The Tenth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2019

Panel on IoT and Sensing
Theme: Challenges in Dealing with Massive Data
Tuesday, October 29th

Moderator

Paulo E. Cruvinel, “Embrapa Instrumentation, Brazil”
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Panelists

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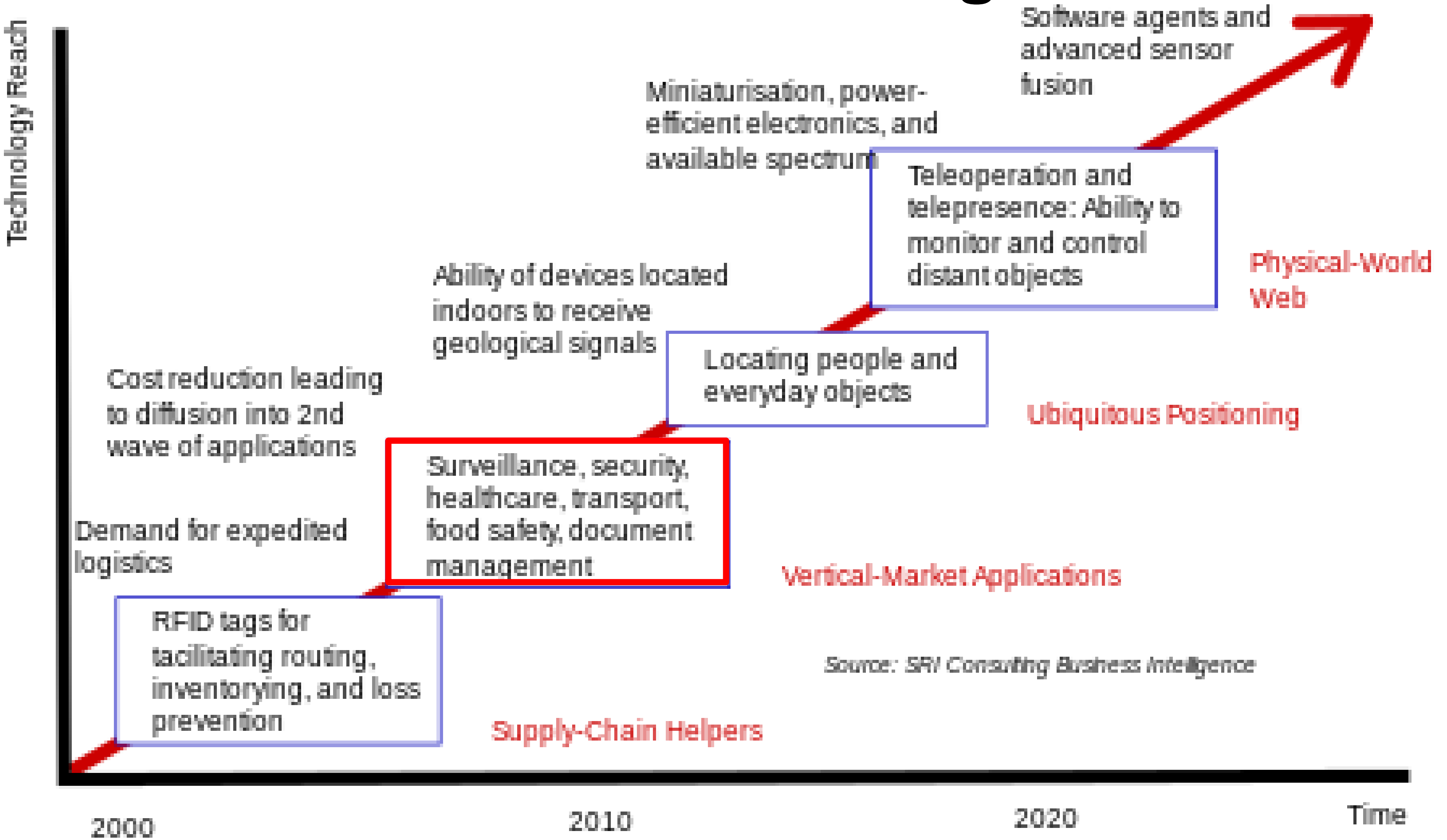
There are challenges in dealing with massive data, and also there are protocols for the Internet of Things (IoT), its analytics and applications. Such challenges are related to both reduce the overloading of the network bandwidth, save battery power and storage space, reduce the amount of data the CPU operates, and data quality, among others. However, mass of data may not have much meaningful value unless one can find an effective way to analyze and understand it. Big data analytics are expected to offer promising solutions. We shall discuss in this Panel some major techniques related to IoT and sensing, i.e., taking into account sensors, statistics, classification models, artificial intelligence, support vector machines, among other related topics. Also, cloud computing platforms, Big Data, Services, and an IoT road map will be considered to demonstrate opportunities in the implementation of such environment.

Technology roadmap:
The Internet of Things



Source: SRI Consulting Business Intelligence, In: 3rd International Conference on Networks, Applications, protocols and Service (NetAPPS), Sept, 2012. Date retrieved: August 10, 2018

Sensing huge data & data quality

<table>
<tr><th>Data Management System
Processes / Procedures</th><th>Data Quality System
Processes / Procedures</th><th>Auditable System & Serviceability</th><td rowspan="7">Risk Verification</td></tr>
<tr><td>Source</td><td rowspan="6">Validity
Reliability
Integrity
Precision
Timeliness</td><td rowspan="6">verification of the entire process, i.e., data acquisition, architectures involved, data processing, information retrieval, decision making models, among others</td></tr>
<tr><td>Collection</td></tr>
<tr><td>Collation</td></tr>
<tr><td>Models and analyses</td></tr>
<tr><td>Reporting</td></tr>
<tr><td>Usage</td></tr>
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First Panelist

Professor Manuela Vieira,
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*Professor **Manuela Vieira** was born in Lisbon, Portugal. She received the Master of Science in Solid State Physics Microelectronic and the Ph.D. in Semiconductor Materials both from the New University of Lisbon. She is a full Professor since 2011 in Electronics in the Department of Electronics Telecommunication and Computers (ISEL) and the head in both the Group in Applied Research in Microelectronic Optoelectronic and Sensors (GIAMOS-ISEL) and the Microelectronic, Material and Processes-(CTS-UNINOVA). She published several scientific papers and has more than 30 years of experience in the field of thin films and devices. Besides, her research activities have been mainly related to the development of optical sensors.*

The integration of the Visible Light Communications in the IoT and the advantages of it use in the Cooperative Intelligent Transport System (C-ITS).

She has discussed the use of modulated visible light, carried out by white low cost LEDs, to provide globally consistent signal-patterns and engage indoor localization, uplink and downlink communications and Vehicular VLC inside a Cooperative Intelligent Transport System (C-ITS) in order to provide a vehicular communication system that can enable quick, cost-effective means to distribute data in order to ensure safety, traffic efficiency, driver comfort, and so forth.

Panel on IoT and Sensing

Challenges in Dealing with Massive Data

VLC inside a Cooperative Intelligent Transportation System (C-ITS)

October 27 to 31, 2019 - Nice, France

Manuela Vieira

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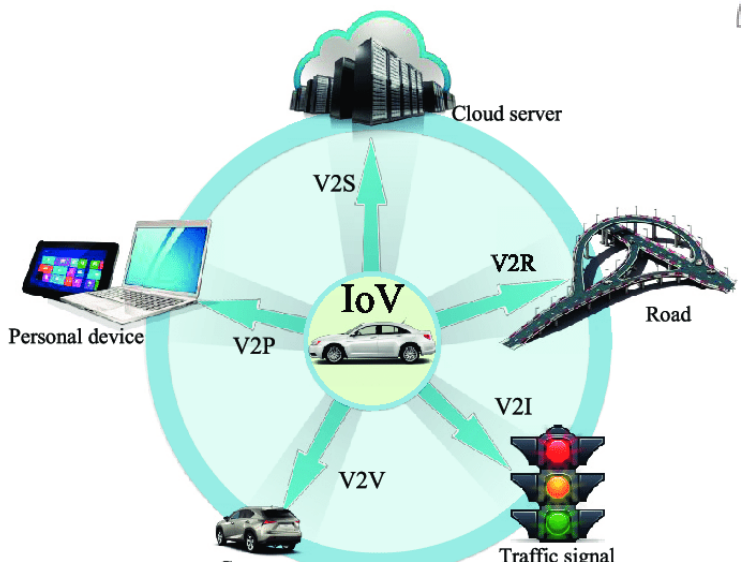
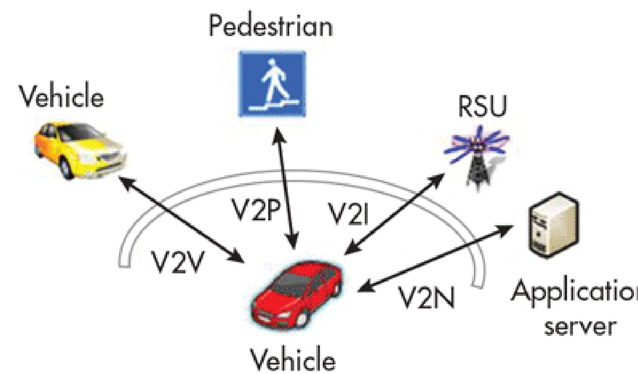
CTS

FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA





instituto de telecomunicações

GLOBAL INTERNET GROWTH AND TRENDS

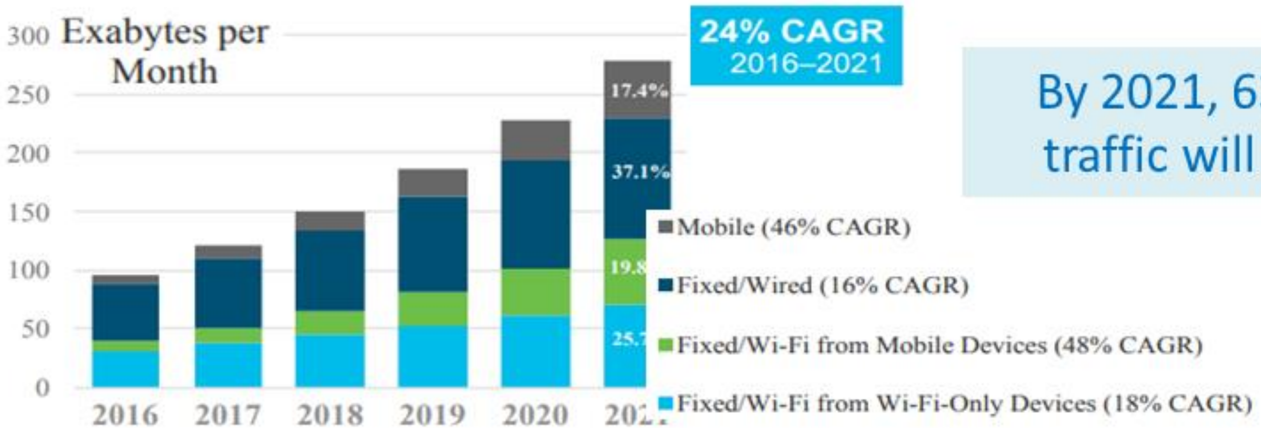
By 2021

	More Internet Users	More Devices & Connections	Faster Broadband Speeds	More Video Viewing
2016	3.3 Billion	17.1 Billion	27.5 Mbps	73% of Traffic
2021	**4.6 Billion**	**27.1 Billion**	**53.0 Mbps**	**82% of Traffic**

Data traffic

CAGR - Compound annual growth rate

Source: Cisco VNI Global IP Traffic Forecast, 2016-2021



By 2021, 63% of total IP traffic will be wireless *

* Wireless traffic includes Wi-Fi and mobile

The Internet of Things

connecting any device with an on and off switch to the Internet (and/or to each other)

The integration of IoT devices and Li-Fi will provide a wealth of opportunities. For example, shop owners could transmit data to multiple customers' phones quickly, securely and remotely.

