The Thirteenth International Conference on Sensor Device Technologies and Applications
SENSORDEVICES 2022
October 16, 2022 to October 20, 2022 - Lisbon, Portugal

Keynote Speech

Manuela Vieira (mv@isel.ipl.pt)

VEHICULAR VISIBLE LIGHT COMMUNICATION

WAIFINDING

Manuel Augusto Vieira
Paula Louro
Pedro Vieira

Visible Light Communication Applications

Acknowledgements: UIDB/00066/2020 | IPL/2020/GEO-LOC/ISEL

- **Manuela Vieira** was born in Lisbon, Portugal. In 1986 she received the Master of Science in Solid State Physics-Microelectronic and in 1993 the PhD in Semiconductor Materials both from the New University of Lisbon. She is a full professor since 2011 in Electronics inside the Department of Electronics Telecommunication and Computers (ISEL- Portugal) and the head of a Group in Applied Research in Microelectronic Optoelectronic and Sensors-GIAMOS in ISEL and another in Microelectronic, Material and processes-(M2P) in CTS-UNINOVA. She has several scientific papers and 30 years of experience in the field of thin films and devices, her research activities have been mainly related to the development of optical sensors .

- **Other scientific activities**:
- Referee for international publications such as: Thin Solid Films, Material Research Society, Sensor Magazine, Sensor and Actuators, Material Science Fórum, Solid State Electronics, Vacuum, Applied Surface Science, Sensors and Transducers, Ibersensors, Physica Status Solidi, Sensors, Journal of Nanoscience Nanotechnology, Journal of Sensors, Journal of Signal and Imaging Systems Engineering) Journal of Optical Engineering, Plasmonics, Journal of Luminiscence, etc.
- Referee for several EU projects as part of the Programme Growth "Innovative Products, Processes and Organisation".
- Supervision and co-supervision of Master and PhD students
- Examiner for Master and Doctoral degrees.
- Authored and co-authored more than *350* publications in international journals cited in *"Science Citation Index"*. Presented more than *500* communications at conferences and seminars most of which with publication in journals and proceedings.

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The Centre of Technology and Systems (CTS) aims to develop theoretical and applied research and encourages technology transfer mostly supported by spin offs and deep involvement in international R&D projects. The scientific results are expected to contribute to improve the graduate training in the academia and contribute to the internationalization of the center. Participates in many international projects financed by the European Union, the European Space Agency, industries and also financed by national funds such as FCT and other companies. Also participates in several international actions as joint papers, international events organization, etc.

- Development, optimization and application of semiconductor based devices: image and color sensors, optoelectronic devices, solar cells, optical amplifiers, biosensors, VLC devices, nanostructures and UV and IV detectors.

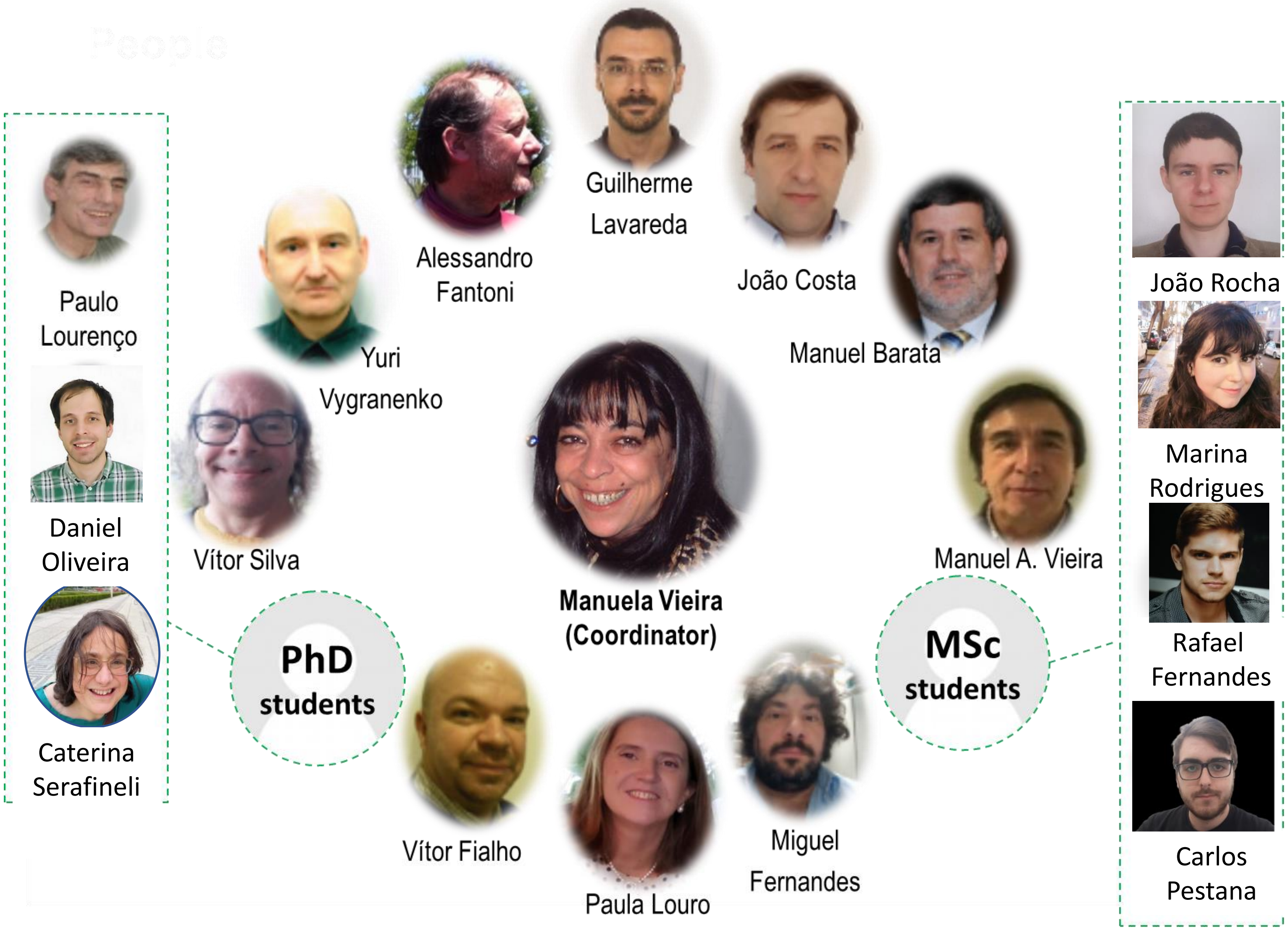
- Design and modeling of optical devices. Photonics.

- Electrical and numerical simulation of optical devices.

- Integration of different technologies, namely optical sensors, wavelength-division multiplexing, Visible Light Communication, X-ray detectors and full digital medical imaging.

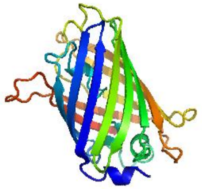
M2P Research group

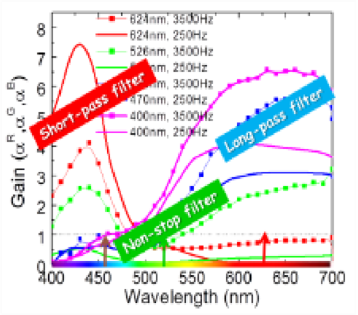
A group of experienced and young researchers covering the areas of materials and devices processing; materials and devices characterization and optimization, well supported by the physics modelling of the devices and the corresponding software for information extraction

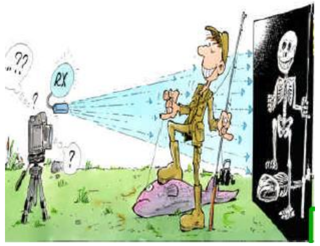


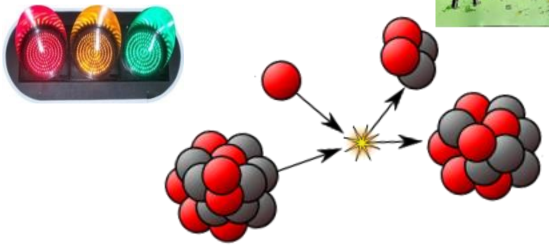
Main Research Areas

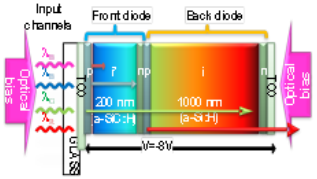
- Applications of semiconductor devices
  - Wavelength Division Multiplexing (WDM)
  - Optical biosensors
  - X-ray flat panel
  - OLEDs
  - Nanodevices



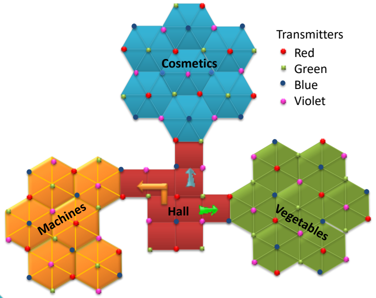


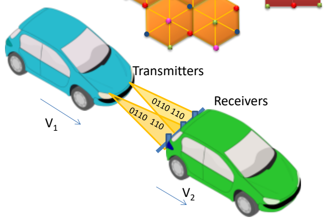






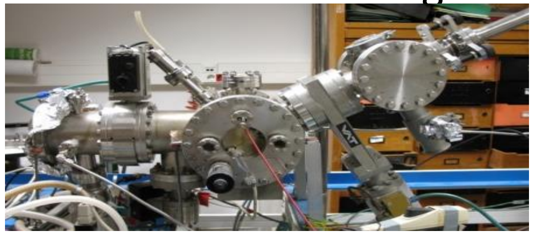
- Visible Light Communications
  - Indoor positioning systems
  - Vehicular Communications



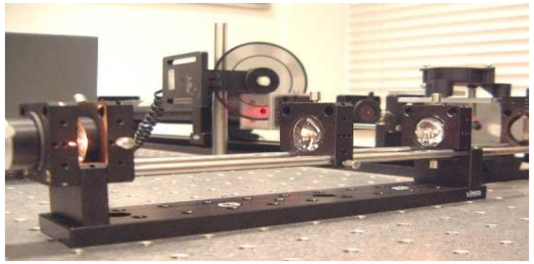


Facilities

- **<u>Deposition facilities:</u>**
  - Laboratories for support of Semiconductor Thin Film Development using the PECVD (Plasma Enhanced Chemical Decomposition) techniques.
  - Laboratories for support of Electronic, Optoelectronic and Microelectronic Device Processing.



