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Connected Car as an IoT Service

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Roadmap

- Introduction
- Challenges
- Uniform Data Exchange
- Management & Discovery of Vehicular Resources
- Data Processing
- IoT Architecture & Operational Phases
- Conclusion

Connected Car

- **Equipped with Internet access**
- **Has computing capabilities and on-board resources (sensors and actuators)**
- **Connect to devices, networks and services external to the car**
  - Other cars, infrastructures etc.

Connected Car Ecosystem

CB INSIGHTS

www.cbinsights.com

History - Two Parallel Ecosystems

- **Automotive [1]**
  - Auto 1.0
  - Auto 2.0
  - Auto 2.5
  - Auto 3.0 🡐 Present evolution
  - Auto 4.0
- **Internet of Things**
  - This is not new as you may thing

[1] The automotive industry as a digital business, available at - http://www.ntti3.com/wp-content/uploads/Automotive_as_a_Digital_Business_V1.03-1.pdf

Automotive Industry

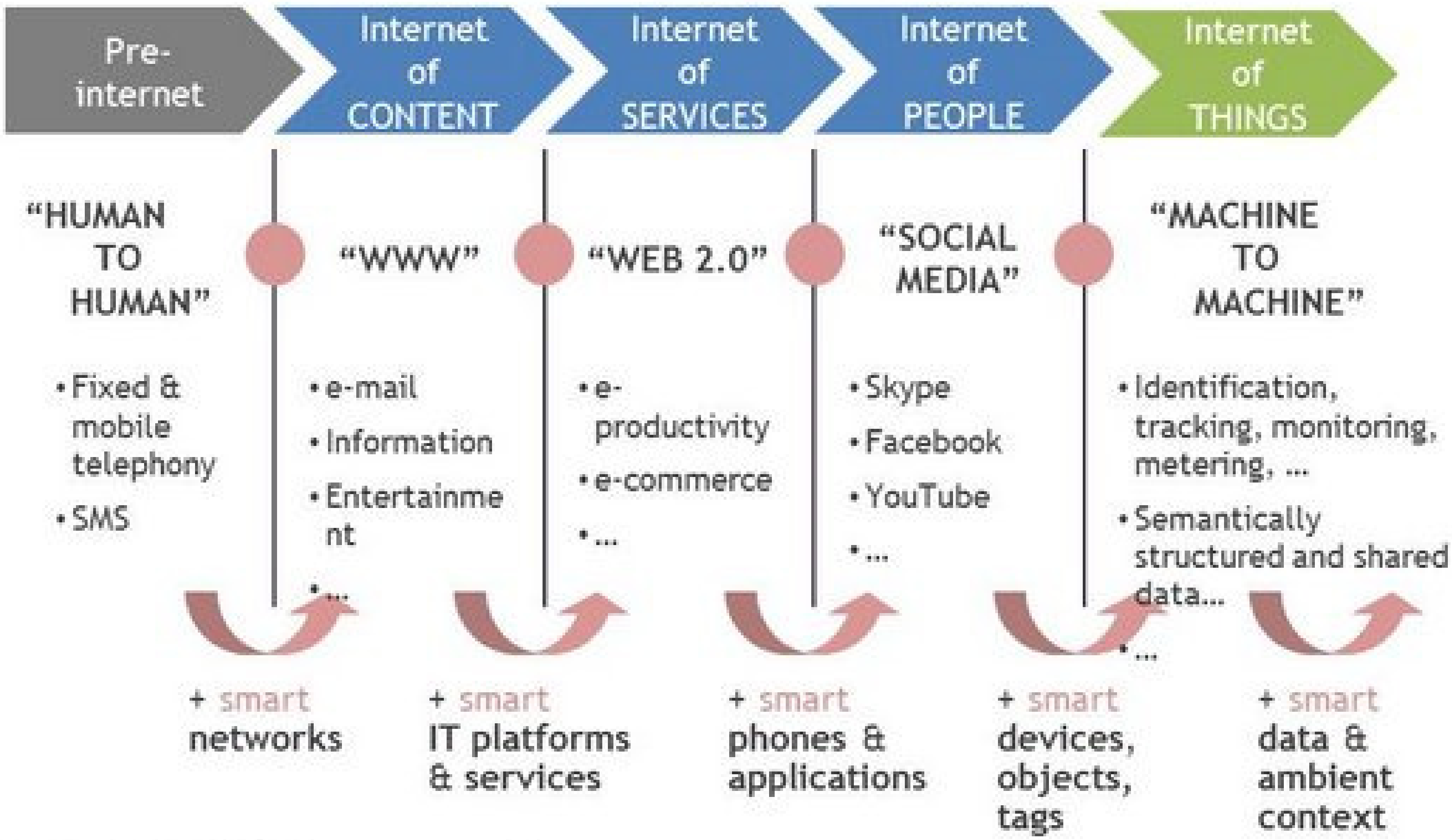
- **Auto 1.0**
  - Dates back to 1886 (modern production of automobile).
  - Cars were novelty, expensive and time-consuming to produce.
- **Auto 2.0**
  - Cultural and economic forces shaped the industry.
  - Focus has been on performance, dealer diagnostics systems, basic infotainment.
  - Technology still is rather invisible to the consumer.
- **Auto 2.5**
  - Cutting edge cars today belong to this category.

Auto 2.5

- **Well established auto OEMs (BMW) and new entrants (Tesla) started looking at the "true" potential of software beyond the infotainment.**
  - BMW ConnectedDrive initiative.
  - Customers can now avail OTA software updates for repair problems, add new features without going to dealers.
  - "Always connected" aspect is one of the driving forces behind the consumer expectation.
    - After all, we live in iPhone and Android era.
- **From Software to Service**

- **In parallel, Internet is evolving too.**

Evolution of Internet



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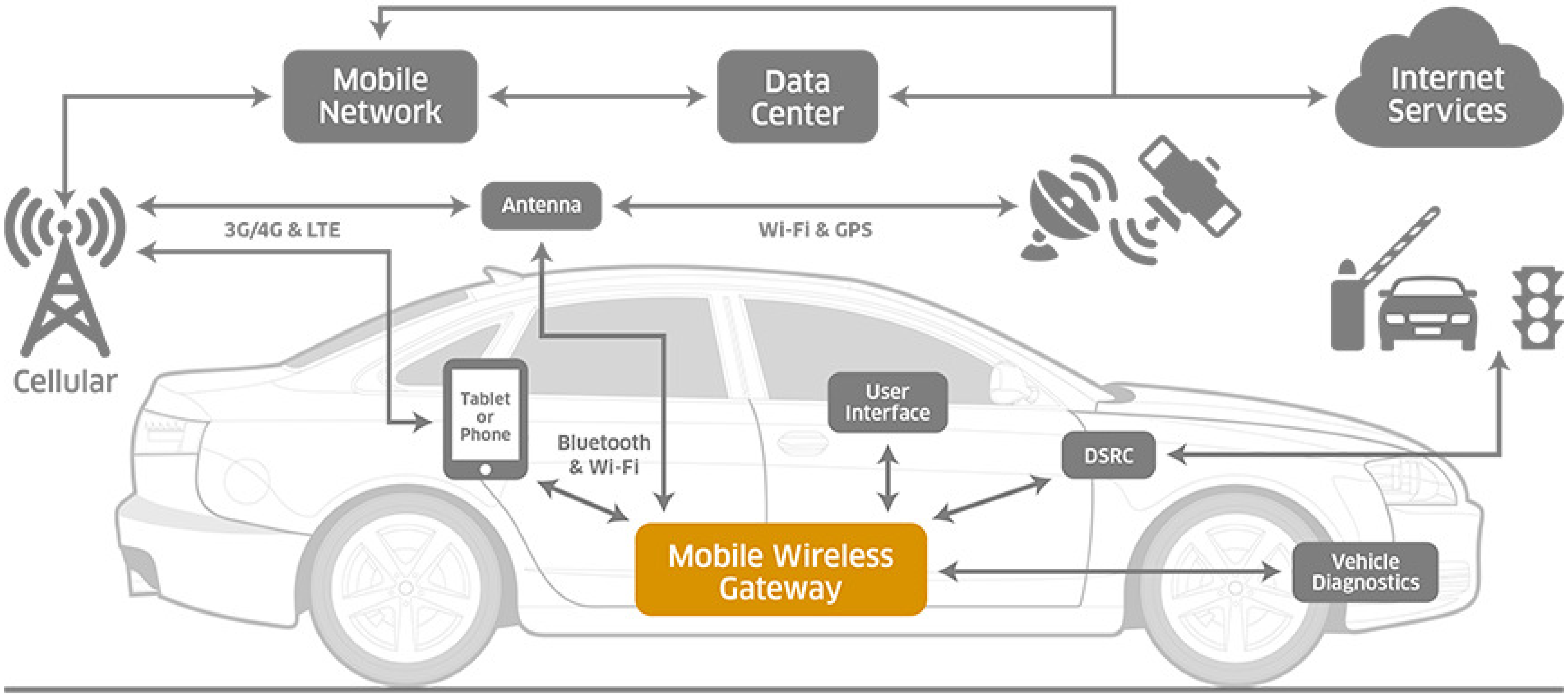
Remember …

- **M2M related concepts existed in 1961**
  - https://www.youtube.com/watch?v=avHo0-qU8xo

Why Merge Two Ecosystems?



Source: http://design.avnet.com/axiom/autorama-connecting-your-car-to-the-internet-of-tomorrow

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Benefits for Auto Industry

M2M

- Automatic diagnostics of cars
  - Data collection from engine management system and analysis.

M2M

- Infrastructure monitoring
  - Structural integrity of a bridge in case of flood.

M2H

- Traffic & emergency alters to drivers.
- Driver assistance and reaction time.
- Blind spot detection and more …

Smart City Effect

- **Deploying infrastructure for**
  - Better road safety
  - Co-operative mobility management
  - Reduce effect on environment
  - Strong social impact through the “sharing based economy”

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- **Auto 1.0 and Auto 2.0 can not meet the requirements due to lack of**
  - Powerful OBUs
  - V2X tools (both software and hardware)
  - Standards
  - Integration with next-gen ICT

Auto Industry Response – Auto 3.0 – Take Away

- **Focus of Auto 3.0**
  - Support Intelligent Transportation System (ITS) through V2X Communications.
  - Expose vehicular resources for data collection, processing, management and storage.
  - Seamless communication and information exchange among vehicular gateways, edge & cloud platforms and consumer devices.
  - Seamless interoperability among vehicles, external computing platforms and consumers.

