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IEEE Internet of Things

M2M Communications and Internet of Things as pillars of Smart City Initiatives

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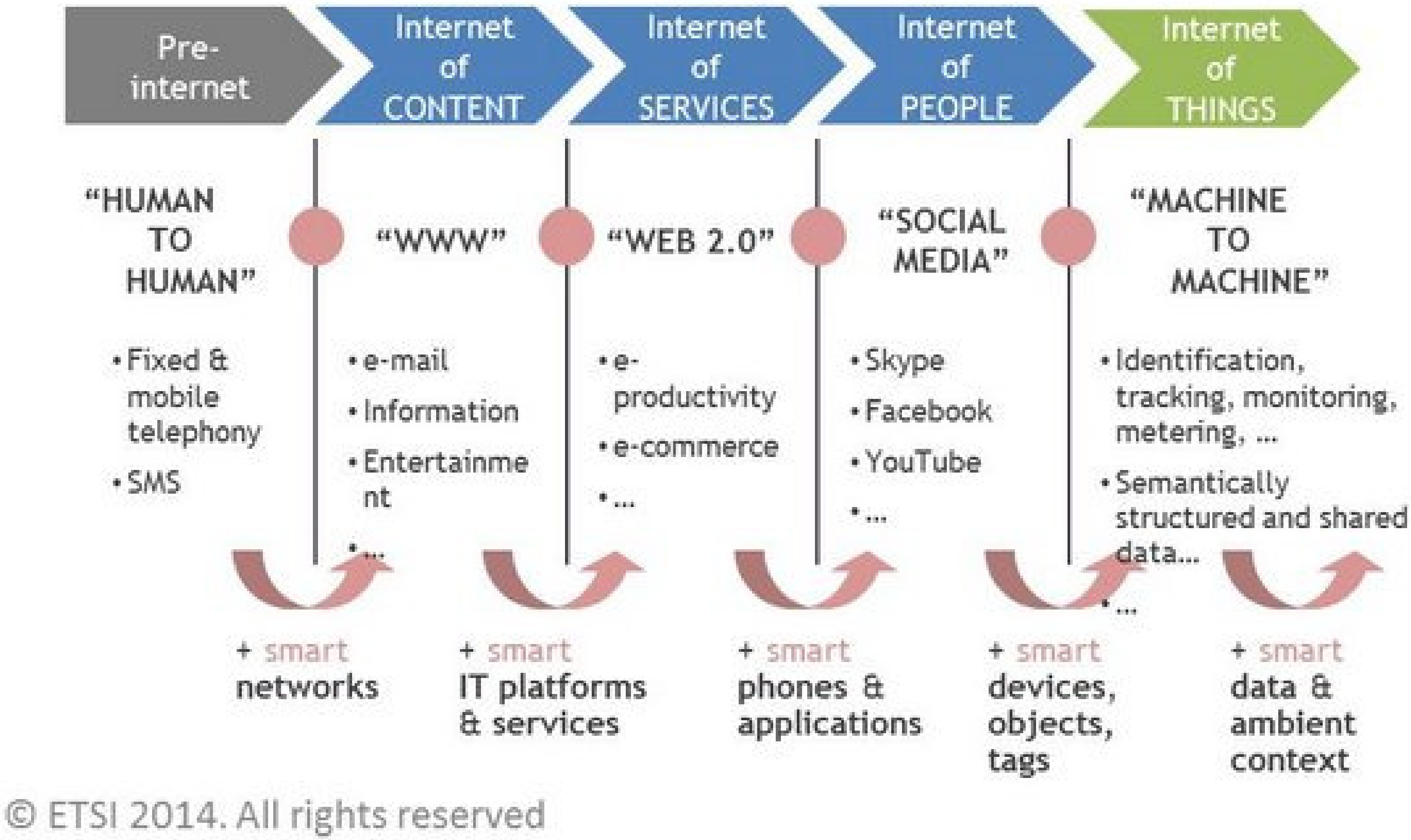
Roadmap

- **First Part**
  - M2M communications & Internet of Things
- **Second Part**
  - Smart City
- **Discussion with Audience**

Roadmap

- **Introduction**
  - Evolution of Internet
  - Internet of Things
  - Machine to Machine communication
  - Smart city initiatives
- **Three Fundamental Operations**
- **Uniform Data Exchange & Management of Connected Things**
- **Communication Network for IoT**
- **M2M Data Processing for Smart City Applications**
- **IoT Architecture**
- **Standards in IoT**

Evolution of Internet



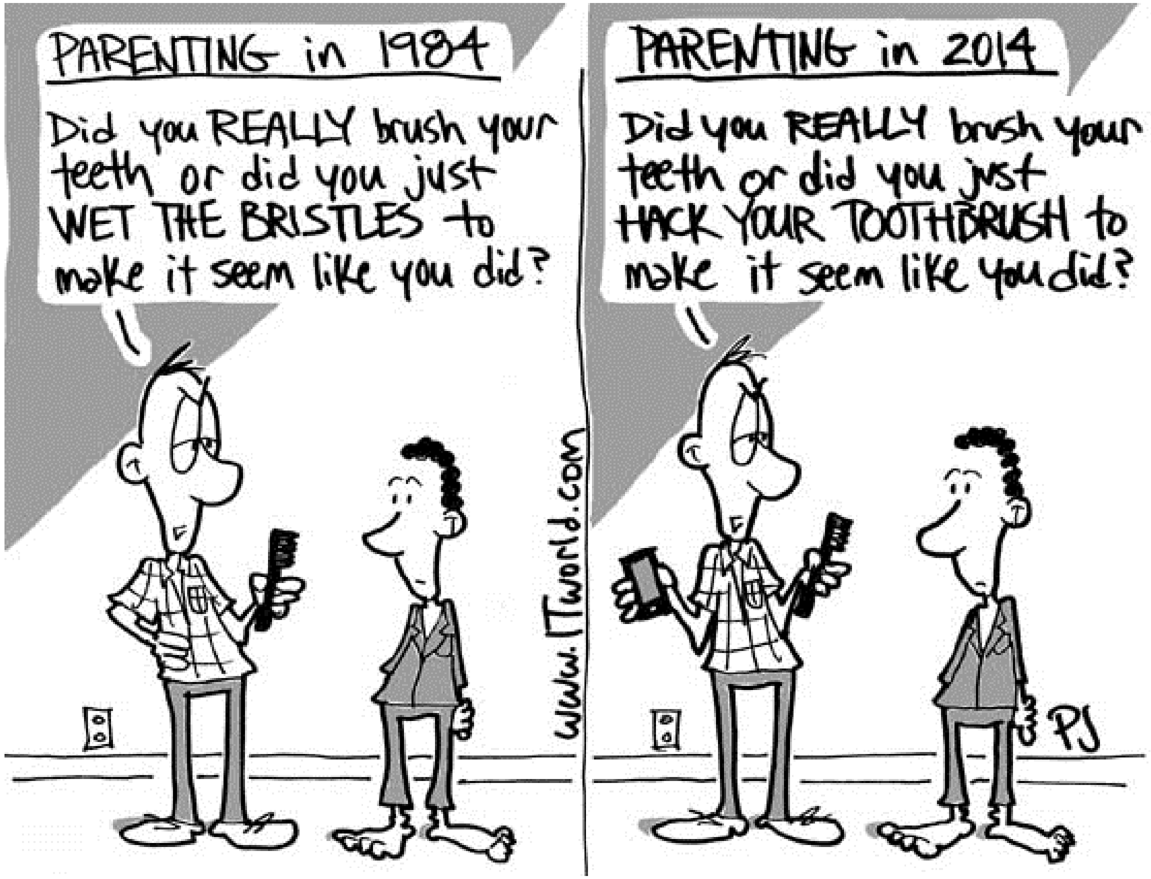
Connecting Things (1/3)

Traditional

Connected

Source: Roberto Minerva, “From M2M to Virtual Continuum”, ICCE 2015, Las Vegas

Connecting Things (2/3)



Source: http://www.itworld.com/

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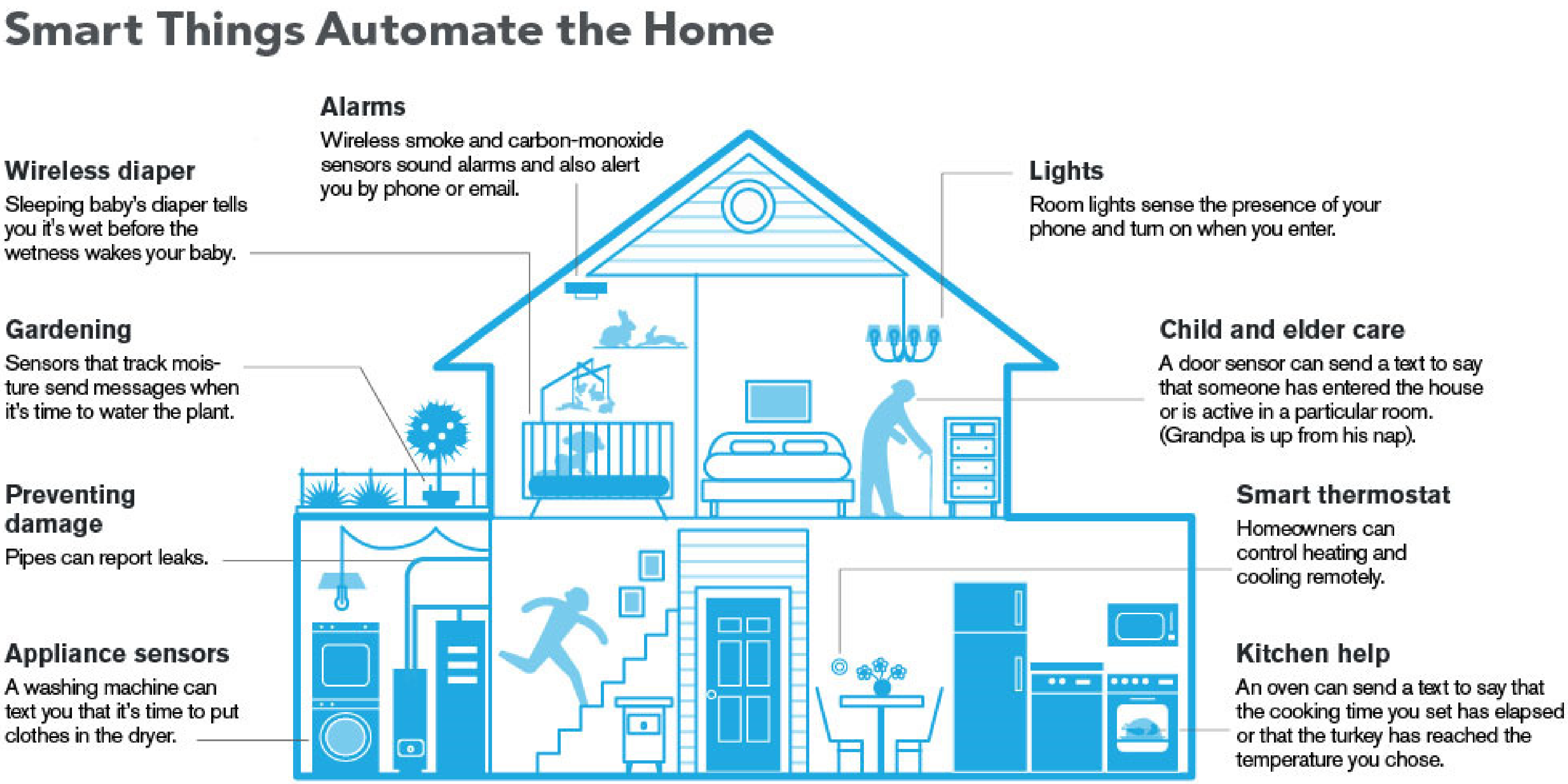
Connecting Things (3/3)



Source: market-intel.info

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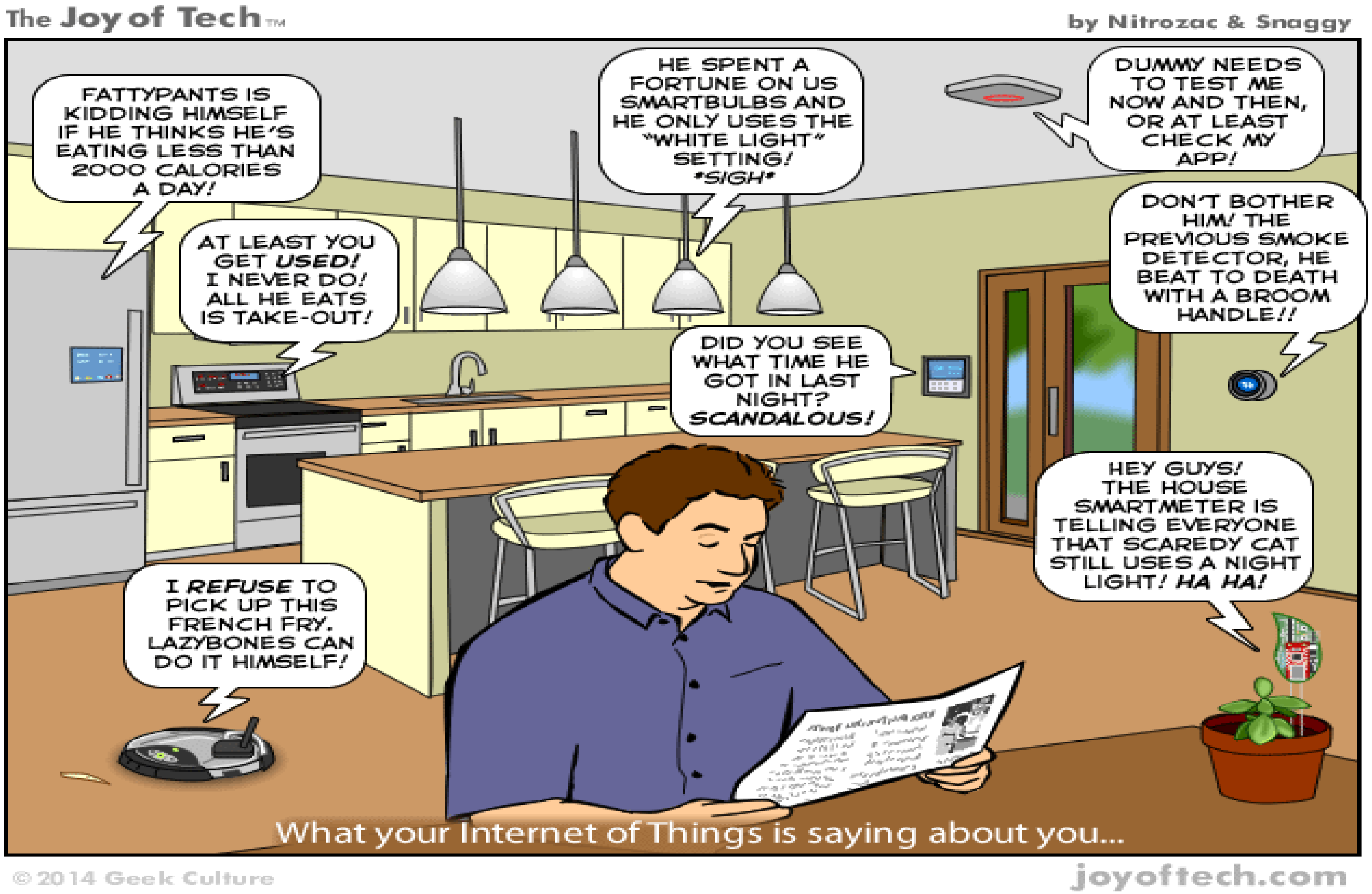
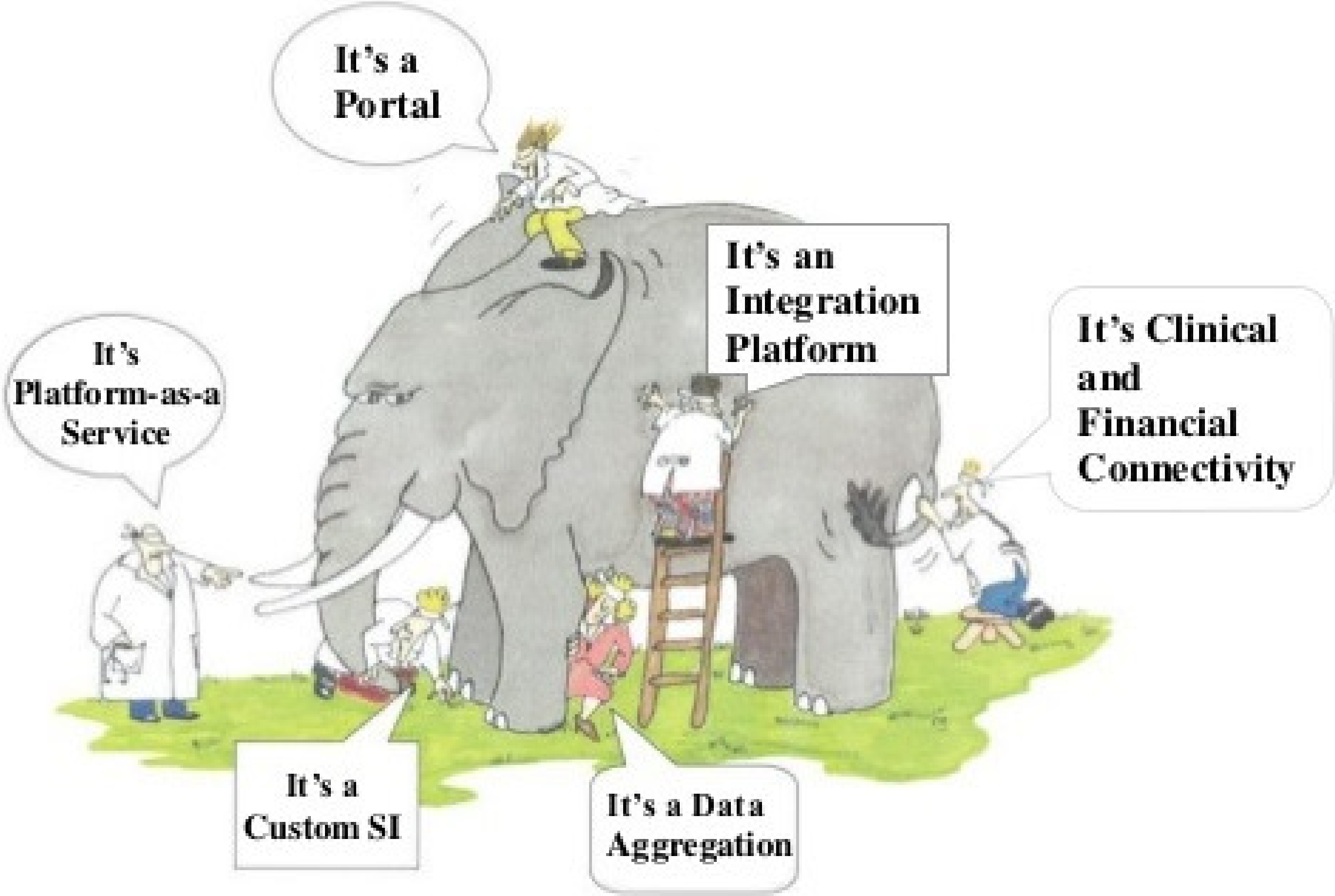
Sometime Soon …



What is IoT?