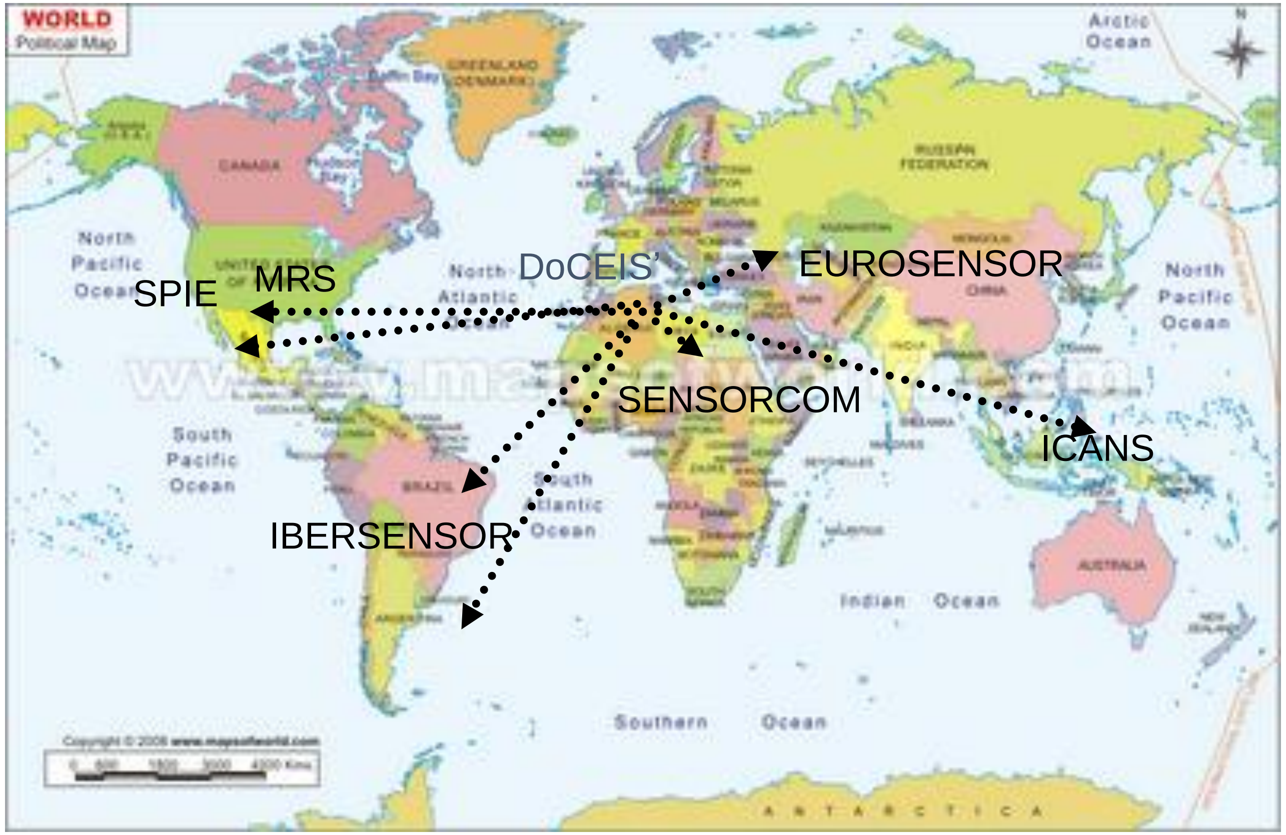
- **<u>Characterization facilities:</u>**
  - UV-VIS-NIR and IR Spectrophotometers (Shimadzu),
  - dark/photo conductivity as a function of temperature;
  - spectral response;
  - Flying Spot Technique-FST;
  - Photothermal Deflection Spectroscopy-PDS;
  - Space Charge Limited Current-SCLC;
  - C(T)/C(V) measurements,
  - Coatings uniformity test-bench,
  - Characterization systems for devices (IV characteristics; annealing test chambers; degradation tests; interface characterization; Electroluminescence) and Solar simulator for small areas.
  - Spectrometers (UV, VIR, NIR, IR) and
  - Optical Characterization Systems (I-V, C-V),
  - Electric Characterization Systems,
  - Material Testing Bench.



Dissemination

Abbreviated Journal Title

- IEEE T ELECTRON DEV
- APPL PHYS LETT
- Sensor and transducers
- J APPL PHYS
- J. NANOSCI NANOTECH
- J. OPTICAL ENG.
- J. LUMINISCENCE
- Optical Engineering
- ChemoIsensors
- Biosensor
- International Journal On Advances in Telecommunications



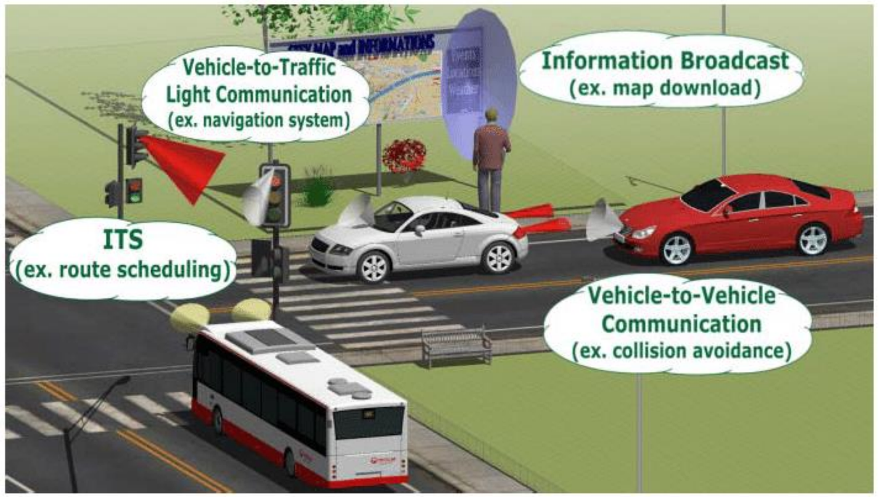
International Cooperation

- Department of Electrical and Computer Eng., Waterloo, Canada.
- Giga to Nano Electronics Group, Univ. Waterloo, Canada.
- University of Cagliari, Italy.
- IPE, Stuttgart University, Germany
- Institute of Semiconductor Physics, Ukrainian Academy of Science, Kiev, Ucraine.
- Institute of Physics, Polish Academy of Sciences, Warszawa, Poland.
- Institute of Molecular Physics University, Polish Academy of Sciences, Poland.
- Wurzburg University, Germany.
- Polish Academy of Sciences, Poland.

- ✓ Production of semiconductor devices,
- ✓ Characterization of materials and devices,
- ✓ Joint publications.

VLC APPLICATIONS

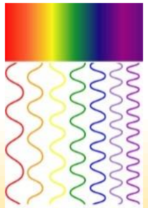
VEHICULAR COMMUNICATION



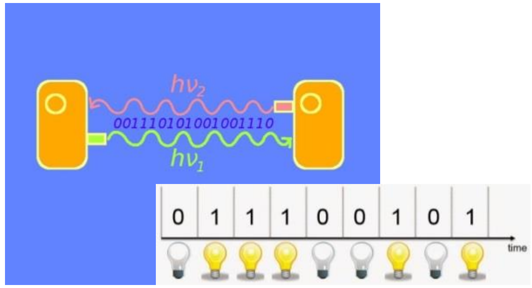
AUTOMATE WAREHOUSE

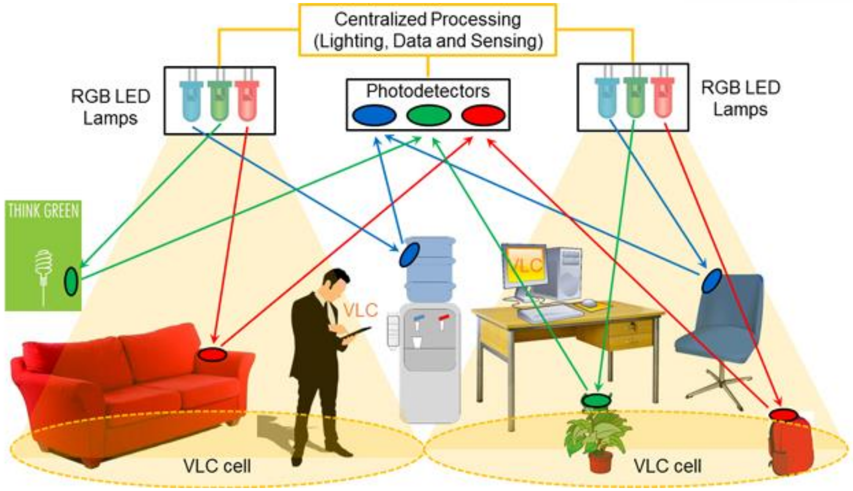
WAIFINDING

VLC – Visible Light Communication



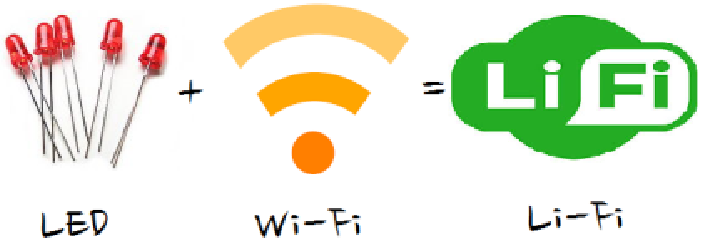
Visible light Communication (VLC) is a data transmission technology that can easily be employed in indoor environments since it can use the existing LED lighting infrastructure with simple modifications.





MOTIVATION

- Compared with other sources of illumination these devices can be modulated at high data rates, offering the opportunity for communications as well as illumination from these sources.



