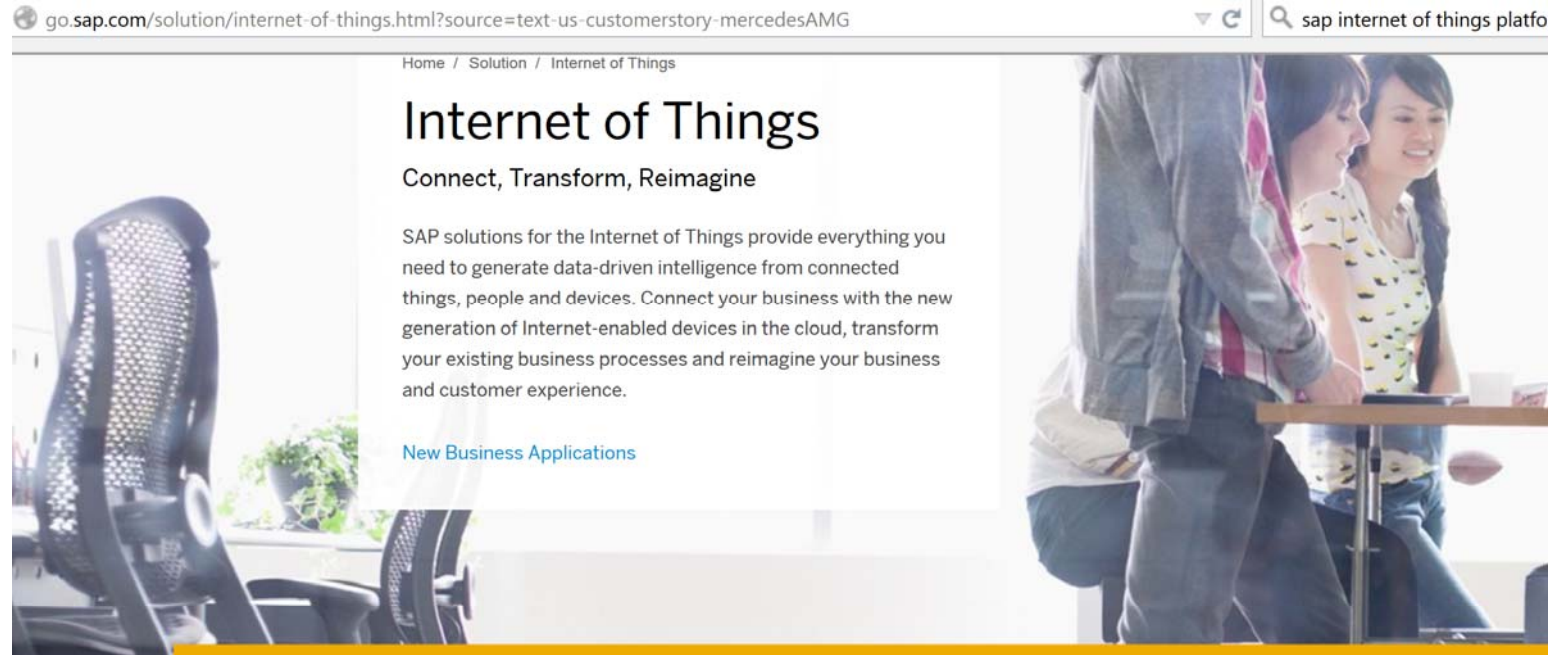The following diagram depicts the components in the FIWARE Lab for most IoT scenarios.

NET**works Research Laboratory**
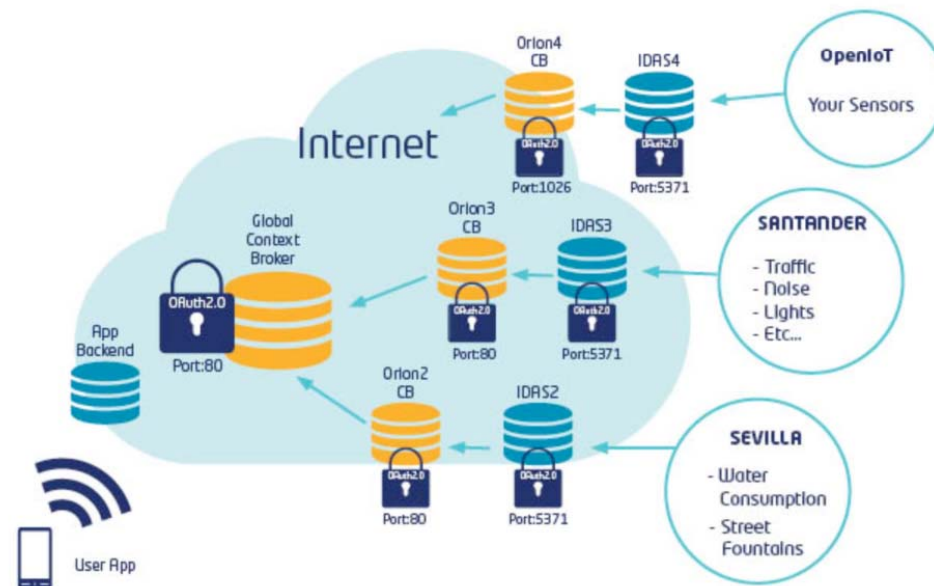
SAP IoTs platfrom

The Internet of Things (IoT) will forever change our personal and professional lives.

Embedded intelligence in a growing network of connected devices will increasingly connect people and businesses to everything else – and become the very fabric of a networked economy.

THE SAP HANA PLATFORM:
READY FOR IoT TRANSFORMATION

> Home / Solution / Internet of Things
>
> ## Internet of Things
>
> Connect, Transform, Reimagine
>
> SAP solutions for the Internet of Things provide everything you need to generate data-driven intelligence from connected things, people and devices. Connect your business with the new generation of Internet-enabled devices in the cloud, transform your existing business processes and reimagine your business and customer experience.
>
> New Business Applications

Explore SAP solutions and expertise for Internet of Things

Microsoft Lab of Things

- Lab of Things (LoT) is a **flexible platform for experimental research that uses connected devices in homes and beyond**. LoT enables easy,
  - interconnection of devices and implementation of application scenarios, using HomeOS.
  - deployment and monitoring of field studies and analysis of data from experiments.
  - sharing of data, code, and participants, further lowering the barrier to evaluating ideas in a diverse set of homes.

Microsoft Research

Getting Started | Sign-in | FAQ | Research | Teaching | Publications | Press | Events | HomeOS | Feedback | @Facebook

What is the Lab of Things?

http://www.lab-of-things.com/

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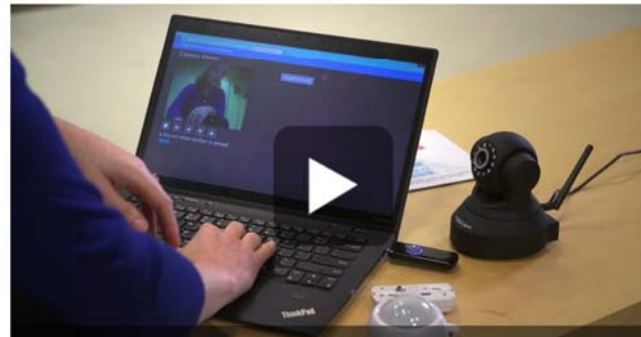
Oracle's Internet of Things Platform

