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NetSys 2015 KiVS

ITG IEEE

M2M Communications and Internet of Things as enablers of Smart City

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Brief Bio

- **Research Engineer at Eurecom, France**
- **R/D activities focus on**
  - Innovation, development of next-generation technologies & standardization
  - Mobile computing, M2M Communications and Internet of Things
- **Member of IEEE ComSoc & CESeoc**
  - TPC member of IEEE conferences

WHAT IS EURECOM

- **A graduate school & research centre in communication systems located in French Riviera**
- **A consortium with a private status (EIG) that brings together:**
  - **7 academic partners**
  - **8 industrial partners**
  - **1 institutional partner**
- **Three Departments**
  - Communication and Computer Security
  - Multimedia
  - Mobile Communications

EURECOM MEMBERS

Academia

TELECOM ParisTech

Politecnico di Torino

Aalto University

TUM Technische Universität München

NTNU Norwegian University of Science and Technology

Vietnam National University Ho Chi Minh City

CHALMERS University of Technology

Industry

SFR

orange™

ST life.augmented

SAP®

Monaco telecom

BMW Group Forschung und Technik

Symantec.

IABG

Institutional member

PRINCIPAUTÉ DE MONACO

UN RÔLE À PART DANS LE MONDE.

Founding member

INSTITUT Mines-Télécom

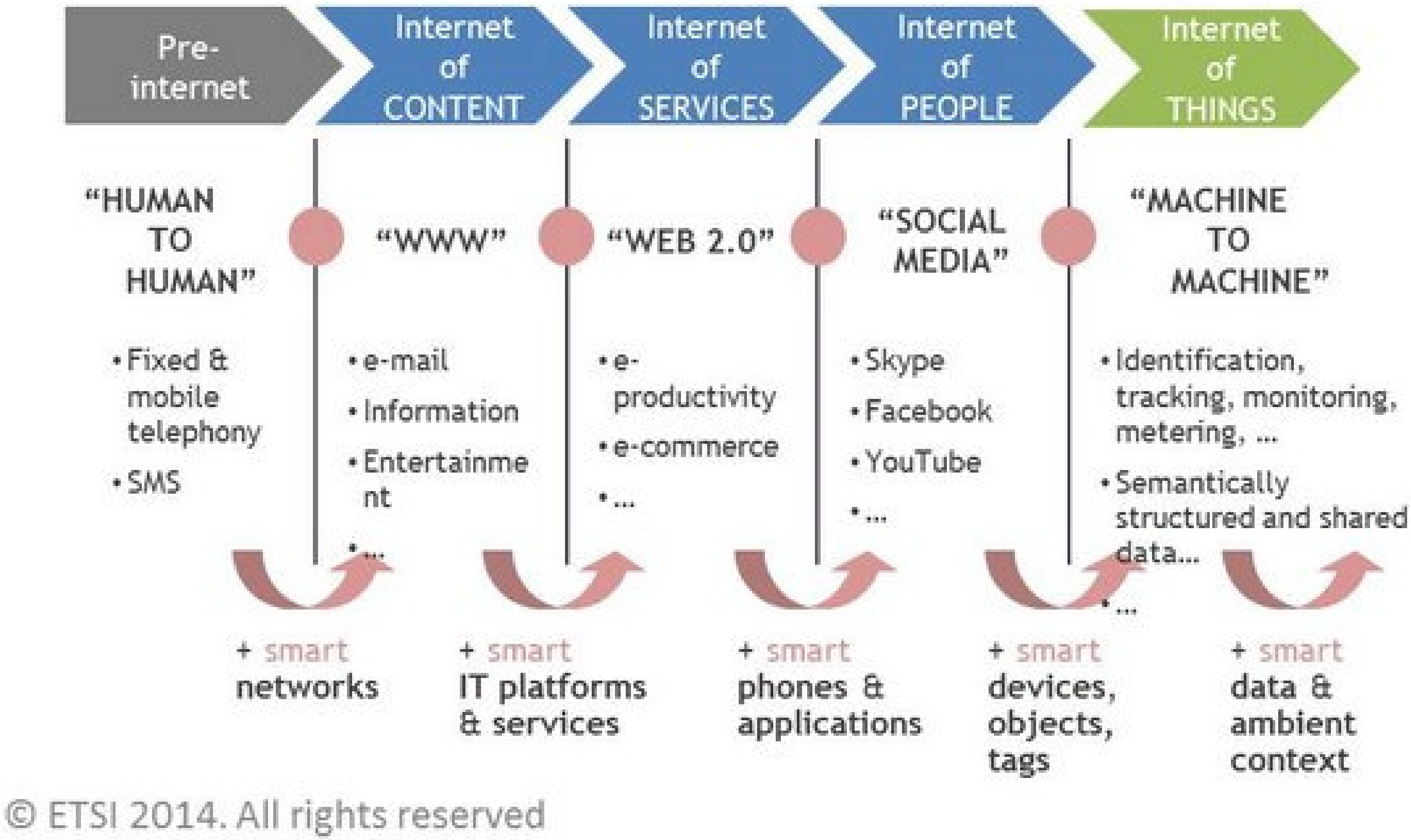
Roadmap

- **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 with Objects**
- **Managing Connected Objects**
- **Sensor Virtualization**
- **M2M Gateway**
- **M2M Data Processing for Smart City Applications**
- **Mobile Application Development for IoT**
- **IoT Architecture**
- **oneM2M Standardization**

Evolution of Internet



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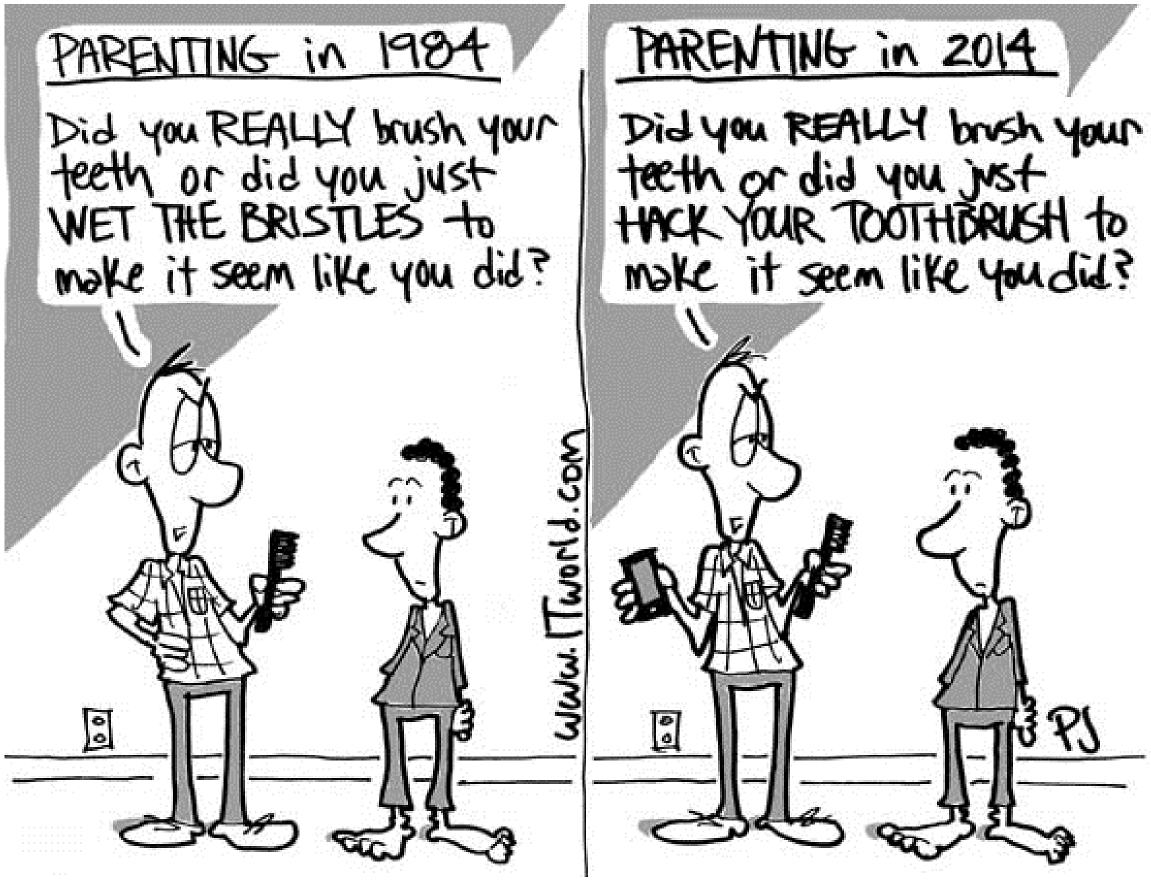
Connecting Things



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

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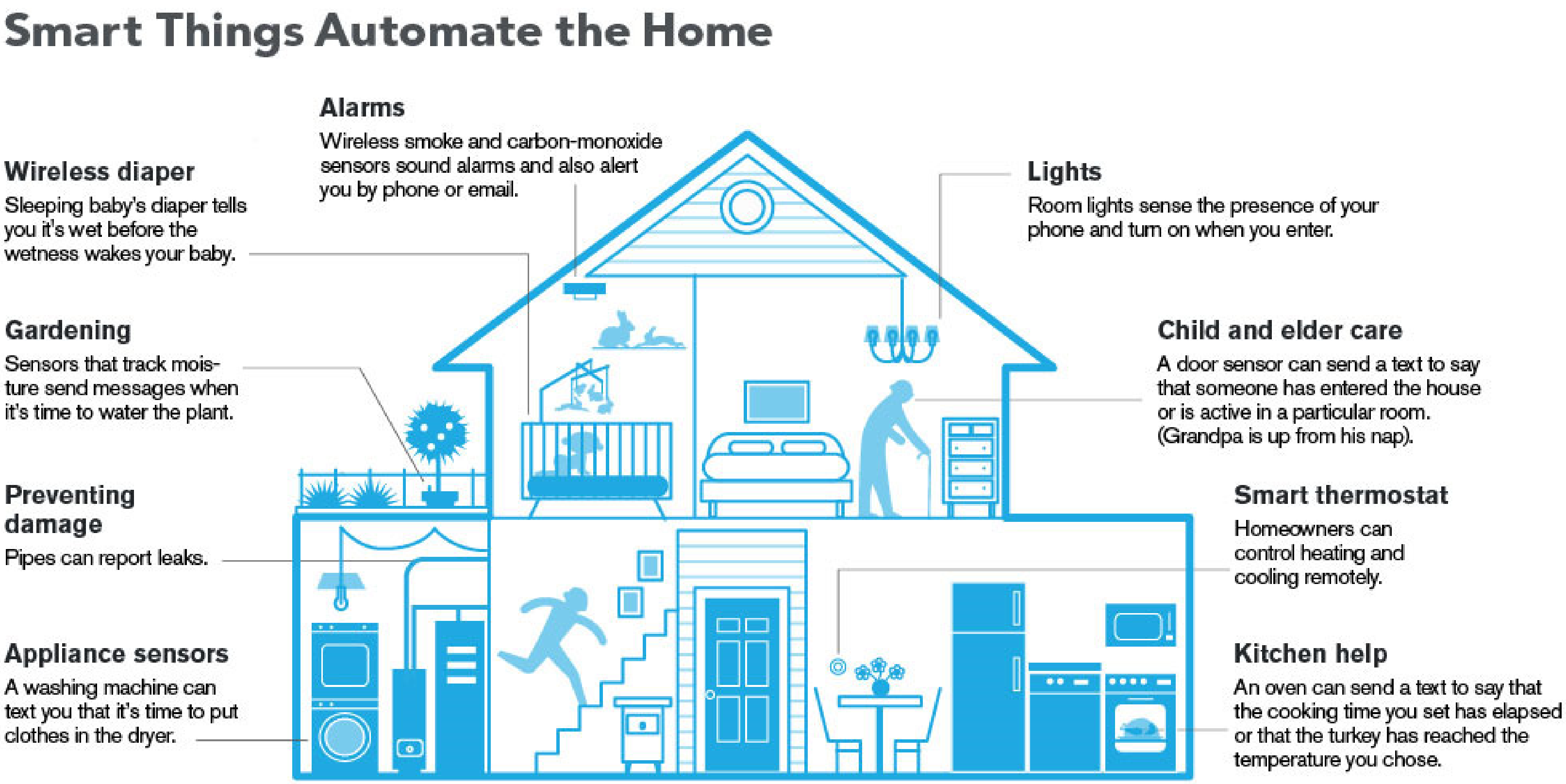
Connecting Things