Speed

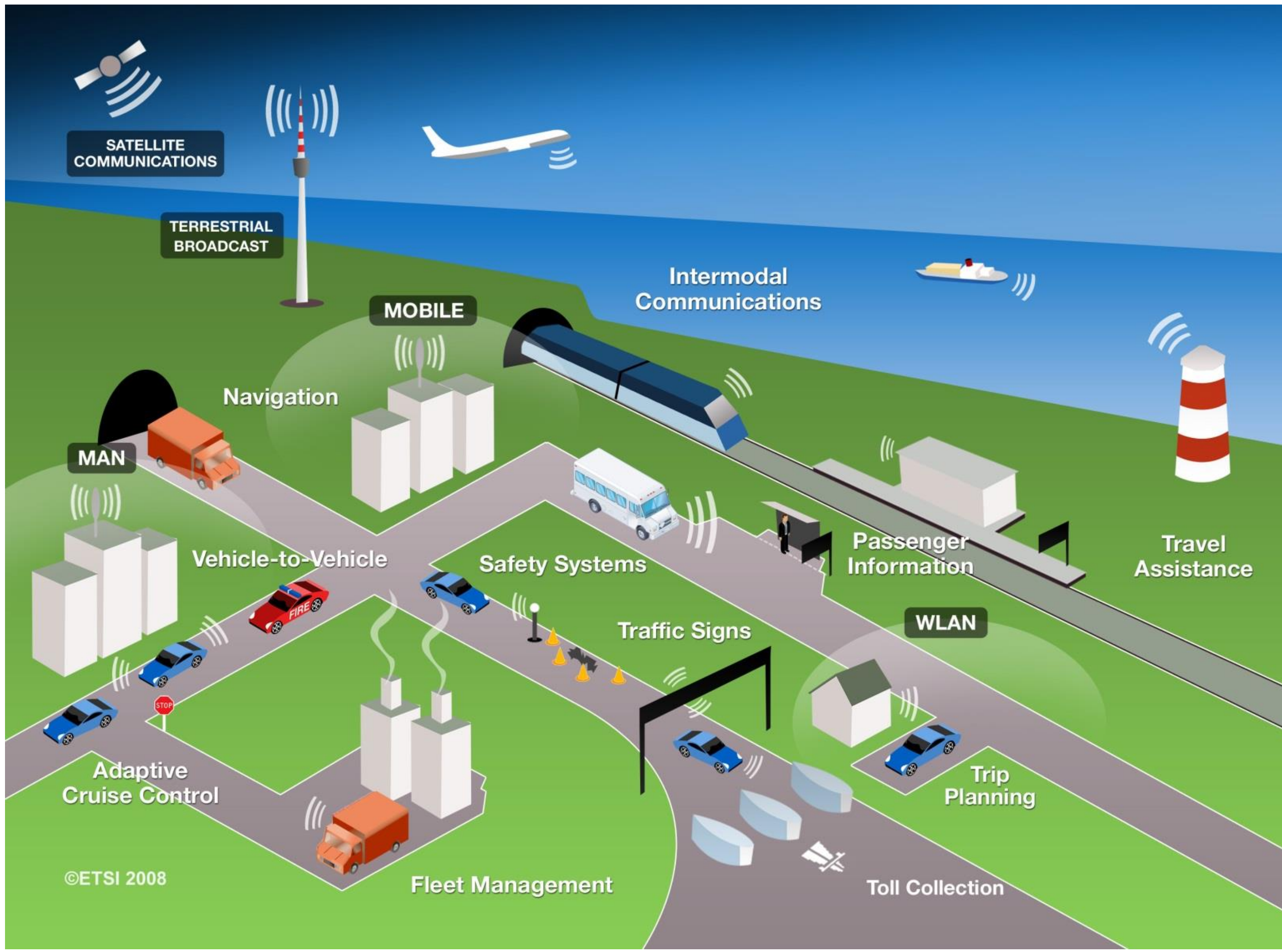
Latency

Capacity

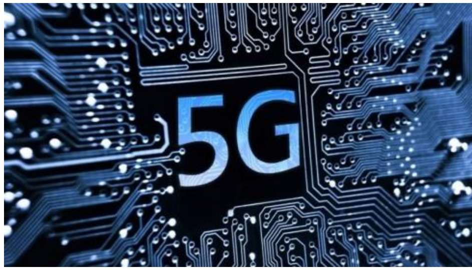
European Commission

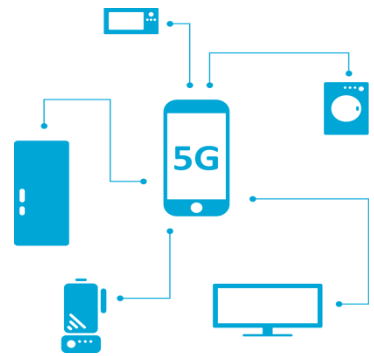
APPLICATION

Vehicular VLC: Road-to-Vehicle



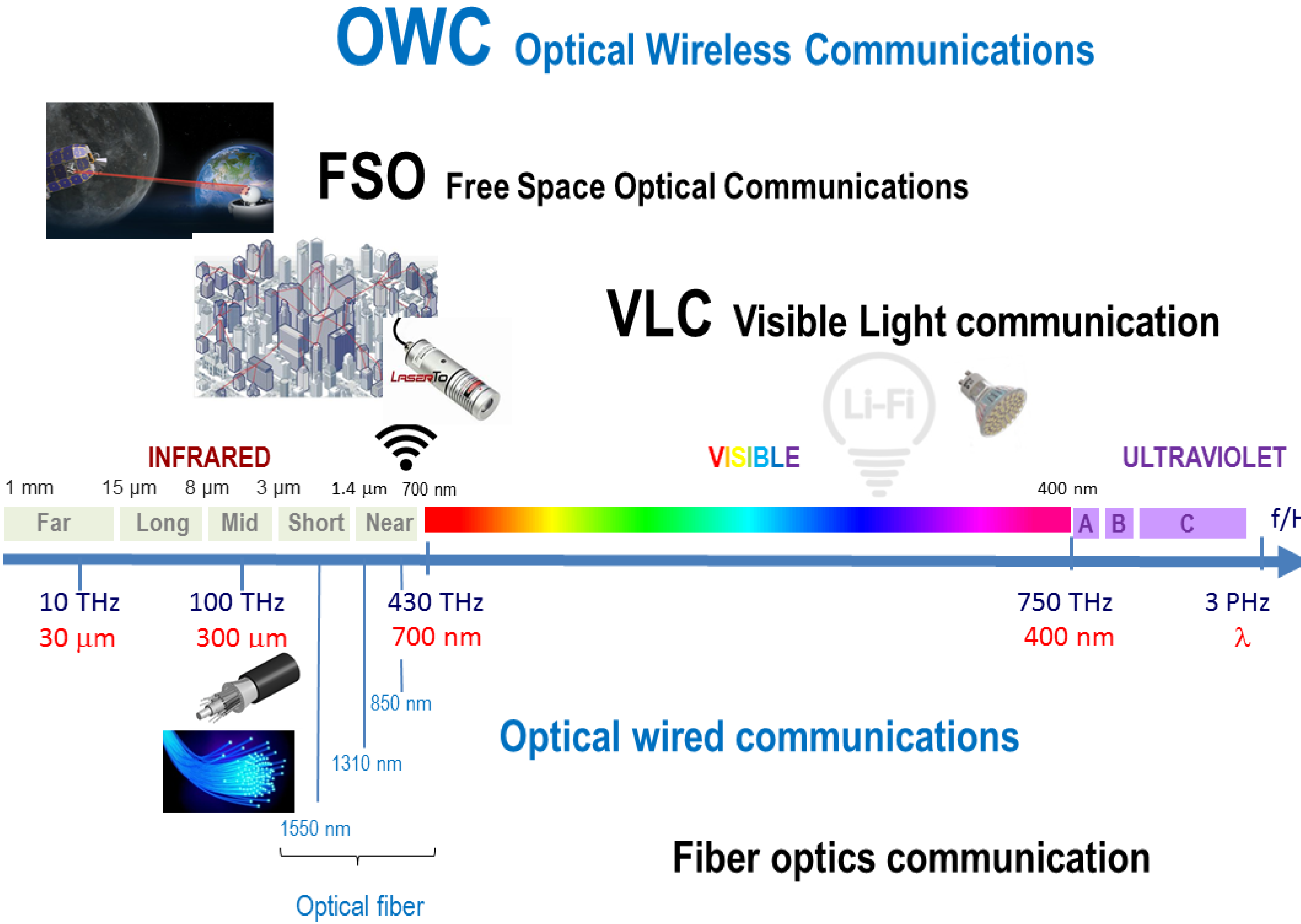
1G	2G	3G	4G	5G
1981	1992	2001	2010	2020(?)
2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Basic voice service using analog protocols	Designed primarily for voice using the digital standards (GSM/CDMA)	First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)	True mobile broadband on a unified standard (LTE)	'Tactile Internet' with service-aware devices and fiber-like speeds





5G will drive the future networked society

5G is expected to use various technologies such as LTE (Long Term Evolution), WiFi, Ultra Wide Band (UWB) and VLC to ensure permanent coverage of the communication network without any interruption of service.

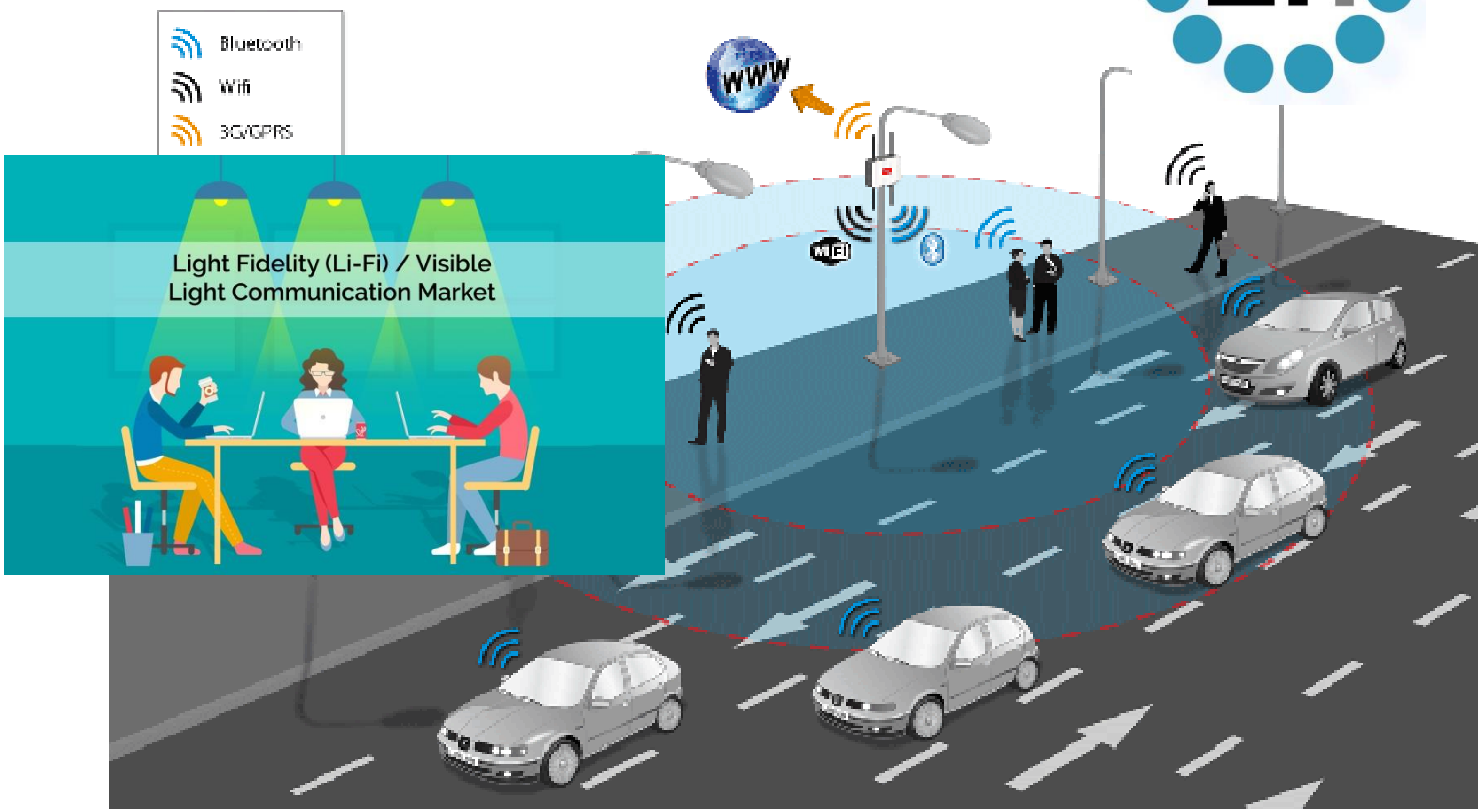


OWC Optical Wireless Communications
FSO Free Space Optical Communications
VLC Visible Light communication
Li-Fi
INFRARED
VISIBLE
ULTRAVIOLET
1 mm
15 µm
8 µm
3 µm
1.4 µm
700 nm
400 nm
Far
Long
Mid
Short
Near
A
B
C
f/Hz
10 THz
30 µm
100 THz
300 µm
430 THz
700 nm
750 THz
400 nm
3 PHz
λ
850 nm
1310 nm
1550 nm
Optical fiber
Optical wired communications
Fiber optics communication

Visible Light Communication

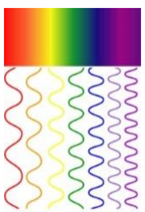
Li-Fi is a Visible Light Communications (VLC) system

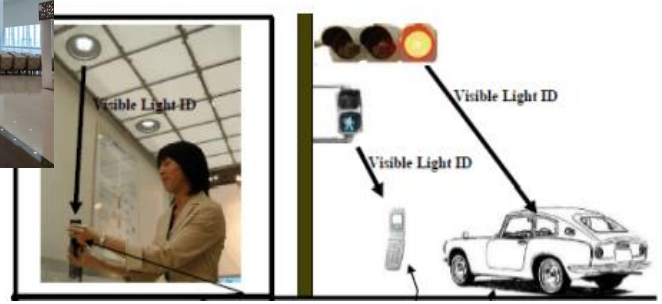
Wi-Fi vs Li-Fi



Li-Fi and Wi-Fi are quite similar as both transmit data electromagnetically

VLC – Visible Light Communication





Wi-Fi will begin to become limited

Indoors environments

- Light atmospheric absorption
- Shadows
- Light dispersion
- Influence of other light sources

Virtual road network:

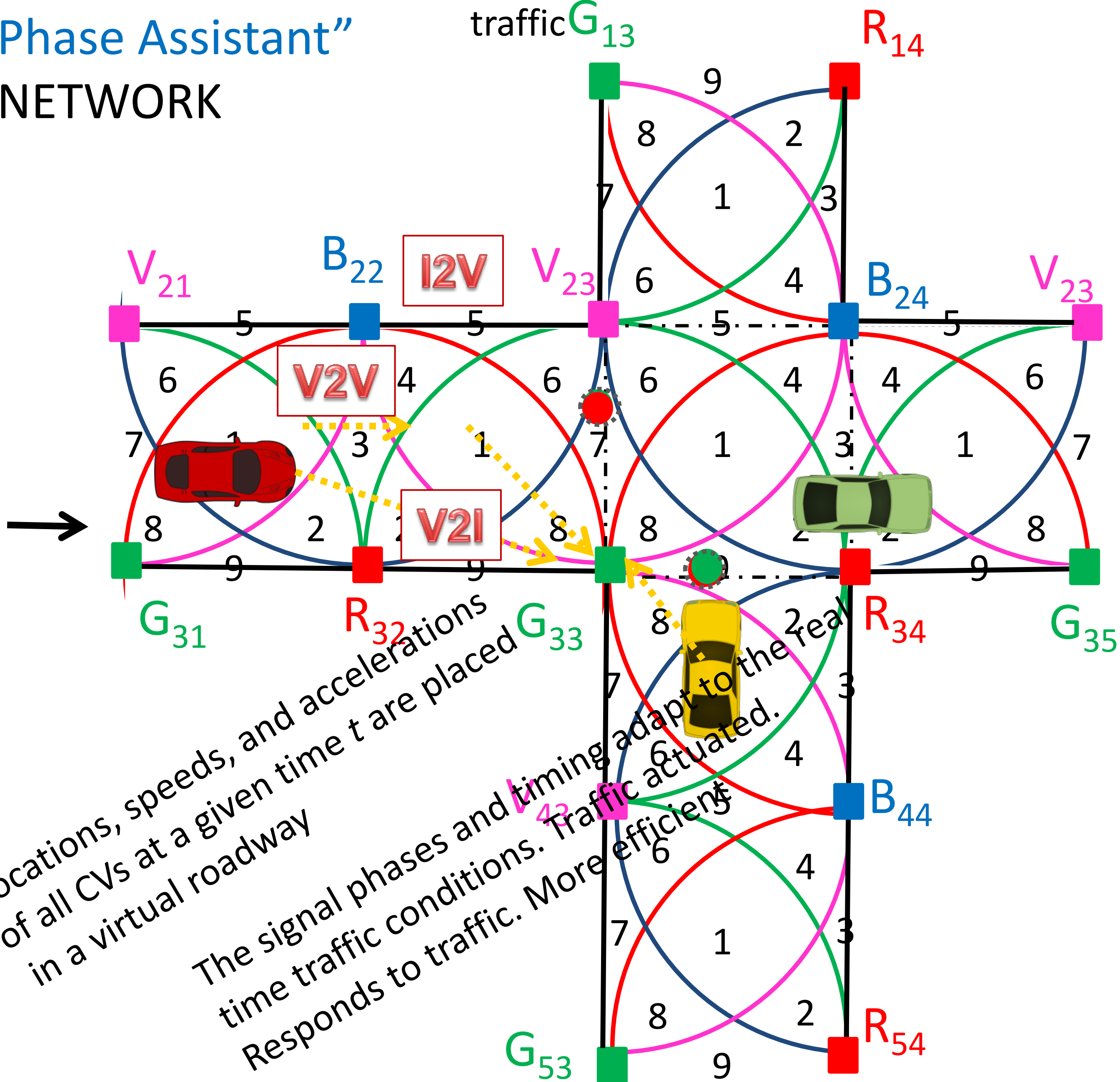
I2V2V2I

Traffic Light

Phase Assistant"

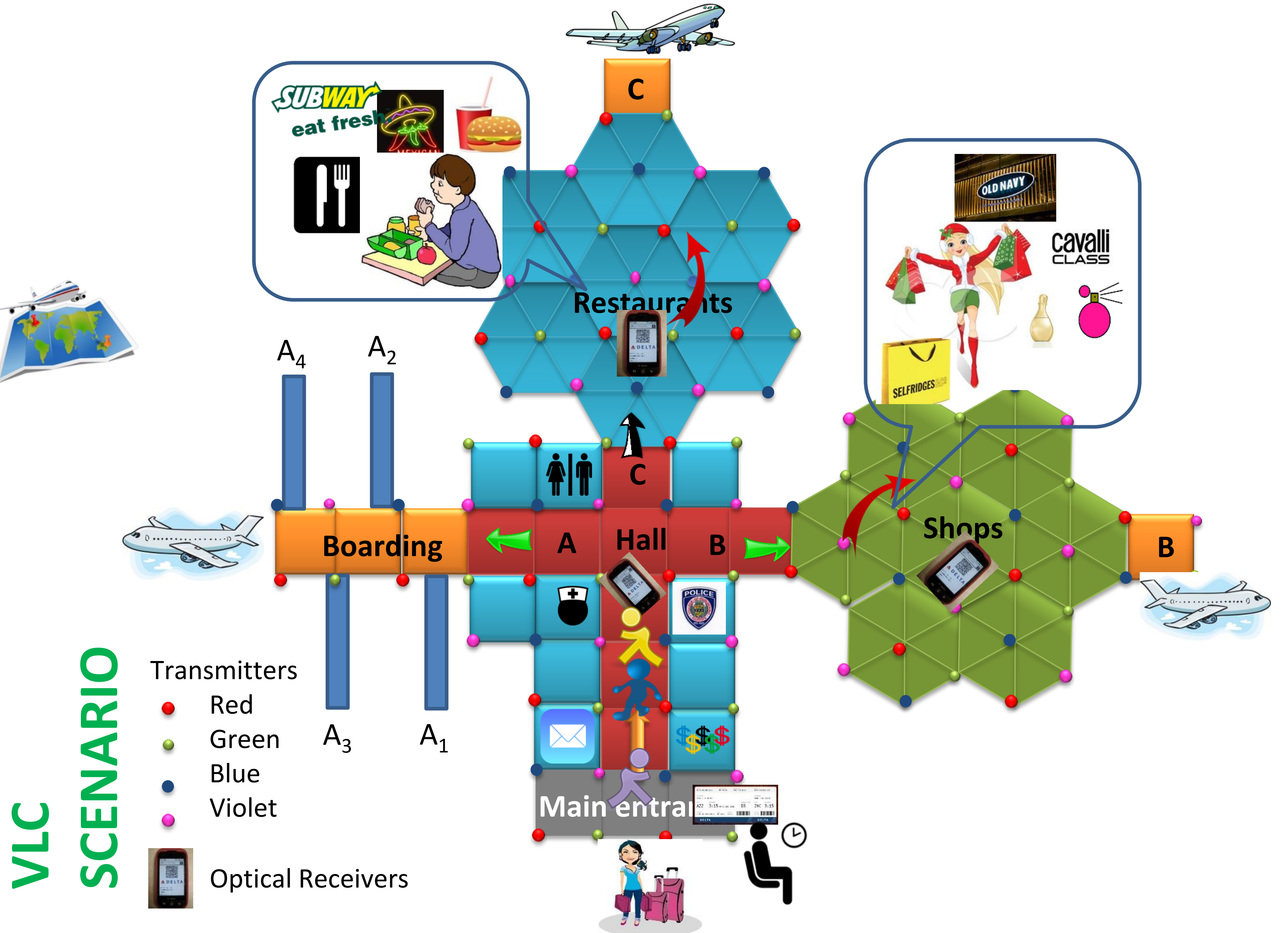
NETWORK

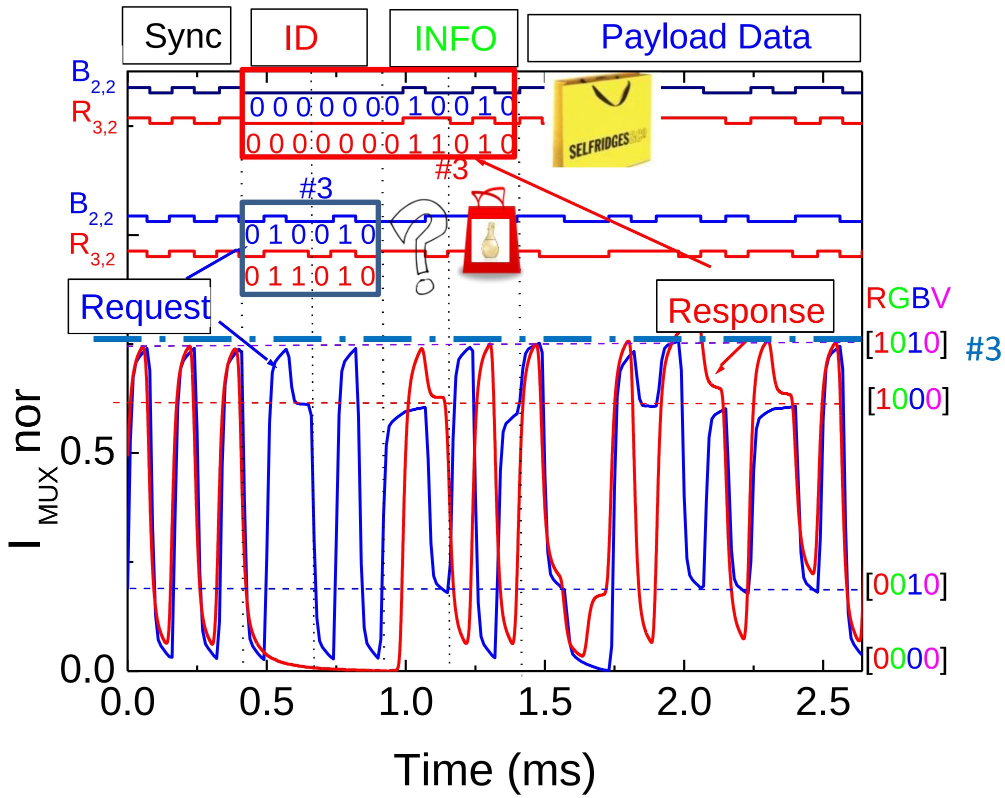
Information flow towards the traffic light:
Improvement of control by precise information about traffic

