Modeling and Processing of Streaming Data in IoT Environment

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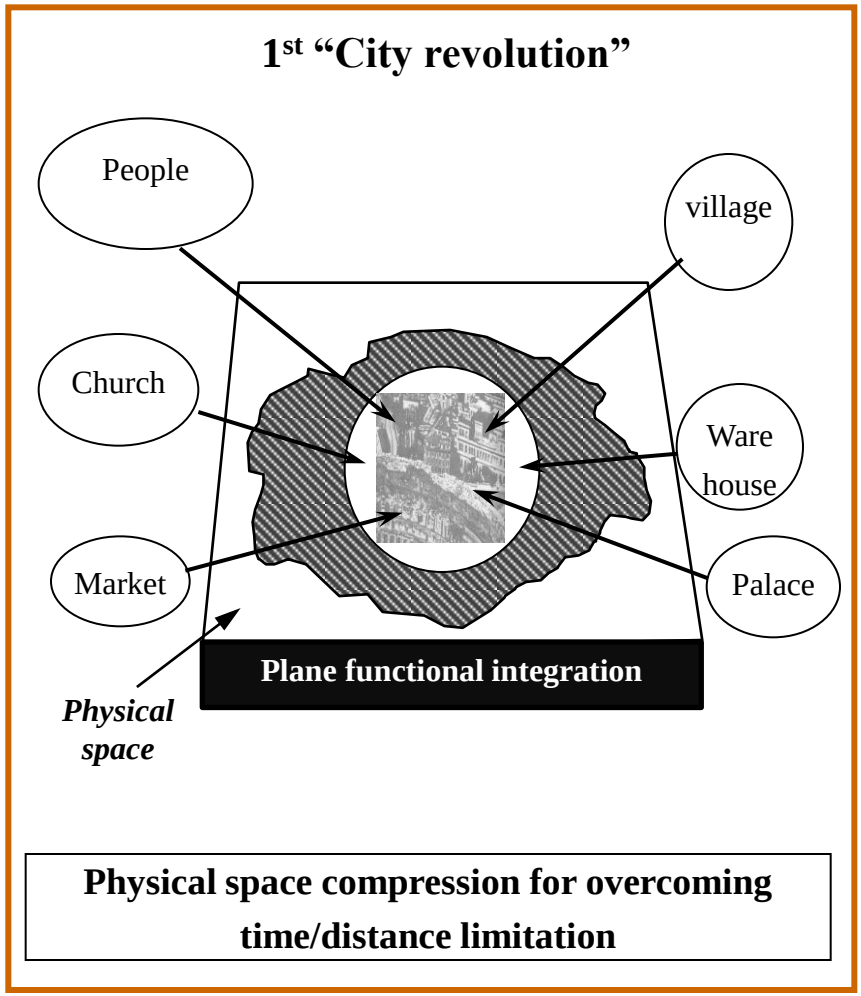
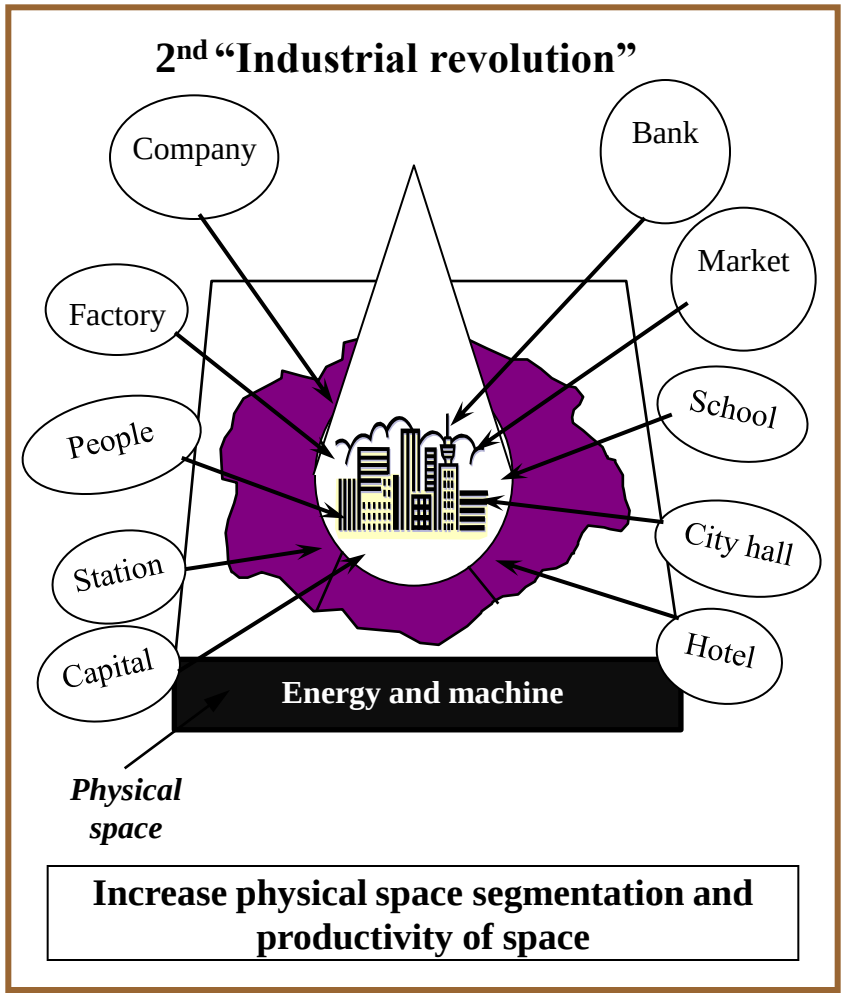
Outline

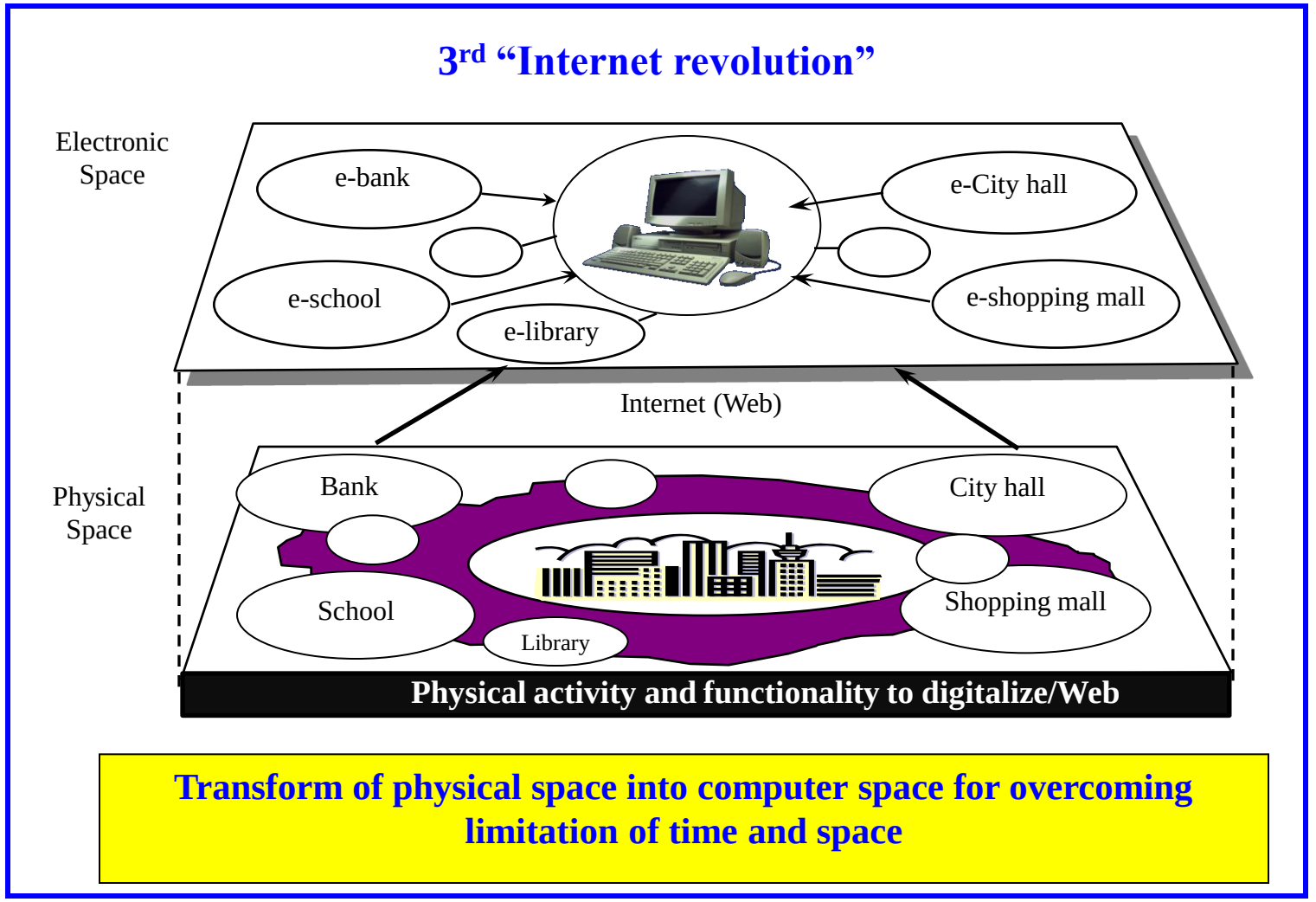
1. Background
2. IoT Standard
3. IoT Platforms
4. Modeling and Processing Streaming Data
5. Conclusion

Background: Revolution in Human History

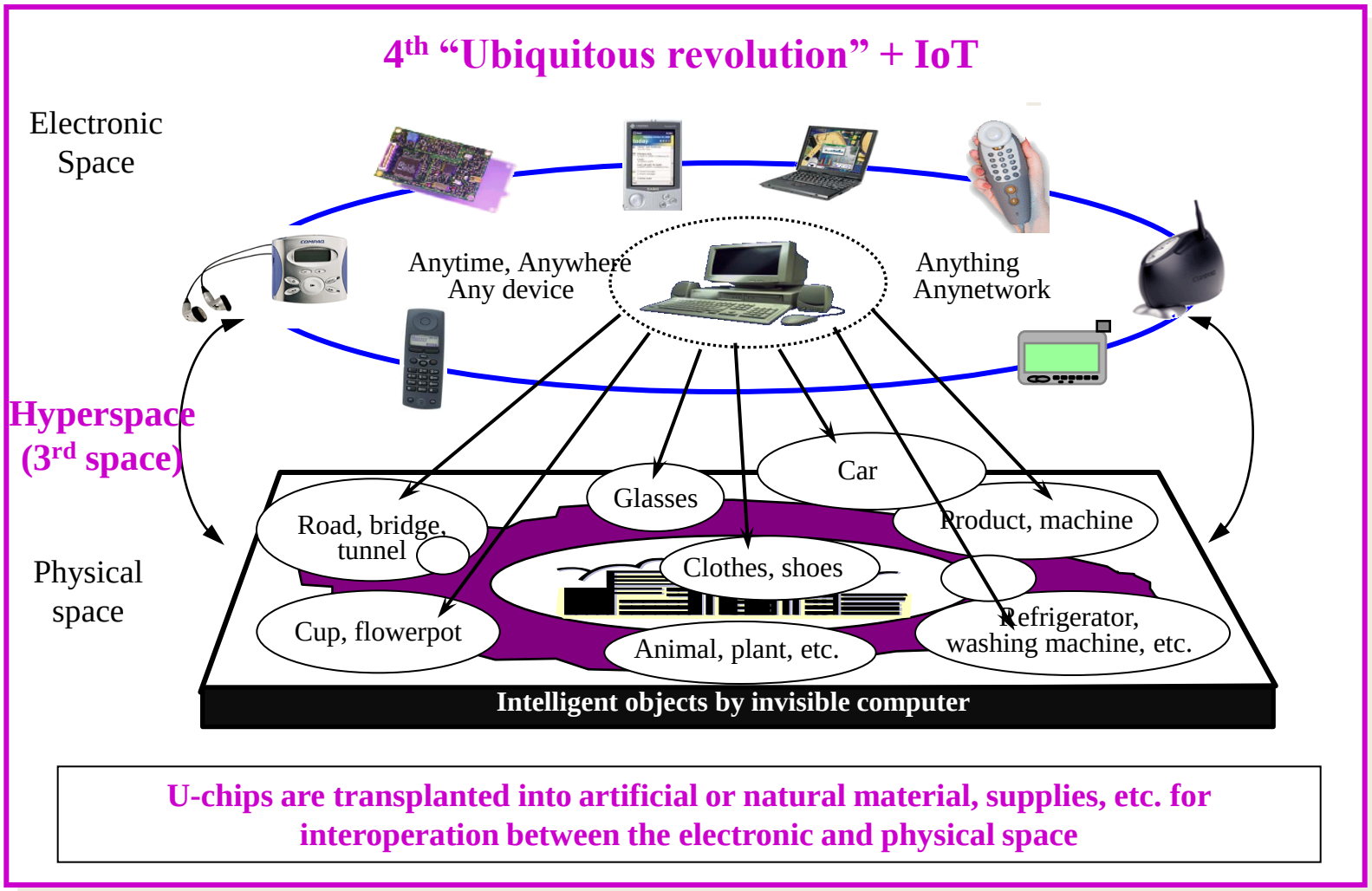




Background: 3rd Revolution

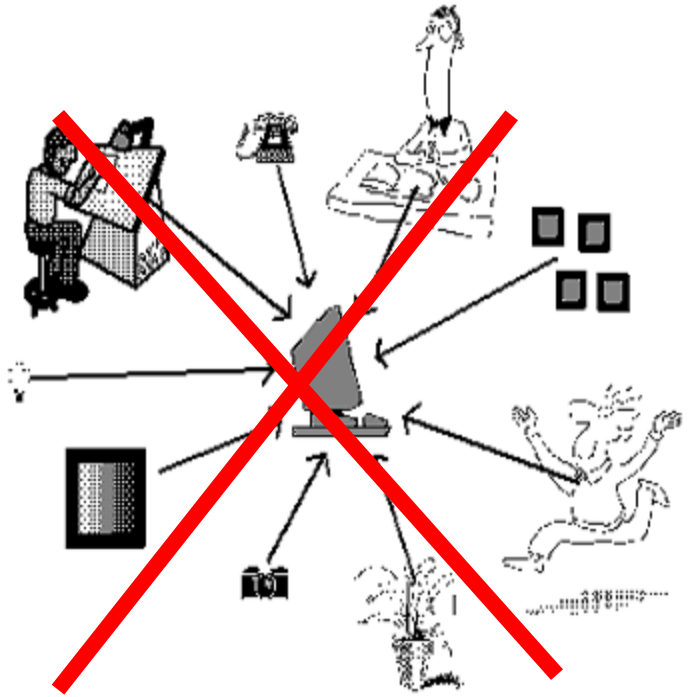


Background: 4th Revolution



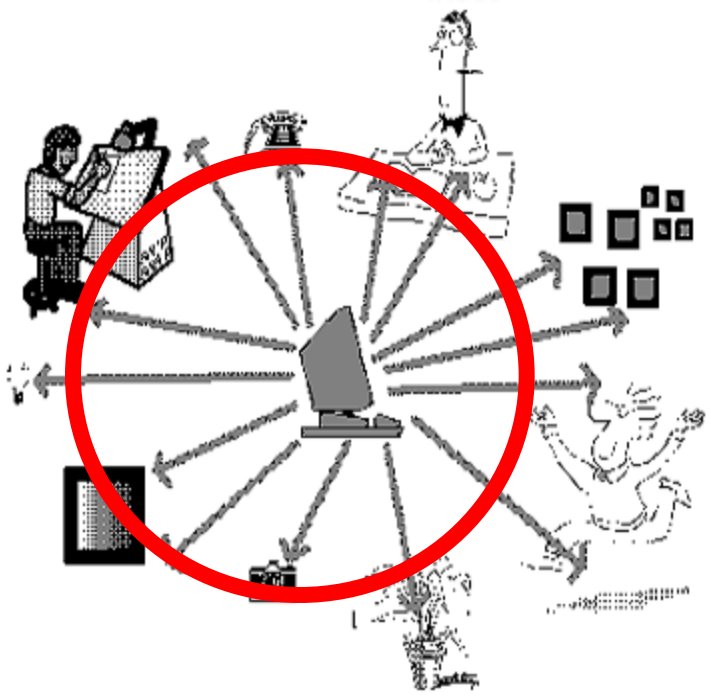
Background Embodied Virtuality

Embedded Virtuality
(Virtual Reality)



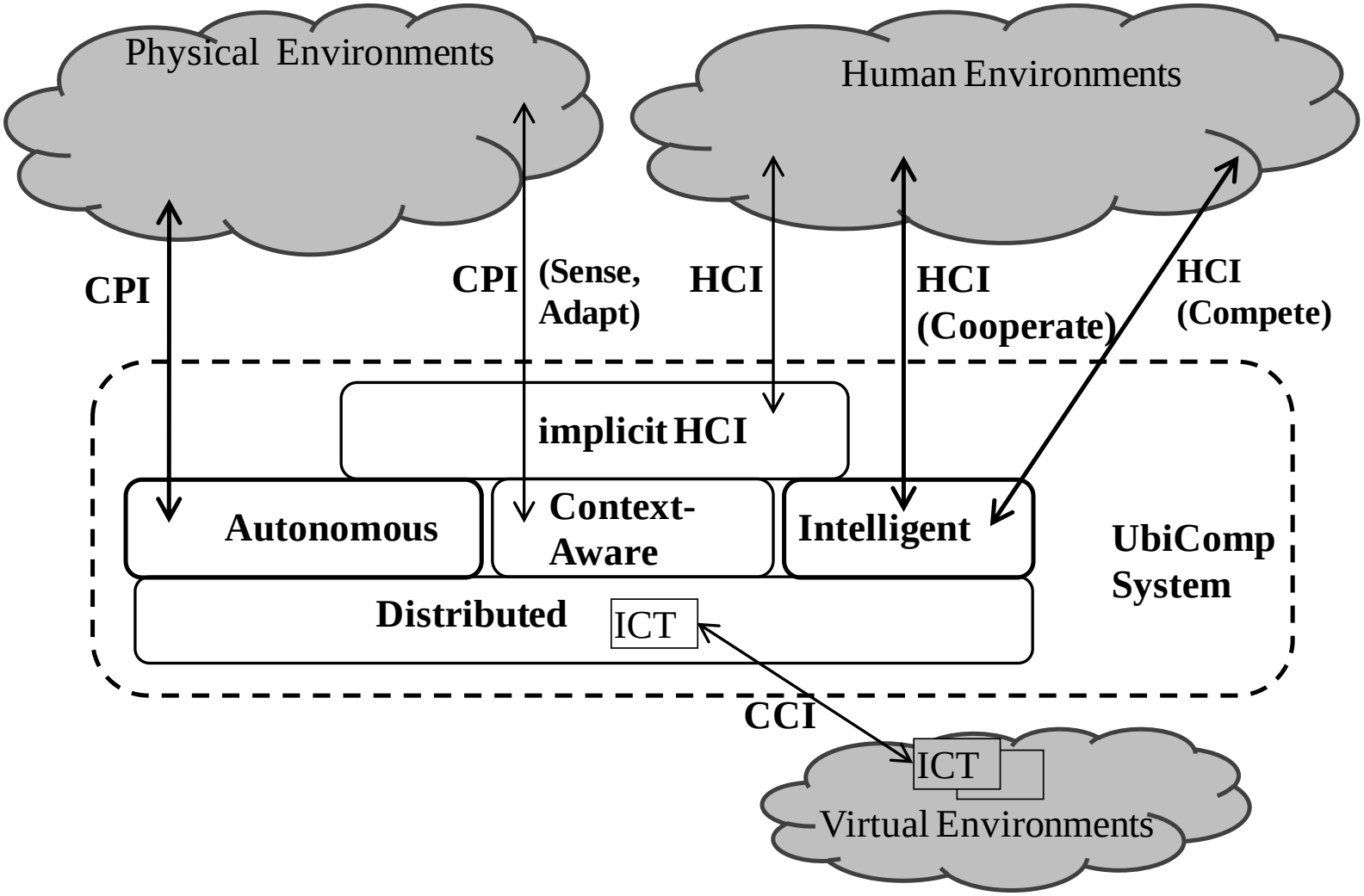
Focus on digital content service

Embodied Virtuality
(Ubiquitous Computing)



Psychical (real life) direct computing service via individual computer at user location

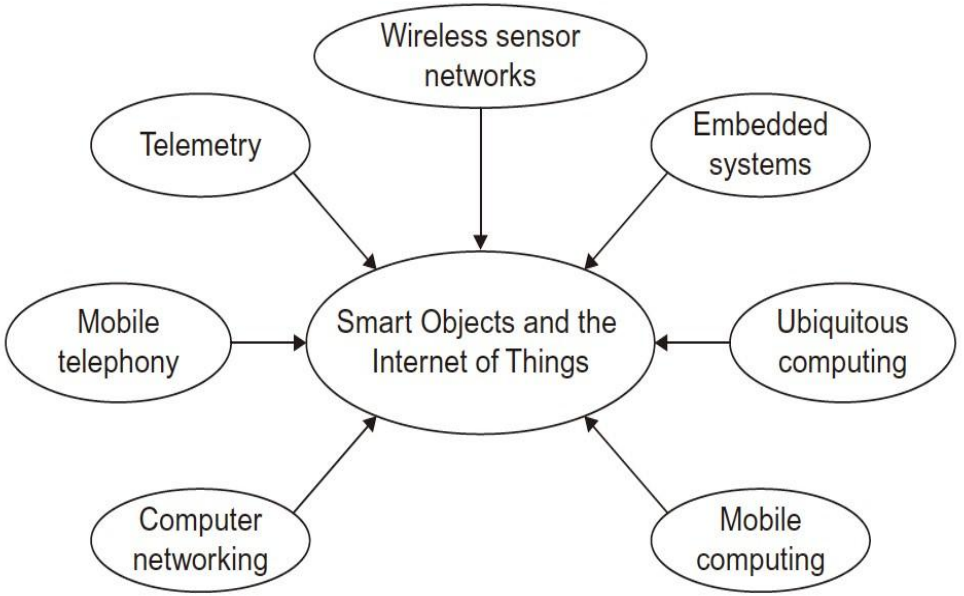
Key Technology



The Internet of Things

- The Internet of Things is the networking and applications concept of connecting **EVERYTHING** to the Internet

