Internet of Things

TIES410 Future Internet
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SIRT

What company is behind this?

✓ Nokia

✓ Skype

✓ Nest Labs

Businesses that have been acquired

Skype acquired by Microsoft for $8.5 billion (May 2011)

Nokia's devices & services business acquired by Microsoft for $7.35 billion (Dec 2013)

Nest Labs acquired by Google for $3.2 billion (announced Jan 2014)

Nest Labs is a rather small company (&unheard by many until acquired), but the potential it brings is big, hence the price tag. And the reason is – Internet of Things (IoT) promise.

Outline

- What is Internet of Things (IoT)
  - Some definitions
  - IoT as a technology
  - IoT from business perspective
- IoT Ecosystem
  - Some definitions
  - The challenge of building an ecosystem
- Digile IoT program

What is the Internet-of-Things?

What is the Internet of Things: Examples of Products

- «Fitbit One» tracker by Fitbit – tracks your steps, distance, calories burned, stairs climbed, it measures your sleep quality, suggests how to sleep better, and wakes you in the morning.

- «Car Connection» by Omnilink and Audiovox – plug-n-play on-board diagnostic (OBDII) device that monitors useful vehicle and driver information to monitor, manage, and maintain a vehicle.

- «WeMo Insight Switch» by Belkin – a switch that connects home appliances and electronic devices to Wi-Fi network, allowing to turn on or off the devices, program customized notifications, and change device status.

…commonality among these examples

- **Device** sensing something in the **environment** or attached thing, or controlling a state (“actuating” something).
- Connected to **Internet** and through it to some applications.
- (Also obs.: limited or no **UI**, often limited computational power and battery **power**, low **price**).

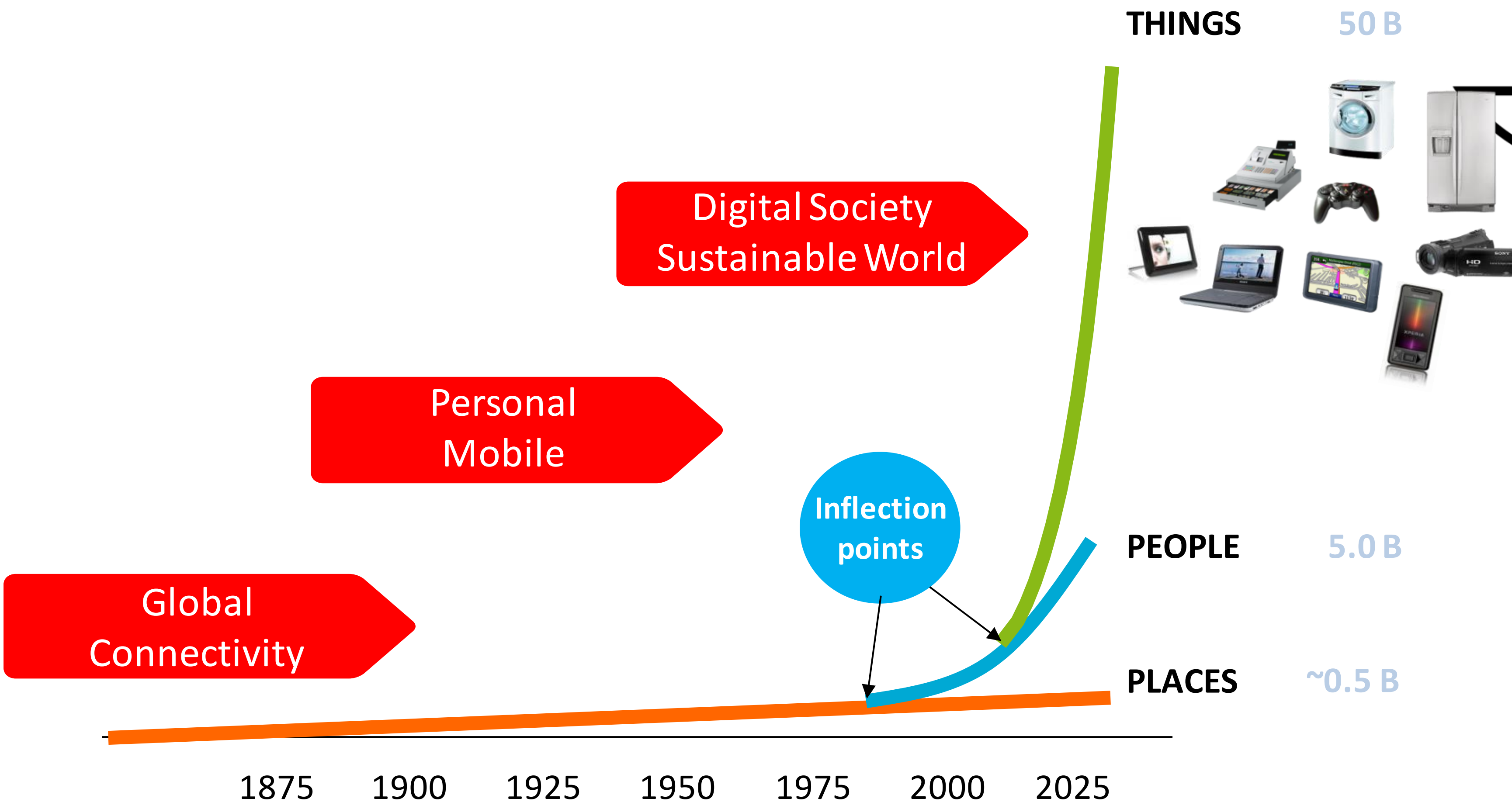
What is the Internet of Things

- The term of IoT was initially introduced by Kevin Ashton in 1999, in relation to the networked radio-frequency identification (RFID) technologies developed at MIT Auto-ID Center.

- The basic idea of the IoT is that virtually every physical thing in this world can also become a computer that is connected to the Internet (Fleisch 2010).

- IoT is thus *connecting the physical world with the digital world.*

Evolution towards "connecting things"



Source: Ericsson

Some Trends Behind and Their Outcomes

Underlying IoT trends including:
- Improving capabilities (processing, communications) of devices,
- Device miniaturization,
- Decreasing price of device HW,
- Increasing number of connected devices,

Offer notable benefits in
- Enabling new applications, as well as in
- Improving existing applications or internal processes,

Despite challenges in
- Communication management,
- Data management,
- Privacy and security,
- Ecosystem formation, etc.,

That shall be analyzed before offering or taking a specific IoT solution into use.

Internet-of-Things: Formal Definition

- A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor (and actuation?) and connection capability as the basis for the development of independent cooperative services and applications (Casagras 2009).

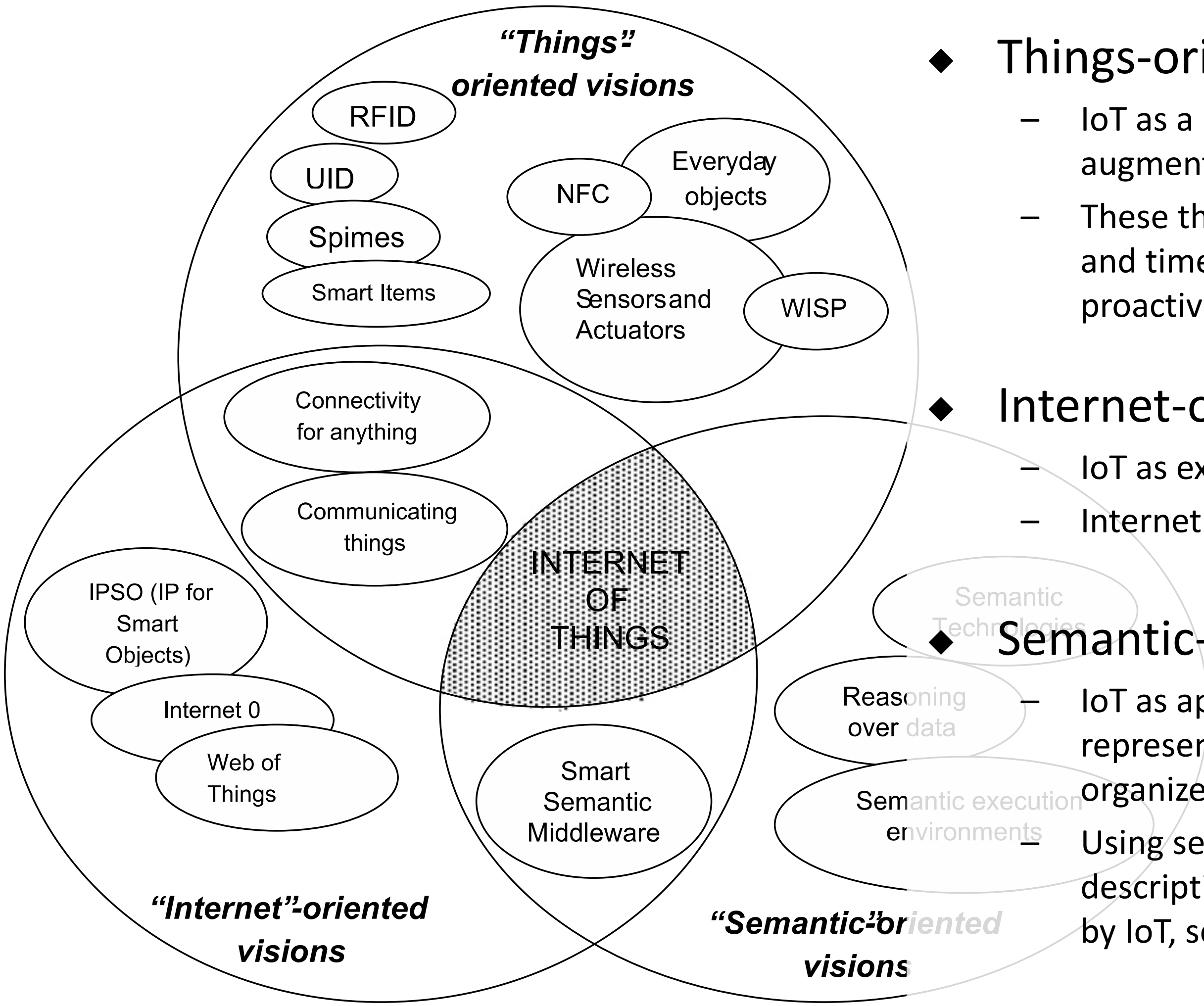
- Is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network (CERP-IoT 2009).