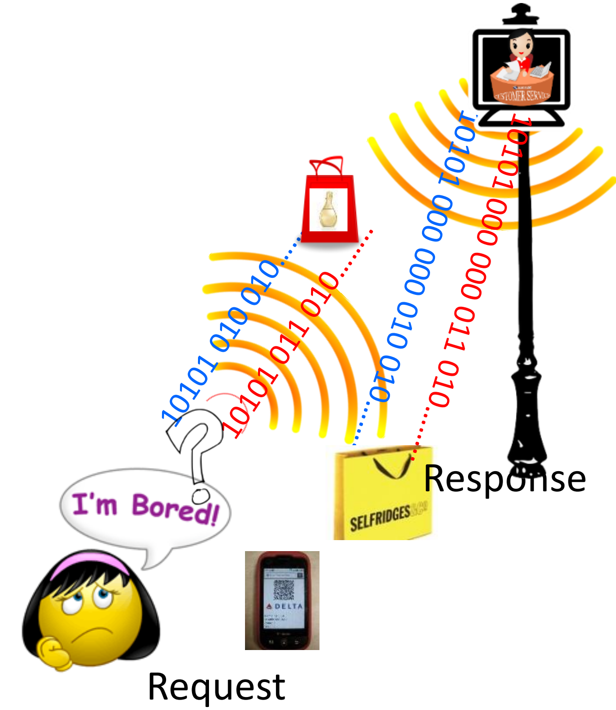


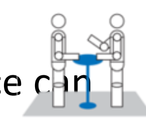
Locations, speeds, and accelerations of all CVs at a given time t are placed in a virtual roadway

The signal phases and timing adapt to the real time traffic conditions. Traffic actuated. Responds to traffic. More efficient.

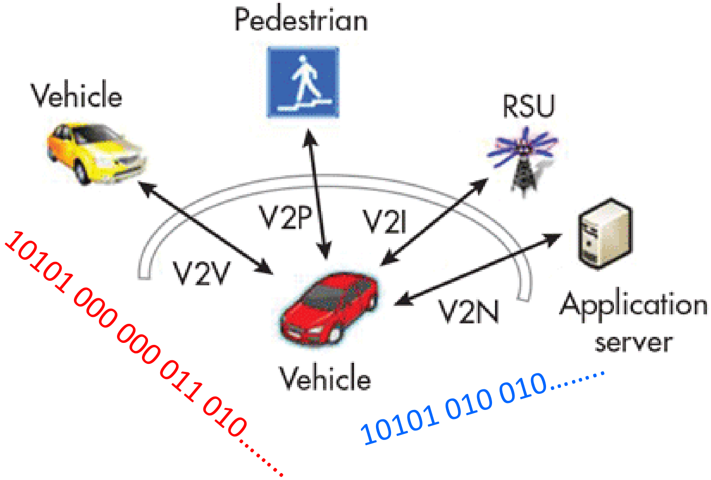

VLC SCENARIO
C
Restaurants
SUBWAY
eat fresh
OLD NAVY
cavalli CLASS
SELFRIDGES
A4
A2
A3
A1
Boarding
A
Hall
B
C
Shops
B
POLICE
Main entra
Transmitters
Red
Green
Blue
Violet
Optical Receivers

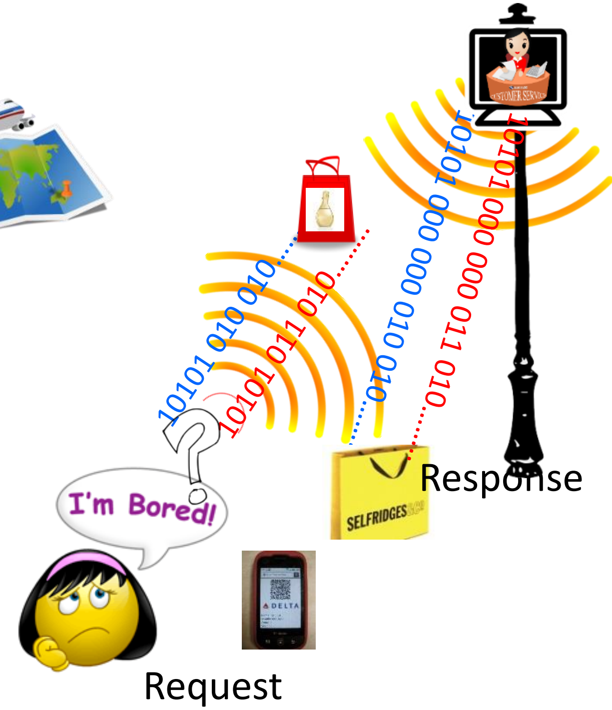


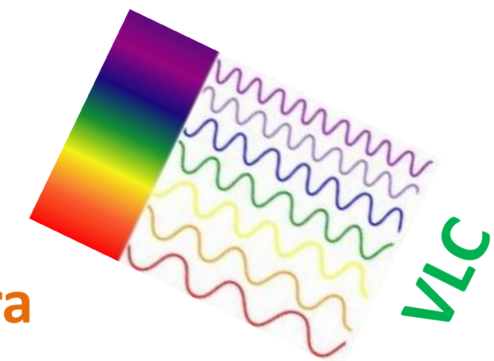


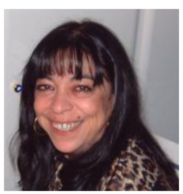


- Bi-directional communication between VLC emitters and receivers at a handheld device can be established through a control manager linked to an indoor billboard.
- Using a white polychromatic LED as transmitter, the receptor sends to the local controller a “request” message with its location (ID) and adds its needs for the available time. For route coordination, the local controller emitter sends the “response” message.
- Each ceiling lamp broadcasts a message with its ID and advertising which is received and processed by the receiver.





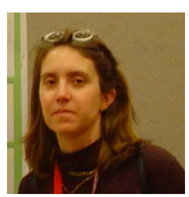




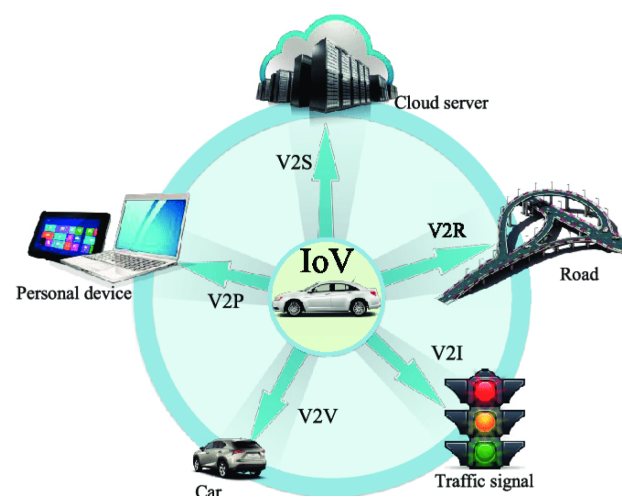
Manuela Vieira

Manuel A. Vieira

Paula Louro



Pedro Vieira



Second Panelist

Professor Tsang-Yi Wang
“National Sun Yat-sen University, Taiwan”
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*Professor **Tsang-Yi Wang** received the B.S. and M.S. degrees from National Sun Yat-sen University, Kaohsiung, Taiwan. Also, he received the Ph.D. in electrical engineering from the Syracuse University, NY. He was with the Graduate Institute of Communication Engineering, National Chi Nan University, Nantou, Taiwan. Today, he is a Professor in the Institute of Communications Engineering, National Sun Yat-sen University. His research mainly focuses on distributed detection and estimation with applications in wireless communications and wireless sensor networks. He has many publications, and has been contributing as a Reviewer Editor of the Journal of Wireless Communications and Mobile Computing.*

Distributed detection of a common random signal in large-scale sensor network

He has discussed the problem related to distributed detection of a common random signal in large-scale sensor networks. In such problem, sensor observations are not conditionally independent. Besides, He has investigated two distributed detectors. Detector 1, that has employed energy detector at the local sensors and a monotone fusion rule at the fusion center (FC). Detector 2 used a Sign detector at each local sensor and a two-sided test at the FC. Results were validated via numerical Monte Carlo Simulations.