Auto 3.0 and IoT – Take Away

- **The technological evolution leading to Auto 3.0 enables**
  - Automatic vehicle information discovery and exchange with computing systems and other vehicles.
  - Enhanced access and core networking
  - Computing on vehicular sensor data
- **As a result**
  - Vehicles are becoming resources for IoT ecosystem [1].
- **Advantage**
  - Use on-board sensors for pollution monitoring, traffic flow management, road intersection management.
  - No need to deploy additional sensors in smart cities.

[1] S. Abdelhamid, H. S. Hassanein, and G. Takahara. Vehicle as a resource (vaar). IEEE Network, 29(1):12–17, Jan 2015.

Combined Ecosystem – Take Away

- **Integrates**
  - Vehicular resources (sensors, actuators).
  - ITS & V2X technologies.
  - Edge and cloud computing platforms with big data.
  - Consumer centric services.
- **Target**
  - Improve complex network systems and vehicular information flow.
  - Ultimately reach a collaborative awareness and cognition among consumers, vehicles, things and computing platforms.
- **Leads to**
  - Connected vehicles as an IoT service.
    - Frequently called as "Automotive IoT"

Connected Car as a Service – Take Away

- **For smart city stakeholders (municipalities etc.)**
  - No need to deploy city wide sensors
  - Instead use vehicular sensors to perceive city environments
- **Enterprises**
  - Real time asset or fleet monitoring and management
  - How DHL utilizes IoT (Joint study between Cisco and DHL)
    - IoT and logistics [2]
- **Consumers**
  - Find and reserve parking spot in a (new) city while traveling and save fuel.
  - Analysis of vehicle health and alert when maintenance is necessary.
- **Autonomous vehicles**
  - Passenger experience

[2] http://www.dhl.com/content/dam/Local_Images/g0/New_aboutus/innovation/DHLTrendReport_Internet_of_things.pdf

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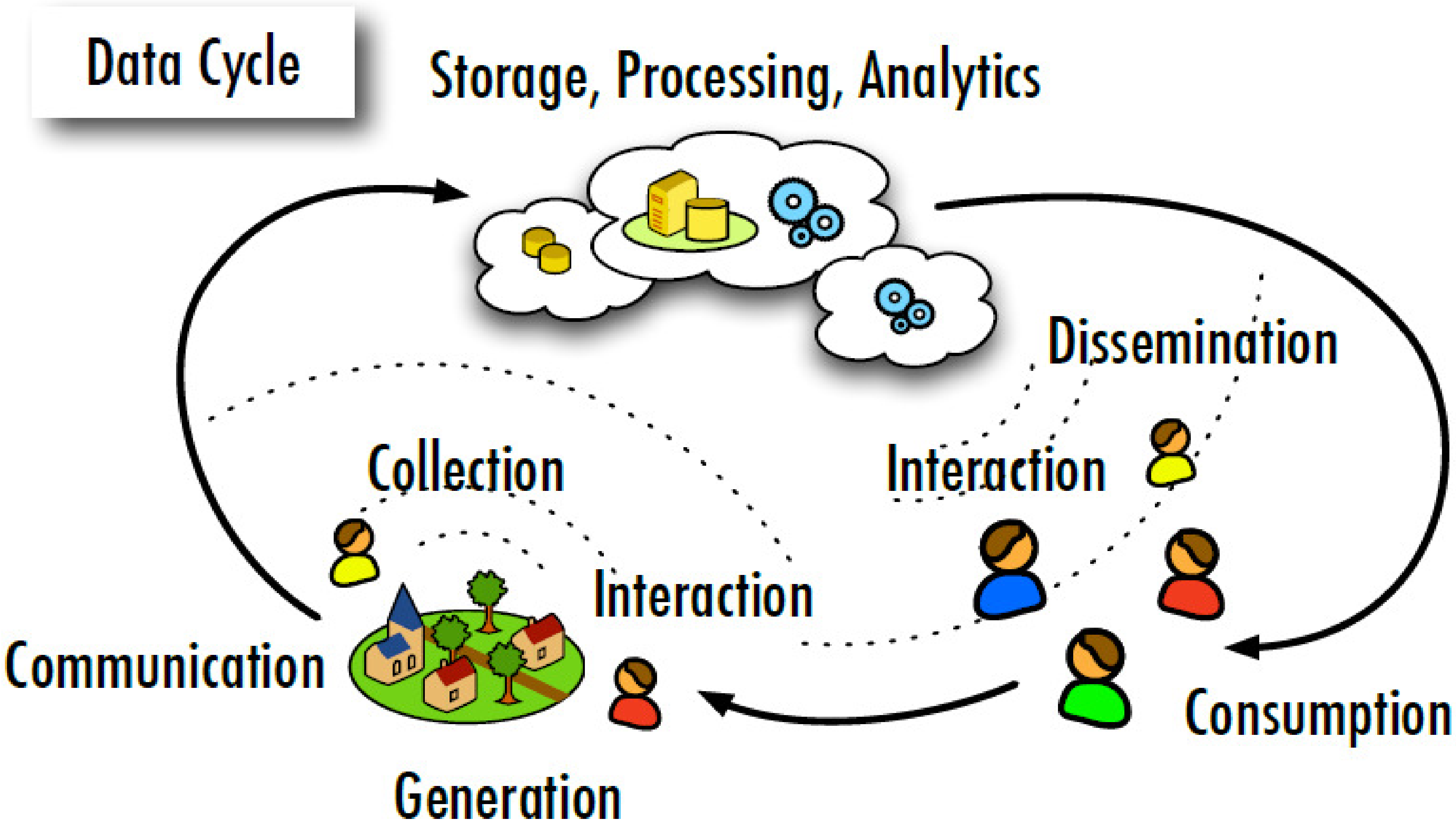
Three Fundamental Operations

- **Generation and collection of data**
  - Vehicular sensors
  - External sensors (smartphone, environmental etc.)
- **Analysis of data**
  - Processing, management and storage
- **Control**
  - Through actuation
  - E.g. automatically switching on fog lamp in a vehicle when fog is detected

IoT Data Cycle



Wait, it is not so simple

- **Heterogeneity at sensors and actuators**
  - Domain of operation, type & frequency of measurement, communication technology
- **Management of vehicle and its resources**
  - Concerns due to high mobility
  - Automatic naming, addressing and discovery of addresses
- **Choice of communication network**
  - Cellular network or DSRC
- **Processing**
  - Utilizing semantic web technologies
  - Cloud platform or edge/Fog platform?
- **Data Dissemination**
  - A mechanism that is independent of vehicle mobility
- **Interoperability**
  - Avoid creating data silos and fragmented market
- **Standardization efforts**
  - W3C Automotive Working Group and Web of Things Interest Group
  - Efforts from oneM2M

Summary of Challenges – Take Away

- **Uniform data and configuration exchange among vehicular resources, computing platforms and consumers.**
- **Data-driven approach**
  - Currently focus is on infrastructure, network and protocols.
  - No cross domain solutions
- **Interoperability among cloud platforms**
  - Closed interfaces and individualized solutions.
- **Co-existence of edge and cloud**
  - Very important for semi/high autonomous vehicles.
- **Data management and repository**
  - No widely followed guidelines.

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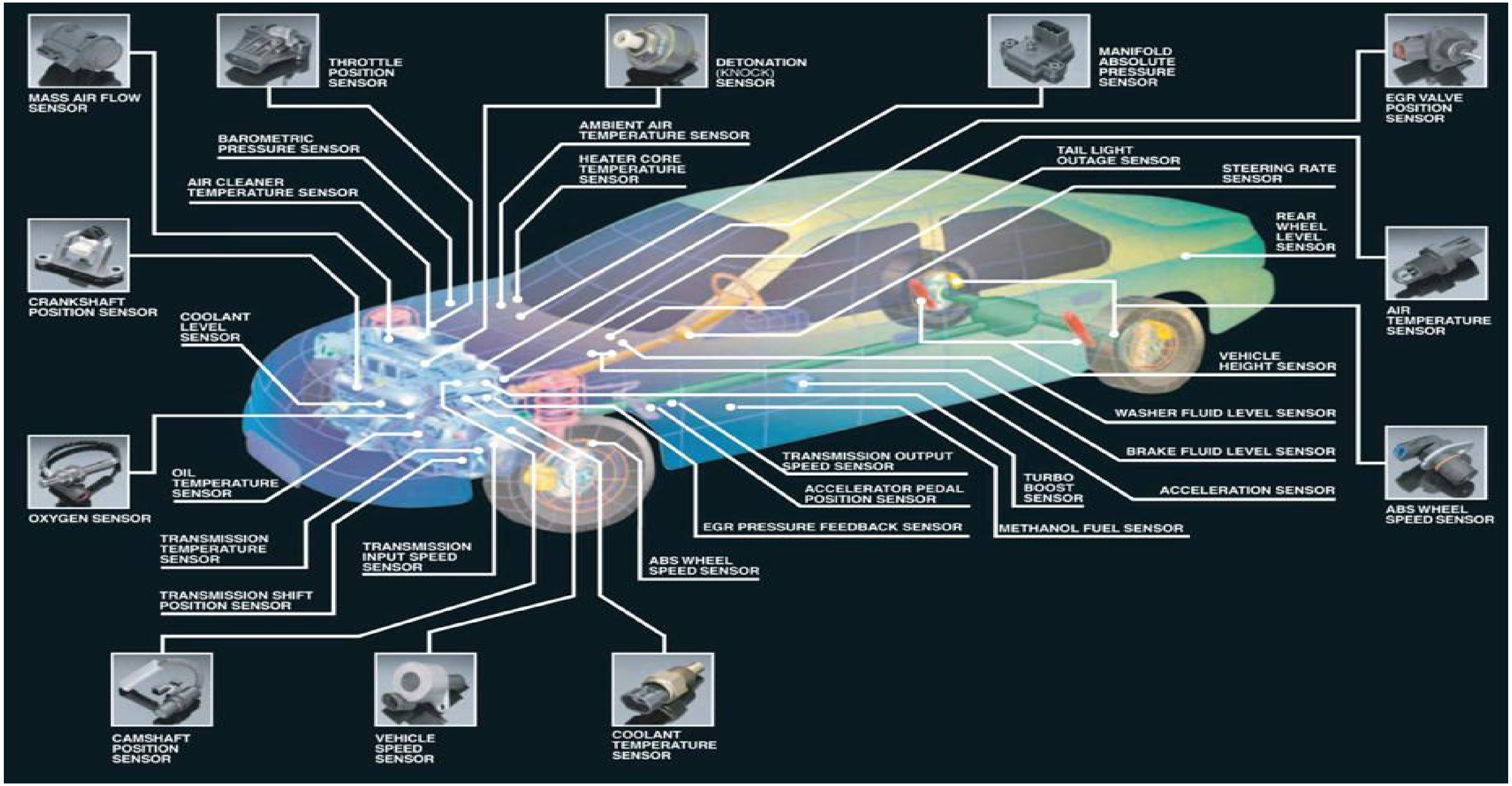
Sensors in Vehicles