Related Concepts

- Machine-to-Machine (M2M) Communications – is also about inter-connecting things, often used in industrial environment to monitor and control machines or the surrounding environment. It doesn’t presume the use of Internet for communications; often relies on cellular connectivity.

- Web-of-Things (WoT) – similar to IoT; assumes that Web standards (e.g., web services or RESTful architecture) are used for information sharing and device interoperation. The focus is on enriching conventional web services with physical world. (Zeng et al. 2011)

IoT as a vision



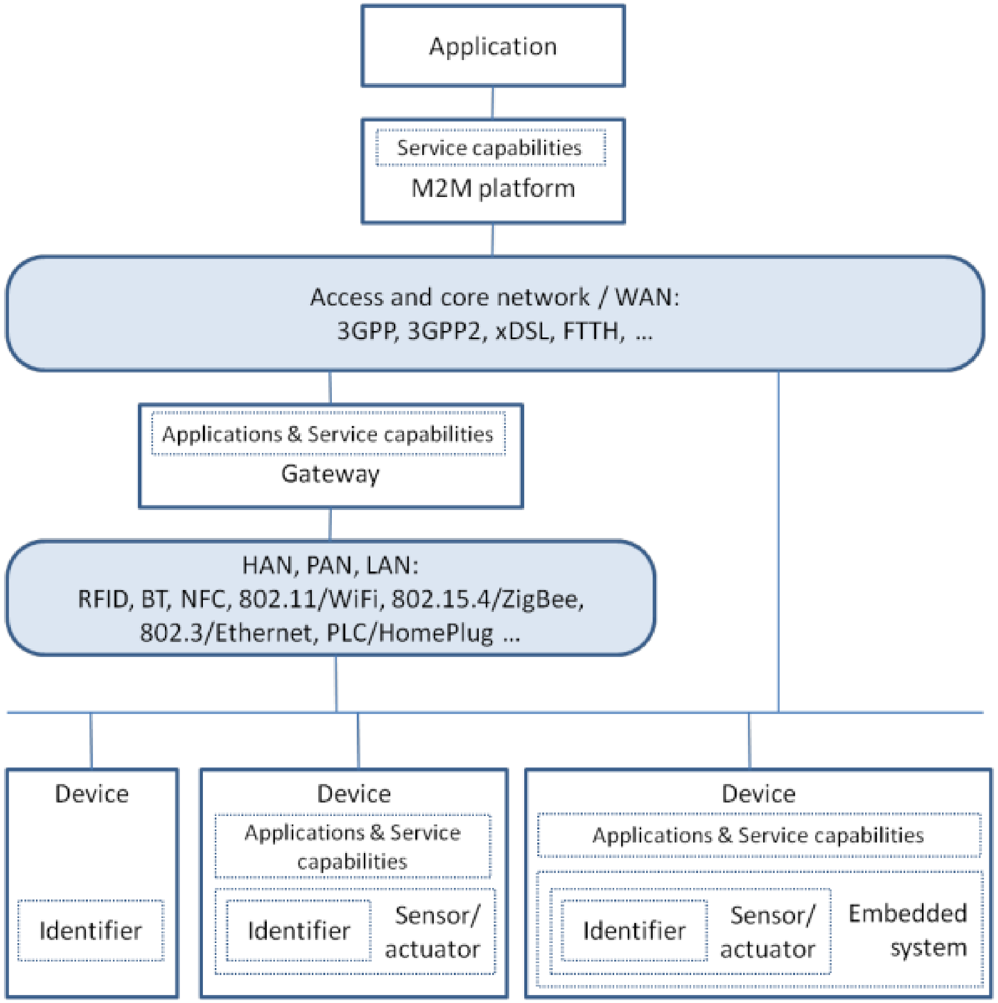
Atzori et al. 2010

- **Things-oriented vision**
  - IoT as a network of everyday *Things*, augmented with some *Intelligence.*
  - These things are traceable through space and time, capable of autonomous and proactive context aware behavior.
- **Internet-oriented vision**
  - IoT as expansion of Internet towards things.
  - Internet and Web protocols (adjusted) used.
- **Semantic-oriented vision**
  - IoT as applying semantic technologies to represent, store, interconnect, search, and organize information about things.
  - Using semantic modeling solutions for things description, reasoning over data generated by IoT, semantic execution environments
  - *Will be discussed in detail in next lecture*

IoT as a Technology: Devices, Protocols, Platforms

- High-level architecture
- Devices and their constraints
- Gateway's role
- Communications protocols
- Application platforms

High-Level IoT Architecture

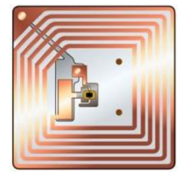


- Structural elements
  - Device (identifier, sensor/actuator, embedded system)
  - Gateway device
  - Application platform
  - Application
- Communications
  - Data communications
  - Control and management plane

(after Hersent et al. 2012)

Things in IoT: IoT "Worlds"

- Tagging world. It is about Identifying things. Identifiers such as RFIDs are attached to things, e.g. packages, to enable their automatic identification and tracking. Based on ID, the information about things can be accessed from a database or from the Web.



- Sensors world. It is about Sensing things, that is “second-hand” access to properties of things, that can be perceived from the outside using a variety of available sensors.

- Embedded systems world. It is about Reading things, that is “first hand” access to data possesses by things, e.g. industrial machines or home electronics, already embedded with some processing and data storage capabilities.

Source: IoT SRA

IoT Device Characteristics

- Taxonomies for the things in IoT:

Dimension	Characteristics
Mobility	Moveable vs. fixed
Size	From tiny microchips to large vessels
Complexity	Dumb vs. smart
Dispersion	Concentrated vs. dispersed
Power supply	Externally powered vs. autonomous
Placement	Attached vs. embedded
Connectivity patterns	Sporadic vs. continuous communication, narrow vs. broadband
Animateness	Non-animate vs. animate

- Possible constraints:
  - limited computational power, memory, radio;
  - limited battery power;
  - low BoM expected;
  - limited or no UI, etc.

IoT Devices: Types of Constrains

- Classes of Constrained Devices:

Name	Data size (e.g., RAM)	Code size (e.g., Flash)
Class 0	<< 10 KiB	<< 100 KiB
Class 1	~ 10 KiB	~ 100 KiB
Class 2	~ 50 KiB	~ 250 KiB

Source: draft-ietf-lwig-terminology

- Note: A notable body of research focuses on "Class 1" devices.

- Similarly, we shall distinguish
  - Classes of energy limitation: from event energy-limited to unlimited
  - Power usage strategy: normally off, low-power (appears connected, perhaps with high latency), always connected

- Does one solution (OS, protocols, etc.) fit all types of devices? Unlikely.