Source: IDC Health Insights

M2M/IoT Definitions

IoT

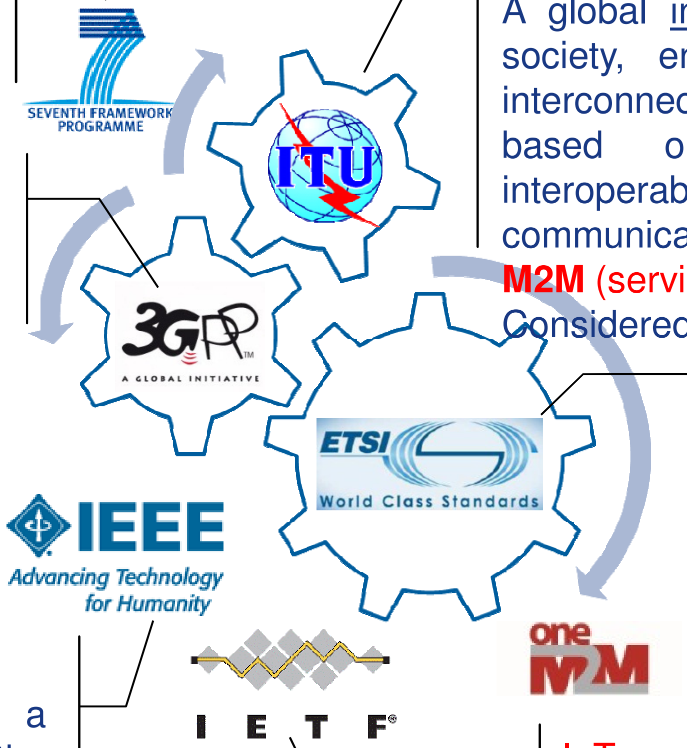
A global <u>network infrastructure</u>, linking physical and virtual objects through the exploitation of data capture and communication capabilities
[EU FP7 CASAGRAS]

MTC

A form of <u>data communication</u> which involves one or more entities that do not necessarily need human interaction

M2M

<u>Information exchange</u> between a Subscriber station and a Server in the core network (through a base station) or between Subscriber station, which may be carried out without any human interaction [IEEE 802.16p]



IoT

A global <u>infrastructure</u> for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies [ITU-T Y.2060]

M2M (service layer)

Considered as a key enabler for IoT

M2M

<u>Communication</u> between two or more entities that do not necessarily need any direct human intervention

IoT

a <u>world-wide network</u> of interconnected objects uniquely addressable, based on standard communication protocols
[draft-lee-iot-problem-statement-05.txt]

Contribute Your IoT Definition

Define IoT

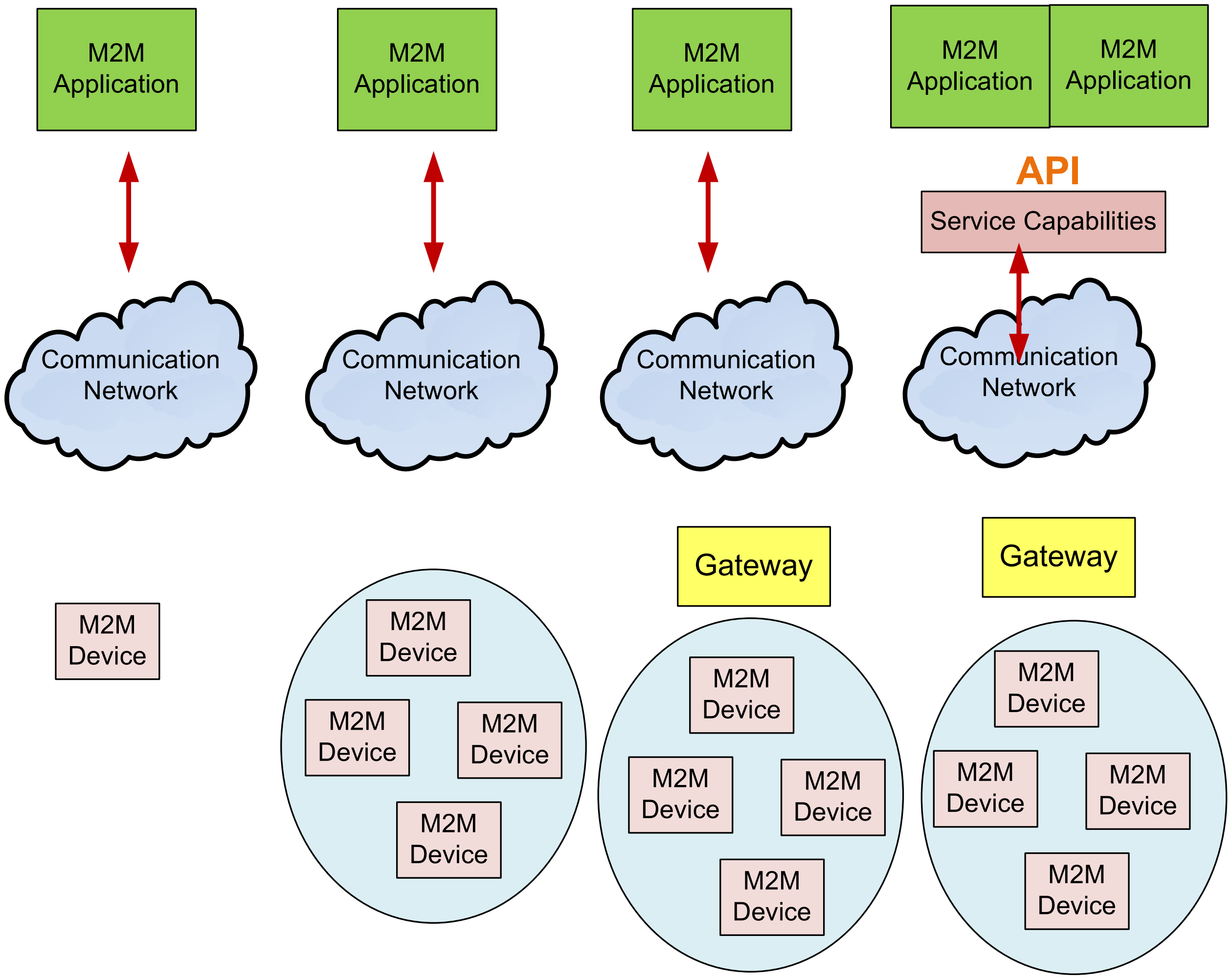
Towards a Definition of the Internet of Things (IoT)

Source: IEEE IoT initiative, http://iot.ieee.org/definition.html

M2M Communications

- **On a very simple terms**
  - Data communication among the physical things which do not need human interaction.
- **Examples:**
  - Data communication between things and a server.
  - Thing to thing communication either directly or over a network.

M2M Models



Source: ETSI

IoT ecosystem

- **To achieve the IoT ecosystem**
  - Things need to be connected to **software**
  - Things need to be made available to be used together as a **system**

- **M2M architecture and protocols address the first item**
- **Second item is a challenge**

Smart City

- **Brief Introduction**
- **More discussion later**

Smart City - Motivation

- Urban population is expected to grow by an estimated 2.3 billion in the next 40 years, having almost 70% of the world population living in cities by 2050.
- This poses diverse challenges
  - public safety, transportation management, waste disposal, noise, air and water pollution and more
- Smart City – a promising solution
  - To provide advanced services to the citizens
  - Enabled by Information and Communication Technologies (ICT).
  - Drives competitiveness, sustainability and improves quality of life.
- IEEE Smart City Initiative [1]

[1] http://smartcities.ieee.org/

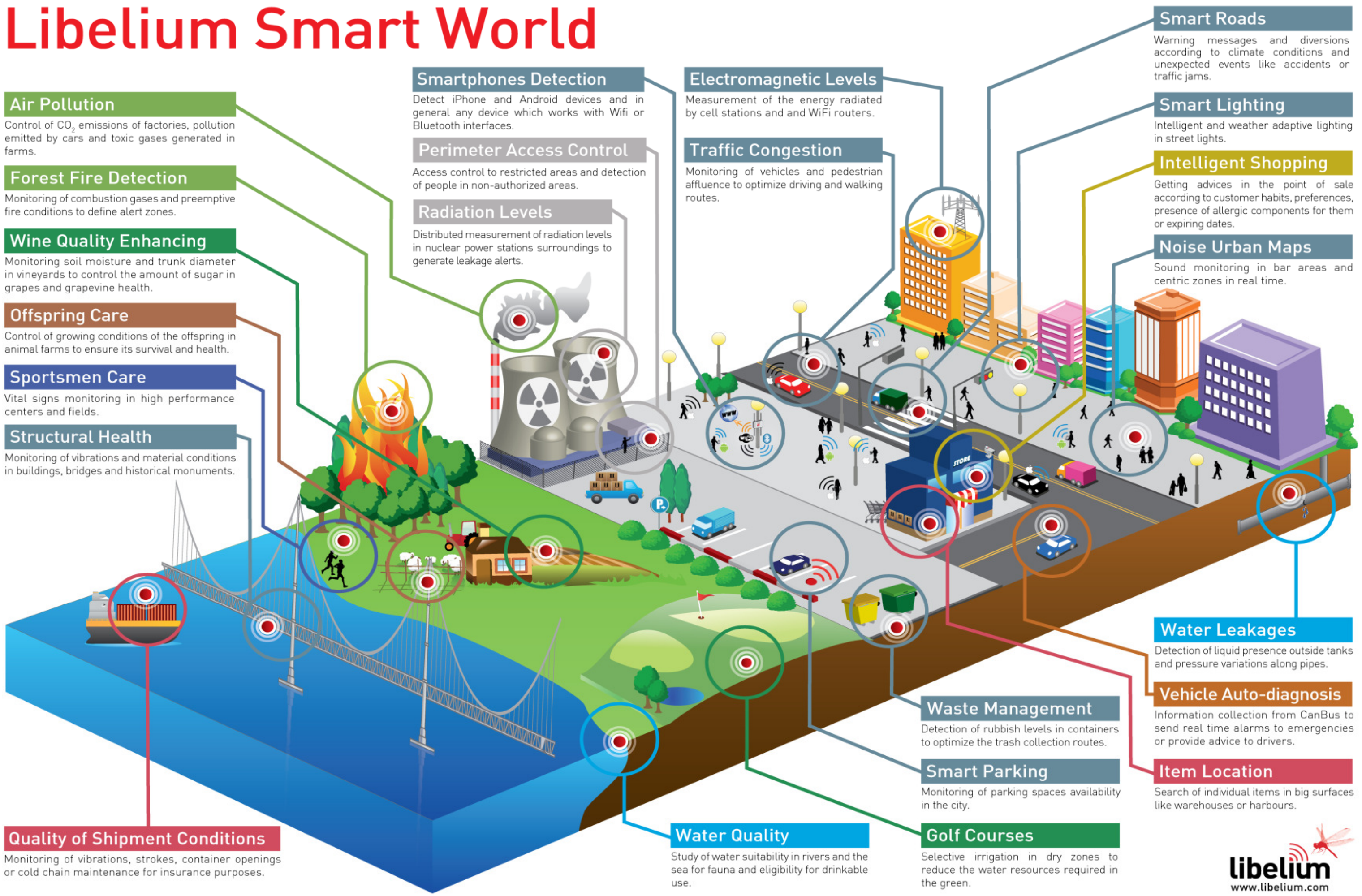
Smart City

- Smart city mainly focuses on applying the next-generation information technology to all walks of life, embedding sensors and actuators to [2]
  - Smart homes
  - Heath-care centres
  - Smart power grids
  - Roads & transportation systems
  - Water systems
  - Oil and gas pipelines
- Internet of Things (IoT) and Machine-to-Machine (M2M) communication are the essences to achieve that.
- IBM Smarter Planet Initiative [3]

[2] Yongmin Zhang, Interpretation of Smart Planet and Smart City [J]. CHINA INFORMATION TIMES, 2010(10):38-41.

[3] http://www.ibm.com/smarterplanet/us/en/?ca=v_smarterplanet

Libelium Smart World Infographic



Source: http://www.libelium.com/libelium-smart-world-infographic-smart-cities-internet-of-things/

Roadmap

- Introduction
- Three Fundamental Operations
- Uniform Data Exchange & Management of Connected Things
- Communication Network for IoT
- Discovery
- M2M Data Processing for Smart City Applications
- IoT Architecture
- Standards in IoT

Three Fundamental Operations

- **Collection of data**
  - Sensor based collection
- **Processing the data**
  - Semantic reasoning
  - Machine learning
- **Control**
  - Through actuation
  - E.g. automatically switching on fog lamp in a vehicle when fog is detected

Wait, it is not so simple

- **Heterogeneity**
  - Sensors belong to different domains
  - Sensors use various technologies to communicate
  - What about actuators?
- **Management of connected objects**
  - Concerns due to high mobility
  - Naming and addressing billions of objects
  - Discovery of objects
- **Choice of communication network**
- **Processing**
  - Utilizing semantic web technologies
  - Cloud platform?
  - Why not do it in an M2M gateway (Fog platform)?
- **Standardization efforts**
  - Efforts by oneM2M
  - EURECOM contribution to oneM2M MAS (WG5), W3C WoT Interest Group

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Uniform Data Exchange with Things

- **Requirement from a smart city perspective**
  - Heterogeneous and multimodal things
  - Can not have one API per thing to exchange data
    - Need a uniform data exchange mechanism
  - Sensor measurement alone has no value
    - Need additional side information like unit, timestamp, type of sensor

Sensor Markup Language (SenML)

- **Uniform way to exchange sensor “metadata”.**
- **Represents simple sensor measurements and device parameters.**
  - Sensor measurement, name, id, unit, timestamp etc.
- **Implementation using JSON/CBOR/XML/EXI.**
- **Server can parse several SenML metadata at the same time.**

Source: Media Types for Sensor Markup Language (SENML) draft-jennings-core-senml-02
https://tools.ietf.org/pdf/draft-jennings-core-senml-02.pdf

SenML Extensions for Actuators

- **No markup language for actuators**
  - Extend capabilities of SenML for actuators
  - Uniform way to exchange actuator “metadata” [4]
- **Used to send commands to actuators**
  - Switch on/off a light, reduce the speed of motor etc.
- **Advantage**
  - **Uniform mechanism to interact with both sensors and actuators.**

[4] Datta, S.K.; Bonnet, C.; Nikaein, N., "CCT: Connect and Control Things: A novel mobile application to manage M2M devices and endpoints," *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2014 IEEE Ninth International Conference on*, pp.1,6, 21-24 April 2014

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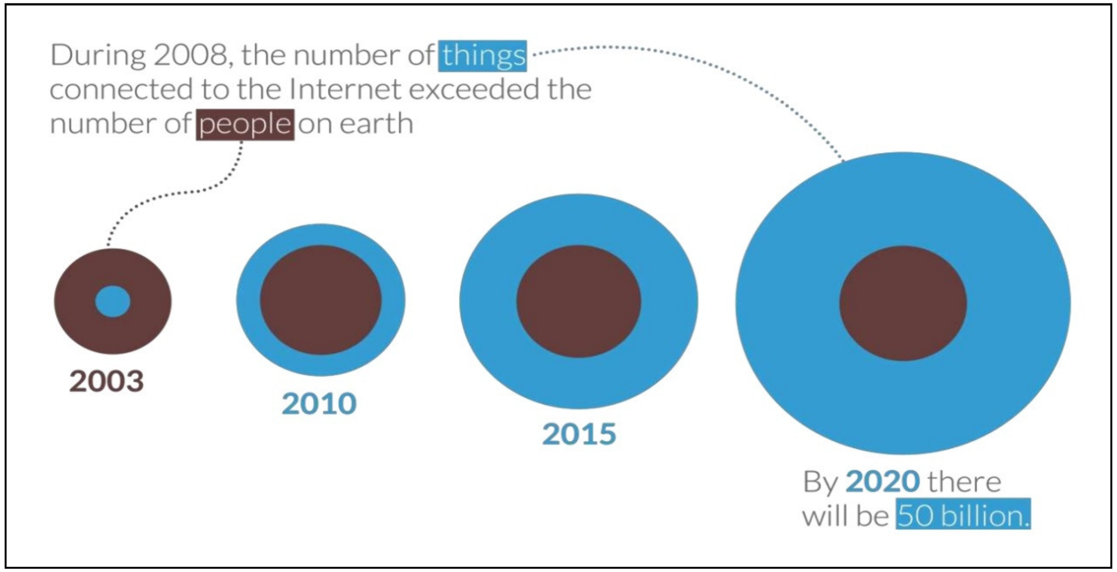
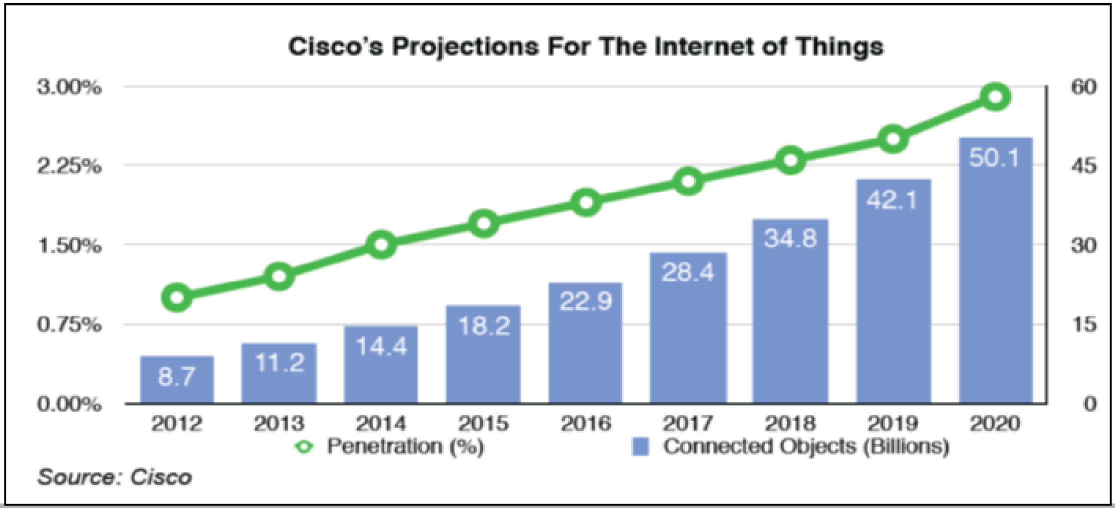
50 Billion Connected Objects