- **Solutions for a Connected World**
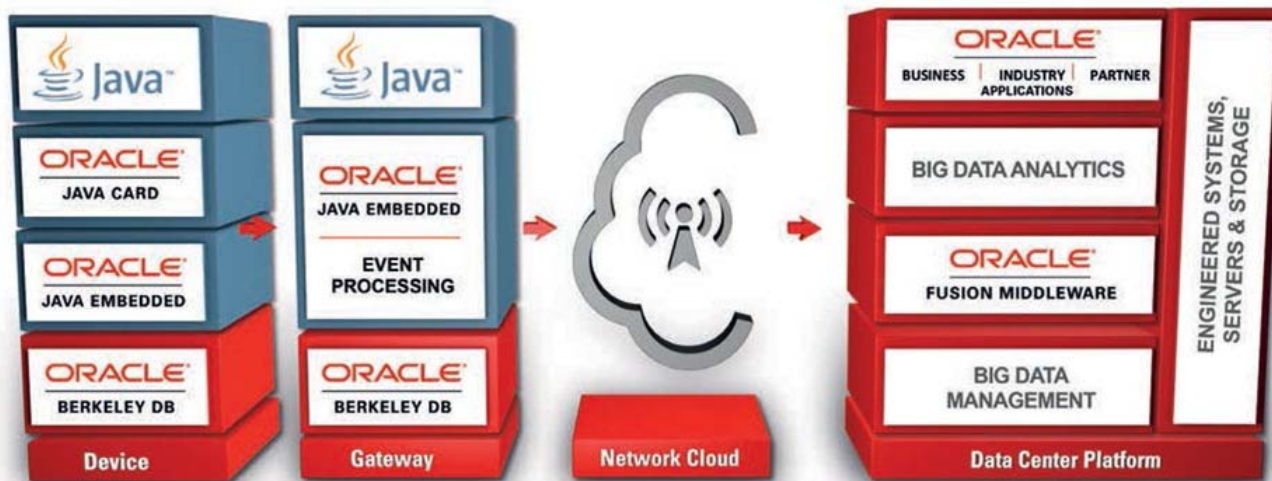
Oracle's Internet of Things Platform:
'No single company can deliver every application in the connected world. But one company can deliver the platform that makes these applications possible'

Figure 2. Oracle provides a complete end-to-end solution
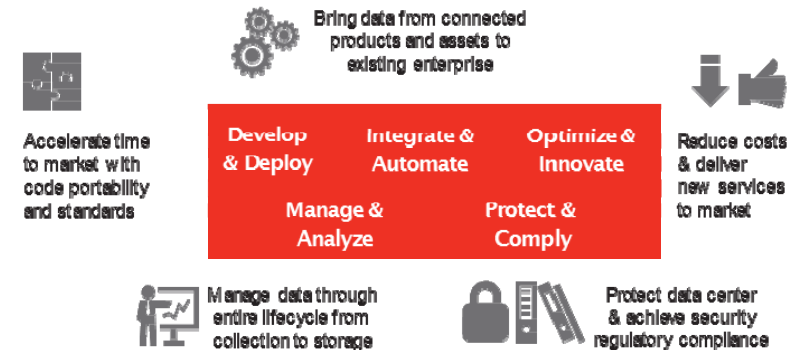
HP Platform

- Announced in Feb 2015

www8.**hp.**com/us/en/hp-news/press-release.html?id=1919110#.VPcgdy4uzo4

News Advisory: February 25, 2015

Topics: Technology and Innovation

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HP Helps Communications Service Providers Drive New Revenue Opportunities with HP Internet of Things Platform

New HP Energy Management Pack targeted at utility vertical leverages Platform to connect, analyze and manage data from interconnected things to improve the user experience for both businesses and consumers

PALO ALTO, Calif., February 25, 2015 —HP today announced the HP Internet of Things (IoT) Platform, a new service that allows CSPs to simultaneously manage heterogeneous sets of IoT sensors, operate vertical applications on Machine-to-Machine (M2M) devices, as well as process, analyze and monetize collected data in a single secure cloud platform.   HP today also announced the new HP Energy Management Pack, the first vertical application developed for the HP IoT Platform.

HP IoT Platform

As CSPs look beyond the traditional telecommunication services to grow revenue, combat competitive pressures and enhance customer loyalty, digital services associated with IoT provide an opportunity to create new industry markets by turning technology into a competitive advantage. The HP IoT Platform provides support for any type of smart

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Windriver IoTs platform

Apple HomeKit

- Apple introduced HomeKit, its **technology for linking and controlling smart home devices**. HomeKit uses the iOS operating system, the software engine of iPhones and iPads.

Apple will allow its upcoming Siri-controlled HomeKit platform to work with certain existing, non-HomeKit home automation products, including ones using competing protocols such as ZigBee or Z-Wave, but there are many limitations.

> According to sources briefed on the new specs, the latest Made for iPhone (MFi) licensing program specifications detail the types of home automation products other than HomeKit that Apple will permit to interact with its platform.

> http://9to5mac.com/tag/homekit/

Apple Inc. (US) https://developer.apple.com/homekit/   Apple HomeKit

HomeKit

HomeKit is a framework in iOS 8 for communicating with and controlling connected accessories in a user's home. You can enable users to discover HomeKit accessories in their home and configure them, or you can create actions to control those devices. Users can group actions together and trigger them using Siri.

App Developers

If your iOS app is primarily designed to provide home configuration or home automation services such as turning on a light or opening a garage door, learn more about the HomeKit APIs used for communicating with HomeKit accessories.

Introducing HomeKit

Designing Accessories for iOS and OS X

Hardware Developers

If you're interested in creating a HomeKit–enabled hardware accessory, you need to be an MFi licensee to access the resources for manufacturing hardware that integrates HomeKit technology. MFi licensees receive:

- HomeKit technical specifications
- MFi Logos and Identity Guidelines
- Hardware technical support

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Intel IoTs developer Kit

- https://software.intel.com/en-us/iot/home

https://software.intel.com/en-us/iot/devkit

The Intel® IoT Developer Kit is **a complete hardware & software solution to help you explore the IoT space and create innovative projects.**

Here is everything you need to get going; a development board and starter kit including Yocto Linux system, Eclipse and XDK IDE, IoT Cloud Analytics, a set of libraries, and more. Order either the Intel® Galileo or Intel® Edison board and the Grove Starter Kit Plus - Intel® IoT Edition.

Intel® IoT Developer Kit

Boards, sensors and software tools to get your dev environments ready for coding.

Introduction to the Dev Kit › (/en-us/blogs/2014/09 /08/announcing-intel-iot-developer-kit)
Dev Kit Overview & Hardware Access › (/en-us/iot/devkit)
Download the Software › (/en-us/iot/downloads)

Get up and Running

Dive into starter guides and sample projects to help get your development environment up and talking to your hardware.

Getting Started Guides › (/en-us/iot/getting-started)
Code Samples for Sensors and More (https://software.intel.com /en-us/iot/sensors) › (/en-us /iot/getting-started)
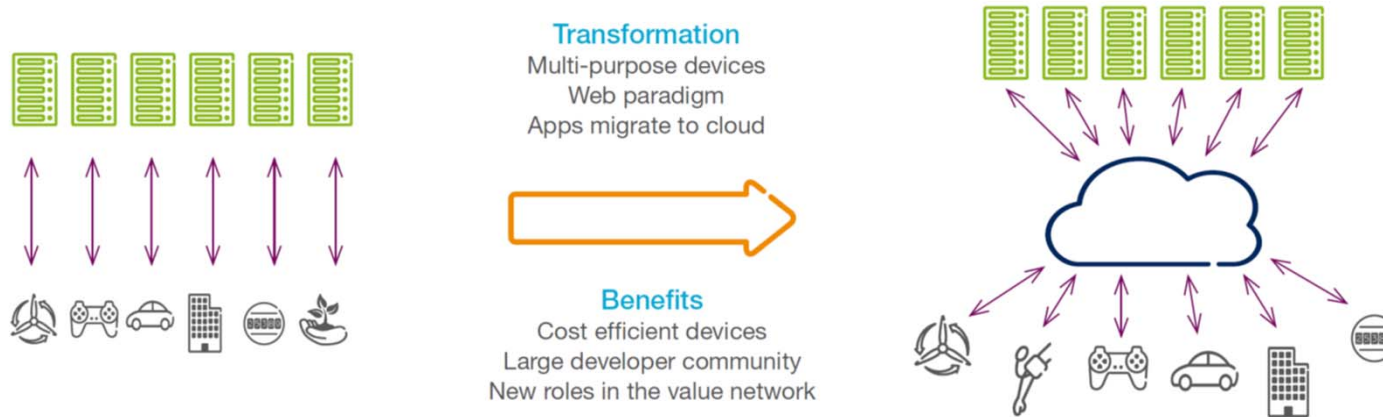
Get Help

Need help with code or hardware? Have a comment? Just want to see what everyone is talking about?