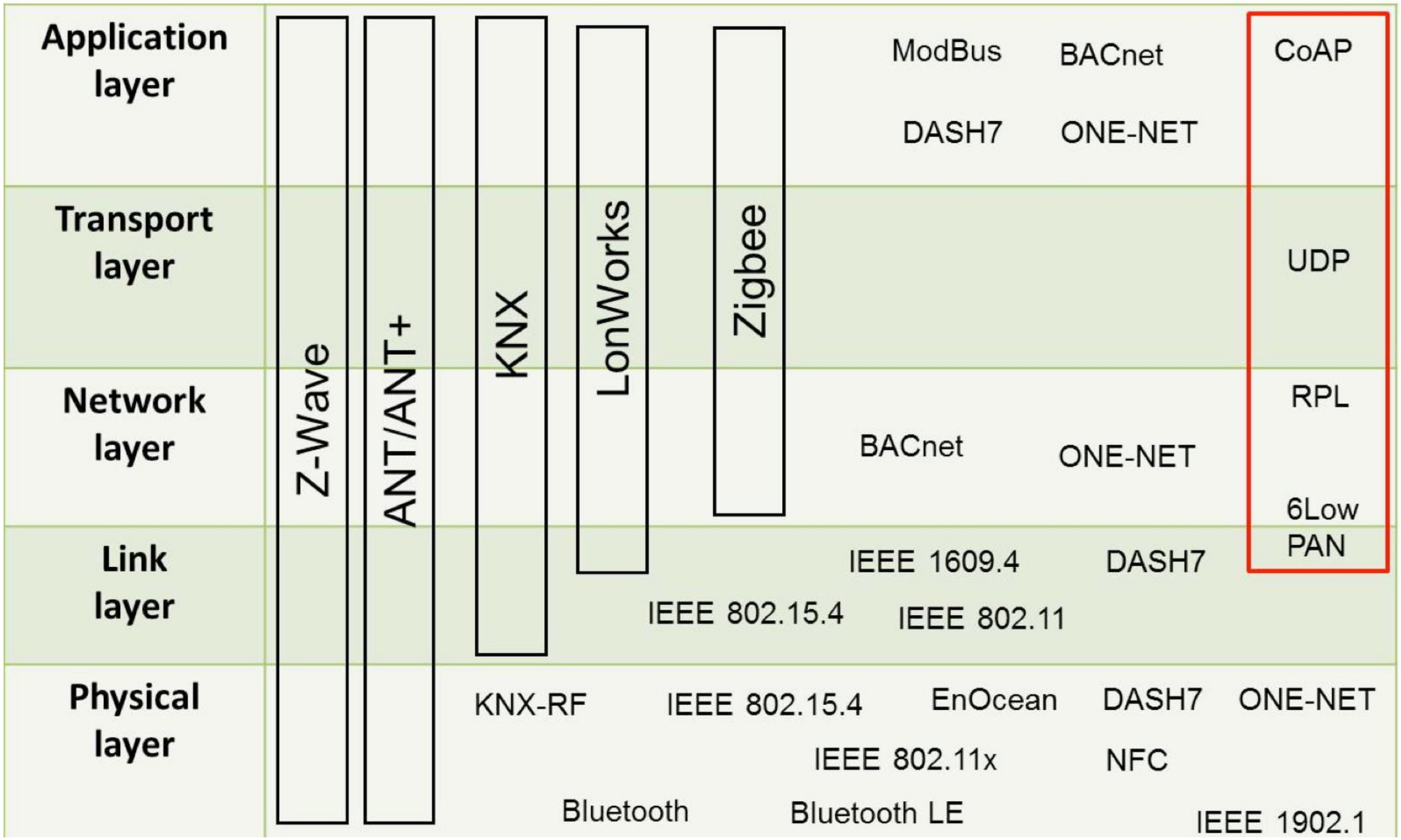
Gateway: Roles

- Gateway device is optional, as devices can directly communicate with their counterparts in Internet.

- But Gateway is still likely needed for:
- Connectivity:
  - Phy & link level bridging, 6lowpan-IPv6 and higher level protocol translation
  - Routing, device discovery
- Management:
  - Management protocol translation, persistence, local management applications
  - Mediation (validation, filtering, aggregation, etc.)
- Context & Semantics:
  - Positioning, presence detection, local semantic reasoning
- Local data handling:
  - Data collection and storage, validation an cleaning, application-specific processing
- Security:
  - Encryption, authentication, authorization, firewall, intrusion detection, bootstrapping
- User interface

- Is a no-gateway solution feasible? Only for some application scenarios.

Short-Range Wireless Protocols



(Henna Suomi 2013)

Short-Range Wireless Protocols

	Network topology	Range	Frequency	Internet GW specs	Protocol inter-operability
Zigbee (IEEE 802.15.4)	Tree, star, mesh	< 100 m	868 MHz 915 MHz	+	GRIP protocol
Z-Wave	Mesh	< 30 m	900 MHz	-	None
Insteon	Mesh	~20-30 m	902 – 924 MHz	+	X10
ONE-NET	Star, multi-hop	50 m – 500 m	868 MHz 915 MHz	+	Open source
KNX	Tree	~50 m	868 MHz	+	Several protocols beneath
WiFi (IEEE 802.11)	Star	30 m – 200 m	2.4 GHz	N/A	Several protocols on top
NFC	P2P	Few cm	13.56 MHz	N/A	N/A
DASH7	Multi-hop (two), star	10 m – 10 km	433 MHz	+	Open source
RuBee (IEEE 1902.1)	P2P	1 m -30 m	132 kHz	N/A	Several protocols on top
EnOcean	Star, mesh	30 m -300 m	868 MHz 315 MHz	+	None
Bluetooth (LE)	Star	5 m – 100 m 50 m (LE)	2.4 GHz	N/A	Several protocols on top
ANT(+)	Star, tree, mesh	~50 m	2.4 GHz	-	None

(Henna Suomi 2013)

Short-Range Protocols vs. Application Areas

	User/device monitoring	Home automation	Large building automation	Automotive
ZigBee	x	x	x	
Z-Wave		x		
Insteon		x		
EnOcean		x	x	
ONE-NET		x		
KNX		x	x	
LonWorks		x	x	
BACnet			x	
Modbus			x	
IEEE 802.11x (e.g. WiFi)	x	x	x	x
DASH7				x
IEEE 1902.1 (RuBee)	x			
Bluetooth (LE)	x			x
ANT/ANT+	x			
Infrared	x	x		

(Henna Suomi 2013)

Short-Range vs. Wide-Range Technologies

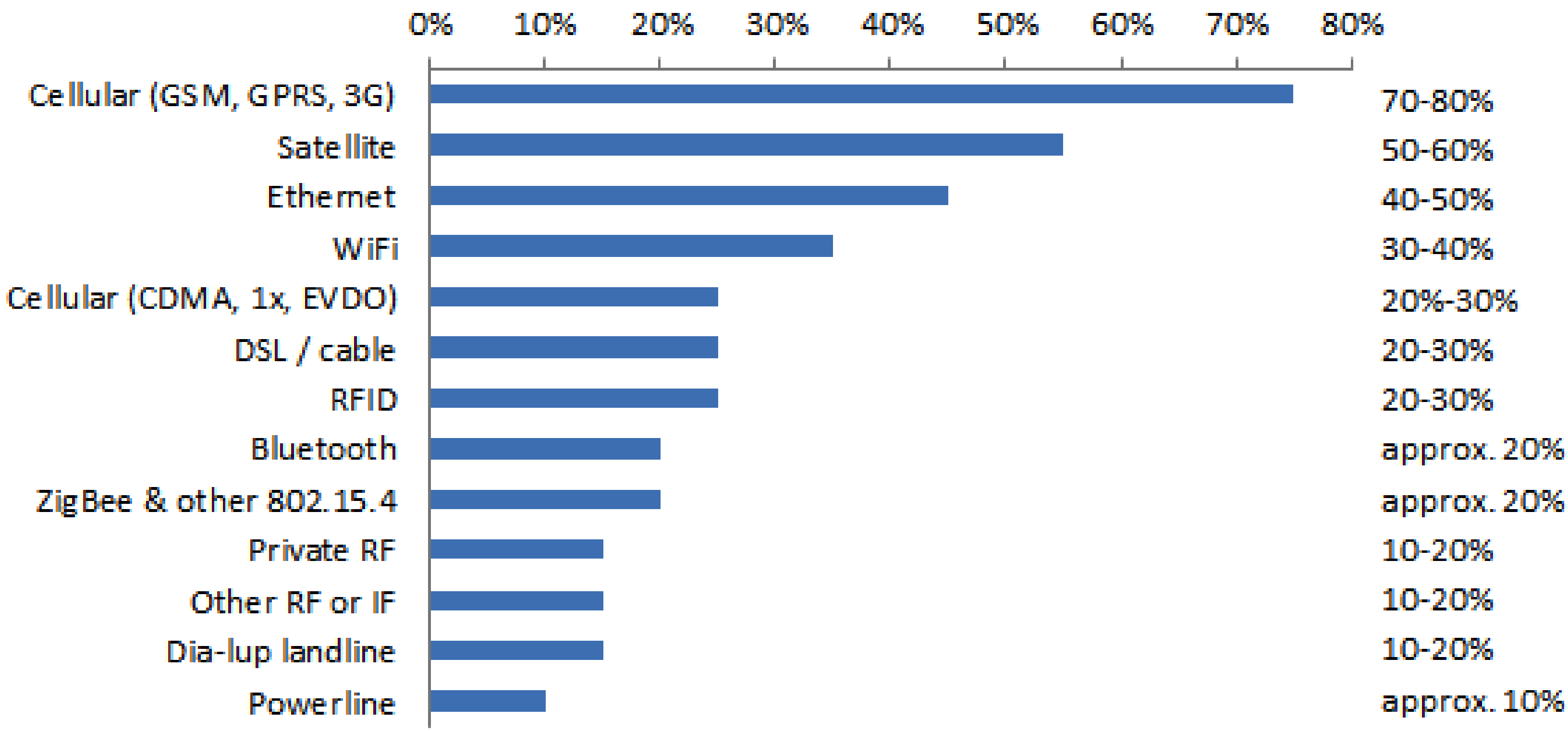
Characteristic	PAN/LAN	WAN
Main standards	ZigBee, WiFi, Bluetooth, Z-Wave. KNX-RF	GPRS/GSM, UMTS, LTE, WiMAX, CDMA, EV-DO
Cost	< $5	≥ $10
Power	~0 dBm	~24 dBm
Spectrum	Unlicensed	Licensed
Topologies	Star and mesh	Star

(Morioka 2011)

- Wide-range protocol implementations
  - Consume an order of magnitude more of energy,
  - Cost twice as much as their short-range counterparts.