Distributed detection of a common random signal in large-scale sensor networks

Tsang-Yi Wang

Institute of Communications Engineering
National Sun Yat-sen University, Taiwan

SENSORCOMM 2019
October 29, 2019

Distributed detection of a common random signal in large-scale sensor networks

A question:

- Does a good detection scheme in a small-scale sensor network also perform well in a large-scale sensor network?

Distributed detection of a common random signal in large-scale sensor networks

Example: Distributed Detection of A Common Random Signal S

$$X_k = S + W_k$$

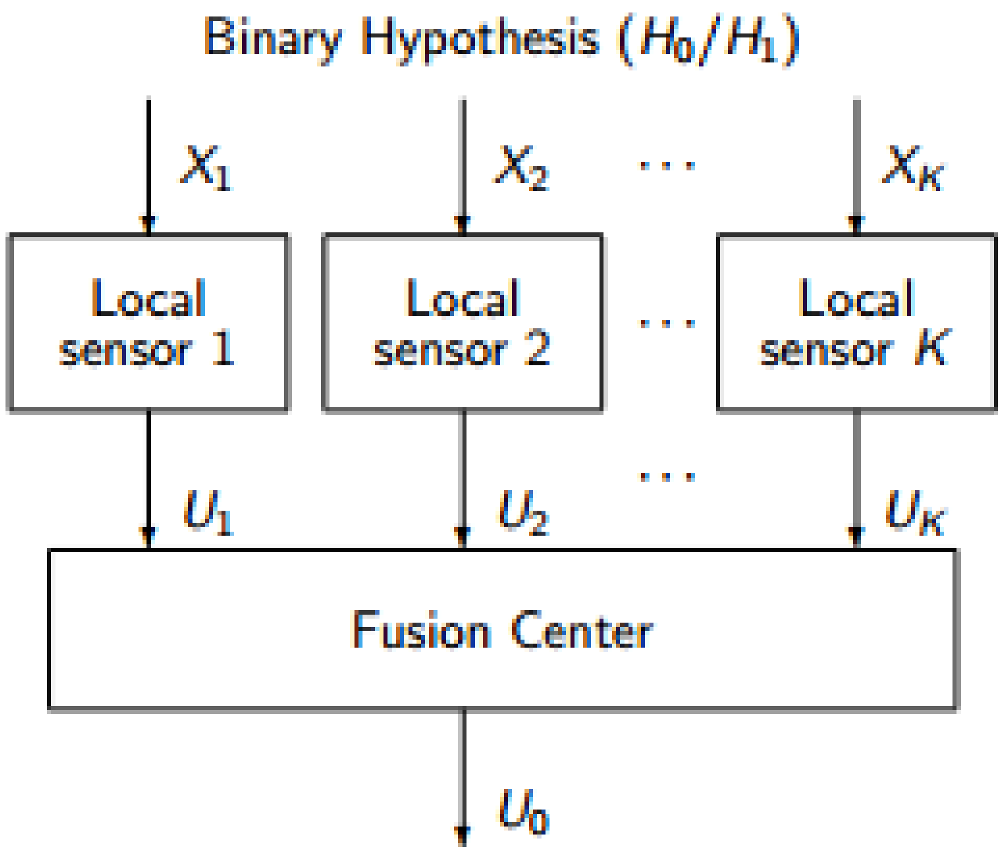
$$H_1 : S \sim \mathcal{N}(0, \sigma^2)$$

$$H_0 : S = 0$$

$$W_k \sim \mathcal{N}(0, 1)$$

W_k i.i.d. Gaussian

$$U_k \in \{0, 1\}$$



Centralized Detector with Unquantized Sensor Observations, D_0

- When the FC has the access to X_k directly
  - Optimal likelihood ratio tests (LRT): two-sided *energy detector* T_0

$$T_0 = \left| \frac{\sum_{k=1}^{k=K} X_k}{\sqrt{K}} \right| \underset{u_0=0}{\overset{u_0=1}{\gtrless}} \eta_0$$

Energy local Detector, D_1 (1)

- Identical energy detectors at the local sensors

$$U_k = \begin{cases} 1 & |X_k| > \eta_1 \\ 0 & |X_k| \le \eta_1 \end{cases} \tag{1}$$

- A counting rule at the fusion center such that

$$\gamma_{o,1} = P_1(U_0 = 1|\mathbf{U}) = \begin{cases} 1, & \sum_{k=1}^{K} U_k > L \\ \lambda_d, & \sum_{k=1}^{K} U_k = L \\ 0, & \sum_{k=1}^{K} U_k < L \end{cases} \tag{2}$$

where η_1, L and λ_d are suitable parameters to satisfy the P_f constraint.

Energy local Detector, D_1 (2)

- D_1 can be viewed as
  - take the comparison at the local sensors (local sensor performs "hypothesis testing")
  - FC performs "counting"

Performance of the Energy local Detector

- When $K = 1$, the sensor network consists of only 1 sensor.
  - D_1: obviously optimal when there is only 1 sensor (the same as the centralized detector).
- However, how well would D_1 perform in large sensor networks? $K \gg 1$

Sign Detector, D_2 (1)

- D_2, taking the sign at the local sensors and two-sided comparison at FC
- Identical sign detectors at the local sensors

$$U_k = \begin{cases} 1 & X_k > 0 \\ 0 & X_k \leq 0 \end{cases} \tag{3}$$

- A two-sided test at the fusion center such that

$$\gamma_{o,2} = P_2(U_0 = 1|\mathbf{U}) = \begin{cases} 1, & |\sum_{k=1}^{K} U_k - \frac{K}{2}| > \eta_c \\ \lambda_c, & |\sum_{k=1}^{K} U_k - \frac{K}{2}| = \eta_c \\ 0, & |\sum_{k=1}^{K} U_k - \frac{K}{2}| < \eta_c, \end{cases} \tag{4}$$

where η_c and λ_c are suitable parameters to satisfy the P_f constraint.

Sign Detector, D_2 (2)

- D_2 can be viewed as a "Correlation Distributed Detector"
- D_2: obviously useless when $K = 1$. The individual local decision X_k doesn't provide any meaning for identifying which hypothesis is true.
- How about when $K \gg 1$?

Experimental Evaluations: Comparison of three Detectors

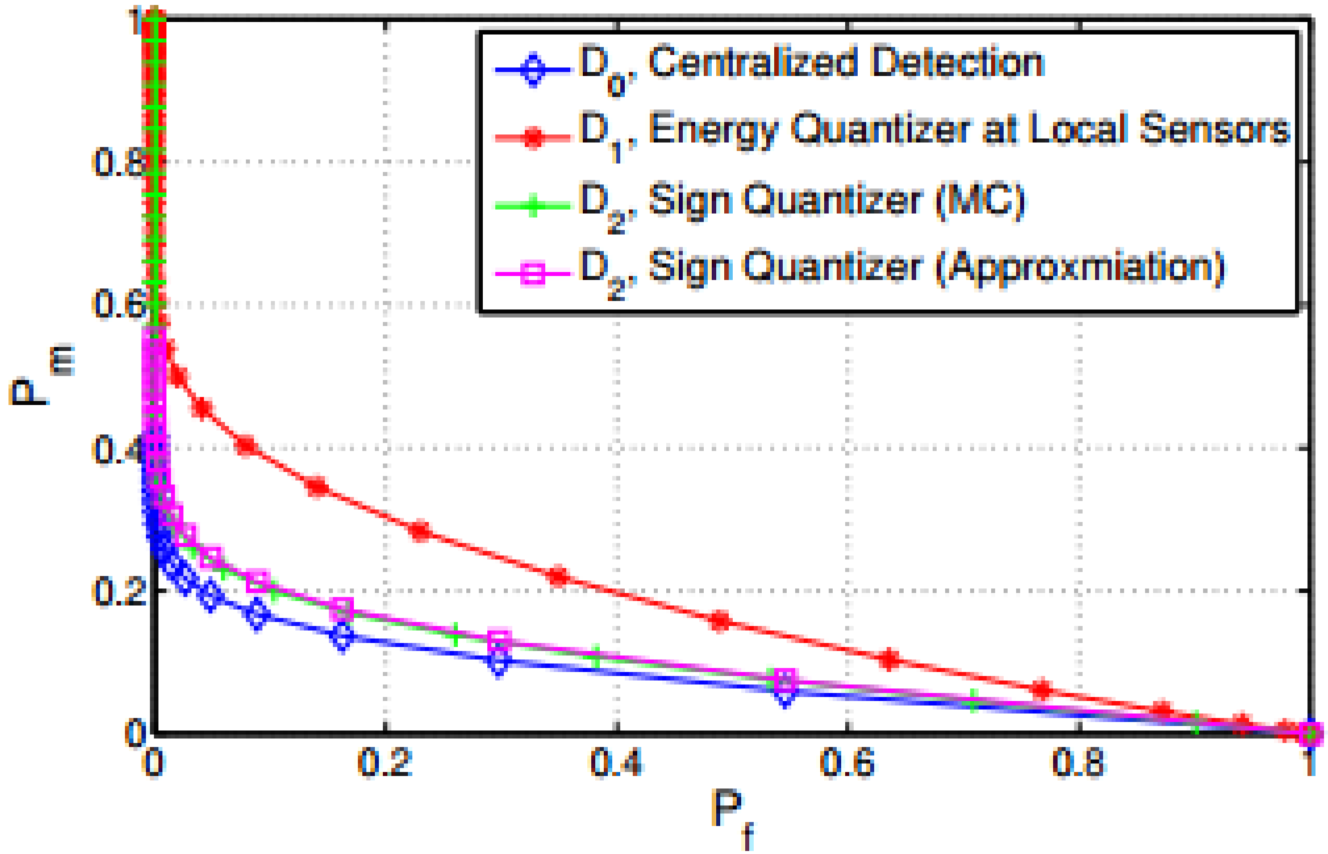


Figure: Detection performance comparison. $K = 64, \sigma = 1$ and $\eta_1 = 1.5$

Discussion

Challenges:

- A good detector in a small-scale sensor network may not necessarily perform well in a large-scale sensor network.
- Detector design using an heuristic approach may not necessarily perform well in a large-scale sensor network.