- What does this mean?
  - Things enable applications
  - Things hold context to exchange
  - Things have connectivity
  - Things have IP address



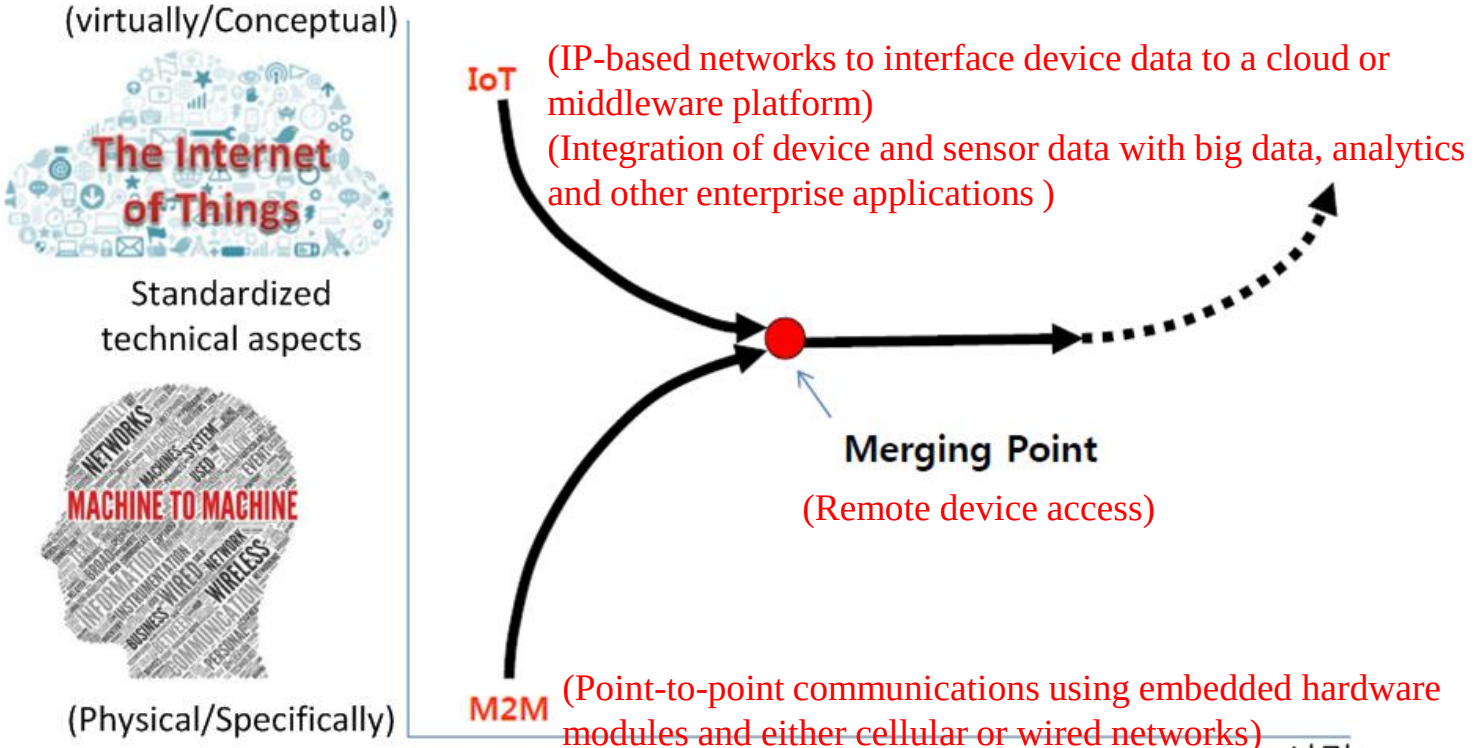
Requirements

- Cost-effectiveness
  - Resource constrained wireless devices
  - Low energy consumption
- Easy installation and maintenance
  - Large scale networks(many devices and /or large area)
  - Distributed vs. centralized channel access
- Reliable and on-time information delivery
  - Determinism on channel access
  - Robustness against channel impairments and network faults

Relationship between M2M and IoT

■ Perspective of M2M/IoT standardization

- Technical direction of the IoT and M2M standardization



(IP-based networks to interface device data to a cloud or middleware platform)
(Integration of device and sensor data with big data, analytics and other enterprise applications)

(Point-to-point communications using embedded hardware modules and either cellular or wired networks)
(Targeted at point solutions in service management applications, where the data are not integrated with enterprise applications to help improve overall business performance)

Organization for Standardization

- oneM2M
  - M2M Global Partnership for Standardization
- ETSI TC M2M (SmartM2M)
  - Independent sub-communications network/End-to-End M2M is service target
  - M2M service requirements, functional structure, interface specification standardization
- 3GPP SA1/SA2 MTC(Machine Type Communication)
  - Mobile network perspective
  - MTC service requirements
- IEEE 802.16's M2M Task Group
  - System requirements for M2M in Wireless MAN/Reference Architecture/Air Interface Specification

Organization for Standardization

- WiMAX Forum
  - WiMAX network perspective
  - M2M standardization in progress on the requirements
- IETF 6LoWPAN/CoRE/ROLL (Constrained RESTful Environments; Routing Over Low power and Lossy networks; Constrained Application Protocol)
  - IPv6 over LAN/CoAP/Routing,…
- ITU-T IoT-GSI/JCA-IoT
  - Creating a standard for IoT reference model
- ITU-T FG-M2M
  - M2M technology standardization for service layer
- W3C
  - Semantic web technology

oneM2M Release

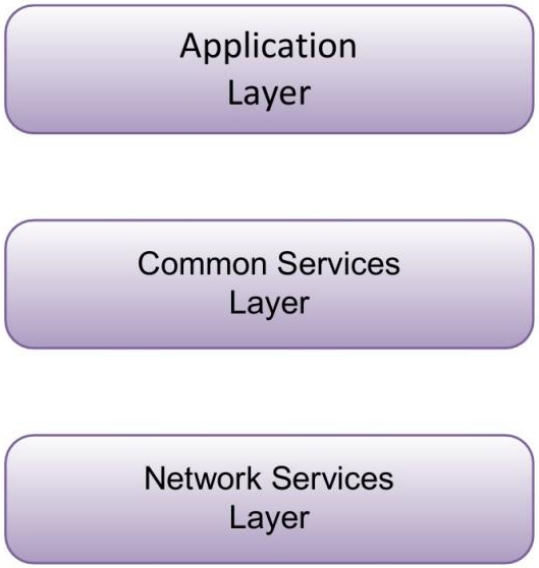
- Global Partnership developing standards for M2M and IoT initial release
  - Sophia Antipolis, France, **Aug. 7, 2014**

- Released standard documents
  - oneM2M Functional Architecture Baseline Draft
  - oneM2M Requirements Technical Specification
  - oneM2M Security Solutions
  - oneM2M Service Layer Protocol Core Specification
  - Management Enablement (OMA)
  - Management Enablement (BBF)
  - Constrained Application(CoAP) Protocol Binding Technical Specification
  - HTTP Protocol Binding Technical Specification
  - Definitions and Acronyms

oneM2M Release

■ oneM2M Functional Architecture Baseline Draft

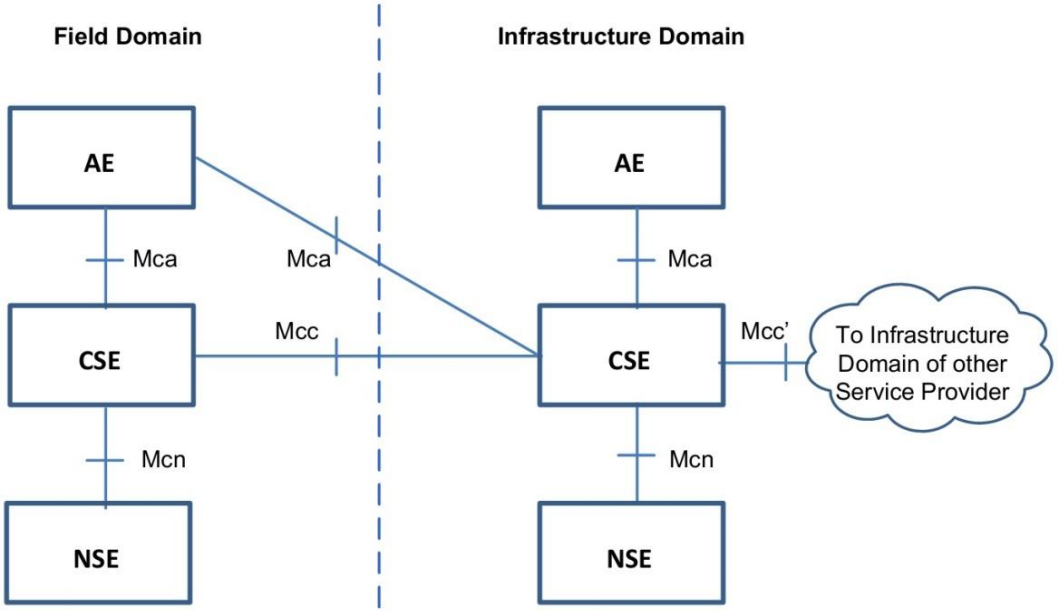
- oneM2M functional architecture focuses on the service layer aspects and takes underlying network-independent view of the end-to-end services
- Underlying network is used for the transport of data and potentially for other services



< oneM2M layered model >

oneM2M Release

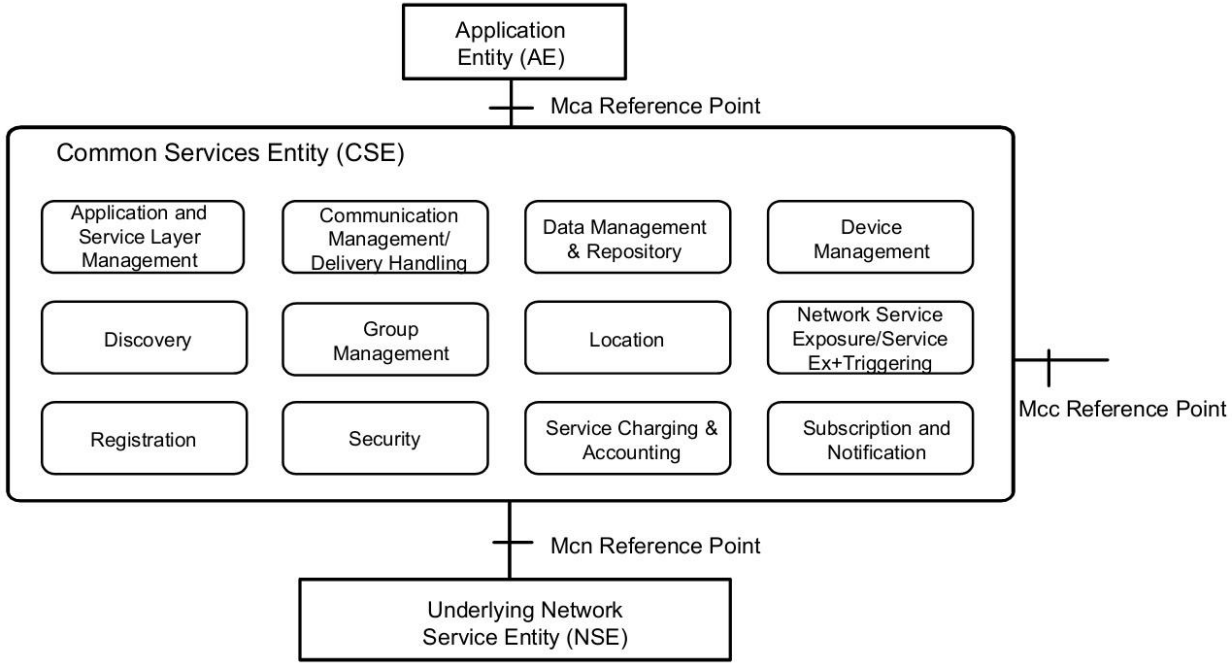
- Functional Architecture
  - ✓ **AE**
    Application Entity
  - ✓ **CSE**
    Common Services Entity
  - ✓ **NSE**
    Network Service Entity
  - ✓ **Mca**
    Reference Point for M2M Communication with AE
  - ✓ **Mcc**
    Reference Point for M2M Communication with CSE
  - ✓ **Mcc'**
    Reference Point for M2M Communication with CSE of different M2M Service Provider
  - ✓ **Mch**
    Reference Point for M2M Communication with external charging server
  - ✓ **Mcn**
    Reference Point for M2M Communication with NSE



oneM2M Release

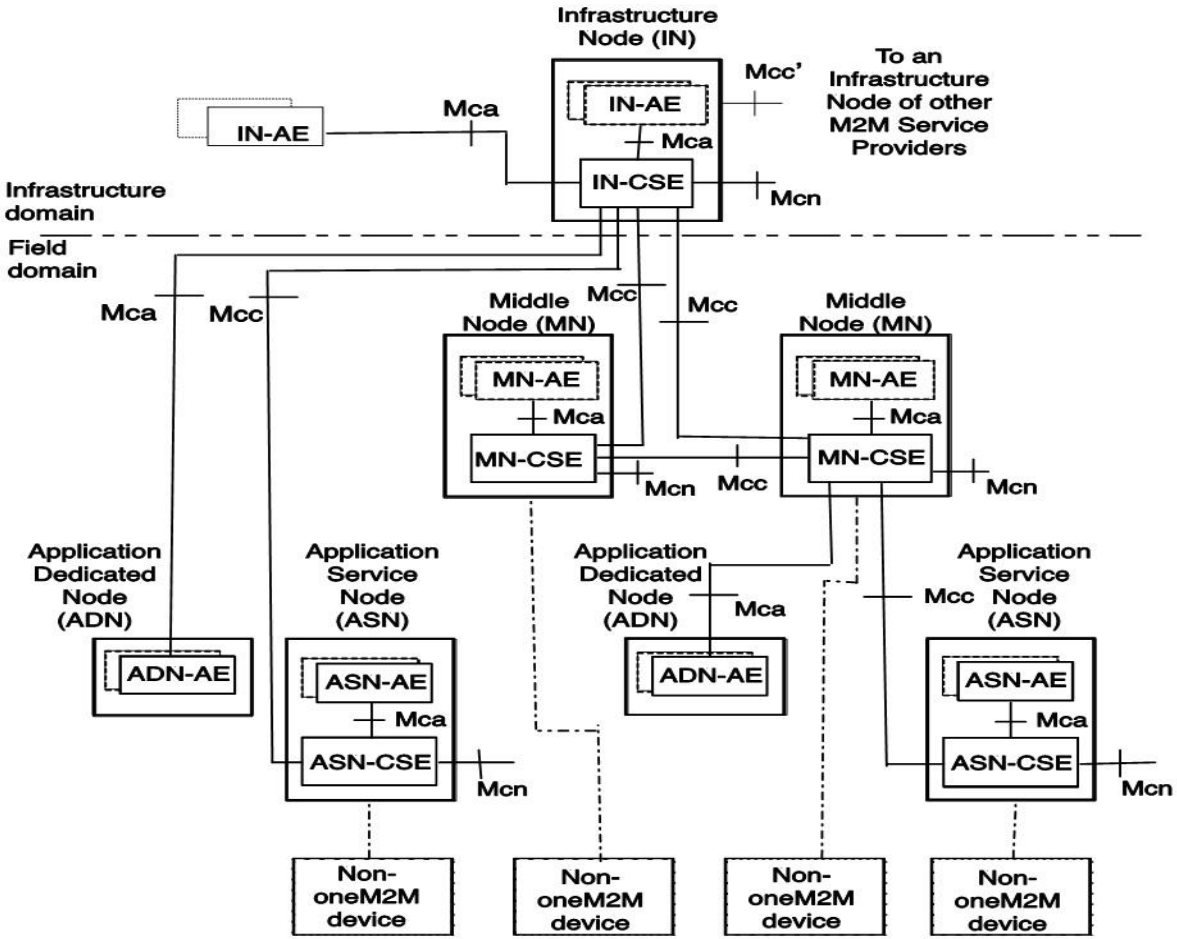
- Common Services Functions

  ✓ Common Service Layer in M2M system
  ✓ Provide services to other CSE via Mcc
  ✓ Provide services to the AE via Mca



oneM2M Release

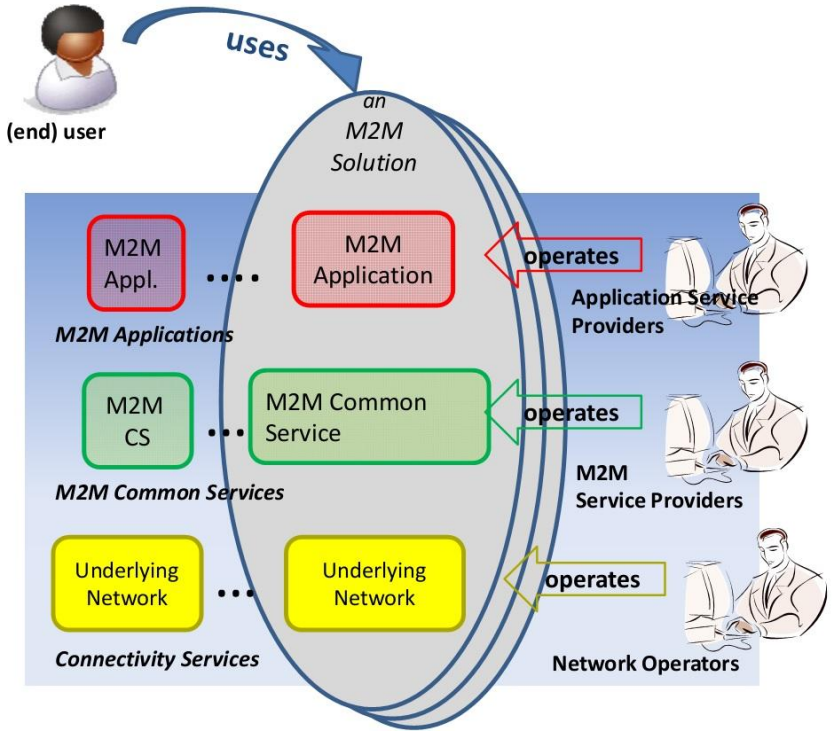
- Relationships among oneM2M entities



oneM2M Release

■ oneM2M Requirements Technical Specification

- Informative functional role model and normative technical requirements for oneM2M

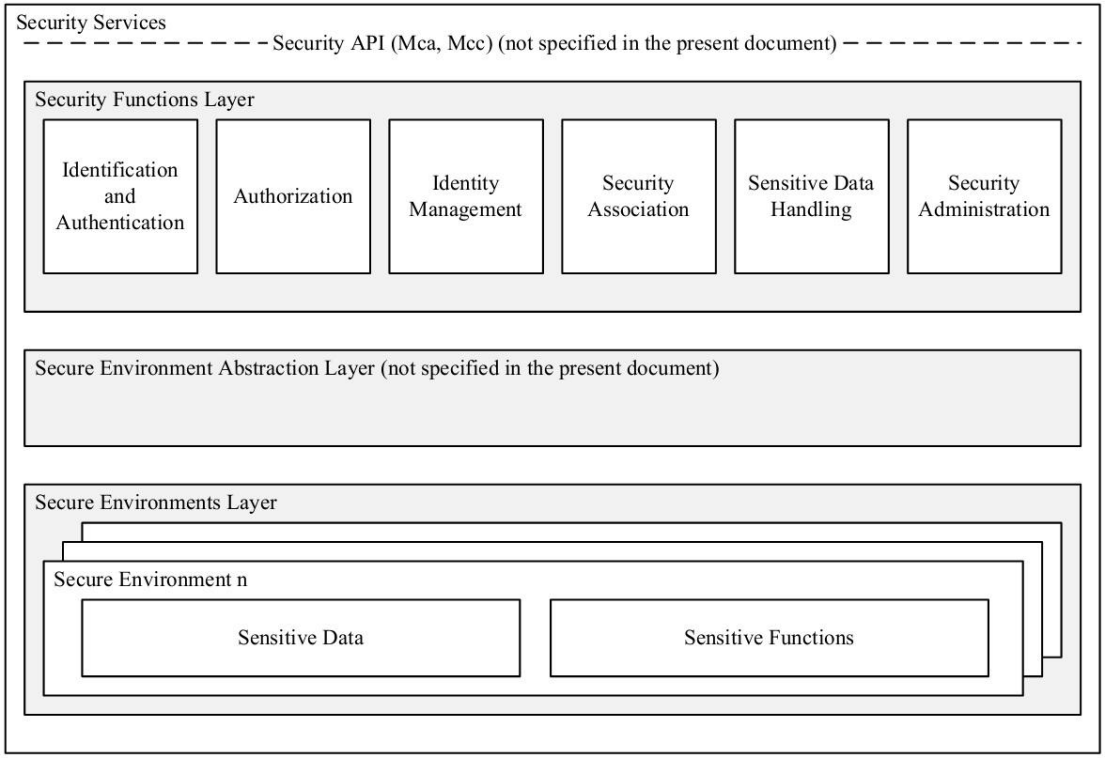


< Functional roles in M2M >

oneM2M Release

oneM2M Security Solutions

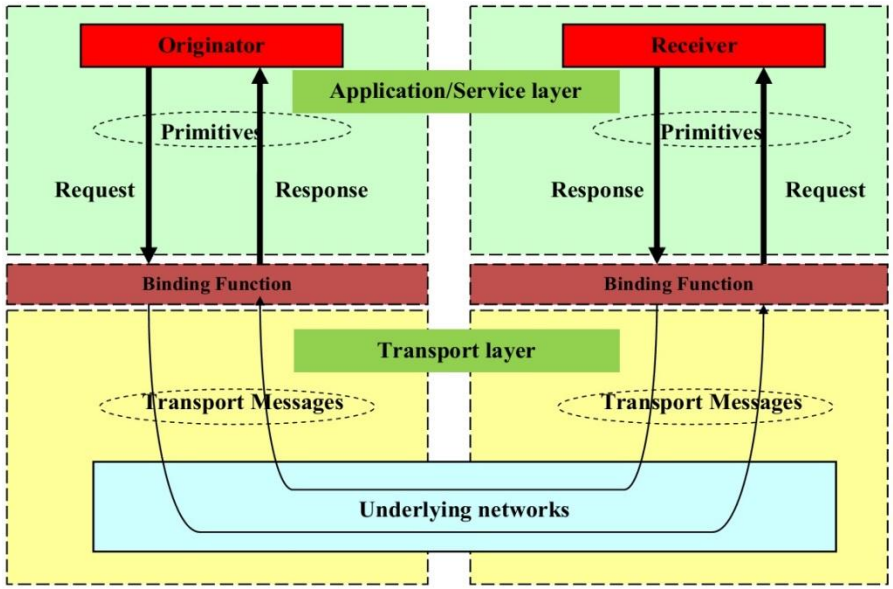
- Defines security solutions applicable within the M2M system