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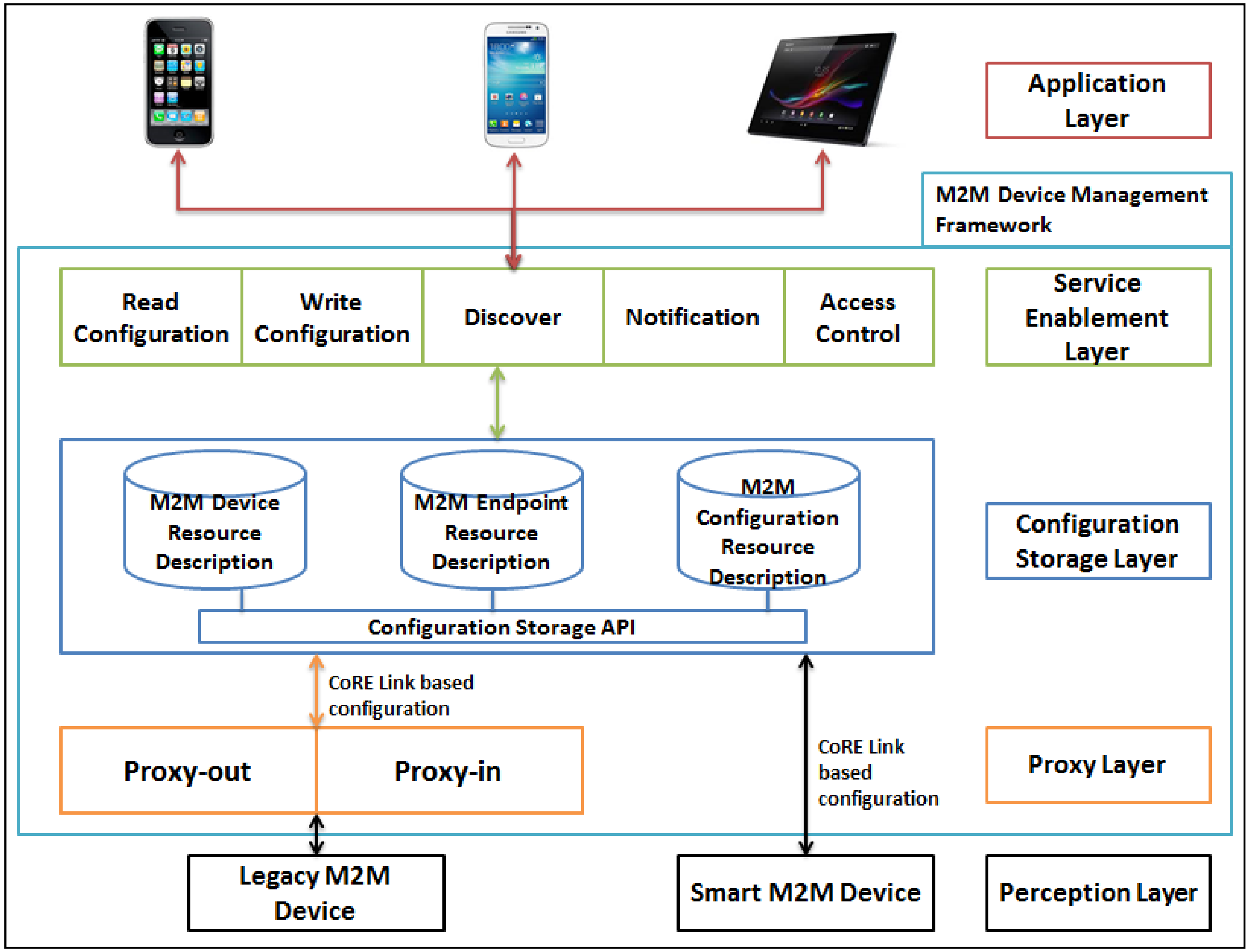
Managing Connected Objects

- **Objective: Ensuring flexibility, scalability and dynamicity**
- **Already developed solutions**
  - Representation of objects for efficient management [5]
    - Both smart and legacy ones
  - Framework for connected object management
  - OMA LwM2M Technical Specifications based API

[5] Datta, Soumya Kanti; Bonnet, Christian, "Smart M2M Gateway Based Architecture for M2M Device and Endpoint Management," IEEE International Conference on Internet of Things 2014, Taipei, Taiwan, 1-3 September 2014.

Connected Object Management Framework



Source: Datta, S.K.; Bonnet, C., "A lightweight framework for efficient M2M device management in oneM2M architecture," in Recent Advances in Internet of Things (RIoT), 2015 International Conference on, pp.1-6, 7-9 April 2015.

Description of Layers

- **Layers and their functionalities are implemented as RESTful web services.**
- **Perception layer**
  - Contains the real M2M devices containing sensors, actuators or RFID tags as endpoints.
- **Proxy Layer –**
  - Unique & novel aspect of the framework to allow management of legacy M2M devices
  - Current standardization efforts do not consider such scenarios but inclusion of legacy devices into IoT ecosystems is crucial.
  - The proxy layer is composed of two RESTful web services – proxy-in and proxy-out to manage sensors and actuators respectively.
  - The proxy layer creates the CoRE Link based configurations and is responsible for registering and un-registering legacy devices.
  - The proxies are dependent on the communication protocol used by the legacy devices.

Description of Layers

- **Configuration Storage Layer**
  - Contains “Configuration Storage API”.
  - The smart devices directly connect to this API during the bootstrap phase
  - It extracts the resource descriptions from the devices or (proxies in case of legacy devices).
  - The layer houses a database and stores the device, endpoint and configuration resources in separate tables.
  - The API translates the CoRE Link based descriptions to appropriate storage format. This layer also keeps track of the configuration “lifetime” attribute.
  - During that period, if it does not receive an announcement that the device is still present or configuration update, it will delete that device configuration.

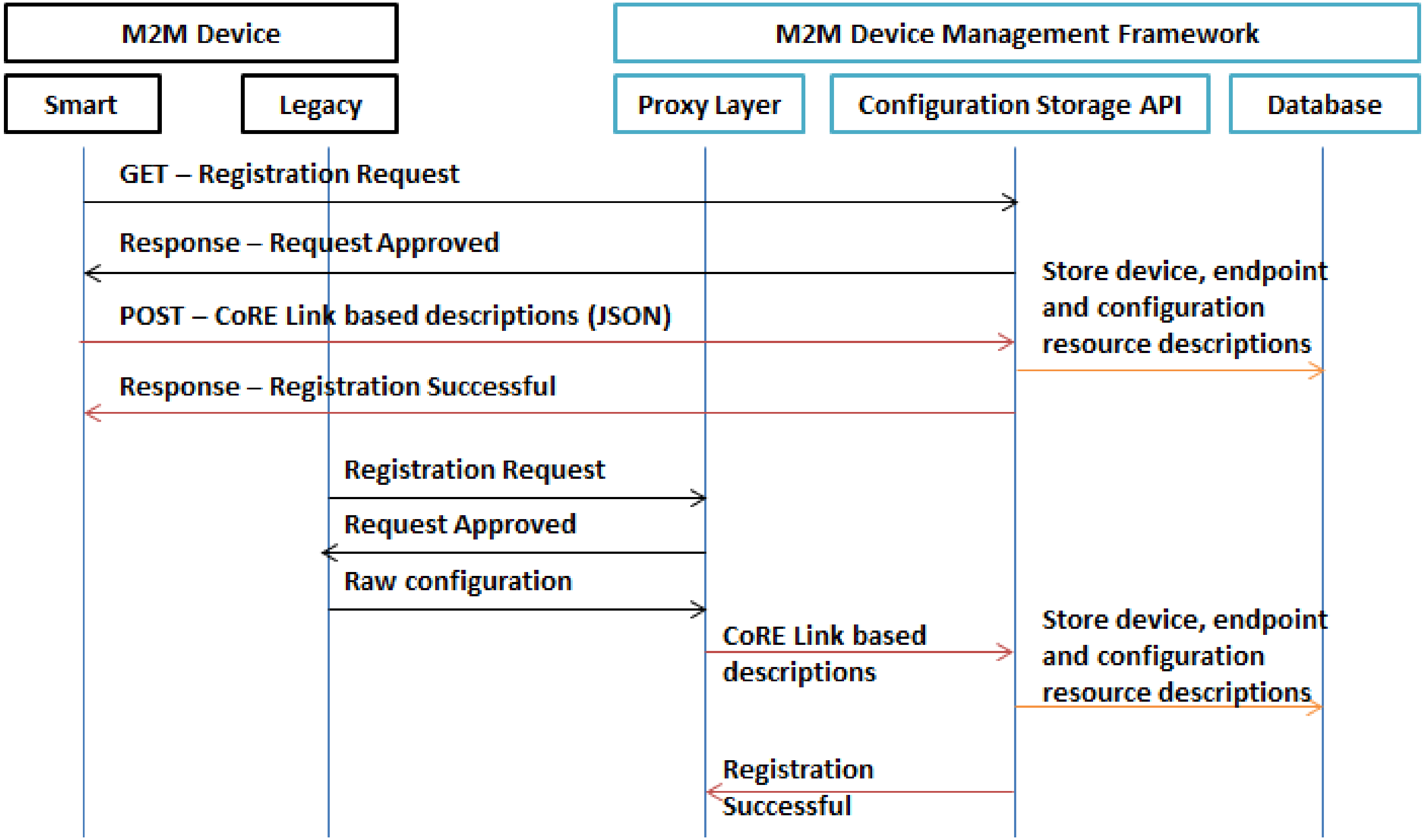
Description of Layers

- **Service Enablement Layer –**
  - Allows the end users to
    - Read, write & update configurations
    - Enable device discovery
    - Receive notification
    - Implement proper access control.
  - These capabilities correspond to OMA LwM2M Technical Specifications
  - Allow remote management of M2M devices from mobile devices of end users.

Different Phases of Operation

- **Bootstrap phase**
  - Perform necessary provisioning
- **Client registration phase**
  - Registration of objects to the framework
- **Service enablement phase**
  - Enables M2M device management
  - Allows end users to discover configurations
  - Configuration(s) update
- **Information reporting phase**
  - Enable observe, notify functions for selected M2M devices

Registration Phase

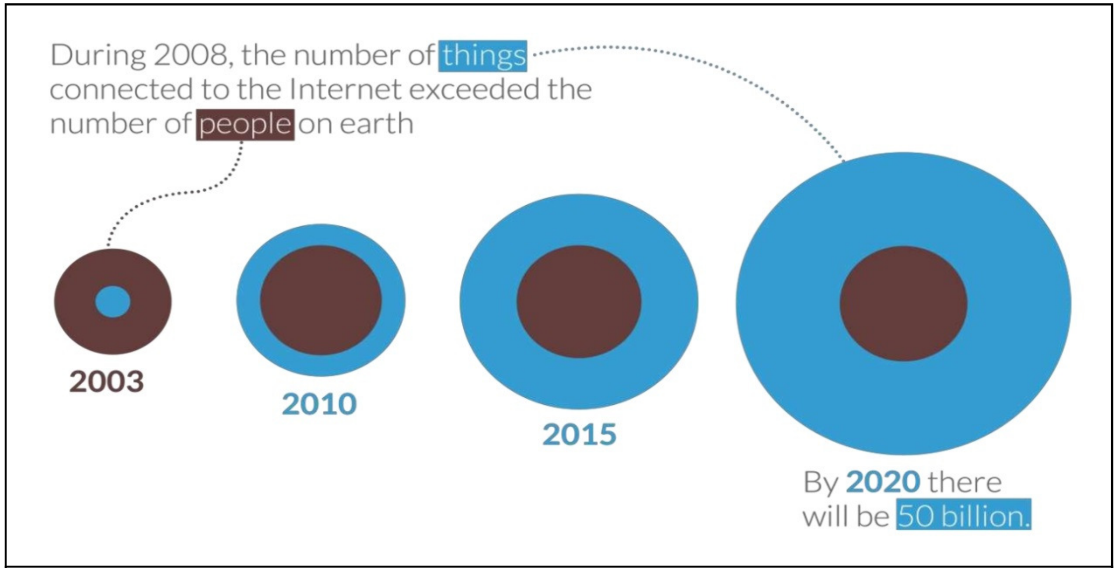


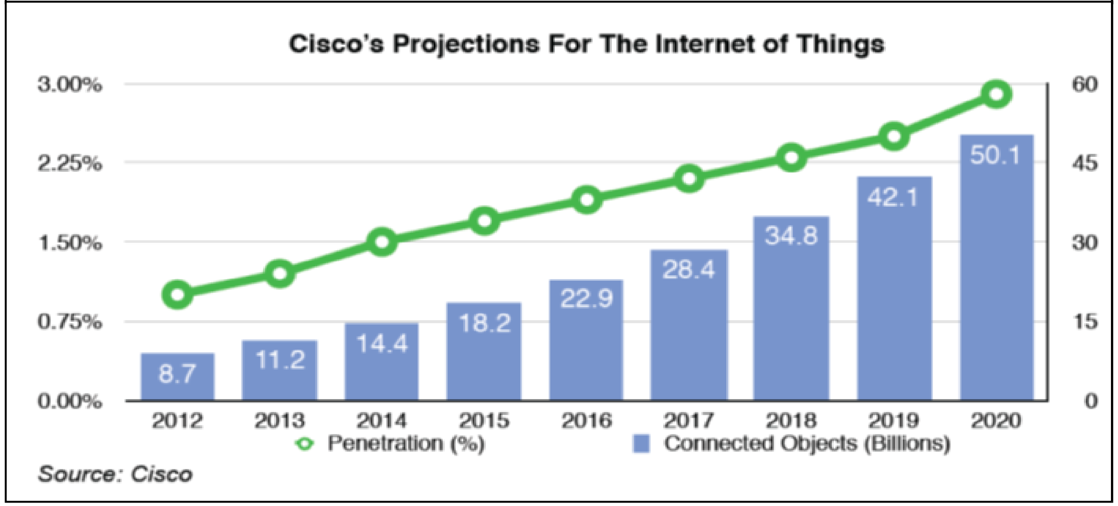
- **Questions???**

Roadmap

- **Introduction**
- **Three Fundamental Operations**
- **Uniform Data Exchange & Management of Connected Things**
- **Communication network for IoT**
  - Bluetooth Low Energy (BLE)
  - Low Power Wireless Personal Area Network (LoWPAN)
  - Low Power Wide Area Network (LPWAN)
  - Cellular technologies
  - Fog Networking
- **Discovery**
- **M2M Data Processing for Smart City Applications**
- **IoT Architecture**
- **Standards in IoT**

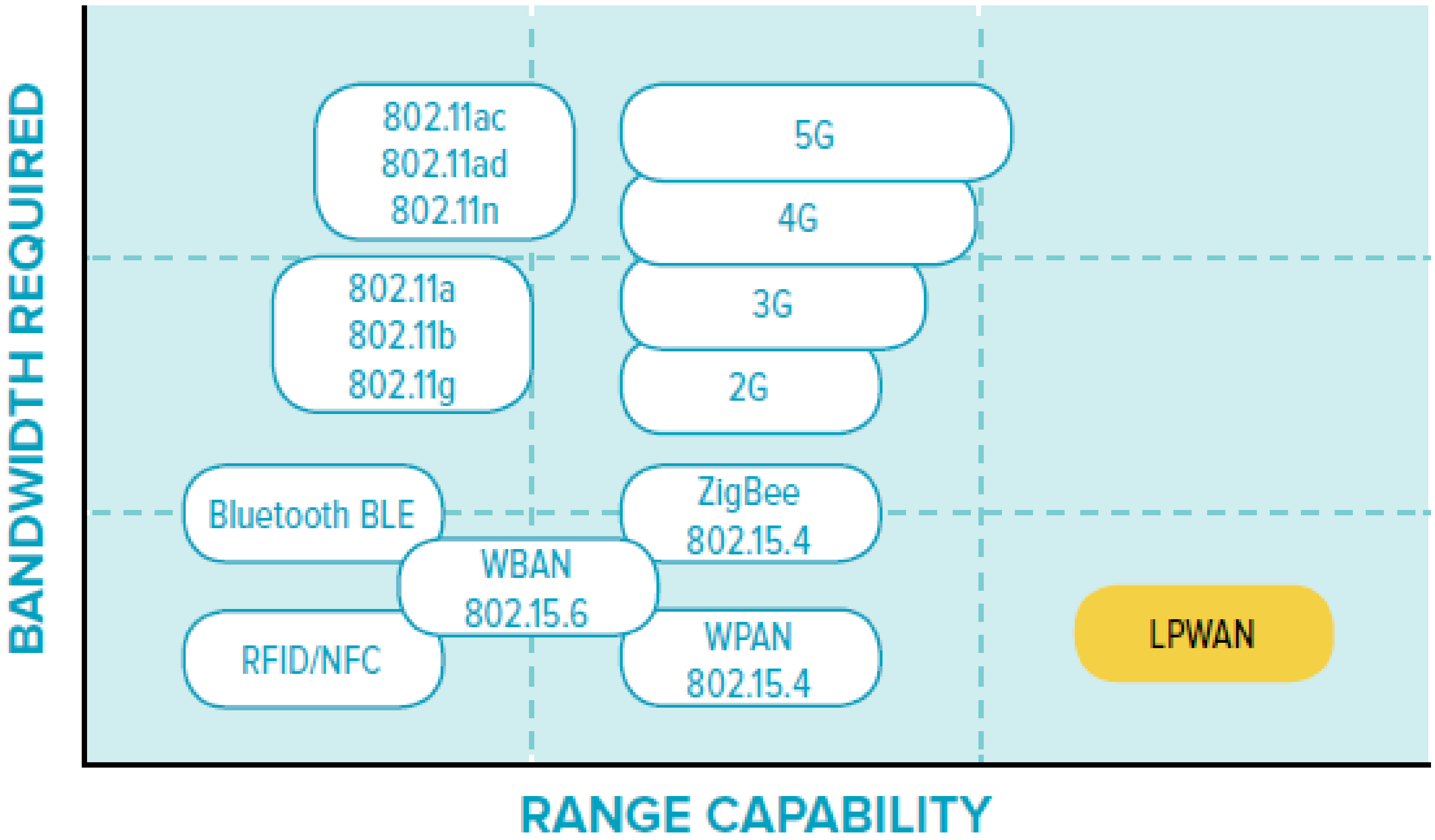
When Connection Matters …





Bandwidth vs Range

SOURCE: PETER R. EGLI 2015 http://www.slideshare.net/PeterREgli/lpwan

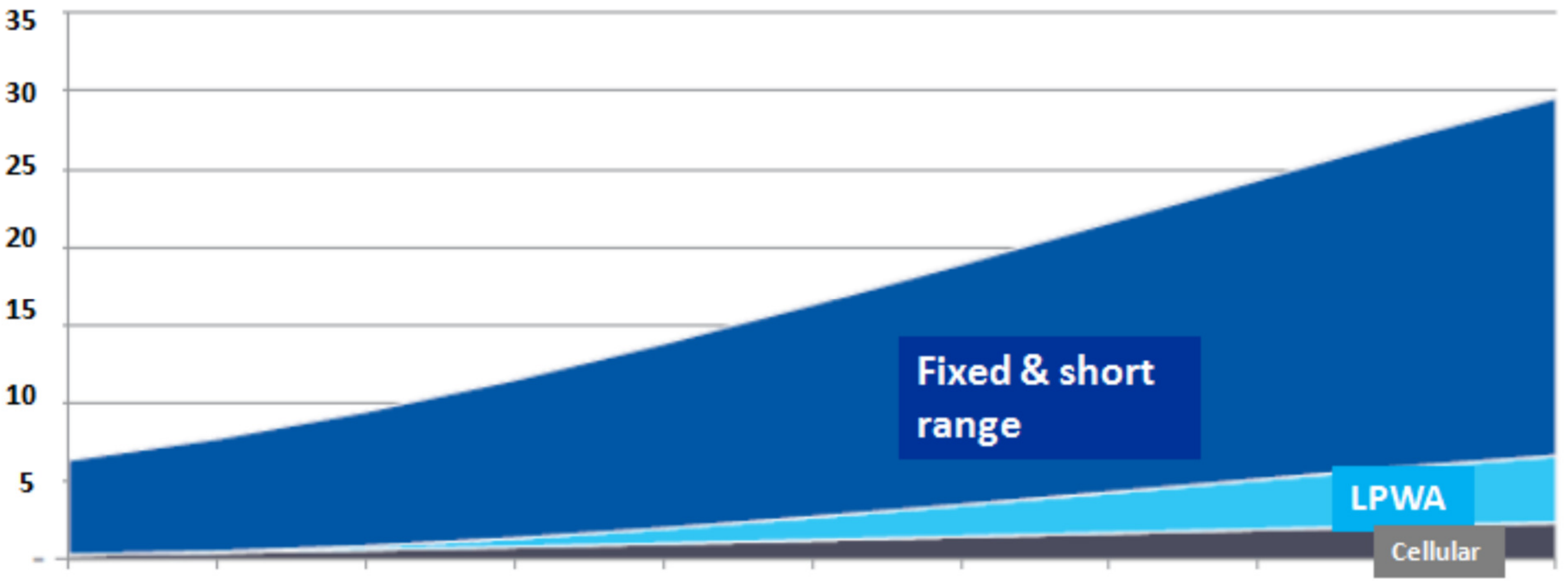


Where Does the Technologies Fit?