Source: http://blogs.intel.com/iot/2015/09/02/intelligent-driving-experience-a-ride-with-intel-internet-of-things

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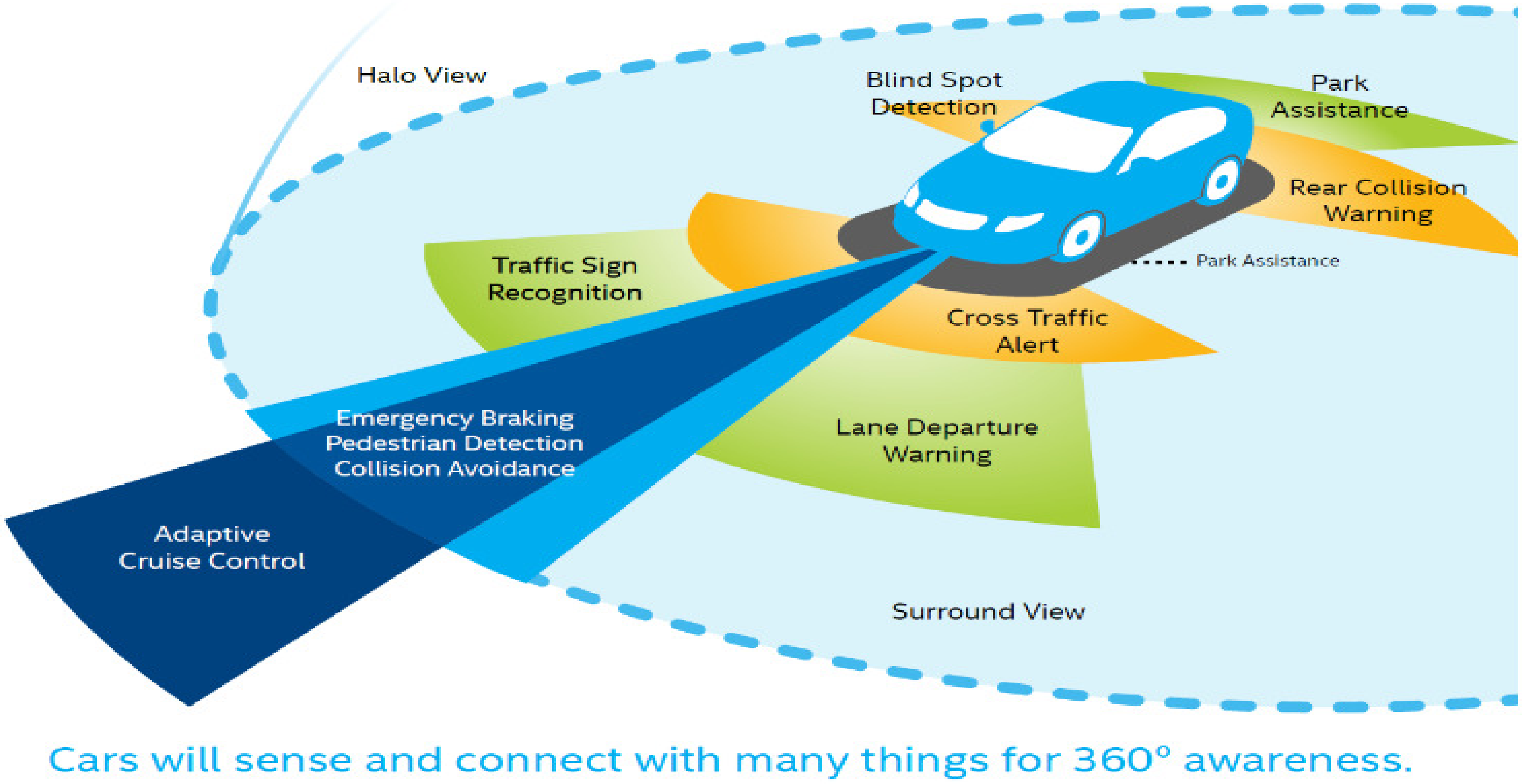
Sensors in Vehicles



Source: http://blogs.intel.com/iot/2015/09/02/intelligent-driving-experience-a-ride-with-intel-internet-of-things

Uniform Data Exchange

- **Requirement from a vehicular 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

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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" [3]
- **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.**

[3] 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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Managing Connected Vehicle Resources – Take Away

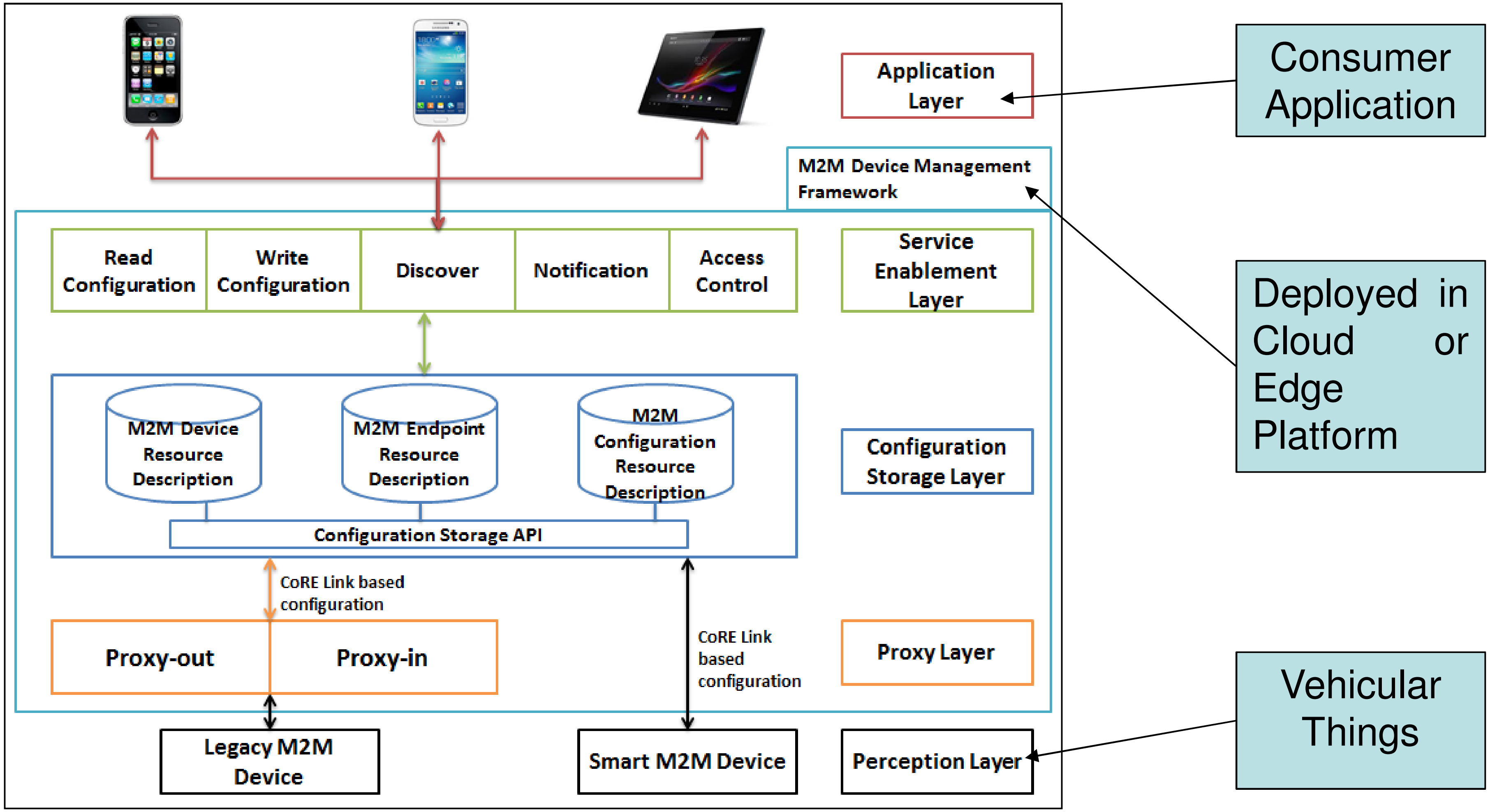
- **Why do we need it?**
  - Due to Machine-to-Machine nature of operation, it is necessary to manage vehicular resources.
  - Enables discovery of resources (sensors, actuators and associated services).
- **What exactly is managed?**
  - Description and configuration of the vehicles and their resources.
- **Application**
  - Useful for cloud based fleet or asset management services.

Managing Connected Vehicle Resources

- **Objective**
  - Ensuring flexibility, scalability and dynamicity of the overall framework.
  - Lightweight and simple description.
  - Automatic management framework.
- **Available solutions (developed by EURECOM)**
  - Representation of objects for efficient management [4]
    - Both smart and legacy ones.
    - Utilize CoRE Link Format or JSON-LD
  - Generic framework for connected things management
    - Applicable to vehicular domain also.
  - OMA LwM2M Technical Specifications based API

[4] 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.

