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Smart Cities and Smart Homes – Part I

Dr. Sudip Misra
Associate Professor
Department of Computer Science and Engineering
IIT KHARAGPUR
Email: smisra@sit.iitkgp.ernet.in
Website: http://cse.iitkgp.ac.in/~smisra/

Introduction

- ✓ A Smart City is-
  - An urban system
  - Uses Information & Communication Technology (ICT)
  - Makes infrastructure more interactive, accessible and efficient.
- ✓ Need for Smart Cities arose due to-
  - Rapidly growing urban population
  - Fast depleting natural resources
  - Changes in environment and climate

Source: Pellicer, Soledad, et al. "A global perspective of smart cities: A survey." IEEE *Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2013*.

Analogy

Humans	Smart Cities
Skeleton	Buildings, Industries, People
Skin	Transportation, Logistics
Organs	Hospital, Police, Banks, Schools
Brain	Ubiquitously embedded intelligence
Nerves	Digital telecommunication networks
Sensory Organs	Sensors, Tags
Cognition	Software

Application Focus Areas

Smart Economy
- Competitiveness

Smart Governance
- Citizen participation

Smart People
- Social and Human Capital

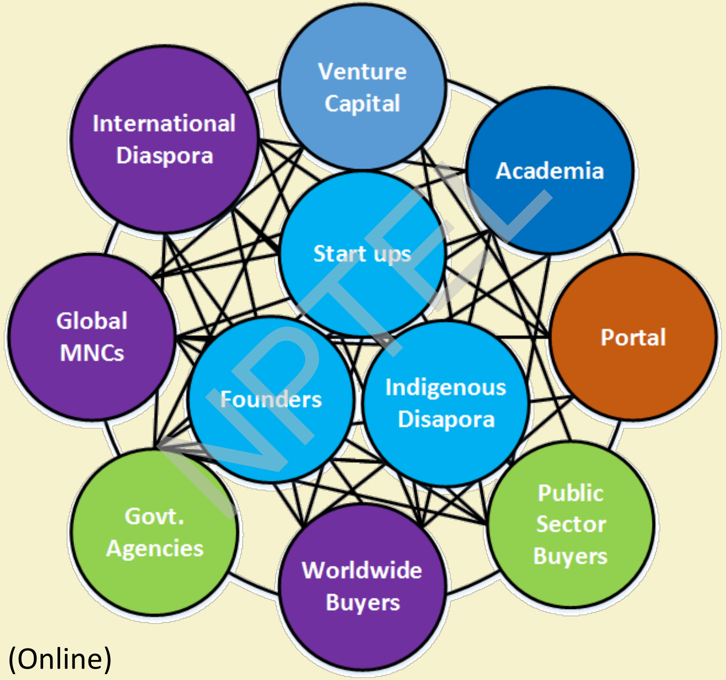
Smart Mobility
- Transport and ICT

Smart Environment
- Natural resources

Smart Living
- Quality of life

Source: Pellicer, Soledad, et al. "A global perspective of smart cities: A survey." IEEE *Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2013*.

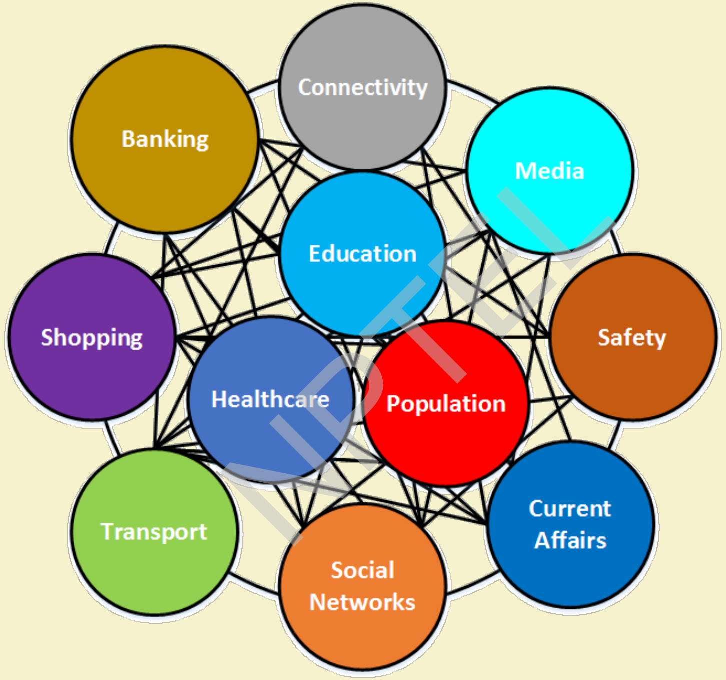
Smart Economy



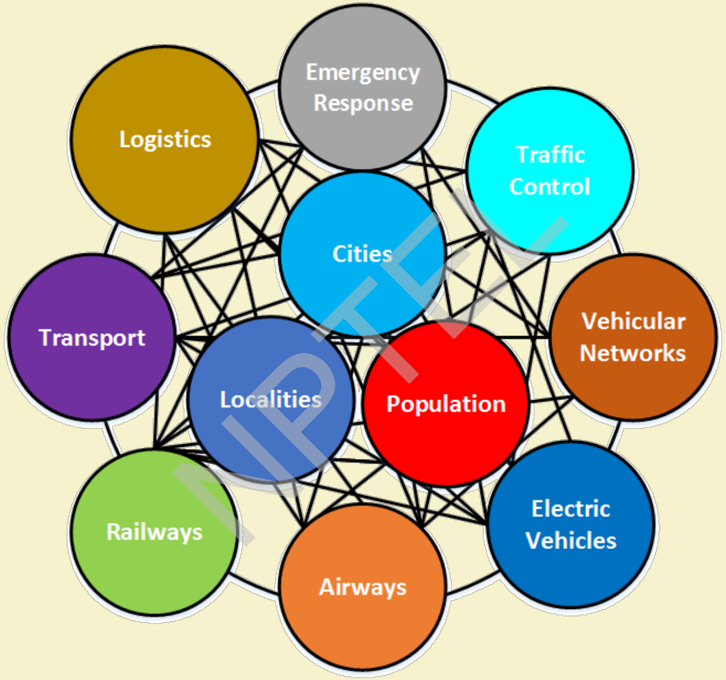
Source: [“Smart Economy”,](#) Project Chapel Hill (Online)

Smart Governance

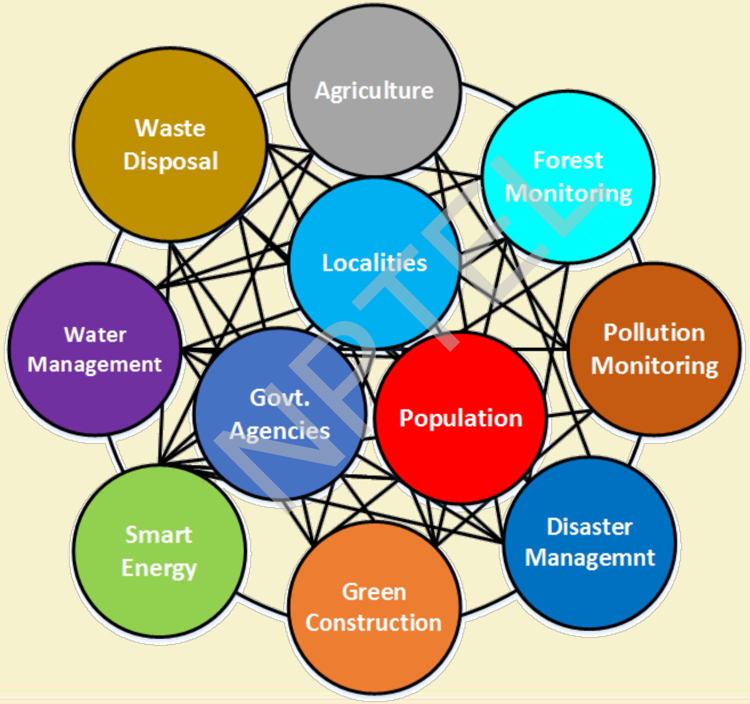
Smart People



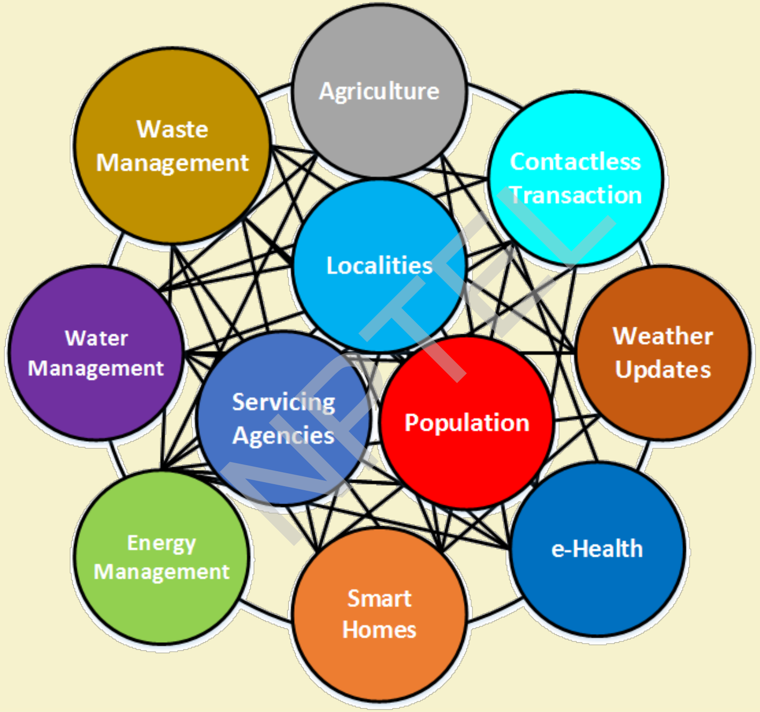
Smart Mobility



Smart Environment



Smart Living



Current Focus Areas

- ✓ Smart Homes
  - Health monitoring.
  - Conservation of resources (e.g. electricity, water, fuel).
  - Security and safety.
- ✓ Smart Parking Lots
  - Auto routing of vehicles to empty slots.
  - Auto charging for services provided.
  - Detection of vacant slots in the parking lot.

Current Focus Areas (contd.)

- ✓ Smart Vehicles
  - Assistance to drivers during bad weather or low-visibility.
  - Detection of bad driving patterns or driving under the influence of substances.
  - Auto alert generation during crashes.
  - Self diagnostics.
- ✓ Smart Health
  - Low cost, portable, at-home medical diagnosis kits.
  - Remote check-ups and diagnosis.
  - On-body sensors for effortless and accurate health monitoring.
  - Auto alert generation in case of emergency medical episodes (e.g. Heart attacks, seizures).

Current Focus Areas (contd.)