	Local Area Network Short Range Communication	Low Power Wide Area (LPWAN) Internet of Things	Cellular Network Traditional M2M
(market share)	40%	45%	15%
(pros)	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
(cons)	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.0, ZigBee, WiFi	LoRa	GSM, 3G+ / H+, 4G

Wireless Technologies for IoT

- forecast breakdown for various wireless technologies for use within IoT over the next decade

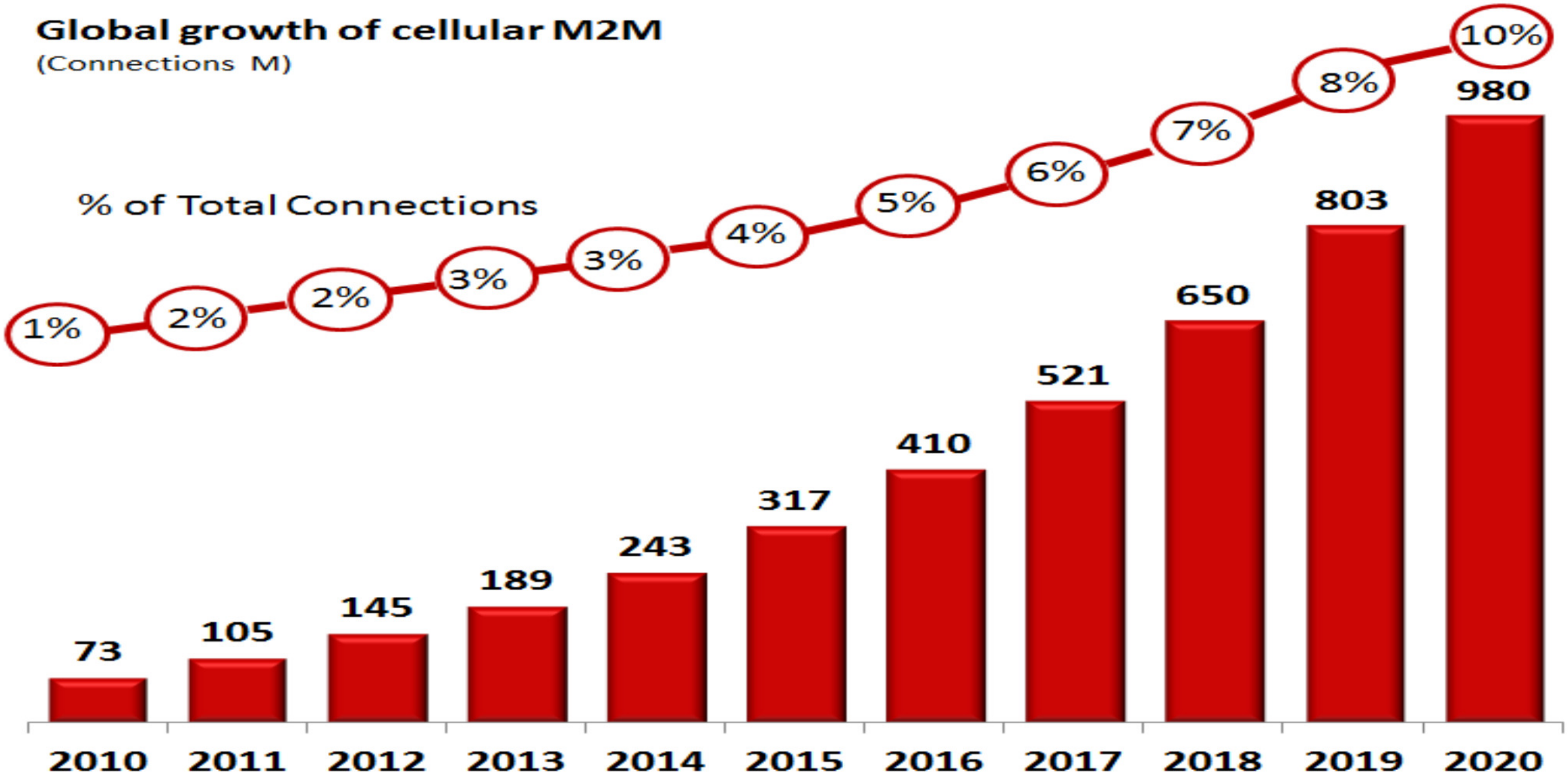


Billion global connections, 2015-2025

Source: Billion Global Connections, Machina Research, May 2015

GSMA Global Mobile Economy report

- GSMA's recently published Global Mobile Economy report provides a view of the growth of cellular IoT connections until 2020.



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BLE is Powering IoT

- **BLE or Bluetooth Smart (Version 4.0+)**
  - Power and application friendly version of Bluetooth
  - Initially proposed in 2010 (V 4.0)
  - Latest specifications came in 2014 (V 4.2)
  - Specifically built to power constrained devices used in IoT
- **Key Features**
  - Version 4.2 supports IPv6
  - Very low duty cycle achieves an overall low power consumption
  - Provides multi-vendor interoperability
  - Security with 128-bit AES encryption

BLE enabled IoT

- **Devices**
  - Wearable devices
    - Fitness bands
    - Smart watches
    - Heart rate monitors
  - Sensors
    - Proximity sensors
  - Gesture-based controlling devices
    - Fin
- **Applications**
  - **UriBeacon** (formerly known as Physical Web, from Google)
    - Novel protocol to discover things around “ME” (in a spatial sense)
    - Periodically transmits an URL to access the thing using BLE

LoWPAN

- **It is a low cost communication network enabling wireless connectivity in applications with limiter power and relaxed power throughput requirements.**
- **Comprises of M2M devices conforming to IEEE 802.15.4-2003 standard.**
- **Key characteristics of IEEE 802.15.4 devices**
  - Designed for short range and low bit rate communication
  - Designed to be low power and low cost
  - Constrained in terms of computational power, memory and battery
  - Note: these devices tend to be unreliable
    - Unreliable radio connectivity, battery drain
    - Physical tampering

Source: RFC 4919

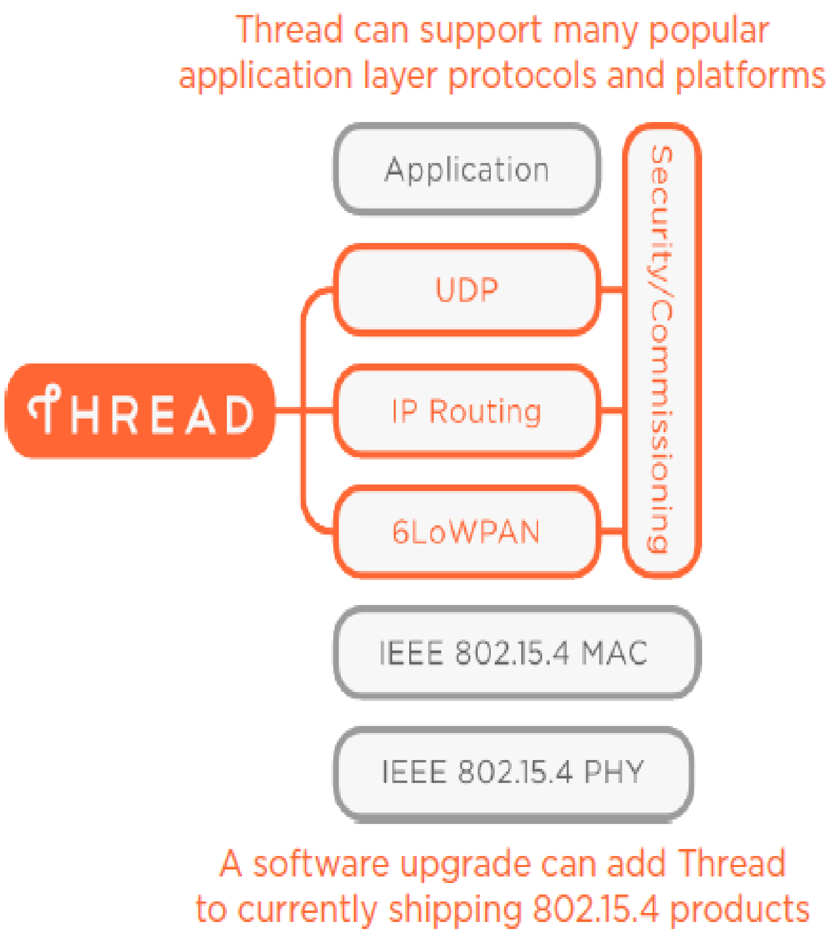
6LoWPAN

- **IETF defined a system to adapt IPv6 and higher level protocols to small devices.**
- **Originated from the idea that**
  - IP should be applied to low power and constrained (M2M) devices which are essential building blocks for IoT.
- **Advantages of IP technology**
  - Existing and well-known technology
  - Open specifications
  - Pervasive nature
  - IP enabled devices can readily connect among each other

Source: RFC 4919

Thread

- **IPv6 based free protocol running over 6LoWPAN**
  - Uses IEEE 802.15.4 with mesh communication
- **Provides cloud access and AES encryption**
- **Intended for communication of smart home devices over a network**
- **Supports 250 devices per network**
- **Thread group includes**
  - Nest (Google), Samsung, ARM, Freescale Semiconductor, Silicon Labs



Source: http://threadgroup.org/portals/0/documents/thread_introduction_website_7-15-14.pdf

Further Reading

- RFC 4944 - Transmission of IPv6 Packets over IEEE 802.15.4 Networks
- RFC 6282 - Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks
- RFC 6775 - Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)

- **LWPAN → Low-Power Wide-Area Network**

LPWAN Enabled IoT use cases

- Utility meters
- Vending machines
- Automotive IoT
  - Fleet management
  - Smart traffic including real time traffic information to the vehicle
- Security monitoring and reporting

LPWAN IoT Requirements

- **Objective: support massive volume of M2M deployment**
- **Key requirements**
  - Long battery life – industry target 10 years of battery operation
  - Low device cost ~ $5
  - Low deployment cost – in terms of both software and hardware
  - Full coverage – things deployed to both indoor and outdoor environments
  - Scalability – support Billions of things

LPWAN Features

Source: LoRa Alliance

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Two Main Areas of Application

Fixed, Medium-High Density Connections

- Alternative to cellular M2M connections
- Deployment in smart cities
- Use cases
  - Street light control
  - GPS based asset tracking

Long Life, Battery Powered Applications

- When IoT scenarios demand longer range than legacy technologies.
- Use cases
  - Wide area water quality monitoring
  - Smart farming

Source: Link Labs white paper – A Comprehensive look at Low Power, Wide Area Networks

Candidate Technologies at a Glance …

	SIGFOX	LoRa	clean slate cIoT	NB LTE-M Rel. 13	LTE-M Rel. 12/13	EC-GSM Rel. 13	5G (targets)
Range (outdoor) MCL	<13km 160 dB	<11km 157 dB	<15km 164 dB	<15km 164 dB	<11km 156 dB	<15km 164 dB	<15km 164 dB
Spectrum Bandwidth	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Licensed 7-900MHz 200kHz or dedicated	Licensed 7-900MHz 200kHz or shared	Licensed 7-900MHz 1.4 MHz or shared	Licensed 8-900MHz 2.4 MHz or shared	Licensed 7-900MHz shared
Data rate	<100bps	<10 kbps	<50kbps	<150kbps	<1 Mbps	10kbps	<1 Mbps
Battery life	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years
Availability	Today	Today	2016	2016	2016	2016	beyond 2020

Source: Nokia Networks white paper, LTE-M – Optimizing LTE for the Internet of Things

Two Sub-Categories

- Proprietary **LPWAN technologies**
  - Ex: SigFox, LoRa.
  - Deployed in the license exempt bands.
- **Licensed Cellular IoT technologies (being standardized by 3GPP)**
  - **LTE-M**, an evolution of LTE optimized for IoT in 3GPP RAN.
  - **Extended Coverage GSM** (EC-GSM), an evolutionary GSM approach.
  - **Narrowband** (NB) radio interface (Clean Slate Cellular IoT), part of RAN Rel. 13 standardization, provides two solutions
    - NB Cellular IoT solution based on narrowband FDMA in the uplink and narrowband OFDMA in the downlink.
    - 200 kHz narrowband evolution of LTE-M (NB-LTE).

- **SIGFOX**

SIGFOX Features

- **Uses a patented radio technology based on Ultra Narrow-Band (UNB).**
  - The SIGFOX UNB radio communication uses the unlicensed ISM bands.
- **Up to 140 messages per thing per day.**
- **Payload size**
  - Uplink -12 bytes/message.
  - Downlink – 8 bytes/message.
- **Wireless throughput up to 100 bits/second.**
- **Message exchange**
  - For a thing to send messages using SIGFOX, it requires integrating a compatible and certified modem.
  - To receive the messages from the thing, it requires integrating with the SIGFOX servers.

SIGFOX – Some Drawbacks

- **Size of downlink message (8 Bytes) limits**
  - Scope of reconfiguring devices
  - Firmware upgrade
  - Provisioning
- **No link adaption mechanisms available**
  - Does not have any fallback mechanisms
  - Robustness gets compromised

- **LoRa → Technology to watch**

LoRa

Source: https://www.lora-alliance.org/

LoRa Technology

Intended for	Focused on	Seamless interoperability
• Wireless battery operated Things in any IoT network.	• Secure bi-directional communication • Mobility • Localization services (a must-have for Industry 4.0 applications)	• No need for complex installations. • Freedom to users, developers and businesses.

Three Classes of Things

Class A

- Allow for bi-directional communications and must be supported by all things.
- Downlink only available after TX.
- Most power efficient communication class.
- Example – battery powered sensor.

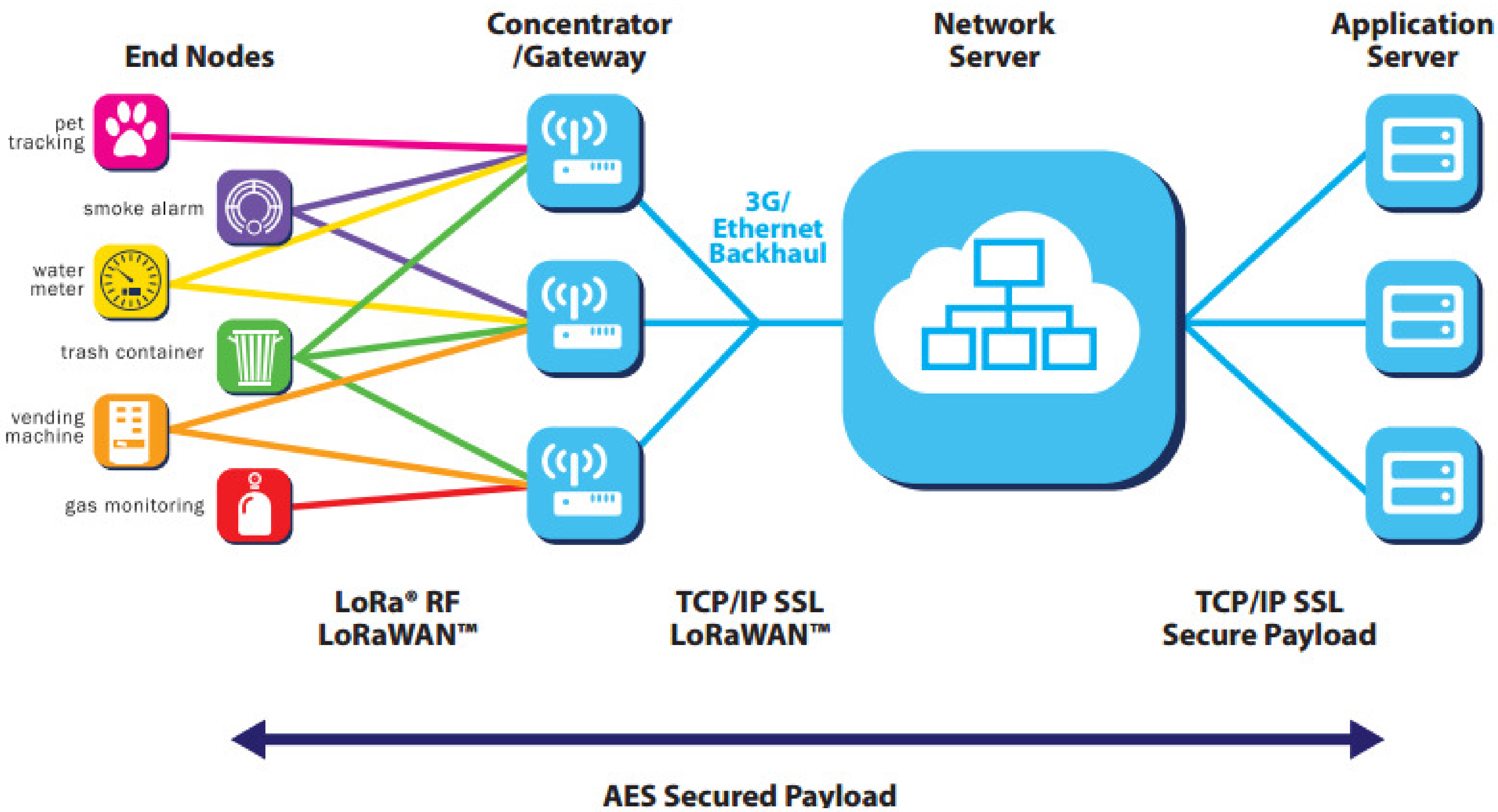
Class B

- Class A with scheduled receive slots.
- In order to open the scheduled receive window, it receives a time synchronized beacon from a gateway.
- Example – battery powered actuators.