Traditional

Connected

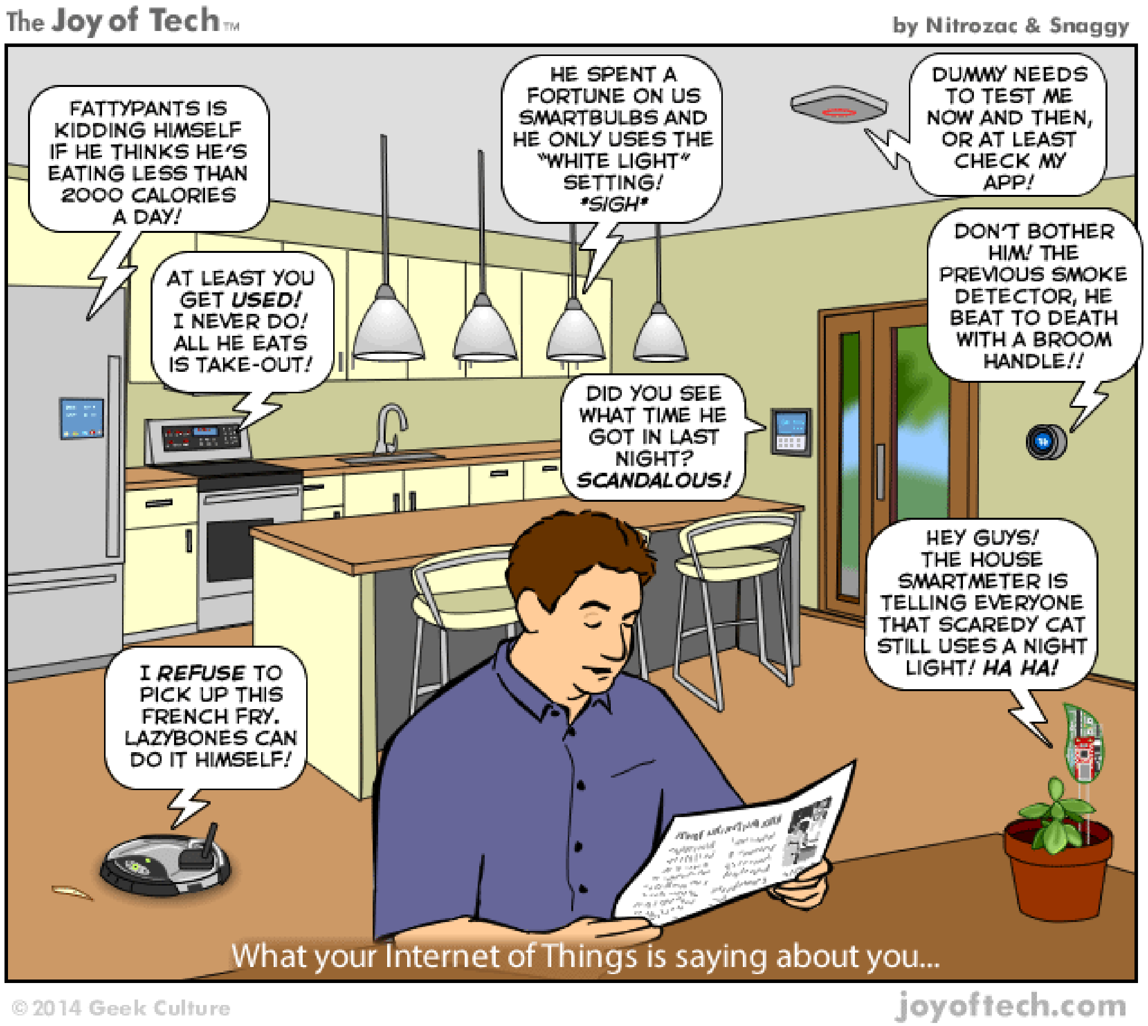
Source: Roberto Minerva, “From M2M to Virtual Continuum”, ICCE 2015, Las Vegas

Connecting Things

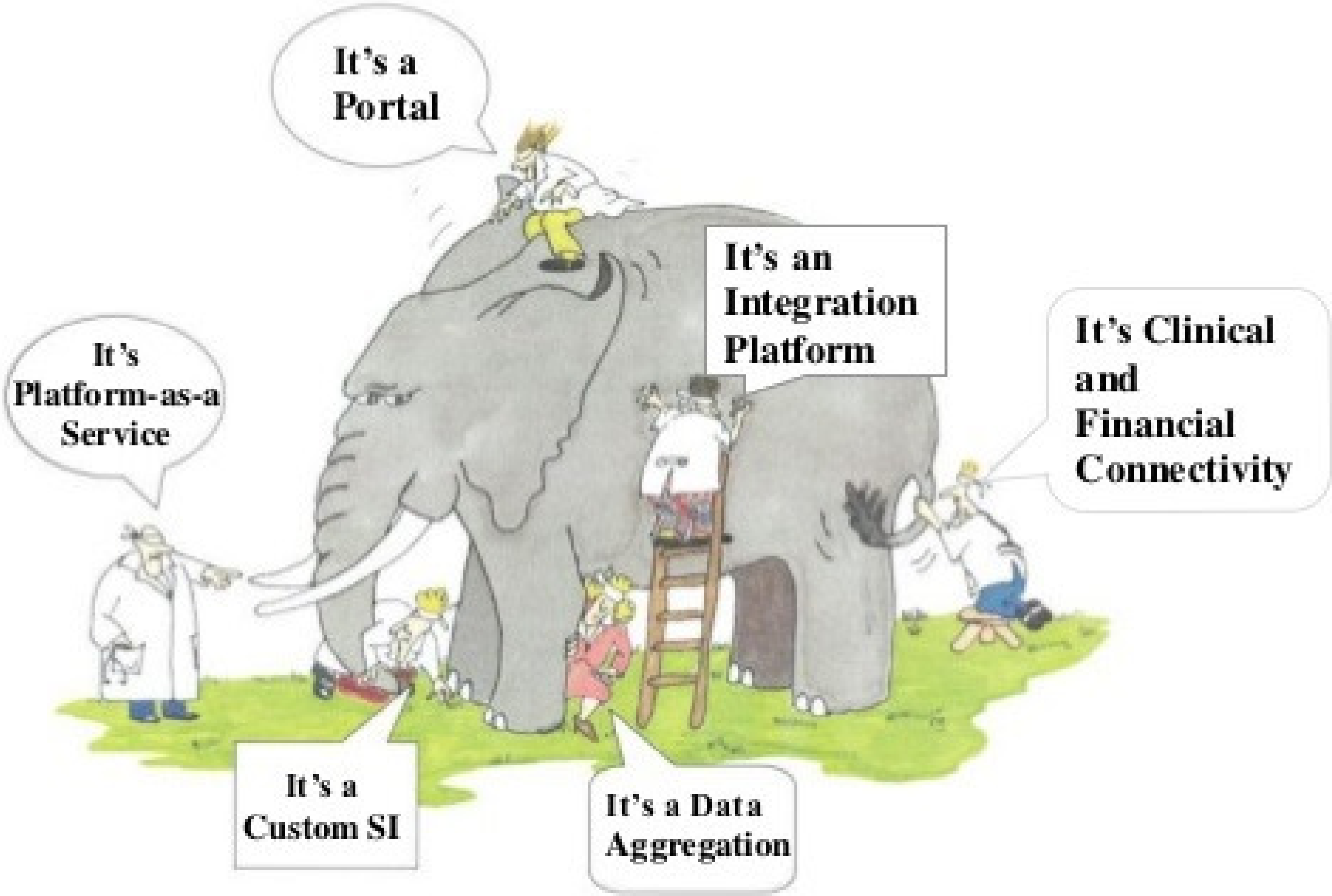


Source: market-intel.info

Sometime Soon…



What is IoT



Source: IDC Health Insights

M2M/IoT Definitions

IoT

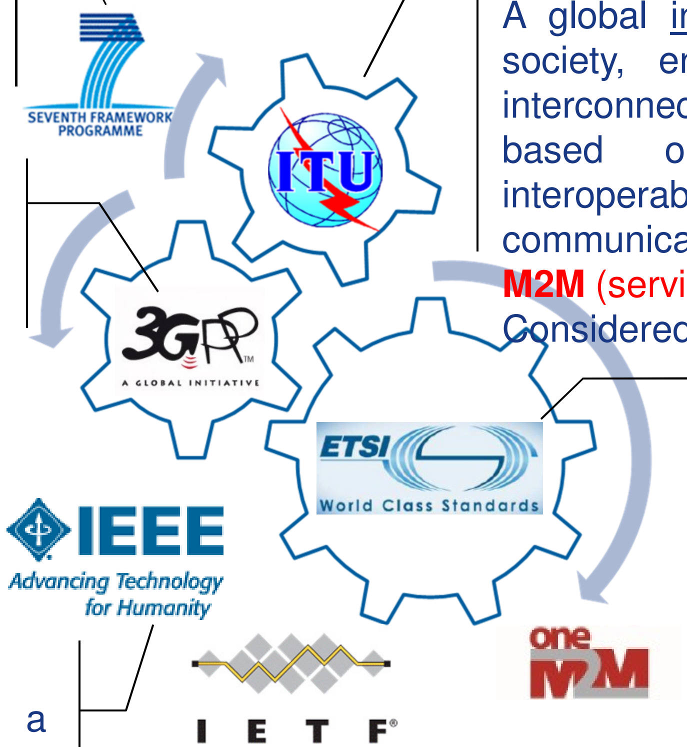
A global <u>network infrastructure</u>, linking physical and virtual objects through the exploitation of data capture and communication capabilities
[EU FP7 CASAGRAS]

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]

M2M Communications

- **On a very simple terms**
  - The communication among the physical things which do not need human intervention

Key M2M Elements

M2M Device

- Device capable of replying to request for data contained within those devices or capable of transmitting data autonomously.

M2M Area Network (Device Domain)

- Provide connectivity between M2M Devices and M2M Gateways, e.g. personal area network.

M2M Gateway

- Uses M2M capabilities to ensure M2M Devices inter-working and interconnection to the communication network.

M2M Communication Networks (Network Domain)

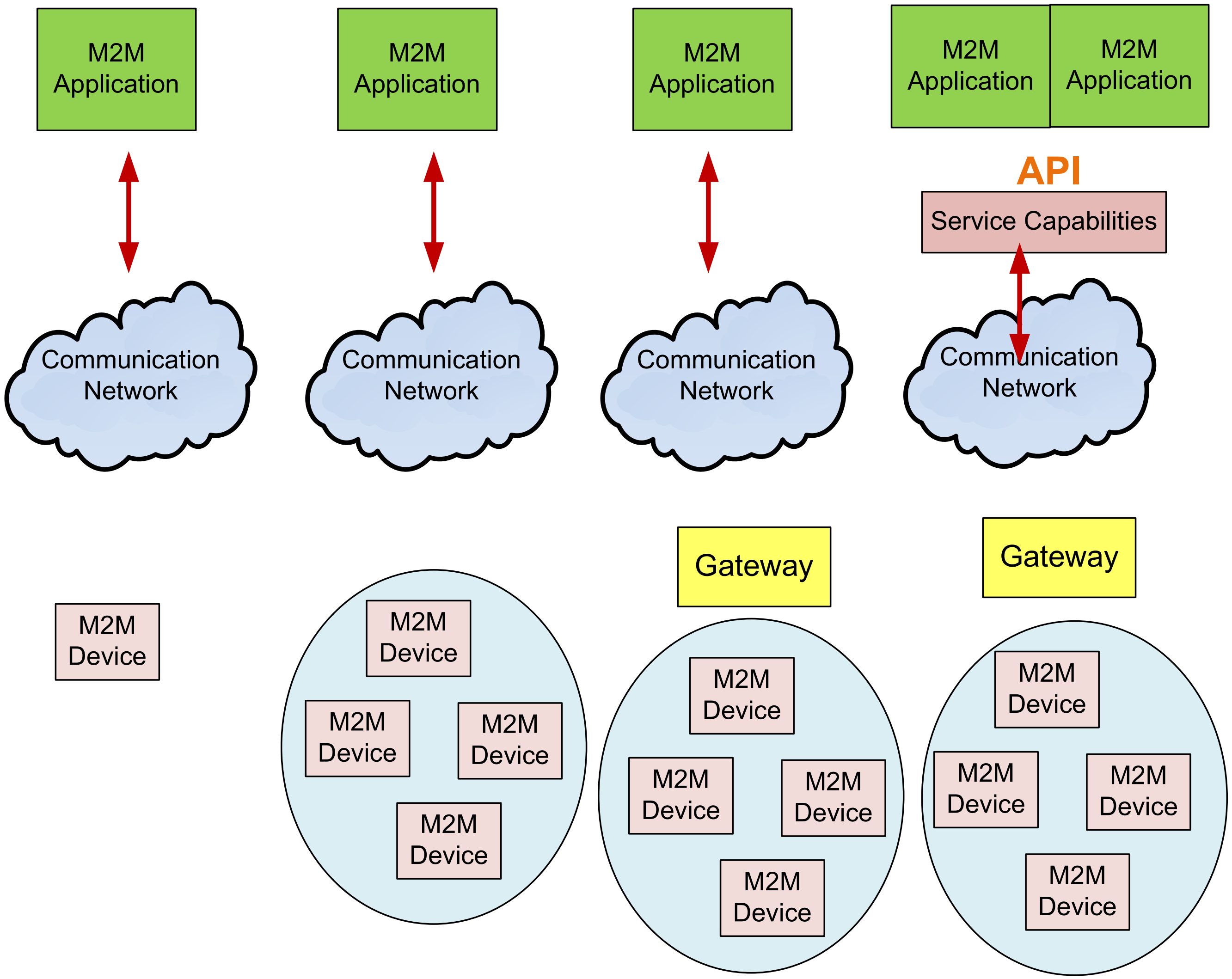
- Communications between the M2M Gateway(s) and M2M application(s), e.g. xDSL, LTE, WiMAX, and WLAN.