Wi-Fi will begin to become limited

GLOBAL INTERNET GROWTH AND TRENDS

Key Digital Transformers

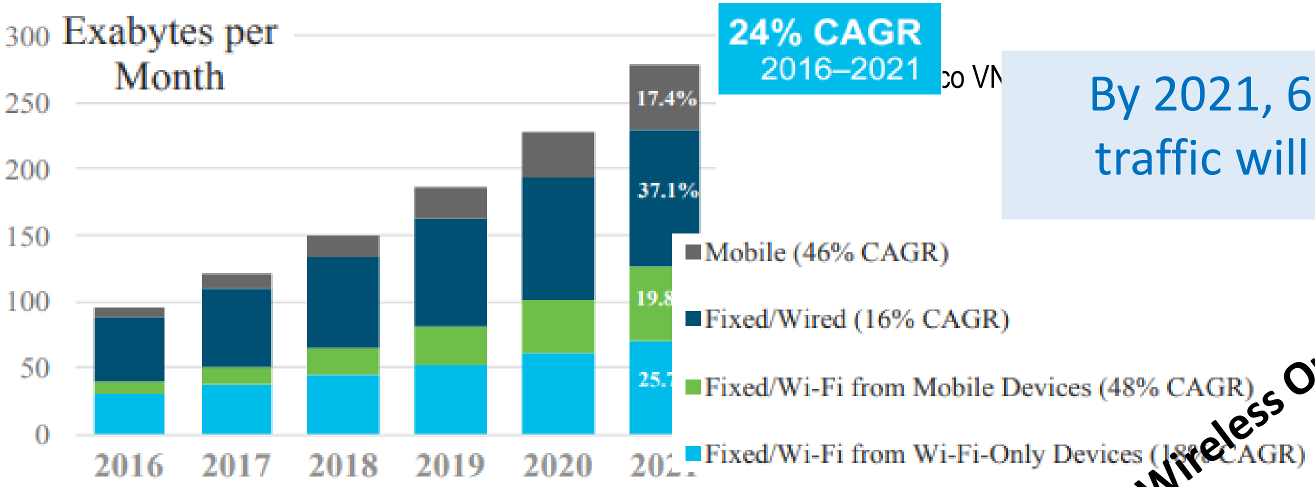
By 2021

Wi-Fi will begin to become limited

	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



24% CAGR
2016–2021

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

Wireless Optical Communications

* Wireless traffic includes Wi-Fi and mobile

FUTURE GENERATIONS OF TELECOMM NETWORKS

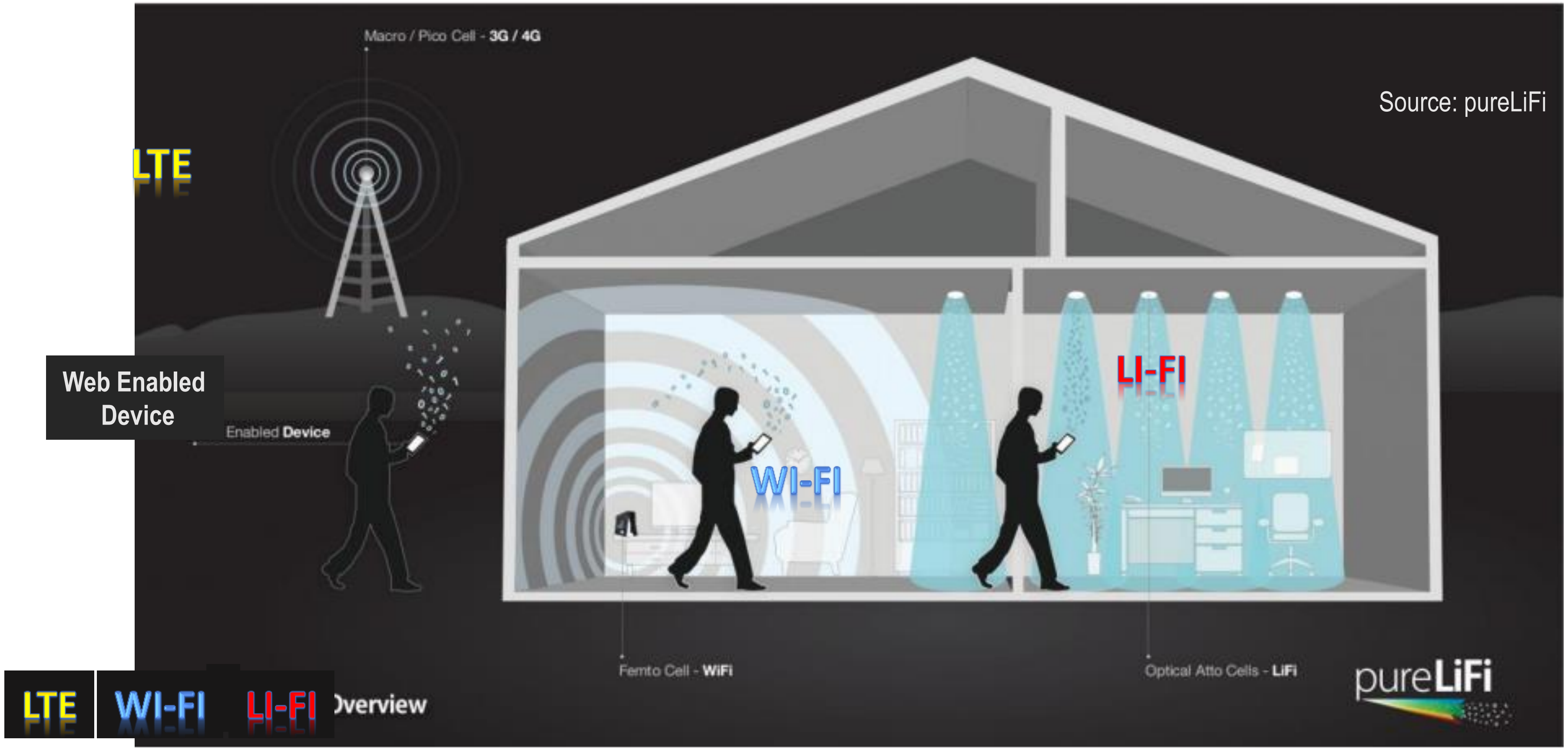
Speed

Latency

Capacity

- **IoT (Internet of Things)**
- **VR (Virtual Reality)**
- **AR (Augmented Reality)**
- **Holograms**

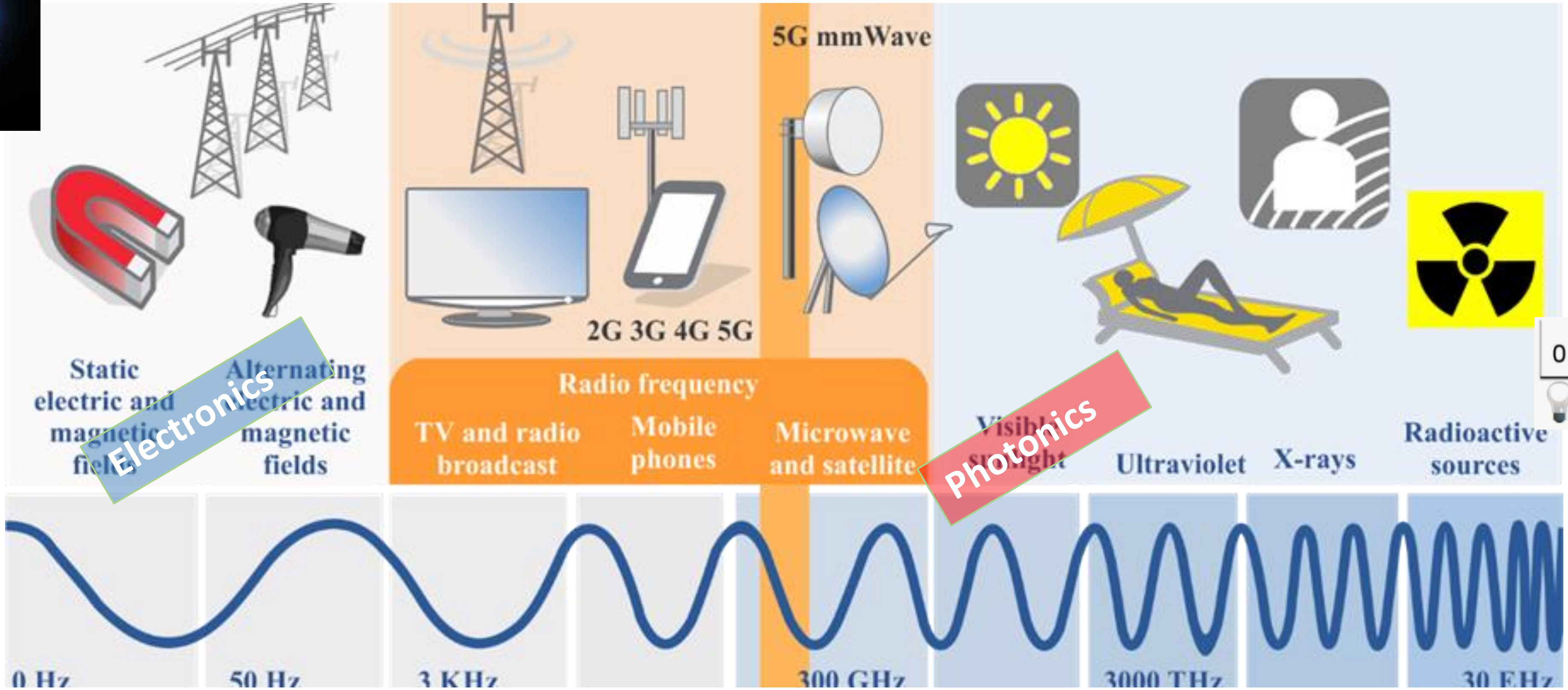
TECHNOLOGY INTEGRATION

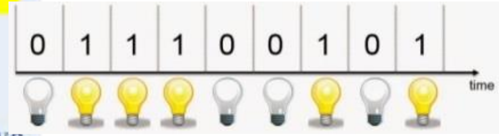


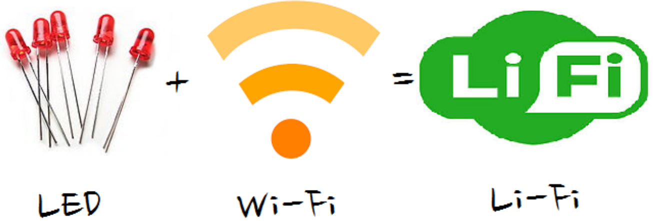
- Li-Fi signals cannot pass through walls, so in order to enjoy full connectivity, capable LED bulbs will need to be placed throughout the home.

- Li-Fi and Wi-Fi are quite similar as both transmit data electromagnetically. However, Wi-Fi uses radio waves, while Li-Fi runs on visible light waves.

VLC – Visible Light Communication







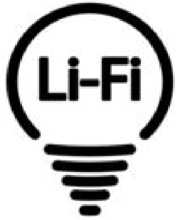
- increased bandwidth
- free and non-regulated spectrum
- line of sight technology (1 – 100 m
- negligible power
- inexpensive (use of already existing lighting infra-structures)