< Security architecture >

oneM2M Release

- oneM2M Service Layer Protocol Core Specification
  - Specifies the communication protocol(s) for oneM2M compliant Systems, M2M Applications, and/or other M2MSystems
  - Specifies the common data formats, interfaces and message sequences to support reference points(s) defined by oneM2M



< Primitive overview >

oneM2M schedule for IoT

- oneM2M show case
  - Dec. 2014
  - Proof and preview of application, platform, etc based on oneM2M standard
- TTA & IoT-Week Korea
  - Nov. 2014
  - 14th Technical Plenary in Korea
  - Source - TTA press release (http://www.tta.or.kr)

(LWM2M:
- management functionality over sensor or cellular networks
- transfer service data from the network to devices
- extend to meet the requirements of most any application)

Internet of Things – Platform

- IoT Platforms

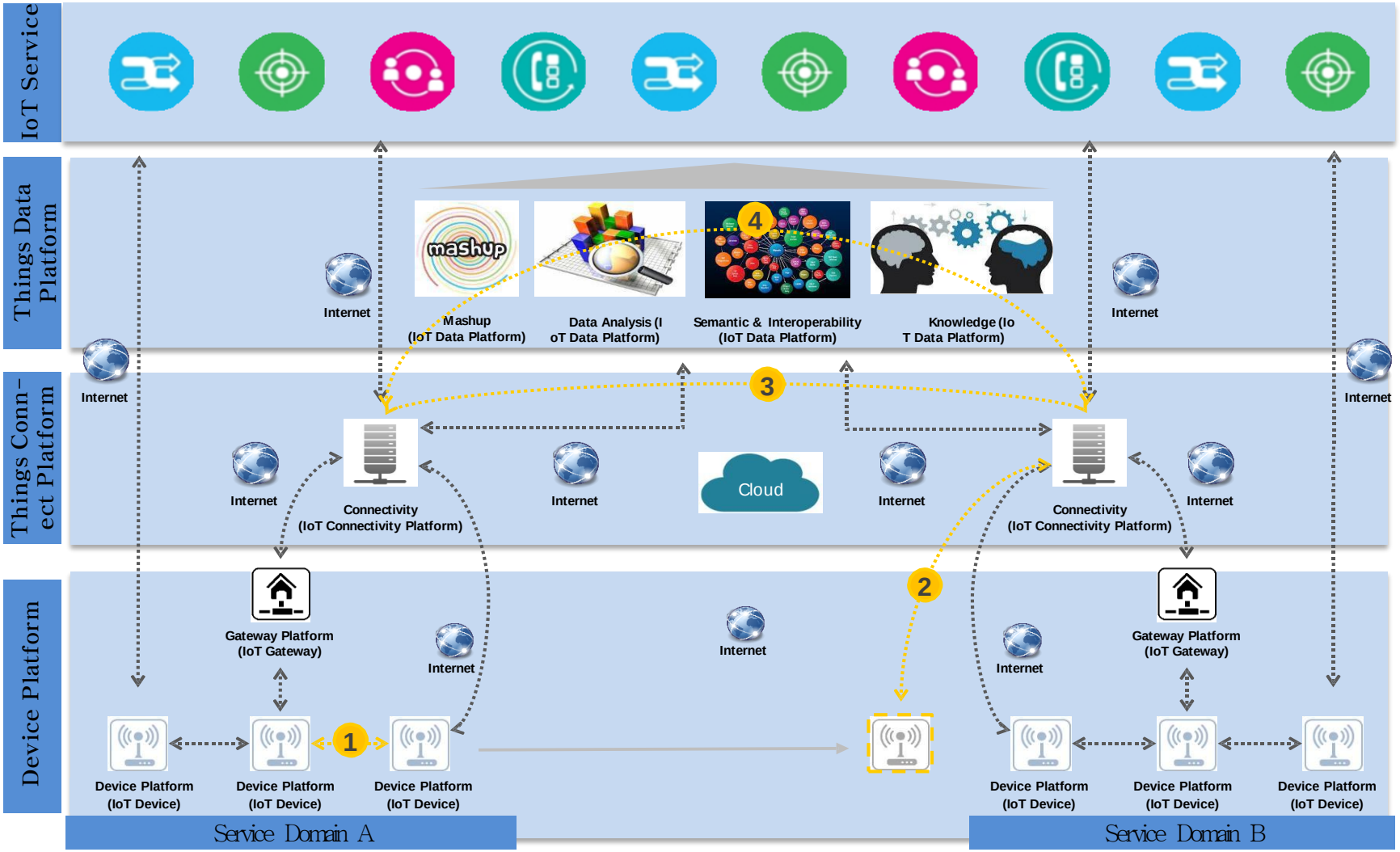
Platform	Company	OS	Interface	Core
IMX53QSB	Freescale	Linux, Android	Ethernet	ARM Coretex A8
SimpleLinks	TI	Linux, Android	WiFi	MSP430
Hitex OM 13031	NXP	FreeRTOS	Ethernet	ARM Cortex M4&M0
RZ Raven	Atmel	Embedded C	6LoWPAN	AVR Atmega 1284P
Beaglebone	TI	Linux, Android	Etherent	ARM Coretex A8
Raspberry Pi	Boradcom	Linux	Ethernet	Arm11
ARM mbed	NXP	Embedded C/C++	Ethernet	ARM Coretex-M3
Arduino Uno	Atmel	Arduino	Etherent, WiFi, Cellular	AVR ATmega328

Internet of Things – Industry

- IoT Companies

Company	Feature	Application Service	Device Collaborator
IBM	MQTT, Inforsphere bigdata platform, Message processing platform for MessageSight-IoT	Smarter Planet Service Strategy (Energy, Traffic, Finance, Distribution, Public security, City management,etc)	Libelium
Cisco	Smart solution for ‘smart city Barcelona’, Drava Networks RuBAN IoE platform	Smart+Connected Communicaties Service Strategy	
Oracle	Java + DB IoT Platform; One Box platform with Freescale	Supports B2B, B2C, P2P	Freescale
Google	Search, cloud, Bigdata technology	Promoting home services	
LogMeIn (Xively)	Provide cloud-based IoT service; support various HW platform	Integration with open IoT HW platform	ARM mbed
Thingspeak	Support Thingspeak-based community platform and ecosystem	Device monitor and control via Tweeter,	ioBridge
Everything	Provide WoT platform by connecting things and web	Integration with SNS, ERP, CRM etc	
ThingWrox	Fast service development using model-based service design; visualization	M2M/IoT service platform based on B2B,	

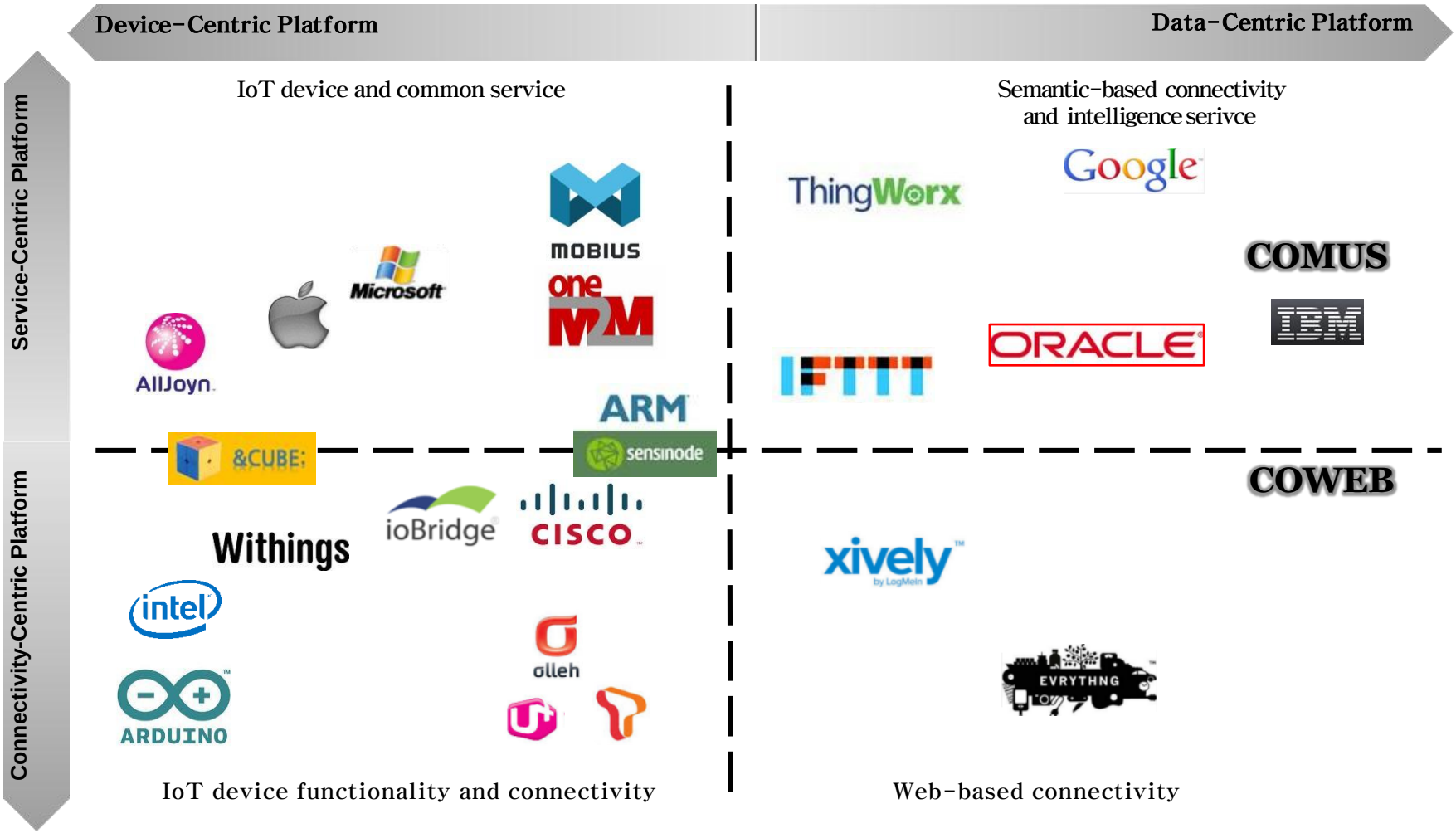
IoT Platform Infrastructure (1)



IoT Platform Infrastructure (2)

Category	Function	Status	Vision
Open HW Platform	Things are created in open HW platform	• Arduino, Respberry Pi, Galileo	• Open HW allowing easy development • Applicable for various creative IoT product
Device Platform (GW, Things)	Device Operating System Device Service Platform	• Lightweight OS such as TinyOS, Contiki, nanoQplus etc. • Ultralight / Ultra low power OS for wearable device • IoT of network devices (Cisco: Fog Computing)	• Customized ultralight/ultra low power OS Release • IoT infrastructure of network equipment
Things Connection Platform	Things Connection, Control, Management, Openness	• Closed / vertical platform → open platform • Telecommunication company centric Open M2M platform • Global Company-based IoT Platform • Specific IoT company open Platform (xively ect.)	• Standardized open platform • Global Company-based IoT Platform
Things Data Platform	Things Data Openness/Connectivity/Search /Analytics	• Commercialization of IoT data analytics platform of Global corporation • Linked data by applying semantic technology to IoT • Things data connectivity platform(IBM etc.)	• Expansion of public data platform • Connection with global search engine platform such as Google

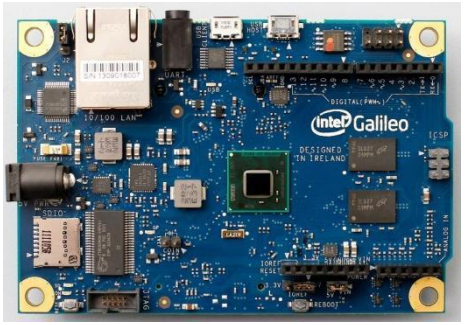
IoT Platform



IoT Platform

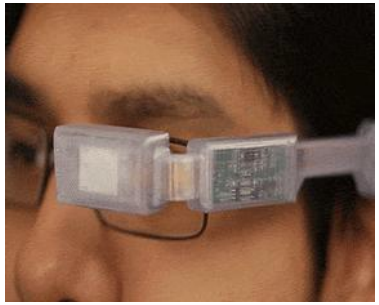
- Arduino
  - Implement various things by connecting sensors and actuators on a single board based on open source

[Arduino shield]



[Intel Galileo pin-compatible]

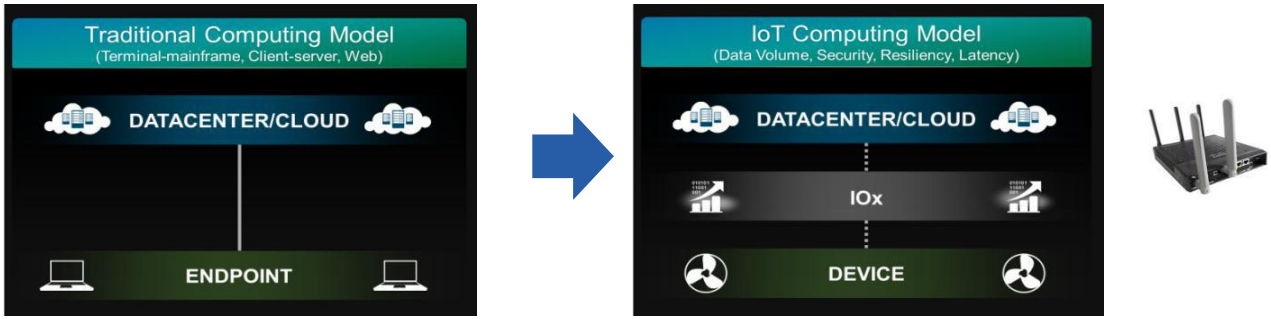
- Raspberry Pi(UK)
  - Single board computers promoting the education of basic computer science in school



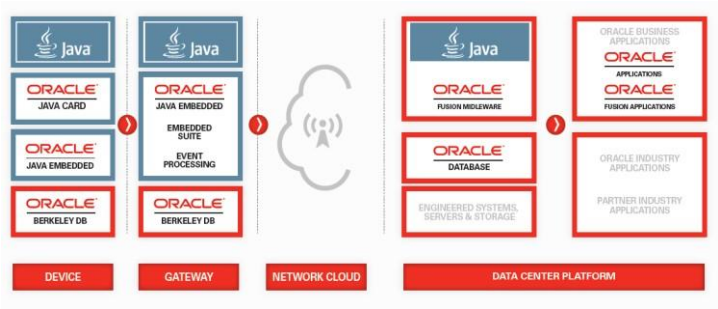
Wearable device combining 3D printing technique with Pi Technology

IoT Platform

- Cisco (Fog)
  - Extend the cloud network device based on Fog computing concept

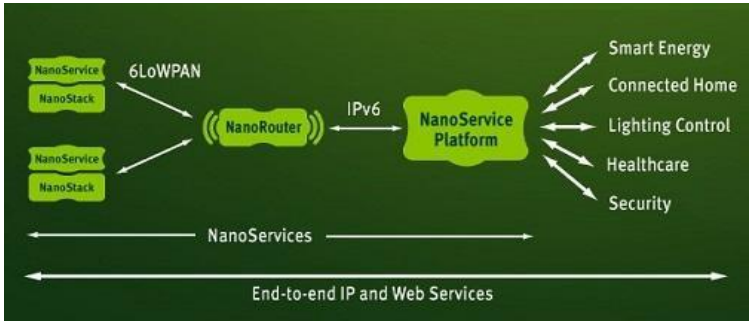


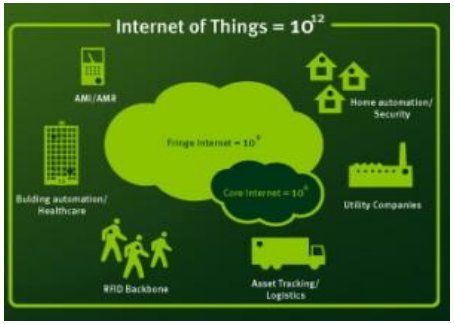
- Oracle + Freescale(Java Solution & oneBox)
  - Freescale : Development of IoT Gateway based on chip technology (with Oracle solutions)
  - Oracle : Provide IoT service development platform based on Java solution



IoT Platform

- ARM + Sensinode
  - ARM: By taking over Sensinode, retain open solution based on All IP





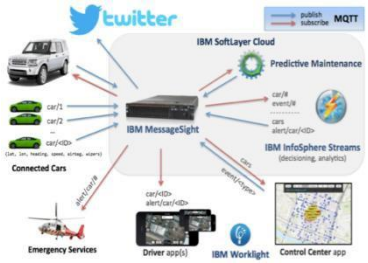
- AllJoyn(Qualcomm)
  - Qualcomn starts AllSeen aliance leading open source things connection platform

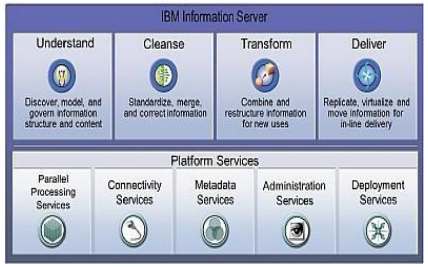
AllJoyn™

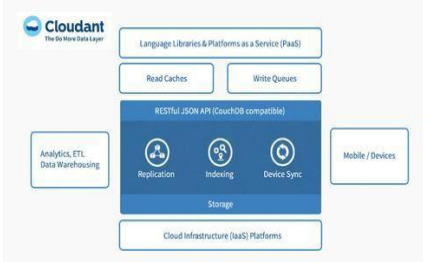
IoT Platform

- SensorCloud (LORD Microstrain)
  - Integration of various sensor devices based on Open API

- IBM + Cloudant
  - Solution: MessageSight(Connectivity), InforSphere(Data Integration/Management/BigData) etc.
  - Acquire cloud technology via M&A of Cloudant

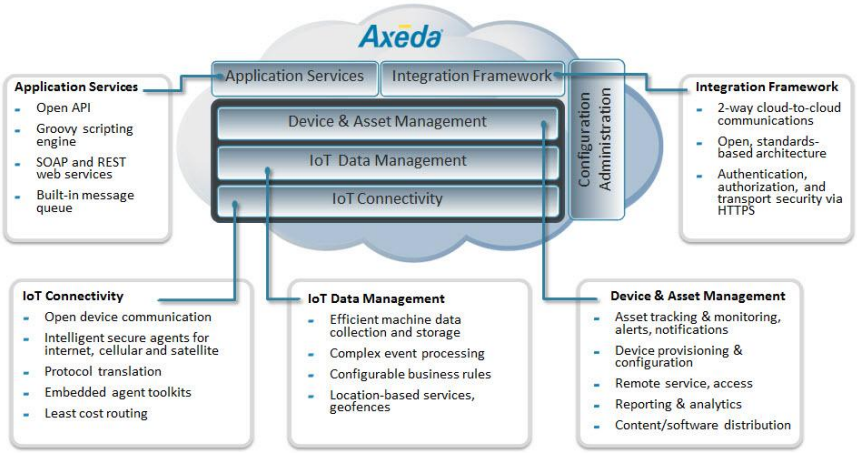






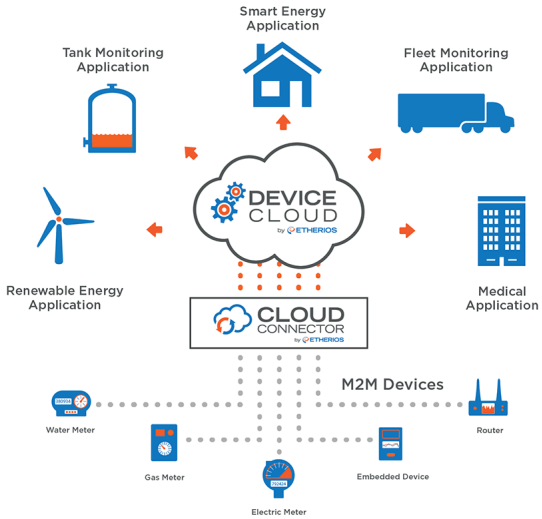
Axeda

- A complete M2M data integration and app development platform
- Cloud-based service infrastructure
- Support scalability and security, and integration with enterprise applications & systems
- Powerful open source API
- Standard-based message queue technology for integration
- Preconfigured application e.g. location tracking, and customized applications
- Provides an agent for connectivity of devices
- Axeda AnyDevice codec server handles protocol to install, configure and use M2M devices which have Axeda agent or Axeda wireless protocol capability