M2M Applications

- Contains the middleware layer where data goes through various application services and is used by the specific business-processing engines.

Source: ETSI TC M2M Release 1

M2M Models



M2M Application
M2M Application
M2M Application
M2M Application
M2M Application
API
Service Capabilities
Communication Network
Communication Network
Communication Network
Communication Network
Gateway
Gateway
M2M Device
M2M Device
M2M Device
M2M Device
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M2M Device

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**

M2M – Market

Market	Description	Applications
Security	• Abnormal situation detection • Homeland/industry security	• Surveillance • Alert
Energy	• Remote collect data on flow rate, pressure, temperature	• AMR (Automatic Meter Reading)
Transport	• Tracking • Telematics services • ITS	• Fleet Management • Toll payment • Emergency alerts
Commerce	• Monetics	• E-payment • Virtual wallet solution
Automotive	• Adapted insurance rate • Telematics services	• "Pay as you drive" • Remote diagnostic
Home Automation	• Remote Monitoring , Managing	• Surveillance • Energy Management
Healthcare	• Patients monitoring, Curing	• Blood pressure check

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. [1]
- 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 [1a]

[1] http://www.alcatel-lucent.com/eco/low-carbon/travel_less.html
[1a] http://smartcities.ieee.org/

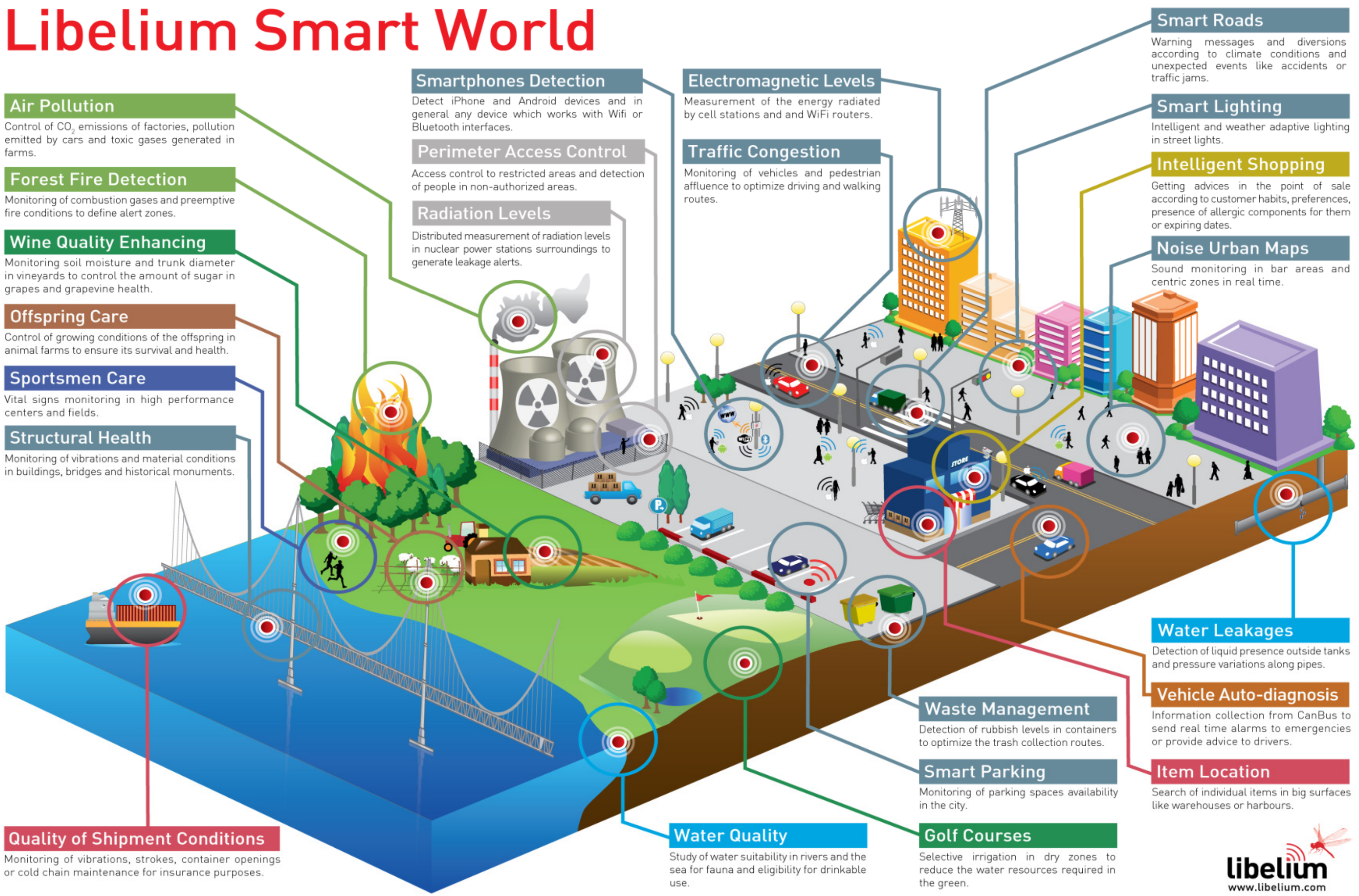
Smart City

- 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



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

Roadmap

- Introduction
- Three Fundamental Operations
- Uniform Data Exchange with Objects
- Managing Connected Objects
- Sensor Virtualization
- M2M Gateway
- M2M Data Processing for Smart City Applications
- Mobile Application Development for IoT
- IoT Architecture
- oneM2M Standardization

Three Fundamental Operations

- **Collection of data**
  - Sensor oriented collection
- **Processing the data**
  - Semantic reasoning
- **Control**
  - Sensing based 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
- **Processing**
  - Utilizing semantic web technologies
  - Why not do it in an M2M gateway?
- **Standardization efforts**
  - Efforts by oneM2M
  - EURECOM contribution to oneM2M MAS (WG5)

Roadmap

- **Introduction**
- **Three Fundamental Operations**
- **Uniform Data Exchange with Objects**
  - Sensor Markup Language (SenML)
  - SenML extensions for actuators
- **Managing Connected Objects**
- **Sensor Virtualization**
- **M2M Gateway**
- **M2M Data Processing for Smart City Applications**
- **Mobile Application Development for IoT**
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- **oneM2M Standardization**

Uniform data exchange with objects

- **Requirement from a smart city perspective**
  - Heterogeneous objects
  - Can not have one API per object to exchange data
    - Need a uniform data exchange mechanism
  - Sensor measurement alone has less value
    - Need additional 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/XML/EXI.**
- **Server can parse several SenML metadata at the same time**

Source: Media Types for Sensor Markup Language (SENML) draft-jennings-senml-10

JSON implementation


```
{"e":[
      { "n": "temperature", "v": 27.2, "u": "Cel" },
      { "n": "humidity", "v": 80, "u": "%RH" }],
 "bn": "http://[2001:db8::2]/",
 "bt": 1320078429,
 "ver": 1
}
```

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**
- **French Research Project – WL-Box 4G**

[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* , vol., no., pp.1,6, 21-24 April 2014

SenML Extensions

- **An Interface Definition:**
  - It is necessary to distinguish between a sensor and an actuator.
- **Name of actuator**
- **Type of actuator**
- **Allowed range of values**
  - Range of values in order to control the actuators.
  - May be continuous (e.g. for a motor) or discreet values (e.g. 0/1 for LED).
- **Unit**
- **Capabilities**
  - It signifies whether an actuator is smart or legacy endpoint.
  - In case of a legacy actuator, another M2M device must translate the instructions to machine executable form.

SenML Extensions

- **Location**
  - It signifies the type of actuator location and can be denoted by GPS co-ordinates, XY location or semantic location (e.g. Room 313 or Building A).
- **Destination**
  - It denotes the URI of the actuator and the control commands are sent to this URI from the clients.

Requesting actuator update

Req: HTTP PUT → proxyout1.mydomain.com/dev1.mynetwork.net

```
<senml bn=urn:dev:mac:6399877>
<e n="temp" t="0" v="20" u="Cel" xbif="a"/>
</senml>
```

Resp: 204 No Content.

Roadmap

- Introduction
- Three Fundamental Operations
- Uniform Data Exchange with Objects
- Managing Connected Objects
  - Management framework
- Sensor Virtualization
- M2M Gateway
- M2M Data Processing for Smart City Applications
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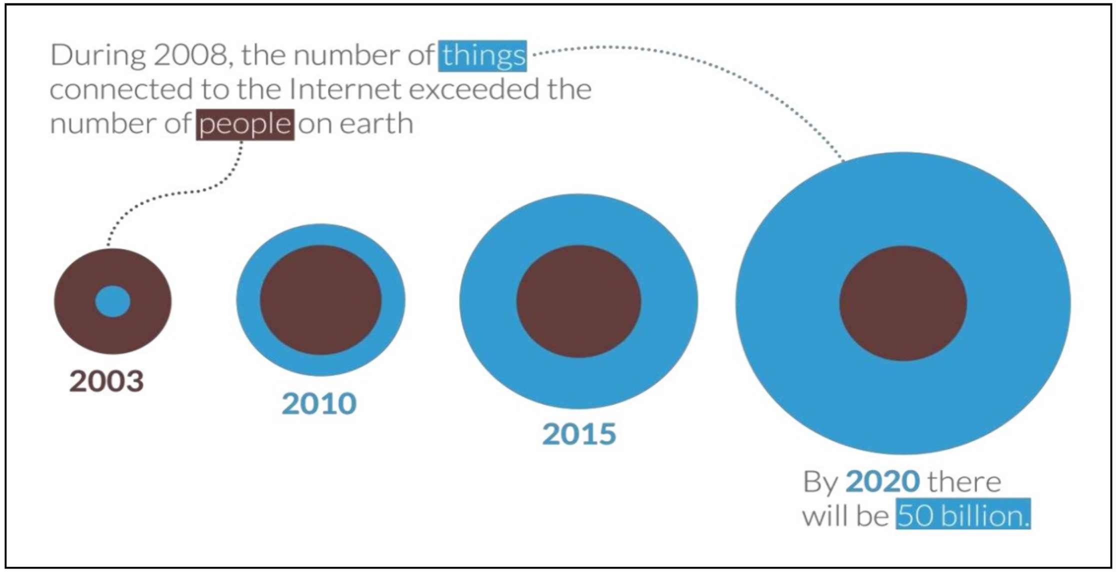
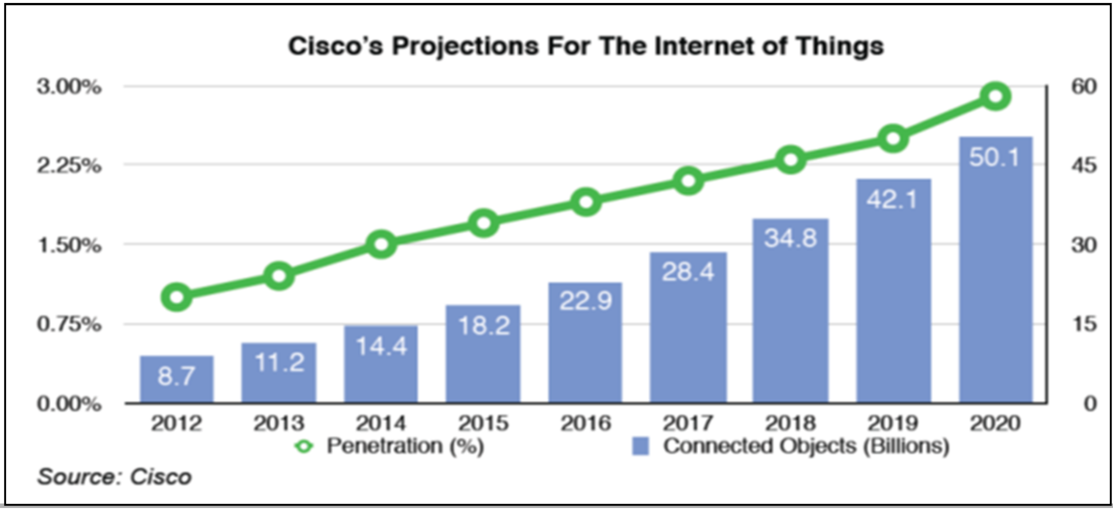
50 Billion Connected Objects





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
- **Work under progress**
  - Automatic discovery of objects

[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.