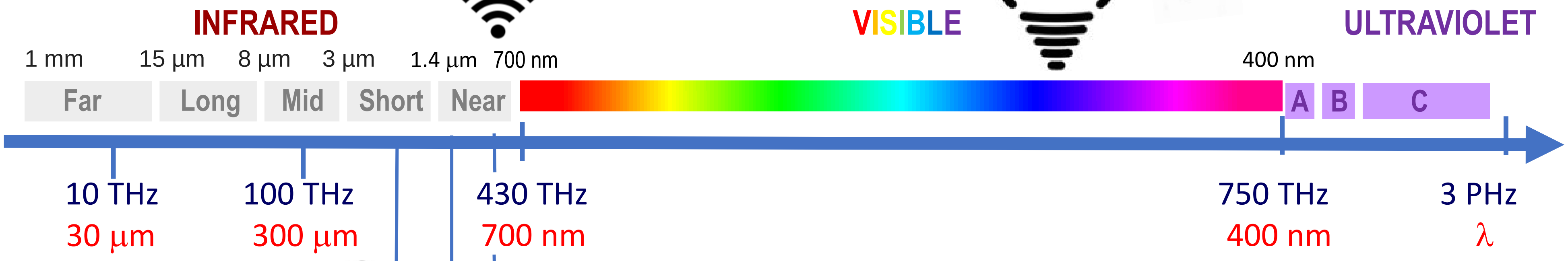
OPTICAL COMMUNICATIONS

OWC Optical Wireless Communications

FSO Free Space Optical Communications

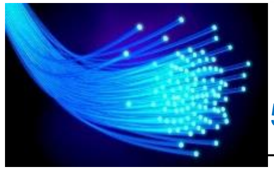
VLC Visible Light communication





850 nm

1310 nm



550 nm

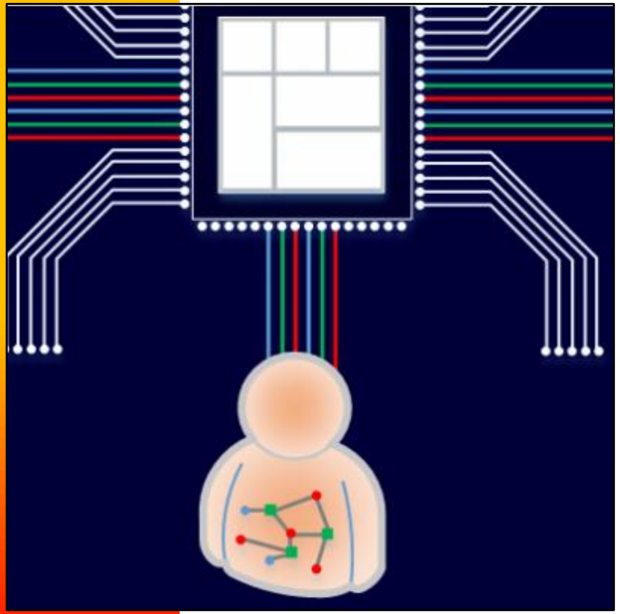
Optical fiber

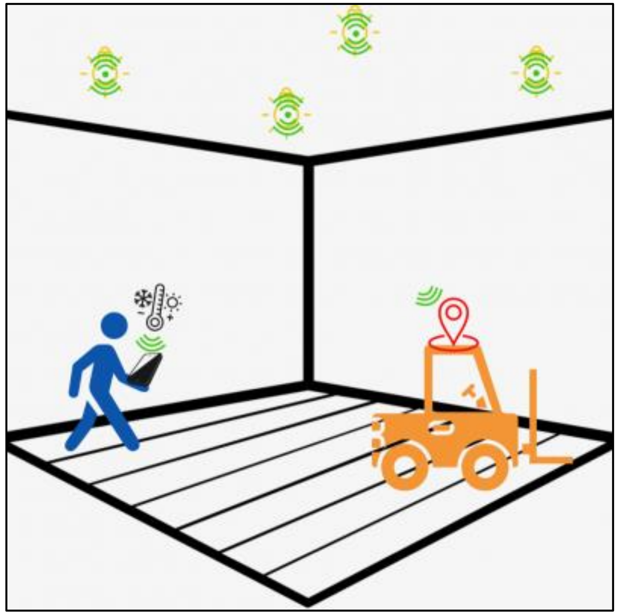
Optical Wired Communications

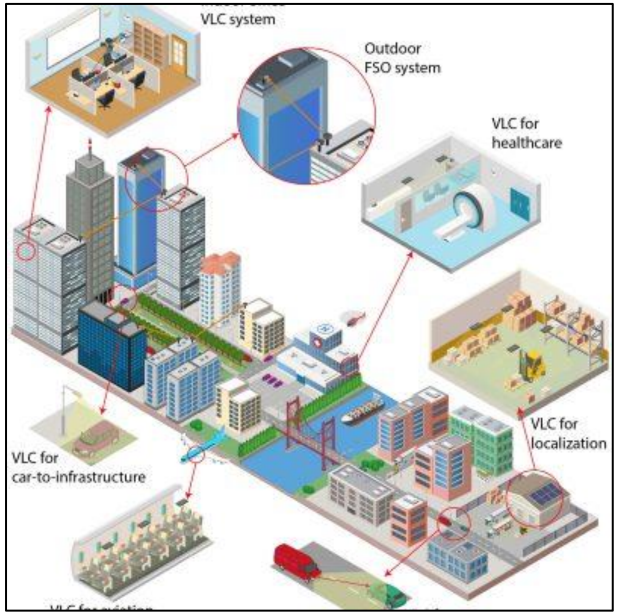
Fiber optics communication

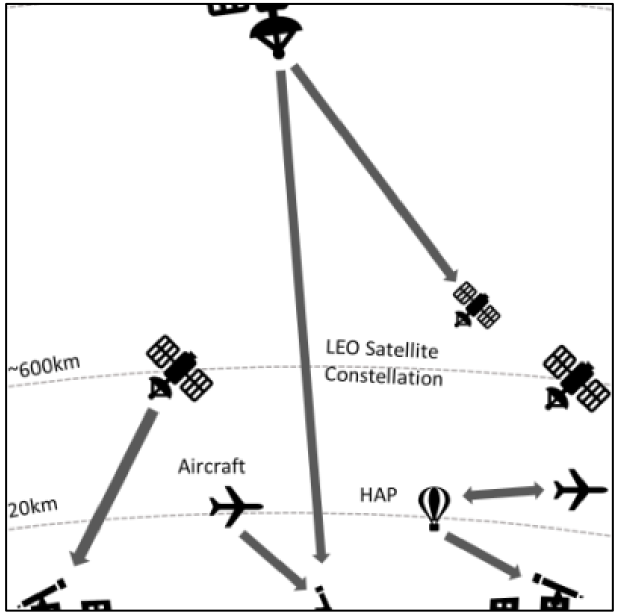
OPTICAL WIRELESS COMMUNICATION (OWC)

ULTRA SHORT RANGE	SHORT RANGE	MEDIUM RANGE	LONG RANGE
sub-meter range	few meters	few meters to few kilometers	many kilometers



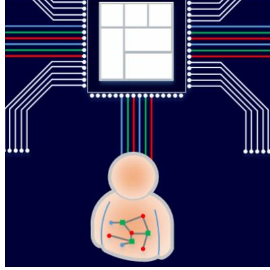






FSO	VLC	VLC	FSO

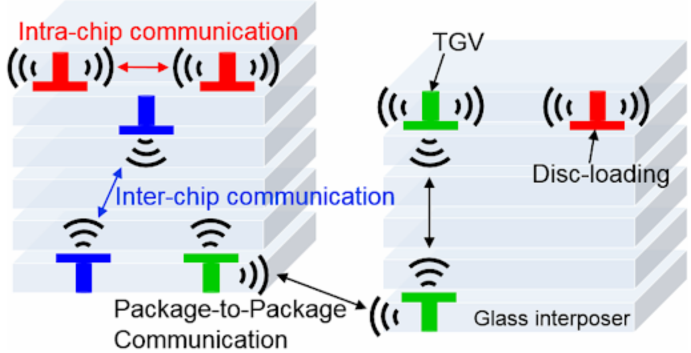
ULTRA SHORT RANGE OWC



Device communication for ultra-high-speed links and **sub-meter** applications. These entail inter and intra-chip communications, high performance computing systems, as well as device to device communications in hyper dense IoT scenarios, such as wireless body-area networks with medical application.

Intra- and inter-chip communication

PHOTONIC CHIP

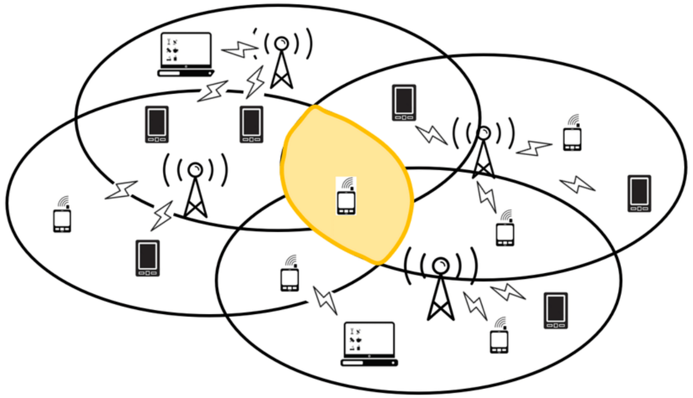


- In IC and PCB designs FSO offers high speed with low energy consumption per bit, compared to metal contacts.
- Optical devices: multiple quantum wells, modulators/Detector and VCSELs.
- In Interchip connectivity **FSO** offers reduced EMI, higher capacity, design flexibility and mitigation of routing and switching issues.

High performance computing platforms (HCP)

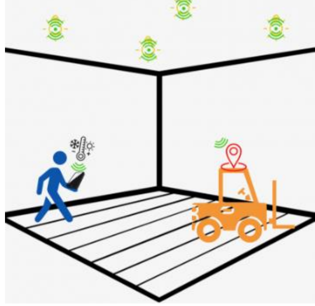
- FSO can be used in HCP platforms: servers, distributed computing systems, etc.

Device-to-device (D2D) communication in hyperdense IoT scenarios



- Connections between smart objects with sensing/actuating and communication capabilities

SHORT RANGE OWC

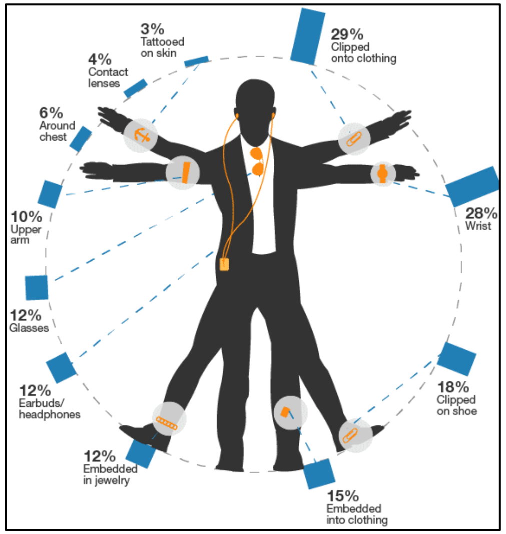


Links up to a few meters: The deployment of intensity modulated artificial optical sources, such as LEDs, enables infrastructures and sensors to communicate with mobile entities, resulting in ubiquitous indoor location-based services, together with wireless communication capacity.

Li-Fi

- **VLC** uses the current day ubiquitous presence of LED lamps

Wearables

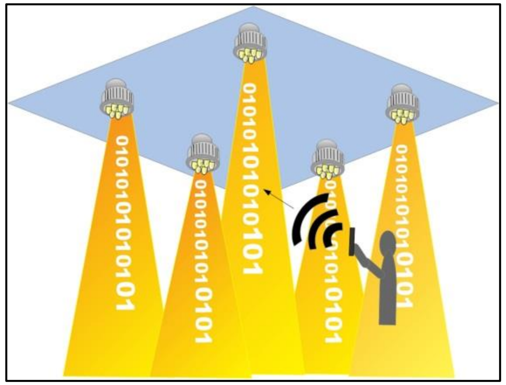


- Current advancements in <u>OLED</u> technology enable the integration of **VLC** transceivers into wearable gadgets and clothing

Short range IoT

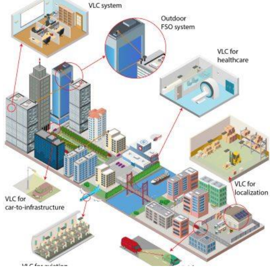
- Smart spaces and buildings
- Smart manufacturing: autonomous machine to machine (M2M) links

Localization



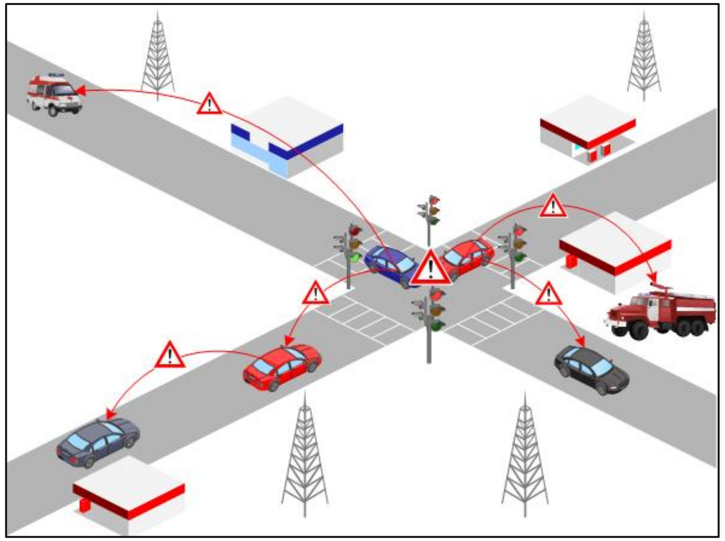
- Location based services provided by **VLC** using LED lamps