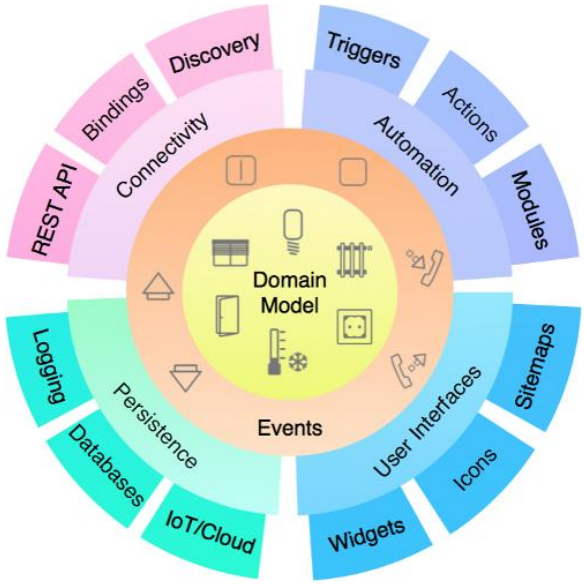
Digi, Etherios

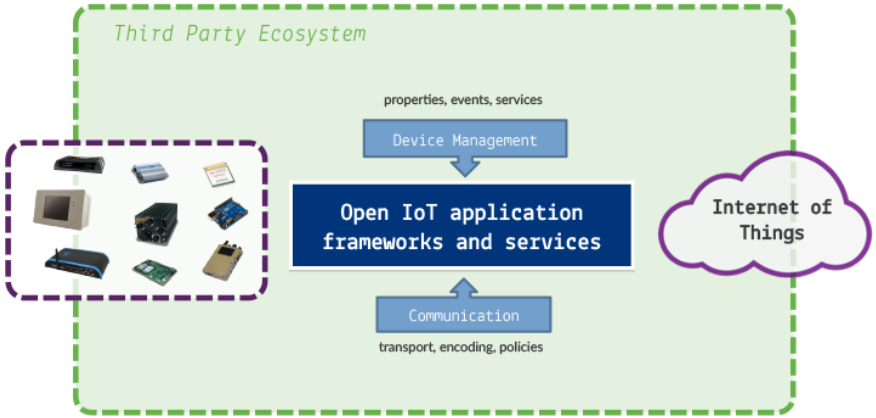
- Device cloud connects devices with open APIs, toolkit for custom solution
  - ✓ Connect devices with open APIs
  - ✓ Toolkit to build custom IoT solutions
  - ✓ Visualization and business intelligence
- Social Machine
  - ✓ Connected product solution on Salesforce AppExchange
  - ✓ Connect product to core business process (e.g. ERP,CRM)
  - ✓ Raw machine date into actionable business information
  - ✓ Remote monitoring of machine
  - ✓ Preventive repair and maintenance
  - ✓ Increase efficient
- Gateways
- Communication modules
- Solutions e.g. IDigi Energy , IDigi Tank



Eclipse M2M

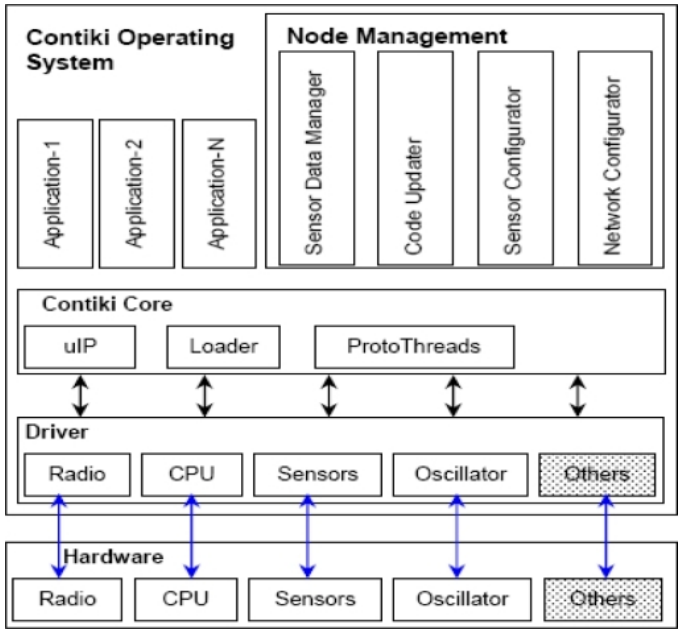
- Consortium of companies
- Projects include
  - ✓ **Kura:** a set of Java and OSGi services that are most commonly required for IoT gateways, including I/O services, Data Services, Cloud Services, Newtorking, etc
  - ✓ **Mihini**, written in the Lua script language, provides low-level connectivity management, Paho, communication M2M devices
  - ✓ **Koneki**, development environment
  - ✓ **OMA-DM**, a simulator for device management
- SmartHome framework for smart home solution
- Eclipse SCADA solution for connecting different industry devices

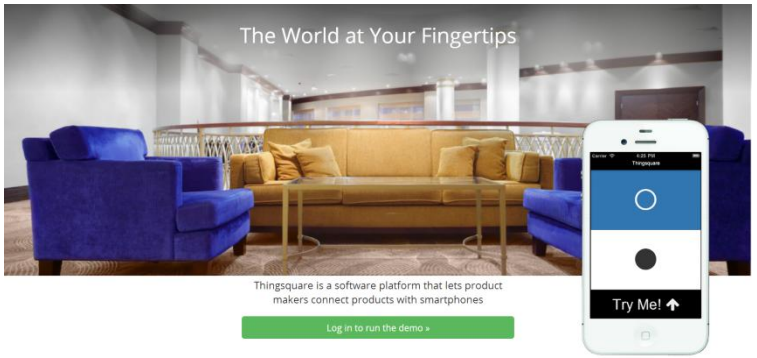




Thingsquare

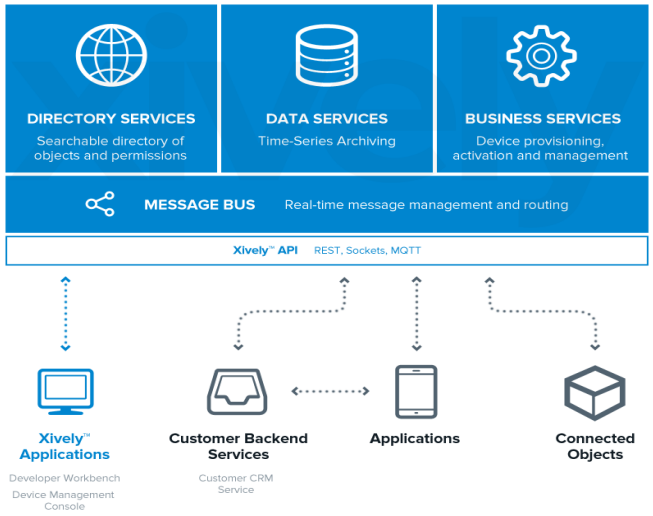
- Contiki, OS for low power, memory constrained, connected devices
- Things(devices) equipped with Thingsquare Mist OS
- Things for low-power wireless mesh network
- Things Code, An IDE for applications
- Connected consumer products
- Wireless industrial monitoring solutions

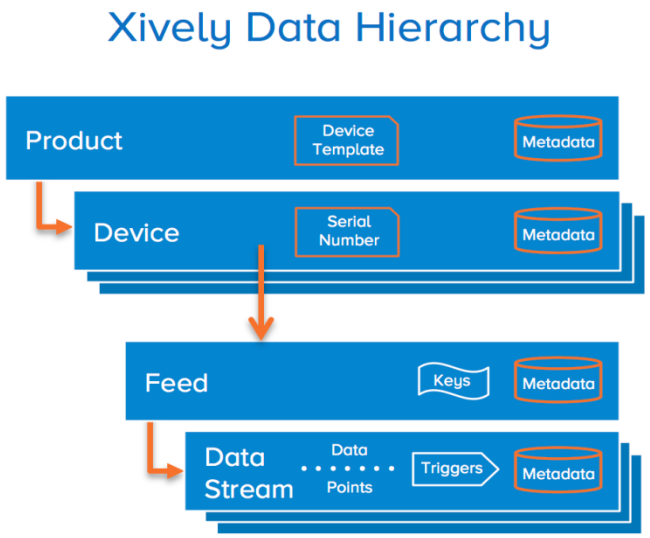




Xively(Pachube)

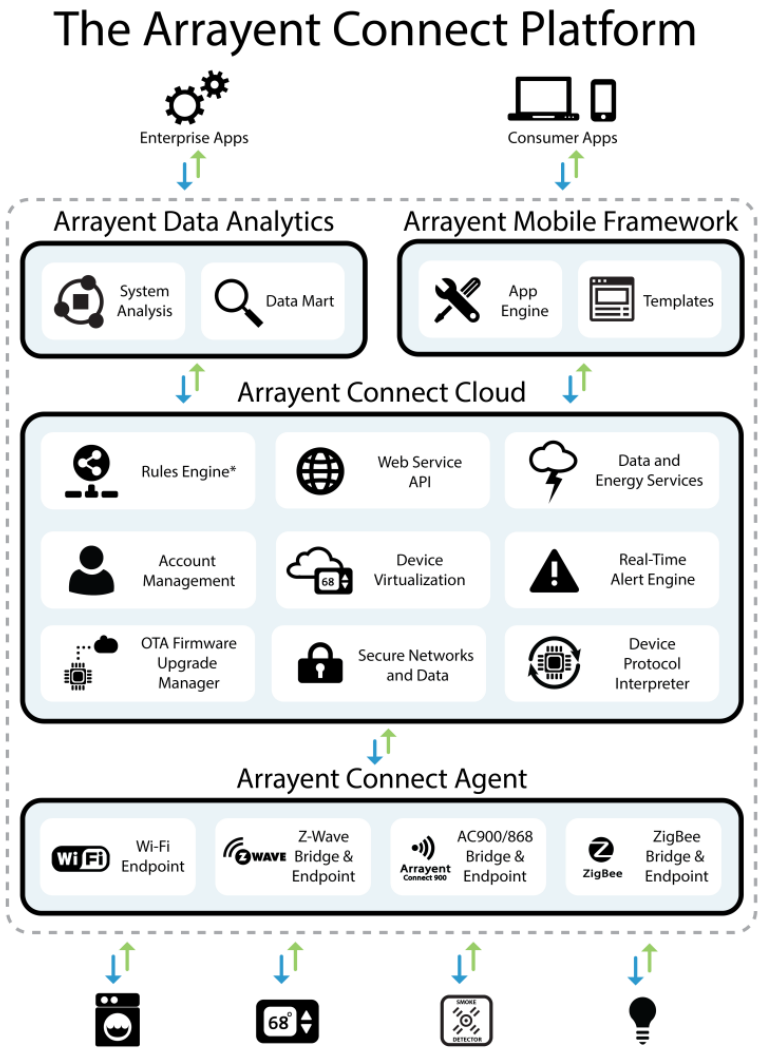
- Public cloud for IoT
- Tools for building and managing connected things
- Consists of Libraries(SDK), Cloud Platform, WebApplication
- Xively can be applied to various fields
- Supports various hardware, platforms, languages
- Provides all the things for the development, deployment, management of IoT





Arrayent

- Connect Things to Smartphone and web apps.
- Scalable to millions of devices
- Major part of platform hosted at Connect Cloud
  - ✓ Connect agent
  - ✓ Connect cloud
  - ✓ Mobile framework
  - ✓ Data analytics
- Features
  - ✓ Device Virtualization
  - ✓ Alert Engine
  - ✓ Over-the-Air (OTA) Firmware Updates
  - ✓ Low Latency
  - ✓ Legacy Product Support
  - ✓ Rich, Scalable Storage
  - ✓ Low-Cost Hardware Support
  - ✓ API Abstraction
  - ✓ Data Mart services

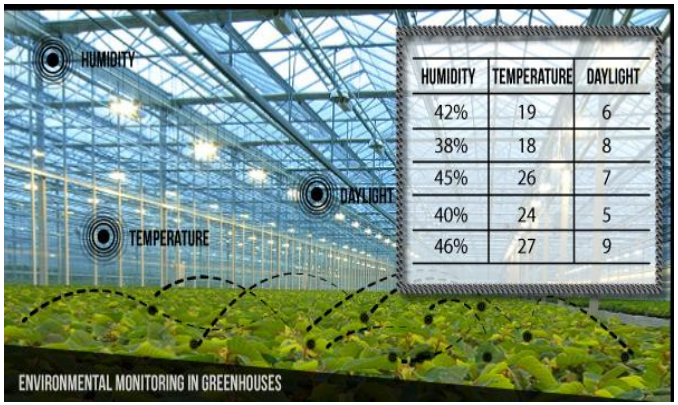


IoT Application - Environmental Monitoring

- **TST** is a wireless products manufacturer for smart applications, M2M and IoT world

TST

- Assist environmental protection by monitoring air or water quality, atmospheric or soil conditions, earthquake and tsunami
  - ✓ Pluviometers (rain gauge)
  - ✓ Anemometers (windmeter)
  - ✓ Flow water meters
  - ✓ Temperature and ground sensors
  - ✓ Humidity and ground sensors
  - ✓ Ground electrical conductivity sensors
  - ✓ Plant's leaf humidity sensors
  - ✓ Sap flow sensors
  - ✓ Level sensors
  - ✓ PH sensors
  - ✓ Gas sensors (CO, CO2, NO2…)



IoT Application - Infrastructure Management

- Monitoring and controlling operations of urban and rural infrastructures such as bridges, railway tracks, on- and offshore-wind-farms. TST provides TSmarT communication platform.

  - Street Lighting
  - Smart Parking
  - Supervision of water canalization
  - Air quality measurement
  - Interactive communication with citizens

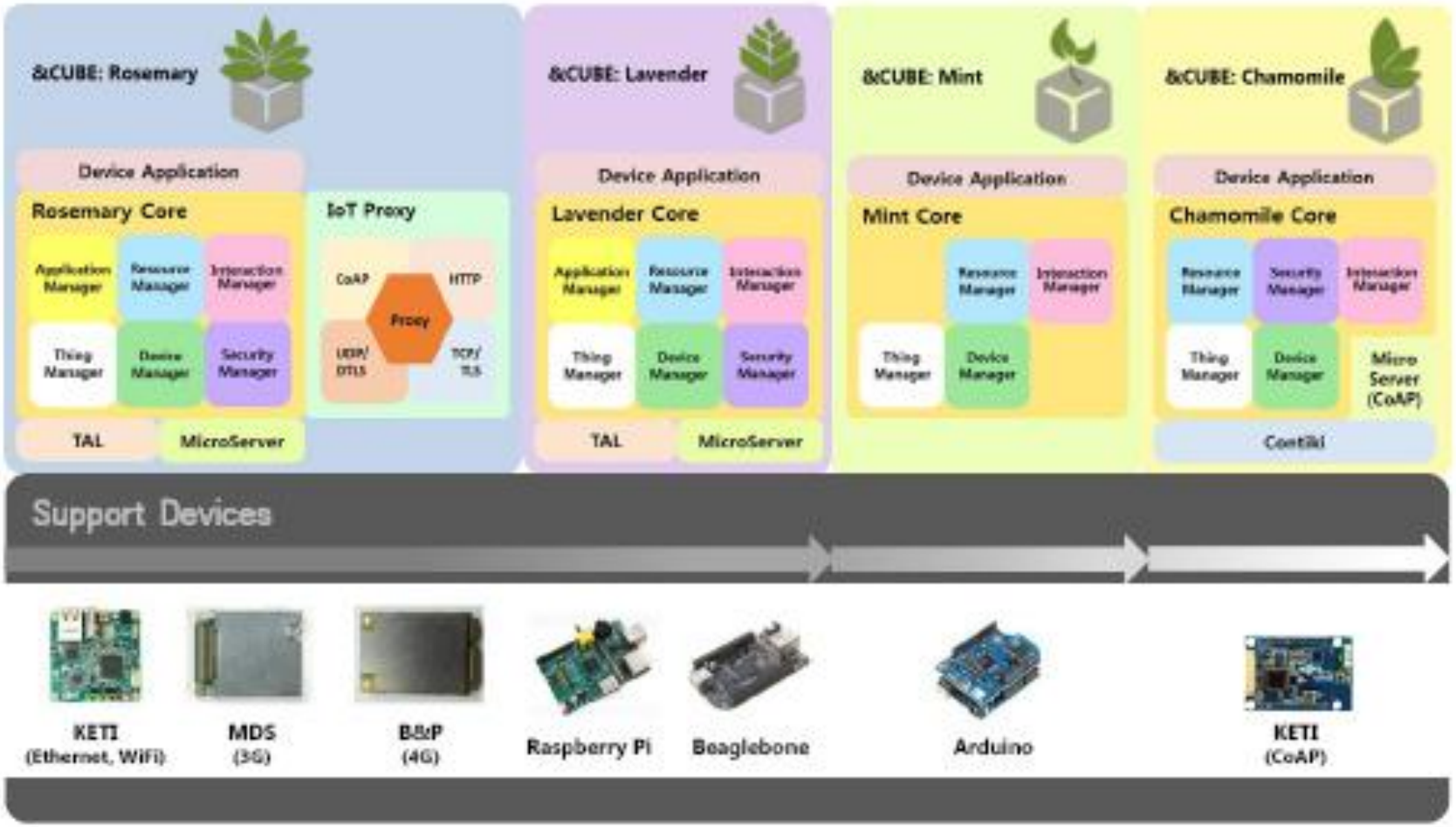
TStreeT light wireless controller

Head lighting control

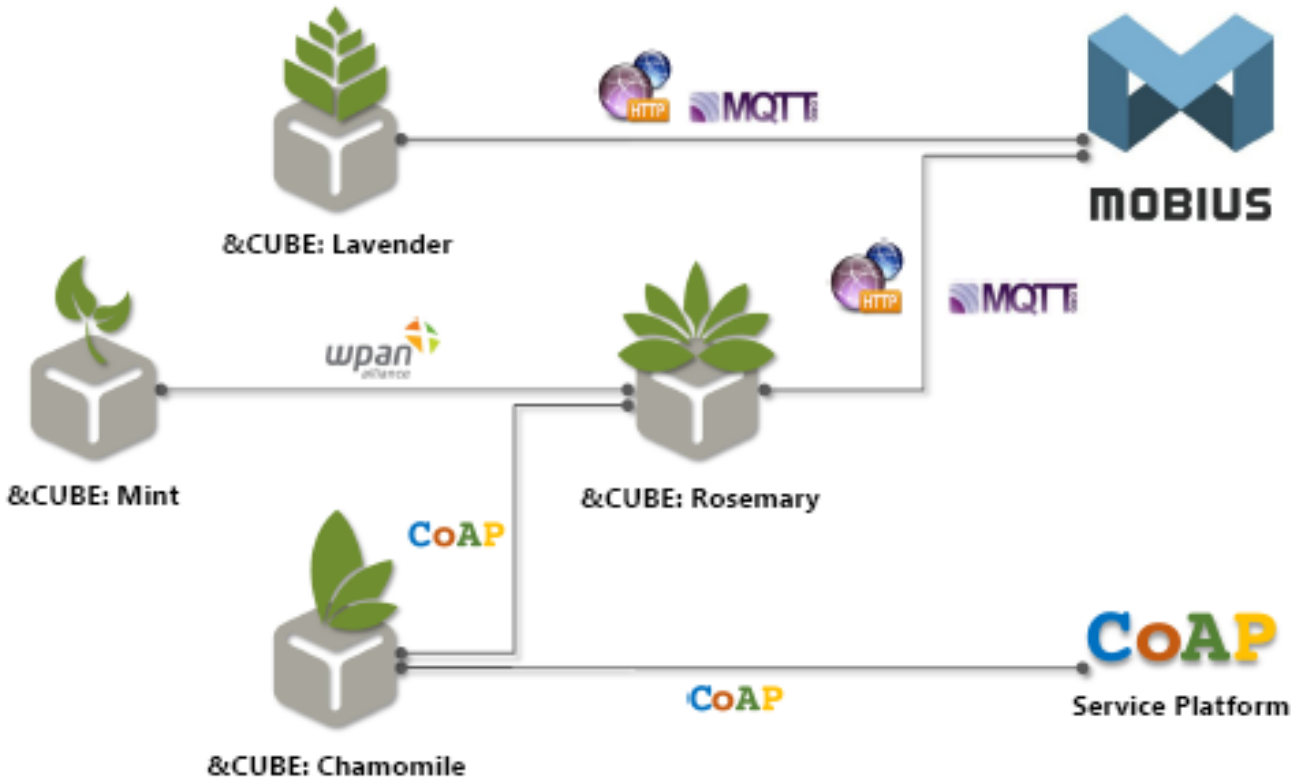
Ferromagnetic sensors detecting the presence of vehicles parked over them

Wireless remote control system to manage the traffic lights at train crossings in Bilbao harbor.