Two Types of Objects to Manage

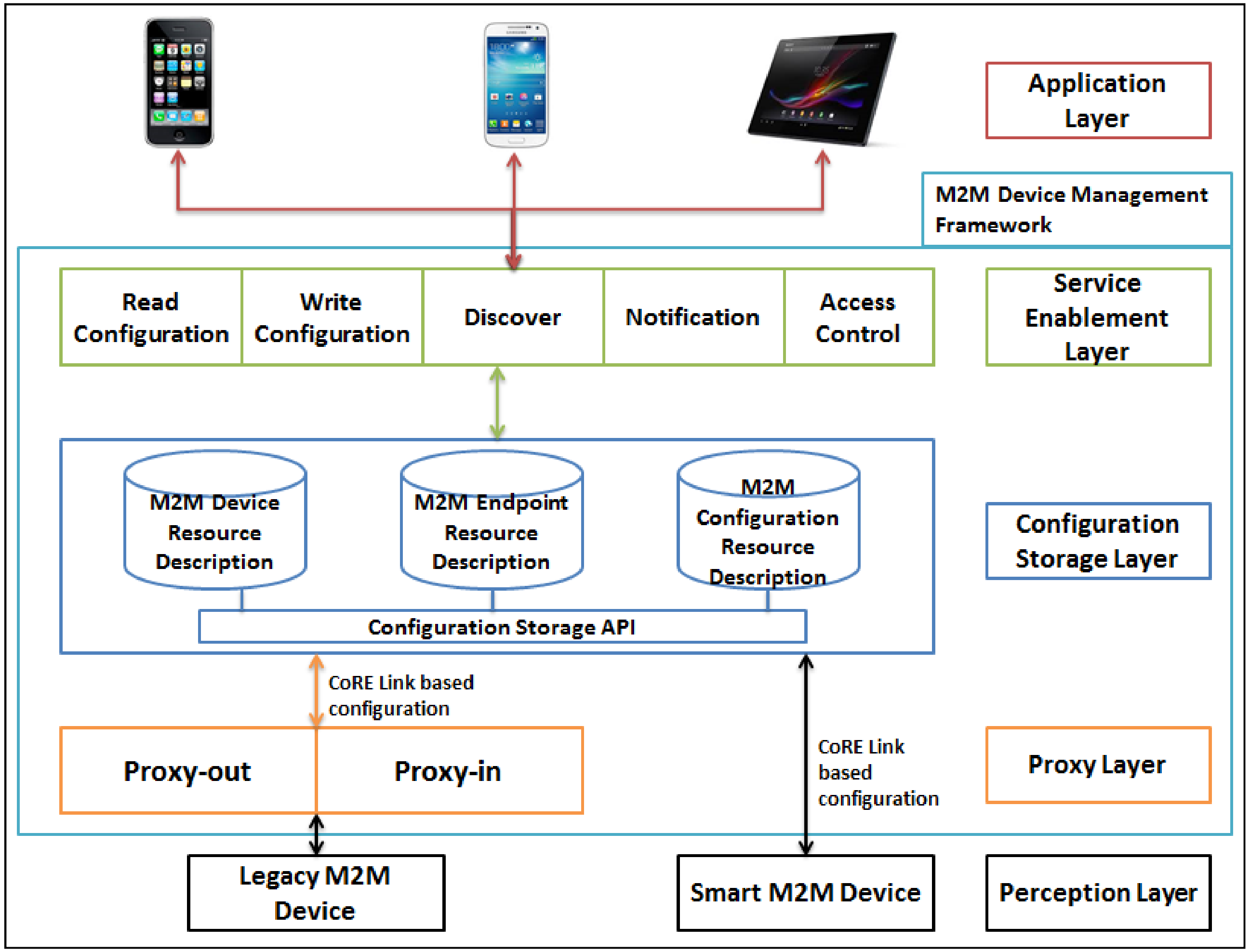
- **Smart object**
  - Interface of this device allows RESTful interaction.
- **Legacy object**
  - Does not allow RESTful interaction.
    - Sends sensor measurement to a gateway.
    - Communicates over Modbus, Bluetooth etc.
    - The gateway interacts with rest of the IoT based systems

Interacting with Legacy Objects

- **Legacy objects can not be replaced overnight**
- **Including them into IoT based systems require [6]**
  - An intermediate gateway or
  - A proxy of the legacy object
- **This is to make the overall system aware of the intelligence of objects**

[6] Datta, S.K.; Bonnet, C.; Nikaein, N., "An IoT gateway centric architecture to provide novel M2M services," *Internet of Things (WF-IoT), 2014 IEEE World Forum on* , vol., no., pp.514,519, 6-8 March 2014

Connected Object Management Framework



Source: Datta, Soumya Kanti; Bonnet, Christian, "A Lightweight Framework for Efficient M2M Device Management in oneM2M Architecture," IEEE ISSNIP 2015, 7-9 April 2015. [Accepted for presentation]

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.

Management Framework Deployment Scenarios

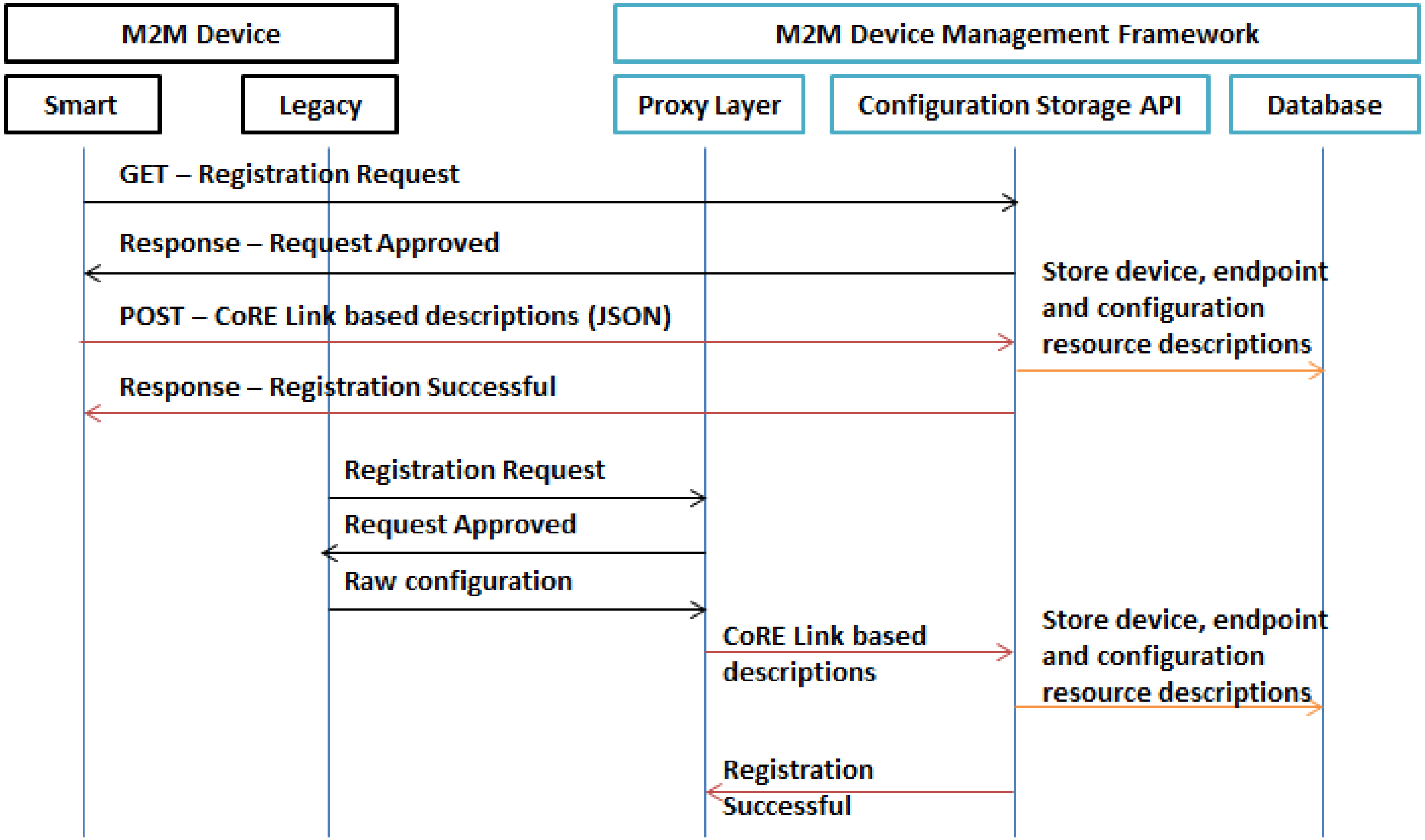
- **Cloud based**
  - For huge volume of objects deployed in a smart city
- **M2M gateway based**
  - Large enterprise consisting of hundreds of smart and legacy objects
  - Smart home with dozens of such objects
- **Mobile application based**
  - Smart home with limited number of objects can utilize a smartphone/tablet to manage them
  - Interaction over a personal area network
  - Needs ultra lightweight implementation of the framework

Different Phases of Operation

- **Registration phase**
  - Registration of objects to the framework
- **Service enablement phase**
  - Allows end users to discover configurations
  - Configuration(s) update
  - End user notification
- **Un-registration phase**

Source: Datta, Soumya Kanti; Bonnet, Christian, “A Lightweight Framework for Efficient M2M Device Management in oneM2M Architecture," IEEE ISSNIP 2015, 7-9 April 2015. [Accepted for presentation]

Registration Phase



- **Questions???**

Roadmap

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- Three Fundamental Operations
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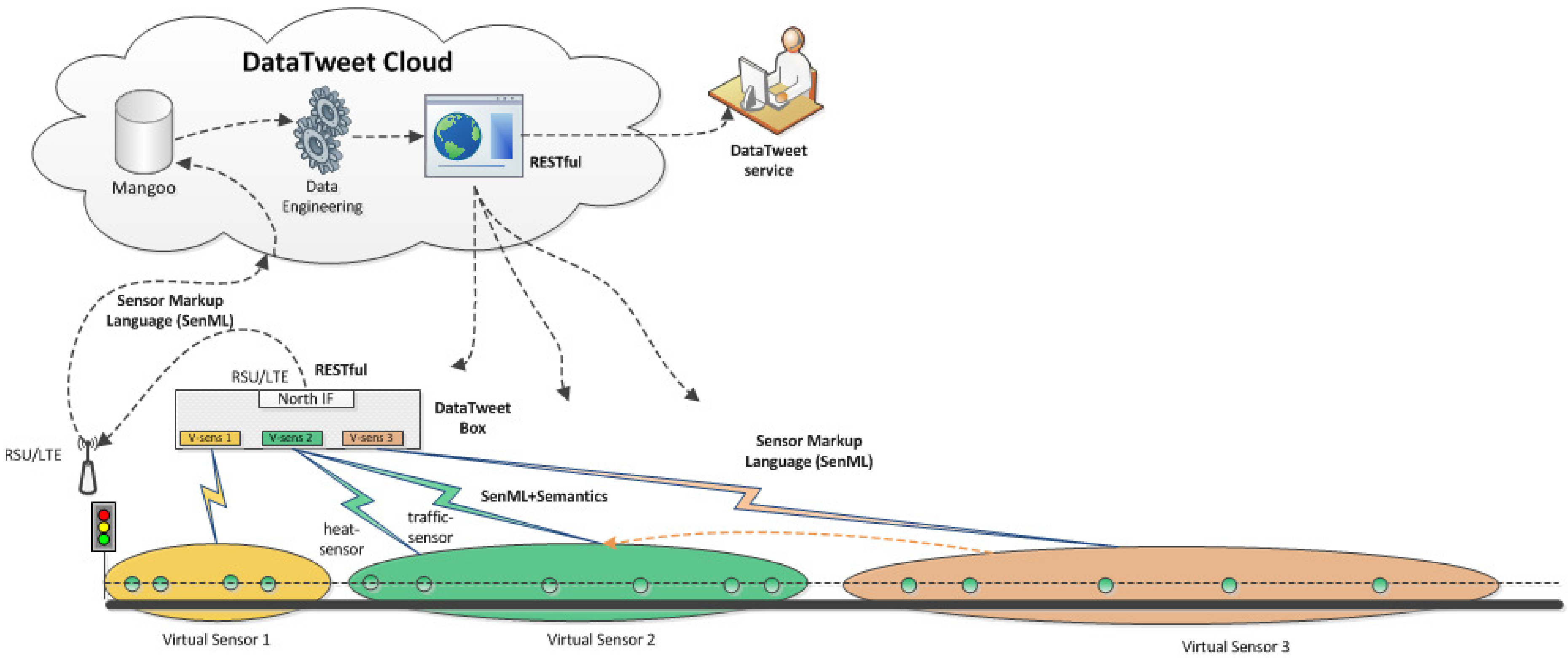
Sensor Virtualization