Troubleshooting and FAQ › (/en-us/blogs/2014/11 /18/intel-edison-troubleshooting-and-faq)
IoT Forum › (/en-us/forums /internet-of-things)
Browse our Library › (/en-us /iot/library)

Select a Board:Intel® Galileo board (where to buy) (http://www.intel.com/content/www/us/en/do-it-yourself/galileo-maker-quark-board.html)
Intel® Edison board (where to buy) (http://www.intel.com/content/www/us/en/do-it-yourself/edison.html)

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Ericsson solution for the IoTs

- Internet of Things: Propelling the Networked Society

Transformation
Multi-purpose devices
Web paradigm
Apps migrate to cloud

Benefits
Cost efficient devices
Large developer community
New roles in the value network

Moving from silos to an Internet of Things.

A key concept is that of **embedded web services**. Embedded web services are the means to get the valuable data in and out of the devices, using a well established technology that is widely used by many developers. It will also ease the integration to existing Internet services and enterprise systems

Resource View
/temp /light /switch
REST (CoAP, HTTP)
UDP/TCP
IPv6, RPL
IEEE 802.15.4 BTLE 2/3G LTE

AT&T M2X service

Top Stories from M2M Magazine 03/06/2015

- Ooredoo And Ericsson Launch M2M Platform

- Panasonic launches MVNO aimed at M2M / IoT

- Eurotech to present at M2M World Congress 2015

- SAP, Jasper team up on IoT Services Initiative

- Jasper, China Unicom Partner on Enterprise IoT

- Libelium Sensors Connect with Microsoft IoT Cloud

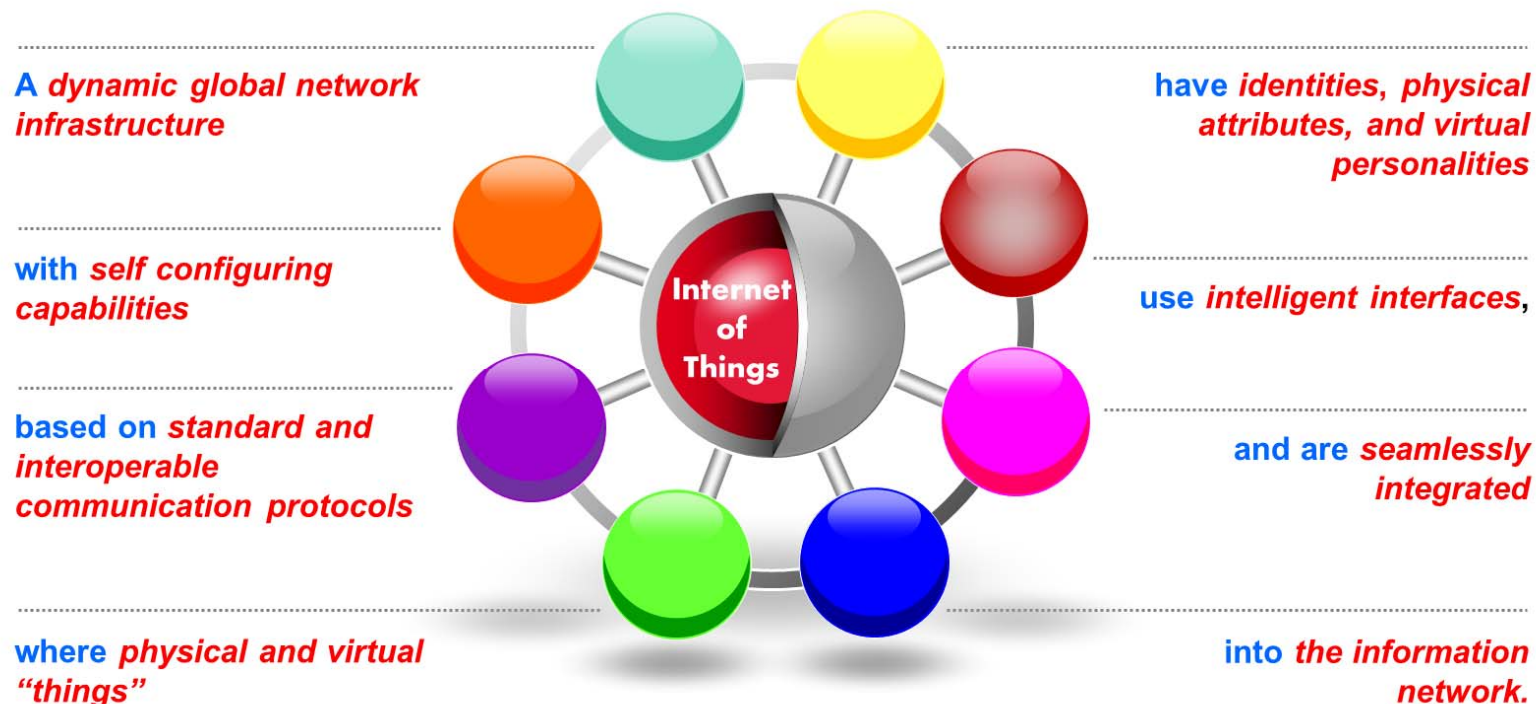- HP announces Internet of Things (IoT) Platform

What is being done / needs to be done

with the recent hype, is there **anything left to do**?

- it appears yes:
  - beyond application side, **still many open issues** regarding the system aspects, the infrastructure, the protocols, …
  - to me, as a researcher, it remains unclear as to what is still needed to make this thing fly, as expected by all market reports and company activities
  - what is clear is that the companies keep announcing not only policies, but also products and applications … **many enablers around, but**

- as evidenced by existing activities, we need:
  - **research** – rich activity exists in many disciplines; which needs to come together (need for some coordination?)
  - **many accompanying measures and activities must be agreed&finalised**
  - **widescale deployment issues must be addressed**

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IoTs in a nutshel (another view)

A **dynamic global network infrastructure**

with **self configuring capabilities**

based on **standard and interoperable communication protocols**

where **physical and virtual "things"**

Internet of Things

have **identities, physical attributes, and virtual personalities**

use **intelligent interfaces**,

and are **seamlessly integrated**

into **the information network.**

Within each of these domains it appears <u>**much work is still needed**</u>, and furthermore this should appear as a <u>**complete system**</u>, also addressing such issues as management, fault tolerance, etc…

Talk summary on IoTs

- What is the IoTs, and what is its vision

- Application spectrum and industry forecasts

- Where are we today?

- Industry "hype" and commercial announcements by key players in the marker

- **Research challenges**

- Accompanying measures and activities

- Realising the IoTs (one supporting approach is the Web of Things)

- Concluding remarks and discussion

A Google scholar search on IoTs

**with 16,000 hits in 2015
and about 89,600 results in 2016**

Google internet of things
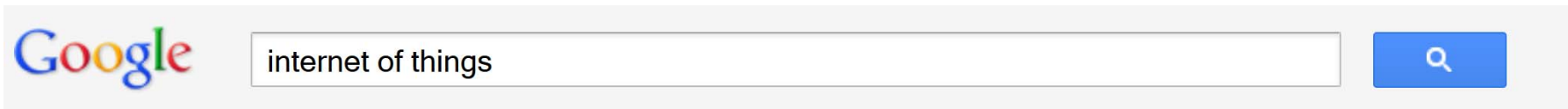
Scholar   About 2,080,000 results (0.04 sec)

Articles

Case law

My library

Internet of things

H Kopetz - Real-time systems, 2011 - Springer

Abstract The connection of physical **things** to the **Internet** makes it possible to access remote sensor data and to control the physical world from a distance. The mash-up of captured data with data retrieved from other sources, eg, with data that is contained in the Web, gives **...**