IoT Application - Industrial Application

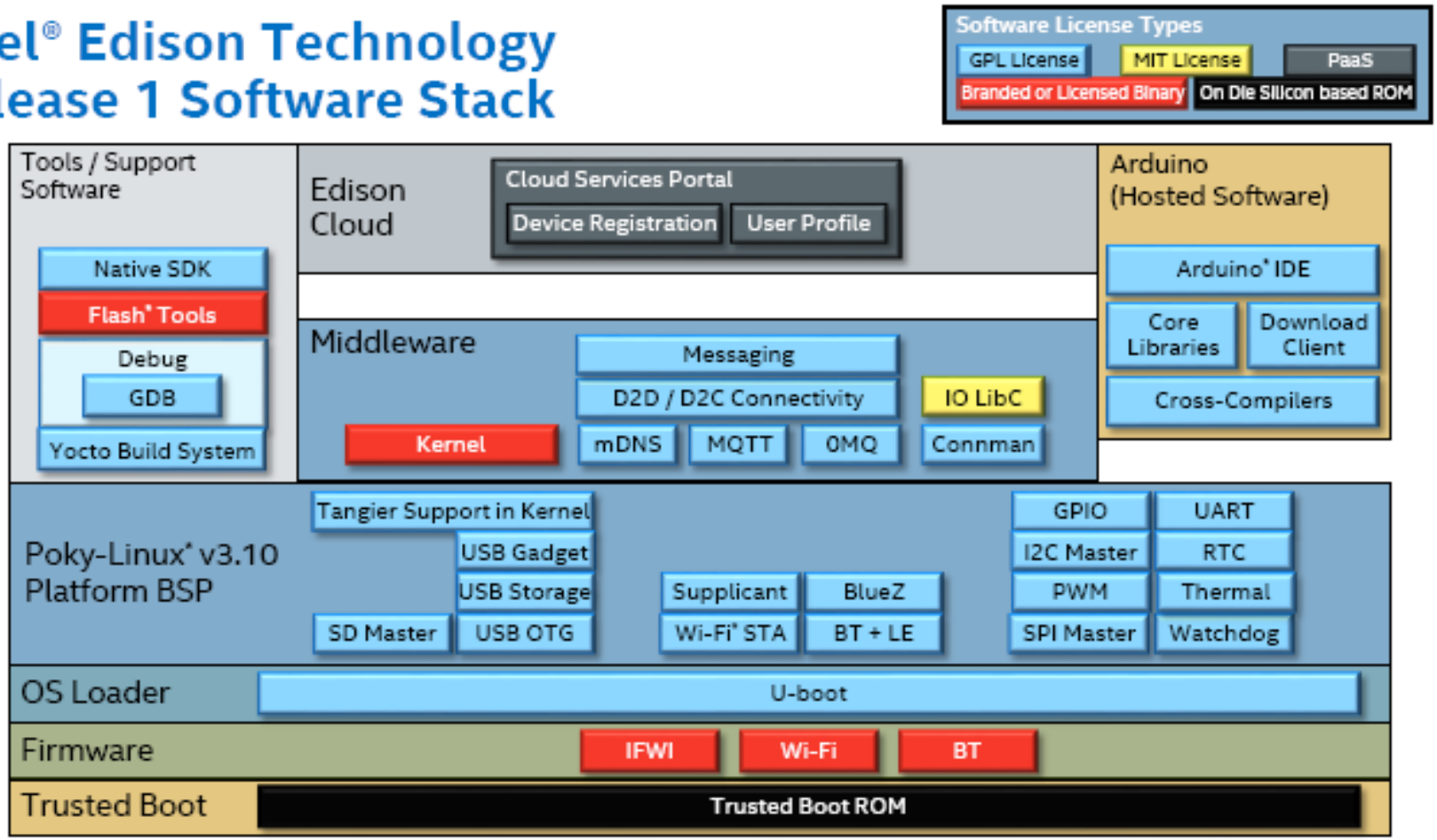


IoT Platform: KETI

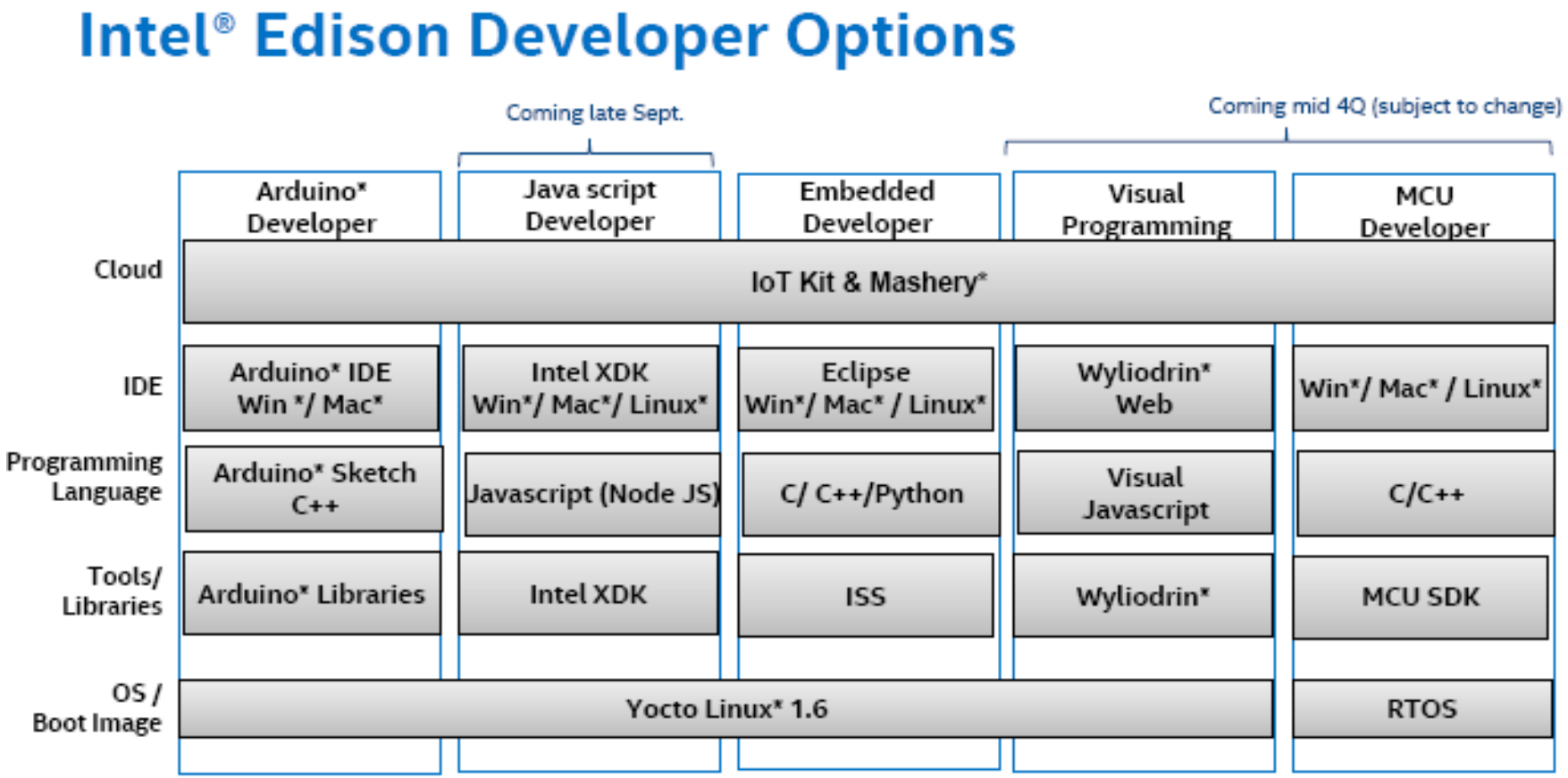


IoT Platform: Intel Edison

Intel® Edison Technology Release 1 Software Stack



IoT Platform: Intel Edison



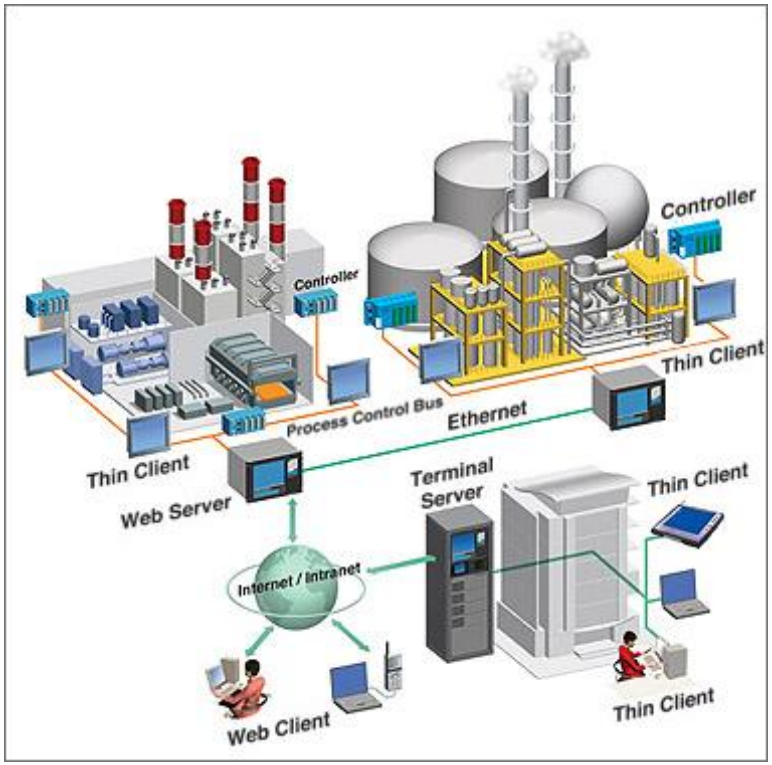
IoT Application - Industrial Application

- Network control and management of manufacturing equipment, asset and situation management, or manufacturing process control

  - Smart Grid
  - Enabling real-time energy optimization
  - Measurements
  - Automated controls plant optimization
  - Health and safety management

IEEE 802.15.4, Zigbee, UHF RFID and SubG (433MHz) RF technologies

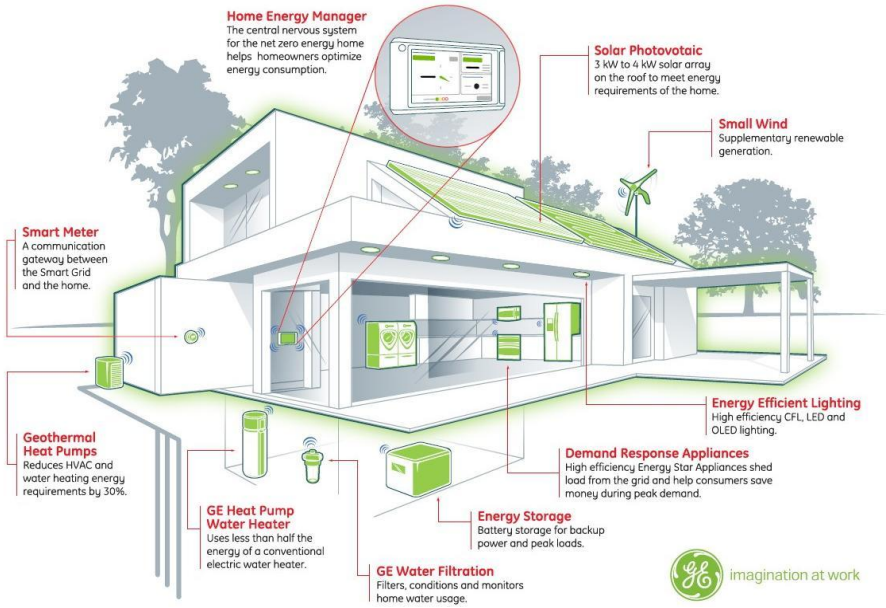
ADVANTECH *Enabling an Intelligent Planet*



IoT Application - Energy Management

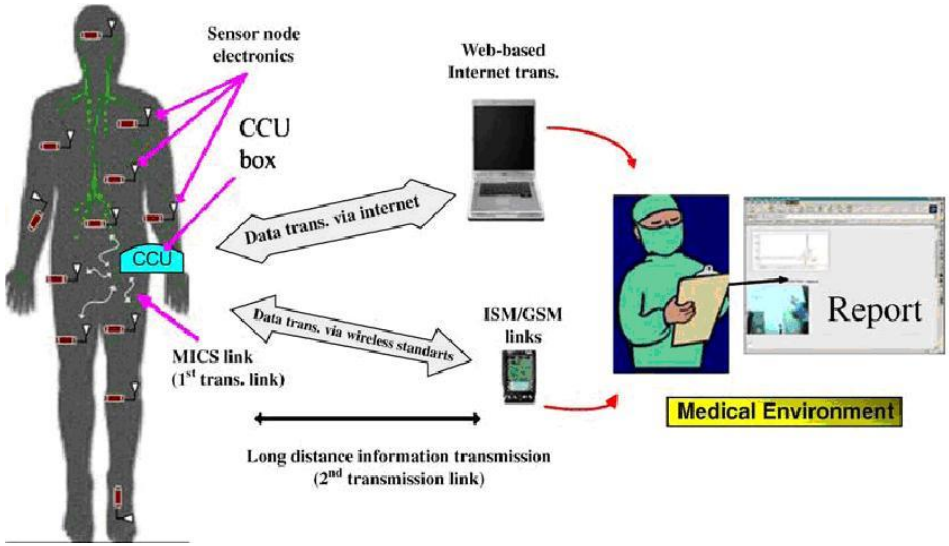
- IoT devices integrated into all forms of energy consuming devices (switches, power outlets, bulbs, televisions, etc.)

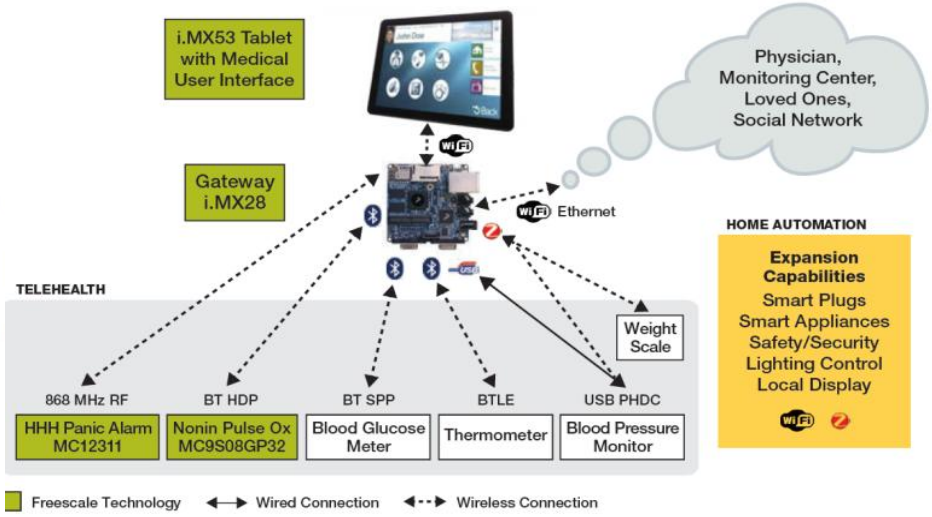
Ayla Networks



IoT Application - Medical and Healthcare System

- IoT devices enable remote health monitoring for blood pressure and heart rate, and emergency notification





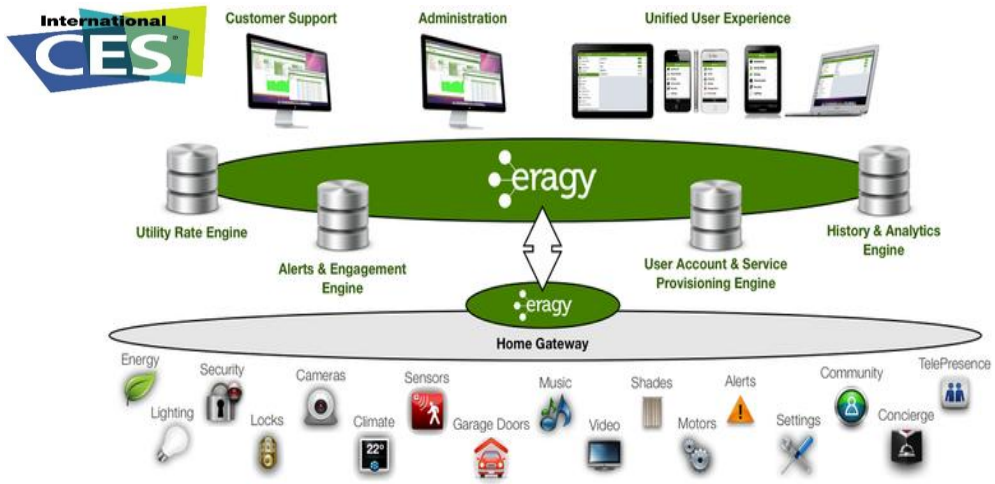
IoT Application - Transport systems

- Integration of communications, control, and information processing across various transportation systems i.e the vehicle, the infrastructure, and the driver or user, electronic toll collection systems

Digi TransPort VC7400

Iot Application - Building and Home Automation

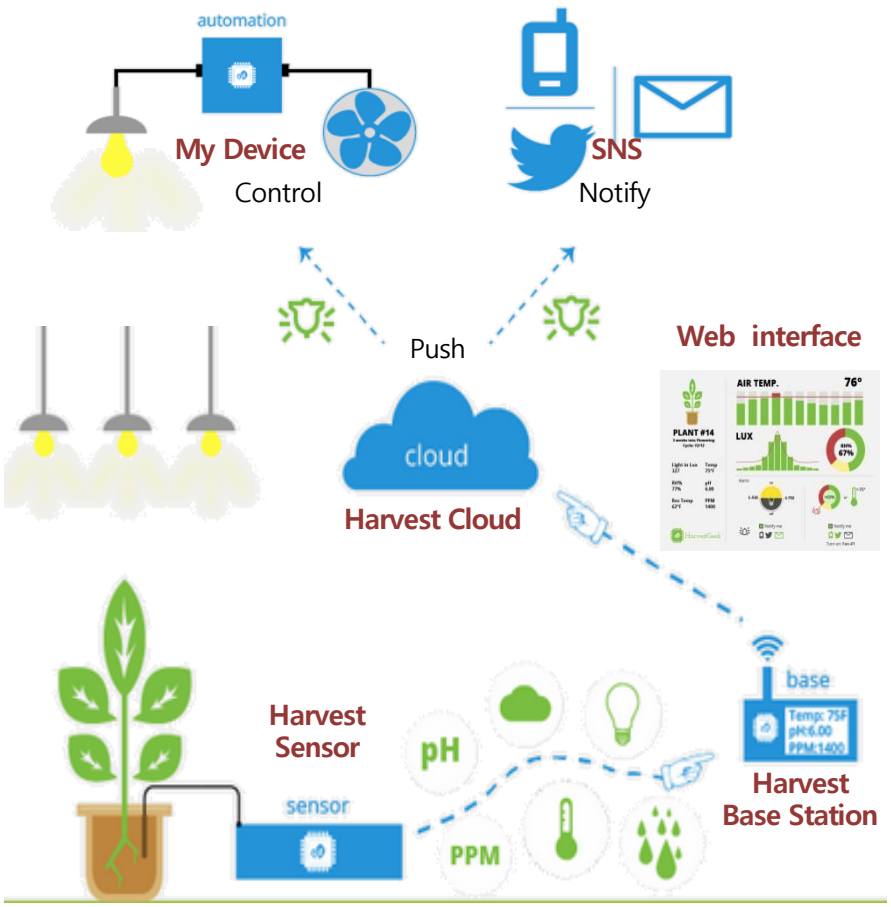
- Home automation system
  - to control
    - ✓heating
    - ✓lighting
    - ✓ventilation
    - ✓air conditioning
    - ✓appliances
    - ✓communication systems
    - ✓entertainment
    - ✓home security devices
  - to improve
    - ✓convenience
    - ✓comfort
    - ✓energy efficiency
    - ✓security



PubNub

IoT Services - Harvestgeek

Article	Detail
Company	Harvestgeek
Method of Communications	Wi-Fi
Product Component	BaseStation, SensorStation
Mobility Support	No
Application area	Farming
Service Characteristic	• Webcloud for farm monitoring and control • Developed in open source
Use case	• **Case 1: Monitoring farm condition** - Measure farming environment (Humidity, acidity, temperature); real-time check on Web • **Case 2: Automatic operation of machine** - If condition is met, farm machines are triggered (fan, light)

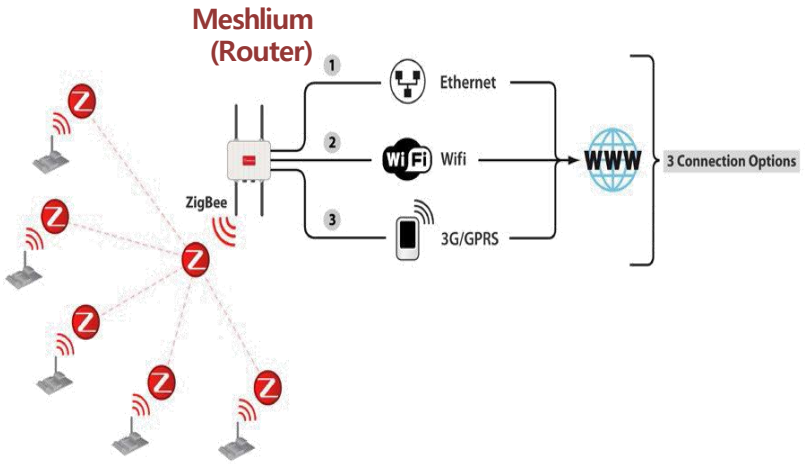


IoT Services - Withings

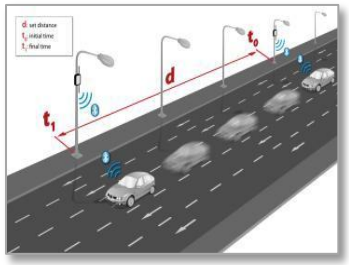
Article	Detail
Company	Withings
Method of Communications	Bluetooth4.0, Wi-Fi 802.11b/g/n(Some), Ethernet(Some)
Product Component	Health condition check devices
Mobility Support	OS/Android, Partner app are available(open API)
Application area	Health care
Service Characteristic	• Cloud service provides data lookup and share • Application push upon the occurrence of some events
Use case	• **Case 1 : Measure weight or BMI** - Measure and share the weight change when diet is started • **Case 2 : Real-time baby monitoring** - Monitor baby condition(24 time), if problem occurs, alarm using an application

IoT Services - Waspmote & Meshlium

Article	Detail
Company	Libelium
Method of Communications	Bluetooth, 3G/GRPS, Zigbee, Wi-Fi
Product Component	Open source hardware(Waspmote, Meshlium)
Mobility Support	No
Application area	All area
Service Characteristic	• After installation, provide OTAP(Wireless programming) • Provide gateway to send the sensor data to external cloud
Use case	• **Case 1 : Smart water project in Valencia** - Monitor and measure the environment of river(PH,DO) • **Case 2 : Smart parking** - Install Waspmote in the parking area, and then monitor parking lot in real-time and air-condition service using Meshlium