Class C

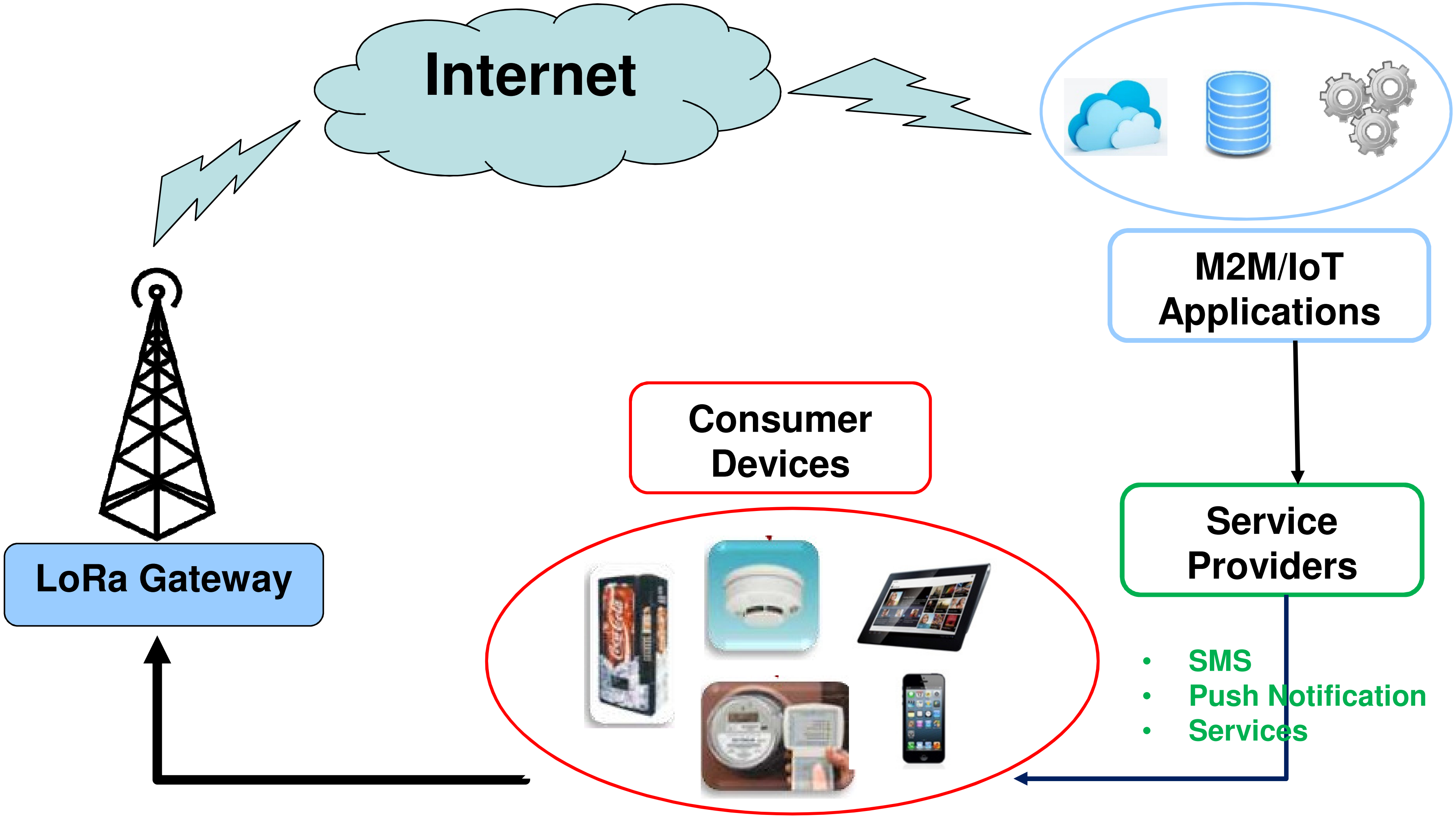
- Class A with maximal receive slots i.e. things which listen continuously.
- Intended for things directly connected to Mains (no shortage of power).

Network Architecture



Source: LoRa Alliance Whitepaper

LoRa in IoT Ecosystem

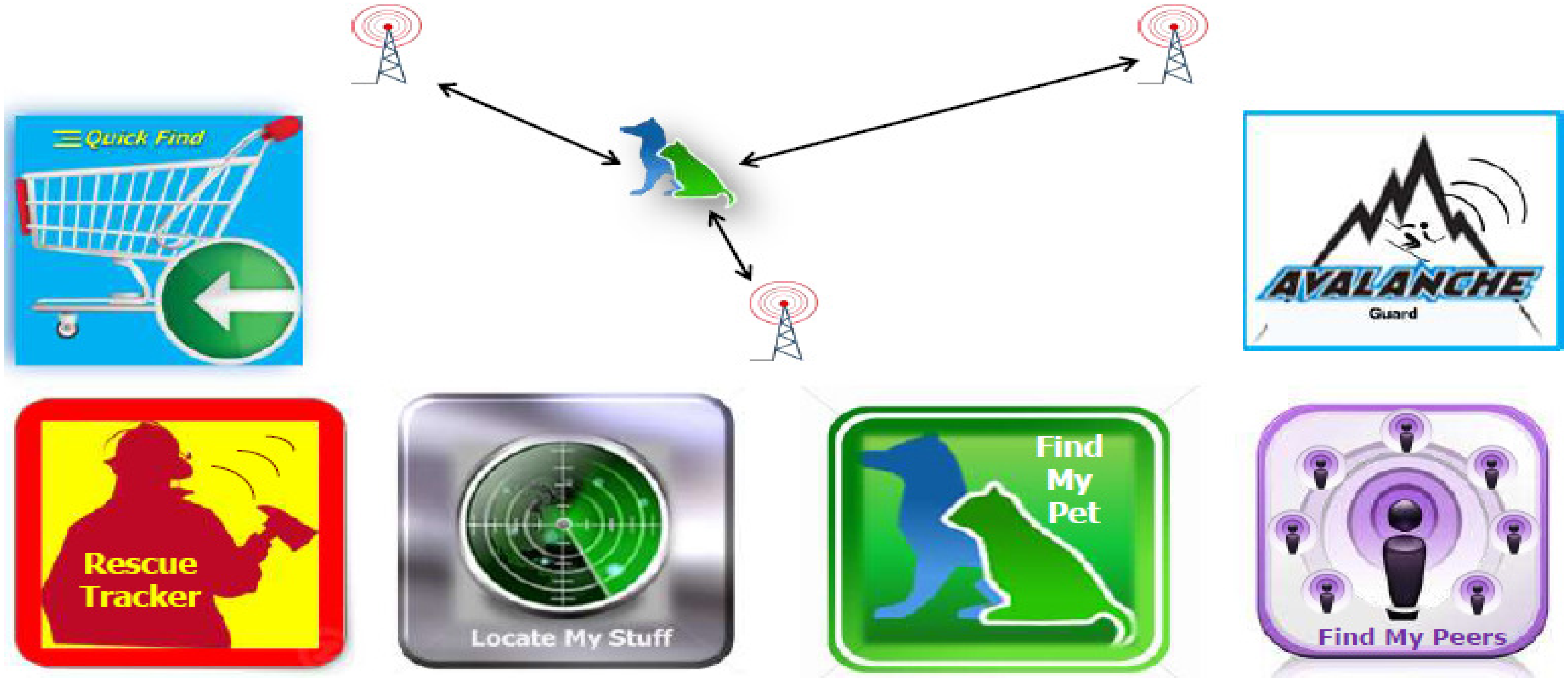


Localization (1/2)

- **An inherent property of LoRa is the ability to linearly discriminate between frequency and time errors.**
- **LoRa is the ideal modulation for radar applications and is thus ideally suited for ranging and localization applications such as real-time location services.**

Localization (2/2)

- Offers ability to locate long range sensors with high accuracy – within 7 meter up to 10KM.
- Opens up new localization based IoT applications.



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- **Cellular for IoT**
  - EC-GSM
  - LTE-M
  - NB-LTE
  - NB-CIoT

Cellular for IoT

Source: Accelerating IoT, Ericsson

Key Requirements for Cellular IoT

- **To enable C-IoT services and compete with non-cellular technologies, following key requirements must be met**
  - Long battery life
  - Full coverage
  - Scalability i.e. supporting huge volume of connected things
  - Low cost of things & their deployments

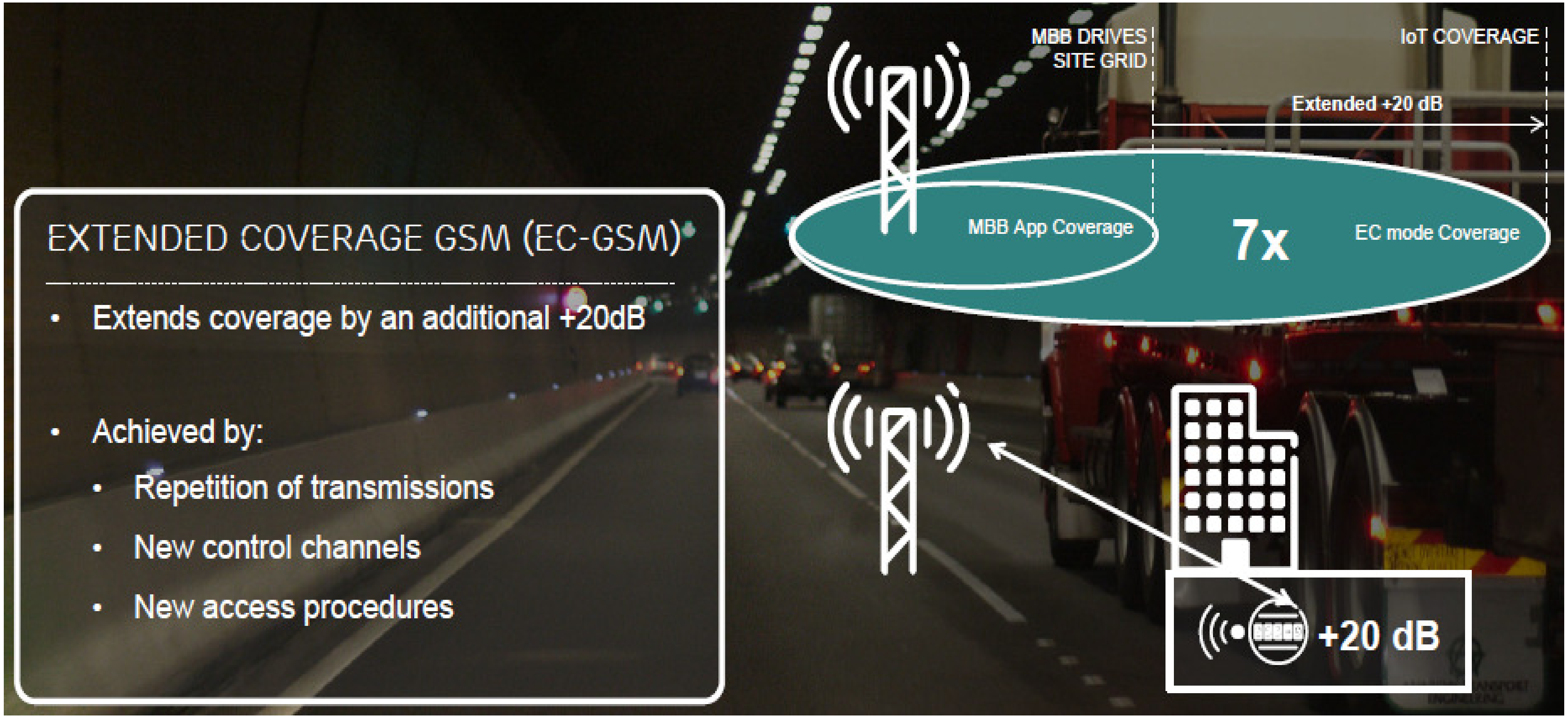
EC-GSM: Extended Coverage GSM

- **Essentially an upgrade of GSM using one carrier for IoT**
- **Coverage enhancement of 20 dB → repetition**
- **Expected with 3GPP Release 13 (Q1, 2016)**
- **Legacy GSM based things need additional hardware support to operate with EC-GSM**
  - not just a simple software upgradation

When they all hung out in the basement …

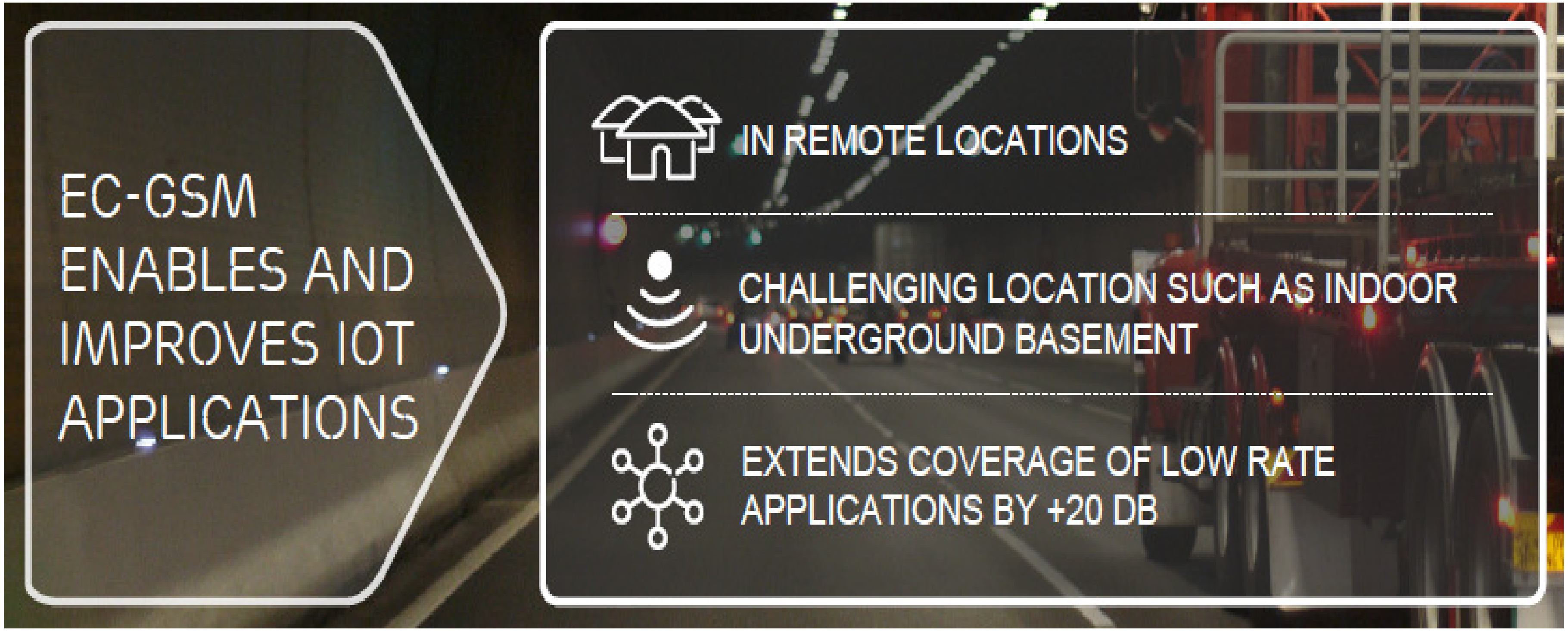
Source: That 70's Show

We Need Extended Coverage



Source: Accelerating IoT, Ericsson

What EC-GSM can offer to IoT Ecosystem?



Source: Accelerating IoT, Ericsson

EC-GSM Unique Advantages

- Ecosystem is in place
- Fast time to market IoT solutions
- Easy to deploy
- Low cost
- Stable

LTE-M

- **LTE-M: Optimizing LTE for IoT connectivity in 3GPP RAN.**
- **First released in Rel. 12 in Q4 2014.**
- **Further optimization will be included in Rel. 13 with specifications complete in Q1 2016.**
- **LTE-M provides 15dB additional link budget enabling about seven times better area coverage capacity on the existing LTE carrier.**

Coverage Enhancement

Combination of Techniques		
Power boosting of data and reference signals	Repetition or retransmission	Relaxing performance requirements (e.g. by allowing longer acquisition time or higher error rate)

NB-LTE

- NB-LTE provides 20dB additional link budget enabling about ten times better area coverage
- Supported by Ericsson, Intel, Nokia

NB-LTE Deployment Options

- **Standalone in a dedicated carrier (e.g. GSM bands)**
  - Utilizing the bands currently being used by GERAN systems
- **Guard band of LTE bands (with no extra guard band required)**
  - Utilizing the unused resource blocks at the edge of an LTE channel
- **In channel within LTE carrier**
  - Utilizing resource blocks within a normal LTE carrier

Narrowband Cellular IoT (NB-CIoT)

- **Promoted by Huawei, Vodafone**
- **Deployment options**
  - Standalone in a dedicated carrier
  - Guard band of LTE bands
- **Note: <u>Non LTE backward compatible</u>, different numerology w.r.t. LTE**

Key Features of Clean Slate Solution

- **IoT network can be deployed in a very small bandwidth (180 kHz downlink, 180 kHz uplink)**
  - Offers a wide range of deployment options.
  - Supports a huge number of terminals per cell (tens of thousands).
- **Optimized for ultra-low terminal cost (< $5)**
  - Removes unnecessary complexity not required for IoT applications.
  - Designed with ground-up approach to deliver the required performance for IoT at very low cost.
  - Reduce potential IPR licensing costs
- **Optimised for very long terminal battery life (> 10 years)**
  - Supports very low duty cycle modes, while things remain connected to network.
  - Supports both scheduled and event driven traffics.

When Comparing ...

NB-LTE	NB-CIoT
Allows a high re-use of already existing LTE network technology for both infrastructure and chipset.	Requires dedicated investments for network infrastructure and chipsets
Favours fast adoption & maximize economies of scale	Requires creation of a new ecosystem

Cellular IoT – Concluding Notes

- The solutions for LTE-M and EC-GSM will equally operate in spectrum shared with existing LTE or GSM networks.
- LTE-M and NB-LTE would be supplementary solutions addressing different use cases with higher capacity on LTE-M and slightly lower cost and better coverage on NB-LTE.
- NB-LTE will provide superior technology that leverages existing investments and an existing ecosystem, which are the key prerequisite for enabling the cellular IoT.