Cited by 47   Related articles   All 2 versions   Cite   Save

Any time

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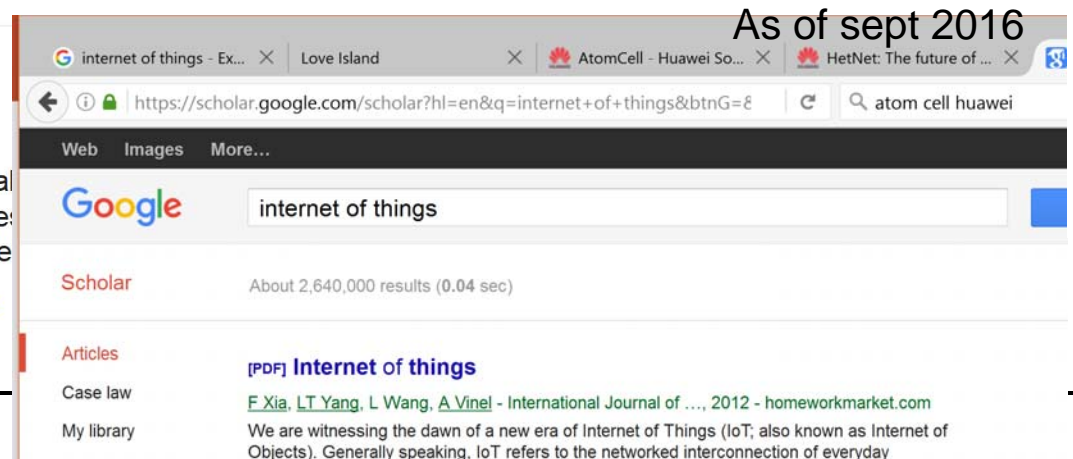Since 2014

Since 2011

Custom range...

[BOOK] Internet of Things

RH Weber, R Weber - 2010 - Springer

The **Internet** of **Things** as an emerging global facilitating the exchange of goods and service technology of the **Internet** of **Things** is still be

Cited by 47   Related articles   All 5 versions

As of sept 2016

G internet of things - Ex... × Love Island × AtomCell - Huawei So... × HetNet: The future of ... ×

https://scholar.google.com/scholar?hl=en&q=internet+of+things&btnG=8   Q atom cell huawei

Web   Images   More...

Google   internet of things

Scholar   About 2,640,000 results (0.04 sec)

Articles

Case law

My library

[PDF] Internet of things

F Xia, LT Yang, L Wang, A Vinel - International Journal of ..., 2012 - homeworkmarket.com

We are witnessing the dawn of a new era of Internet of Things (IoT; also known as Internet of Objects). Generally speaking, IoT refers to the networked interconnection of everyday

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Research challenges (indicative list)

- robustness and scalability at a massive scale (trillions of devices/objects/machines)
- diverse traffic requirement needs
- interoperable architecture(s)
- protocol convergence
- dependencies between shared resources
- big data and knowledge creation
- openness and standards
- security and privacy, and the impact of privacy laws
- human-in-the-loop
- cultural impact

- new technologies: Nanonetworks and IoTs

Research: Robustness and Scalability

- eventually **trillions of things will be on the Internet**.
  - How to name, authenticate access, maintain, protect, use, and support such a large scale of things are major problems. Will IPv6 suffice? Will protocols such as 6LowPAN play a role? Will entirely new standards and protocols emerge?
  - New transport and congestion control protocols that can handle effectively enormous amounts of data
  - How will devices including mobile devices be discovered? Many protocols and variations will coexist. What will be the architectural model that can support the expected heterogeneity of devices and applications?
  - many of the things on the Internet will require their own energy source, will energy scavenging and enormously low-power circuits eliminate the need for batteries?
  - How will the massive amounts of data be collected, used, and stored?
  - How will the real-time and reliability aspects be supported?

- The goal is for a collection of solutions to create a robust system in spite of noisy, faulty, and nondeterministic underlying physical world realities. In certain case, e.g. safety critical ones, certification may be required

Research: Diverse traffic requirement needs

- IoT with its envisioned billions of devices producing information of very different characteristics will place additional requirements on the underlying **communications and networking layers**

- networks should accommodate not only the number of devices but also the **very different traffic requirements** including delay tolerance, latency and reliability.
  - This is of particular importance for wireless access networks which traditionally have been optimized based on a different set of characteristics

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Research: Interoperability

- **key challenges** **in IoT, due to e.g.:**
    - high–dimensionality, with the co-existence of many systems (devices, sensors, equipment, etc.) that need to communicate and exchange information
    - highly-heterogeneous, vast in number systems, conceived by many manufacturers, designed for much different purposes, targeting diverse application domains, make it extremely difficult (if not impossible) to reach out for global agreements and widely accepted specifications
    - highly dynamic, where new Things (that were not even considered at start) are entering (and leaving) the environment all the time and that support new unforeseen formats and protocols but that need to communicate and share data in the IoT
    - hard to describe/model due to existence of many data formats, described in different languages, that can share (or not) the same modelling principles, and that can be interrelated in many ways with one another, within and across different applications

- **thus,** **interoperability in the IoT is a complex problem**

Research: Interoperable architecture

- need **innovative architecture and platforms to support highly complex and interconnected IoT applications**, for billions of devices that permit easy connectivity, control, communications, and applications
  - must include both the physical and cyber elements based on enabling technologies
- need to interact in and across applications, where things and information at one instance may be shareable, and yet in another instance these objects are too personal to share (e.g. dynamic facebook of things)
- yet, many applications would share sensing and actuation resources, but when multiple applications are running simultaneously interference problems will arise
- to stimulate application development, an IoT ecosystem defining open APIs, similar to app stores, can be established
  - e.g. standards and automatic checks can be made to ensure that an app can execute on a given platform: correct version of underlying operating system (OS) and the required sensors and actuators are checked when the app is installed

Research: IoT Protocols Convergence

- interconnected devices need to communicate using **lightweight protocols**:

  - e.g. C, Java, MQTT, Python and some scripting languages prefered choices by IoT applications

  - if protocol conversion needed, IoT nodes use separate IoT gateways: e.g. database storage, or decision making

- must be capable to convey the information (data) contained in a particular domain to other domains

- two dominant architectures for data exchange protocols: bus-based, and broker-based

Research: IoT Protocols Convergence

- a way to classify IoT protocols is whether they are
  - **message-centric**. AMQP, MQTT, JMS and REST focus on the delivery of the message to the intended recipient(s), regardless of the data payload it contains.
  - **data-centric**: DDS, CoAP and XMPP focus on delivering the data and assume the data is understood by the receiver. Middleware understands the data and ensures that the subscribers have a synchronized and consistent view of the data.

- Yet another fundamental aspect of these protocols is whether it is **web-based** like CoAP **or application-based** such as with XMPP, and AMQP

Research: Dependencies between shared resources

- if **several systems are integrated**, e.g. responsible for energy management (controlling thermostats, windows, doors.shades) and home health care (controlling lights, TVs, body nodes measuring heart rate and temperature, and sleep apnea machines).

- then information can be shared,

  - E.g. the energy management system can adjust room temperature depending on the physiological status of the residents as detected by the home health care system
  - Or even avoid negative consequences. E.g. integrated system will not turn OFF medical appliances to save energy, while being used as suggested by home health care system
  - additionally all the systems can share sensors and actuators, which will reduce the cost of deployment, improve aesthetics of the rooms, and reduce channel contention

- **however, integrating multiple systems is very challenging**, as each individual system has its own assumptions and strategy to control the physical world variables without much knowledge of the other systems, which leads to conflicts when these systems are integrated without careful consideration.

- detecting and resolving such dependency problems is important for correctness of operation of interacting IoT systems

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Research: Big Data and Knowledge Creation

- ennormous amount of raw data being continuously collected
  - need techniques to convert this raw data into usable knowledge
  - large number of real-time sensor data streams will exist
  - often a given stream of data will be used by multiple applications at the same time
- so, different inference, privacy and security issues need taken care of:
  - e.g. in the medical area, raw streams of sensor values must be converted into semantically meaningful activities performed by or about a person such as eating, poor respiration, or exhibiting signs of depression
- main challenges for data interpretation and the formation of knowledge include addressing noisy, physical world data, and developing new inference. Consequently, uncertainty in interpreted data can easily cause users not to trust the system

Research: Openness and standards

- majority of deployed sensor-based systems have been **closed systems**. E.g. cars, airplanes, and ships have had networked sensor systems that operate largely within that vehicle
  - however, these systems' capabilities are expanding rapidly, e.g.
    - Vehicles are automatically transmitting maintenance information and airplanes are sending real-time jet engine information to manufacturers
  - increasingly greater cooperation and 2-way control on a wide scale:
    - cars (and aircraft) talking to each other and controlling each other to avoid collisions, humans exchanging data automatically when they meet and this possibly affecting their next actions, and physiological data uploaded to doctors in real-time with real-time feedback from the doctor
- these systems **require openness** to achieve these benefits
- **however, supporting openness creates many new research problems**
  - all of our current composition techniques, analysis techniques, and tools need to be rethought and developed to consider this openness.
  - new unified communications interfaces will be required to enable efficient information exchange across diverse systems.
  - of course, openness also causes difficulty with security and privacy, and achieving the right balance

Research: Security and Privacy

- **necessary aspect of the IoTs**, especially since objects/devices/things will be interconnected, and mostly wirelessly, and humans will rely on the services offered by the IoTs, even for their everyday life and wellness.