Third Panelist

Professor Eugen Borcoci,
“University Politehnica Bucharest, Romania”
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Professor ***Eugen Borcoci*** *is with the University Polytechnic of Bucharest. His expertise, teaching activities and research have been oriented to specific domains of telecommunications and computer networks architectures, technologies and services, like: communication protocols and control/data plane, quality of service assurance and management over multiple domains networks, multicast and multimedia services over IP networks and heterogeneous access. Recently, his research interest and activities are on new technologies like Software Defined Networking, Network function virtualization, Cloud/fog/edge computing, 4G/5G networking and slicing, vehicular communications and Information Centric Networking. He has published many scientific papers, 5 books, 4 textbooks and scientific reports. He has been a team leader in several European research projects.*

Managing massive IoT data in 5G networks

Internet of Things (IoT) systems require high data rates, low latency, efficient use of spectrum, and coexistence of different network technologies. The fifth generation (5G) technology is a major candidate, able to support such requirements, including construction and offering of dedicated IoT slices.
He has brought a presentation related to the 5G context, the main trends to make efficient decisions based on the massive data generated by the large number of IoT devices.

Panel on IoT and Sensing
Theme: Challenges in Dealing with Massive Data

Managing massive IoT data in 5G networks

Eugen Borcoci
University POLITEHNICA of Bucharest, Romania
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Managing massive IoT data in 5G networks

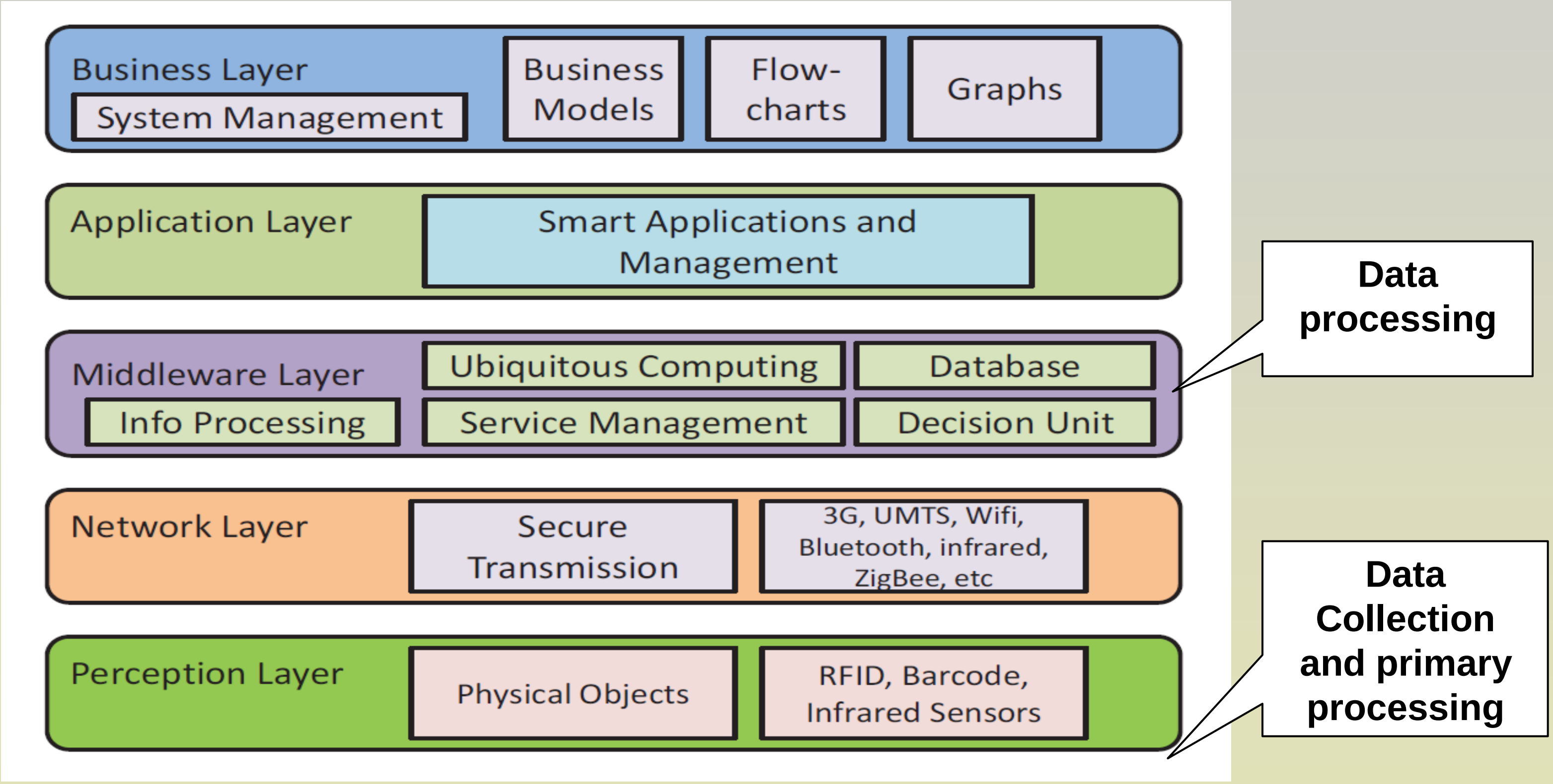
- **Internet of Things (IoT) systems**
  - high number of devices: Cisco prediction: IoT devices will be 50 billion by ~ 2020
  - specific requirements related to data rates, latency, efficiency use of spectrum, energy, etc.
  - produce high volume data
    - mostly generated by a large number of IoT devices in the form of small packets
  - many IoT communication are based on narrowband applications
  - the existing technologies (3G, 4G, etc.) cannot cope with very large communities of devices and particularly with massive growth of IoT data
  - **5G is considered a strong candidate to support the massive IoT traffic**
    - including construction and offering of dedicated IoT slices

Managing massive IoT data in 5G networks

- ITU-R has defined the following main usage scenarios for IMT for 2020 and beyond in their Recommendation ITU-R M.2083.
- **Generic slice types**
  - **Enhanced Mobile Broadband (eMBB)** high - data rates, user density, high traffic capacity for hotspot scenarios as well as seamless coverage and high mobility scenarios with still improved used data rates
  - **Massive Machine-type Communications (mMTC) focused on IoT (low power consumption and low data rates for very large numbers of connected devices)**
  - **Ultra-reliable and Low Latency Communications (URLLC)** to cater for safety-critical and mission critical applications

Managing massive IoT data in 5G networks

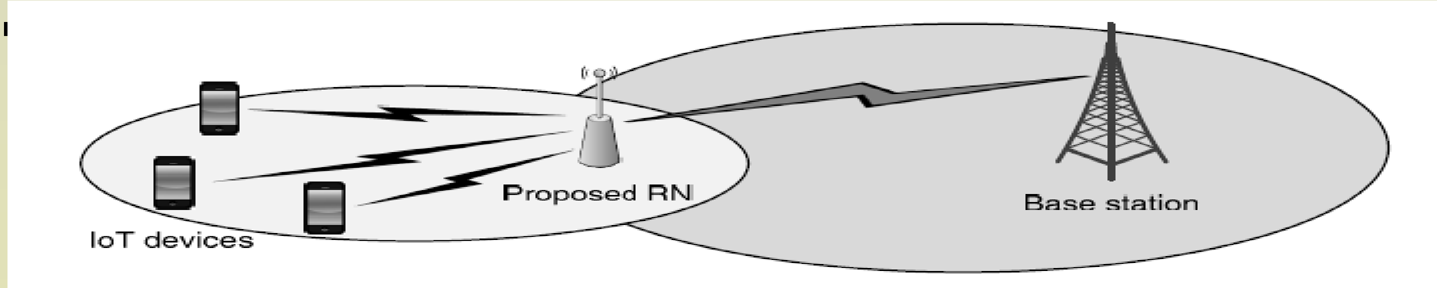
- **IoT functional architecture (one example)**