- ✓ Pollution and Calamity Monitoring
  - Monitoring for weather or man-made based calamities.
  - Alert generation in case of above-threshold pollutants in the air or water.
  - Resource reallocation and rerouting of services in the event of calamities.
- ✓ Smart Energy
  - Smart metering systems.
  - Smart energy allocation and distribution system.
  - Incorporation of traditional and renewable sources of energy in the same grid.

Current Focus Areas (contd.)

✓ Smart Agriculture

- Automatic detection of plant water stress.
- Monitoring of crop health status.
- Auto detection of crop infection.
- Auto application of fertilizers and pesticides.
- Scheduling harvesting and arranging proper transfer of harvests to warehouses or markets.

Technological Focus Areas

Data Collection
- **Mobile devices, Sensors, Architecture**

Data Transmission
- **Radios, Networking, Topologies**

Data Storage
- **Local storage, Data warehouses**

Data Processing
- **Data cleaning, Analytics, Prediction**

Source: Pellicer, Soledad, et al. "A global perspective of smart cities: A survey." IEEE *Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2013*.

IoT Challenges in Smart Cities

- ✓ Security and Privacy
  - Exposure to attacks (e.g. cross-site scripting, side channel, etc.).
  - Exposure to vulnerabilities.
  - Multi-tenancy induces the risk of data leakage.
- ✓ Heterogeneity
  - Integration of varying hardware platforms and specifications.
  - Integration of different radio specifications.
  - Integration of various software platforms.
  - Accommodating varying user requirements.

Source: Arasteh, H., et al. "Iot-based smart cities: A survey." *IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 2016*.

IoT Challenges in Smart Cities (contd.)

- ✓ Reliability
  - Unreliable communication due to vehicle mobility.
  - Device failures still significant
- ✓ Large scale
  - Delay due to large scale deployments.
  - Delay due to mobility of deployed nodes.
  - Distribution of devices can affect monitoring tasks.

Source: Arasteh, H., et al. "Iot-based smart cities: A survey." *IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 2016*.

IoT Challenges in Smart Cities (contd.)

- ✓ Legal and Social aspects
  - Services based on user provided information may be subject to local or international laws.
  - Individual and informed consent required for using humans as data sources.
- ✓ Big data
  - Transfer, storage and maintenance of huge volumes of data is expensive.
  - Data cleaning and purification is time consuming.
  - Analytics on gigantic data volumes is processing intensive.

Source: Arasteh, H., et al. "Iot-based smart cities: A survey." *IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 2016*.

IoT Challenges in Smart Cities (contd.)

- ✓ Sensor Networks
  - Choice of appropriate sensors for individual sensing tasks is crucial.
  - Energy planning is crucial.
  - Device placement and network architecture is important for reliable end-to-end IoT implementation.
  - Communication medium and means play an important role in seamless function of IoT in smart cities.

Source: Arasteh, H., et al. "Iot-based smart cities: A survey." *IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 2016*.

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Smart Cities and Smart Homes – Part II

Dr. Sudip Misra

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Data Fusion

- ✓ Enormous volume of data is produced periodically in a smart city environment.
- ✓ Challenges include making the available/ incoming large data volume precise and accurate.
- ✓ Quality of data precision and accuracy affects the quality of decision making in IoT-enabled smart cities.
- ✓ Data fusion enables optimum utilization of massive data gathered from multiple sources, and across multiple platforms.

Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Multi-sensor Data Fusion

- ✓ Combines information from multiple sensor sources.
- ✓ Enhances the ability of decision making systems to include a multitude of variables prior to arriving at a decision.
- ✓ Inferences drawn from multiple sensor type data is qualitatively superior to single sensor type data.
- ✓ Information fusion generated from multiple heterogeneous sensors provides for better understanding of the operational surroundings.

Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Challenges

Imperfection	Inaccurate or uncertain WSN sensor data
Ambiguity	Outliers, missing data
Conflicts	Same sensor type reports different data for the same location.
Alignment	Arises when sensor data frames are converted to a singular frame prior to transmission
Trivial features	Processing of trivial data features may bring down the accuracy of the whole system

Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Data Fusion Opportunities in IoT

- ✓ Collective data is rich in information and generates better intelligence compared to data from single sources.
- ✓ Optimal amalgamation of data.
- ✓ Enhancing the collective information content obtained from multiple low-power, low-precision sensors.
- ✓ Enables hiding of critical data sources and semantics (useful in military applications, medical cases, etc.).

Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Stages of Data Fusion

Decision level	Feature level	Pixel level	Signal level
• Ensemble of decisions	• Fusion of information prior to decision making	• Fusion of information at the imaging device level itself	• Fusion of information at the sensor node/ within the local network itself.

Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Mathematical Methods of Data Fusion

Probability based

- Bayesian analysis, Statistics, Recursive methods

AI based

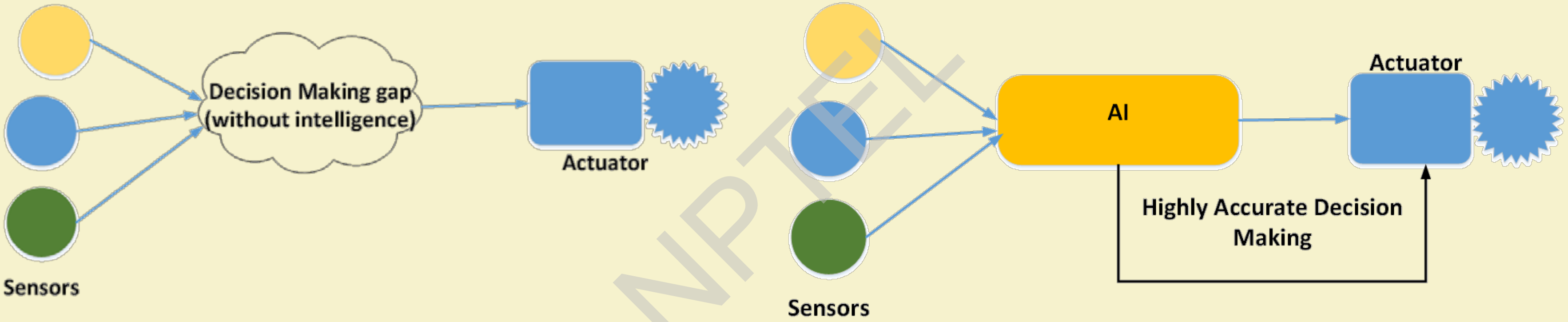
- ANN, Machine Learning, CNN

Theory of Evidence based

- Belief functions, Transferable belief models

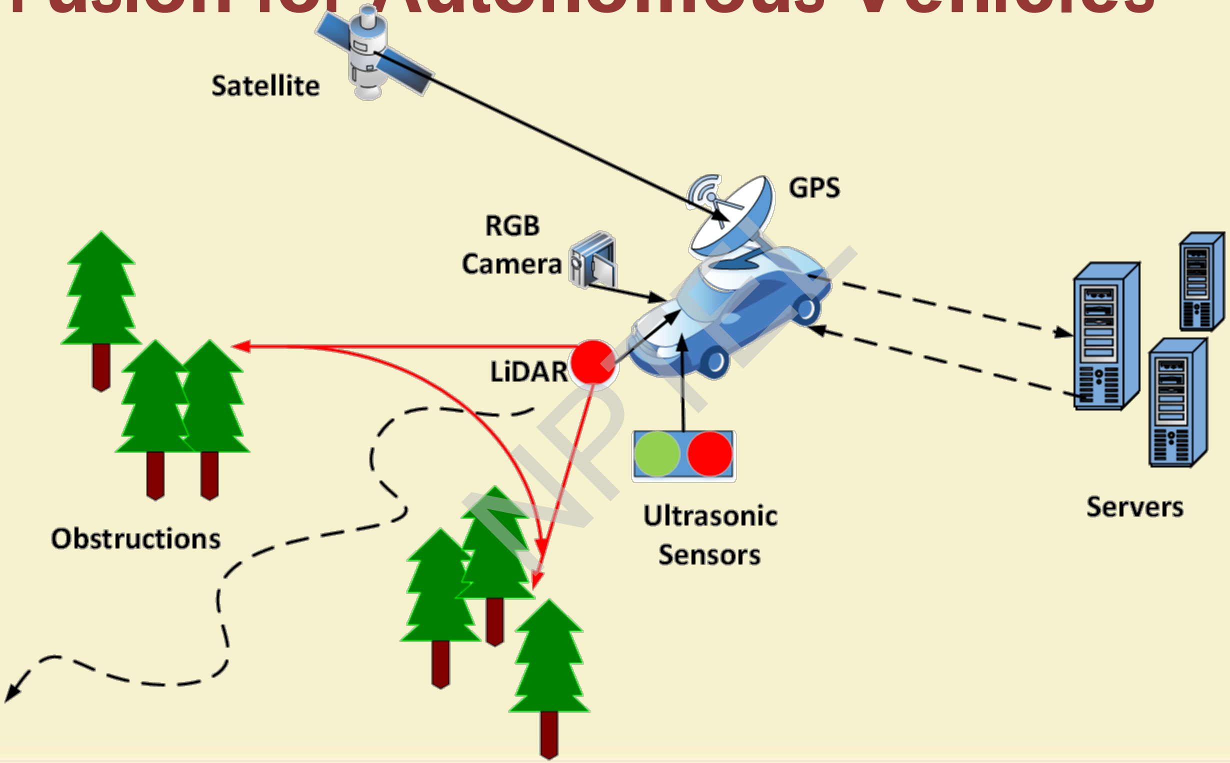
Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

AI in IoT Decision Making



Source: Alam, Furqan, et al. "Data Fusion and IoT for Smart Ubiquitous Environments: A Survey." *IEEE Access* (2017).

Data Fusion for Autonomous Vehicles



Smart Parking

- ✓ Shortens parking search time of drivers.
- ✓ Reduces traffic congestion.
- ✓ Reduces pollution by keeping unnecessarily lingering vehicles off the roads.
- ✓ Reduces fuel consumption and costs.
- ✓ Increases urban mobility.
- ✓ Shorter parking search time results in more parked time, and hence, more revenue.

Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Functional Layers in Smart parking

- Information Collection
- System Deployment
- Service Dissemination

Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Smart Parking: Information Collection

- Sensors
- Parking Meters
- Sensor Networks
- Crowd sensing

Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Smart Parking: System Deployment

- Software System
- Information Management
- E-parking
- Guidance
- Data Analytics

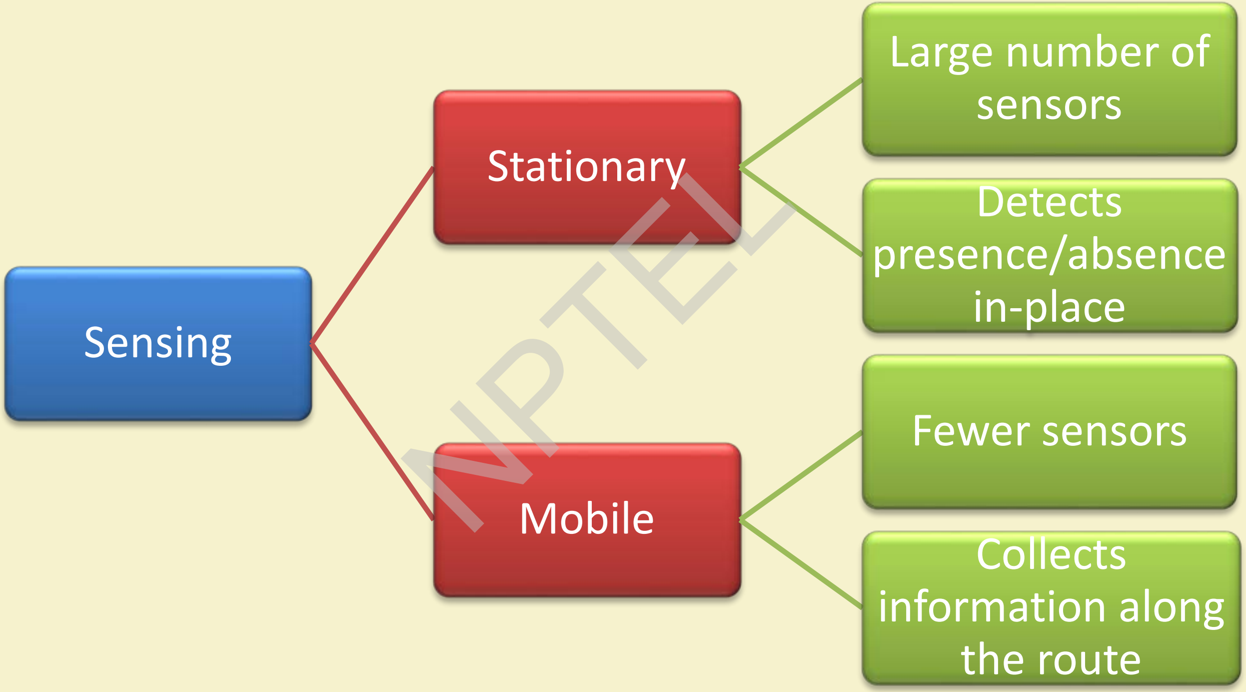
Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Smart Parking: Service Dissemination

- Dynamic Pricing
- Strategies
- Infrastructure-based information
- Infrastructure-free information
- Parking Choice
- Vehicular Activities

Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Information Sensing in Smart Parking



Source: Lin, Trista, Hervé Rivano, and Frédéric Le Mouël. "A Survey of Smart Parking Solutions." *IEEE Transactions on Intelligent Transportation Systems* (2017).

Energy Management in Smart Cities

✓ Energy efficient solutions

- Lightweight protocols
- Scheduling optimization
- Predictive models for energy consumption
- Cloud-based approach
- Low-power transceivers
- Cognitive management framework

Source: Ejaz, Waleed, et al. "Efficient Energy Management for Internet of Things in Smart Cities." IEEE Communications Magazine, 2017

Energy Management in Smart Cities

- ✓ Energy harvesting solutions
  - Ambient energy harvesting
    - RF sources
    - Wind
    - Sun
    - Heat
    - Vibration

Source: Ejaz, Waleed, et al. "Efficient Energy Management for Internet of Things in Smart Cities." IEEE Communications Magazine, 2017

Energy Management in Smart Cities

- ✓ Energy harvesting solutions
  - Dedicated energy harvesting
    - Energy sources intentionally deployed near IoT sources.
    - Amount of energy harvested depends upon:
      1. Sensitivity of the harvesting circuit
      2. Distance between the device and source
      3. Environment

Source: Ejaz, Waleed, et al. "Efficient Energy Management for Internet of Things in Smart Cities." IEEE Communications Magazine, 2017

Thank You!!

Smart Cities and Smart Homes – Part III

Dr. Sudip Misra
Associate Professor
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IIT KHARAGPUR
Email: smisra@sit.iitkgp.ernet.in
Website: http://cse.iitkgp.ac.in/~smisra/

Introduction

- ✓ Smart home infrastructure consists of:
  - Intelligent networking device infrastructure
  - Seamless integration of various devices using wired/wireless technologies
- ✓ Allows ease of use for household systems.
- ✓ Creates a highly personalized and safe home space
- ✓ Corporations seriously indulging in smart home systems include GE, Cisco, Google, Microsoft, and others.

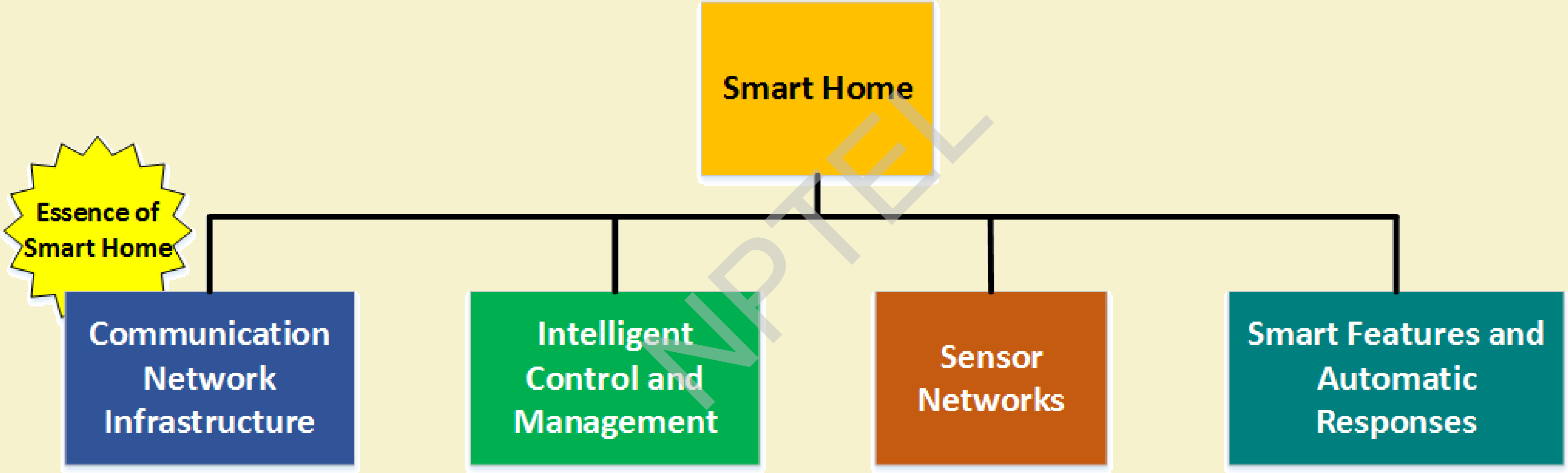
Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

Smart Home

- ✓ Provides productive and cost-efficient environment.
- ✓ Maximizes the effectiveness of the occupants.
- ✓ Provides efficient management with minimum life-time costs of hardware and facilities.
- ✓ Optimizes-
  - Structures
  - Systems
  - Services and management
  - Interrelationships between the above three

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

Smart Home Aspects



Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

Home Area Networks (HANs)

- Elements
- Standards
- Architectures
- Initiatives

✓ Network contained within a home.

✓ Enables remote access and control of devices and systems.

✓ Provides amalgamation of various systems within a home, such as – security systems, home automation systems, personal media, communication, etc.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Elements

- ✓ Internet Protocol (IP)
  - Multi-protocol gateway bridges non-IP network to IP network.
  - Bridging between new technologies is limited.
  - For new technologies or networks, a new mapping is required for bridging to perform satisfactorily.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

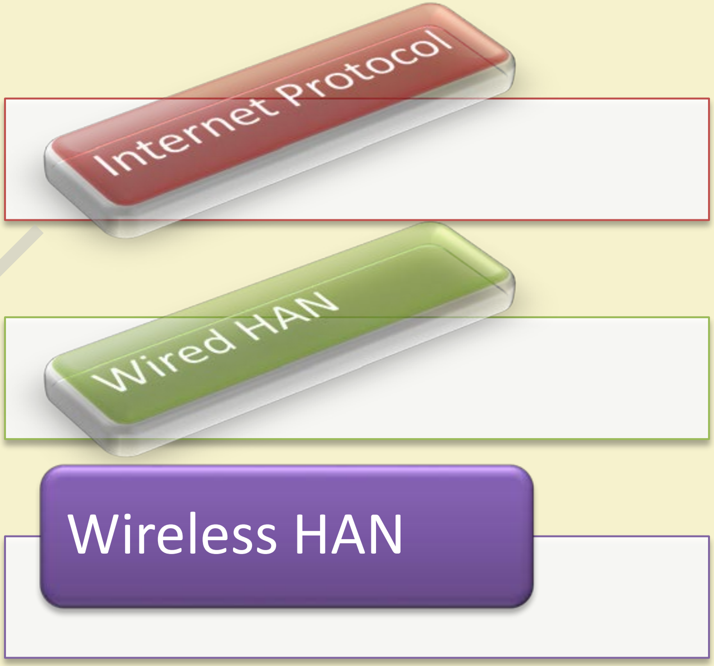
HAN Elements

- ✓ Wired HAN
  - Easy integration with pre-existing house infrastructure.
  - Low cost.
  - Can use power lines, coaxial cables, telephone lines, optical fibers, and other such technologies for communication.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