  – providing security for the IoT is even more difficult as devices will mostly have very limited computational and (wireless) communication resources, will be failure prone, and may be difficult to access easily

  – as in the internet, level of security will depend on the application, and also the level of recovery (redundancy). To recover, an imminent attack needs to be detected, identified and recovery measures must be in place to 'self-heal', or at least provide (safe) graceful degradation of service

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Research: Security and Privacy

- as much of the information in an IoT system may be personal data, need to **support anonymity** and restrictive handling of personal information

- when dealing with information related to individuals' positions, destinations, schedules, and user habits, **privacy concerns gain highest priority**. They even might become blockers for such technologies. Consequently not only secure communication paths but also procedures which guarantee anonymity and de-personalization of sensible data are of interest

- number of areas where advances are required, e.g.:
  - cryptographic techniques that enable protected data to be stored processed and shared, without the information content being accessible to other parties
  - techniques to support Privacy by Design concepts

Research: Nanonetworks and IoTs

- **Nanotechnology** witnessing tremendous developments, e.g.

  - novel materials (e.g. graphene) could be integrated to create nanomachines

  - nanomachines can lead to new applications for various industries, e.g.: healthcare, military

  - new emerging field of *nano communications* aims to enable communication between the nanomachines

  - Interconnecting these nanoscale communication networks to Internet, could bring new promising applications

- this in turn will extend the *Internet of Things* to the **Internet of Nano Things (IoNT)**

- **NetRL currently investigating IoNTs through a novel concept: Software Defined Materials (SDN)**

Talk summary on IoTs

- What is the IoTs, and what is its vision

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- Where are we today?

- Industry "hype" and commercial announcements by key players in the marker

- Research challenges

- **Accompanying measures and activities**

- Realising the IoTs (one supporting approach is the Web of Things)

- Concluding remarks and discussion

Accompanying measures and activities

- **Many accompanying measures and activities are required**
  a) Standards, regulation and legislation
  b) Research funding
  c) IoTs knowledge integration (e.g. IoTs European Research Cluster)
  d) Privacy and trust issues
  e) Policies

(a) Standards, regulation and legislation

- **standards** needed for interoperability **both within and between domains**
  - Within a domain, standards provide cost efficient realizations of solutions; a domain can mean even a specific organization or enterprise realizing an IoT
  - Between domains, interoperability ensures cooperation between the domains
- need to consider the **life-cycle process** in which standardization is one of the activities.
  - focus should also be given to **regulation, legislation, interoperability and certification** as other activities in the same life-cycle

(a) Standards, regulation and legislation

- IoT intends to support a number of different applications covering a wide array of disciplines that are not part of the ICT domain

- requirements in these different disciplines can often come from legislation or regulatory activities

  - as a result, such policy making can have a direct requirement for supporting IoT standards to be developed.

- develop a wider approach to standardization including anticipation of (different) policy making in target application areas, and thus be prepared for its potential impact on IoT-related standardization. An example is Smart Grid standardization

(a) Standards, regulation and legislation

- current IoTs related standards and technologies landscape **highly fragmented**
  - fragmentation seen across different applied domains; very little or no re-use of technologies beyond basic communications or networking standards
  - even within a particular applied sector, a number of competing standards and technologies are used and promoted
- entire ecosystem would greatly benefit from less fragmentation
  - faster time to market, economy of scale and reduced overall costs
- another view is **standards targeting protocols vs. systems**
  - emphasis on communications and protocol standards, but little effort in standardizing system functions or system architectures that support IoT
- **integration of data** coming from various application domains not easy
  - data and information does not adhere to any standardized formats including their semantics

(b) The Internet of Things -EU Funding model

- **IoTs is allocated about 1 billion research funding over the H2020 program**

- New call in May 2015

- CT 30 – 2015: Internet of Things and Platforms for Connected Smart Objects
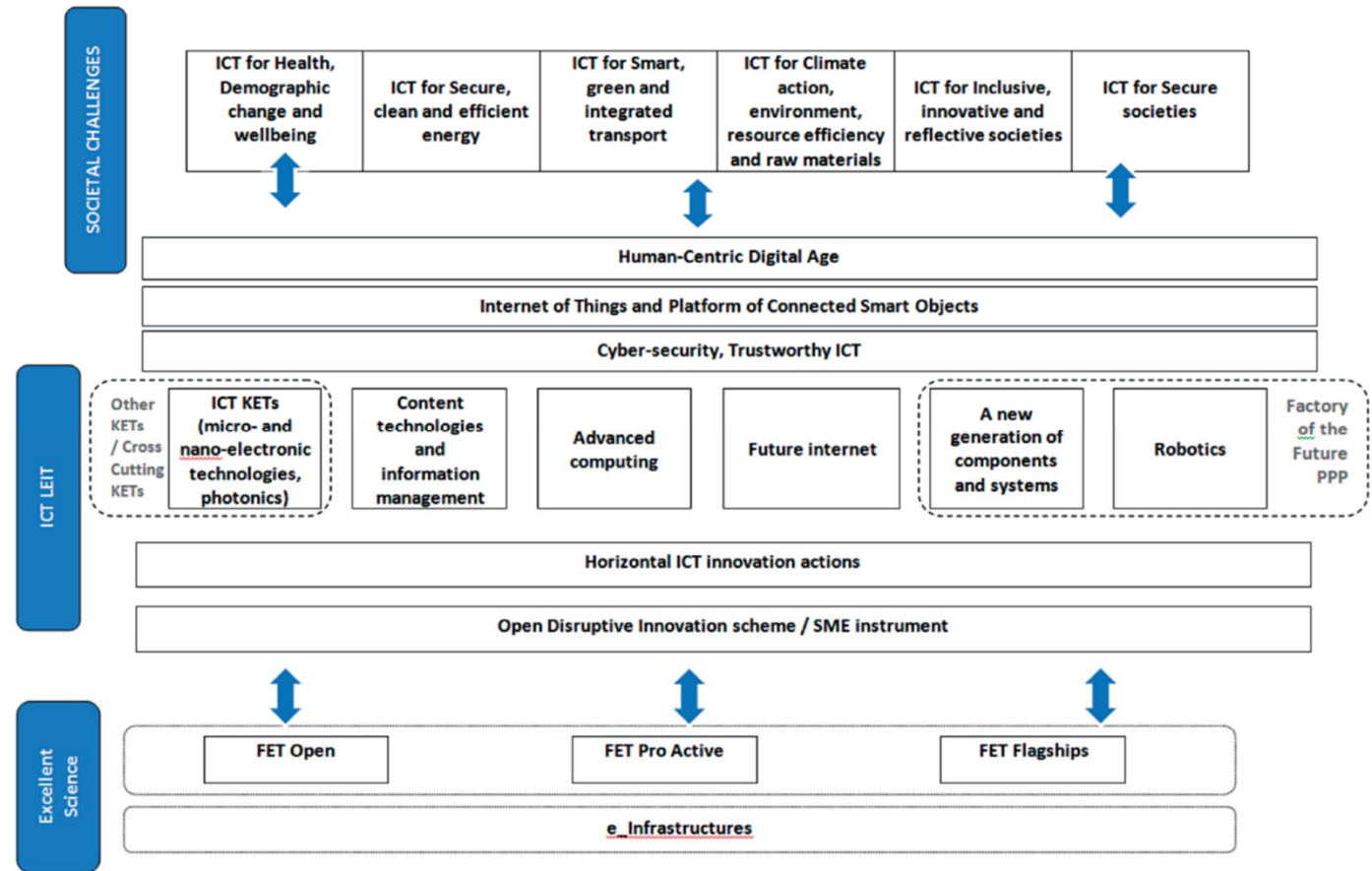
(c) IoTs knowledge integration

- **IoTs knowledge integration remains a big unsolved issue**

- many EU projects and initiatives address diverse IoTs technologies and knowledge.