Source: R,Khan et al., "Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges", Dec. 2012, https://www.researchgate.net/publication/261311447

Managing massive IoT data in 5G networks

- **How to increase the efficiency of collection and processing of high volume of data?**
- **Methods applicable in RAN for data collection, aggregation, etc. - from devices**
- **Example:**
  - The **aggregation of IoT data** at an intermediate node before transmission can increase the spectral efficiency
  - Use of the low cost 3GPP fixed, in-band, layer-3 Relay Node (RN) for integrating IoT traffic into 5G network by multiplexing data packets at the RN before transmission to the Base Station (BS) in the form of **large multiplexed packets**



Source: S.N. Khan Marwatet.al., "Method for Handling Massive IoT Traffic in 5G Networks", https://www.ncbi.nlm.nih.gov/pubmed/30445755

Managing massive IoT data in 5G networks

- **Methods applicable in RAN for data collection (cont'd)**

  - Resources are demanded by the RN for a bunch of IoT nodes

  - The IoT packets are aggregated and multiplexed at the RN.
    - firstly, aggregating packets from several IoT devices and then multiplexing them into one large packet

    - On the BS side, a resource demand for the multiplexed large packet would be considered as one distinct radio resource demand

Managing massive IoT data in 5G networks

▪ IoT data processing - new trends- more general approach

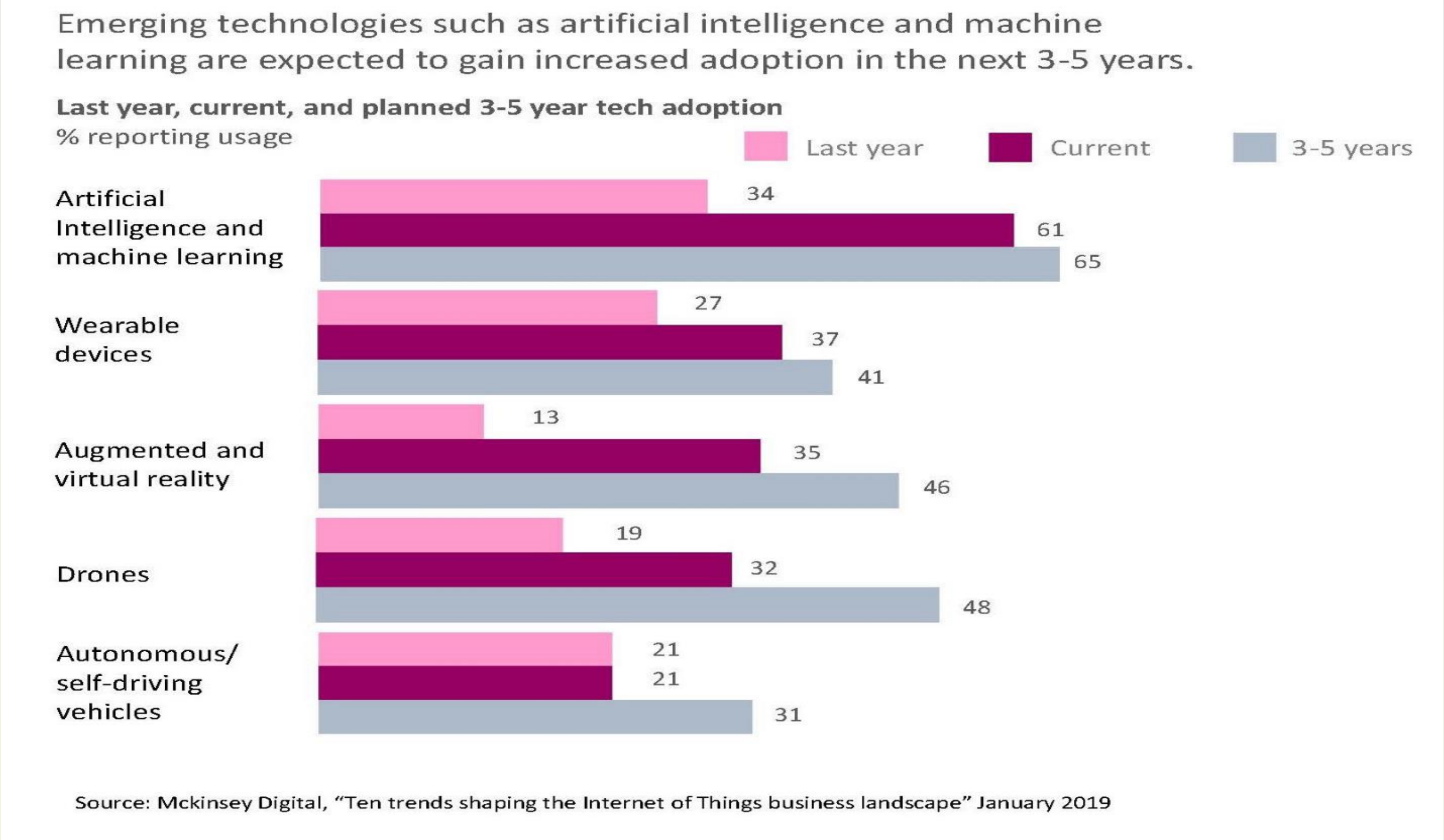
▪Using **artificial intelligence (AI) (e.g. machine learning (ML))** based methods

- analyzing the data to extract patterns and make sense of the data to prescribe action to the end devices

- efficient decisions can be taken, based on the massive data generated by the large number of IoT devices

Managing massive IoT data in 5G networks

- Using **(AI/ML)** based methods in IoT (area cont'd)
  - AI and ML Adoption in IoT **2017-2024**



Managing massive IoT data in 5G networks

- Using **(AI/ML)** based methods in IoT area (cont'd)
  - **Kipling's method: Five Ws** (**What, Where, When, Who, How and Why (5W1H)** - questions whose answers are considered basic in information gathering or problem solving

  - ***What*** is enhanced ? : treatment of heterogeneity, advanced big data analytics, latency, spectrum management, etc.
    - **IoT-5G:** mmWave, mMIMO, HetNets, RANs, RATs, etc.

  - ***Where*** is AI needed?: Firmware and app. levels, Comm. technologies: Wi-Fi, LTE,etc.
    - **IoT-5G com. technologies**: RPL, 6LowPAN, BLE, etc.

  - ***When*** is AI required?: Reactive or proactive spectrum and energy, Management, , latency, data rate, etc.
    - **IoT-5G:** D2D, PSM, NS, CR, mMIMO, URLLC, mMTC, etc.

Adapted from source:N.Javaid et al., "Intelligence in IoT-Based 5G Networks: Opportunities and Challenges" IEEE Communications Magazine, June 2018

Managing massive IoT data in 5G networks

- **Kipling's method (cont'd)**

▪***Who*** needs to be intelligent?: sub-systems dealing with: aPaaS, energy constraint, IoT devices connectivity, latency, bandwidth, etc.

- **IoT-5G:** Cloud and fog nodes, routers, smart phones, BS, mobile edge networks (MEC), RANs, etc.

▪***How*** can AI be brought to IoT devices?: Advanced analytics of big data, energy management, mobility, heterogeneity, etc.

- **Iot-5G:** NB-IoT, PSM, RATs, RANs, NS, CR, etc.

▪***Why*** is AI required in IoT?; need of- security, latency, spectrum crunch, data rate, data management, interoperability, mobility, etc.

- **IoT-5G:** Cloud and fog/MEC/edge computing, CR, NB-IoT, SDN, NFV, etc.

Adapted from source:N.Javaid et al., "Intelligence in IoT-Based 5G Networks: Opportunities and Challenges"
IEEE Communications Magazine, June 2018

- **Thank you !**

List of Acronyms

6LowPAN	IPv6 over Low-Power Wireless Personal Area Networks
aPaaS	application Platform as a Service
BLE	Bluetooth Low Energy
CR	Cognitive Radio
D2D	Device to Device
NB-IoT	Narrow Band IoT
MEC	Mobile Edge Computing
mMIMO	massive MIMO
NFV	Network Function Virtualisation
NS	Network Slice
PSM	Power Saving Mode
RAN	Radio Access Network
RAT	Radio Access Technology
RPL	Routing Protocol for Low Power and Lossy Networks
SDN	Software Defined Networking

Conclusions

In this Panel occurred an excellent discussion about challenges in dealing with massive data and sensing. Big data consists of high-valued data, however mixed with noise, and erroneous data. It is expected that the advanced systems and innovative technologies will allow the society to efficiently process massive amounts of data, i.e., taking into account data quality and decision making in life quality based on the use of IoT and sensing. In such context, the Panelists have shown concepts and application related to the integration of visible light communications in the IoT and the advantages of its use in cooperative intelligent transport system, also a topic related to distributed detection of a common random signal in large-scale network, as well as, topics related to managing massive IoT data in 5G networks. Finally, all the attendee have pointed out that is still quite important to concentrate efforts to understand the entire usefulness of cloud computing platforms, Big Data, Services, IoT, and the 5G in society.