- Short-range protocol implementations
  - Usually require a dedicated gateway device,
  - Usually do not support mobility.

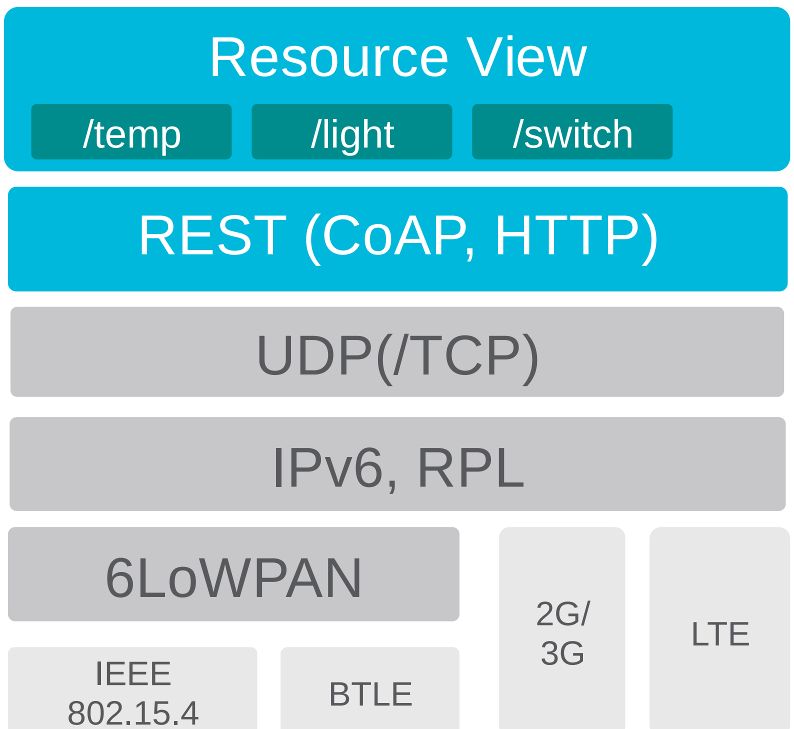
Communications Technologies Used



(Duke-Woolley 2012)

Cellular, satellite, Ethernet, and WiFi are commonly used, whereas the technologies optimized for constrained devices – exemplified by ZigBee and Bluetooth – are still utilized relatively rarely.

Protocol Stack for Constrained Environments: IETF View



(Arkko & Höller 2013)

- Communications characterized by:
  - Low volume of data
  - Sporadic need for communications
- Low cost, low speed physical (and link) layers
  - 802.15.4 (also Bluetooth LE)
  - 10m (50m) communications range, transfer rate up to 250kbit/s (1Mbit/s)
- Integration to IPv6 envisioned
  - 6LoWPAN defines encapsulation and header compression to send IPv6 packets over 802.15.4 networks
- RPL (“Riple”)
  - Defines routing over low- power and lossy networks
- HTTP/TCP is suboptimal, replaced by CoAP/UDP (maybe HTTP 2.0)

Constrained Application Protocol (CoAP):

A Lightweight Alternative to HTTP

- Minimal subset of REST requests including GET, POST, PUT, and DELETE allows the protocol implementations to be less complex as compared to HTTP, thus lowering the hardware requirements for the smart objects on which it executes.

- A compact binary header of 10-20 bytes, along with UDP-based transport minimize the volume of overhead data, and increase battery lifetime.

- Resource caching and built-in resource discovery.

- Reliability with a simple built-in retransmission mechanism – hence can be used without TCP.

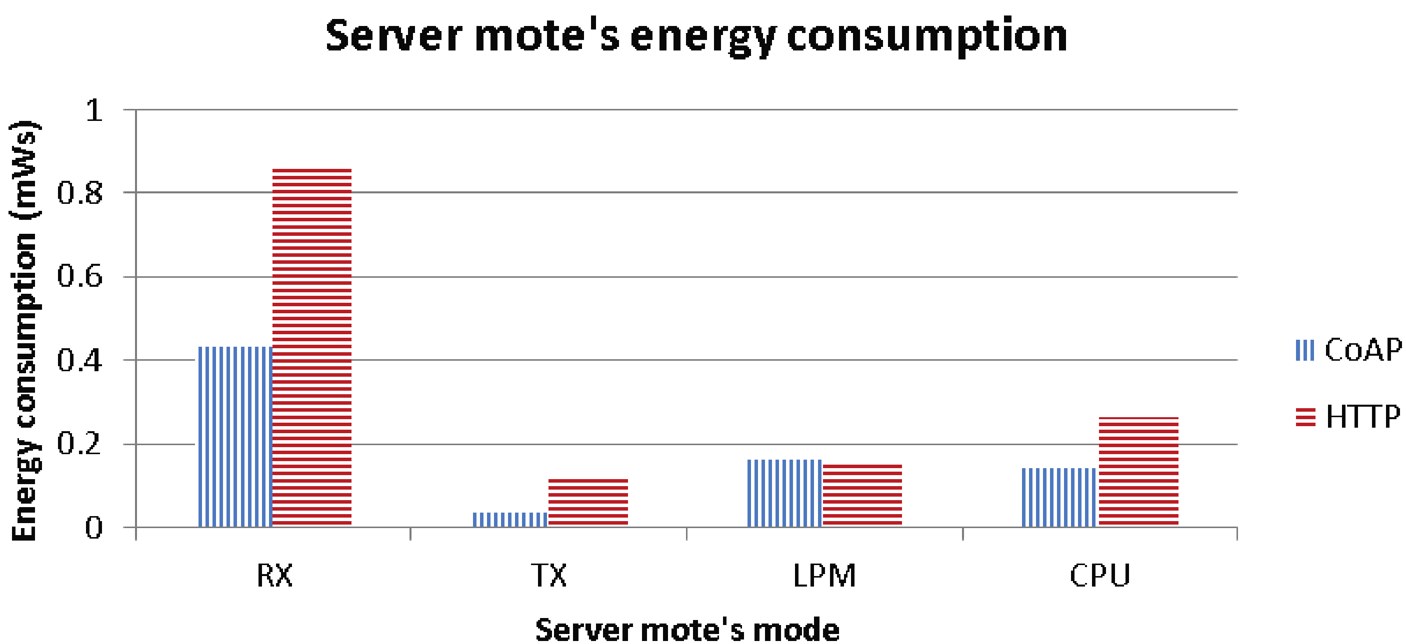
- The support for the asynchronous information push (the *Observe* option) enables the smart objects to send information about the resource only when it changes, allowing the objects to be asleep most of the time.

CoAP vs. HTTP

Bytes transferred per transaction in CoAP and HTTP Protocol

Protocol	CoAP	HTTP
Bytes per transaction	184	1288
Packets per transaction	2	17

Colitti et al. 2011



Thingworx: Example of IoT Application Platform

- Thingworx (http://www.thingworx.com/)
  - application development and execution platform for connected devices, with model-based development environment, mashup builder, semantic data storage.
- *1) Design and implementation of applications/solutions:*
  - *Device:* AlwaysOn Connectivity supports two-way "non-polled" communications (e.g. via REST API or MQTT).
  - *Gateway:* No information has been found.
  - *UI:* The UI development is facilitated by "drag and drop" mashup builder, with a set of widgets for collaboration (blogs, forums, wiki), further expandable via a script engine. The APIs are RESTful, public and open.
  - *Web:* A model-based development environment, with integrated search-query-analysis capabilities. Deployment alternatives: cloud, hosted, on-premise, embedded, and hybrid deployments. Interoperability with other systems and (web) applications is achieved via RSS/Atom, REST, and web services integration.
- *2) Operations:*
  - *a) Fulfillment:* Some support for remote software installation and file transfer. However, neither application discovery nor application purchasing are supported.
  - *b) Assurance, Billing:* No information has been found.

Application Platforms for Internet of Things

- Platform: The extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it, and the interfaces through which they interoperate.
- Several listings of IoT platforms are available:
  - http://postscapes.com/internet-of-things-platforms?order=rhits
  - http://iotensense.wikispaces.com/IOT+PLATFORMS
  - http://thingvibe.net/blog/iot-state-of-the-art/
  - In total, ~40 IoT platforms are available. How mature are they? Are they needed?

- Mobile application distribution platform: Digital distribution platform for application software. Users browse through apps in online store, view meta information, purchase, download and install applications on their device.
  - MobyAffiliates lists over 70 mobile app stores. How many application (distribution) platforms are there for Internet of Things?