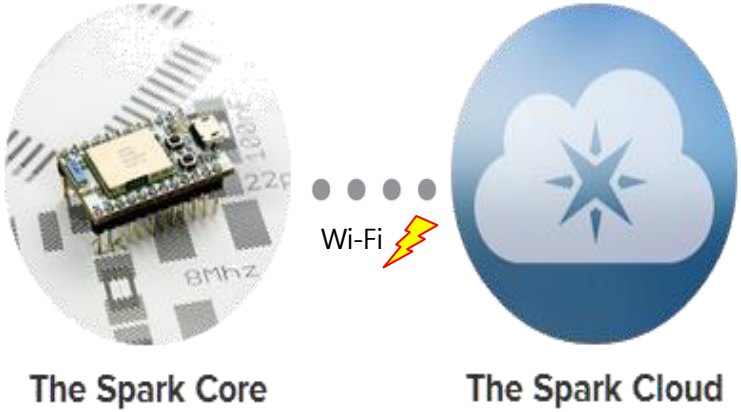
Install Sensor, programming
(Over-The-Air-Provisioning)



Sensor Traffic condition
(Bluetooth)

IoT Services - Spark

Article	Detail
Company	Spark Devices
Method of Communications	Wi-Fi 802.11 b/g
Product Component	Cloud Mobile Platform(Real-time Data transmission), Spark Core Chipset, Shield
Support Mobile	iOS / Android
Application area	All areas
Service Characteristic	• Attached Spark Core and Shield onto things • Install/Programming available after wireless connection to Spark Core • Chipset is cheap and compatible with Arduino
Use case	• **Case 1: Wireless motion awareness** - Send SMS if wireless motion sensor recognizes an object • **Case 2: Robot control** - Control robot to which a core is attached



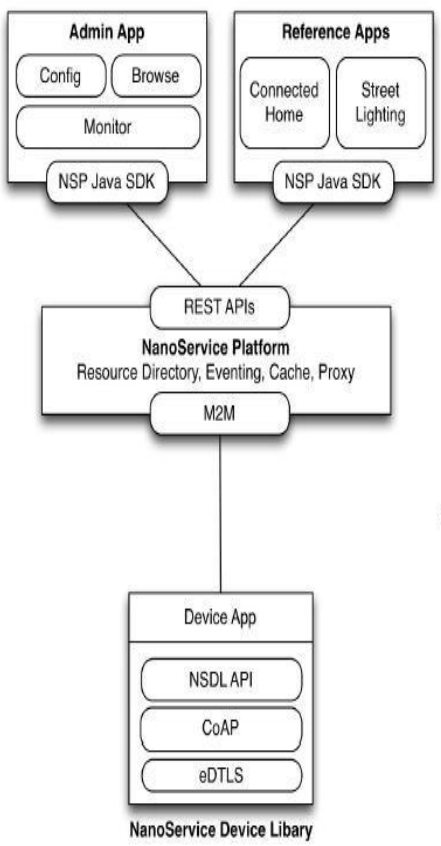
Smart Config
(install Core on Wireless)

Spark Flash
(Programming core on Wireless)

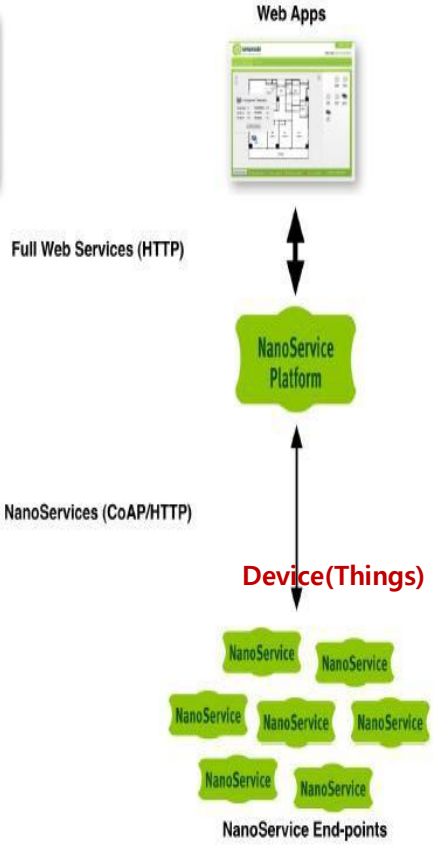
Operate Devices
attached Core

IoT Services - NanoService

Article	Detail
Company	Sensinode -> M&A by ARM(13.08')
Method of Communications	IP (6LoWPAN to Cellular)
Product Component	Closed M2M platform (Web Application, REST APIs, Device Libraries)
Mobility Support	No
Application area	Smart Energy, Connected Home, Healthcare etc
Service Characteristic	• Provide M2M Embedded Web service based on 6LoWPAN and CoAP • Web Application Reference for each M2M Market Segments
Use case	• **Case 1: Connected home** - Control home appliances using web browser • **Case 2: Lightening** - Control and monitor streetlamp using web browser (including firmware)



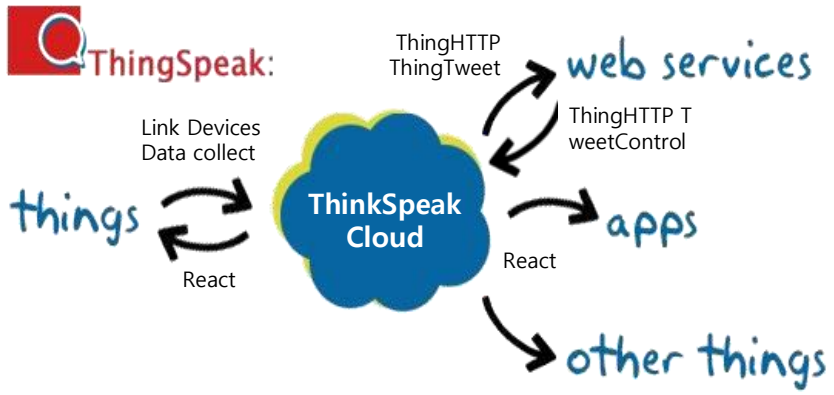
NanoService Architecture

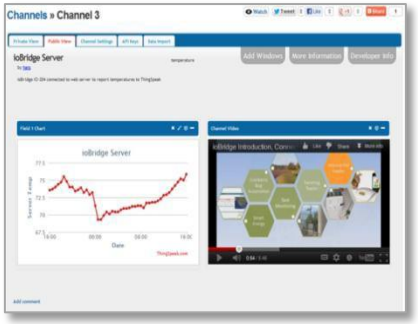


Platform Component

IoT Services - ThingSpeak

Article	Detail
Company	ioBridge
Method of Communications	IP based(Ethernet, Wi-Fi, Cellular)
Product Component	Libraries(SDK), Cloud Platform, WEB Application
Mobility Support	No
Application area	All areas
Service Characterstic	• Provide OPEN Source APIs • Support Arduino • Control and monitor device via Tweeter • Share data channel • Support time zone and localization
Use case	**•Case 1: Tweeter mash-up services on temperature** - If the room is very hot, a message is sent to user by Tweeter



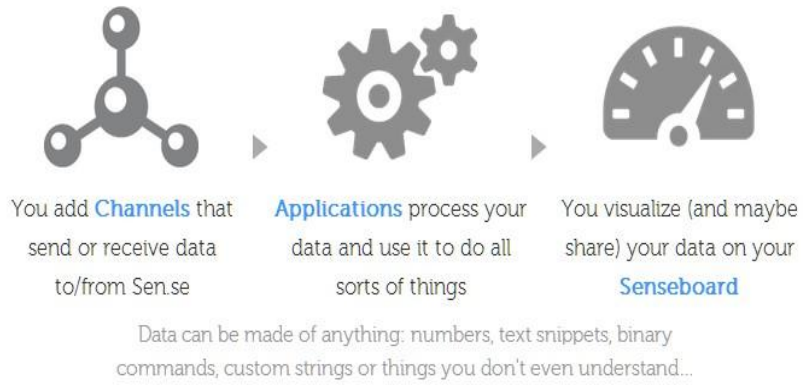


Data search, share

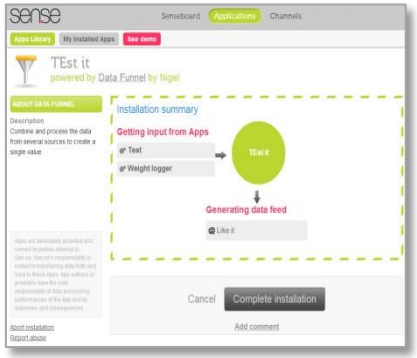
APP·Device register

IoT Services - Open.Sen.se

Article	Detail
Company	Sen.se
Method of Communications	IP based(Ethernet, Wi-Fi, Cellular)
Product Component	Libraries(SDK), Cloud Platform, WEB Application
Mobility Support	No
Application area	All areas
Service Characteristic	• Process sensor data as web application - Process, Trigger, Visualize • Support Arduino • Allow manual data input • Various data mash-up
Use case	**• Case 1: Withings weight - weather data mash-up** - Available to check the relation between weight/energy consumption and weather using mash-up Withings weight machine and weather data obtained by Sen.se



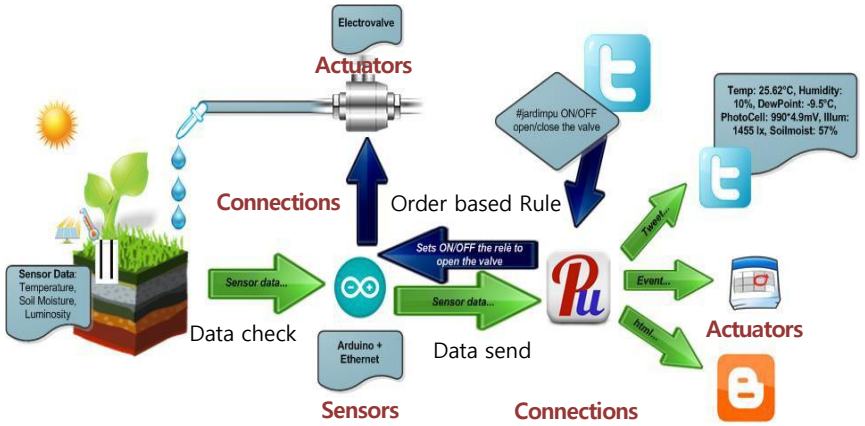
Register Devices

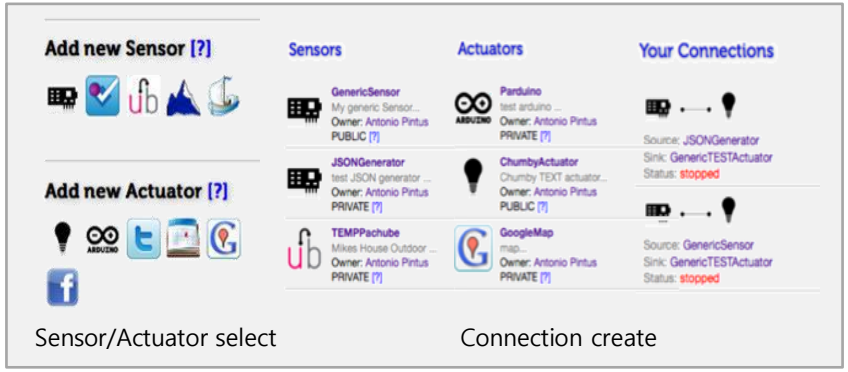


Data Mash-up using Application

IoT Services - Paraimpu

Article	Detail
Company	CRS4
Method of Communications	IP based(Ethernet, Wi-Fi, Cellular)
Product Component	Libraries(SDK), Cloud Platform, WEB Application
Mobility Support	No
Application area	All areas
Service Characteristic	• Provide connection between things, services • Allow to share the things • Support various 3rd party(Arduino, Xively etc)
Use case	• **Case 1: Foursquare + Gmail** - Send information on the restaurant to the Gmail account, if people mark it 'Good' in Fourquare • **Case 2: Arduino + water switch** - If sensor recognizes the land is dry, open the water.





Examples of IoT Services

※ n.thing, Smart plant services

planto

plantree

planty

Examples of IoT Services

※ Beam Brush

※ Livescribe Sky Wifi Smartpen

※ Sphero, robotic ball

※ Deeper Smart Fish Finder

Examples of IoT Services

※ Nike Fuelband, Fitbit etc. device for fitness

※fibit Aria Wifi Smart Scale

※ LG electronics Co. Home Chat

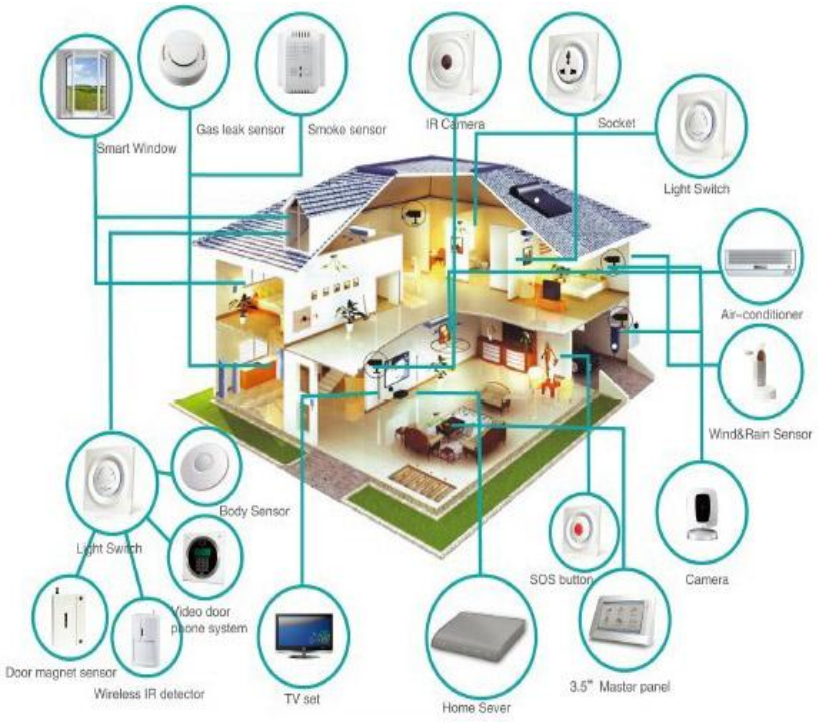
※Smart Toaster

IoT Home & City

Smart Home

- Provide various functions
  - household appliances control
  - lighting control
  - curtain control
  - remote telephone control
  - indoor and outdoor remote control
  - burglar alarm
  - environment monitoring
  - HVAC control
  - programmable timing control

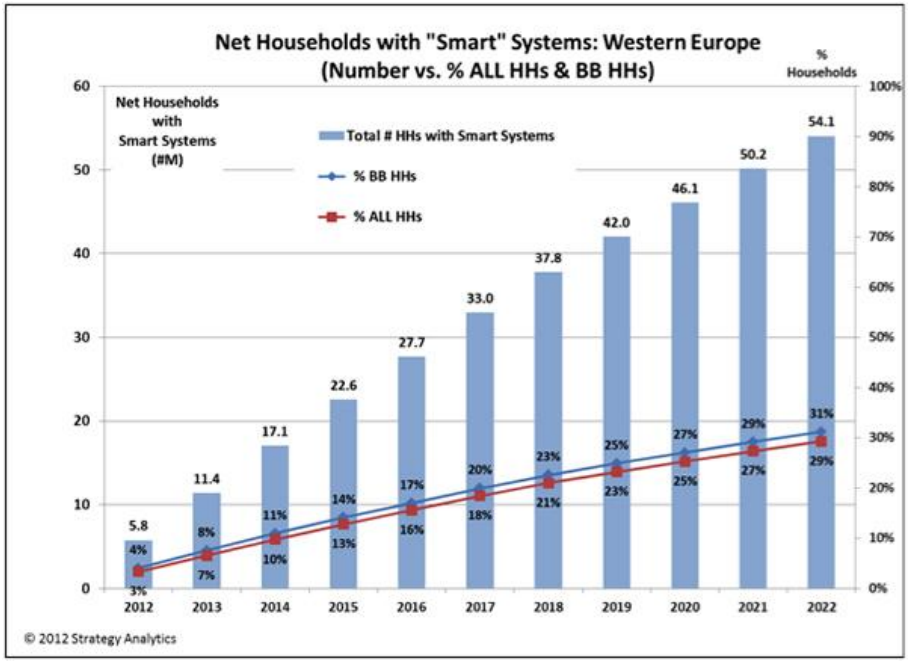
Optimize the way people live and help people arrange time, improving the safety and cutting the energy cost

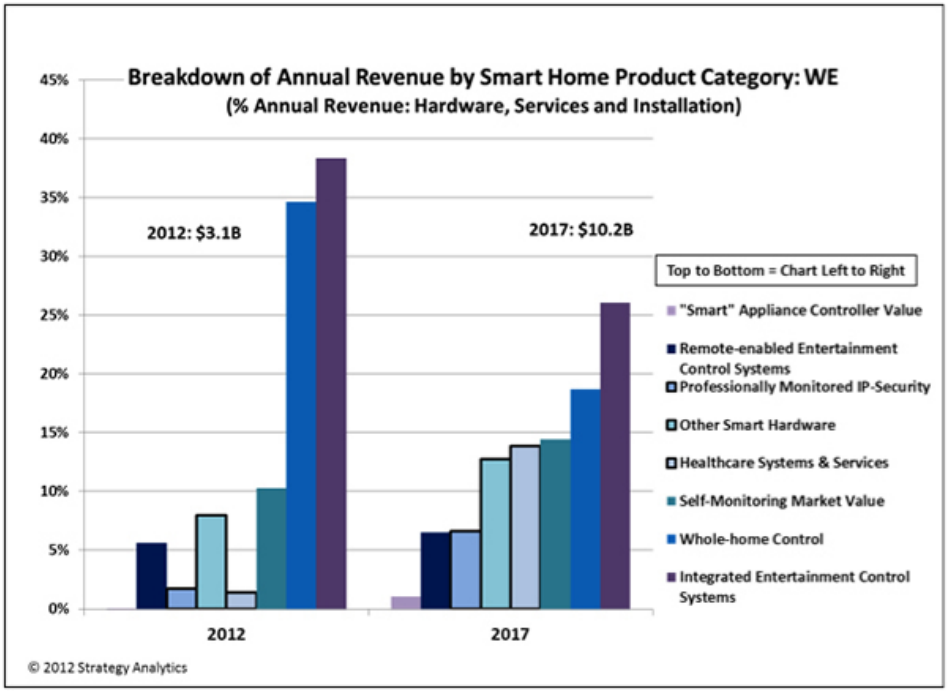


IoT Home & City Growth

Smart Home Growth

- In 10 years 30% of broadband households will have a smart system
- Approximately 65% of households will have multiple systems by 2017





- By 2017, revenues > US$10 billion
- Professionally installed integrated entertainment and smart home

IoT Home & City Domain

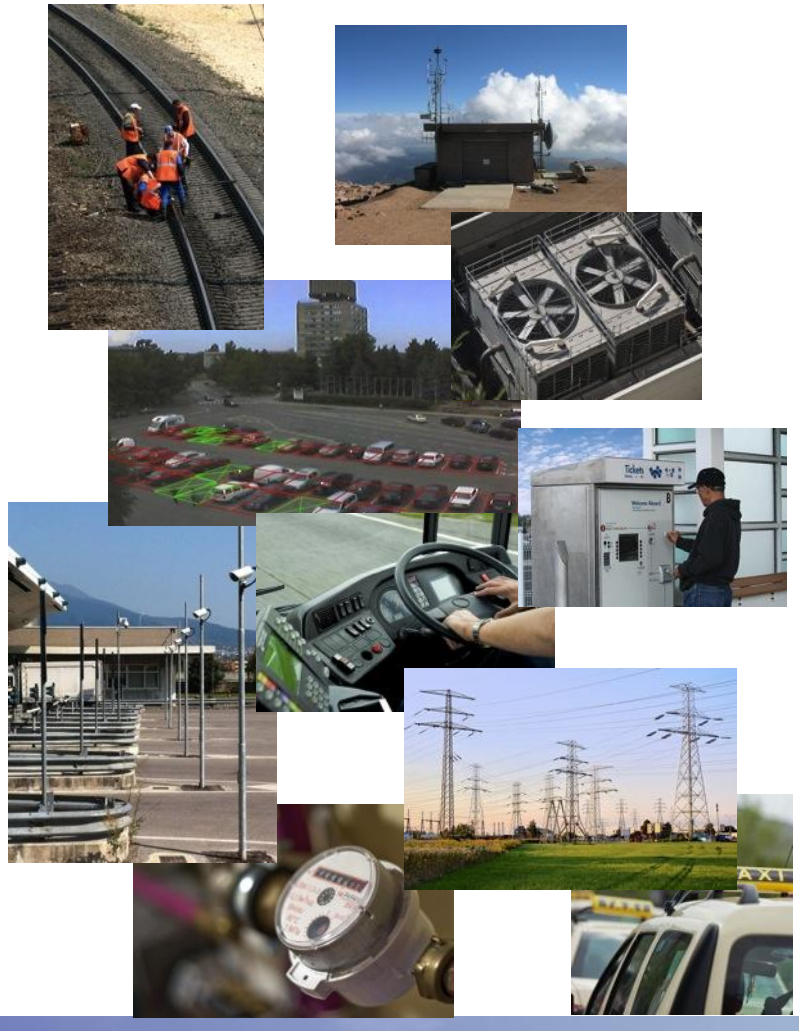
- Application domains

	Smart home/office	Smart retail	Smart city	Smart agriculture/forest	Smart water	Smart transportation
Network size	Small	Small	Medium	Medium/large	Large	Large
Users	Very few, family members	Few, community level	Many, policy makers, general public	Few, landowners, policy makers	Few, government	Large, general public
Energy	Rechargeable battery	Rechargeable battery	Rechargeable battery, energy harvesting	Energy harvesting	Energy harvesting	Rechargeable battery, Energy harvesting
Internet connectivity	Wifi, 3G, 4G LTE backbone	Wifi, 3G, 4G LTE backbone	Wifi, 3G, 4G LTE backbone	Wifi, satellite communication	Satellite communication, microwave links	Wifi, satellite communication
Data management	Local server	Local server	Shared server	Local server, shared server	Shared server	Shared server
IoT devices	RFID, WSN	RFID, WSN	RFID, WSN	WSN	Single sensors	RFID, WSN, single sensors
Bandwidth requirement	Small	Small	Large	Medium	Medium	Medium/large
Example testbeds	Aware home	SAP future retail center	Smart Santander citySense	SiSViA	GBROOS SEMAT	A few trial implementations