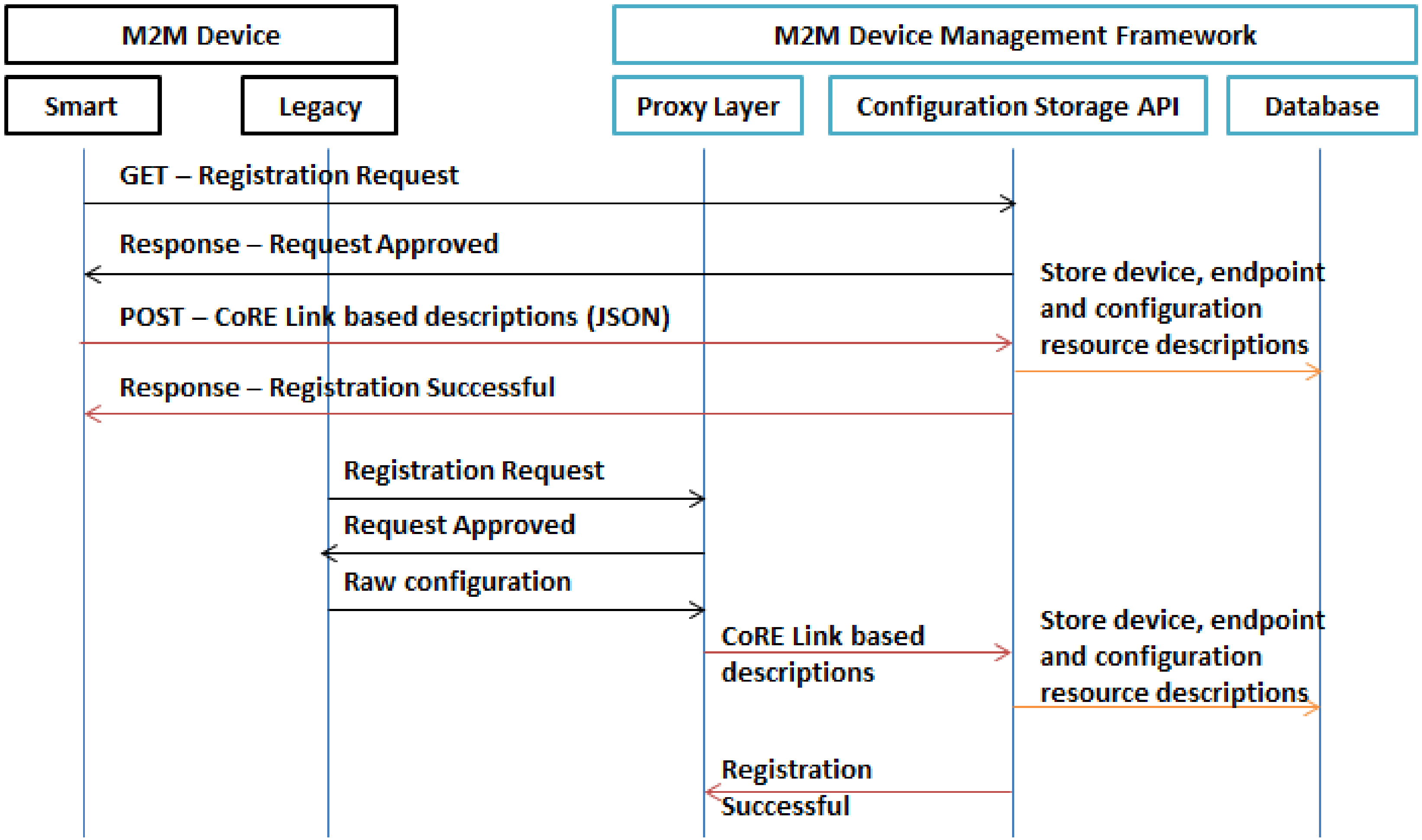
Description of Layers

- **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



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Discovery

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

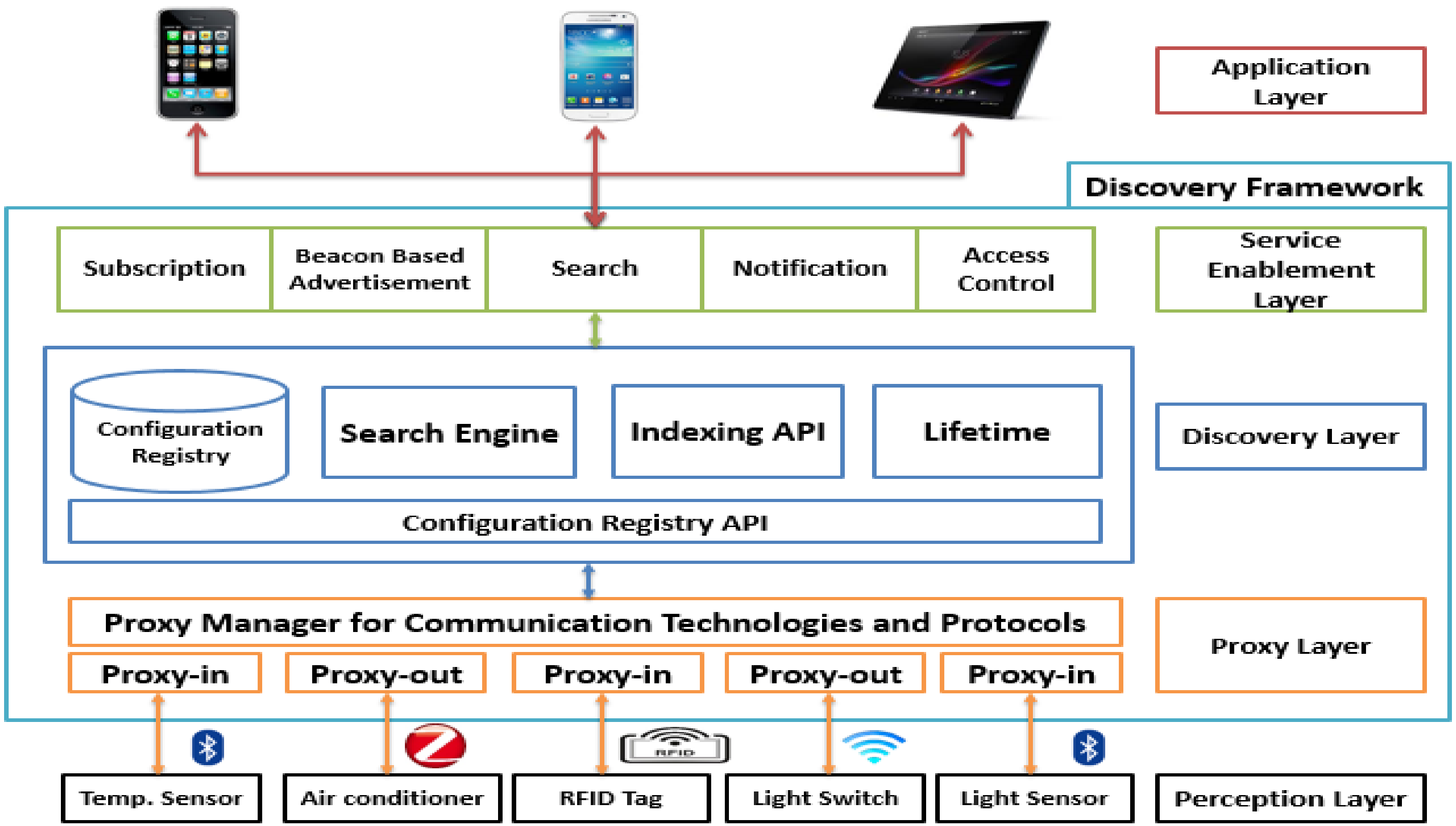
Source : www.iotdex.com

Discovery Categories

- **Scenarios**
  - Search around "ME"
    - UriBeacon, NFC
    - Discover sensors from a smartphone
  - Search in the network
    - mDNS, SSDP
  - Search in a directory (can be used in vehicular domain)
    - CoAP
  - Search across peers
    - DHT based
  - Search for metadata
  - Semantic based search

Source - https://w3c.github.io/wot/landscape.html

Search Engine Based Discovery Framework



Source: S. K. Datta, R. P. F. Da Costa and C. Bonnet, "Resource discovery in Internet of Things: Current trends and future standardization aspects," *Internet of Things (WF-IoT), 2015 IEEE 2nd World Forum on*, Milan, 2015, pp. 542-547.

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

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Data Processing

- **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
- **IoT ecosystem comprises of several domains**
  - There are rules associated with the knowledge of the each domain
- **What if you want to build automotive applications combining several domains**

Semantic Reasoning

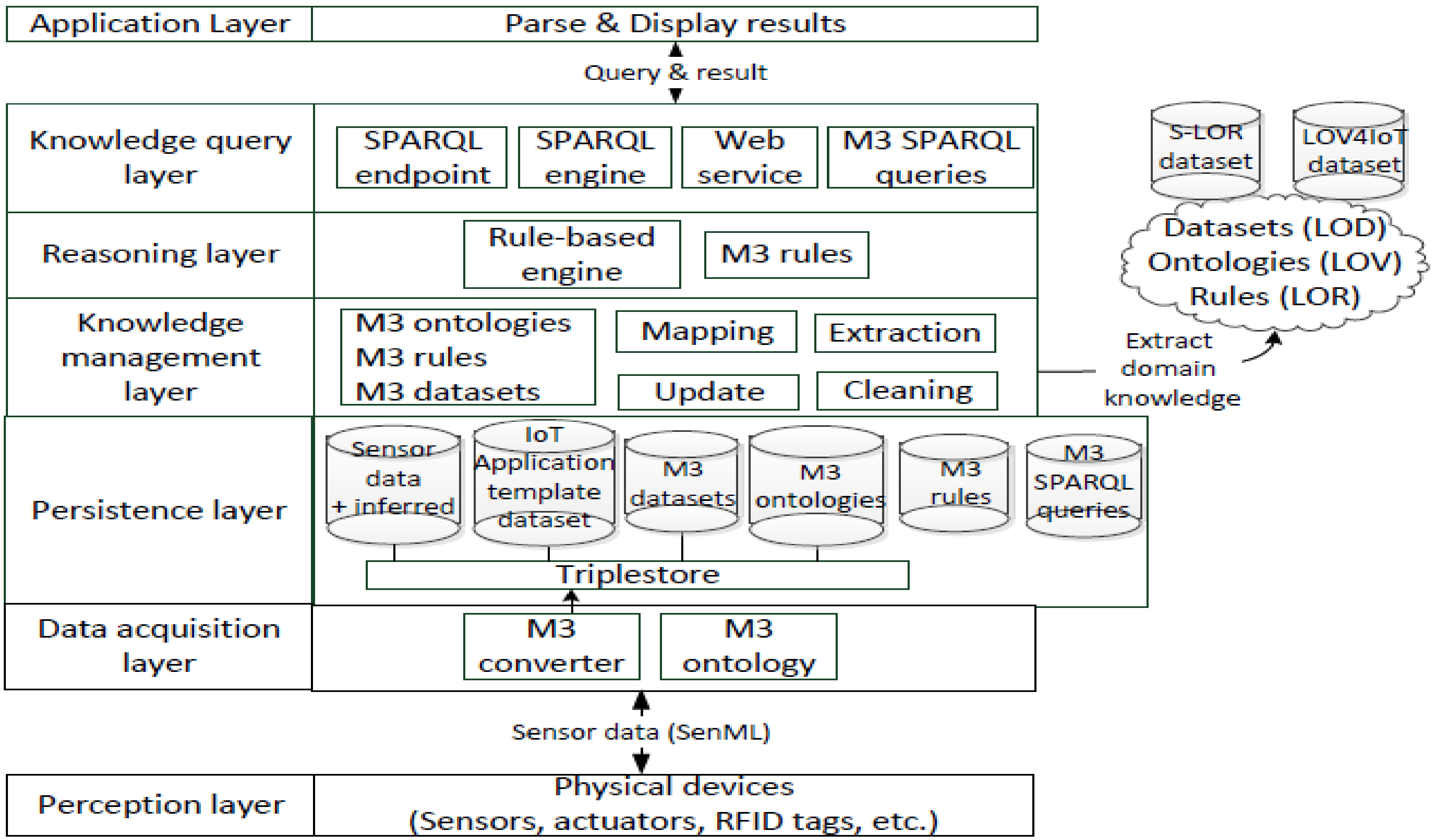
- **Use of semantic reasoning to enrich M2M data**
  - First step – SenML to add some side information creating metadata
  - Second step – decorate the metadata with additional semantic reasoning
- **Link the data with the meaning**
  - From the point of view of different domains