MEDIUM RANGE OWC



Typical range of few meters to few kilometers . VLC-based solutions for smart-cities and intelligent transportation systems, first- and last-mile access and backhaul/fronthaul wireless networks, hybrid FSO/RFadaptive wireless connections, and underwater communications for sensor networks

Vehicular networking (VN)



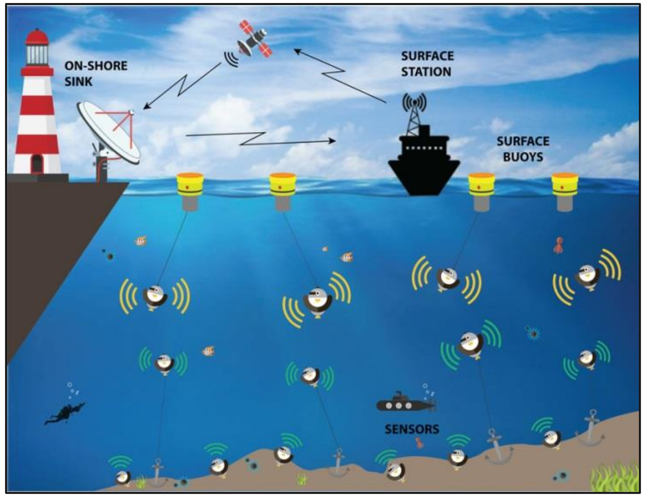
- Wide use of LEDs for vehicle, traffic and street lights
- **VLC** emerges as a natural solution
- VLC-based VNs: V2V, V2I, I2V links

- Additional noise sources due to background radiations, roads and visibility-limiting weather conditions

PtP WA links

- Outdooor PtP terrestrial **FSO** links as a solution for first and last mile access WNs.
- Typical applications: high speed trains, low altitude drones, data centre networks,

Under Water (UW) communications

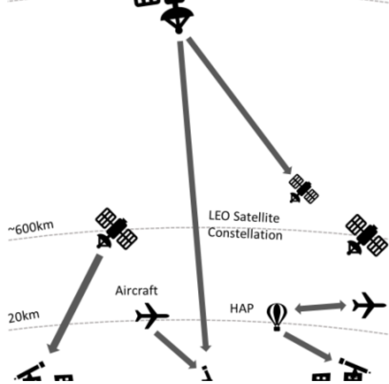


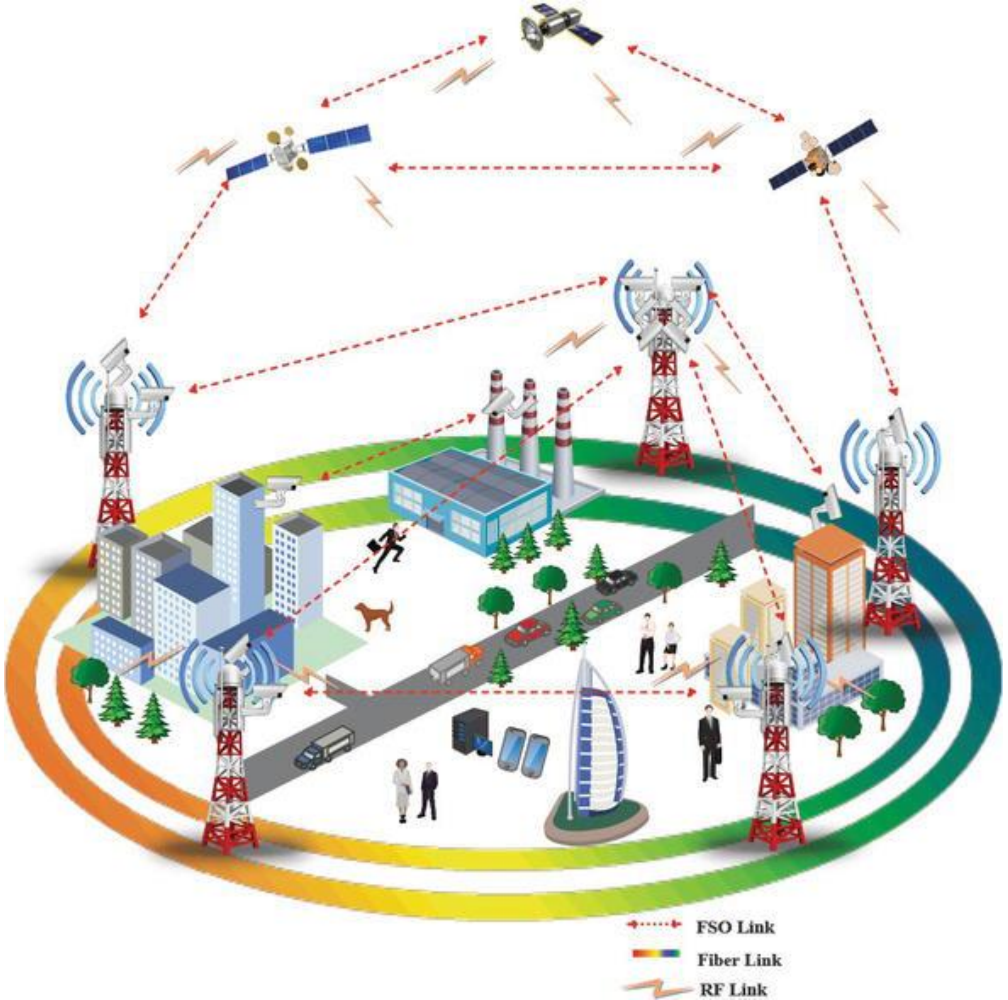
- **VLC** enables high data rates, low latency and high energy efficiency (outperforms acoustic and RF communication)
- Applications: environmental monitoring, UW exploration, port security, disaster prevention

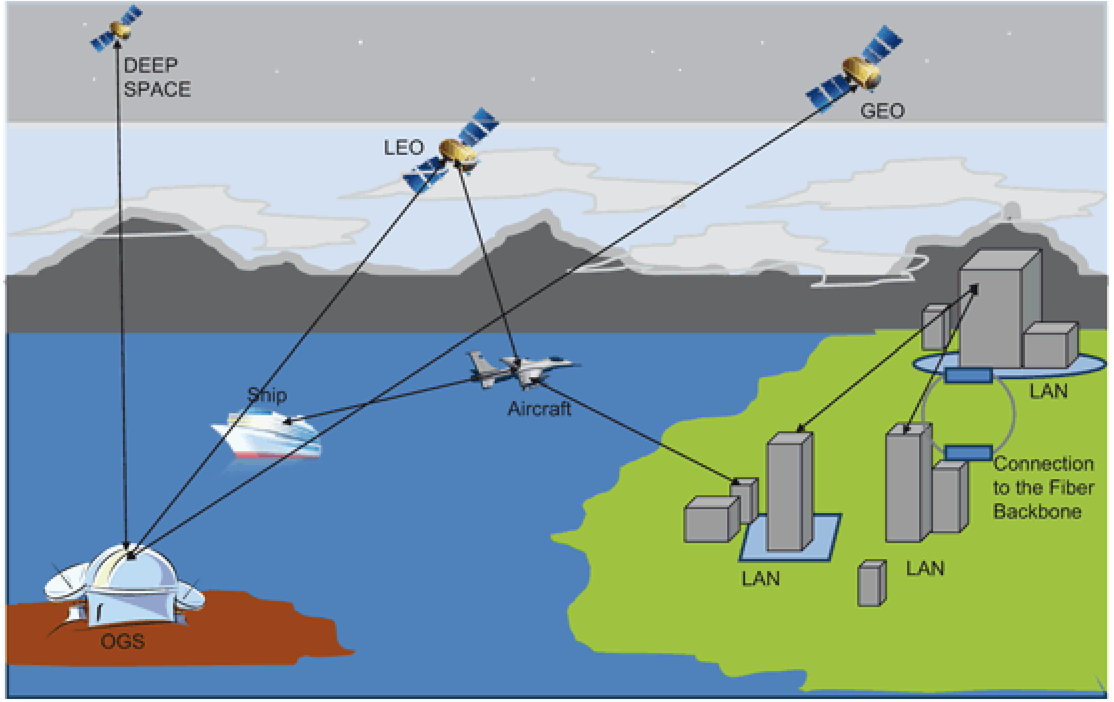
- Challenges: strong signal attenuation of the aquatic channel and the LoS requirement.

LONG RANGE OWC

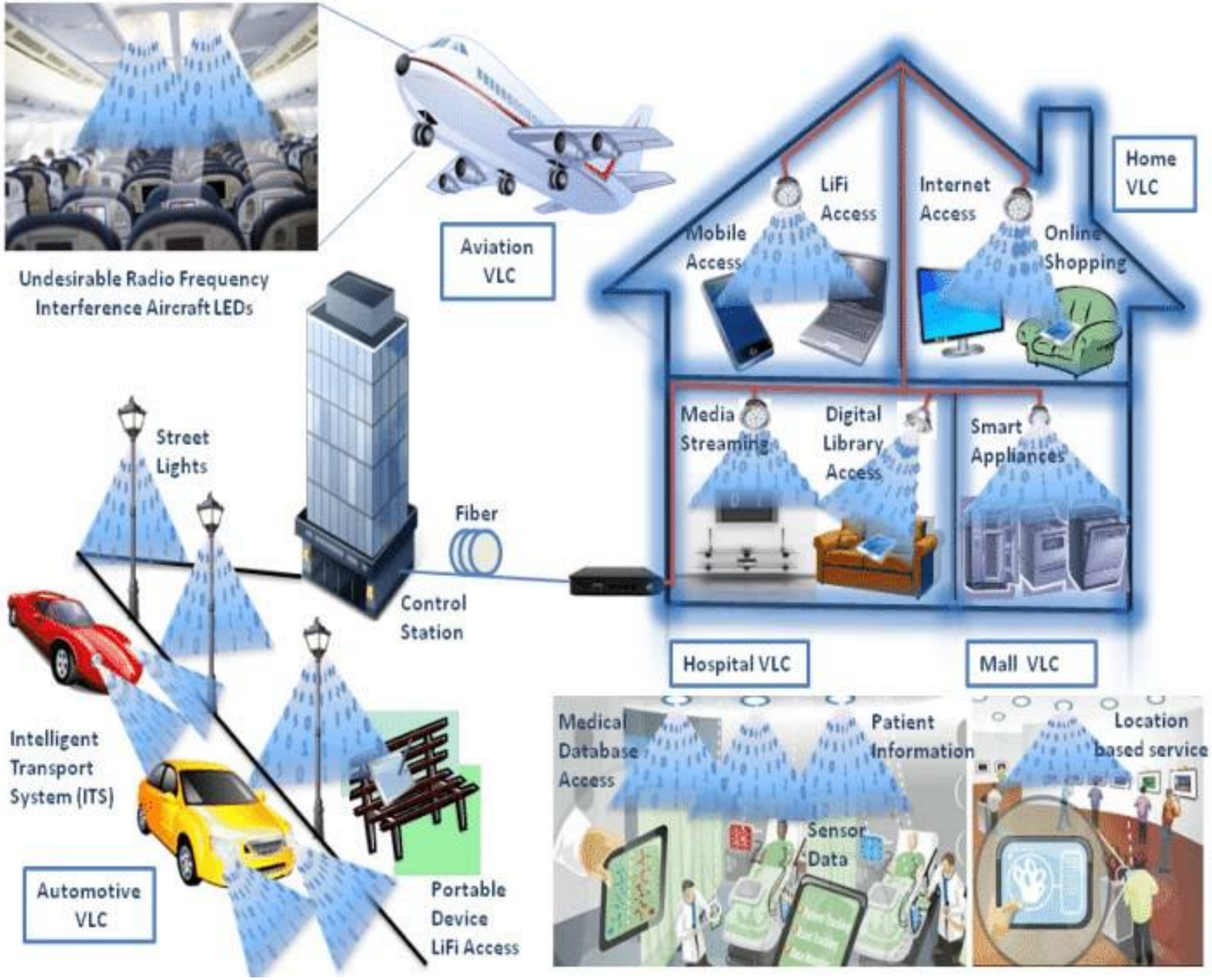
Typical **range of many kilometers.** Airborne and satellite FSO links for deployment in the backhaul/fronthaul wireless networks infrastructure and long-range non-LoS ultra violet links, space-to-ground optical data links, inter-satellite communication links, ground-to-air and air-to-air links, and long-range ultraviolet transmissions.