IoT Home & City Applications

Smart City – A Combination of Vertical Solutions

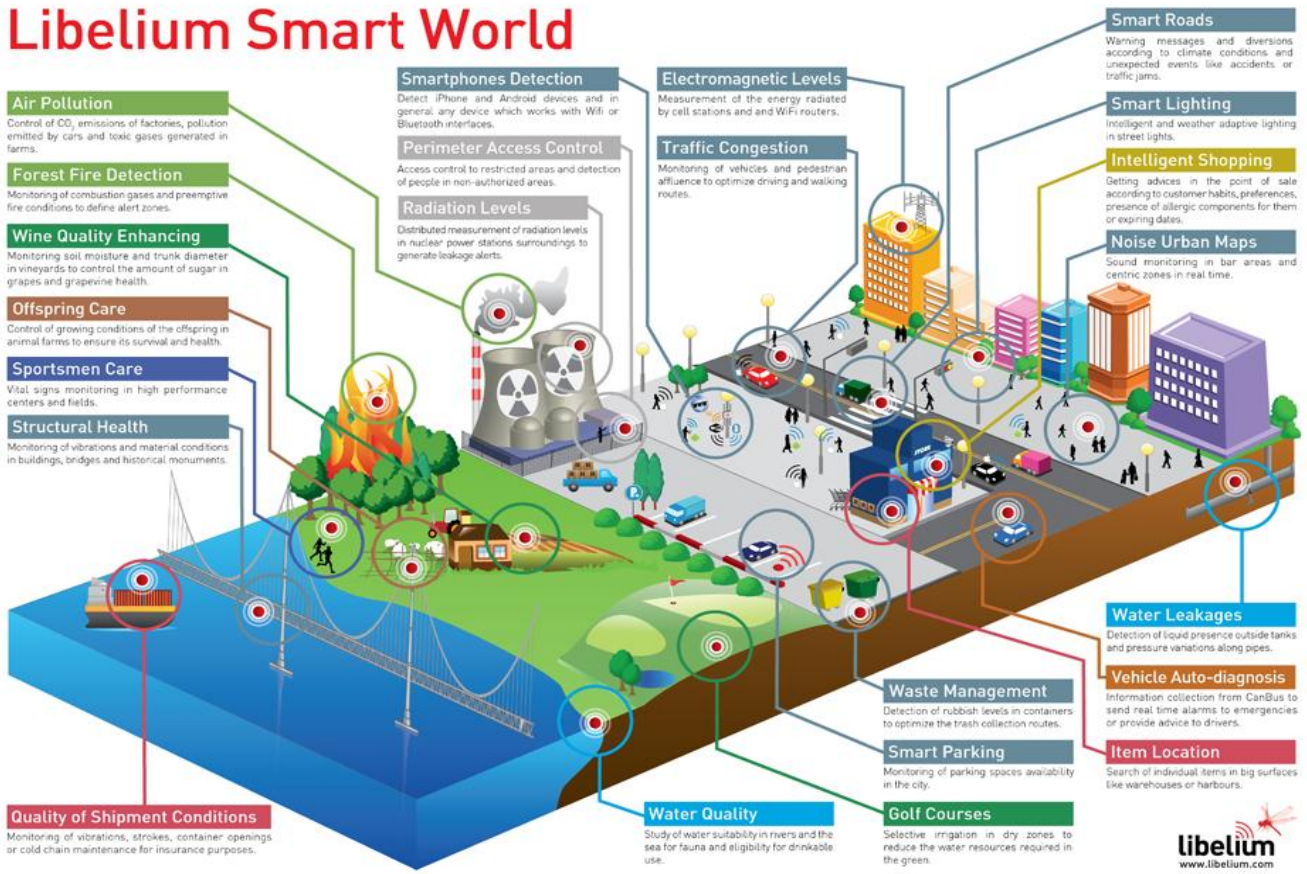
- **Smart Transportation & Public Transport**
  - Smart Ticketing
  - Signage
  - Geo-Services
  - Communication Gateways
- **Public Safety & Security**
  - Surveillance & Security
  - Emergency Services
  - Public Infrastructure
- **Smart Well-being**
  - Healthcare
  - Elderly living
- **Smart Energy / Smart Grid**
- **Smart Building**
- **Smart Water Management**
- **Smart Retail**



IoT Home & City Infographic

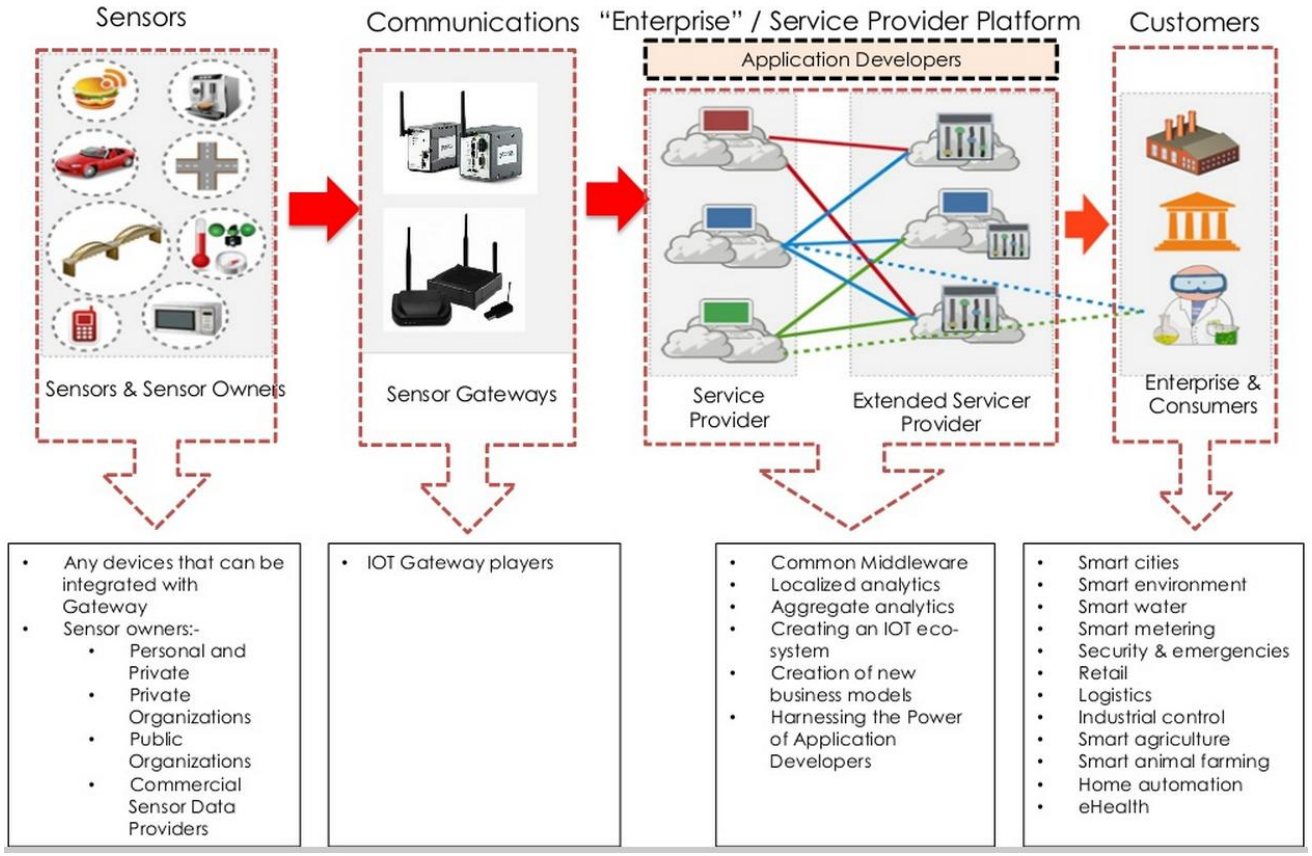
- Libelium Smart World Infographic

  - Sensors for Smart Cities, Internet of Things and beyond



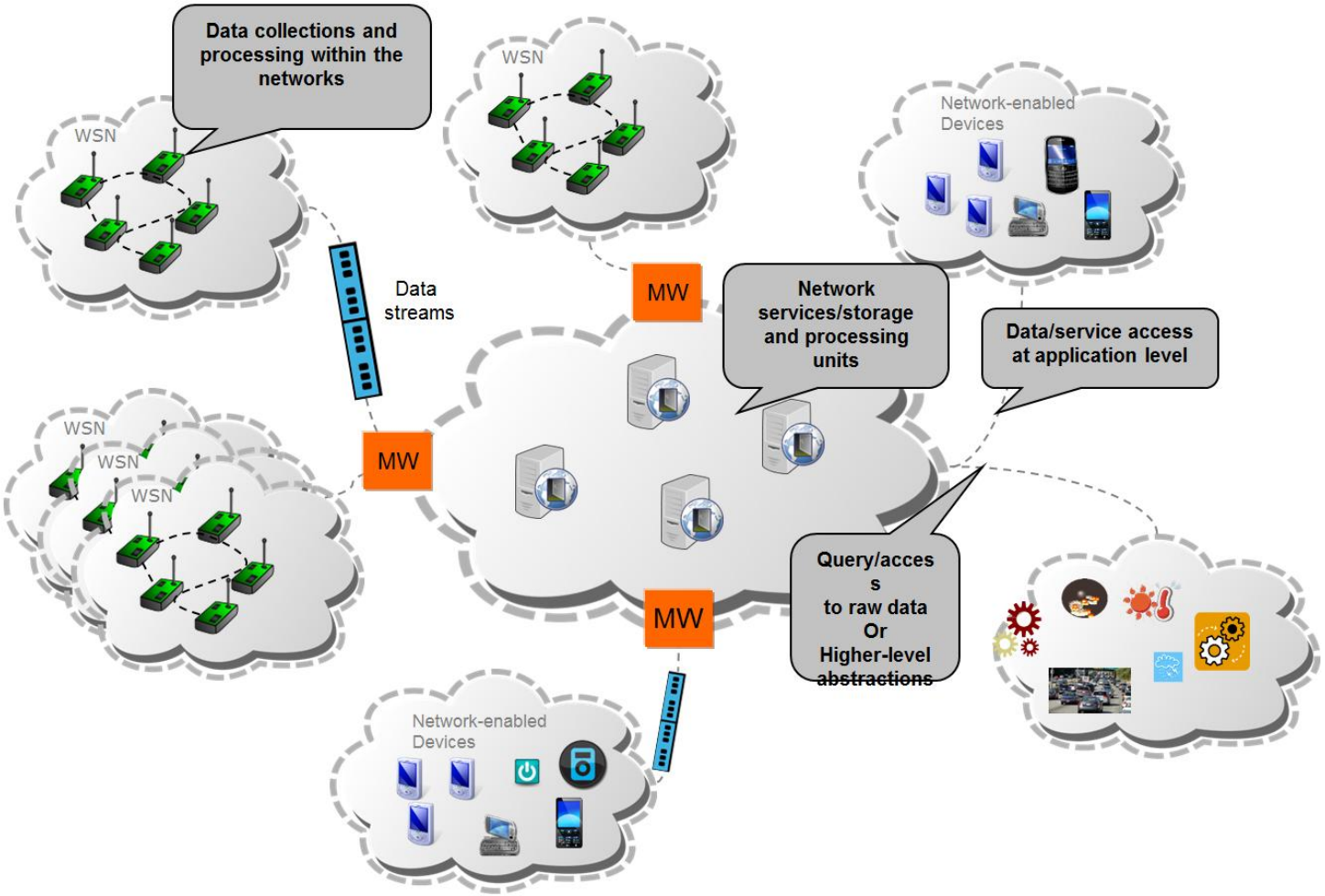
IoT Home & City SaaS

- Sensing-as-a-Service Model



Stream Processing

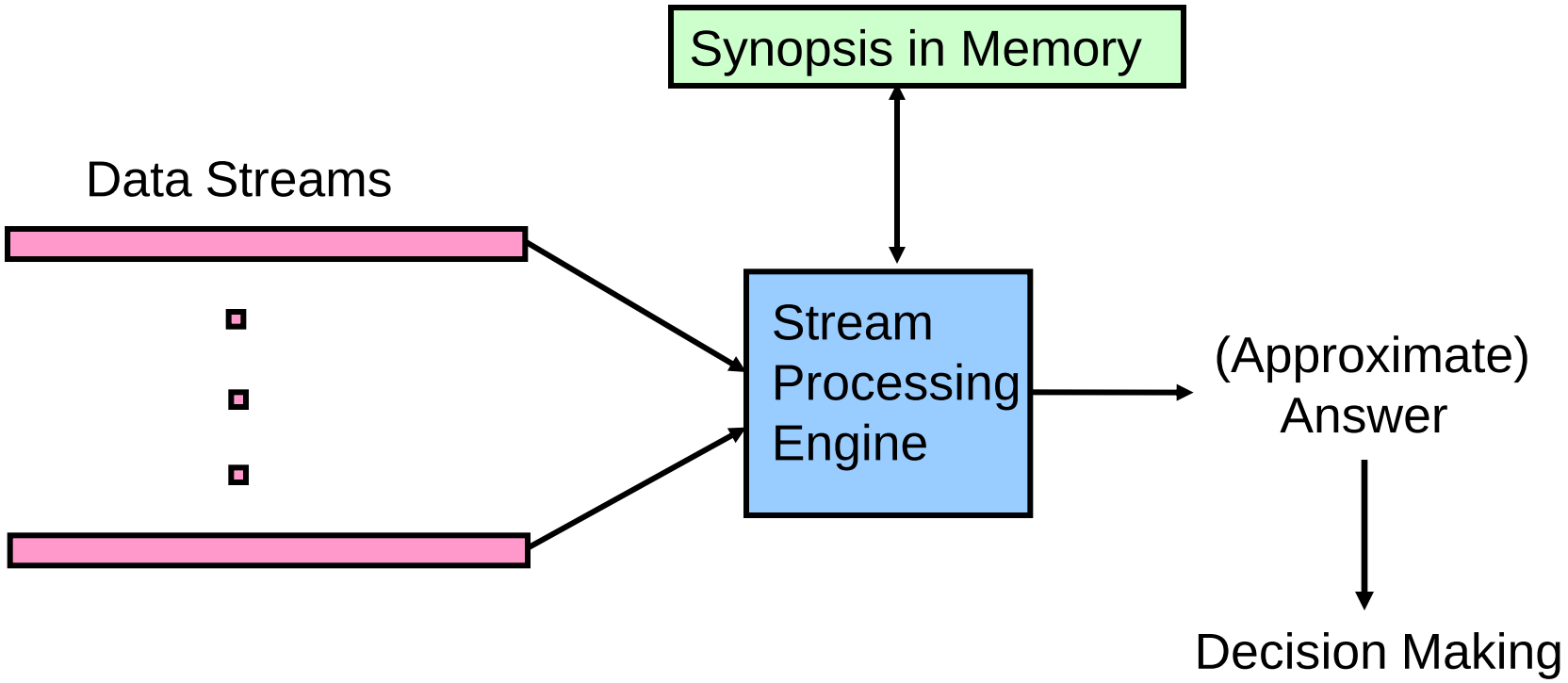
- IoT Stream Processing



Streaming Data Processing

- What is stream data processing
  - Method of making audio, video and other multimedia available in real-time over the Internet or corporate intranets
  - Streaming ensures no download wait
- Why is stream processing important?
  - Large scale data cannot be easily stored because of their volume, and accurate analysis is no simple matter
  - With stream processing technology, you can continuously analyze massive volumes of your data in memory to take action in real-time

Streaming Computation Model



Stream Processing in IoT Environment

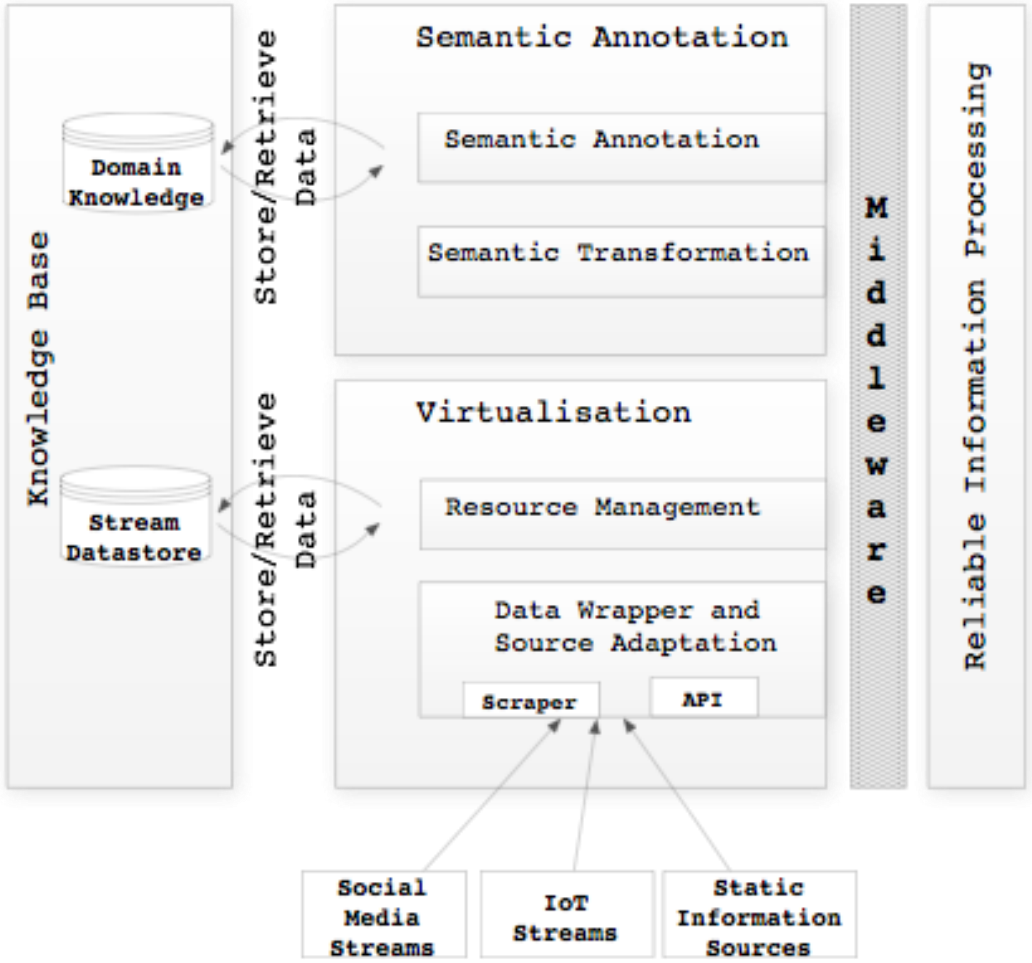
- What are needed for IoT?
  - analyze the arriving sensor and device data in real-time
  - provide comparisons against the trend data by joining the real-time data with historical, stored data
  - provide real-time dashboards and alerts for visualization
  - provide continuous streaming integration with operational systems for process automation
  - stream the data through the existing Hadoop and data warehouse platforms

Essentially, stream processing is to the Internet of Things, what Big Data and Hadoop has been to the Internet