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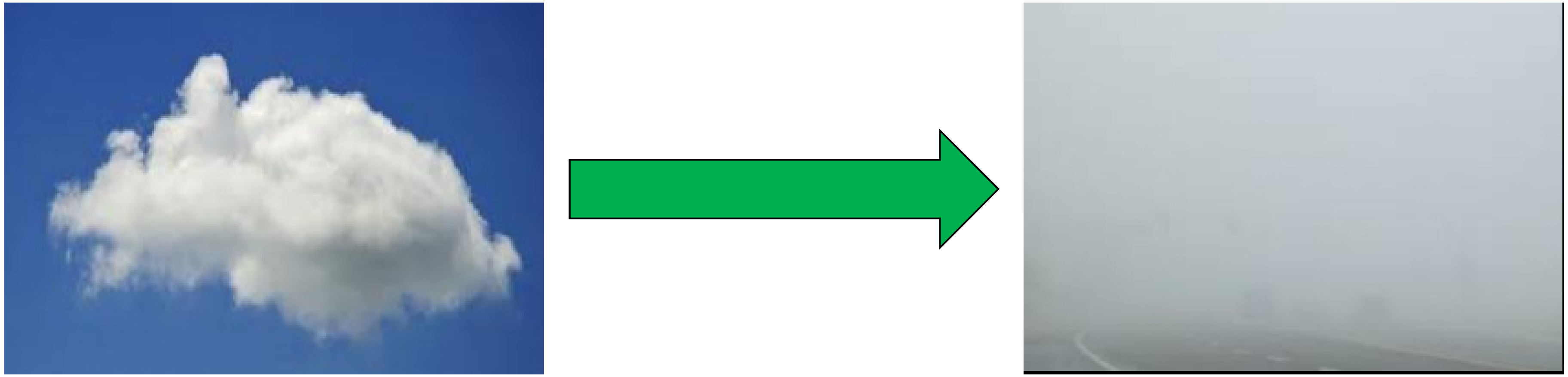
Further Reading

- **Introduction to "Clean-Slate" Cellular IoT radio access solution by Huawei and Neul**

- **Fog Networking**

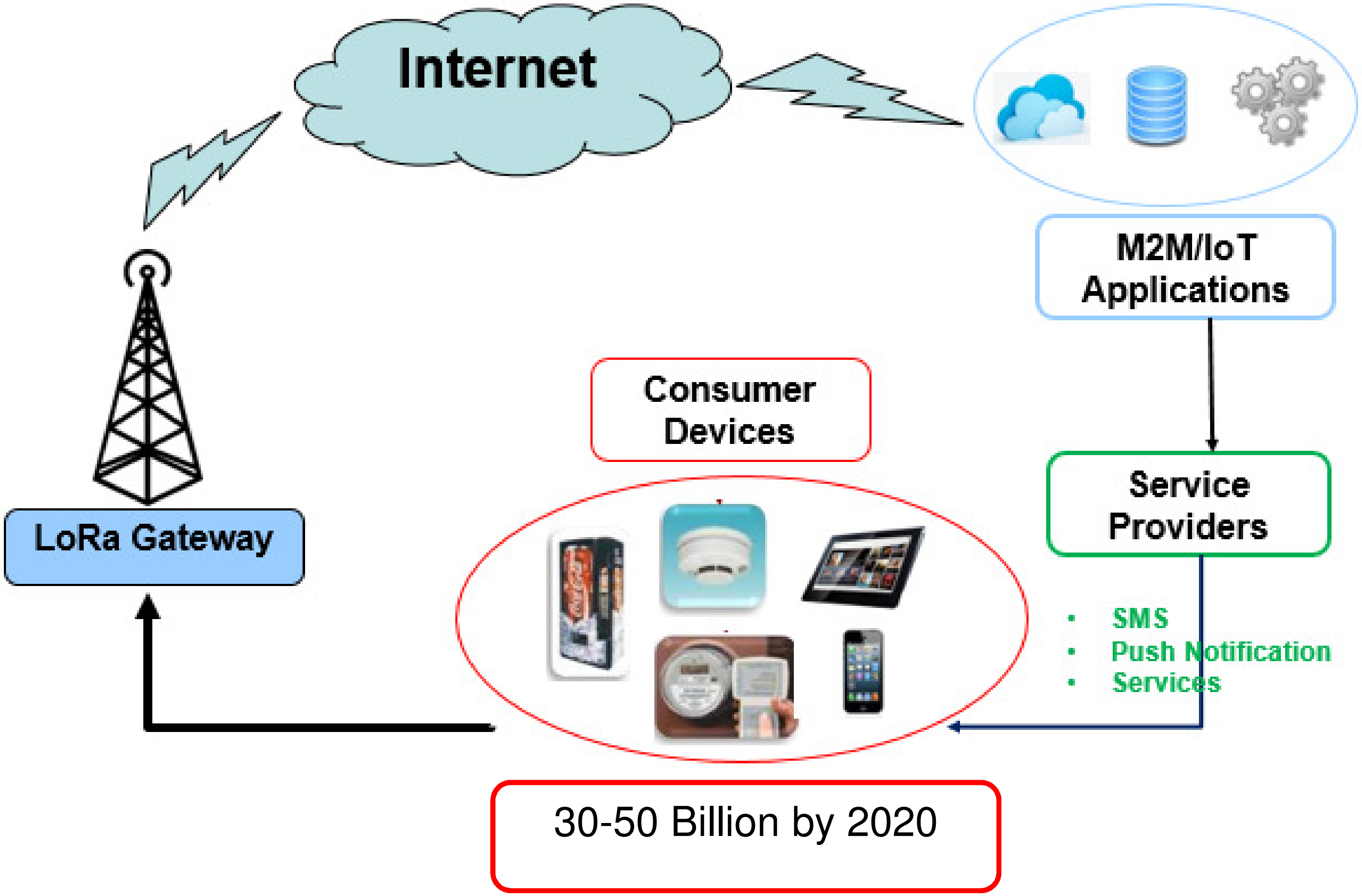
From Cloud to Fog

- **Witnessing a Paradigm Shift**
- **<u>But why?</u>**



Source: Datta, S.K.; Bonnet, C.; Haerri, J., "Fog Computing architecture to enable consumer centric Internet of Things services," in *Consumer Electronics (ISCE), 2015 IEEE International Symposium on*, pp.1-2, 24-26 June 2015

Explosion of Things at the Edge



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A Closer Look at Edge Devices …

- **Nature**
  - Powerful as well as constrained devices
  - Dense
  - Highly distributed
  - Majority of them are mobile
- **Some applications need**
  - Real time operation with very low latency and high QoS
    - Highly autonomous and interactive driving

Fog Networking Characteristics

- **"Fog" characteristics**
  - Proximity to end-users, dense geographical distribution
  - Open platform, Support for high mobility
- **Value addition**
  - Provide consumer centric services with reduce latency and improved QoS

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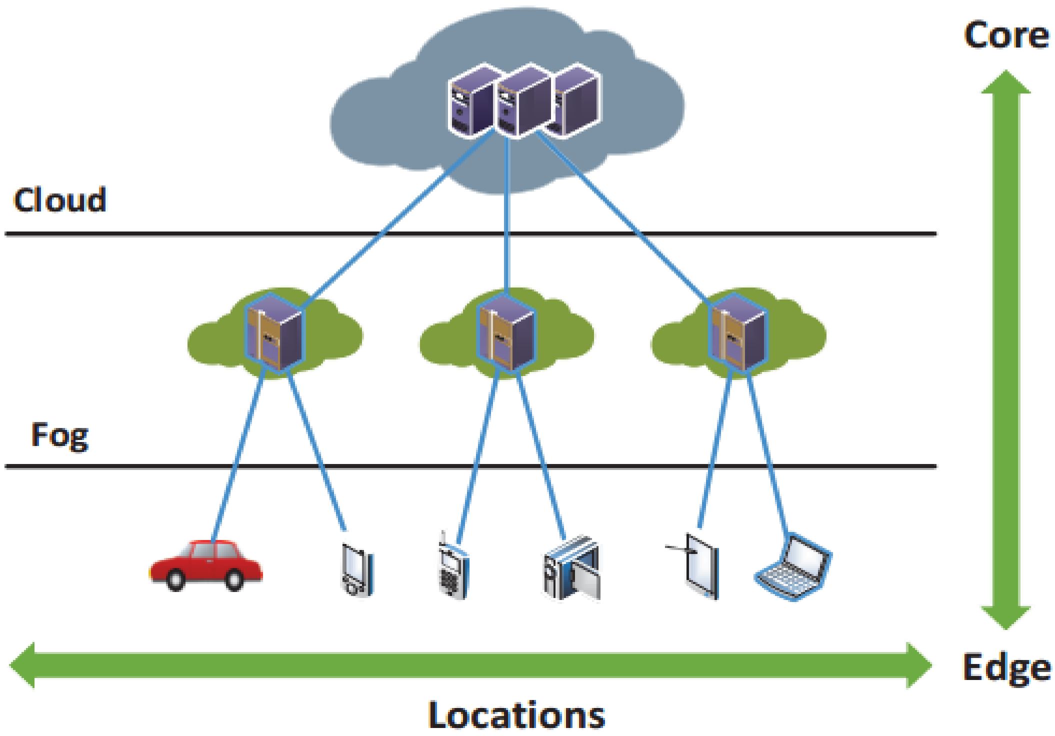
Benefits

- **Utilizing the Fog computing platforms, IoT applications and services could be operated from edges of networks as well as from end devices like access points, set top boxes, Road Side Units (RSUs) and M2M gateways.**
- **Such efforts in turn reduce latency, improve QoS, and allow real time data analysis with actuation resulting in superior user experience and creation of consumer centric IoT products.**
- **Additionally Fog computing saves bandwidth as data are processed at the edge of network, promotes distributed architecture.**
- **Due to dense geographic coverage and distributed operations, “Fog” promotes fault tolerance, reliability and maintains scalability of the system.**

Source: Datta, S.K.; Bonnet, C.; Haerri, J., "Fog Computing architecture to enable consumer centric Internet of Things services," in *Consumer Electronics (ISCE), 2015 IEEE International Symposium on*, pp.1-2, 24-26 June 2015

Concluding Note

- **Cloud and Fog can co-exist**



Roadmap

- Introduction
- Three Fundamental Operations
- Uniform Data Exchange & Management of Connected Things
- Communication Network for IoT
- Discovery
- M2M Data Processing for Smart City Applications
- IoT Architecture
- Standards in IoT

Discovery

- **Search functionalities provided to Humans**
  - Google
  - Yahoo
  - Bing
- **Search Engine for things?**

Source : www.iotdex.com

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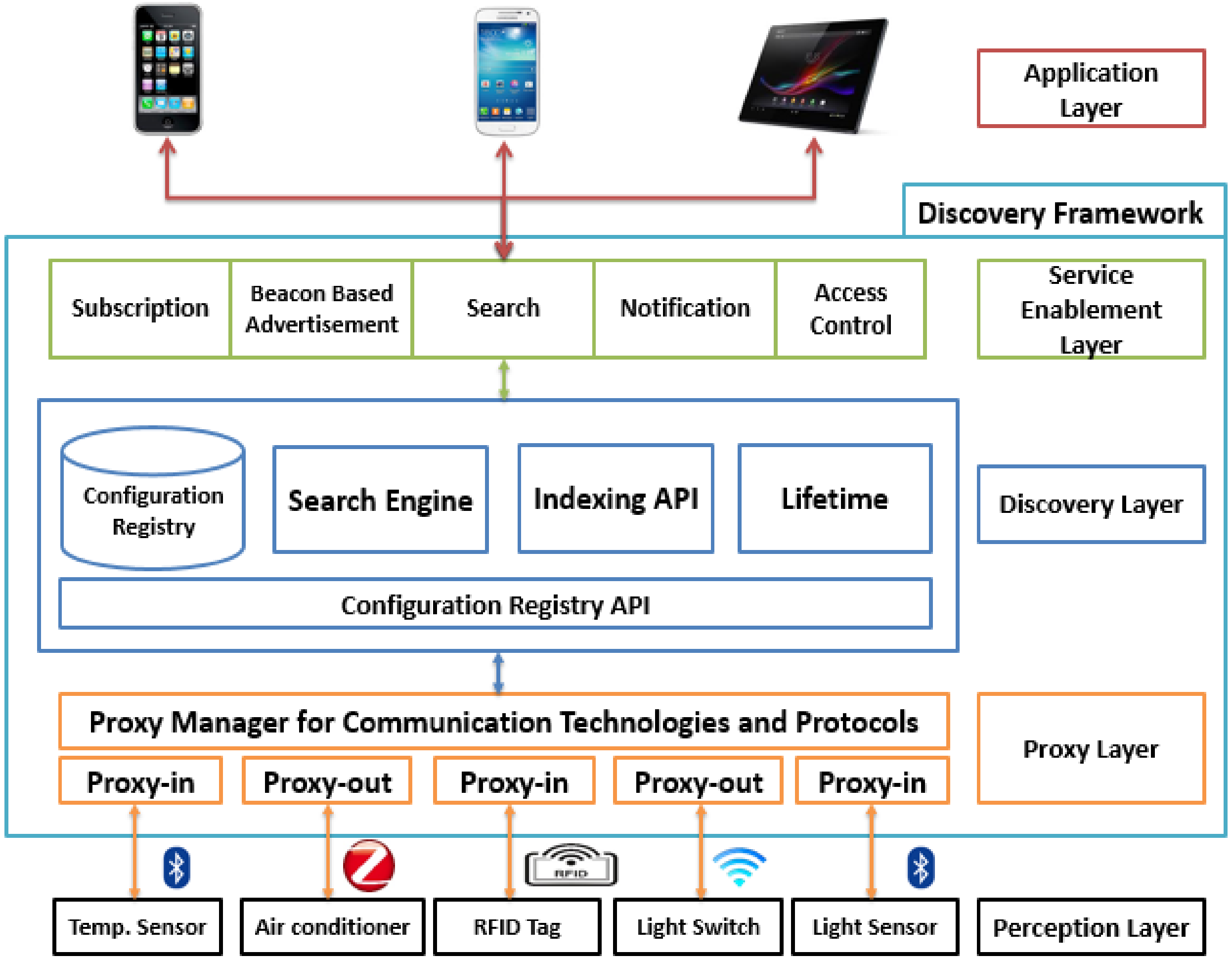
Discovery Categories

- **Scenarios**
  - Search around “ME”
    - UriBeacon, NFC
  - Search in the network
    - mDNS, SSDP
  - Search in a directory
    - CoAP
  - Search across peers
    - DHT based
  - Search for metadata
  - Semantic based search

Sources -
https://www.w3.org/WoT/IG/wiki/Discovery_Categories_and_Tech_Landscape
https://github.com/w3c/wot/blob/master/TF-DI/Interactions.md

Search Engine Based Discovery Framework



The Three Layers (1/2)

- **Proxy layer**
  - Enable discovery and interaction with smart and legacy things regardless of communication technology and protocols.
- **Discovery layer**
  - Configuration registry: manages registration, un-registration of things and provides storage of configurations.
  - Indexing API: registered things are indexed to expedite the search operation.
  - Search engine
    - Receives the discovery request (keywords/parameters) from clients
    - Extracts indices
    - Provides look up facility (discovers the matching things)
    - Ranks the results based on relevance, availability, access control policies.
  - Lifetime: A time period through which resources remain discoverable

The Three Layers (2/2)

- **Service enablement layer**
  - Exposes discovery layer functionalities through RESTful web services.
  - Enforces strict access control policies.
  - Provides subscription and notification facilities.
  - Includes semantic components for discovery.
  - Incorporate security mechanisms

- **We can deploy things & M2M gateway**
  - Exchange uniform metadata
  - Manage as well as discover the things
  - Communication and networking aspects
- **These things generate data**
- **What can we do with the data**
  - How to get meaning out of data
  - Understand the context
  - Combine data from different domains

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M2M Data Processing for Smart City Applications

- **Same sensor can be used in**
  - Different contexts
  - Across different domains
  - E.g. – Accelerometer in smartphones can be used to judge road conditions as well as determining earthquakes
- **Smart city comprises of several domains**
  - There are rules associated with the knowledge of the each domain
- **What if you want to build applications combining several domains**

Semantic Reasoning

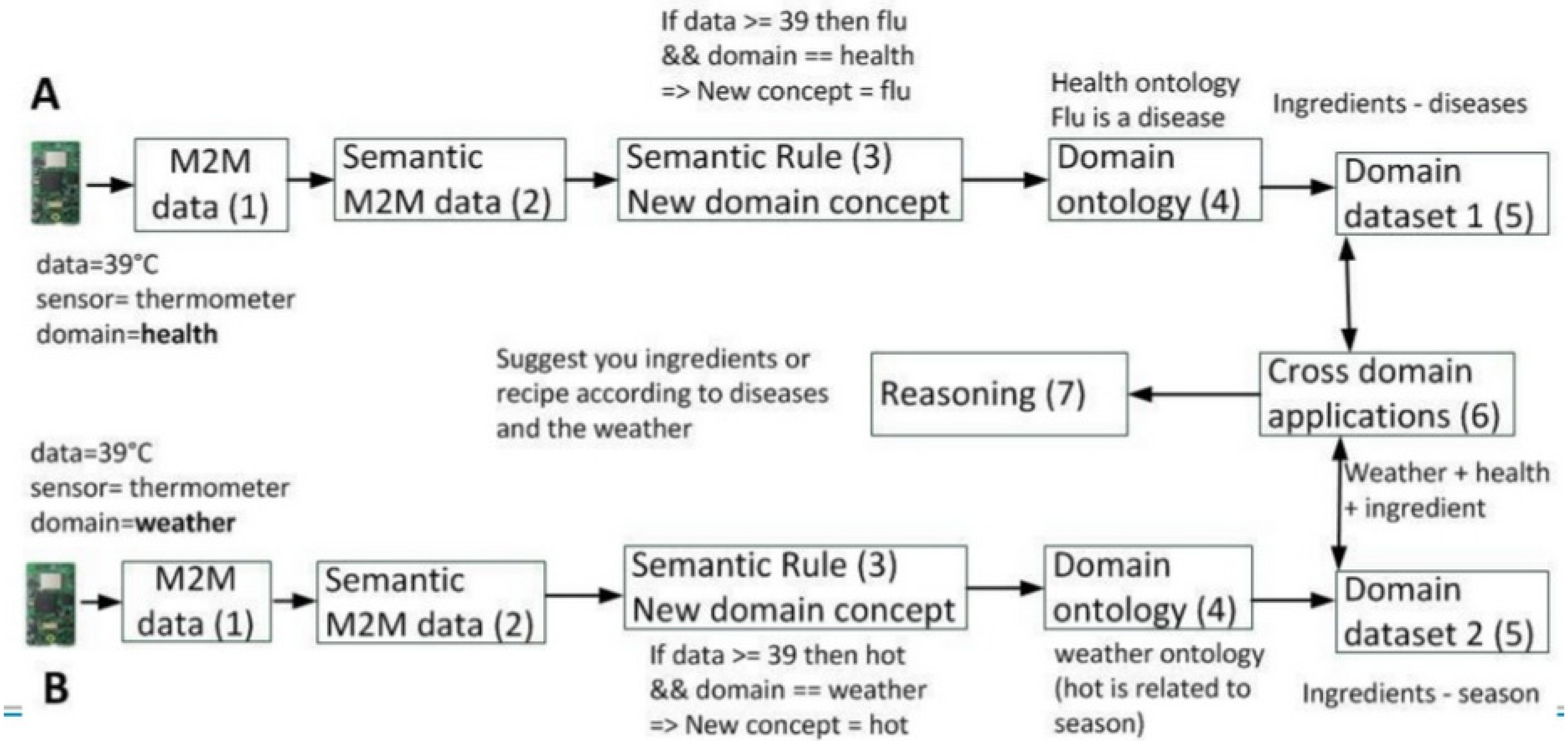
- **Use of semantic reasoning to enrich M2M data**
  - First step – SenML to add some side information
  - Second step – decorate the M2M data with additional semantic reasoning
- **Link the data with the meaning**
  - From the point of view of different domains