- can be highly diverse and specialized, therefore a strong need for integration of the individual results.

    – Knowledge integration, in this context is conceptualized as the process through which disparate, specialized knowledge located in multiple projects across Europe is combined, applied and assimilated.

(c) IoTs knowledge integration

IoTs European Research Cluster

(c) IoTs knowledge integration

IoTs European Research Cluster Topics

Also there is an EU IoT expert group: 3 year mandate to discuss the policy aspects of the IoT

(d) Privacy and trust issues

- privacy and trust issues are of major concern and may become the most important stumbling block in the wide deployment of the IoTs

- a range of technical and legislative measures are required

(e) The IoTs Policy Environment (EU view)

- creating a climate for trust and responsible innovation is essential, as the development of IoT touches upon questions of security, privacy and trust

- as IoT becomes widespread in citizens' lives at home, in the office, in public or on the move, need to identify any policy or regulatory requirements, where an impact could be foreseen, as well as in terms of education

- A EU 14 action plan to ensure that the use of IoT technologies:
  - Stimulate economic growth
  - Improve individuals' well-being
  - Address some of today's societal problem
    (see Florent Frederix, European Policy in support of the emerging Internet of Things, May 3, 2011, IT-University in Copenhagen)

Deployment isues: Platform(s) for the IoTs

- different platform(s) that support the IoTs vision can vary from one global to many (e.g. offered by commercial operators, such as a Telecom Operator). These platforms could be federated

- a 'global' sensing and actuation "IoTs utility*" connected to the Internet is an appealing vision; like other utilities it can offer ubiquitous services on demand (e.g. electricity and water)

  - in such a setting many 'ready-made' applications and services will be offered with ease; these could be personalised, home-wide, city-wide, or even global

  - many research issues arise from such a setting, from many different directions and disciplines

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* John A. Stankovic, Research Directions for the Internet of Things, IEEE Internet of Things Journal, Vol. 1, No. 1, February 2014

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Talk summary on IoTs

- What is the IoTs, and what is its vision

- Application spectrum and industry forecasts

- Where are we today?

- Industry "hype" and commercial announcements by key players in the marker

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- Accompanying measures and activities

- **Realising the IoTs (one supporting approach is the Web of Things)**

- Concluding remarks and discussion

Enabling the Internet of Things?

- one supporting approach to realise the IoTs is via the **Web of Things (WoTs)**, e.g.

  Roy Want, Bill N. Schilit, and Scott Jenson, Google, states merging the virtual World Wide Web with nearby physical devices that are part of the Internet of Things gives anyone with a mobile device and the appropriate authorization the power to monitor or control anything

  Ericsson state that embedded web services means to get the valuable data in and out of devices, using a well established technology. Also eases integration to existing Internet services and systems. Variants of Web Services model suitable for the tiniest devices exist

  Google scholar lists over 2 million hits

The Embedded IP Toolbox.

The Networks Research Lab (NetRL) has been active in the WoTs for the past 4 years; see www.NetRL.cs.ucy.ac.cy

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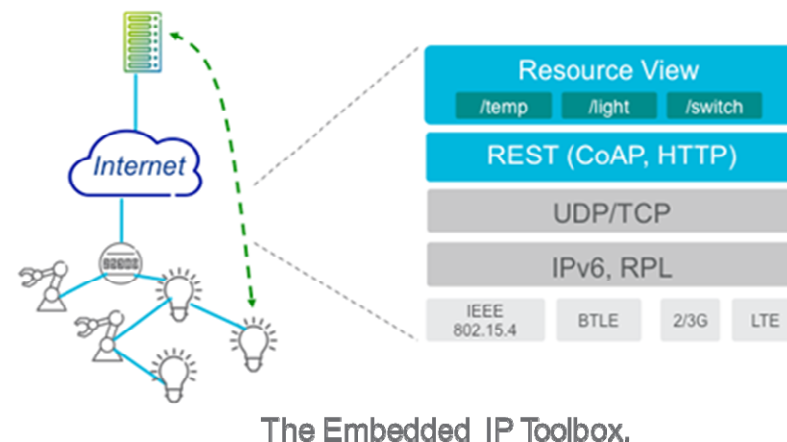
- **Concluding remarks and discussion**

Internet of Things future

- homes, cities, and the world itself will be overlaid with sensing and actuation, embedded in "things" creating a smart world, encompassing Smart devices, Smartphones, Smart cars, Smart homes, Smart cities, Smart Spaces (Urban/Rural)

- **nowadays**:
  - people have smartphones with sensors for running many useful apps
  - sensors are deployed in home automation for security, lighting and HVAC control
  - cars have devices to try and improve safety and transportation
  - buildings have sensors and actuators for user comfort and energy saving
  - industrial plants are connecting their sensors and actuators to the Internet
  - healthcare services are relying on increased remote patient monitoring

- however, all this is just the beginning; all are still at early stages of development and density of deployment. Only when we have dense deployment, we can expect objects to synergistically interact to form totally new and unpredictable services

EU IoT Strategic Research and Innovation Directions

- development of enabling technologies such as nanoelectronics, communications, sensors, smart phones, embedded systems, cloud networking, network virtualization and software essential to provide to things the capability to be connected all the time everywhere.

- also support important future IoT product innovations affecting many different industrial sectors.

  – Some of these technologies such as embedded or cyber-physical systems form the edges of the Internet of Things bridging the gap between cyber space and the physical world of real things, and are crucial in enabling the Internet of Things to deliver on its vision and become part of bigger systems in a world of "systems of systems".

The Internet of Things: suggestions

- move away from proprietary and legacy technologies and solutions, thus opening up and reducing application development costs and time to market

- allow devices to serve multiple applications, and applications to employ multiple devices

- move to a horizontal system with a focus on reuse of common enablers, and a true transformation to using the benefits of IP and web technologies all the way even in the tiniest device
  - Connectivity, access to data, data representation, and processing and storage elements are important common capabilities in such a system

- allow a truly open market to develop and deploy the different solution components, allow commodity components to be used, and enable easier interconnection with existing applications and Internet services

END

A snippet of references used

- A number of references are listed at the point of reference. This is not always done. May colleagues are to be thanked, ad I apologise if I missed referring to their miost valuable work.

- Indicatively, below is a list of references I have drawn considerable input to this talk:

- http://postscapes.com/internet-of-things-resources/
- Internet of Things – From Research and Innovation to Market Deployment, Editors Ovidiu Vermesan, Peter Friess, River Publishers
- Eleonora Borgia, The Internet of Things vision: Key features, applications and open issues, Review Article, Computer Communications, Volume 54, 1 December 2014, Pages 1-31
- John A. Stankovic, Research Directions for the Internet of Things, IEEE Internet of Things Journal, Vol. 1, No. 1, February 2014
- http://www.sciencedirect.com/science/article/pii/S0140366414003168
- http://www.ericsson.com/res/docs/2014/consumerlab/interactivity-beyond-the-screen.pdf
- http://www.forbes.com/sites/gilpress/2014/06/18/a-very-short-history-of-the-internet-of-things/2/