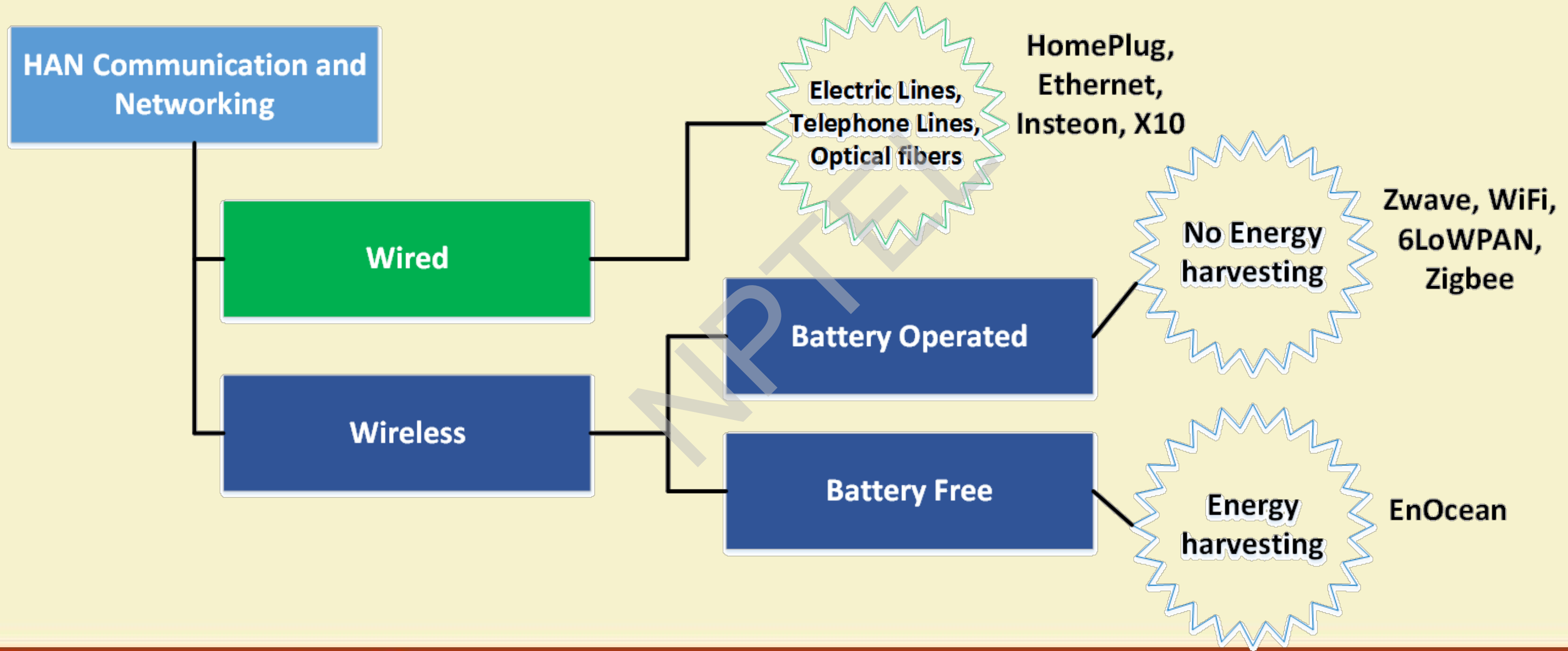
HAN Elements

- ✓ Wireless HAN
  - Can use popular home Wi-Fi, ZigBee, and even new standards, such as 6LoWPAN.
  - Wireless makes implementation easy.



Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Medium Classification



HAN Standards

- ✓ Universal Plug and Play (UPnP).
- ✓ Application layer technology, mainly web-based.
- ✓ TCP/IP protocol stack provides support for the lower layers, and enables seamless integration of various technologies.
- ✓ Provides transparent networking with support for zero-configuration networking and automatic discovery of devices.

- **UPnP**
- DLNA
- Konnex
- LonWorks
- Zigbee
- X-10

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Standards

- ✓ Digital Living Network Alliance (DLNA)
- ✓ Trade organization created by Sony, Intel, and Microsoft.
- ✓ Connects cable-based networks with wireless networks for increased sharing of media, control and access.
- ✓ Domestically shares network media resources.

- UPnP
- DLNA
- Konnex
- LonWorks
- Zigbee
- X-10

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Standards

- ✓ Konnex (KNX): an open important standard for home and building networks.
- ✓ Utilizes the full range of home communication infrastructure – Power lines, coaxial cables, twisted pair, RF, etc.
- ✓ Must be setup and configured via a software before its proper usage.

- UPnP
- DLNA
- **Konnex**
- LonWorks
- Zigbee
- X-10

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Standards

- ✓ Local Operation Networks (LonWorks).
- ✓ Every device includes a Neuron Chip, a transceiver and the application electronics.
- ✓ Neuron chip is a SOC with multiple microprocessors, RAM, ROM and IO interface ports.
- ✓ Splits device groups into intelligent elements, which can communicate through a physical communication medium.

UPnP

DLNA

Konnex

LonWorks

Zigbee

X-10

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Standards

- ✓ Zigbee consists of four layers – Physical, Medium Access Control, Network, and Application.
- ✓ Physical and MAC layers are defined by IEEE802.15.4, whereas Network and Application are defined by Zigbee.
- ✓ Aims at low-cost, low-energy devices.
- ✓ ZigBee Alliance is composed of Mitsubishi, Honeywell, Invensys, Motorola and Philips

- UPnP
- DLNA
- Konnex
- LonWorks
- **Zigbee**
- X-10

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Standards

- ✓ X-10 enables remote control of compliant transmitters and receivers over power lines and electrical wirings present in the house.
- ✓ Adopted by GE and Philips.
- ✓ Standard defines procedures for transmission of bits over AC carrier signals.
- ✓ Low-speed and low data rate.
- ✓ Mainly used for control of lighting, appliance networks and security sensors.

- UPnP
- DLNA
- Konnex
- LonWorks
- Zigbee
- **X-10**

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Architectures

- ✓ Uses XML for description and web-services for control.
- ✓ Follows a Service oriented Architecture (SOA).
- ✓ Not tied to any software, language or architecture.
- ✓ A central gateway connects different technologies.
- ✓ A tech Manager for each technology provides web services for control and access.

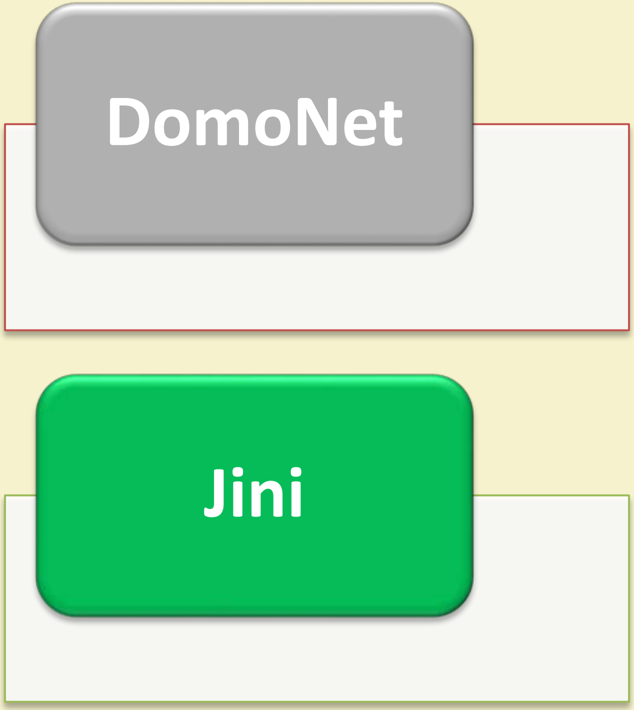
DomoNet

Jini

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Architectures

- ✓ Connects various devices sharing their resources with auto-configuration and auto-installation.
- ✓ Based on JAVA environment and pursued by Sun Microsystems (Now, Oracle).
- ✓ Constructs an organized distribution system without a central node (federation).
- ✓ Jini apps use bytecode to run JVM, and are portable.
- ✓ Follows Object Oriented Paradigm.



Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Initiatives

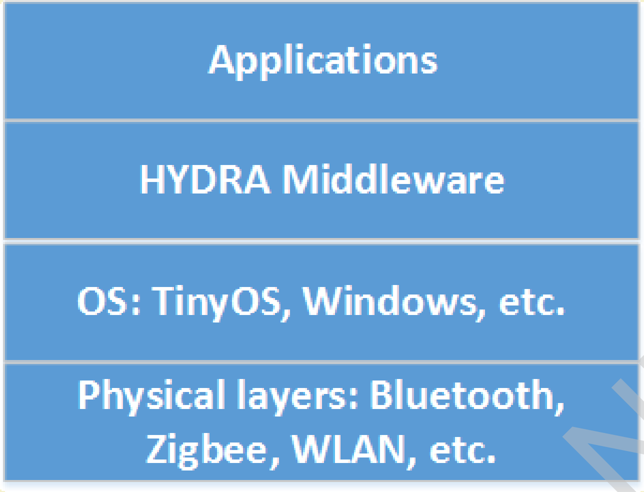
- ✓ Middleware for embedded intelligent systems.
- ✓ Connects a Service Oriented Architecture Network.
- ✓ Connected devices may have limited resources, low processing power, memory or energy consumption.
- ✓ Each device has an embedded HYDRA client which acts as a proxy between the device and the middleware.

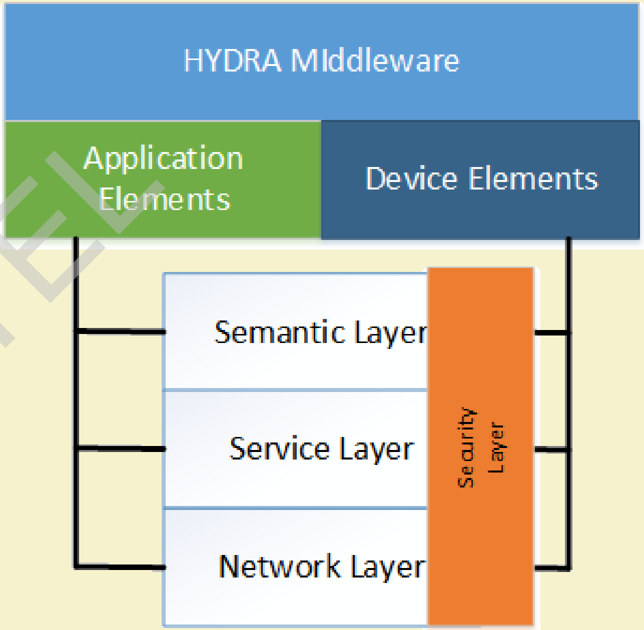
Project HYDRA

Amigo

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HYDRA Protocol Stack





Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

HAN Initiatives

✓ Aimed at:-

- Ambient intelligent systems
- For networked home systems

✓ Features user-friendly interfaces, interoperability, and automatic discovery of devices and services.