M. Compton et al, "The SSN Ontology of the W3C Semantic Sensor Network Incubator Group", Journal of Web Semantics, 2012.

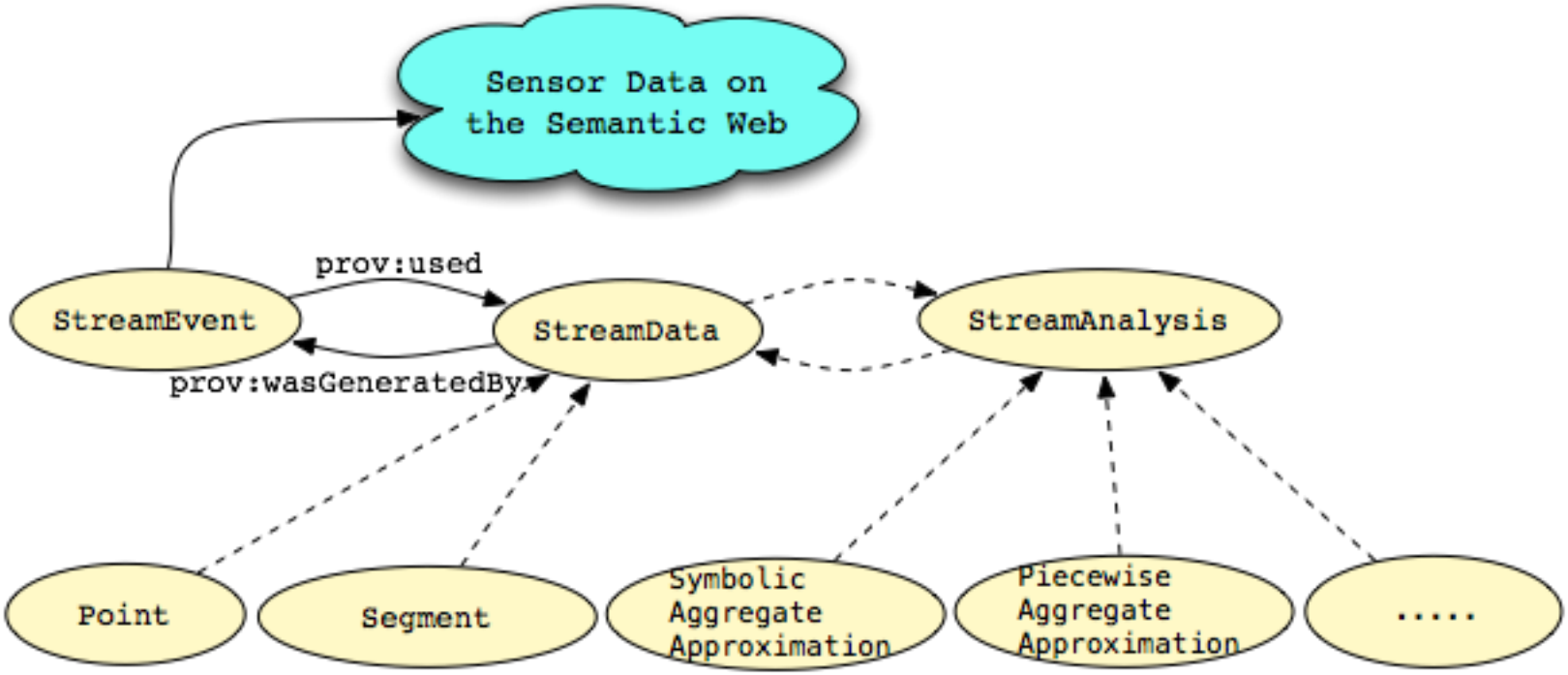
Stream Annotation

- Real-Time Stream Annotation Framework



Stream Annotation Ontology

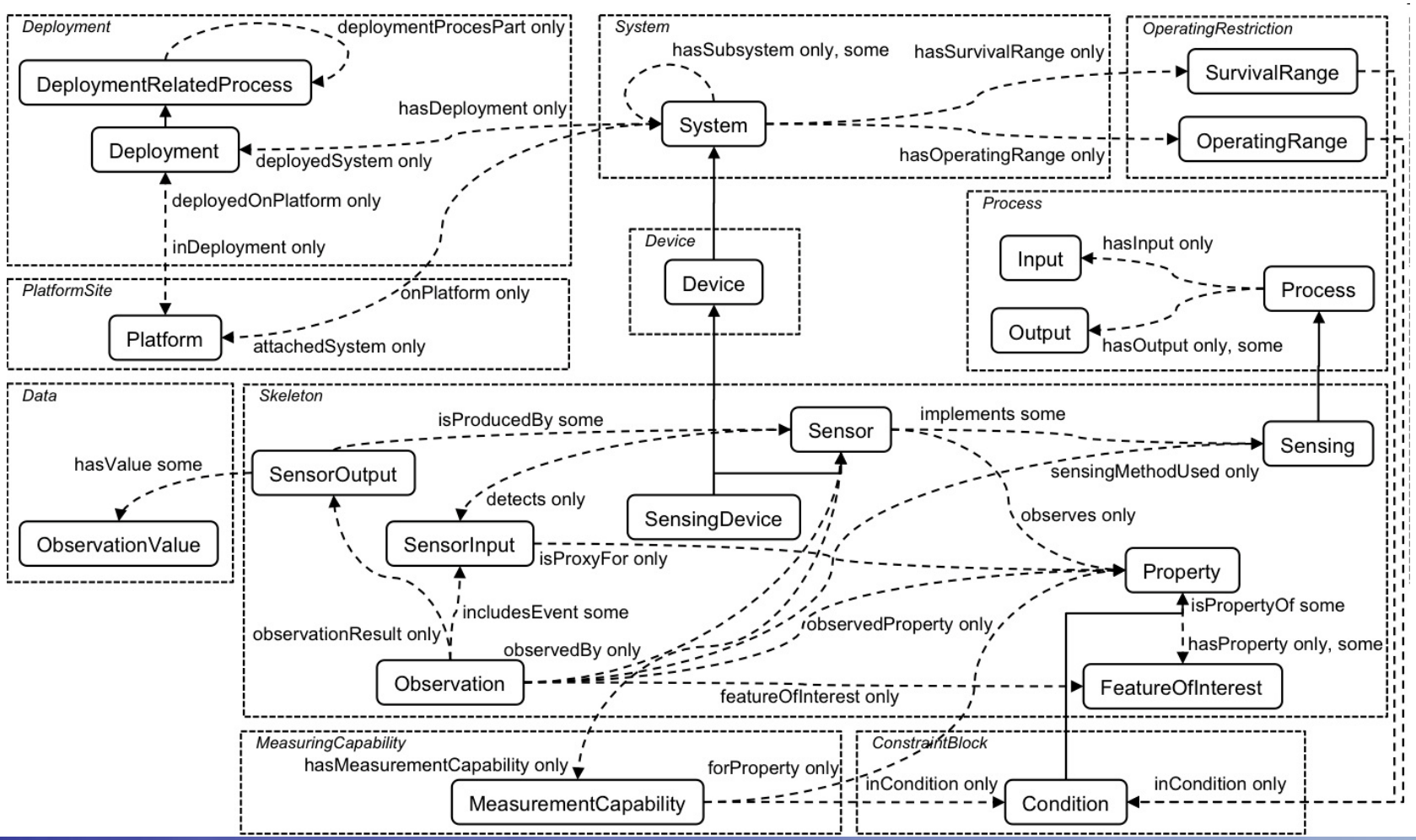
- Stream Annotation Ontology



The SAO allows representation of aggregated stream data and temporal characteristics, based on the SSN ontology and Timeline ontology.

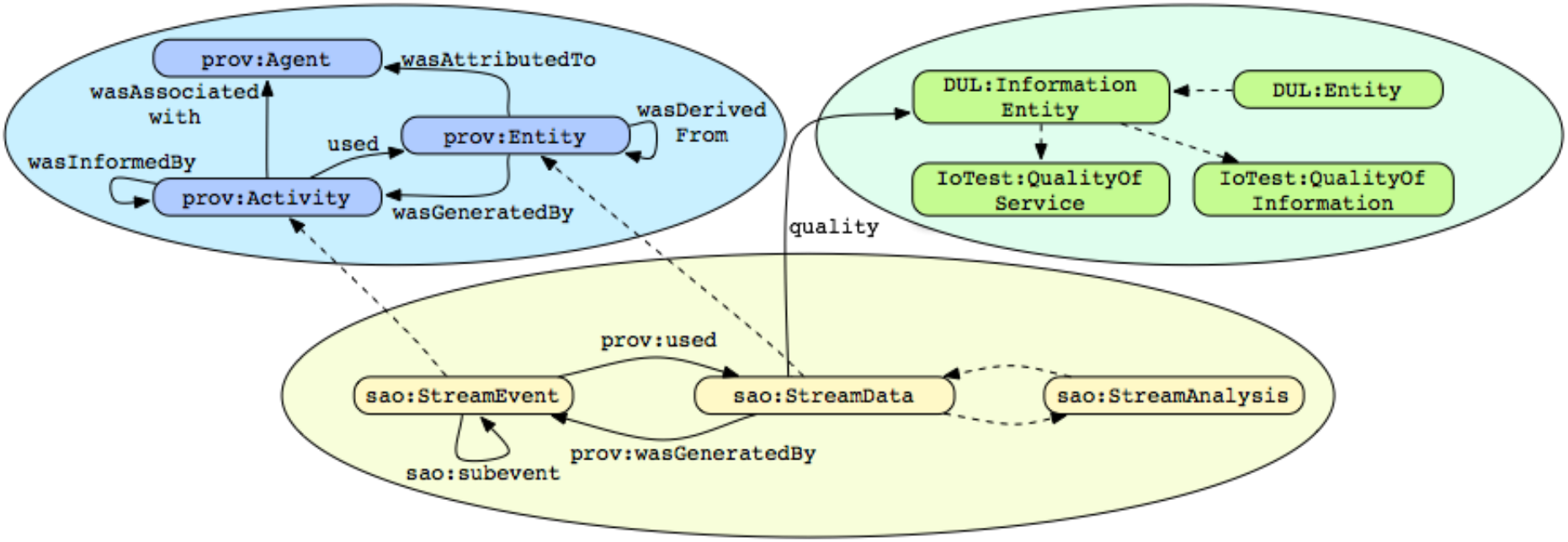
Ontology for SSN

- Existing models - e.g. W3C SSN Ontology



Stream Information Model

- Information Model

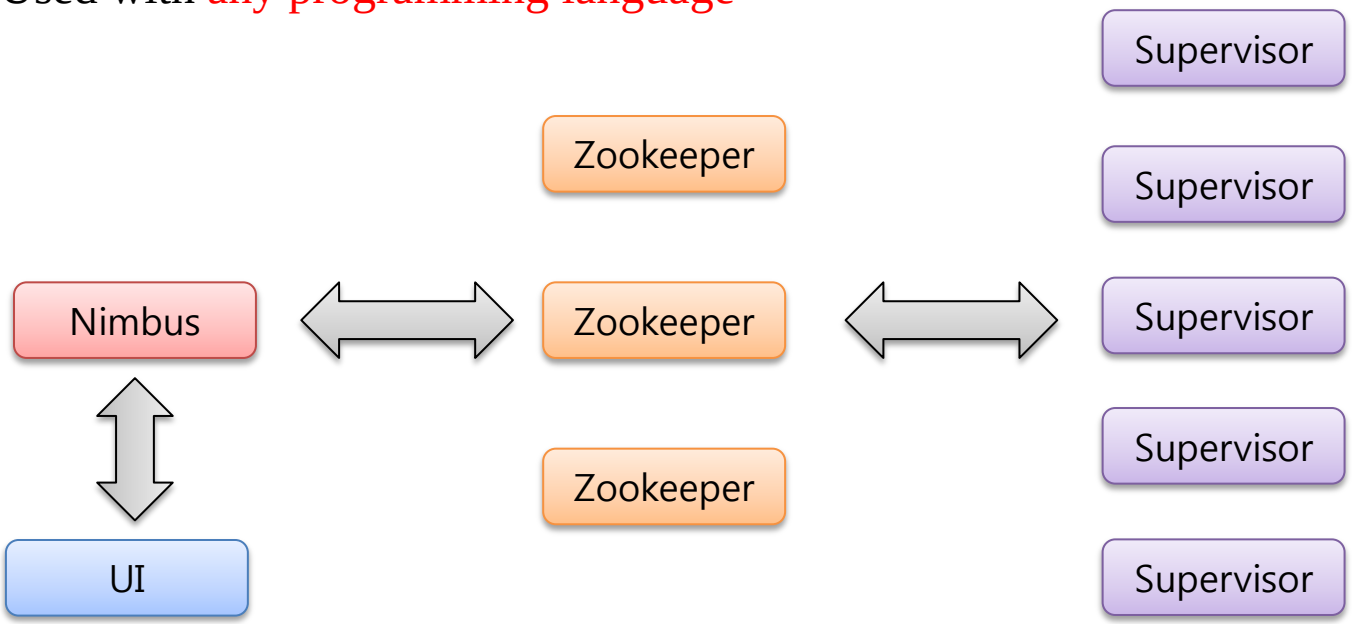


Describing a stream annotation work flow using the Stream Annotation Ontology (SAO)

Stream Processing with Storm

What is Storm?

- Free and open source distributed real-time computation system
- Easy and simple to reliably process unbounded streams of data
- Real-time processing, while Hadoop batch processing
- Used with any programming language



< Storm Architecture >

Storm

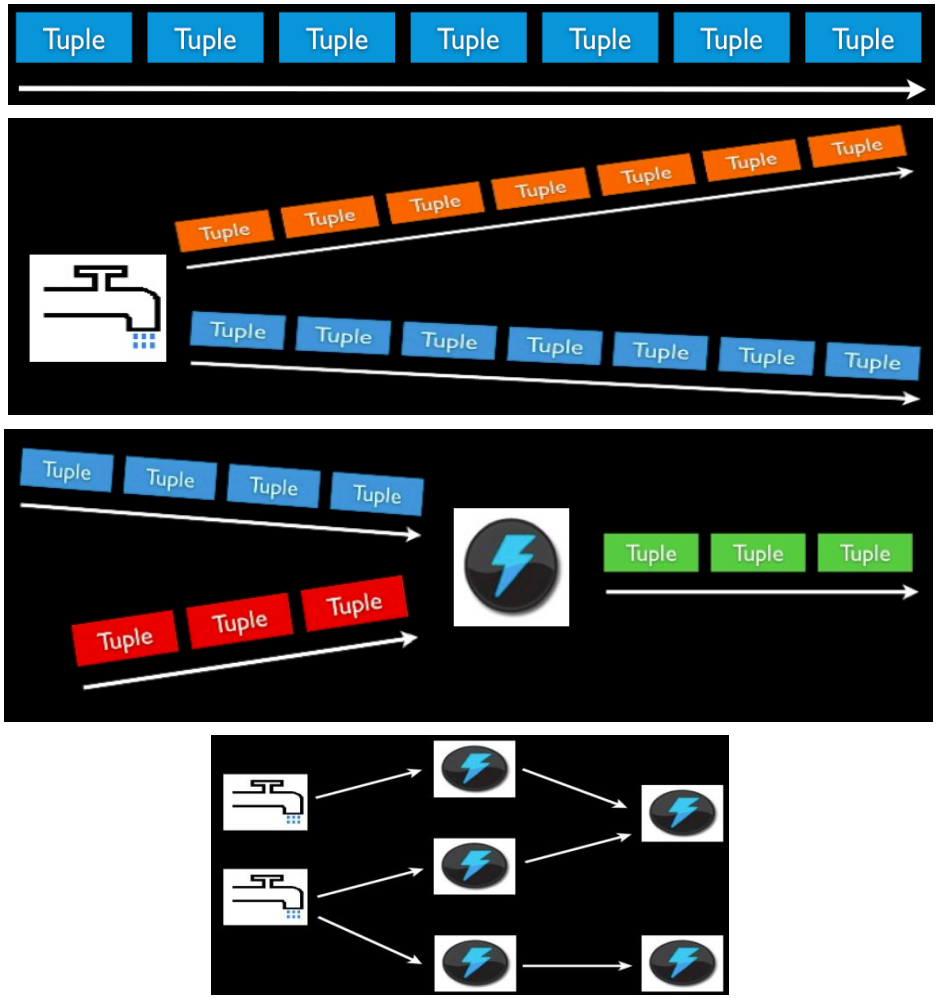
Concepts

- Streams
  - Unbounded sequence of tuples

- Spout
  - Source of Stream
  - E.g. Read from Twitter streaming API

- Bolts
  - Processes input streams and produces new streams
  - E.g. Functions, Filters, Aggregation, Joins

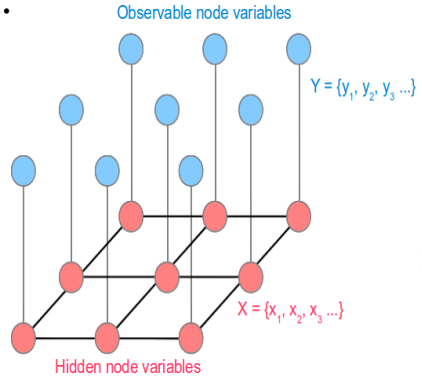
- Topologies
  - Network of spouts and bolts

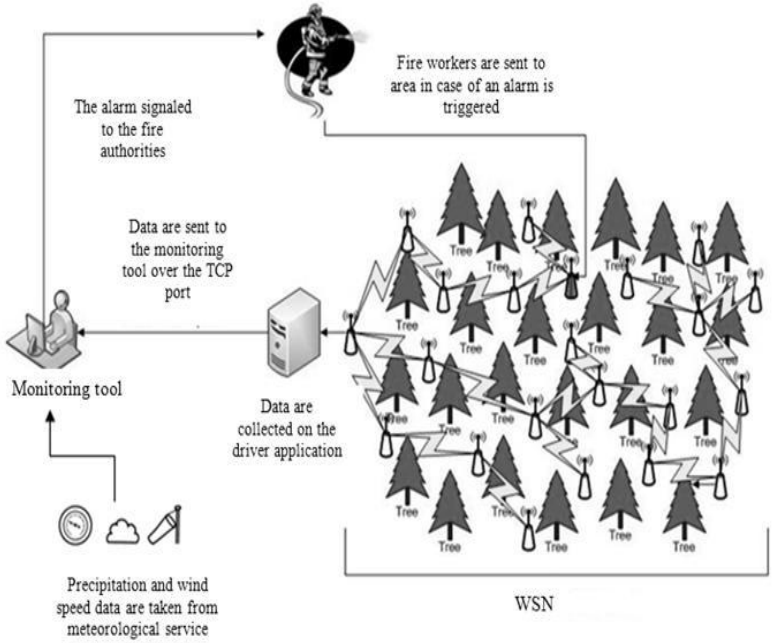


Case study: MRF for Environmental Monitoring

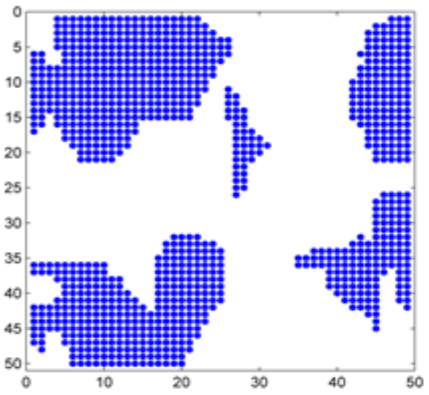
- Noise is induced to data observation:
  - Harsh environment
  - Sensor uncertainty
  - Transmission jitter…

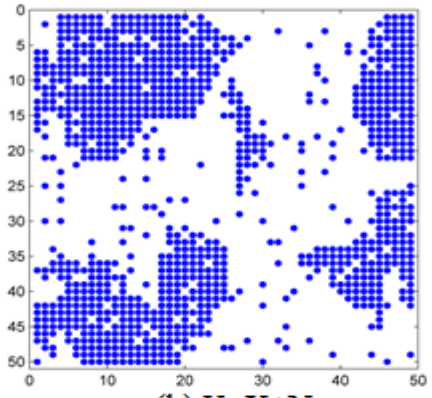
$$Y_s = X_s + N_s, \; for \; all \; s \in S$$

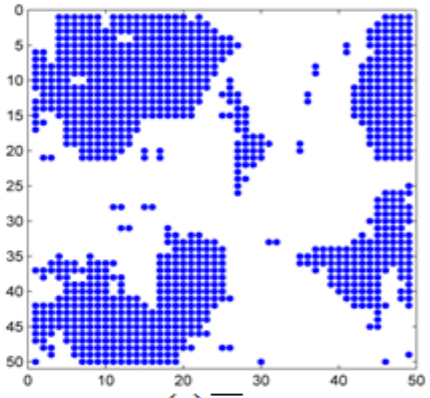




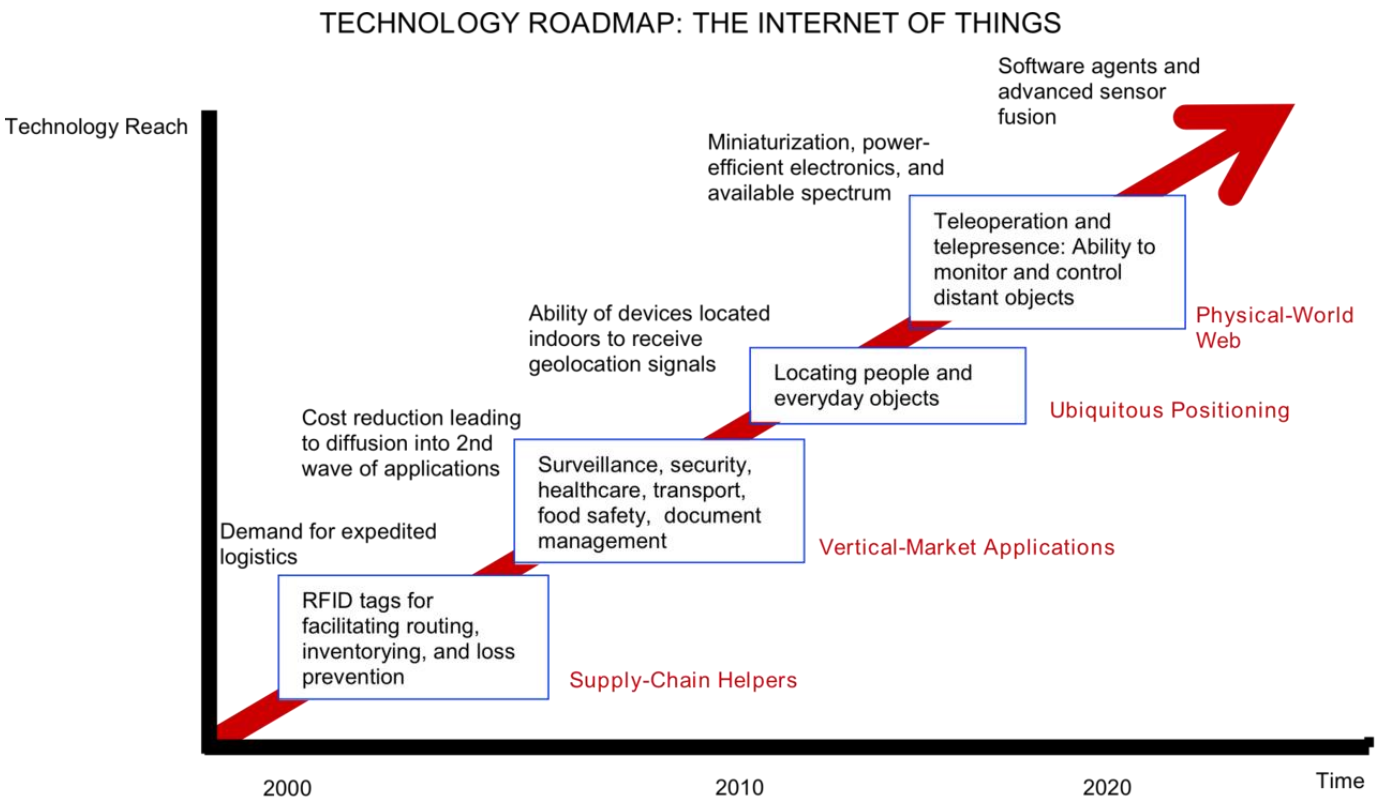
- Markov random fields (MRF)
  - Analyze spatial & contextual dependencies of physical phenomena
  - Restore data from noised data


(a) X


(b) Y=X+N


(c) $\overline{X}$

Conclusion



Source: SRI Consulting Business Intelligence