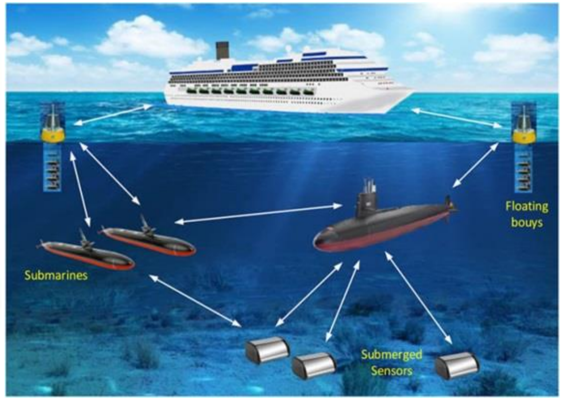




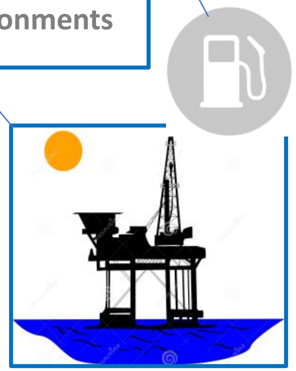
MAIN APPLICATIONS OF VLC



Underwater

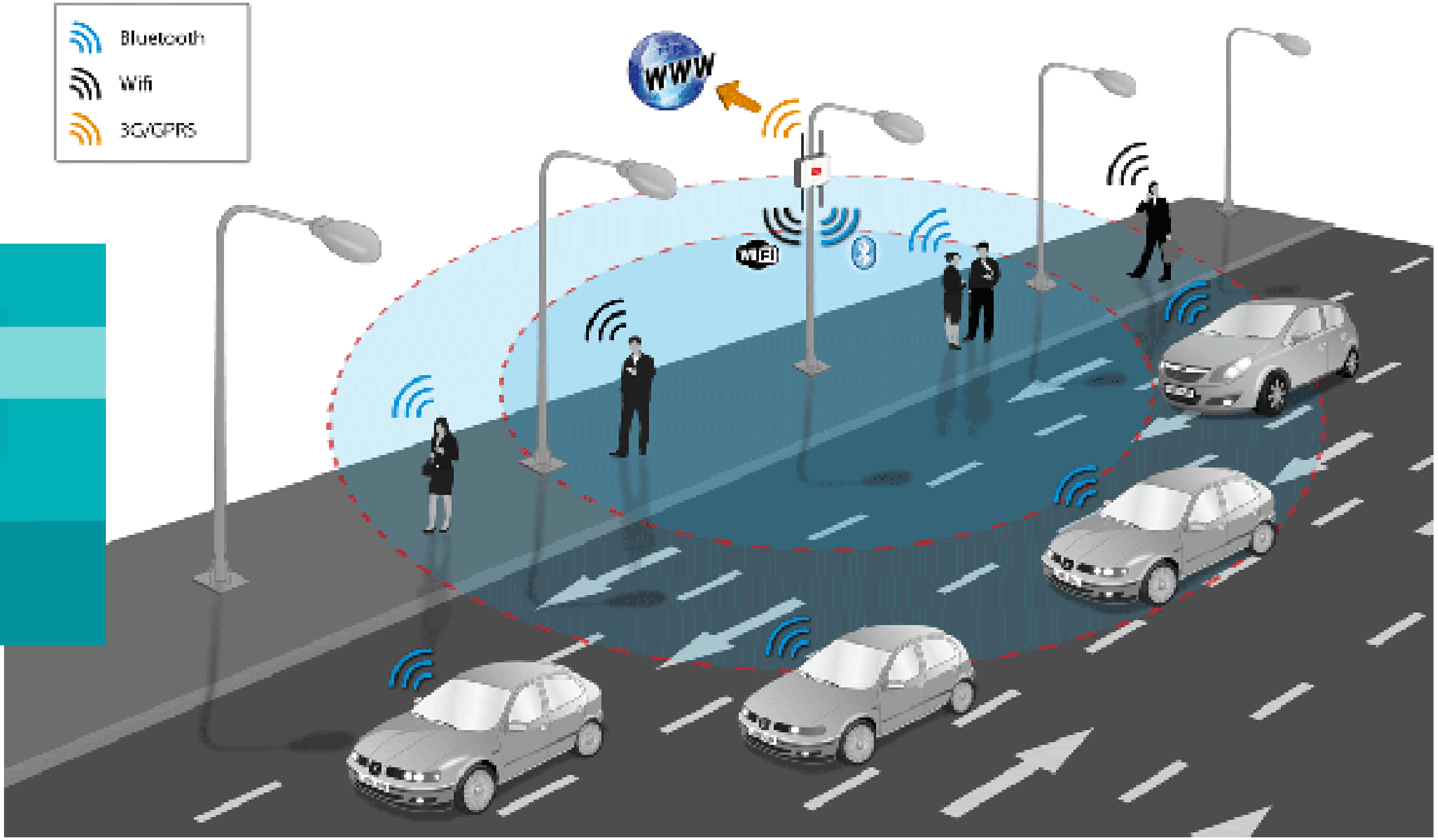


Industrial RF restricted environments



Wi-Fi vs Li-Fi

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



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

ADVANTAGES/DISADVANTAGES

- Dual operation: light + comm
- Infrastructure advantage
- Free and non-regulated spectrum
- No **EM** interference
- High spatial confinement (security)
- High energy efficiency (negligible power)
- Harmless to human health

- Line of sight technology (LoS)
- Obstructions
- Atmospheric absorption
- Shadows
- Light dispersion
- Influence of other light sources

- **OWC (FSO/VLC) can be a good alternative or complementary technology to RF wireless solutions**

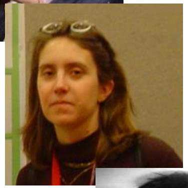
SENSORDEVICES 2022

October 16, 2022 to October 20, 2022 - Lisbon, Portugal

VLC Based Guidance System to Be Used by Mobile Users Inside Large Buildings.

Manuela Vieira (mv@isel.ipl.pt)

Manuel Augusto Vieira

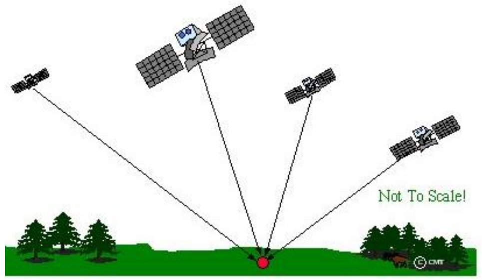


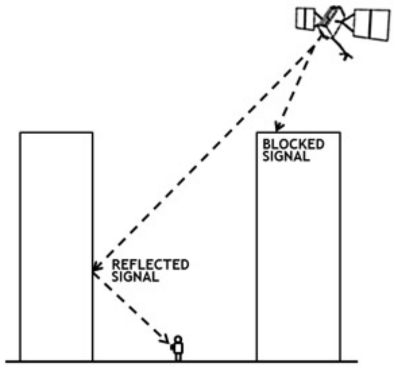
Paula Louro

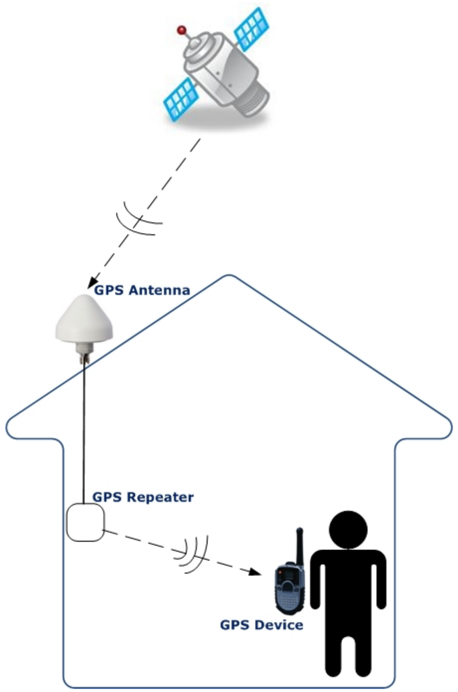
Pedro Vieira

ACKNOWLEDGEMENTS

- FCT /CTS (UIDB/00066/2020)

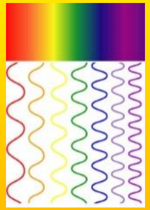






INDOOR POSITIONING SYSTEMS

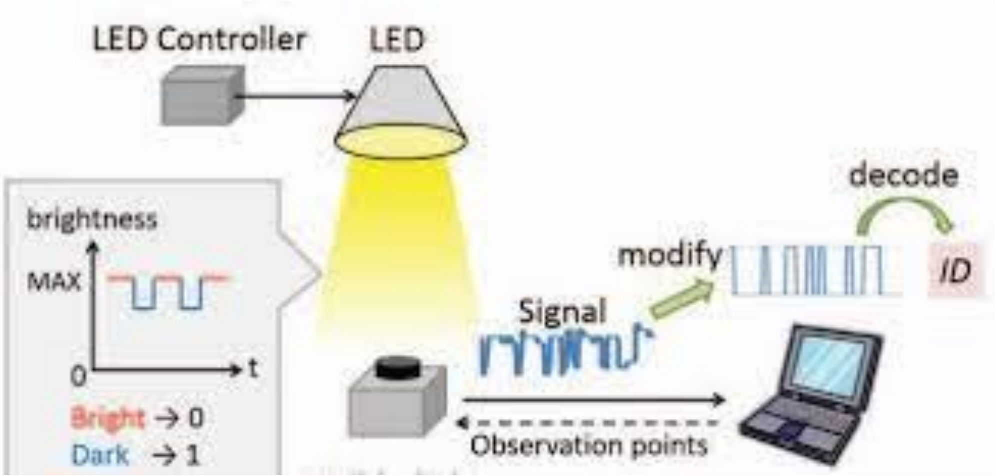
RADIO	OPTICAL	MAGNETIC	ACOUSTIC
UWB (Ultra-wideband)	Video camera	Magnetic strength	Ultrasound
Bluetooth (e.g. Beacons)	Lidar (Light Detection and Ranging)		
UHF RFID	Infrared light pulses		
Wi-Fi (Wireless Fidelity)	$\boxed{\text{VLC (Visible light communications)}}$		