M3 Approach

- **The M3 (Machine to Machine Measurement) approach**
  - Enrich M2M data with semantic web technologies [7]
  - The M3 ontology: A hub for cross-domain ontologies and datasets
    - e-Health: weather, recipe, health
    - Smart city: weather, home automation, transport, vacation
    - STAC (security): sensor, cellular, web, mobile phone
  - LOR (Linked Open Rules): share and reuse domain rules
- **M3 integrated in a semantic-based M2M architecture**
- **Prototype: http://sensormeasurement.appspot.com/**

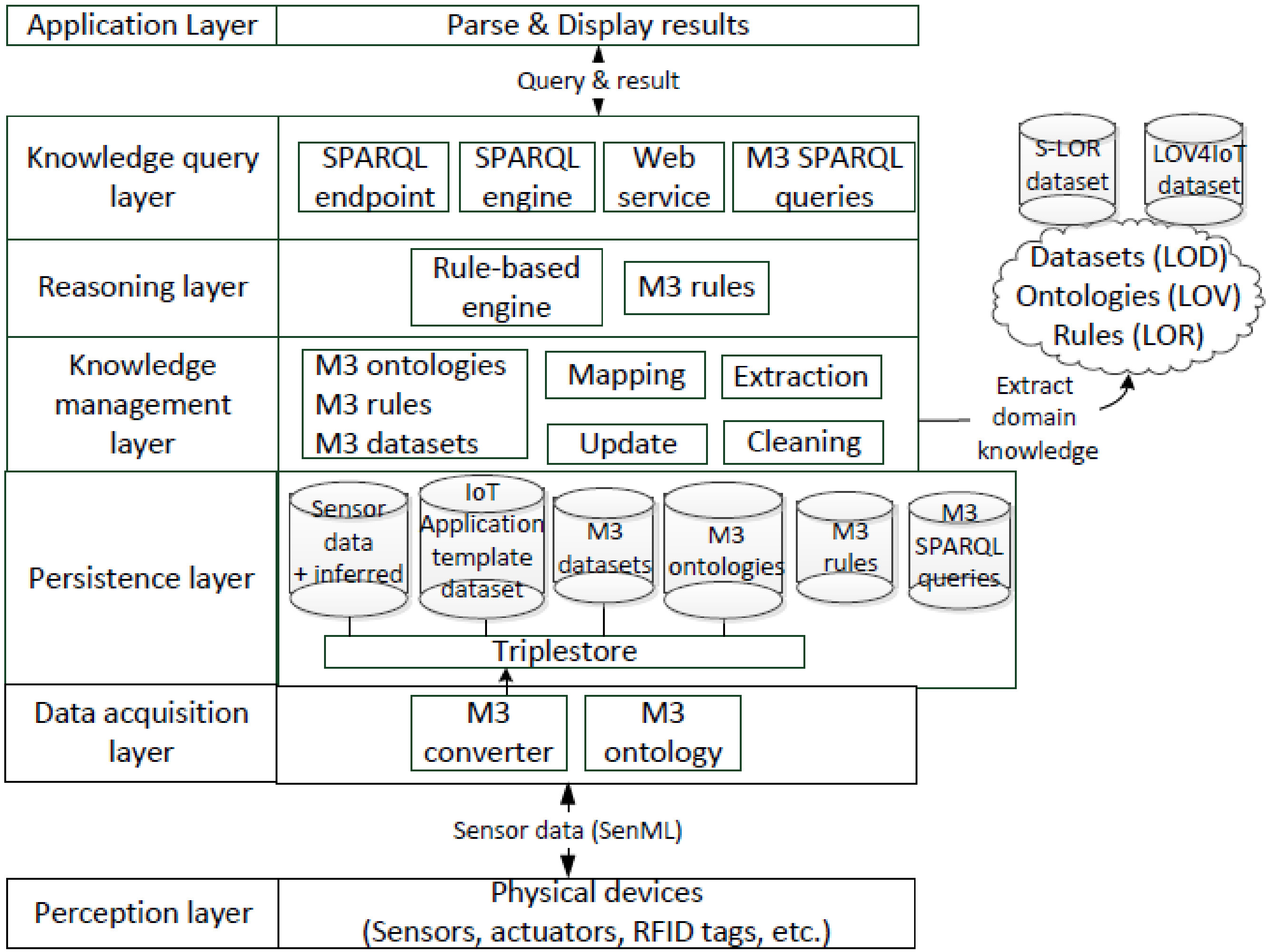
[7] Gyrard, A.; Bonnet, C.; Boudaoud, K., "Enrich machine-to-machine data with semantic web technologies for cross-domain applications," *Internet of Things (WF-IoT), 2014 IEEE World Forum on*, pp.559,564, 6-8 March 2014

How to Combine IoT Data?



Source: Gyrard, A.; Bonnet, C.; Boudaoud, K., "Enrich machine-to-machine data with semantic web technologies for cross-domain applications," in *Internet of Things (WF-IoT), 2014 IEEE World Forum on*, pp.559-564, 6-8 March 2014

Architecture of M3 Framework



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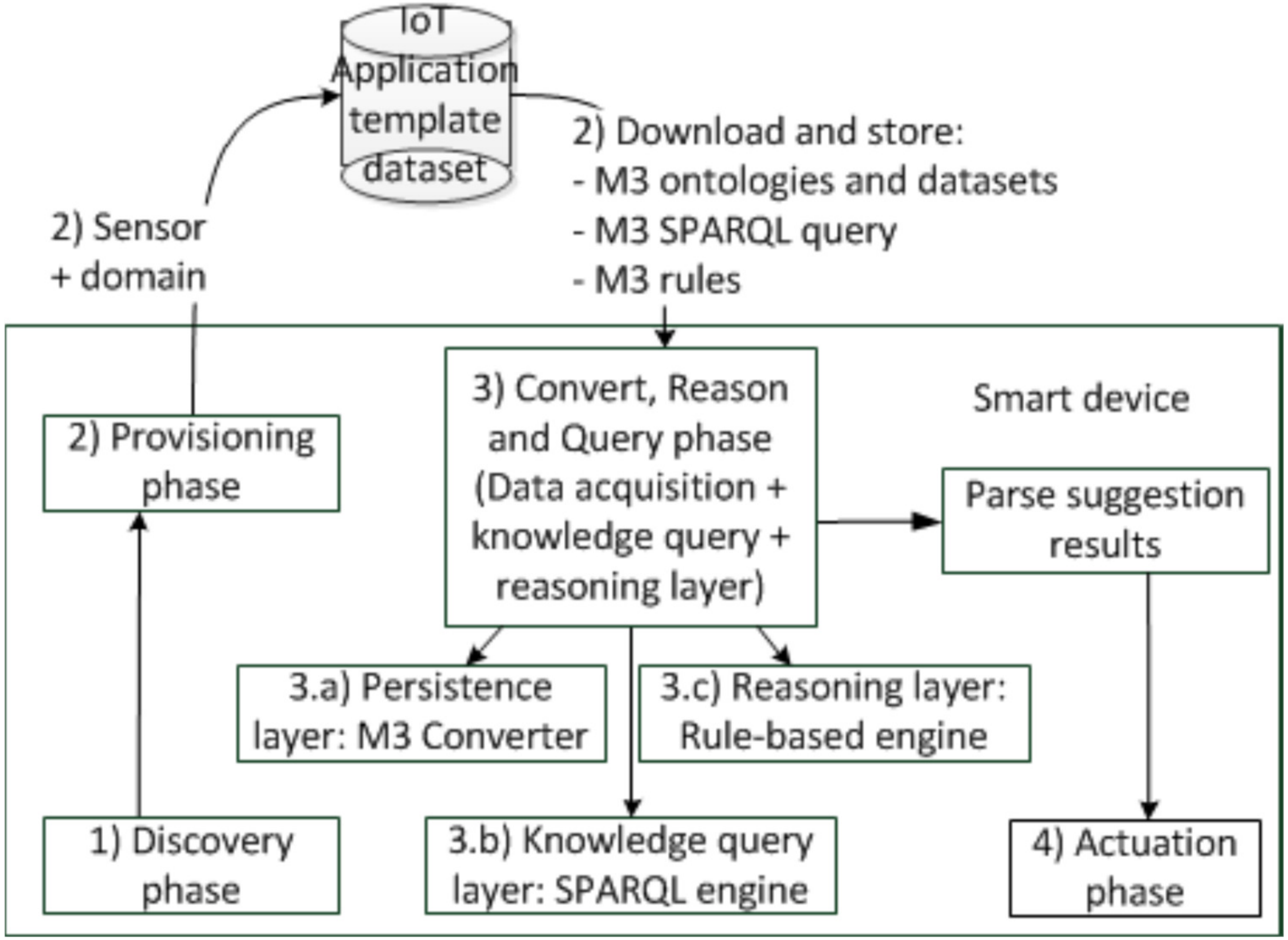
IoT Application Template Generation

- **A template is generated based on**
  - Type of sensor (e.g. temperature)
  - Associated domain
    - E-Health for body temperature
    - Weather for outside temperature
- **Template contains**
  - Ontologies, datasets, rules and generic sparql query

Deployment

- **Cloud based approach**
  - This stores all the templates needed to build various kinds of applications for IoT.
  - Developed using Apache Jena framework.
- **Mobile application / Gateway (Fog approach)**
  - A lightweight version of the M3 is implemented into Android powered smart devices.
    - The Jena Framework can not be directly integrated into smart devices. AndroJena is used instead.
    - The requirements for the smart devices is different where only one application template is required and can be easily downloaded from the cloud.
    - The smart devices need not have the entire set of IoT application templates.

Integrating M3 into Constrained Devices



Source: Datta, S.K.; Gyrard, A.; Bonnet, C.; Boudaoud, K., "oneM2M Architecture Based User Centric IoT Application Development," in *Future Internet of Things and Cloud (FiCloud), 2015 3rd International Conference on*, pp.100-107, 24-26 Aug. 2015

- **Questions???**

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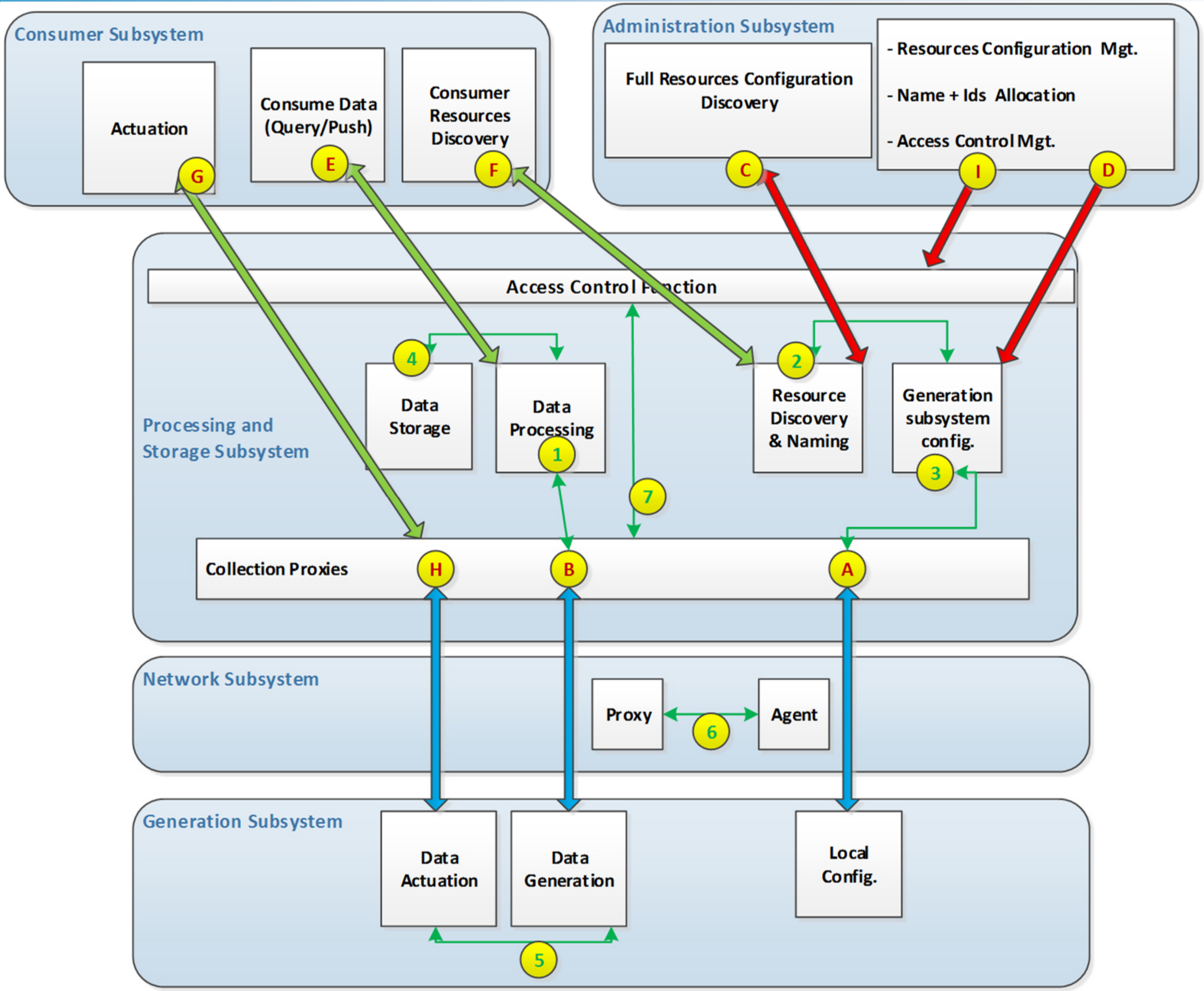
IoT Architecture



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Roadmap

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It’s Sort of a War …

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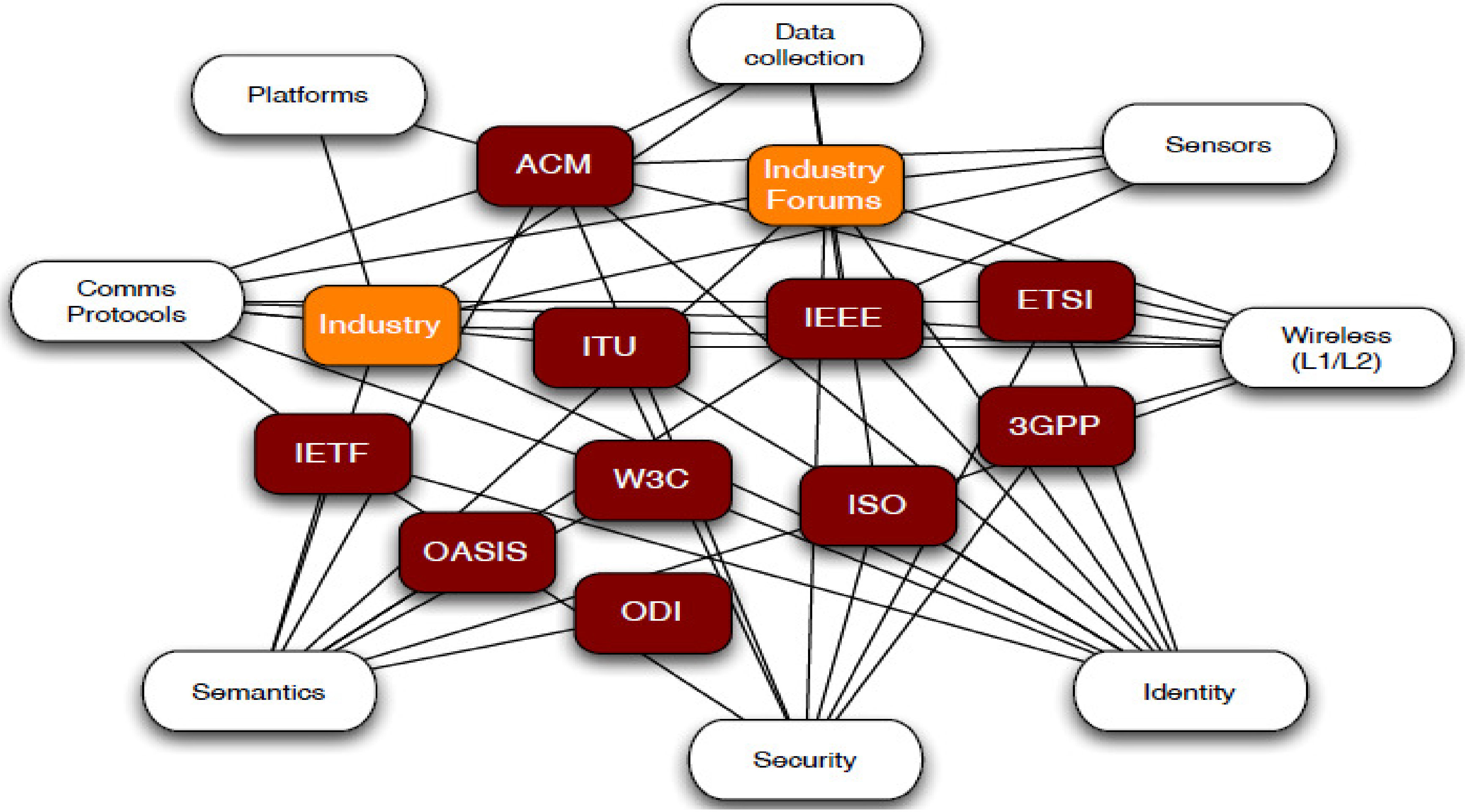
IoT Standardization Activities