M3 Approach

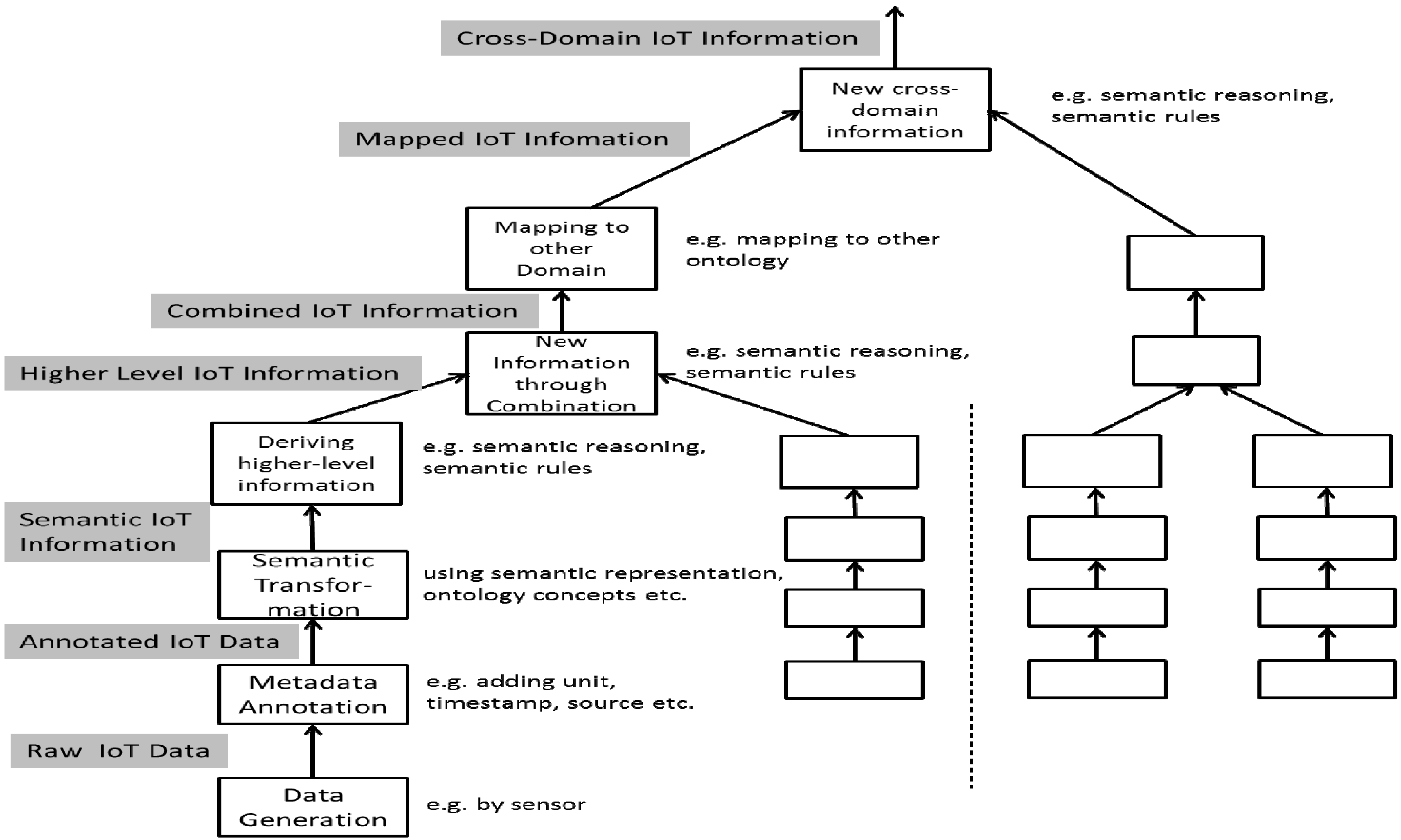
- **The M3 (Machine to Machine Measurement) approach**
  - Enrich M2M data with semantic web technologies [5]
  - The M3 ontology: A hub for cross-domain ontologies and datasets
    - e-Health: weather, recipe, health
    - Smart city: weather, home automation, transport, vacation
    - STAC (security): 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/**

[5] 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



Combining Cross Domain IoT Data – Take Away



IoT Application Template Generation

- **A template is generated based on**
  - Type of sensor (e.g. engine temperature)
  - Associated domain
    - Automotive for engine temperature
- **Template contains**
  - Ontologies, datasets, rules and generic SPARQL query necessary for semantic computing.
  - Eases generation of high level abstraction from raw sensor data.

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Cloud Deployment

- **Cloud based approach**
  - A cloud computing platform stores all the templates needed to build various kinds of applications for IoT.
  - Developed using Apache Jena framework.
  - Currently running in Google Cloud Platform
- **Challenge**
  - Raw metadata must be transported to cloud for processing
  - Inferred information must be again transported to consumer devices for dissemination.
- **Not suitable for latency sensitive automotive applications.**

Edge/Distributed Deployment – Take Away

- **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.
- **Advantage**
  - Distributed computing approach
  - Single hop from vehicles
  - Higher fault tolerance

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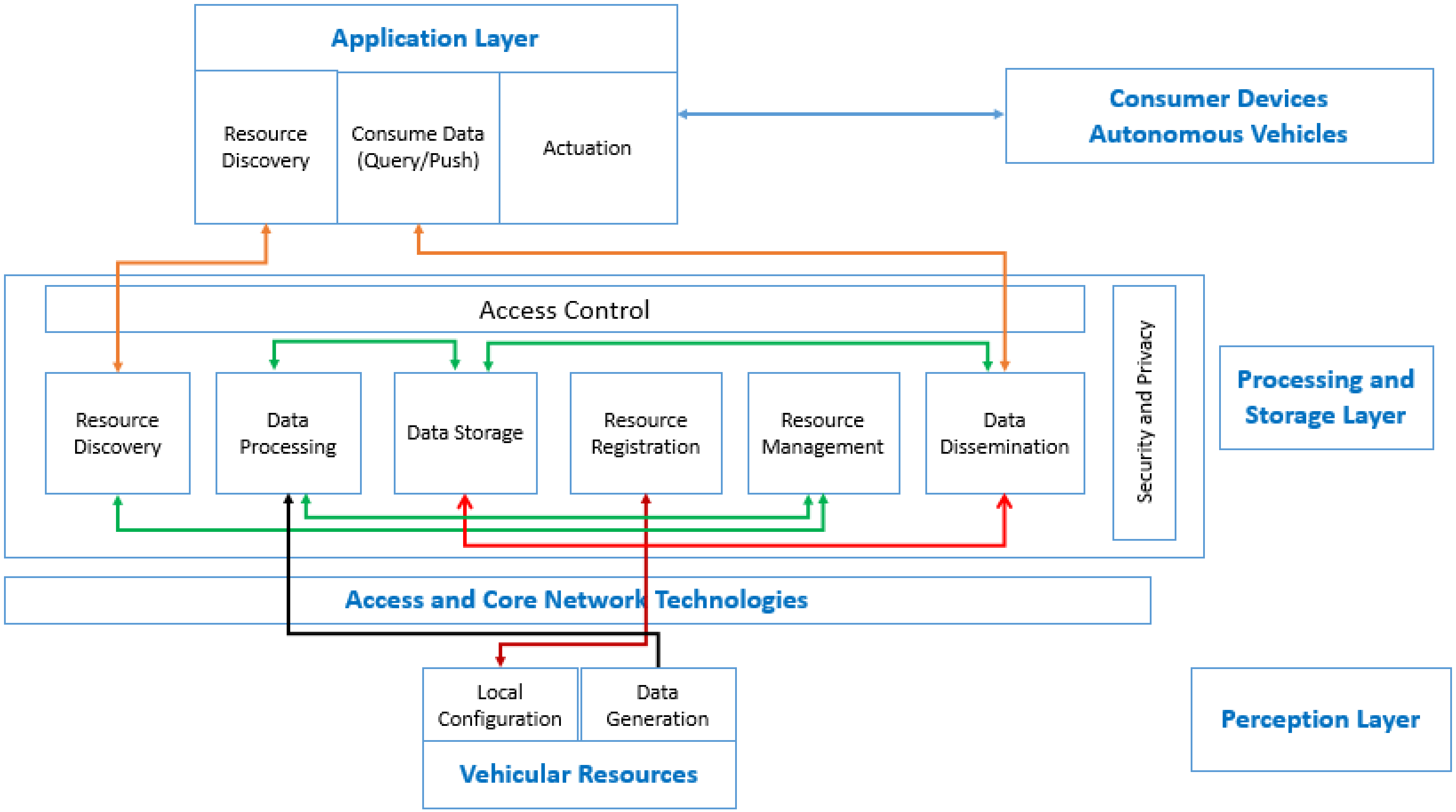
- **IoT architecture integrating vehicles as resources**