- **When it is not possible to deploy real sensors**
  - Use virtual sensors to monitor the zone of interest
- **Scenario –**
  - Utilize the sensors in vehicles passing through a predefined geographical location
- **French Research Project – DataTweet**
  - Ongoing project

Sensor Virtualization



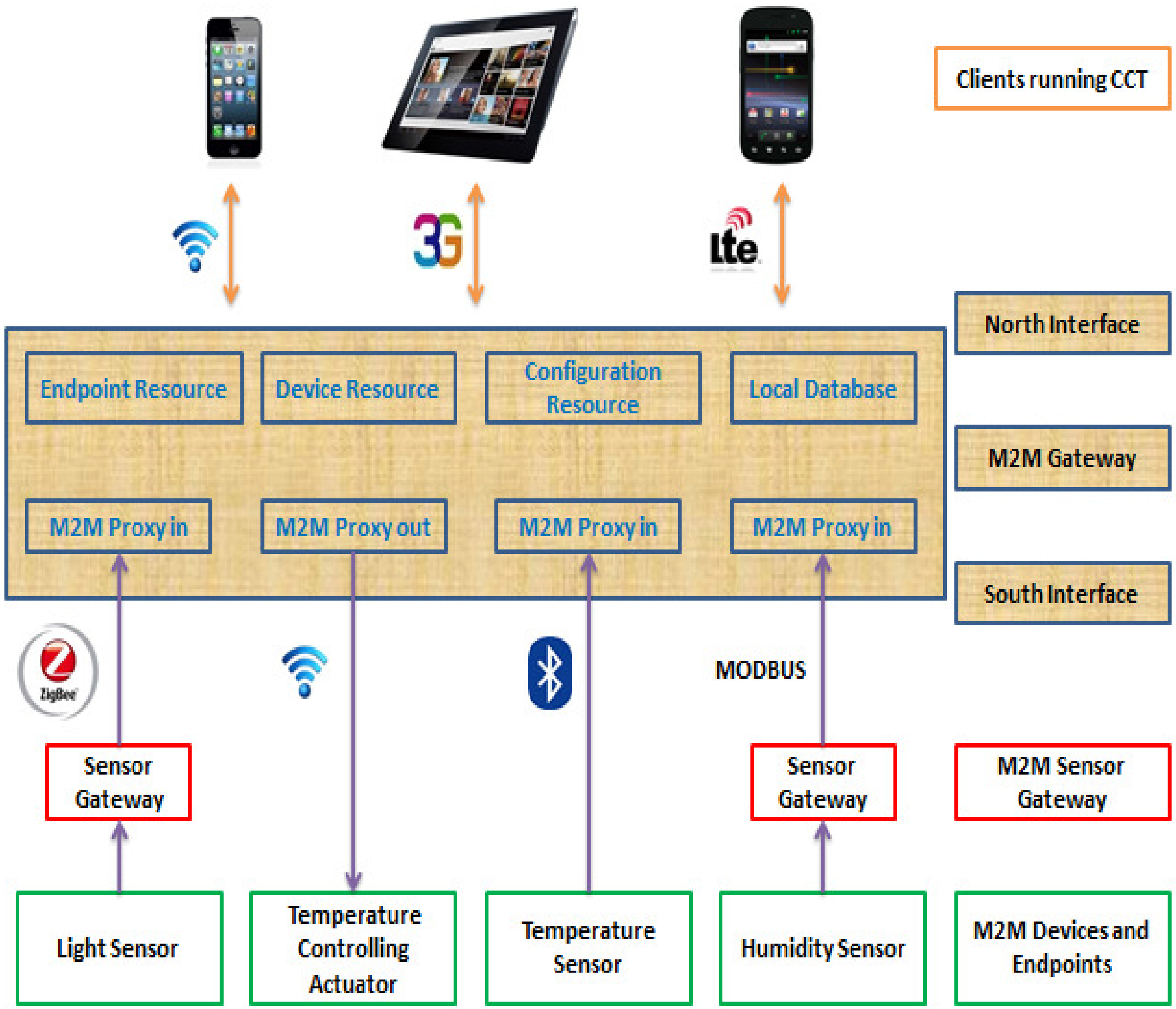
Roadmap

- **Introduction**
- **Three Fundamental Operations**
- **Uniform Data Exchange with Objects**
- **Managing Connected Objects**
- **Sensor Virtualization**
- **M2M Gateway**
  - Internal mechanisms
  - North and south interfaces
- **M2M Data Processing for Smart City Applications**
- **Mobile Application Development for IoT**
- **IoT Architecture**
- **oneM2M Standardization**

M2M Gateway

- **Backbone of our IoT architecture**
- **Designed and implemented as a web application based on REST paradigm**
- **Web services are categorised into two interfaces**
  - North
  - South

Deploying Scenario



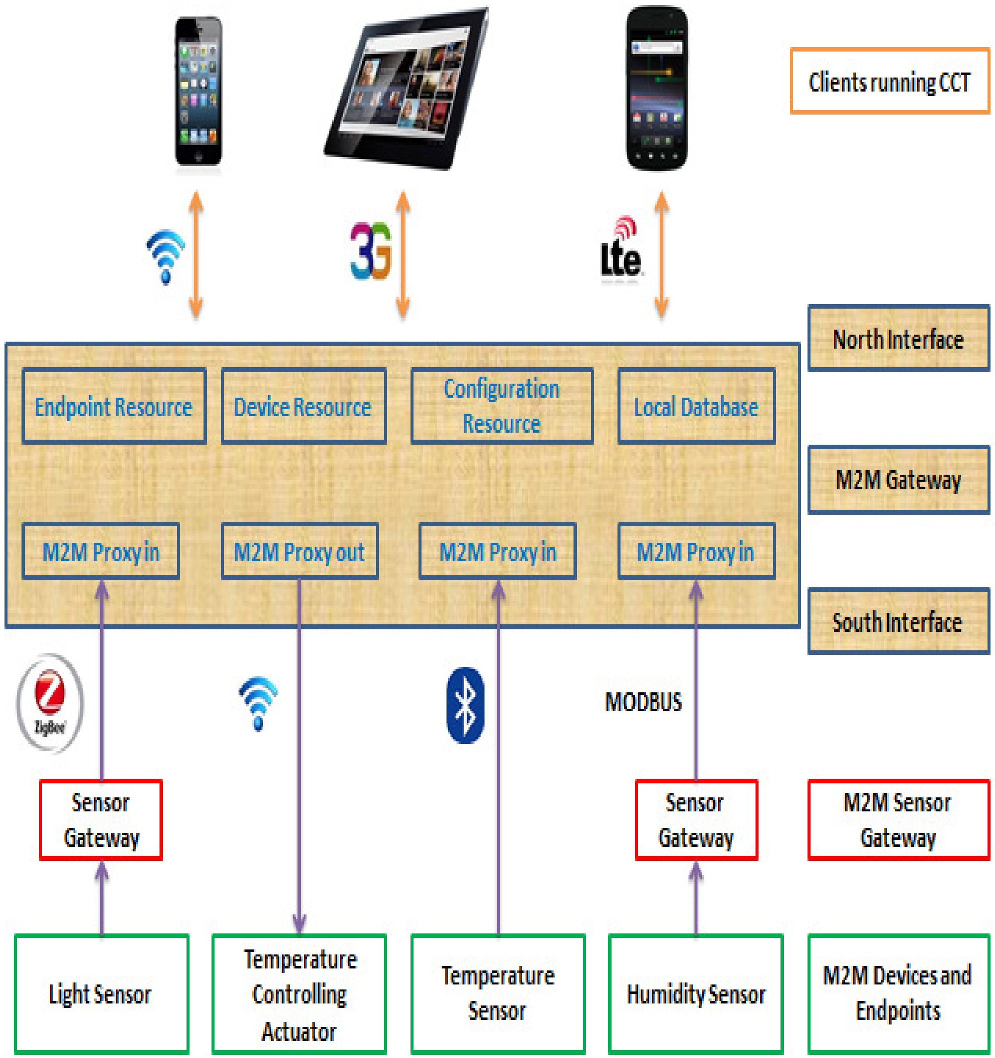
North Interface

- **Facilitates**
  - Object discovery, management, access control etc.
- **Clients do not have any information on the M2M devices and endpoints initially.**
- **Clients establish a connection to the gateway to retrieve a list of connected devices and endpoints.**
  - The list is maintained in a local database.
- **Addition or removal of devices and endpoints automatically updates the local database.**

North Interface

Reporting sensor metadata

- After discovery phase, client selects sensors.
- A GET request is sent to gateway to retrieve the metadata



South Interface

Proxy-in	Proxy-out
• Legacy M2M device is actually connected to a proxy-in which registers the device. • It facilitates real time interaction between the clients and legacy sensors. • Proxy-in collects sensor metadata.	• It links clients with actuators. • There is a protocol that translates the HTTP payload into a specific command which the legacy actuator will understand.

- **We can deploy objects & M2M gateway**
  - Interact in a standardized manner
  - Manage the objects
- **These objects generate data**
- **What can we do with the data**
  - How to get meaning out of data
  - Understand the context

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- **M2M Data Processing for Smart City Applications**
  - Semantic Reasoning
  - Machine to Machine Measurement Framework
- **Mobile Application Development for IoT**
- **IoT Architecture**
- **oneM2M Standardization**

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

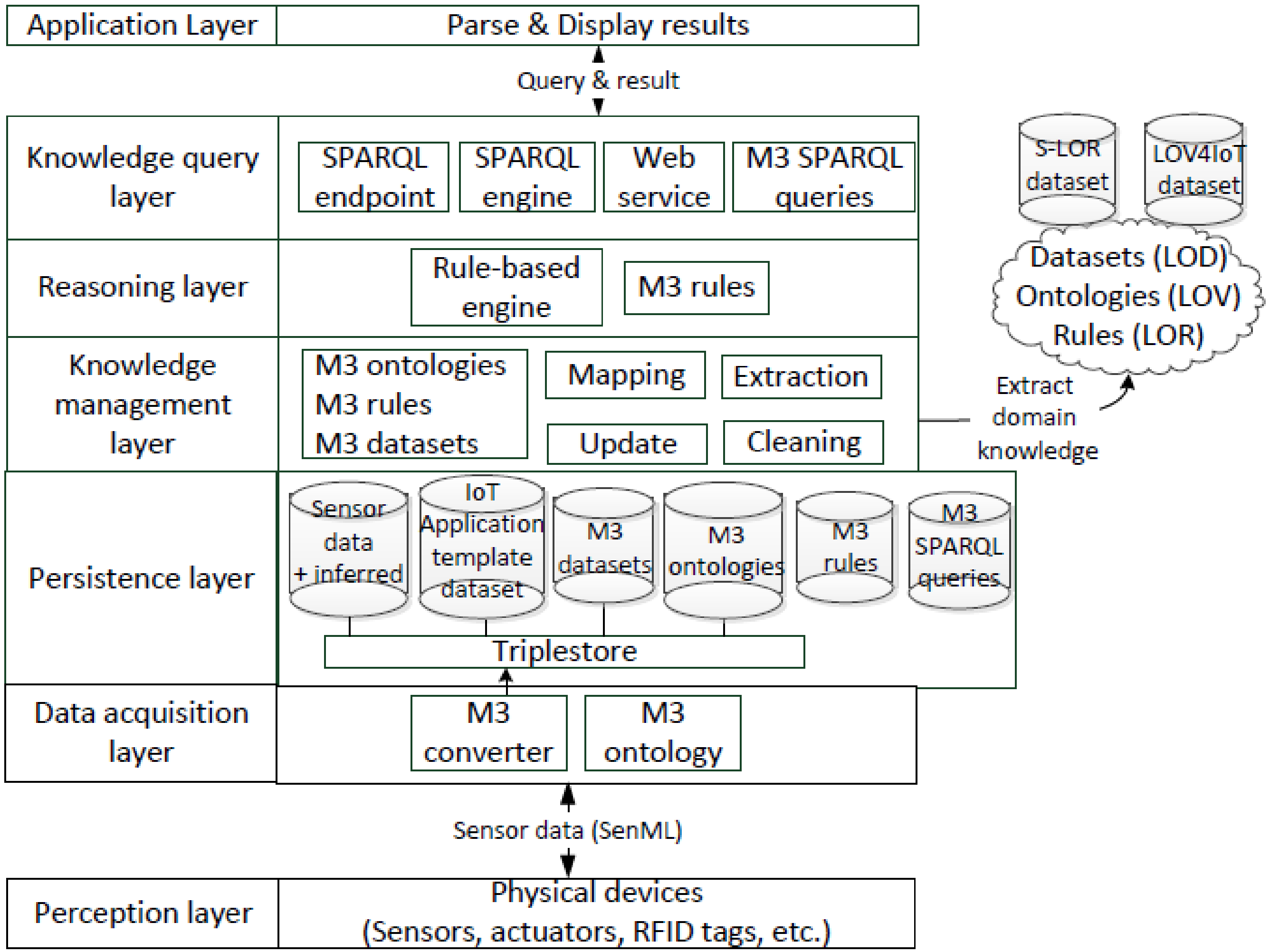
- **Use of semantic reasoning to enrich M2M data**
  - First step – SenML to add some side information
  - Second step – decorate the M2M data with additional semantic reasoning
- **Link the data with the meaning**
  - From the point of view of different domains