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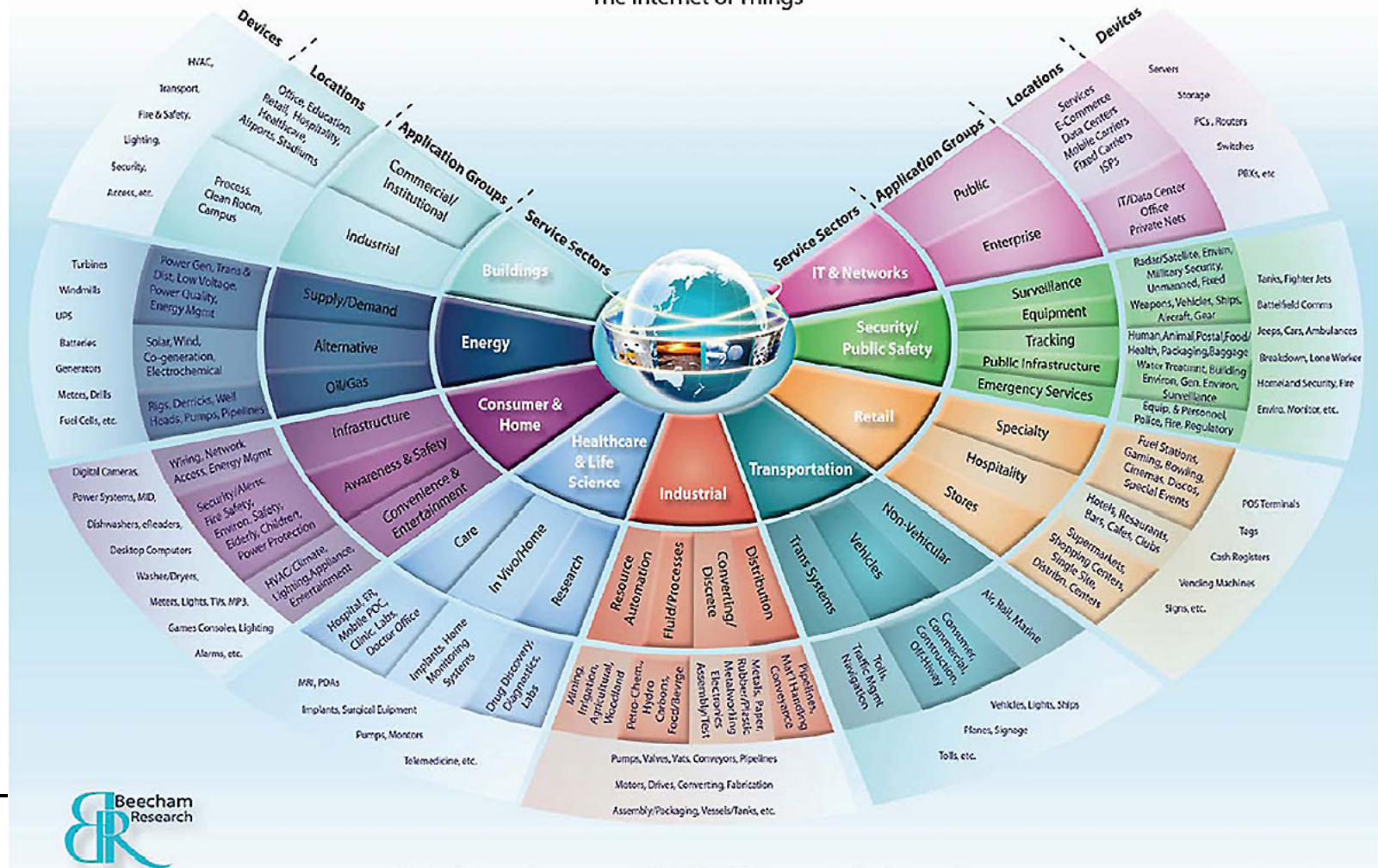# LINKED SLIDES

IoTs application spectrum

numerous applications domains

IoTs application spectrum

across **many industries**

IERC Cluster Book, Internet of Things – From Research and Innovation to Market Deployment, Editors Ovidiu Vermesan, Peter Friess, River Publishers Series in Communication, 2014

IoTs application spectrum
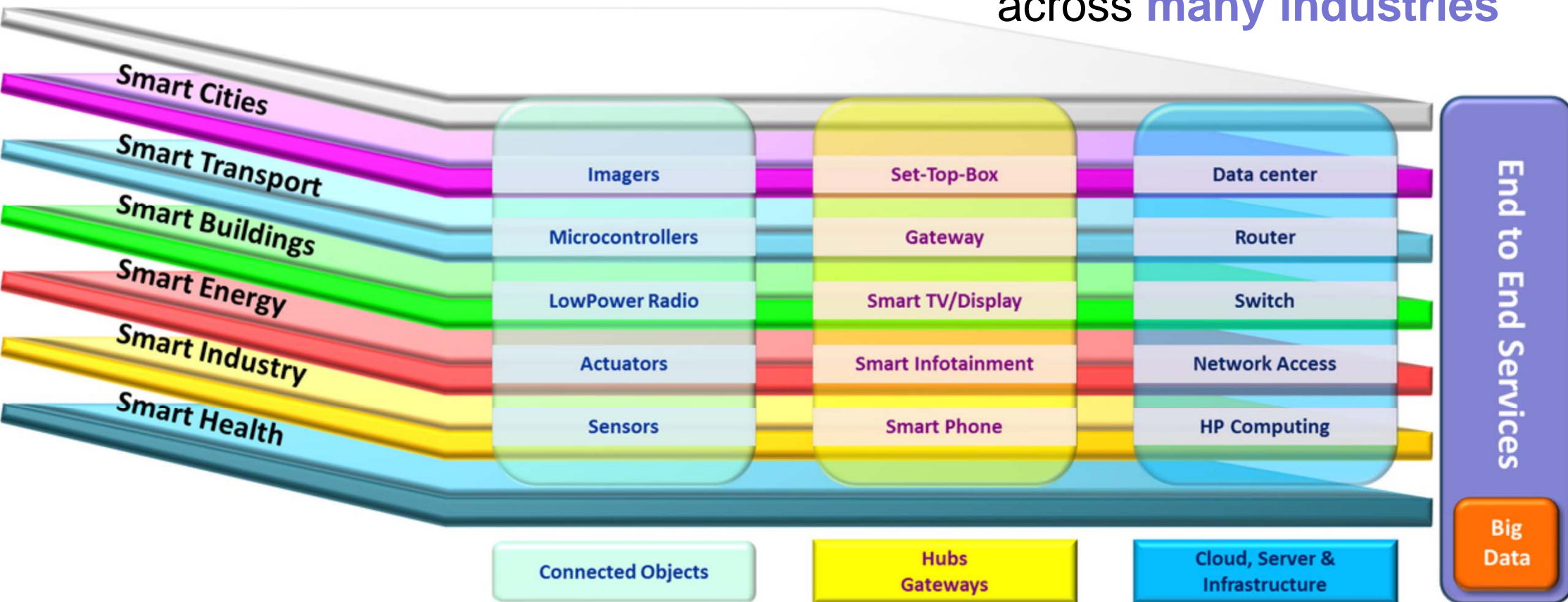
many enabling technologies
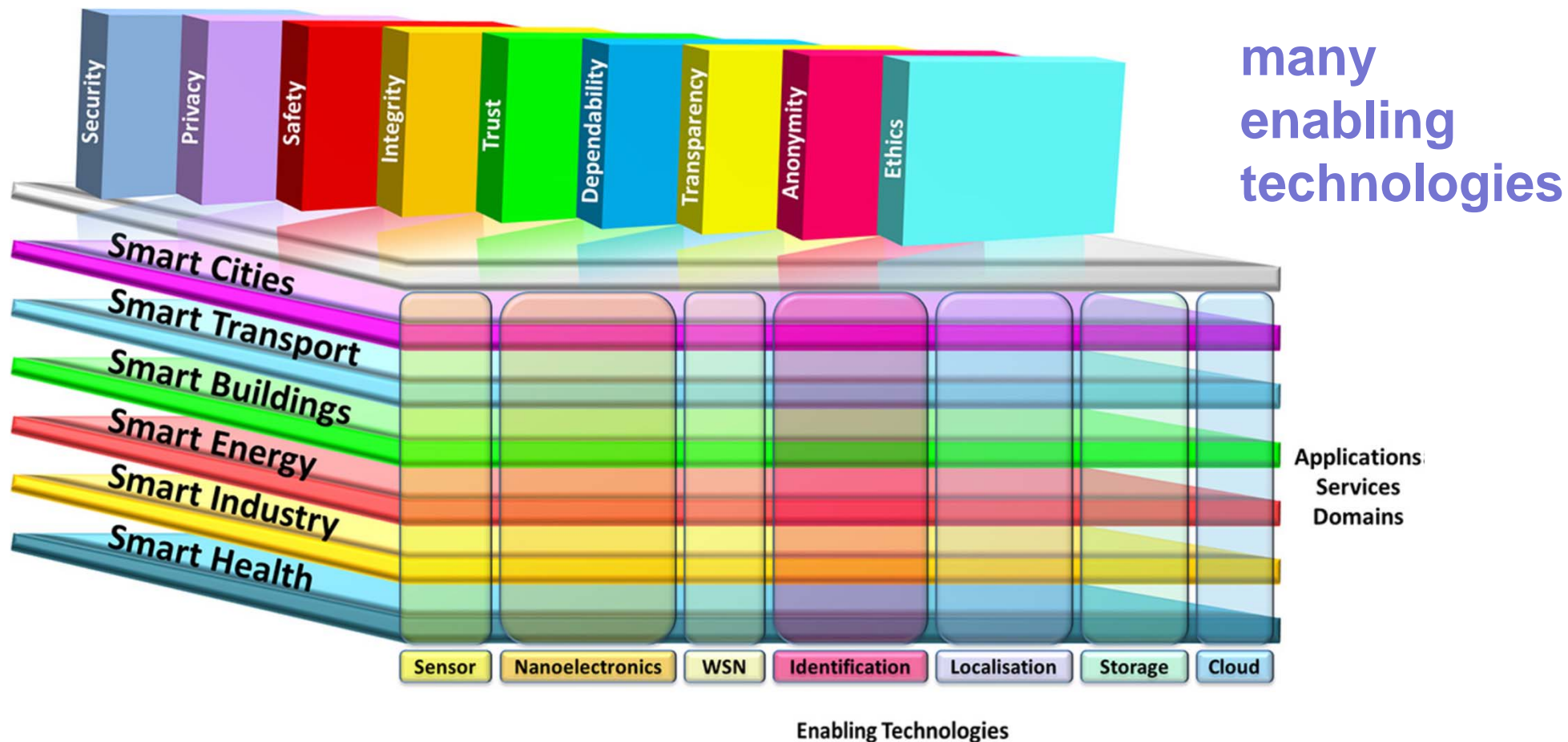
IoTs application spectrum