IoT Platforms vs. Business Processes

Platform	Design & implementation	Operations: Fulfillment		Operations: Assurance	Operations: Billing
NanoService	Device, GW, Web, UI	AppStore* – No	Provisioning - Yes	Yes	No
OnePlatform	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	Yes	No
SensorCloud	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	No	No
Thingworx	Device, Web, UI	AppStore – No	Provisioning – Yes	Yes	No
Arkessa	Device, Web, UI	AppStore – (Yes)	Provisioning – Yes	Yes	No
Etherios	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	Yes	No
Axeda	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	Yes	Yes
ioBridge RealTime.io	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	No	Yes
ioBridge Thingspeak	Device, Web, UI	AppStore – No	Provisioning – No	No	No
Nimbits	Device, Web, UI	AppStore – No	Provisioning – No	No	No
Xively	Device, GW, Web, UI	AppStore – No	Provisioning – Yes	Yes	Yes
TempoDB	Device, Web, UI	AppStore – No	Provisioning – No	No	No

*AppStore refers to the support for application discovery and purchasing

What is IoT, business-wise?

- Value drivers are in place
- Market forecasts are promising
- Adoption is slowed by some challenges
- Ecosystem formation as the biggest challenge

Examples of IoT Value Drivers

- Simple and automatic identification and tracking:
  - Vehicle tracking,
  - RFID passports.
- Remote state monitoring:
  - Environment monitoring,
  - Community pothole detection,
  - Remote healthcare monitoring.

Further IoT Value Drivers

- *Simplified manual and automatic proximity triggering*. The things are able to communicate their identity in a fast and robust way when in the proximity of a sensor/reader.
- *Automatic sensor-based triggering*. The smart things are able to process the gathered information about the environment and use e.g. rule-based logic to trigger processes and/or actions.
- *Automatic product security*. Using their unique identities, the past behavior of the things can be traced and documented making it much easier to spot (multiple) counterfeiting copies.
- *Entertainment* value, by providing the user with *direct feedback* in the form of beeping, flashing or otherwise.
- *Extensive user feedback* through a gateway (e.g. smartphone) about the properties of the thing (or the object to which it is attached).
- *Mind-changing feedback*, by monitoring of consumer behavior (e.g. driving style or electricity consumption) and provision of information aimed at changing the behavior towards a desired outcome.

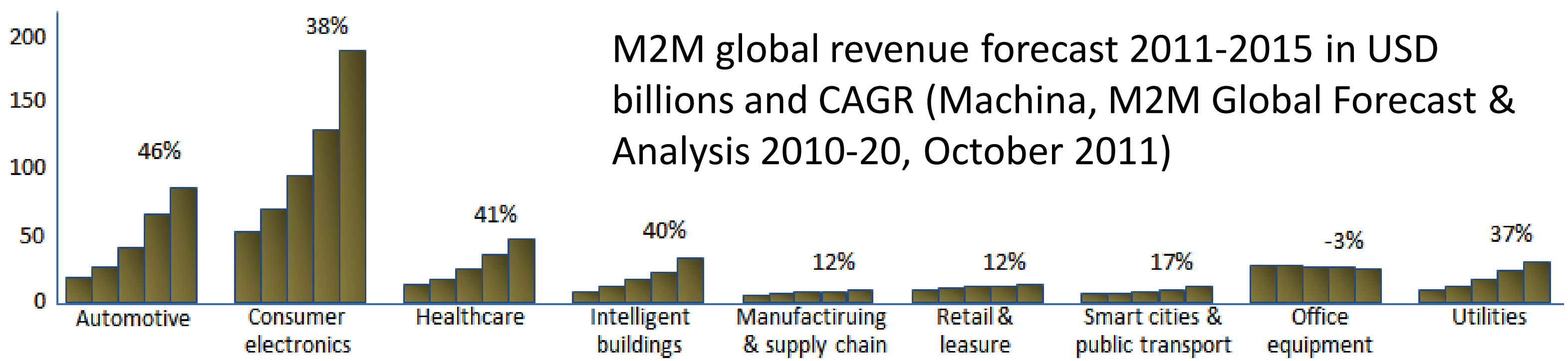
(Fleisch 2010)

Growth Forecasts

- Number of installed devices
  - 26B by 2020 (Gartner)
  - 50B by 2025 (Ericsson)

- Economic impact
  - IoT supplier revenue – $300B by 2020 (Gartner)
  - Total impact (aggregate benefit from IoT) $1.9T by 2020 (Gartner)
  - Total impact (aggregate benefit from IoT) $2.7T…$6.2T by 2025 (MGI)

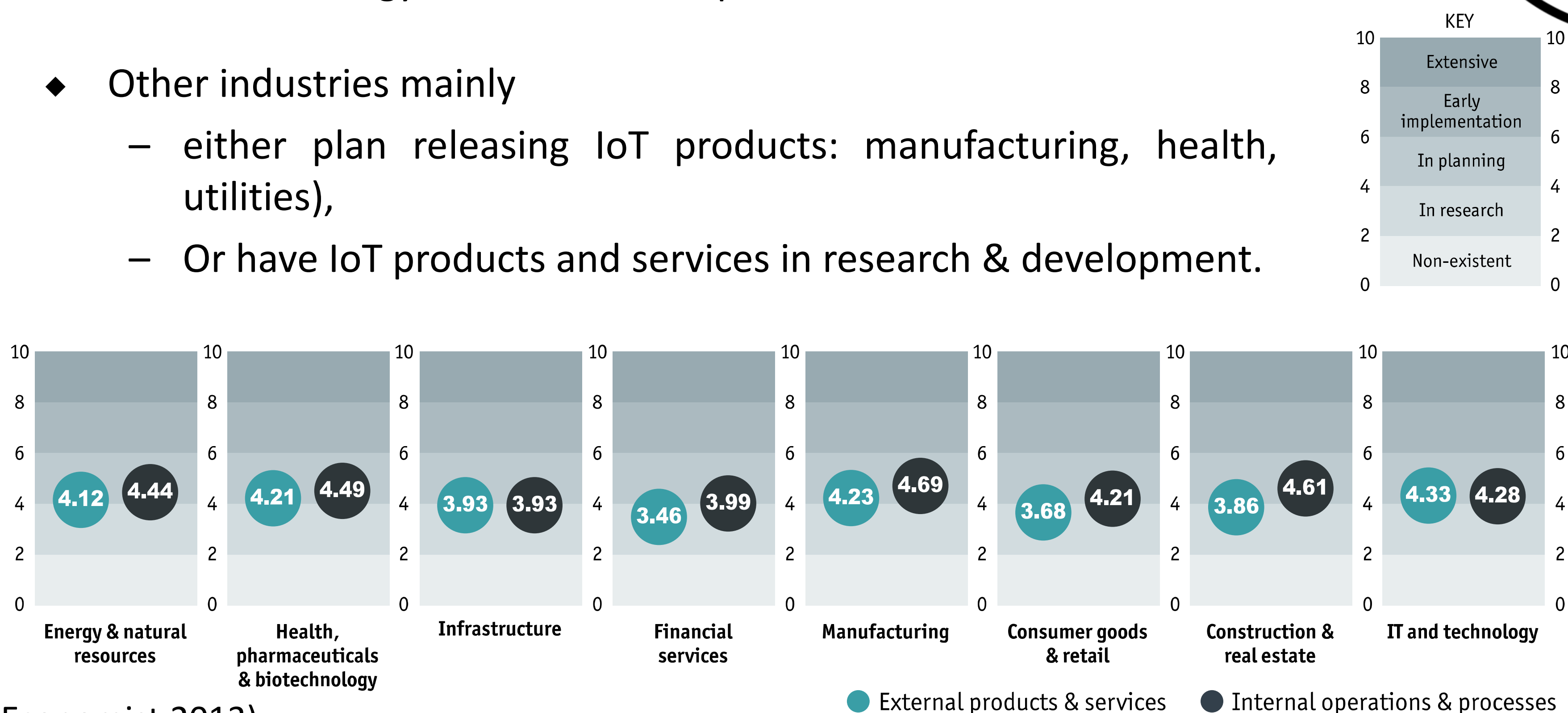
- Leading verticals by 2020 (Gartner): manufacturing (15%), healthcare (15%); insurance (11%).



M2M global revenue forecast 2011-2015 in USD billions and CAGR (Machina, M2M Global Forecast & Analysis 2010-20, October 2011)

IoT current adoption

- IoT is used more in internal operations & processes, e.g. to optimize warehousing or supply chain.
- IT and technology firms lead in IoT products and services.
- Other industries mainly
  - either plan releasing IoT products: manufacturing, health, utilities),
  - Or have IoT products and services in research & development.