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

Architecture of M3 Framework



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**
  - This stores all the templates needed to build various kinds of applications for IoT.
  - Developed using Apache Jena framework.
- **Mobile application**
  - 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.

- **Questions???**

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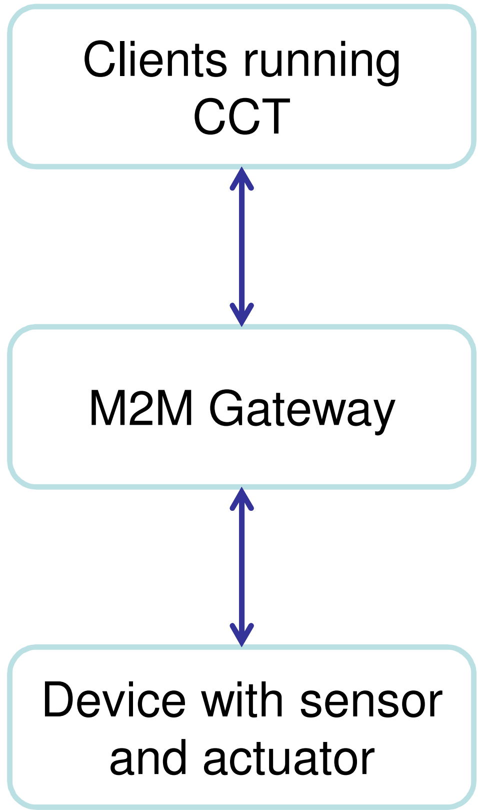
Introducing CCT: Connect and Control Things

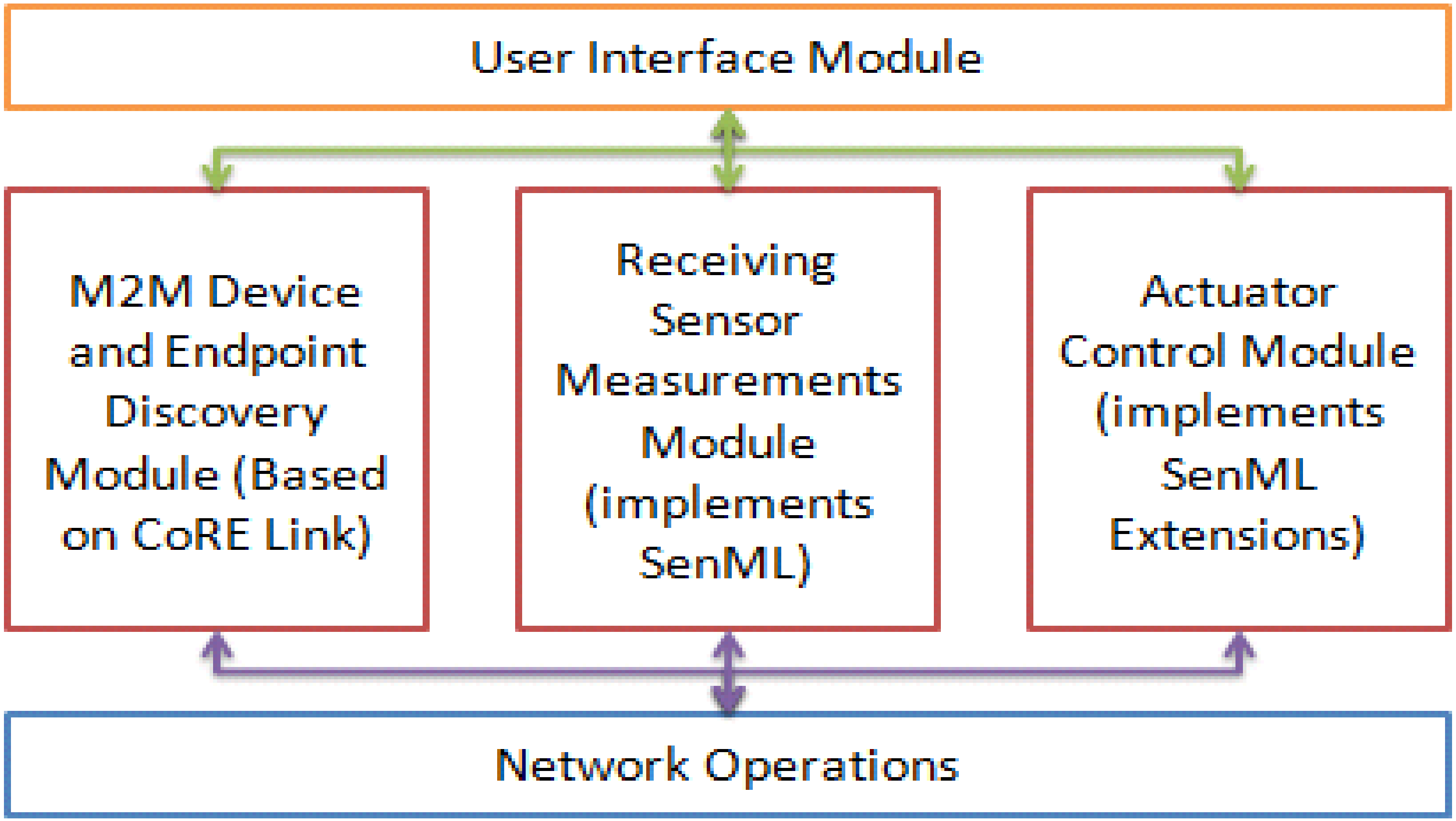
- **It enables real time interaction with connected objects**
- **One possible deployment scenario**
  - CCT interacts with the M2M devices via the M2M gateway.



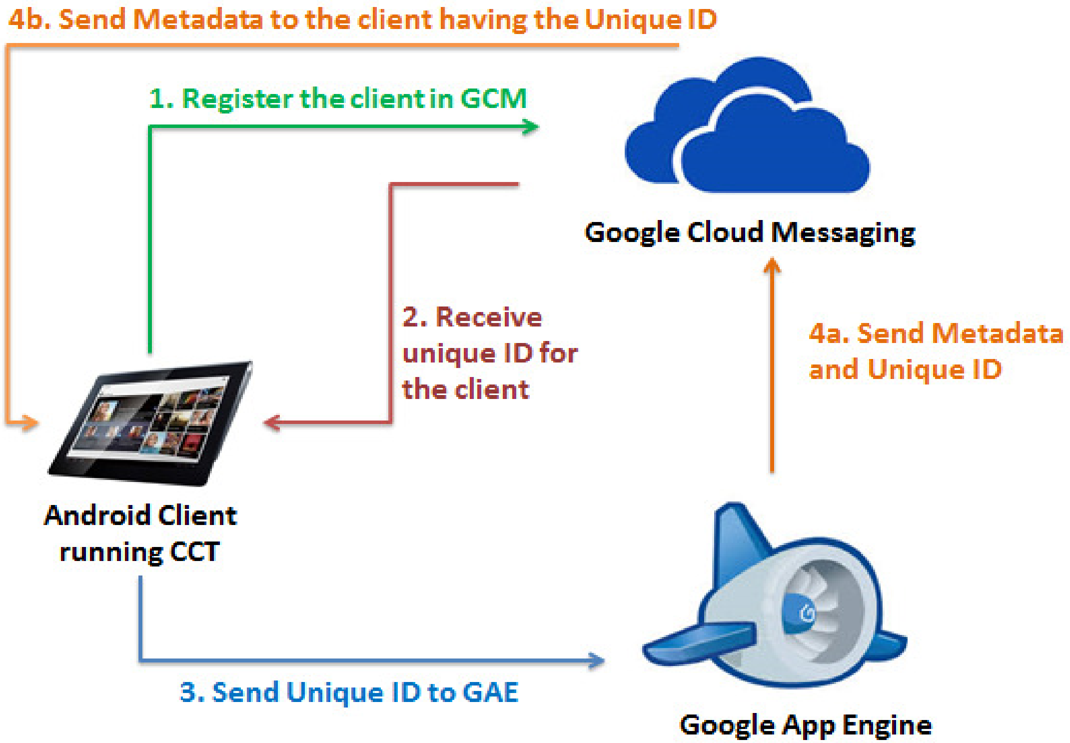
Functionalities

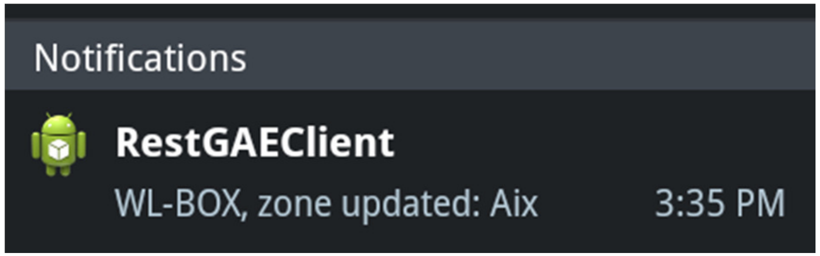
- **Dynamic discovery**
  - Devices and endpoints attached to the M2M gateway
- **Real time interaction**
- **Connecting to both smart and legacy things**
- **Subscription to receive push notifications**
- **SenML implementation**
- **Actuator control**
  - Sensing based actuation
  - SenML extensions

Software Architecture of CCT



PUSH Notification





Prototype Implementation

- **Connect and Control Things (CCT)**
  - Using cross platform tools PhoneGap 2.9.0 and JQuery Mobile 1.3.1.
  - Using Android SDK
- **Tested with real and simulated M2M devices and Endpoints**
- **Performance evaluation**
  - CPU loads
  - Power consumption

CPU Usage Results: PhoneGap

Android Device	Device and Endpoint Discovery	Parsing Sensor Values & Display	Actuation
Archos Tablet	32%	37%	4%
Nexus 5	41%	40%	8%
Nexus 7	35%	36%	3%

CPU Usage Results: Android SDK

Android Device	Device and Endpoint Discovery	Parsing Sensor Values & Display	Actuation
Samsung Galaxy S2	1%	1%	1%
Nexus 5	2%	1%	1%
Nexus 7	1%	1%	1%

Power Consumption Results: PhoneGap

- **Measured using Power Tutor**

Device	Power Consumption (mW)	
	Mobile Data	Wi-Fi
Archos Tablet	723	592
Nexus 5	819	718
Nexus 7 (Wi-Fi only)	--	479

Power Consumption Results: Android SDK

- **Measured using Power Tutor**

Device	Power Consumption (mW)	
	Mobile Data	Wi-Fi
Samsung Galaxy S2	277	214
Nexus 5	301	250
Nexus 7 (Wi-Fi only)	--	379

FI-WARE Generic Enablers

- **FI-WARE is an initiative that provides an open cloud-based infrastructure to**
  - Create and deliver cost-effective applications and services for future internet.
  - Build Generic Enablers (GE) for IoT service enablement.
- **Generic Enablers**
  - Allow physical things to be available, searchable, accessible and usable by high level applications.
  - Consists of a set of functionalities, APIs and interoperable interfaces compliant with open specifications.