- **Many technologies** are **converging** to support and enable IoT applications:
  - IoT architecture
  - Identification
  - Communication
  - Networks technology
  - Network discovery
  - Software and algorithms
  - Hardware technology
  - Data and signal processing
  - Discovery and search engine
  - Network management
  - Power and energy storage
  - Security, trust, dependability and
  - Interoperability
  - Standardization

Internet of Things - Smart Environments and Smart Spaces Creation

Research: IoT Protocols Convergence

Broker based architecture for data exchange protocols
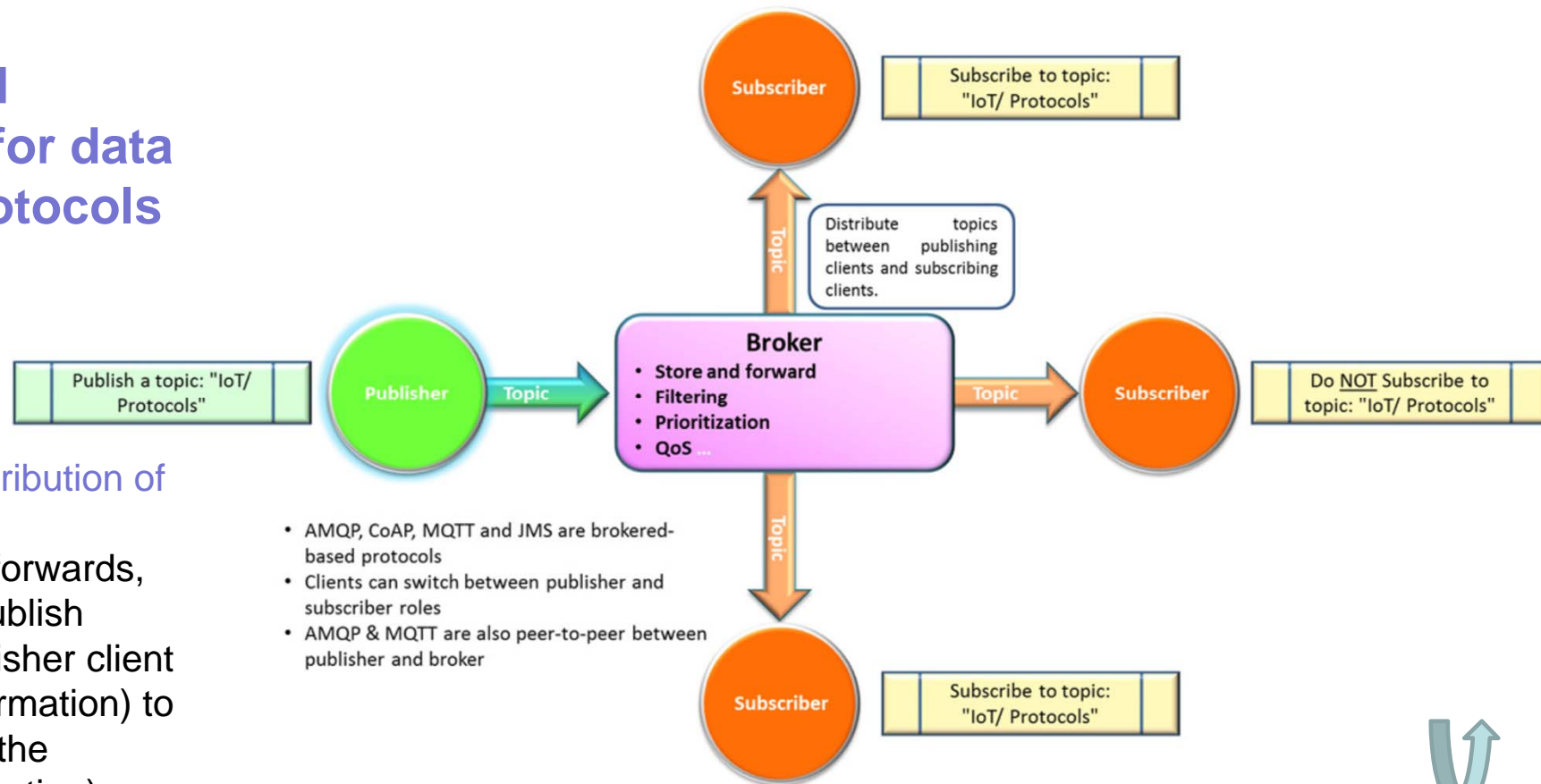
broker controls the distribution of the information:

for example, it stores, forwards, filters and prioritizes publish requests from the publisher client (the source of the information) to the subscriber clients (the consumer of the information)

Subscriber — Subscribe to topic: "IoT/ Protocols"

Distribute topics between publishing clients and subscribing clients.

Publish a topic: "IoT/ Protocols" — Publisher — Topic →

Broker
- Store and forward
- Filtering
- Prioritization
- QoS ...

Topic → Subscriber — Do NOT Subscribe to topic: "IoT/ Protocols"

- AMQP, CoAP, MQTT and JMS are brokered-based protocols
- Clients can switch between publisher and subscriber roles
- AMQP & MQTT are also peer-to-peer between publisher and broker

Subscriber — Subscribe to topic: "IoT/ Protocols"

Research: IoT Protocols Convergence

Bus-based architecture for data exchange protocols

clients publish messages for a specific topic which are directly delivered to the subscribers of that topic. No centralized broker or broker-based services
example protocols
- Data Distribution Service (DDS),
- Representational State Transfer (REST)
- Extensible Messaging and Presence Protocol (XMPP).

Subscribe to topic: "IoT/ Protocols"

Subscriber

Publisher

Publish a topic: "IoT/ Protocols"

Topic

Topic

Data Bus

Topic

Topic

- DDS, REST & XMPP support a broker-less architecture
- Subscriber model shown

Do NOT Subscribe to topic: "IoT/ Protocols"

Subscriber

Subscriber

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