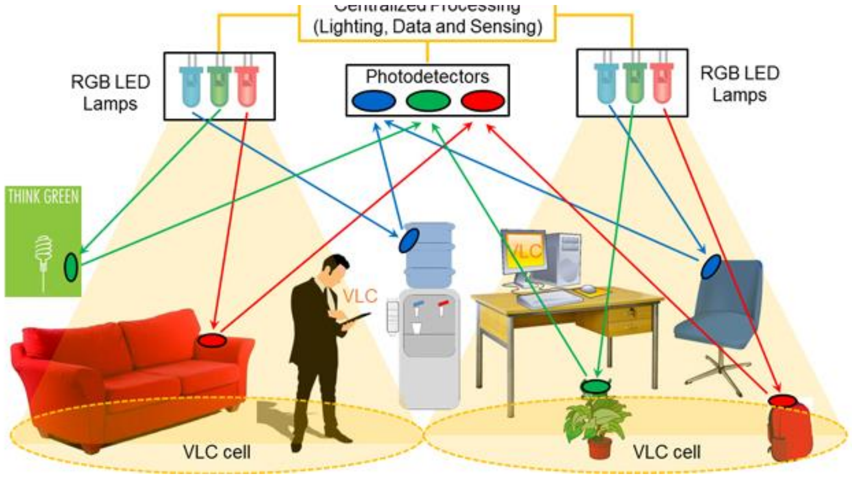


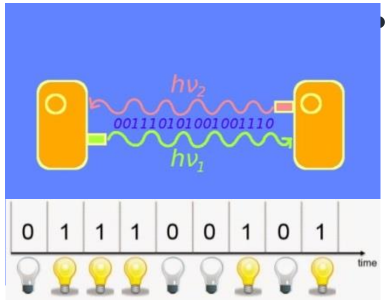
MOTIVATION

VLC – Visible Light Communication

Visible light Communication (VLC) is a data transmission technology that can easily be employed in indoor environments since it can use the existing LED lighting infrastructure with simple modifications.







- Compared with other sources of illumination these devices can be modulated at high data rates, offering the opportunity for communications as well as illumination from these sources.

Wi-Fi will begin to become limited

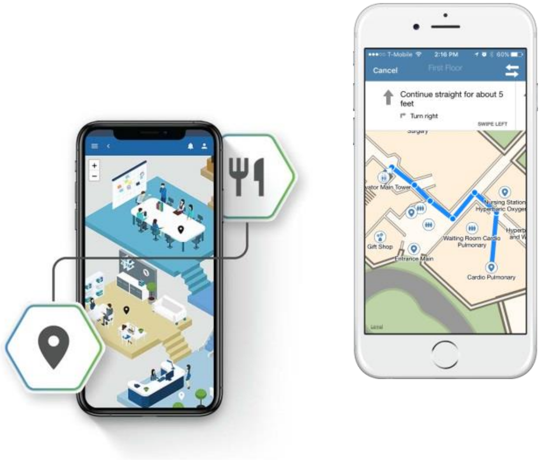
Guidance Services

Guidance Services

Interaction between planning, control, and localization is important.

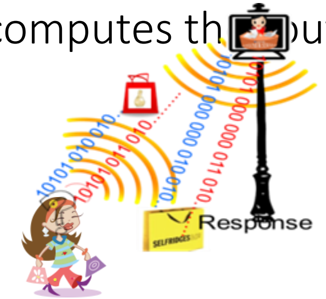
Where am I?

The localization senses the environment and computes the user position



Where am I going?

The planning computes the route to follow from the position,



How do I get there?

The control moves the user in order to follow the route.

Scenario and Guidance Services

A destination can be targeted by user request to the Central Manager (CM).

Different users are considered.

Arriving, they alert the CM to their location and ask the right track to follow.
A code identifies each user. A common code is also required for a schedule meeting.

Request

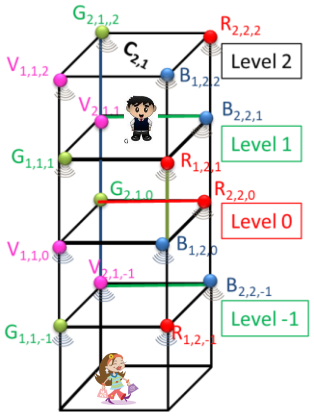
The first arriving initiates the alert notification to be triggered when the other is in his floor vicinity.
The buddy finder service uses the location information from the network's VLC location from both users to determine their proximity.

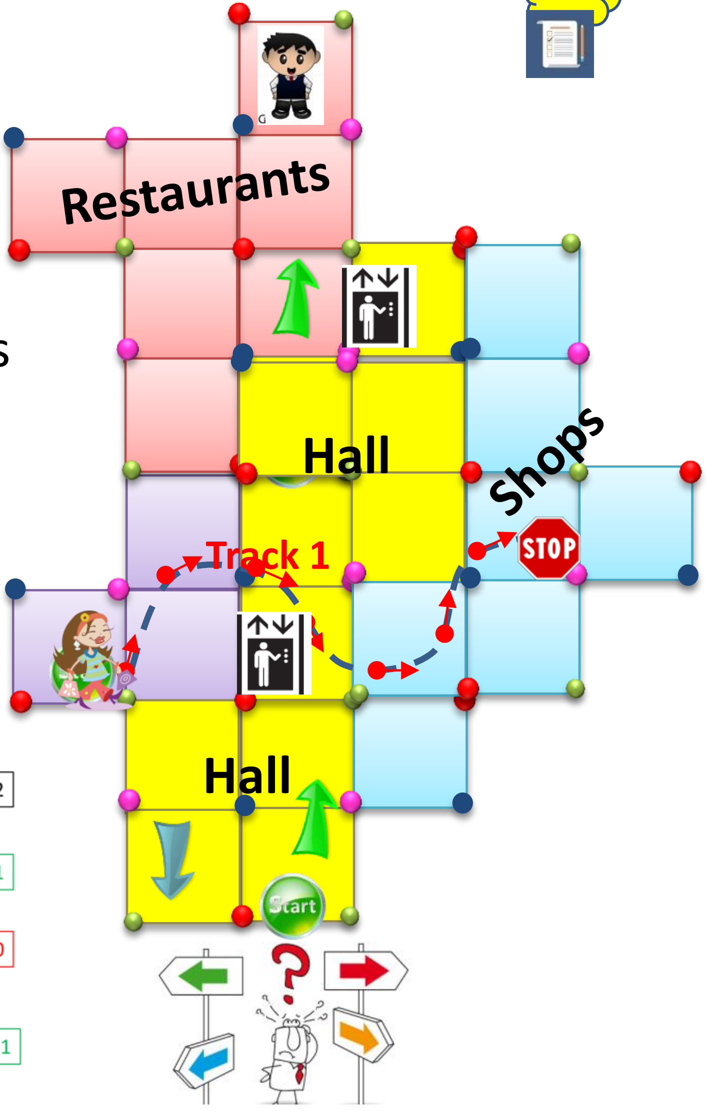
A response message with the location and path of the meeting point is sent.