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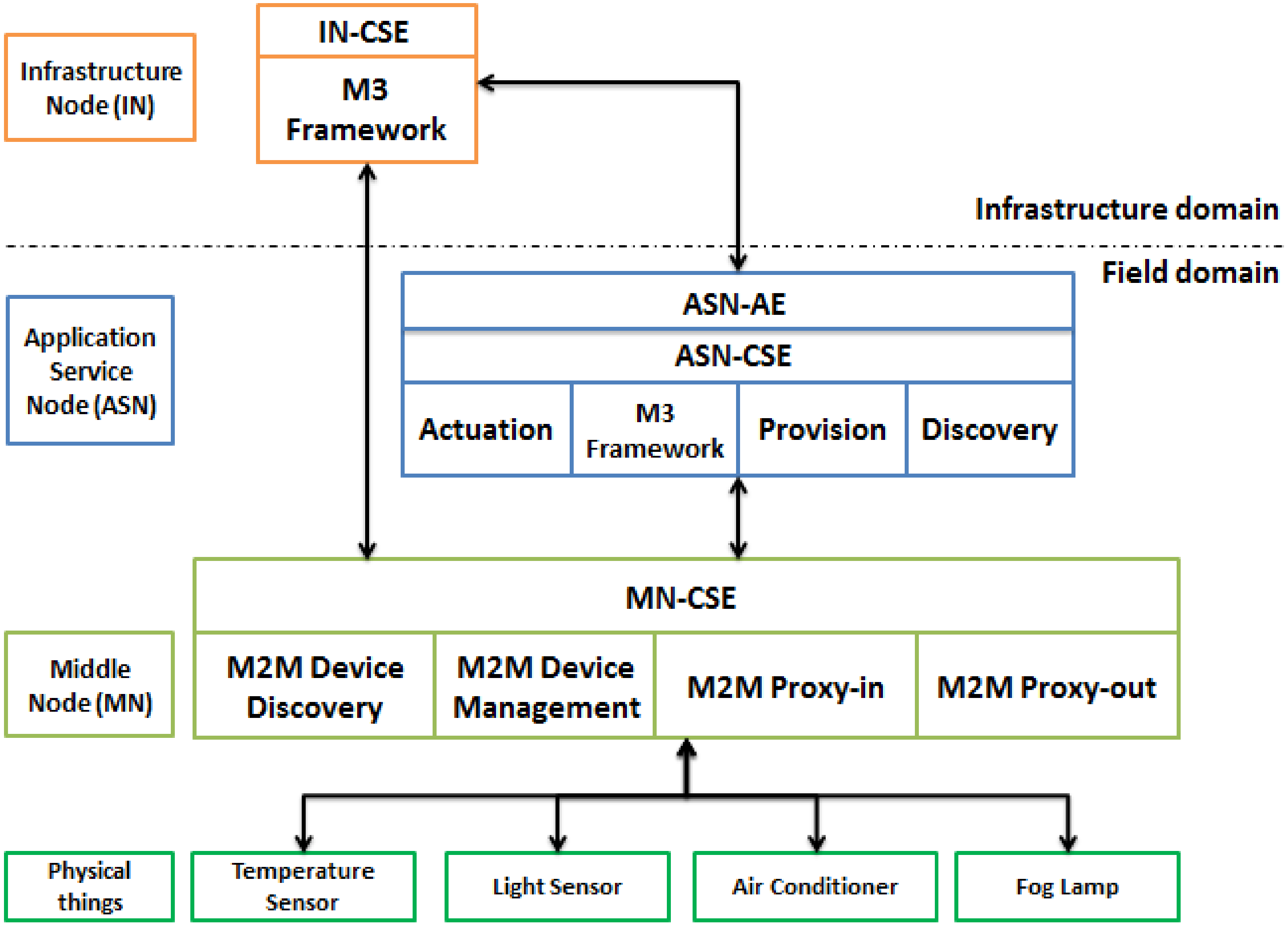
SDOs and Alliances

General oneM2M Architecture



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oneM2M Architecture Elements

- **Elements of each domain consists of**
  - Application Entity (AE)
    - Contains the application logic for end-to-end M2M solutions.
    - E.g. application for automated driving or fitness monitoring.
  - Common Service Entity (CSE)
    - Represents a set of common functions of the M2M ecosystem.
    - E.g. discovery, management

Application Service Node (ASN)

- **Contains at least one AE and CSE.**
- **Equivalent to a mobile application running in smart devices.**
- **ASE-AE**
  - May implement a user interface
- **ASN-CSE**
  - Modules for discovery, provisioning etc.

Middle Node (MN)

- **Contains only CSE and not an AE.**
- **Equivalent to M2M gateway.**
- **Communicates with infrastructure node and ASN.**
- **MN-CSE implements**
  - Dynamic object discovery
  - Management framework
  - Security and access control
  - M2M data management

Infrastructure Node (IN)

- **It provides M2M services in the infrastructure domain.**
- **Contains a CSE and zero or more AE.**
- **Interacts with one or more MN(s) and ASN(s).**
- **Equivalent to a cloud system.**

Limitations in Current Standards

- **Existing standards (W3C, ETSI M2M, oneM2M) lack**
  - A common format or syntax to describe sensors, measurements, units and domains.
  - Interoperable and standardized domain knowledge (ontologies, datasets and rules).
  - Semantics components are not explicitly described in M2M architectures.
  - Uniform methods to interpret high level abstraction from M2M data.

Source: Gyrard, A.; Datta, SK.; Bonnet, C.; Boudaoud, K., "Standardizing Generic Cross-Domain Applications in Internet of Things," *3rd IEEE Workshop on Telecommunication Standards: From Research to Standards, Part of IEEE Globecom 2014*, 8 December 2014.

Vision to Standardize the M3 Approach

- **Describe sensor measurements in a uniform way**
  - Utilize Sensor Markup Language and **our proposed extensions**.
- **Standardize common domain ontologies for IoT domains**
  - Tackles the interoperability issues related to combining cross domain knowledge.
- **Interpreting M2M data based on Sensor based Linked Open Rules (S-LOR)**
  - Enables efficient sensor-based domain knowledge interoperability to combine rules, ontologies and datasets.
- **Already proposed to oneM2M MAS group.**

Peek into W3C WoT

- **Interest Group wiki page**
  - http://www.w3.org/WoT/IG/wiki/Main_Page
- **I co-ordinate the Task Force on Discovery & Provisioning**
  - http://www.w3.org/WoT/IG/wiki/Discovery_TF
  - http://www.w3.org/WoT/IG/wiki/Provisioning
- **A Working Group on Web of Things is under preparation.**
  - http://www.w3.org/WoT/IG/wiki/Proposals_for_WoT_WG_work_items

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First Part over

- **Shading lights on some specific points**
  - Uniform data exchange with Sensor Markup Language
  - Management framework for smart and legacy things
  - Communication networks
  - Resource discovery
  - Data processing at cloud and constrained devices
  - Standards
- **Any Questions???**

Issues not discussed in the tutorial

- **In-depth discussion on privacy, security and trust**
- **Provisioning**
- **Global access**
  - Naming, announcement
- **Ubiquity**
  - Mobility, service continuity
- **M2M data management**
  - Data life cycle
- **Consumer centric IoT application**
- **FI-WARE Generic Enablers**

Source: http://global.singularityu.org/india/2015/01/20/smart-city-contest/

Second Part

- Smart City Challenges
- What We Need
- Use Cases
- Conclusion

City Challenges (1/3)

- **Rapid Urbanization**
  - 6.3 Billion people to live in cities and surrounding areas by 2050
    - Increases pressure on city infrastructure
    - Makes it harder to maintain quality of life
- **Energy**
  - Demands 60-70% of world's energy
    - Power cuts
  - Emission of green house gases
    - Manage carbon footprint
- **Water resource**
  - Consumption is around 60% of world's water
    - 20% results in water leak

City Challenges (2/3)

- **Urban traffic related**
  - Congestion due to increase in vehicles
    - Creates poor traffic flow
    - Increases fuel consumption
  - Pollution
  - Creates a negative experience altogether
- **Parking problem**
  - People looking for parking creates additional traffic congestion
  - Limited parking places
    - Waste of time and fuel to find a parking
  - Loss of revenue and local business

City Challenges (3/3)

- **Public safety**
  - Remote monitoring of public attractions, homes, other places
  - Place with poor records become unattractive for citizens & businesses
    - In turn it slows the growth
- **City lighting**
  - Problem with maintenance
    - Physical inspection
  - Lights are not intelligently operated
    - Intensity remains the same throughout the night

Traditional Approach of Cities

- **Local city Govt. makes independent investments for**
  - Traffic management
  - Waste collection
  - Pollution control
  - Parking management
- **This creates silos**
  - No sharing of infrastructure, sensor data etc.
  - No sharing of expertise, information, intelligence
  - Sometimes redundant investments
- **The approach is fragmented and has very limited efficiency**

Second Part

- **Smart City Challenges**
- **What We Need**
- **Use Cases**
- **Conclusion**

What We Need…

‘Smart’ solutions are instrumented, interconnected and intelligent

Instrumented	+	**Interconnected**	+	**Intelligent**
Event capture and filtering for timely response		*Any to any linkage of people, process, and systems*		*Deep discovery, analysis and forecasting*

=

Source: IBM Corporation

Second Part

- **Smart City Challenges**
- **What We Need**
- **Use Cases**
  - IoT based waste collection
  - IoT based pollution monitoring
- **Conclusion**

Let’s Look at Use Cases …

Vehicle telematics
- Traffic information
- eCall

energy/smart grid
- Smart grids

smart city
- Traffic sensors & control
- Street lighting
- Infrastructure monitoring
- Trash and waste containers
- Public events – location services
- Advertising displays
- ATM’s, Vending machines
- Smart parking

agriculture
- Irrigation control
- Environment sensing
- Animal tracking

smart metering
- Electric
- Water
- Gas
- Heat
- Infrastructure & production

secure/smart home
- Smoke detectors
- Security systems
- Smart appliances
- Smart Heat
- control / monitoring
- video surveillance

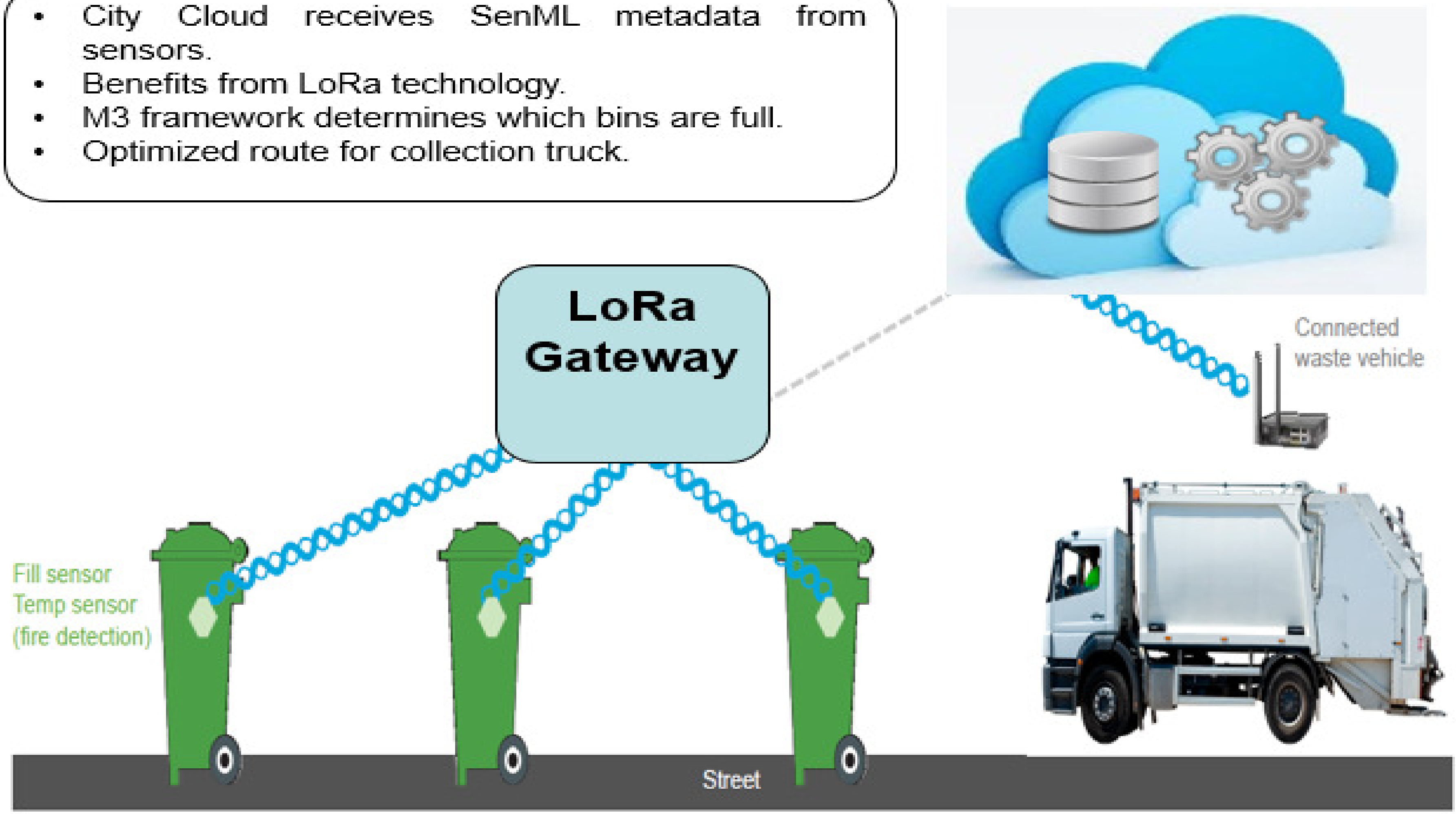
tracking
- Motorcycles, Bicycles
- Cars
- Truck Trailers
- Shipping Containers
- Kids, Pets
- Insurance – valuable assets
- Find My Stuff

environment & industrial
- Earthquake sensors
- Avalanche and flooding
- Heating and AC
- Equipment status
- Forest fires
- Air pollution

mHealth
- Medical wearable's

IoT Based Waste Collection

- City Cloud receives SenML metadata from sensors.
- Benefits from LoRa technology.
- M3 framework determines which bins are full.
- Optimized route for collection truck.



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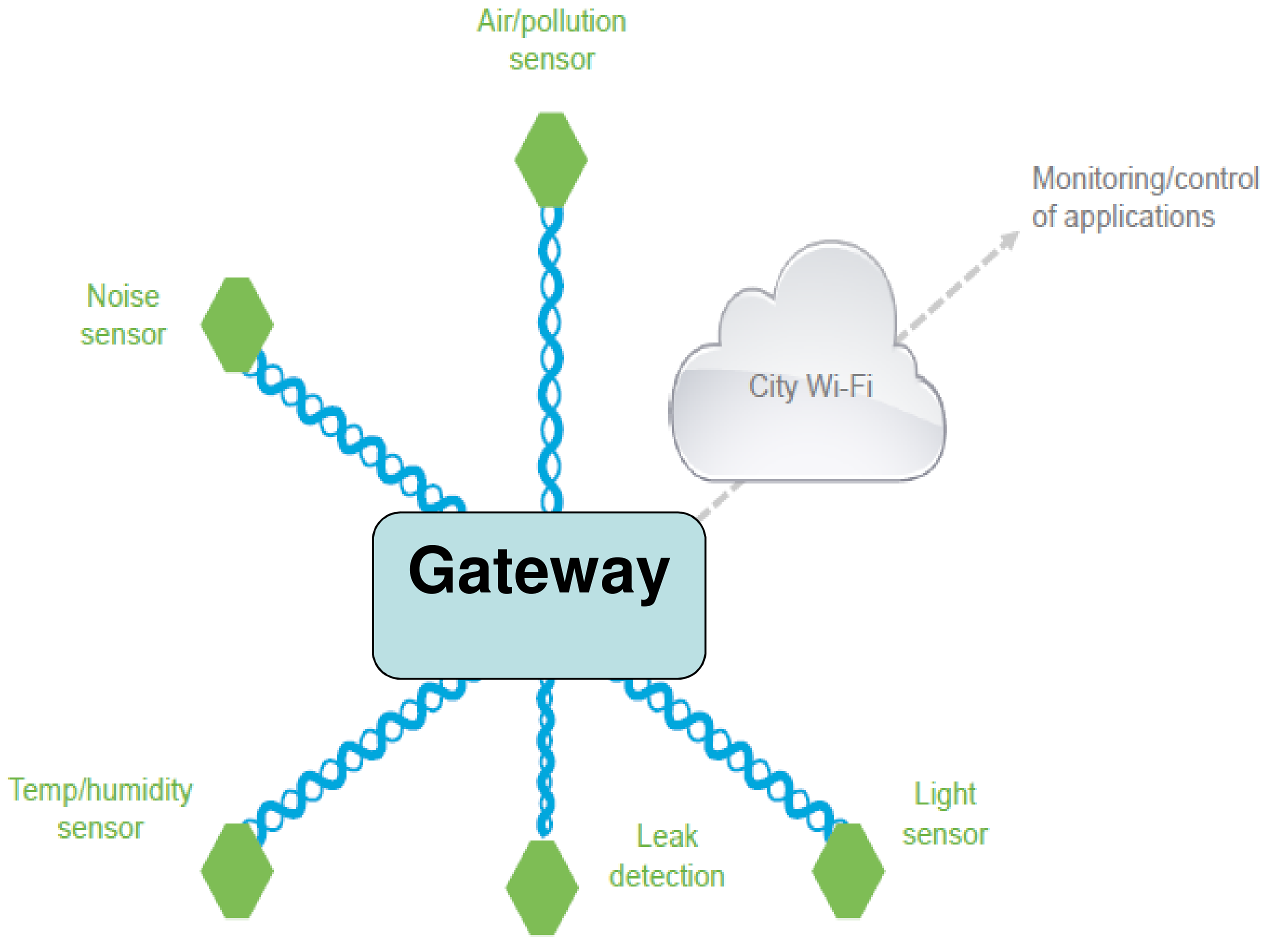
IoT Based Pollution Monitoring

Installation of environment sensors:
air, light, humidity, noise, etc.

Benefits include:

- Leverages parking sensor infrastructure
- Provides valuable data for improving analytics applications and forecasting



Still….

- **Massive adoption of IoT for smart city is not yet a reality**
- **Inhibitors**
  - Technology – fragmented solutions
  - Standard – no clear winner
  - Business – no proper business plan
  - No consumer centric ecosystem
  - Government policies
  - Privacy

How Can Standards Help?

- **Open data, interoperability**
- **City centric solutions**
- **Engaging all players of the IoT market**

Second Part

- Smart City Challenges
- What We Need
- Use Cases
- Conclusion

Second Part Complete

- **Focused discussion on**
  - Smart city challenges
  - Uses cases and how M2M/IoT technologies are powering them


감사합니다
Natick
Grazie
Danke
Ευχαριστίες
Dalu
Obrigado
Thank You
Köszönöm
Tack
Спасибо
Dank
Gracias
谢谢
Merci
Seé
ありがとう

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