IoT Gateway and Backend GEs

- **IoT Gateway GE**
  - Provides inter-networking, protocol conversion & network traffic optimization for IoT backend.
  - Implements CoRE Link based Description APIs.
  - Additional capabilities
    - Gateway based M2M device discovery.
    - Integration of legacy endpoints into the IoT ecosystem.
- **IoT Backend GE**
  - Typically addresses domain specific applications.
    - Enables Android application to provide M2M services to end-users.

Data/Context Management GEs

- **Generate M2M data**
  - Combine sensor measurement with additional data e.g. unit, type, id, name, version and timestamp to create metadata.
- **Collect context information**
  - Timestamp and location of M2M devices.
- **Generate new information**
  - Semantic reasoning on the M2M data to generate it's meaning.

Source: 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**

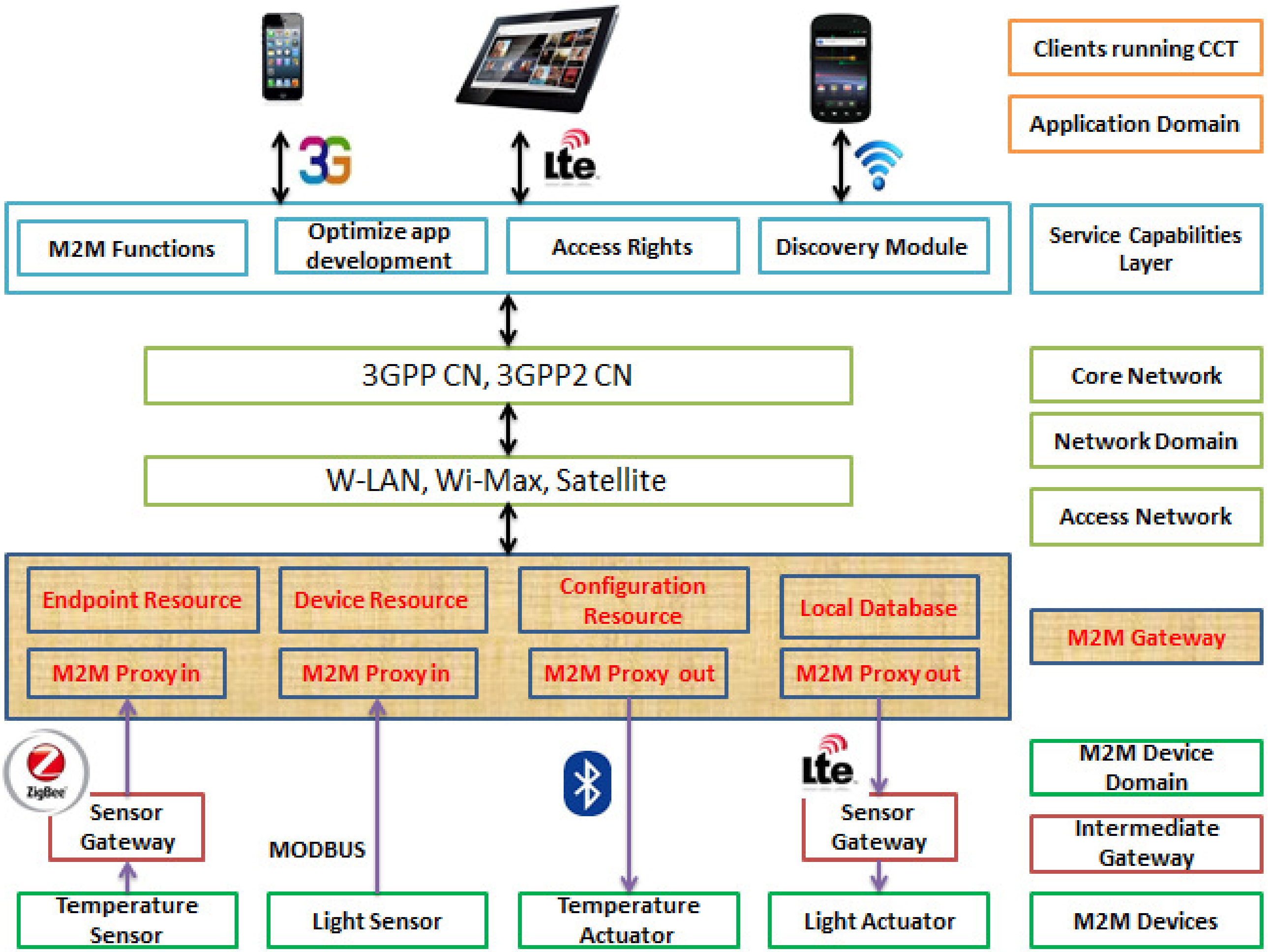
Interface to Networks and Devices (I2ND) Architecture GEs

- **Connected Device Interface (CDI) GE**
  - It equips the mobile clients with real time and remote access to M2M devices and endpoints.
  - Implemented as the mobile application “Connect and Control Things”.
- **Service Capability, Connectivity and Control (S3C) GE**
  - Runs in Service Capabilities Layer (SCL) and offers
    - Self-adaptive framework for battery and context aware mobile application development.
    - Framework to optimize the mobile application development using cross platform tools.
    - API for dynamic M2M device discovery.
    - Ecosystem of mobile applications to serve different IoT domains (**under development**)

Roadmap

- Introduction to Smart City
- Three Fundamental Operations
- Uniform Data Exchange with Objects
- Managing Connected Objects
- Sensor Virtualization
- M2M Data Processing for Smart City Applications
- Mobile Application Development for IoT
- IoT Architecture
- oneM2M Standardization

IoT Architecture



S.K. Datta, C. Bonnet, "Smart M2M gateway based architecture for M2M device and Endpoint management“, *IEEE Conference on Internet of Things 2014, Taipei, Taiwan, 1-3 Sept. 2014*

Discovery – Sensors, Applications, Services

- **How to discover**
  - Find out desired objects
  - M2M applications and services
- **Ongoing R/D activity**
  - DataTweet Project

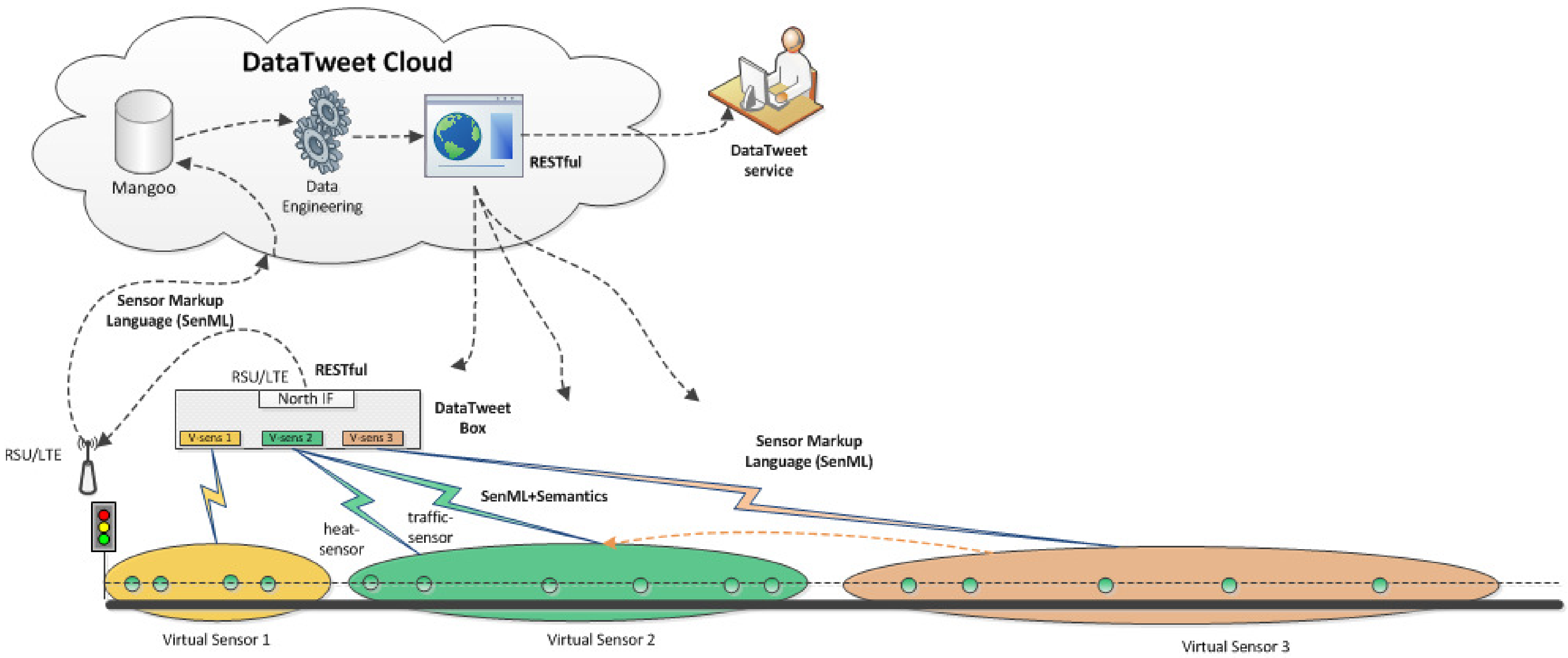
Discovery requirements

- **Scalability**
  - tackles the exponential growth in physical devices
- **Dynamic**
  - to take care of high mobility of such devices
- **Payload size**
  - Lightweight, as such data will be processed by constrained devices
- **Support multiple devices and services discovery**
- **RESTful interfaces**
  - To be compliant with current IoT trends in ETSI, oneM2M
- **Support several technologies**
  - Protocols – MQTT, CoAP, 6LowPAN etc.
  - Transmission technology – BLE, Zigbee, IEEE 802.11p (WAVE) etc.
- **Compliant with ETSI M2M architecture, oneM2M**

Discovery

- **Hierarchy based**
  - Query a well-known entry point Cloud
  - Search database containing the descriptions
    - M2M devices (sensors), M2M gateways
    - M2M services associated with the devices
    - Based on context awareness and geo-location
  - Return the result
- **Peer-to-peer based**
  - An M2M gateway queries all neighbouring gateways to the desired M2M device and service
    - Based on geo-location

Hierarchy Based Discovery



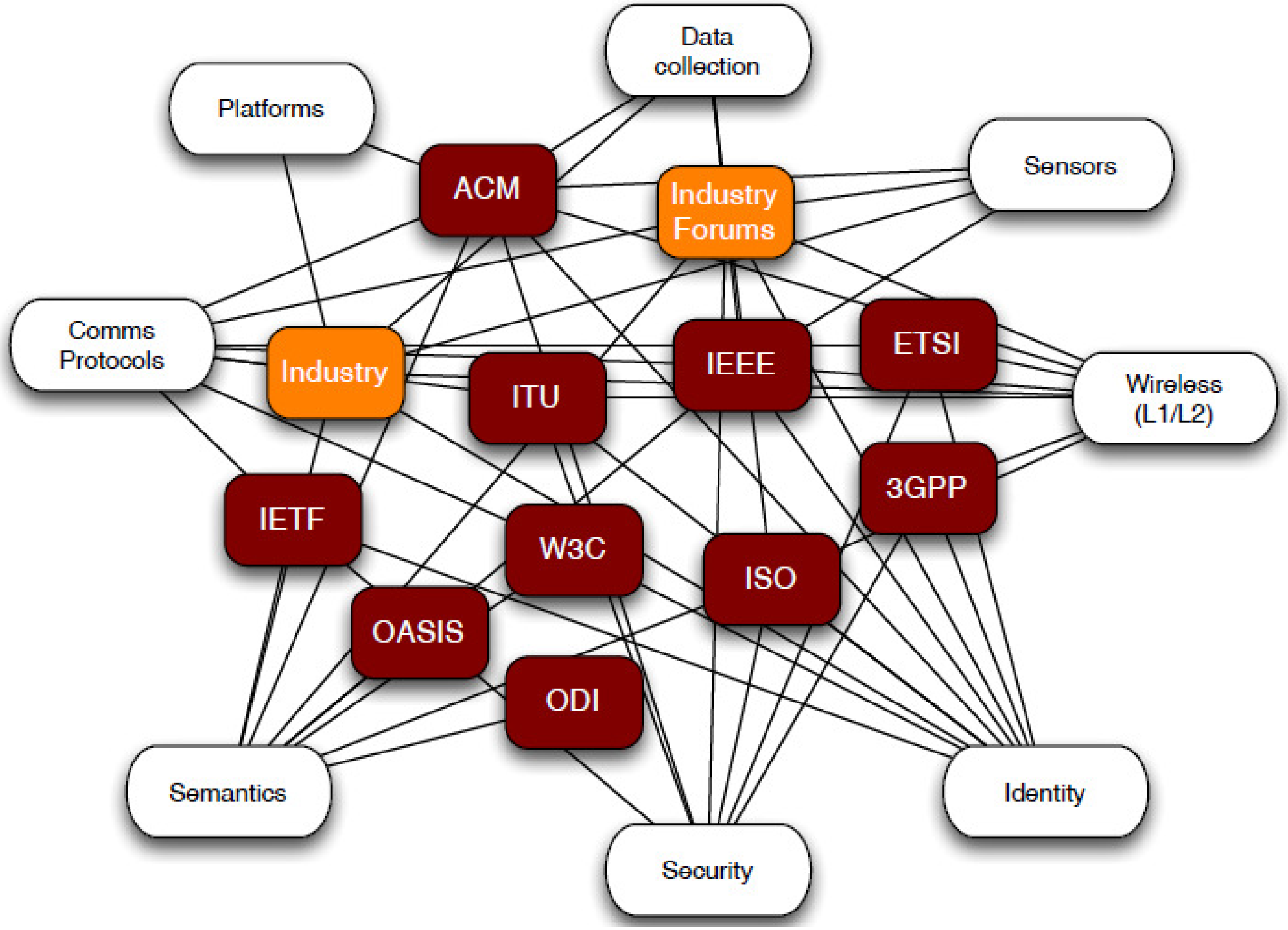
Search Engine

- **Need to implement a search engine which provides**
  - Query facility
  - Filtering of resources
    - Resource types
    - Geo-location criteria
  - Advertisement of M2M devices and services