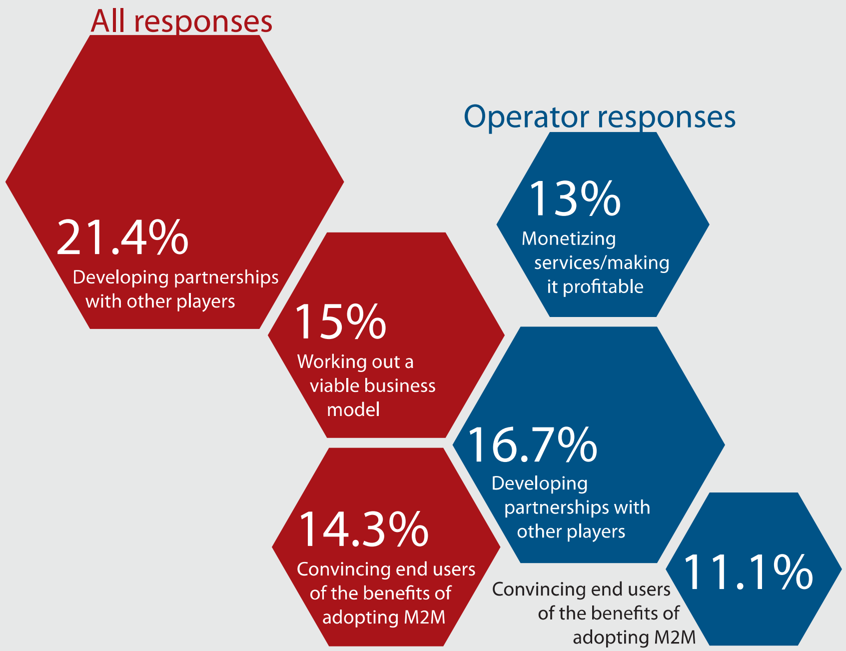
(Economist 2013)

Some of the Challenges

- The IoT data traffic patterns will be different from the current Internet. Thus, it will be necessary to define new QoS requirements and support schemes.
- Security mechanisms (using PKI for authentication, encryption) may be too heavy for Class 1 devices.
- Fragmented solutions specific to vertical industry applications, with little or no interoperability resulting in a **lock-in** for the customers.
- Scattered **standardization** efforts and the general lack of standardized infrastructure/middleware, making the **costs** of IoT solutions high.
- Sound **business models** are still missing.
- Developing efficient **partnerships** and **ecosystem** formation is challenging.

Challenges: Operator Viewpoint

What do you think is the greatest challenge that must be overcome in order for operators to succeed in M2M?



Building scale	4.3%	3.7%
Developing customized services such as billing, data intelligence	7.1%	11.1%
Improving the service/s you offer	5.0%	7.4%
Lack of qualified staff	2.9%	1.9%
Lack of technical standards/regulation	7.9%	11.1%
Monetizing services/making it profitable	10.7%	13.0%
Privacy/security issues	1.4%	0.0%
SIM/device management	3.6%	7.4%
Supply chain issues	2.1%	3.7%
Understanding the market better	4.3%	3.7%

- Developing partnerships is seen as the most challenging by the operators

European Communications 2012

What is a (business) ecosystem?

Business Ecosystem

- A business ecosystem is "the network of buyers, suppliers and makers of related products or services” plus the socio-economic environment, including the institutional and regulatory framework. (Moore, 1996)

- Biological ecosystem is a useful metaphor for understanding a business network, since both the species in a bio ecosystem and firms in a bus ecosystem have to interact and co-evolve: *the survival of each is related to the survival of others thus supporting a balance of both cooperation and competition* (Corallo and Protopapa 2011).
  - In Moore’s BE, firm's *capabilities co-evolve around innovations* (compared to species' evolutionary paths)
  - Evolution of organizations occurs through *natural selection* (fittest survive; routines as genes) and *niche construction* (through their actions, species modify each other's niches)

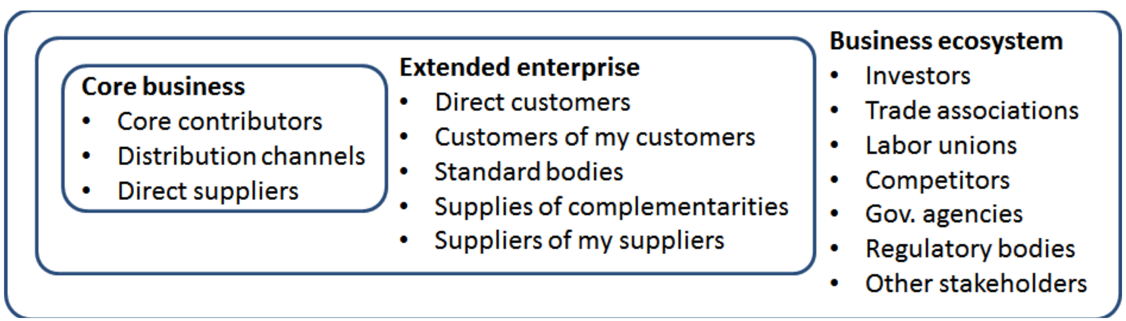
Business ecosystem

- Organizations form an ecosystem around a core (Talvitie 2011)
  - A business ecosystem is a collection of businesses and companies collaborating or competing by utilizing a common and shared set of assets
  - Is founded on an ecosystem core – platforms, technologies, processes, standards or other assets common to and used by members of the ecosystem in their businesses
- Ecosystem is an abstraction; either a whole industry or a small consortium of companies could be seen as an ecosystem (Nachira 2007). Two models:
  - Keystone model implied by Moore (1996), elaborated by Iansiti and Levien (2004) with the ecosystem dominated by a large firm interacting with a large number of small suppliers. The health of the ecosystem depends on the health of the keystone firm. Matches the typical structures in the US.
  - Flat model more typical for Europe – composed of mainly small and medium firms, accommodating also large ones. More dynamic, well-adapted for the service and the knowledge industries (Corallo, 2007).

Ecosystem: Levels of Analysis

- Industry vs. Ecosystem vs. Firm level
  - Industry/market – verticals, customer needs, evolution phase
  - Ecosystem – players and roles, core and auxiliary products
  - Firm – business model, role in ecosystem(s)
- Example:
  - PC Industry: Microsoft vs Apple
  - Smartphone industry: Apple vs Android

- Ecosystem vs. Value network vs. Core business
  - Value network: Includes partners providing complementary products needed to deliver the "whole product"
  - Ecosystem adds to the value network the stakeholders, government agencies, and competitors

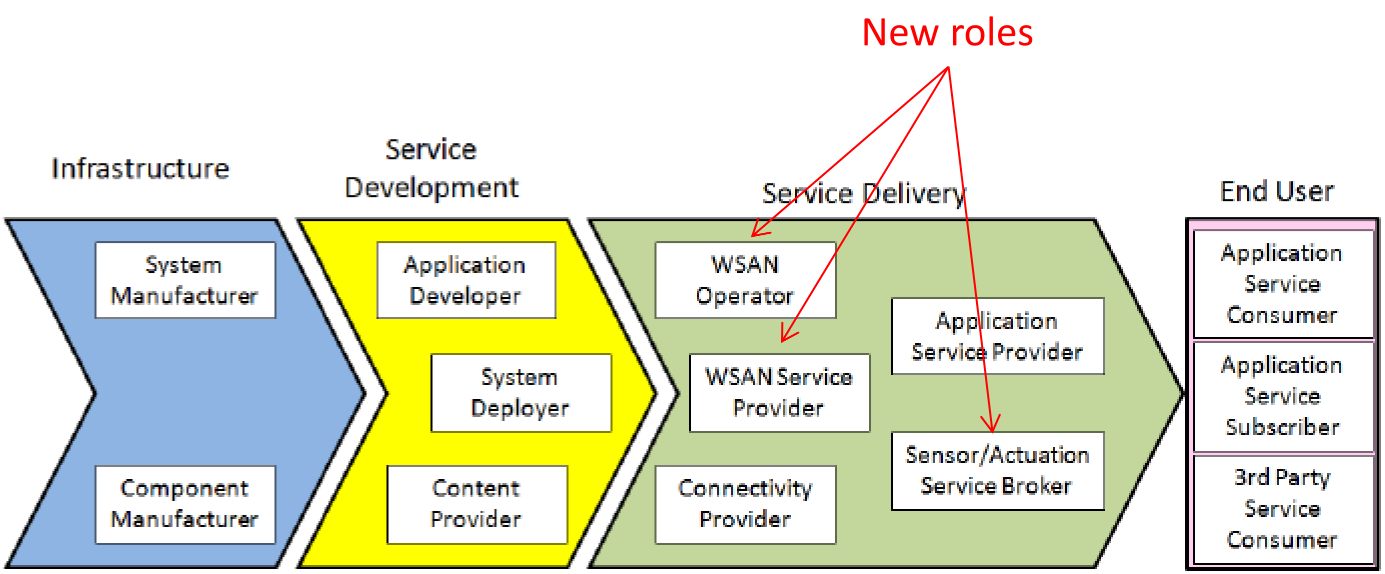


http://www.provenmodels.com

IoT Ecosystem(s)

New IoT Ecosystems

- The “things” in IoT expand existing Internet applications and services and enable new ones. This new functionality creates and requires new technical components and roles and enables the configuration of new business models in ecosystems.