IoT Architecture – Take Away



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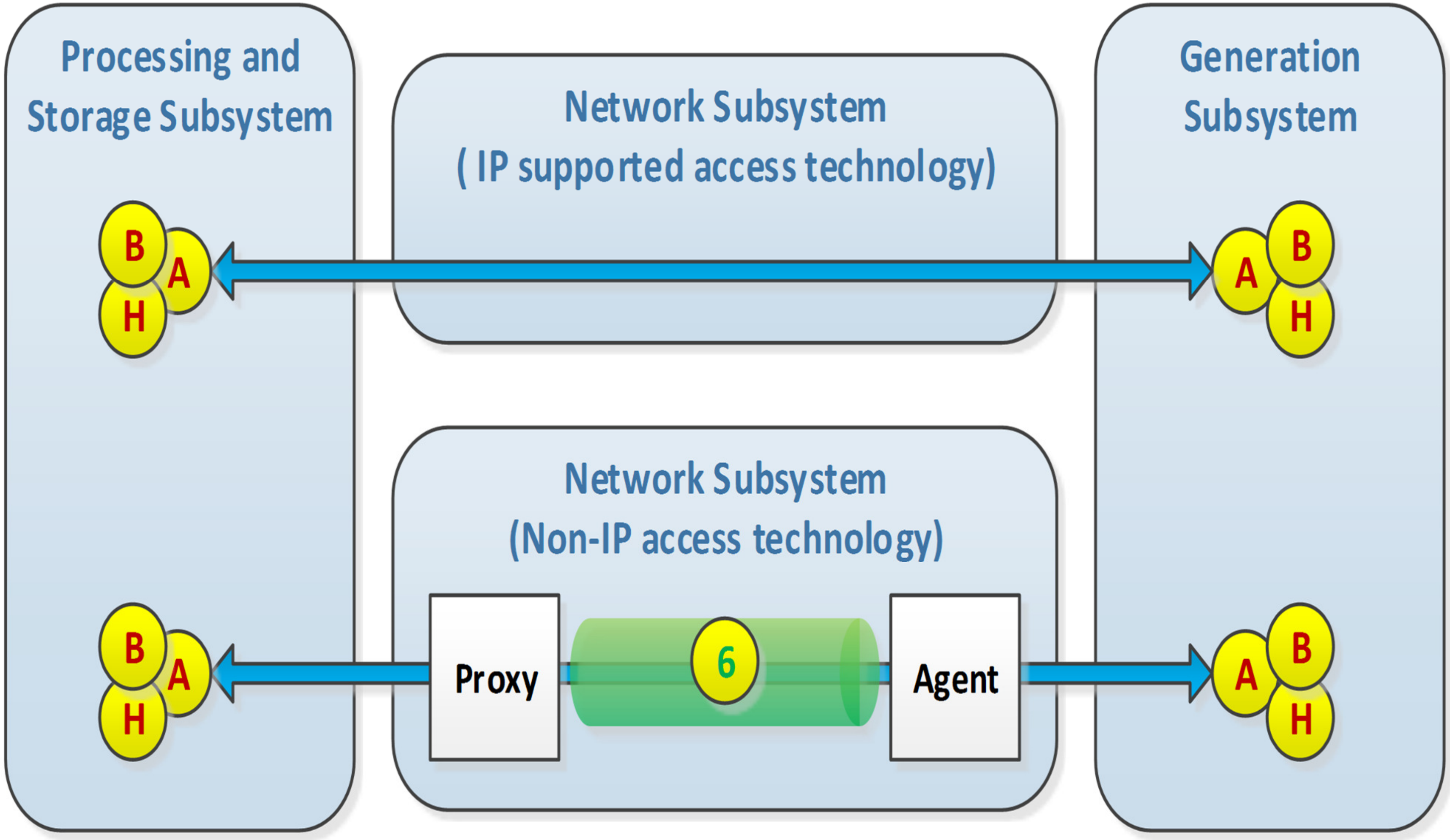
Generation Subsystem

- **Data generation**
  - Sensor Markup Language (SenML) is used to create vehicular sensor metadata.
  - SenML extensions for data exchange with vehicular actuators.
- **Local configuration**
  - CoRE Link Format is used to describe the vehicular resources.
- **RESTful interfaces**
  - Communicates sensor configuration and metadata.
  - Supports HTTP (GET, POST) and CoAP (GET, PUT).

Network Subsystem



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Processing and Storage Subsystem

- **Its elements**
  - Collection proxies.
  - Data processing.
  - Data storage.
  - Resource discovery and naming.
  - Configuration management of generation subsystem.

For details: S. K. Datta, C. Bonnet, R. P. F. Da Costa and J. Haerri, “DataTweet: An Architecture Enabling Data-Centric IoT Service”, Region 10 Symposium (Tensymp), IEEE, Bali, 2016.

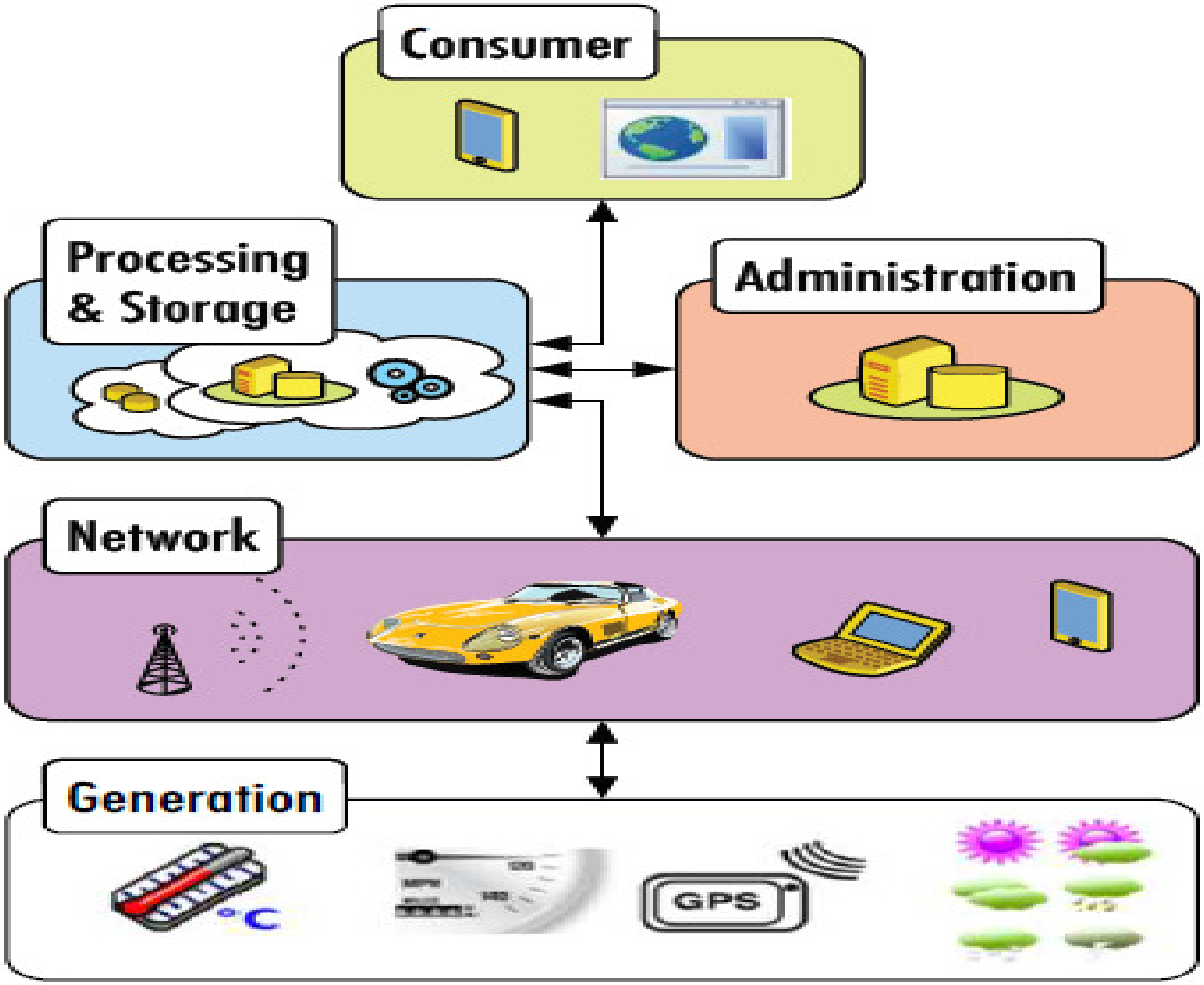
Consumer Subsystem

- **Its elements**
  - Resource discovery.
  - Consume data
    - Both raw data and high level abstraction.
  - Actuation
    - Supports SenML extensions for actuators.