Project HYDRA

Amigo

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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Connected Vehicles – Part I

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IIT KHARAGPUR

Email: smisra@sit.iitkgp.ernet.in

Website: http://cse.iitkgp.ac.in/~smisra/

Introduction

- ✓ Vehicles equipped with
  - Sensors
  - Networking and communicating devices
- ✓ Capable of :
  - Communicating with other devices within the vehicle
  - Communicating with other similar vehicles
  - Communicating with fixed infrastructure

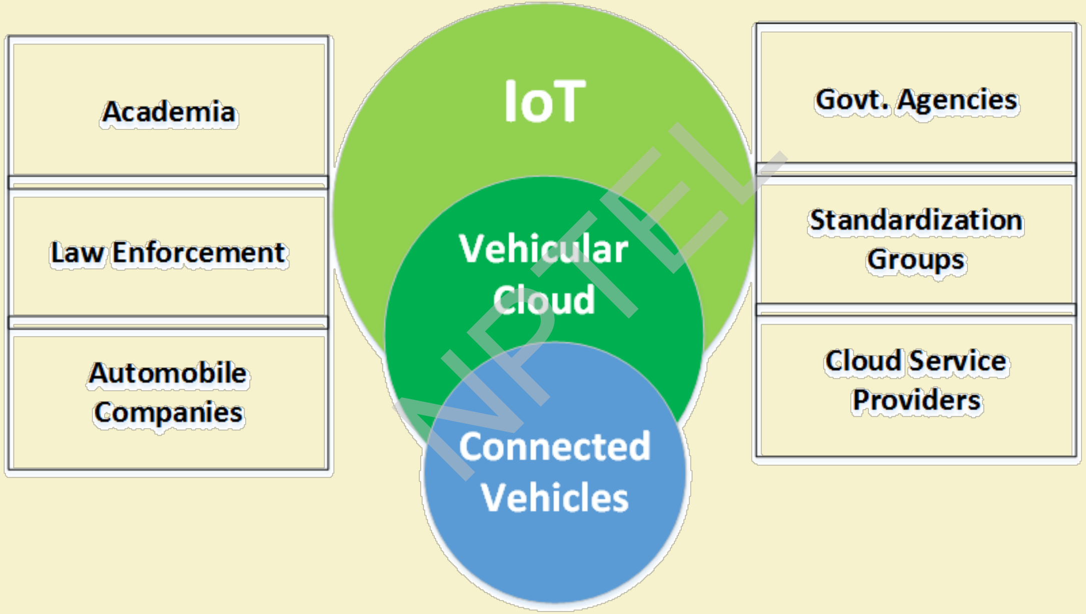
Source: Kim, Younsun, Hyunggoy Oh, and Sungho Kang. "Proof of Concept of Home IoT Connected Vehicles." *Sensors* 17.6 (2017): 1289.

Challenges

- ✓ Security
- ✓ Privacy
- ✓ Scalability
- ✓ Reliability
- ✓ Quality of service
- ✓ Lack of global standards

Source: Kim, Younsun, Hyunggoy Oh, and Sungho Kang. "Proof of Concept of Home IoT Connected Vehicles." *Sensors* 17.6 (2017): 1289.

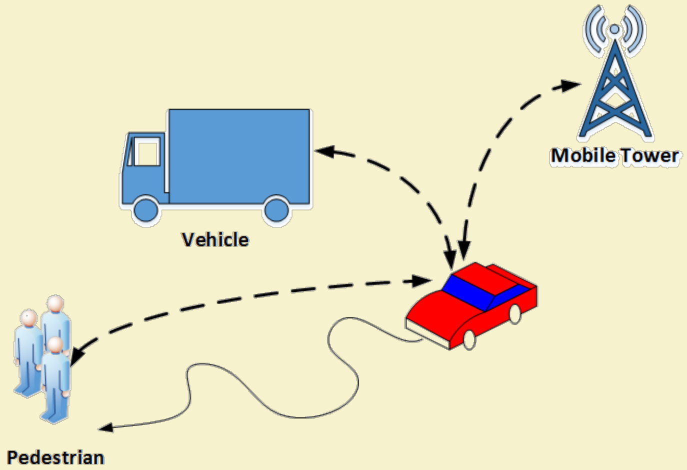
Connected Vehicles



Source: Kim, Younsun, Hyunggoy Oh, and Sungho Kang. "Proof of Concept of Home IoT Connected Vehicles." *Sensors* 17.6 (2017): 1289.

Vehicle-to-Everything (V2X) Paradigm

- ✓ Main component of future Intelligent Transportation System (ITS).
- ✓ Enables vehicles to wirelessly share a diverse range of information.
- ✓ Information sharing may be with other vehicles, pedestrians, or fixed infrastructures (mobile towers, parking meters, etc.)
- ✓ Allows for traffic management, ensuring on-road and off-road safety, mobility for traveling.



Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

V2X

- ✓ Follows a distributed architecture, where contents are widely distributed over the network.
- ✓ Not restricted to single source information provider.
- ✓ Designed mainly for highly mobile environments.
- ✓ Can share information to nodes in vicinity, as well as remotely located.
- ✓ Has greatly enhanced travel efficiency, as well as safety.
- ✓ The network is mainly used as a tool for sharing and disseminating information.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

Failures of TCP/IP in V2X

- ✓ Designed mainly for handling information exchange between a single pair of entities.
- ✓ Information exchange dependent on the location of data.
- ✓ Can only identify the addresses of endpoints, which alone is not useful for content distribution.
- ✓ Increase in number of wireless devices, restricts the mobility of the nodes.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

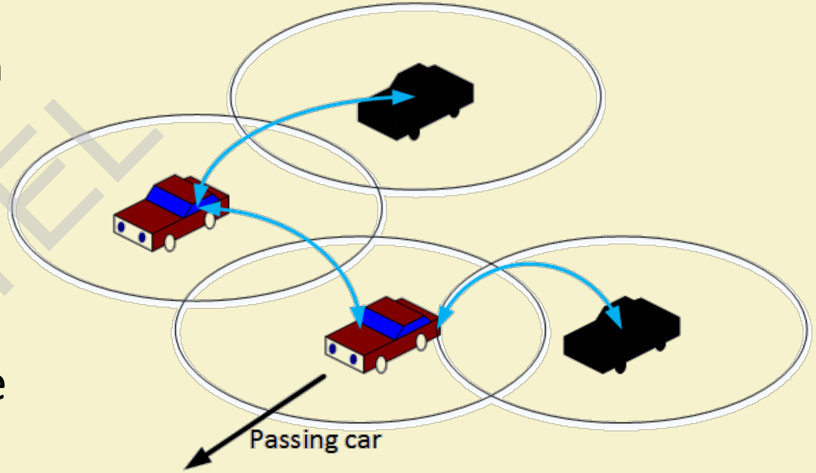
Content Centric Networking (CCN)

- ✓ CCN is derived from Information Centric Networking (ICN) architecture.
- ✓ Focuses more on the data than its actual location.
- ✓ Hierarchically named data.
- ✓ Hierarchical data is transmitted directly instead of being part of a conversation.
- ✓ Enables scalable and efficient data dissemination.
- ✓ In-network caching allows for low data traffic.
- ✓ Works well in highly mobile environments.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

Vehicular Ad-hoc Networks (VANETs)

- ✓ Based on:
  - Dedicated Short-Range Communication (DSRC)
  - Wireless Access in Vehicular Environment (WAVE)
- ✓ Routing protocols derived from MANETs.
- ✓ High throughput achievable in mobile environments.
- ✓ Guaranteed low-latency in mobile environments.



Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

VANET Features

High Dynamic Topology

- Vehicles in highly mobile environments causes constant changes in network partitioning and topology.

High transmission and computation capability

- Vehicle-stored energy sources and computational power do not restrict capabilities.

Unstable connectivity

- Link durations are short due to highly dynamic nature of VANETs.

Large scale

- Can be easily scaled up to include all vehicles on roads.

Predictable mobility pattern

- Vehicular restriction within roads, makes mobility pattern predictable.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

Applications of VANETs

Safety

- Emergency braking, lane change warning, collision avoidance, hazard notification

Efficiency

- Congestion management, electronic toll collection, parking availability

Commercial

- Internet access, multimedia stream

Comfort

- Weather information, autonomous driving, journey time estimation

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

CCN for VANETs

- ✓ Routing
  - Forwarding and routing based on name of content (not location).
  - Individual content's name prefixes are advertised by routers across the network.
  - This helps to build a Forwarding Information Base (FIB) for each router.
  - The name of content remains same and unique globally.
  - No issues of IP address management or address exhaustion.
  - Communication does not depend on speed or direction of nodes.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

CCN for VANETs

✓ Scalability

- An in-network caching mechanism at each router.
- Uniquely identifiable (named) data chunks are stored in Content Store (CS), which acts as a cache.
- Subsequent requests for a stored data chunk can be made to a CS.
- The naming system in the CS enables a data to be used multiple times, unlike normal IP-based routers.
- Reduced network load during increased network size, as a result of the caching mechanism.

Source: Zhu, Z., et al. "Recent advances in connected vehicles via information-centric networking." *Intelligent and Connected Vehicles (ICV 2016), IET International Conference on*. IET, 2016.

Body and Brain Architecture

- ✓ An in-vehicle networking architecture.
- ✓ Three layered architecture.
- ✓ The body consists of intelligent networking nodes (INN) which constantly collect information from the vehicle.
- ✓ The brain manages central coordination.

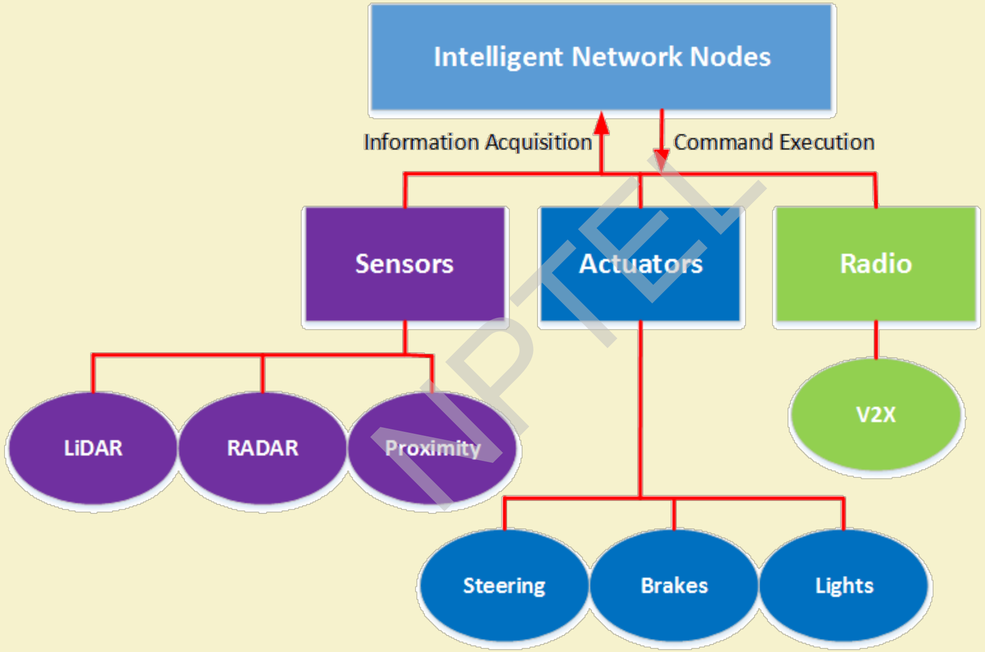
Decision
- Brain

Network and Transmission
- Nervous system

Sense and Execution
- Body

Source: J. Wang, D. Yang and X. Lian, "Research on electrical/electronic architecture for connected vehicles," *IET International Conference on Intelligent and Connected Vehicles (ICV 2016)*, Chongqing, 2016, pp. 1-6