Roadmap

- **Introduction to Smart City**
- **Three Fundamental Operations**
- **Uniform Data Exchange with Objects**
- **Managing Connected Objects**
- **Sensor Virtualization**
- **M2M Data Processing for Smart City Applications**
- **Mobile Application Development for IoT**
- **IoT Architecture**
- **oneM2M Standardization**

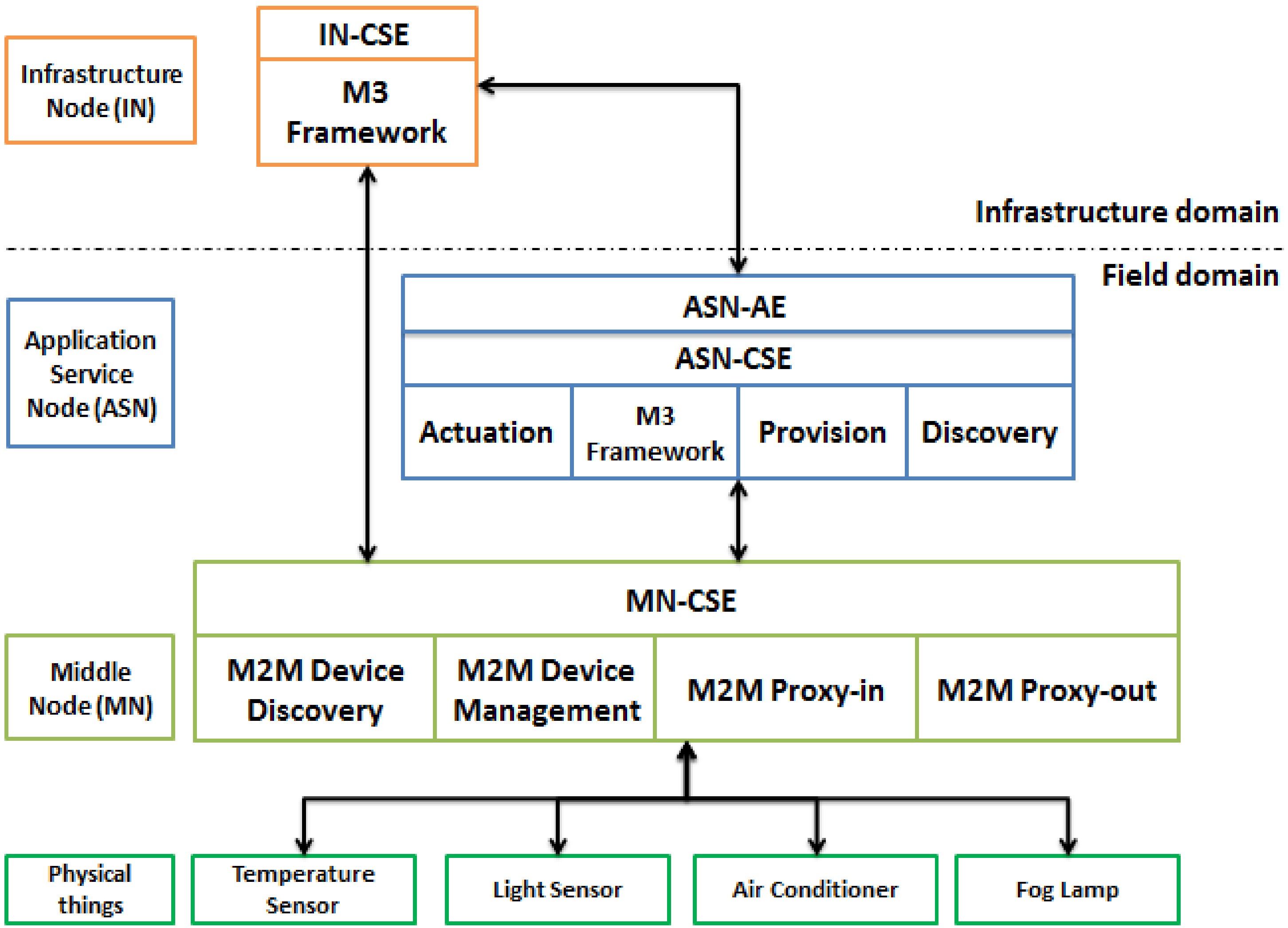
IoT Standardization Activities



IoT Standardization Activities

- IEEE STANDARDS ASSOCIATION
- ALLSEEN ALLIANCE
- industrial internet CONSORTIUM
- HomeKit
- ITU
- OPEN INTERCONNECT CONSORTIUM
- ETSI World Class Standards
- ipso Alliance
- oneM2M

General oneM2M Architecture



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 WoT, ETSI M2M, oneM2M, W3C SSN Ontology) lack [8]**
  - 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.

[8] 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.**

First Part over

- **Shading lights on some specific points**
  - Uniform data exchange with Sensor Markup Language
  - A framework to manage both smart and legacy objects
  - Sensor virtualization
  - M2M data processing using semantic web technologies
  - Android application for IoT
- **Any Questions???**

Issues not discussed in the tutorial

- **Low power**
  - Low power sensors & communication protocols
- **Interoperability**
- **Privacy, security and trust**
- **Global access**
  - Naming, announcement
- **Ubiquity**
  - Mobility, service continuity
- **M2M data management**
  - Data life cycle
- **Consumer centric IoT application**
- **FI-WARE Generic Enablers**

IEEE CE Society Future Directions on IoT

- **Encouraging**
  - Creating an ecosystem with consumers at the core
  - Developing consumer centric IoT applications
- **Past activities**
  - Special session on consumer centric IoT at IEEE GCCE 2014, Japan
  - Panel discussion at ICCE 2015, Las Vegas
- **Planned activities for 2015**
  - More special sessions at ISCE 2015, ICCE-Berlin 2015, GCCE 2015
  - Panel discussion on "**Humanitarian aspects of IoT**" in GHTC 2015, Seattle
  - Articles for CE Magazine
  - Summer school on IoT in August, 2015
  - White paper on consumer centric IoT

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

- **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

- **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

- **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
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- 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
  - Smart water project
  - IoT based pollution control
- **Conclusion**

IoT Based Waste Collection

Sensors deployed in recycling containers monitor waste levels in real time, send alert, and identify most appropriate collection method based on volume and waste type.

Benefits include:

- Waste collection consumes less cost and carbon
- Reduced fire/safety risk
- New contracts/SLAs can be defined

Source: Cisco

Smart Water Project

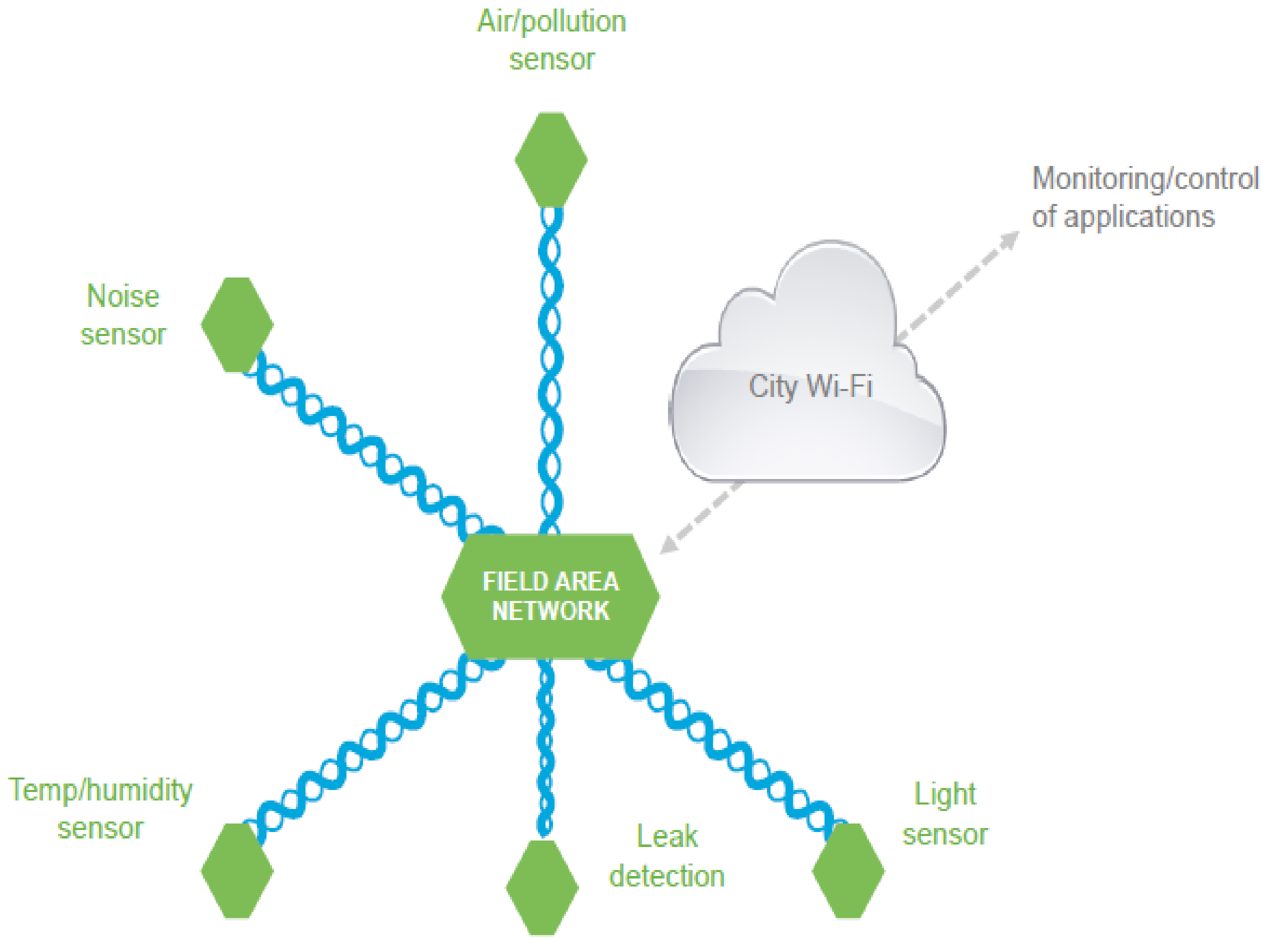
- **Objectives**
  - Leakage detection & demand forecasting
  - Water quality management
  - Automatic flow management
  - Providing high availability
- **Operational flow**
  - Deploying sensor to gather real time data
  - Monitor & process sensor data to detect leakage
  - Ability to control the flow based on demand forecasting

IoT Based Pollution Management

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

Benefits include:

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



Source: Cisco

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 manufacturers**

Other R/D Activities

- Benchmarking IoT deployments in a smart city
- Heat and electricity management
- Sustainable smart city
- Open source information framework
- Participatory sensing & role of end-users
- Cloud based IoT systems for smart city

Second Part

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

Second Part Complete

- **Discussion**
  - Smart city challenges
  - Specific IoT based solutions
  - Inhibitors

Thank you!

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