Administration Subsystem

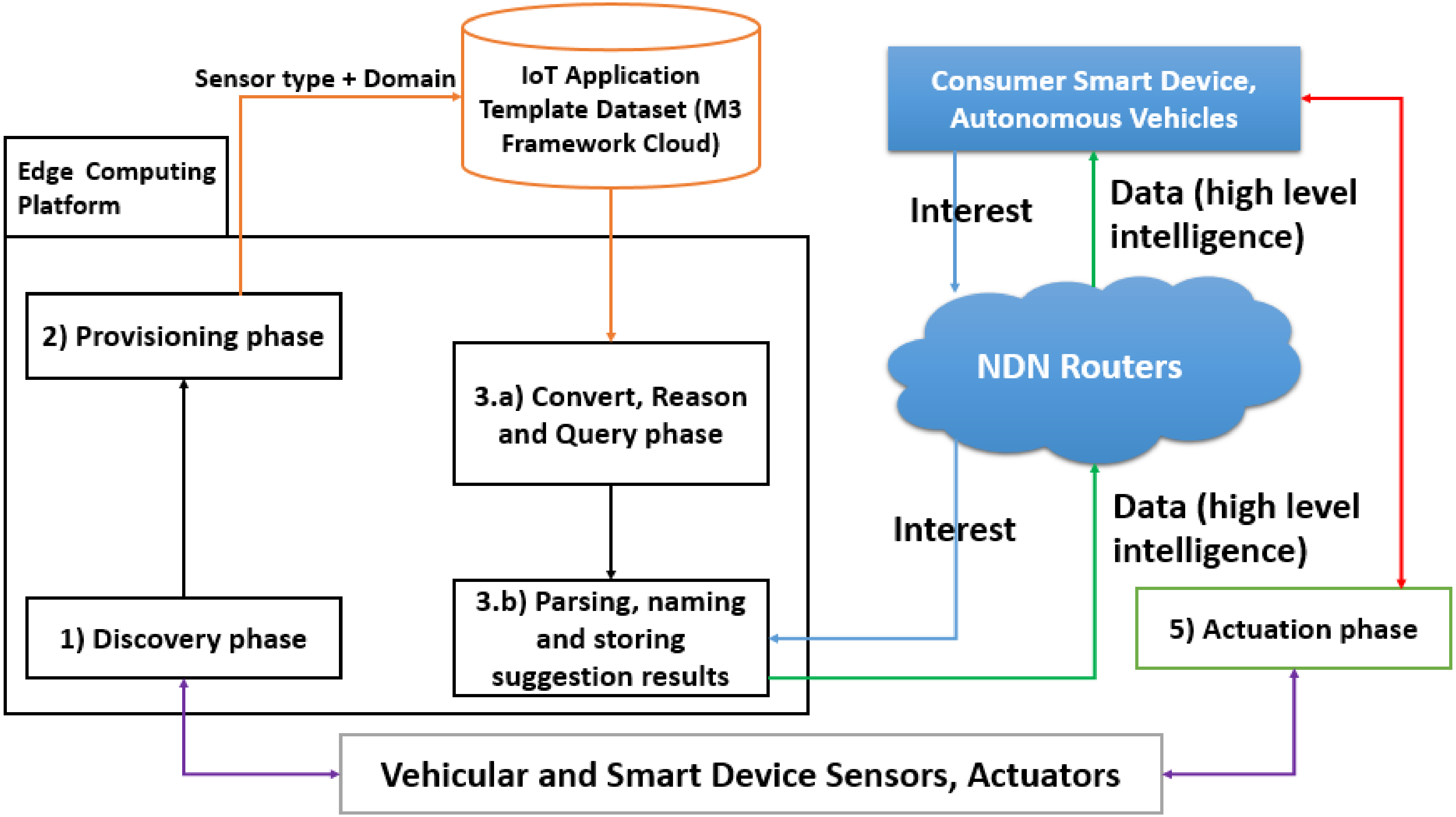
- **There may be an administration subsystem attached to the IoT architecture.**
  - Assigns naming and addressing schemes to the other subsystems.
  - Determines and enforces the access control policies at the processing and storage subsystem.

Mapping of Elements



- **Operational Phases of the IoT architecture**

Our Framework – Take Away



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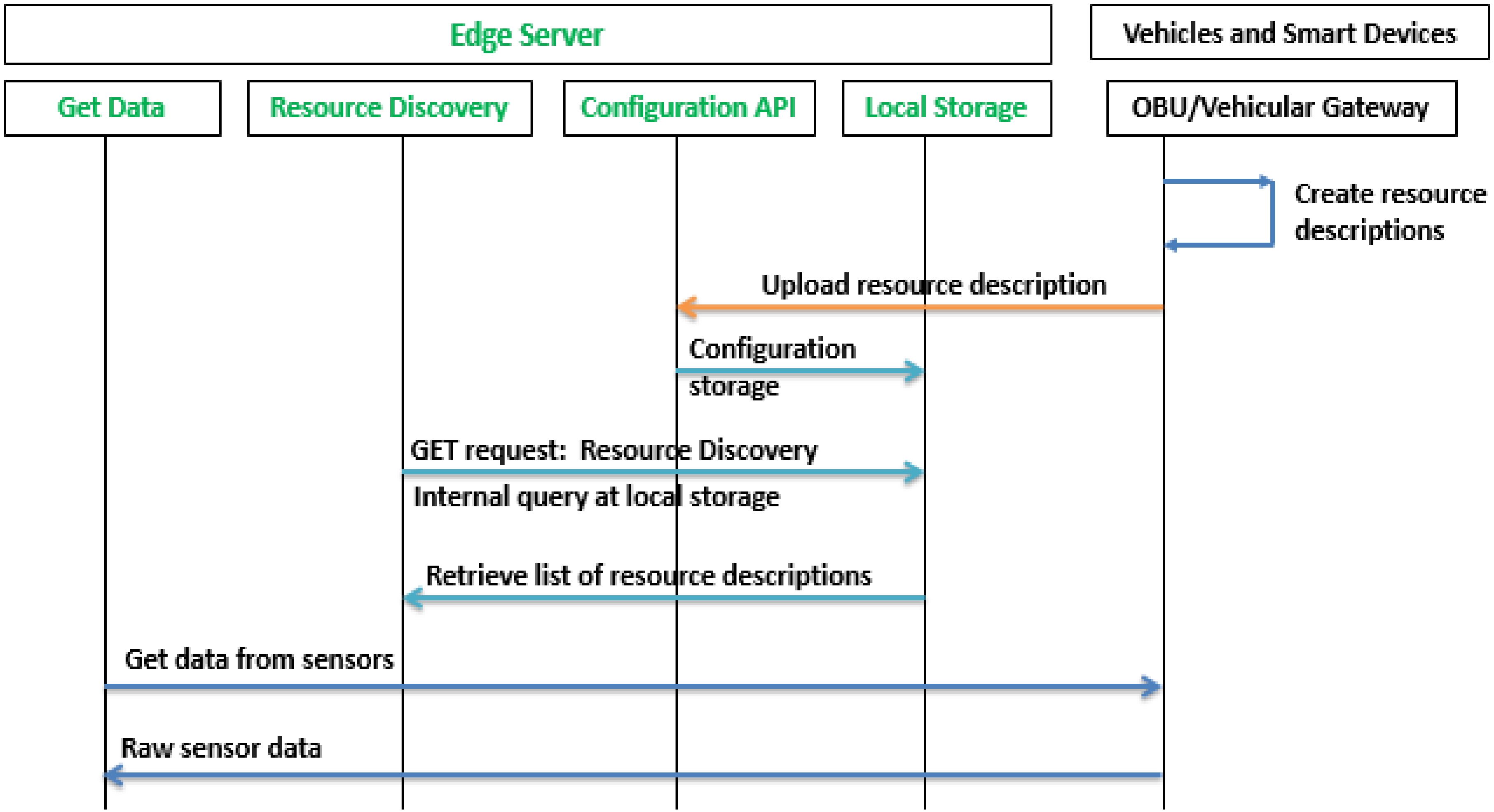
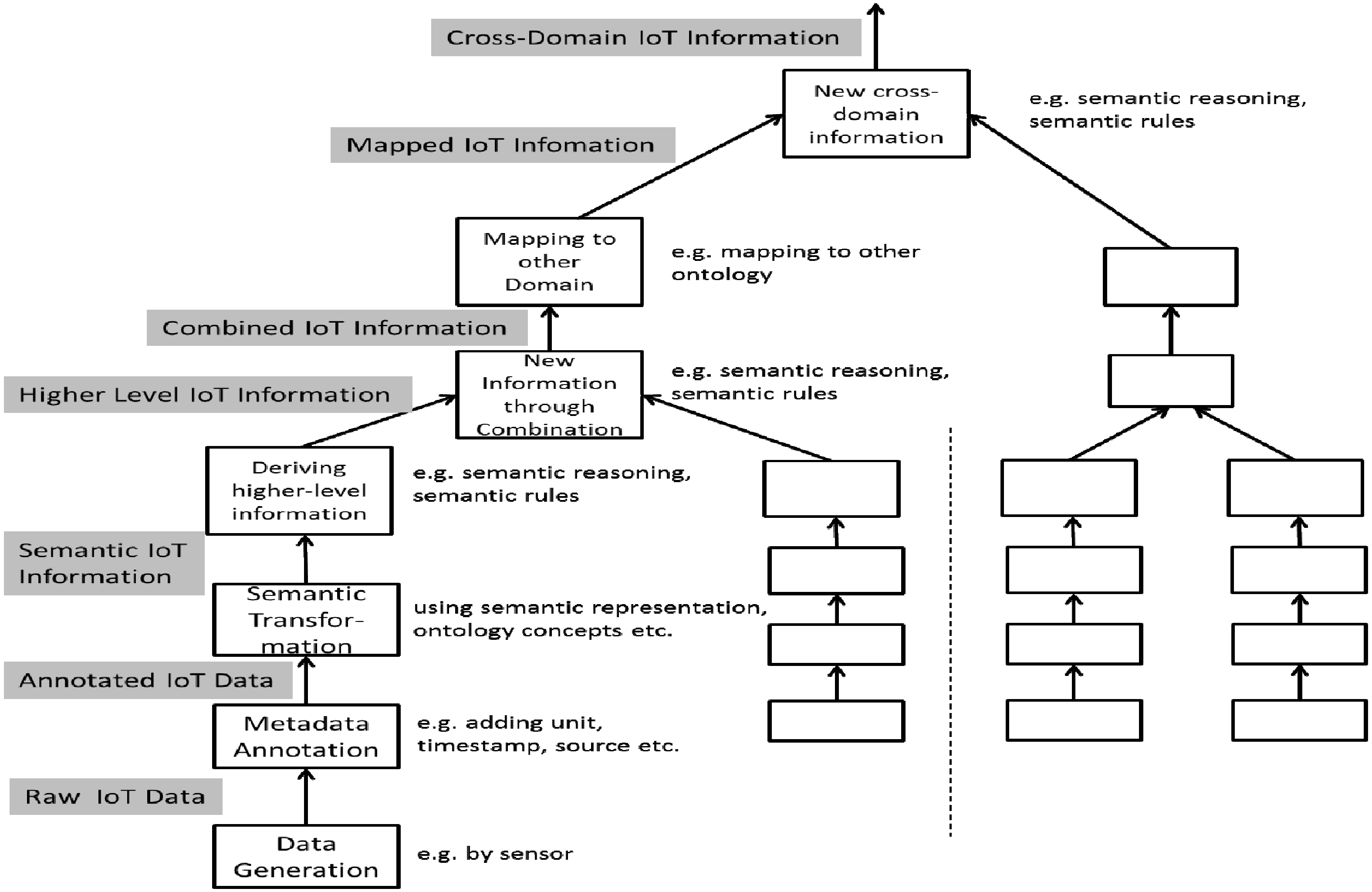
Discovery Phase