Sense and Execution Layer

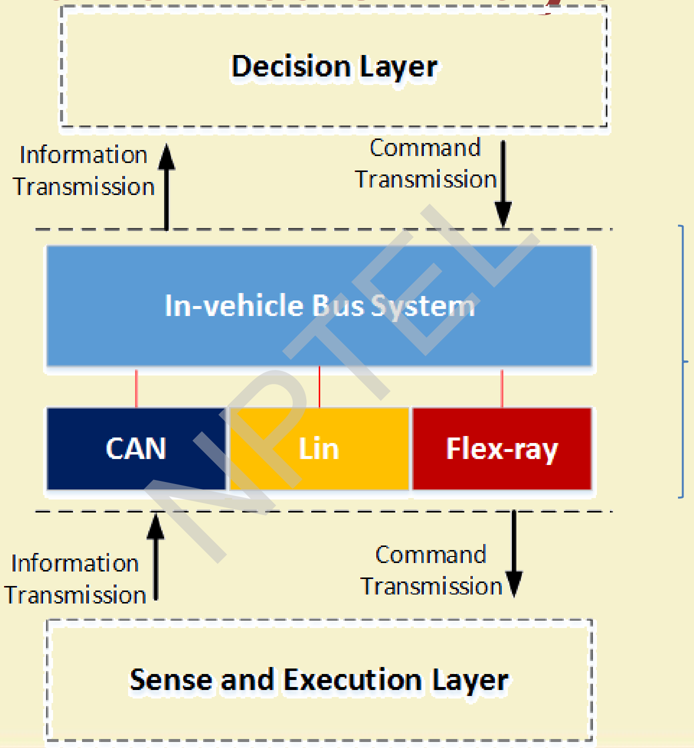


Classification of INN

- **Resistor Type**
  - Open
  - Close
- **Motor Type**
  - Clockwise
  - Counter clockwise
  - Stop
- **Switch Type**
  - Knob
  - Pneumatic
  - Electromagnetic
- **Sensor Type**
  - Rheostatic
  - Transformer
  - Transducer
- **Assembled**
  - Separate electronic control

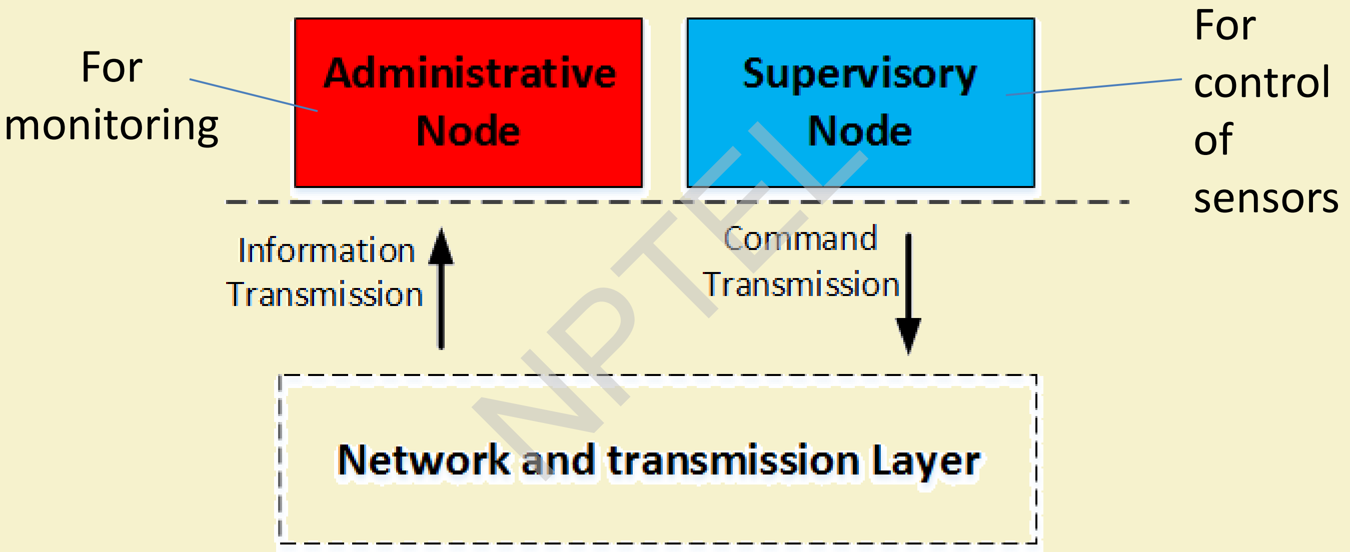
Source: J. Wang, D. Yang and X. Lian, "Research on electrical/electronic architecture for connected vehicles," *IET International Conference on Intelligent and Connected Vehicles (ICV 2016)*, Chongqing, 2016, pp. 1-6

Network and Transmission Layer



For communication

Decision Layer

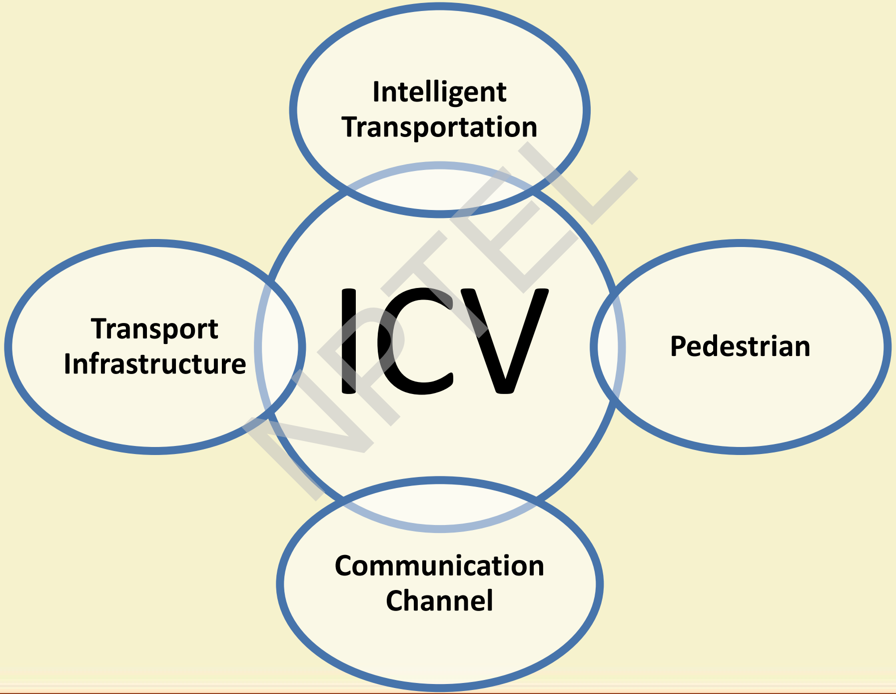


Thank You!!

Connected Vehicles – Part II

Dr. Sudip Misra
Associate Professor
Department of Computer Science and Engineering
IIT KHARAGPUR
Email: smisra@sit.iitkgp.ernet.in
Website: http://cse.iitkgp.ac.in/~smisra/

Intelligent Connected Vehicles (ICVs)



Technological Background

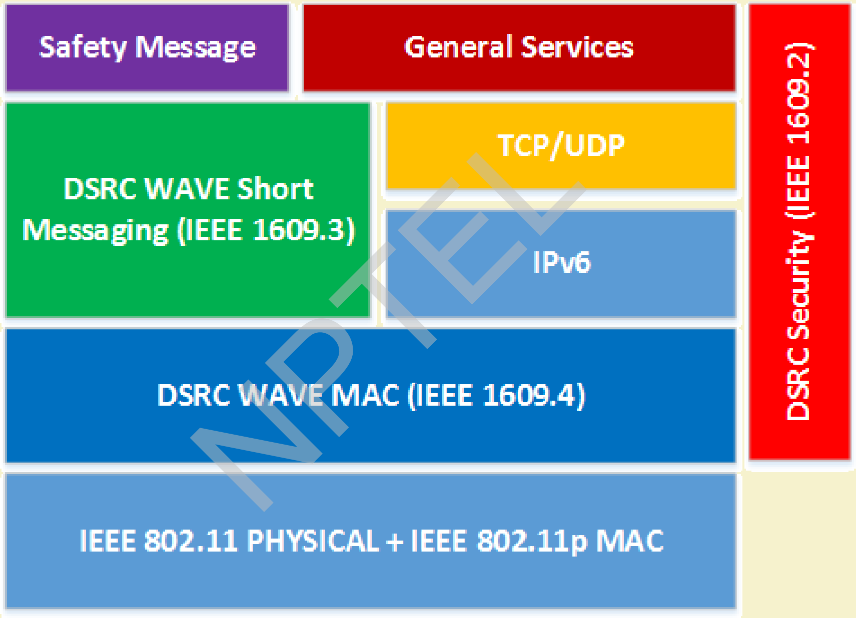
- ✓ The US Department of Transport and Federal Communications Commission allocated 75MHz (5850-5925MHz) as the dedicated spectrum for ICVs.
- ✓ It is based on Dedicated Short Range Communication (DSRC) technology.
- ✓ IEEE developed IEEE 802.11p and IEEE 1609 as DSRC standards.
- ✓ Society of Automotive Engineers (SAE) came up with SAE J2735 and J2945 as DSRC standards.

Source: Li, Yan, et al. "Big wave of the intelligent connected vehicles." *China Communications* 13.Supplement2 (2016): 27-41.

IEEE 1609 Family

- ✓ **IEEE P1609.0** Draft Standard for Wireless Access in Vehicular Environments (WAVE) - Architecture
- ✓ **IEEE 1609.1**-2006 - Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) - Resource Manager
- ✓ **IEEE 1609.2** -2006- Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages
- ✓ **IEEE 1609.3** -2007 - Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
- ✓ **IEEE 1609.4** -2006- Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-Channel Operations
- ✓ **IEEE P1609.11** Over-the-Air Data Exchange Protocol for Intelligent Transportation Systems (ITS).

DSRC Outline



Source: Li, Yan, et al. "Big wave of the intelligent connected vehicles." *China Communications* 13.Supplement2 (2016): 27-41.