Source: SENSEI Deliverable D1.4 Business Models and Value Creation

Studying IoT Ecosystem Aims at:

- Realizing where IoT is going to
  - What technology is going to get the dominance
  - Considering core, value chain/network, ecosystem
  - Considering time frame, customer base, resulting cost structure
- Realizing how the companies should act, e.g. for vendors
  - In early market – focus on the business customers with critical needs
  - In bowling alley – focus on the niches with unserved demand
  - In tornado – focus on the whole market
  - After tornado – serve your existing customer base

  - Taking into account time, expected dominating technology, expected customer base and cost structure

IoT Ecosystem: Core

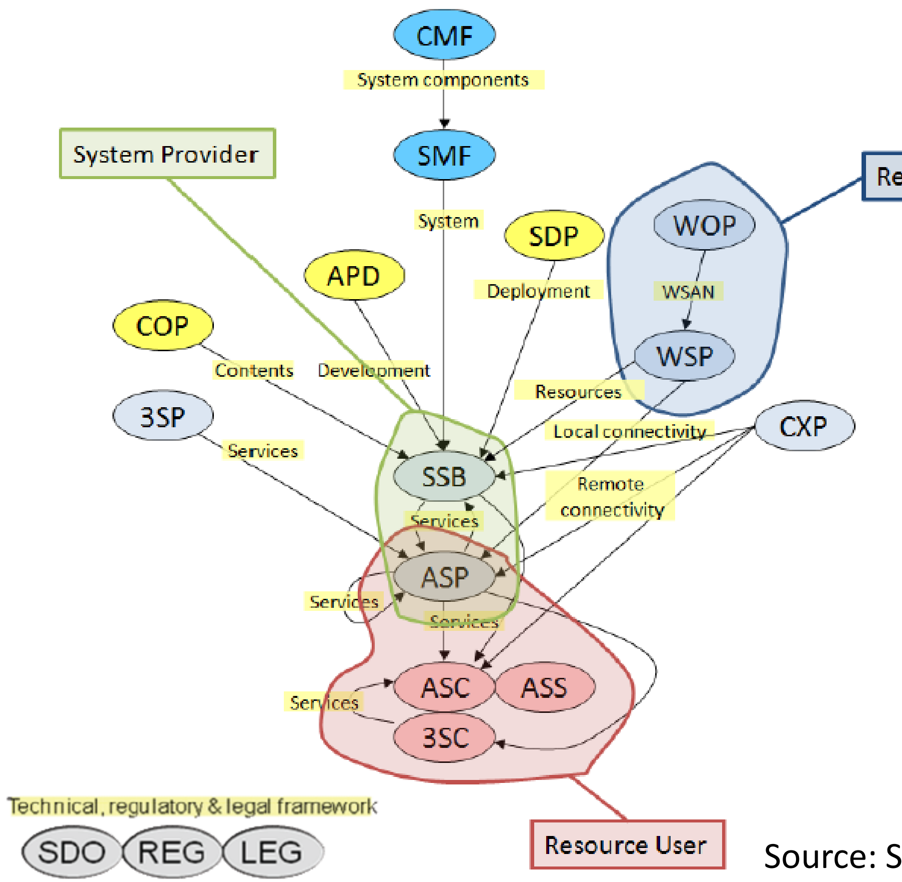
- Core of the IoT ecosystems
  - Formed around an innovation: innovative ways of connecting physical world to the virtual world
  - Involves common platforms, technologies, processes, standards or other common assets

- Examples of a core:
  - Tagging, sensing, communications technologies (RFID databases)
  - Mediating platform (Thingworx, Xively/Pachube, etc.)
  - Supporting systems and services

Core	Hardware platform	Software platform	Standards
Connected device	Arduino, T-Mote Sky	TinyOS, Processing, Contiki OS	HGI
Connectivity	Wi-Fi or ZigBee systems-on-chip	Californium, Erbium	IPSO Alliance, ZigBee Alliance
Application services	Cloud infrastructure	Pachube	SOA, JSON, EPC
Supporting services	M2M optimized GGSN	NSN M2M suite, EDCP	ETSI M2M TC

IoT Ecosystem: Value networks

- In addition to core, a VN includes partners providing complementary products needed to deliver the "whole product“, as well as relevant standard bodies



Code	Role
SMF	System Manufacturer
CMF	Component Manufacturer
APD	Application Developer
SDP	System Deployer
COP	Content Provider
ASP	Application Service Provider
CXP	Connectivity Provider
SSB	Sensor and Actuation Service Broker
WOP	WSAN Operator
WSP	WSAN Service Provider
3SP	3rd Party Service Provider
ASC	Application Service Consumer
ASS	Application Service Subscriber
3SC	3rd Party Service Consumer
SDO	Standards Development Organisation (SDO)
REG	Regulatory Body
LEG	Legislative Body

Source: SENSEI Deliverable D1.4 Business Models and Value Creation

IoT field development: Value networks (ctd)

- Example: On-Star provides "subscription-based communications, in-vehicle security, hands-free calling, turn-by-turn navigation, and remote diagnostics systems throughout the United States, Canada and China"
- Partners:
  - GM (vehicle, distribution)
  - EDC (sys development)
  - HW manufacturers (Hughes, now LG)
  - MNO (Verizon Wireless)
  - Emergency Call Centers
  - Roadside assistance: dealerships, towing service, gas stations
  - Insurance companies
- Standard bodies:
  - Society of Automotive Engineers, ISO - CAN bus
  - CDMA 2000 - Wireless link (CDMA)
  - GPS positioning

http://www.onstar.com

IoT field development: Ecosystems

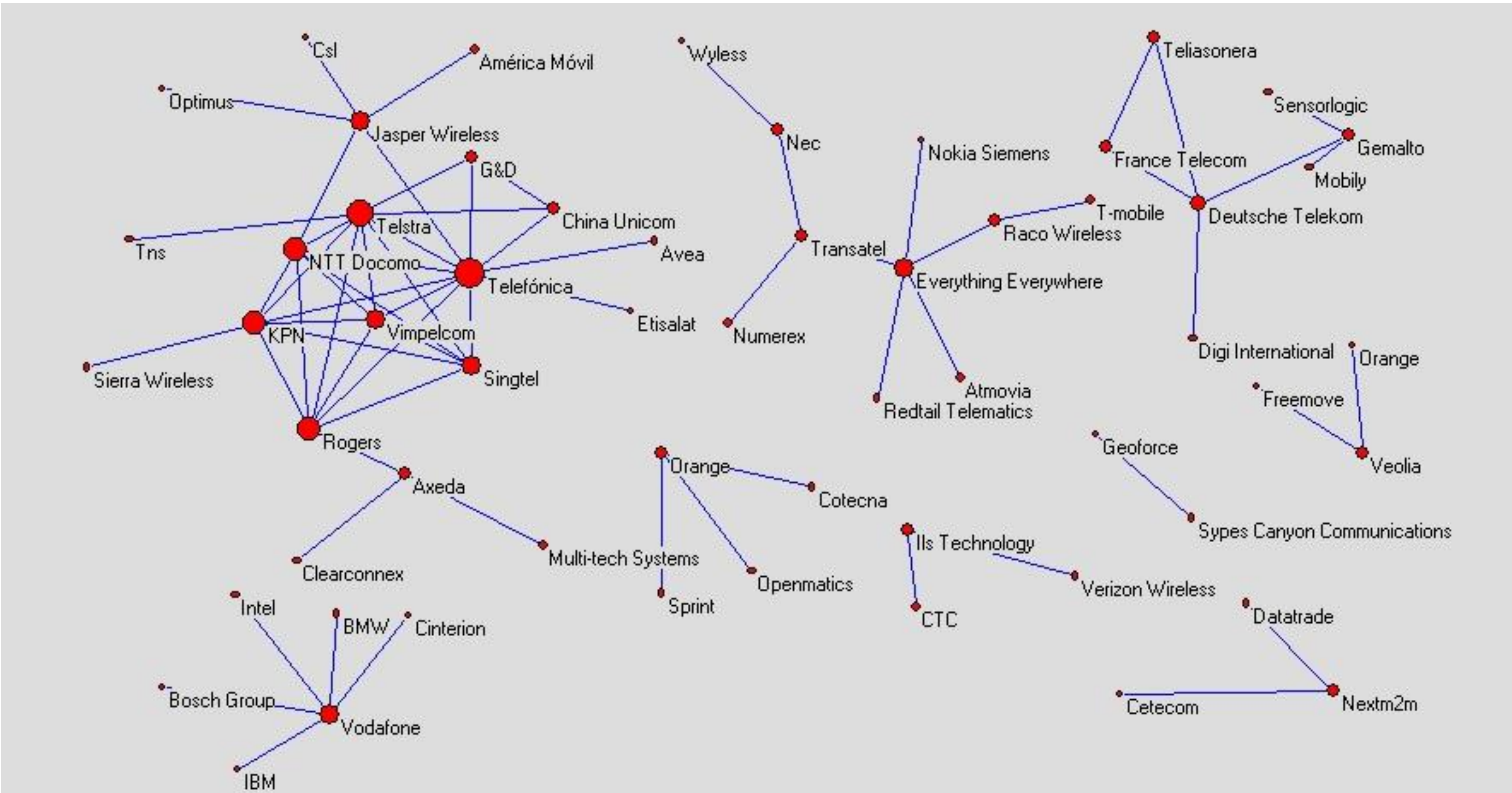
- Different verticals/segments may host different ecosystems. In addition to value network ingredients, these include:

- Government agencies
  - FP7 IoT European Research Cluster (IERC)
  - Artemis JU
  - IPSO Alliance
  - ZigBee Alliance
- Stakeholders
  - Investors
  - Trade unions

- Competing organizations with shared products and service attributes, business processes, organizational arrangements. For the case of OnStar example, competing organizations include
  - Ford (Sync)
  - Volvo (OnCall)
  - BMW (Assist)
  - Mercedes-Benz (mbrace)
  - Toyota (G-book)
  - Honda (Internavi)
  - Nissan (CarWings)

Sample of M2M Ecosystem

Network of 43 major M2M alliances, as reported by MindCommerce for 2011-2012



- No clear hubs – keystone firms – can be identified.
- Some firms (operators) have many interactions, making them hub candidates.
- Among platform vendors, only Jasper Wireless has many connections.