Provisioning Phase

- **Prepares the system for**
  - Data processing, management and storage
- **Provisioning info used are**
  - Resource type and domain of operation
  - Obtained from SenML metadata and resource descriptions
- **Result**
  - Downloads resources necessary for semantic computing from a cloud platform.
    - Ontologies, rules, datasets

Data Processing and Fusion



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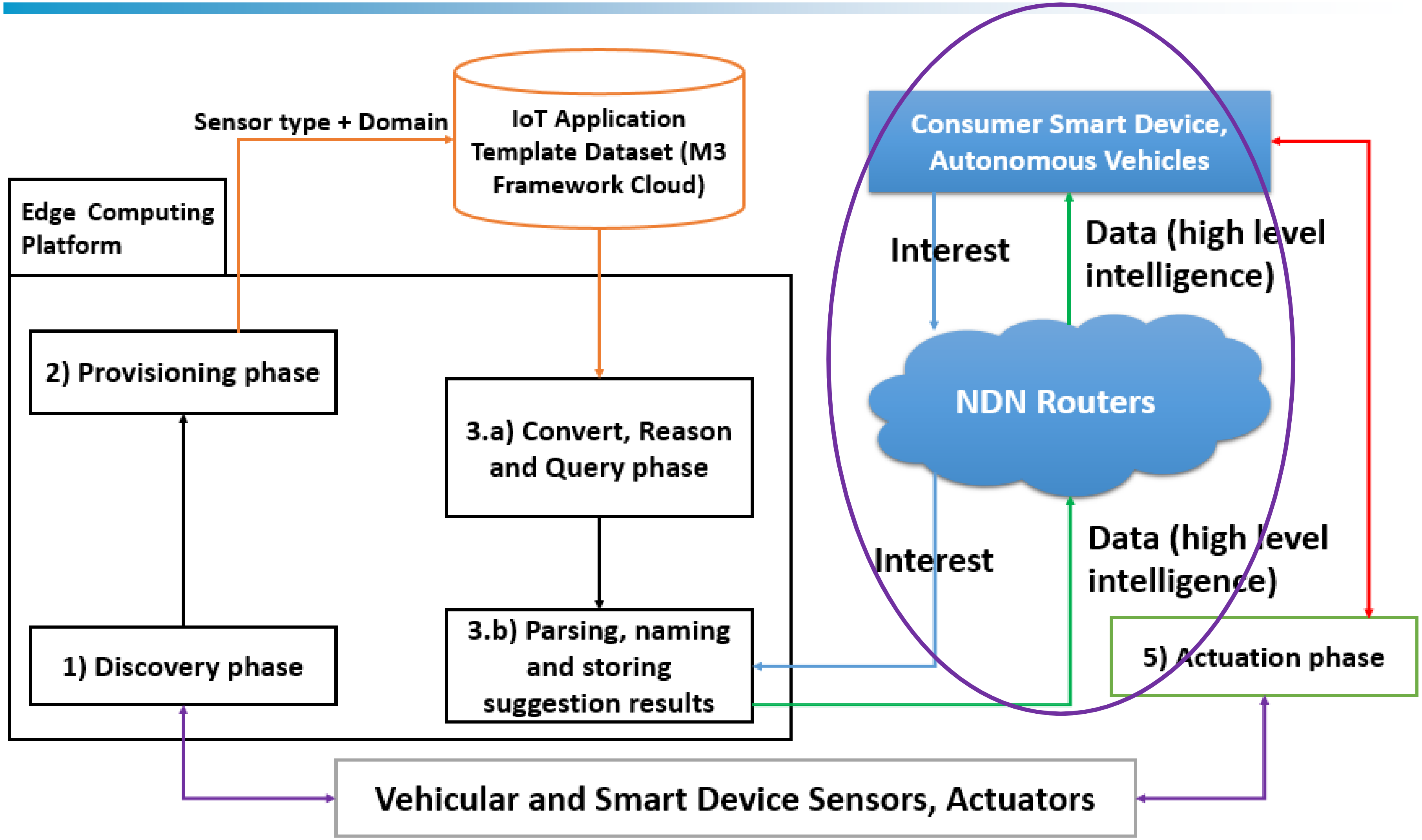
Data Dissemination



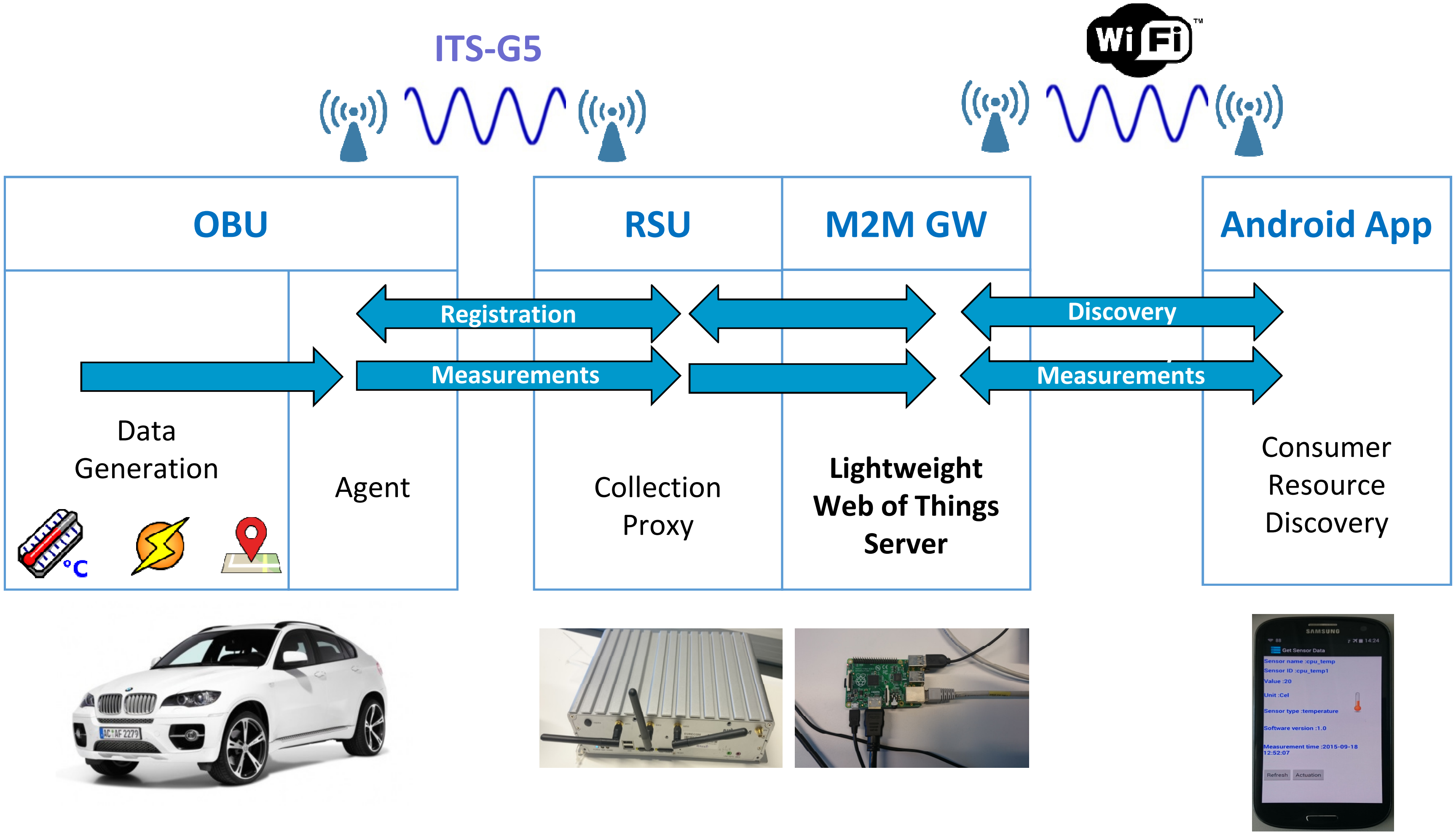
Actuation Phase

- **Respond to the environment**
  - Send command to actuators.
- **Example**
  - If there is fog in the driving environment of an autonomous vehicle
    - Actuation command: reduce vehicle speed.
    - Actuation command: turn on fog lamps.

IoT Architecture Prototype

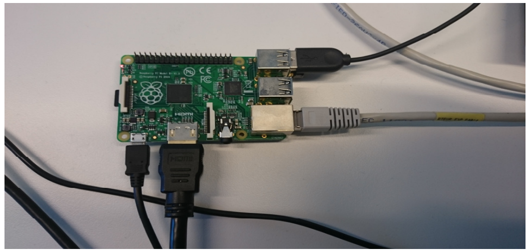
- **Connected car as an IoT service**

Prototyping Scenario



Components (1/2)

- **Hardware**
  - Nexcomm VTC-6201 – 1x OBU (vehicle) and 1x RSU (base-station)
    - IEEE 802.11p radio (5.9GHz), GPS, Wi-Fi and Ethernet.
    - ITS-G5 stack protocols embedded.
  - Raspberry Pi acting as M2M gateway
    - Supports Discovery, Registration and Data Collection
  - Android phone acting as client.



Components (2/2)

- **Software**
  - OBU and RSU
    - Ubuntu 12.04 with ITS-G5 stack protocols and DSRC logic interface.
    - Gpsd and ntpd for GPS data manipulation.
    - Data generation, Proxy and Agent modules implemented in C.
  - **M2M Gateway running Lightweight WoT server**
    - SQLite database for sensor data storage.
    - Python language for developing the web services.
  - Android Application
    - Consumer application

Demonstration

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Conclusion

- **Next phase in auto industry evolution will be defined by smart city and consumer centric requirements.**
- **Automotive IoT**
  - Both vehicle and smartphone sensors will participate and generate tons of data.
  - OEMs will need to collect them and process to derive intelligence.
  - Deliver ‘value’ to consumers through the modern “sharing based” economy.
- **Seamless interoperation among vehicular resources, computing platforms and consumer devices will be the key.**

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

Thank you!

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- **Twitter: @skdatta2010**
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