Phases of ICV Development

Phase-1

- Infotainment service with remote information processing
- Based on 2G/3G

Phase-2

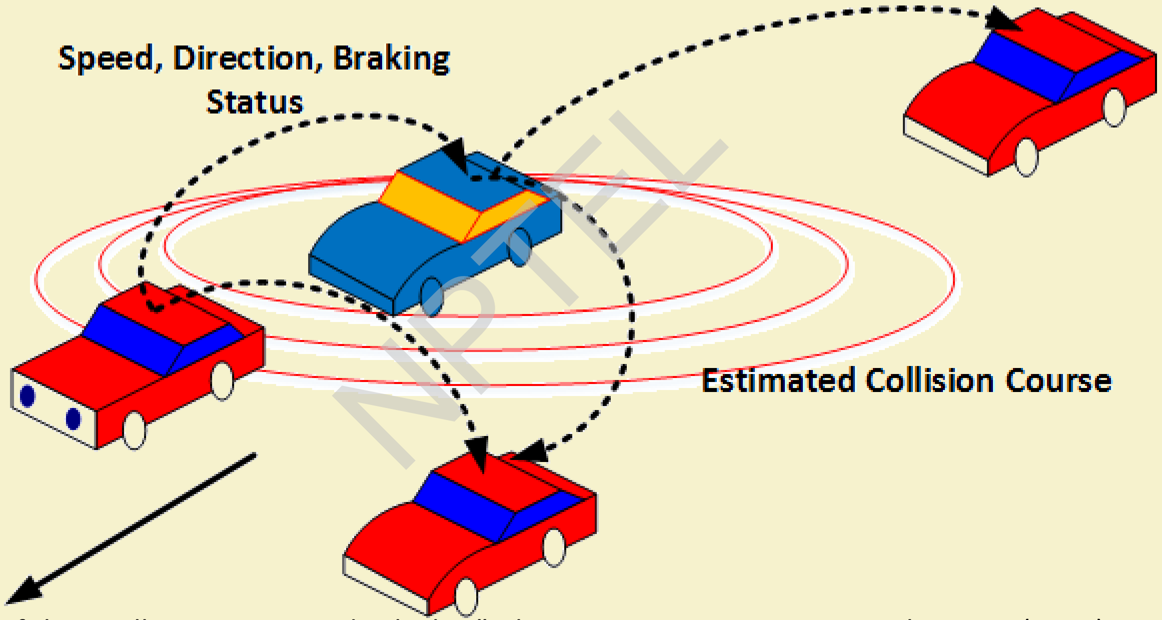
- Intelligent transportation service
- Based on 4G LTE or DSRC

Phase-3

- Vehicles connected to the cloud

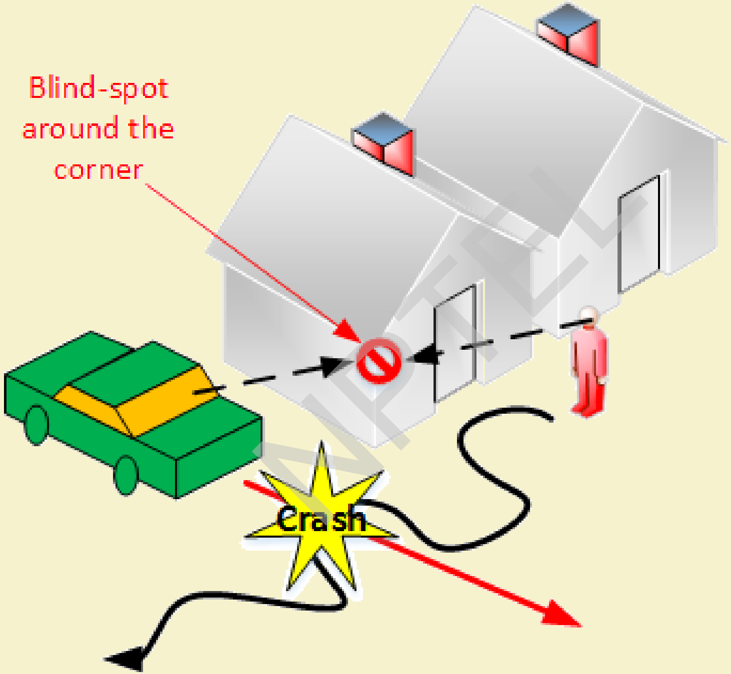
Source: Li, Yan, et al. "Big wave of the intelligent connected vehicles." *China Communications* 13.Supplement2 (2016): 27-41.

Forward Collision Warning (V2V)



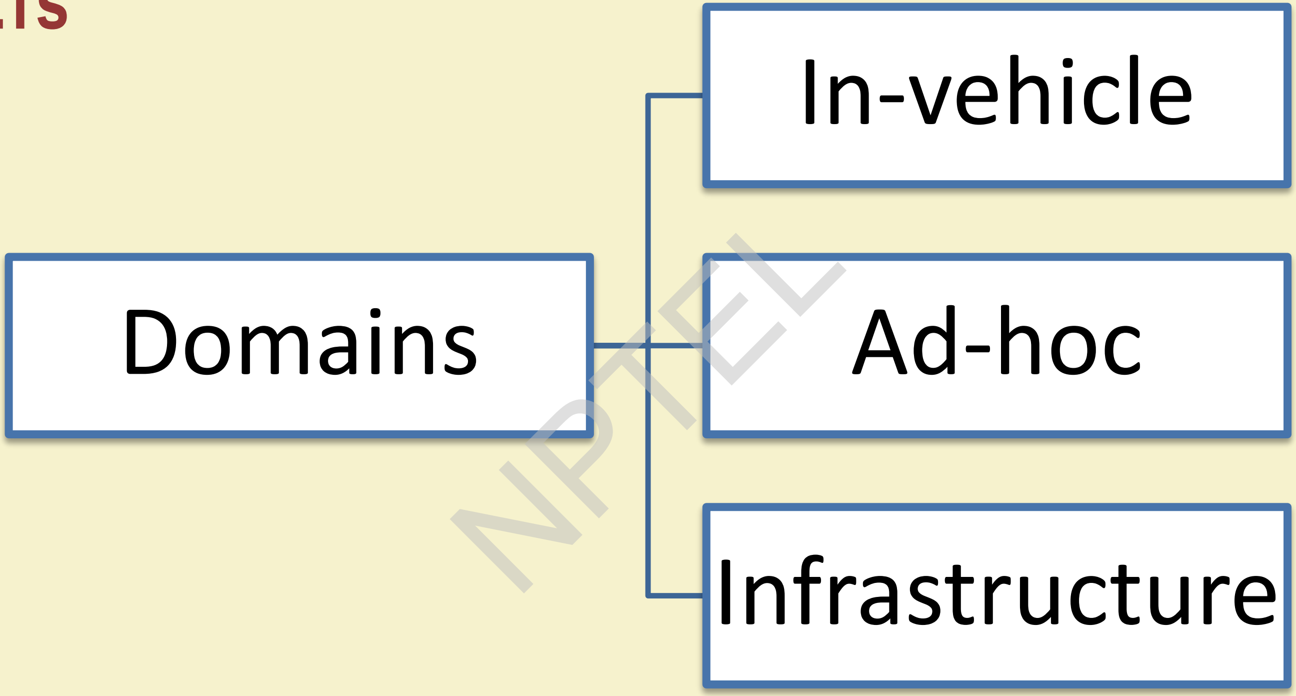
Source: Li, Yan, et al. "Big wave of the intelligent connected vehicles." *China Communications* 13.Supplement2 (2016): 27-41.

Vulnerable Road User Safety (V2P)



Source: Li, Yan, et al. "Big wave of the intelligent connected vehicles." *China Communications* 13.Supplement2 (2016): 27-41.

VANETs

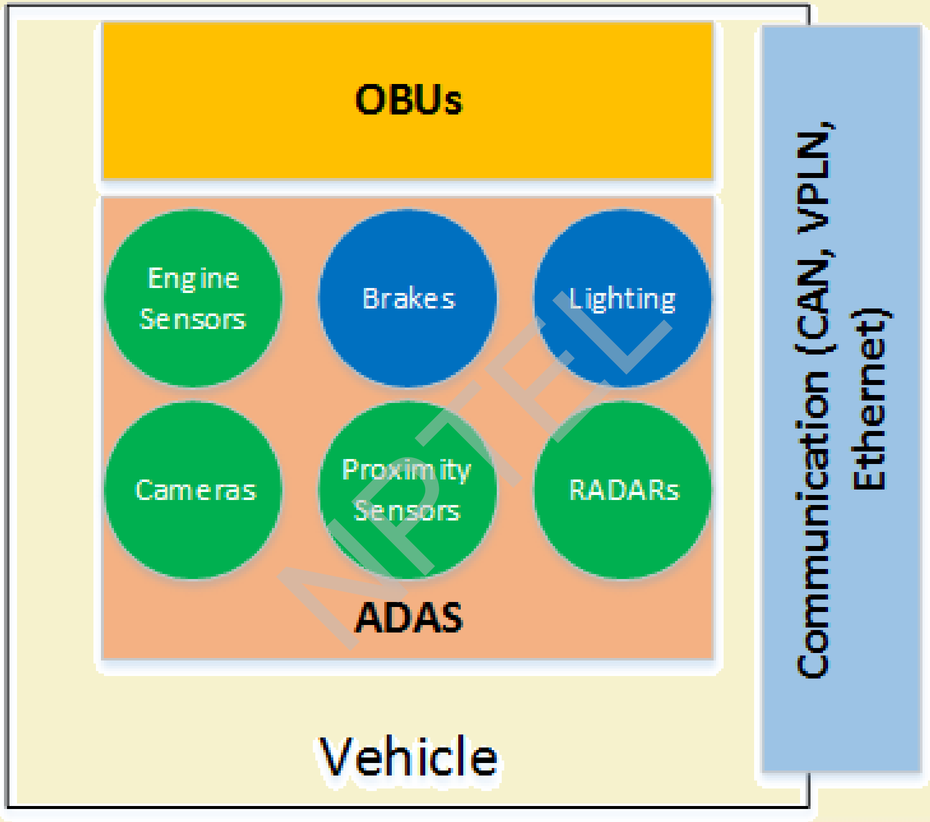


Source: Pressas, Andreas, et al. "Connected vehicles in smart cities: interworking from inside vehicles to outside." *Sensing, Communication, and Networking (SECON), 2016 13th Annual IEEE International Conference on*. IEEE, 2016.

In-Vehicle Domain

- ✓ Composed of one or more on-board units (OBUs).
- ✓ Additional presence of Advanced Driver Assistance Systems (ADAS) sensors such as-
  - cameras
  - proximity sensors
  - Engine sensors
  - Radars
  - Actuators
- ✓ Communication is mainly through Controller Area Network (CAN), Vehicular Powerline Networks (VPLN), and Ethernet.