Research questions

- Industry:
  - Are there possibilities for horizontalization in IoT field through standards and open interfaces?
  - What is the cost structure of possible IoT applications using the technology and methods available today?
  - Where can the biggest impact on price be made with common platforms, standardized building blocks, self-configuration, optimized communication, etc.?
  - How to describe and quantify the forces affecting the adoption of new IoT applications, services and protocols?

- Ecosystem/value network:
  - What is an IoT ecosystem, who are the relevant players in it, and what are roles of the players in the IoT ecosystems?
  - How to identify, describe and evaluate the alternative technical architectures and corresponding value networks of the IoT services?
  - What is the role of platforms, standards, open interfaces in an IoT ecosystem?
  - How will an IoT ecosystem emerge, and what may hamper this process?

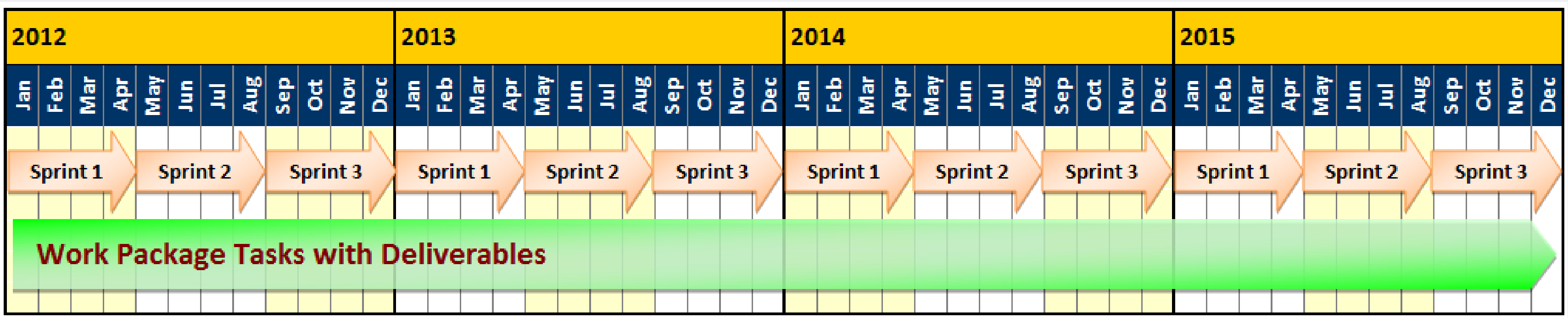
Digile/TiViT Internet of Things Program

(slides by Wilhelm Rauss and Sasu Tarkoma)

IoT Program Overview

[Overview] Setup

- 4-year-program
- Subsidized by the Finnish government
- Program started Q1/2012
- Program ends Q4/2015



- Agile Teams
- 3 sprints per year
- More than 250 experts involved
- Estimated program budget (4 years): 50 - 60 million €
- More than 35 consortium partners from industry and research organizations

[Overview] IoT Program Partners 2012/2013

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Big companies

- Elektrobit
- Ericsson
- Finnpark
- F-Secure
- Intel
- Metso
- Nokia
- Polar Electro
- Renesas Mobile
- TeliaSonera

SMEs

- 4G-Service
- Arch Red
- Componentality
- Cybercube
- Finnet Group
- Finwe
- FRUCT
- Laturi
- Mattersoft
- Mikkelin Puhelin
- Mobisoft
- Refecor
- There Corporation

Research Organizations

- Aalto University
- Laurea University of Applied Sciences
- Tampere University of Technology
- University of Helsinki
- University of Jyväskylä
- University of Oulu
- University of Tampere
- VTT Technical Research Centre of Finland

[Overview] Vision

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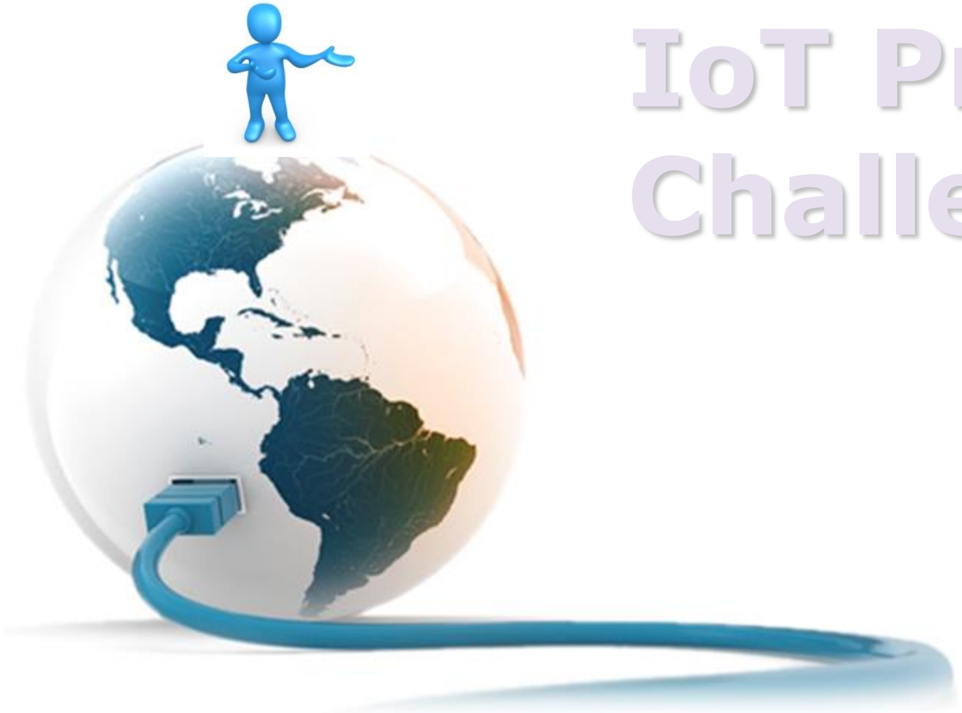
By 2017 the Finnish ICT industry is a recognized leader in the IoT domain due to its expertise in standards, software, devices, and business models integrating various vertical industry segments



IoT Program Challenges

[Challenges] Program Challenges and Goals

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- **Establishing a competitive IoT ecosystem**
  - New revenue models for participating companies in the emerging IoT market.
  - Local ecosystem formed for proof of concept, initial market, and critical mass for international business.
  - Solutions for establishing and sustaining global IoT ecosystems.
  - Develop generic horizontal solutions that can be used across verticals.
- **Creating IoT business enablers**
  - Generate IoT product concepts and prototypes and test them in real-life environments.
  - Supply critical components for IoT proliferation (such as gateway/border router to connect IoT with Internet).
- **Improving Finland's global IoT visibility**
  - Demonstrate Finnish cutting-edge IoT technology in pilots and prototypes.
  - Impact recognition of Finnish research partners as top-level institutions in IoT domain, high-impact publications.
- **Impacting IoT technology evolution and standardization**
  - Significantly influence IoT standards at IETF, 3GPP, IEEE, W3C, and other relevant forums.
  - Bring IoT technology to pilot implementations (prototypes, showcases, testbeds etc.).

Program Activities

[Activities] Teams

[Activities] Task Overview

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- **WP1: Networking and Communications**
  - 1.1 Radio technologies
  - 1.2 Networking
  - 1.3 Security, privacy and trust
- **WP2: IoT Management**
  - 2.1 Adaptive Security
  - 2.2 Network configuration and management
  - 2.3 Enterprise Service Portal
- **WP3: Services & Applications Dev. Support**
  - 3.1 Integration with Web (task of year 2012)
  - 3.2 IoT data analysis and visualization
  - 3.3 Integration with Social Web
  - 3.4 Collaborative data gathering and analysis
  - 3.5 Data dissemination
  - 3.6 Flow based platform for IoT devices
  - 3.7 End-to-end data transport
  - 3.8 IoT applicability for mHealth and e-Tourism
  - 3.9 Platforms supporting new applications & services
- **WP4: Human Interaction**
  - 4.1 Co-creation & validation of IoT UI's
  - 4.2 Interactive environmental aware IoT services
  - 4.3 Usable security for IoT services
  - 4.4 Visualization of IoT services and devices
- **WP5: IoT Ecosystem**
  - 5.1 IoT Evolution and Diffusion
  - 5.2 IoT value networks vs. technical architectures and platforms
  - 5.3 Business models of IoT firms
- **WP6: Trials and Demos**
  - 6.1 Home automation pilot in apartment buildings
  - 6.2 Secure and automatic IoT service provisioning
  - 6.3 Communications in Mines
  - 6.4 IoT for Intelligent Traffic System
  - 6.5 New Battery Management System
  - 6.6 Device Connection Platform Test Bed
- **XWP – Cross-WP issues**
  - 7.1 Security, Privacy and Trust (SPT)
  - 7.2 Energy efficiency issues
  - 7.3 Standardization and architecture issues

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Thank you!

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