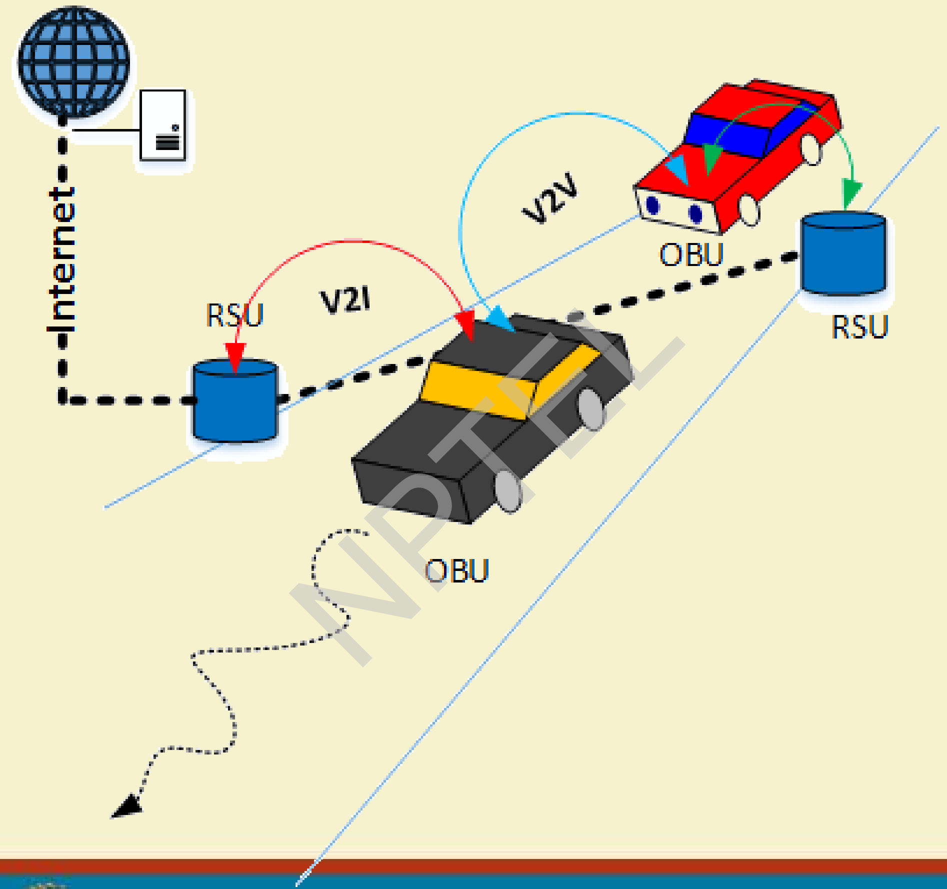
Source: Pressas, Andreas, et al. "Connected vehicles in smart cities: interworking from inside vehicles to outside." *Sensing, Communication, and Networking (SECON), 2016 13th Annual IEEE International Conference on*. IEEE, 2016.


OBUs
Engine Sensors
Brakes
Lighting
Cameras
Proximity Sensors
RADARs
ADAS
Vehicle
Communication (CAN, VPLN, Ethernet)

Ad-hoc Domain

- ✓ Composed of vehicles and road-side units.
- ✓ The vehicles (OBUs) are mobile.
- ✓ The road-side units (RSUs) are static.
- ✓ Communication mode may be either V2V or V2I.
- ✓ Communication through DSRC stack (IEEE 802.11p)

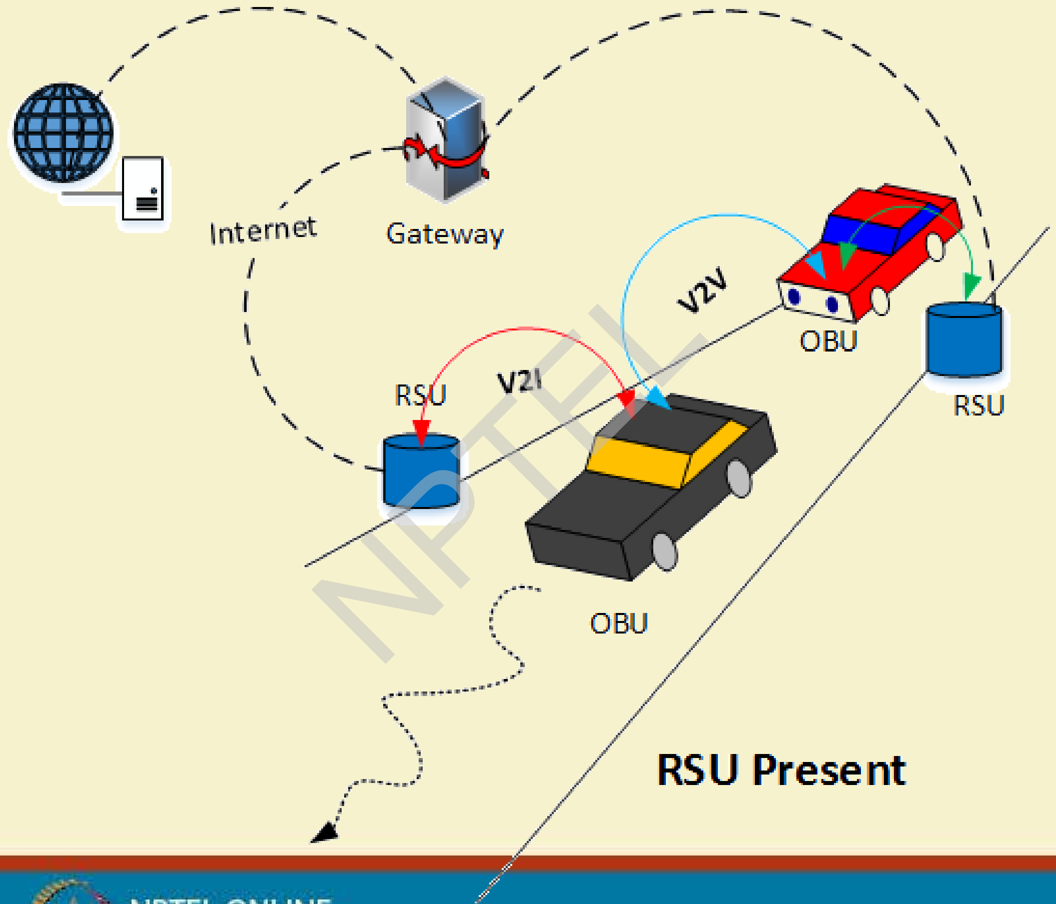
Source: Pressas, Andreas, et al. "Connected vehicles in smart cities: interworking from inside vehicles to outside." *Sensing, Communication, and Networking (SECON), 2016 13th Annual IEEE International Conference on*. IEEE, 2016.

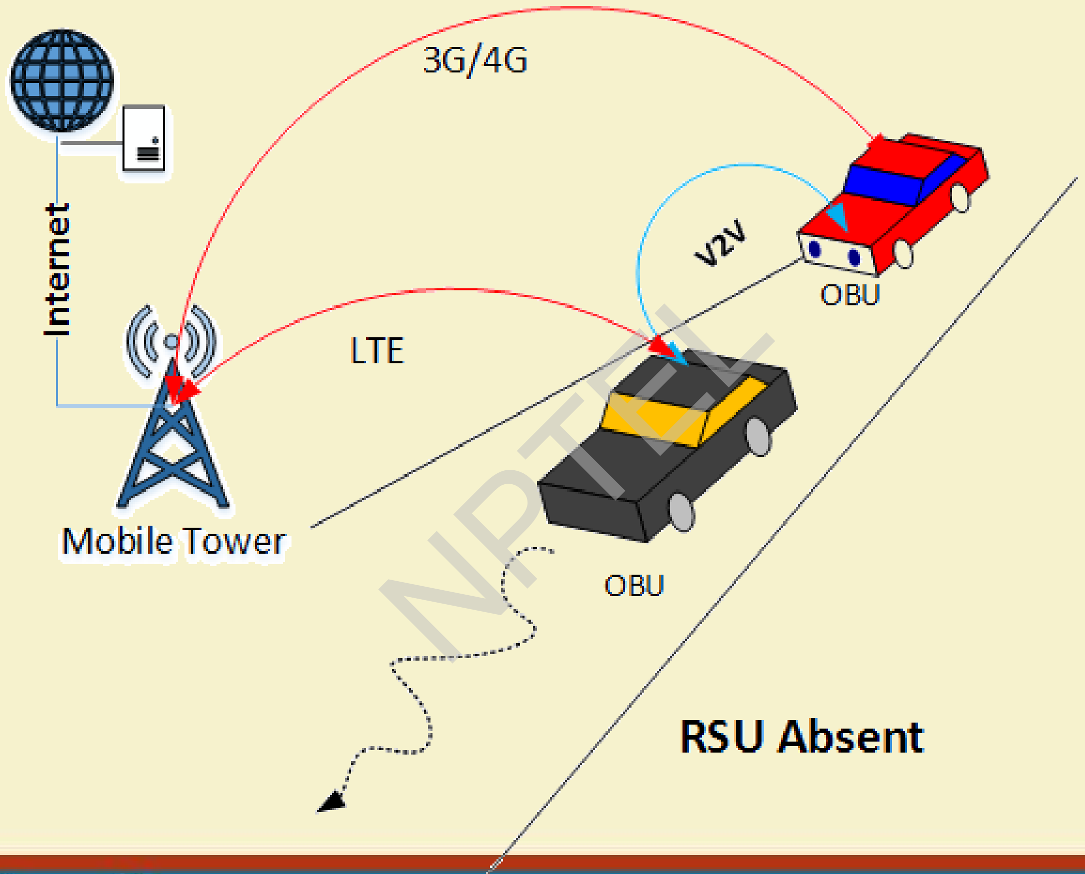

Internet
RSU
V2I
V2V
OBU
RSU
OBU

Infrastructure Domain

- ✓ RSUs connected to Internet by means of Gateways.
- ✓ In the presence of RSUs, the vehicles may communicate to the Internet via V2I interfaces.
- ✓ In the absence of RSUs, the vehicles may communicate with each other or the Internet through cellular networks such as 3G/4G, LTE, etc.

Source: Pressas, Andreas, et al. "Connected vehicles in smart cities: interworking from inside vehicles to outside." *Sensing, Communication, and Networking (SECON), 2016 13th Annual IEEE International Conference on*. IEEE, 2016.


Internet
Gateway
V2V
OBU
RSU
V2I
RSU
OBU
RSU Present


3G/4G
Internet
LTE
V2V
OBU
Mobile Tower
OBU
RSU Absent

V2X Communication: Advantages

- ✓ Increased traffic safety.
- ✓ Increased driver safety.
- ✓ Optimized time of travel.
- ✓ Efficiency of fuel consumption.
- ✓ Secure travel.
- ✓ Easier drive in low-visibility or unfavorable weather conditions.

Source: Schmidt, Teresa, et al. "Public perception of V2X-technology-evaluation of general advantages, disadvantages and reasons for data sharing with connected vehicles." *Intelligent Vehicles Symposium (IV), 2016 IEEE*. IEEE, 2016.

V2X Communication: Disadvantages

- ✓ Violation of privacy.
- ✓ Loss of data control.
- ✓ Collection of personal data.
- ✓ Second use of data.
- ✓ Data use by unauthorized entities.
- ✓ Tracking of movements.
- ✓ Localization of position.

Source: Schmidt, Teresa, et al. "Public perception of V2X-technology-evaluation of general advantages, disadvantages and reasons for data sharing with connected vehicles." *Intelligent Vehicles Symposium (IV), 2016 IEEE*. IEEE, 2016.

Thank You!!