Response

Transmitters

- Red
- Green
- Blue
- Violet

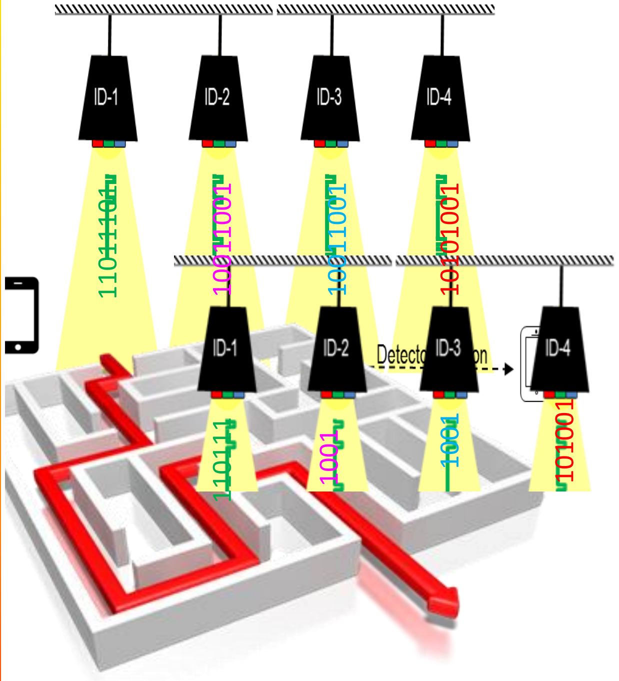


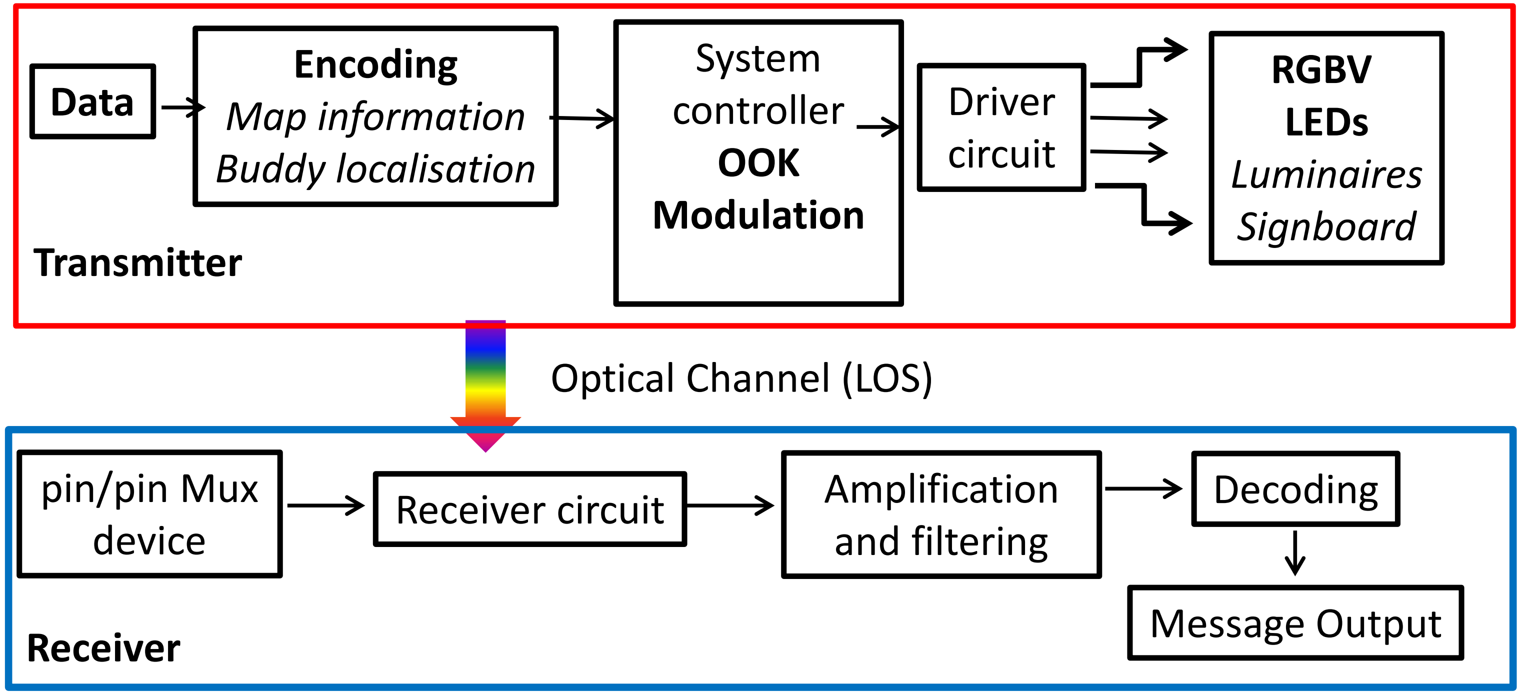


Main entrance

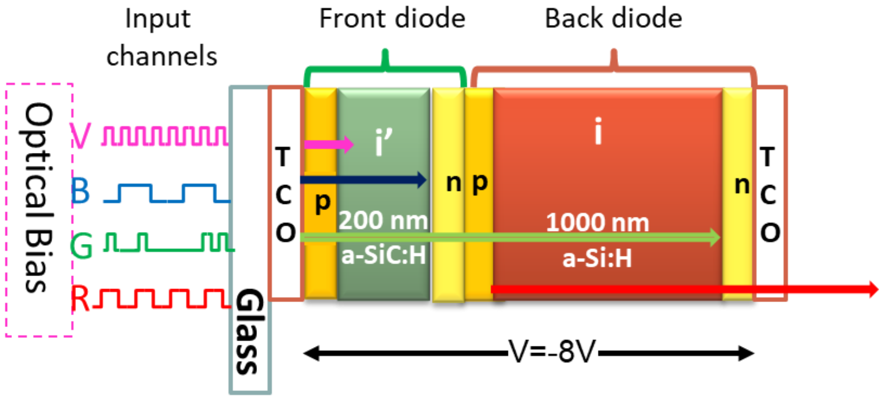
VLC communication system

Transmitter





Receiver



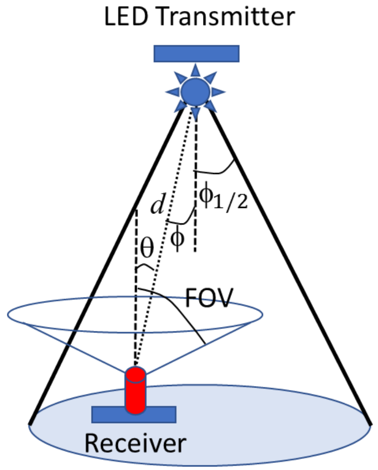
p-i'(a-SiC:H)-n/p-i(a-Si:H)-n heterostructure produced by PECVD.

- High sensitivity and linear response
- Signal conditioning techniques (adaptive bandpass filtering and amplification, triggering and demultiplexing) are used.
- Data signal is reconstructed at the data processing unit (digital conversion, decoding and decision).

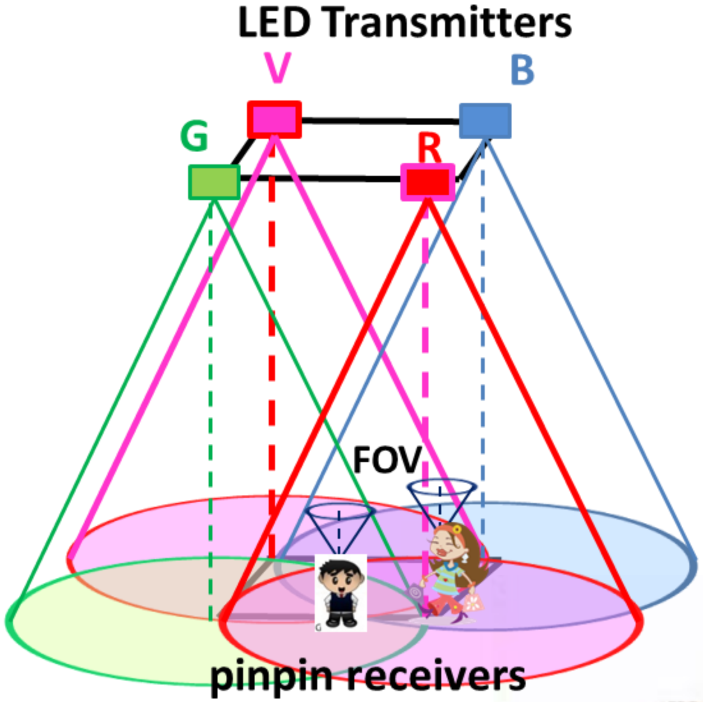
VLC link models

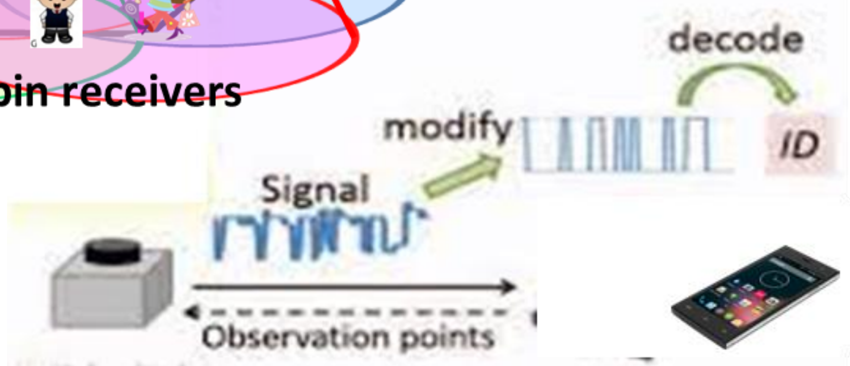
- LEDs are modeled as **Lambertian sources** where the luminance is distributed uniformly in all directions, whereas the luminous intensity is different in all directions.

$$I(\emptyset) = I_N(\cos\emptyset)^m \qquad m = -\frac{\ln(2)}{\ln\ \cos(\emptyset_{1/2})}$$



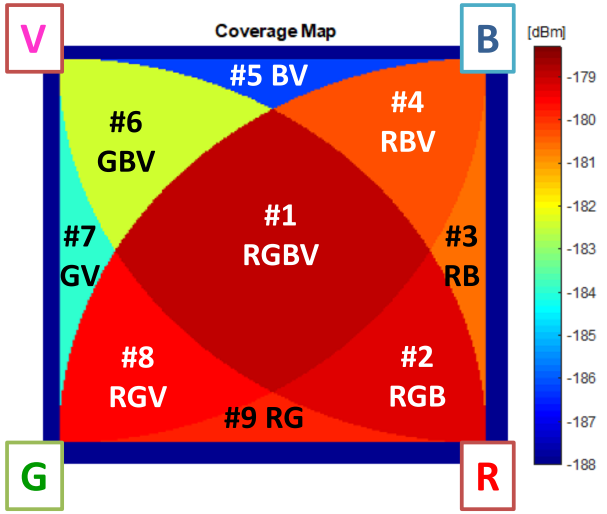
- Commercial white LEDs were designed for illumination purposes, exhibiting a wide half intensity angle of 60º (m = 1).





- MatLab simulations are used to infer the signal coverage of the LEDs in the illuminated indoors space

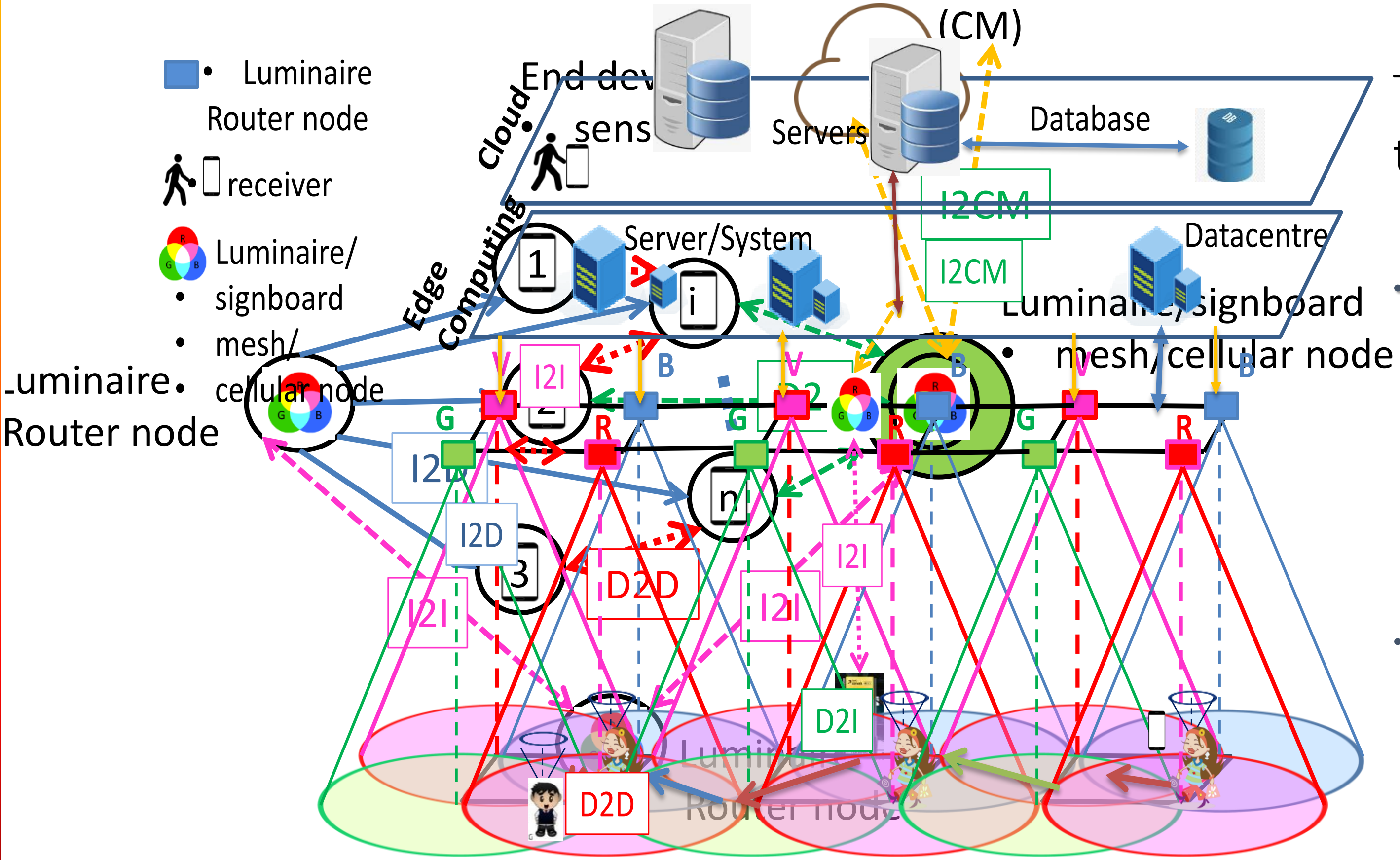
- Coverage map in the unit cell: footprint regions (#1-#9)



Architecture and Geolocation

Fog/Edge computing bridges the gap between the cloud and end devices by enabling computing, storage, networking, and data management on network nodes within the close vicinity of IoT devices.

- A mesh cellular hybrid structure is proposed. This architecture consists of VLC-ready access equipment, that provide the computing resources, end devices, and a controller that is in charge of receiving service requests and distributing tasks to fog nodes.



The luminaires are equipped with one of two types of controllers:

- A "mesh" controller that connects with other nodes in its vicinity and forward messages to other devices (I2D) in the mesh, effectively acting like routers nodes in the network.
- A "mesh/cellular" hybrid controller, equipped with a modem providing IP base connectivity to the central manager services (I2CM). These nodes act as border-router and can be used for edge computing.

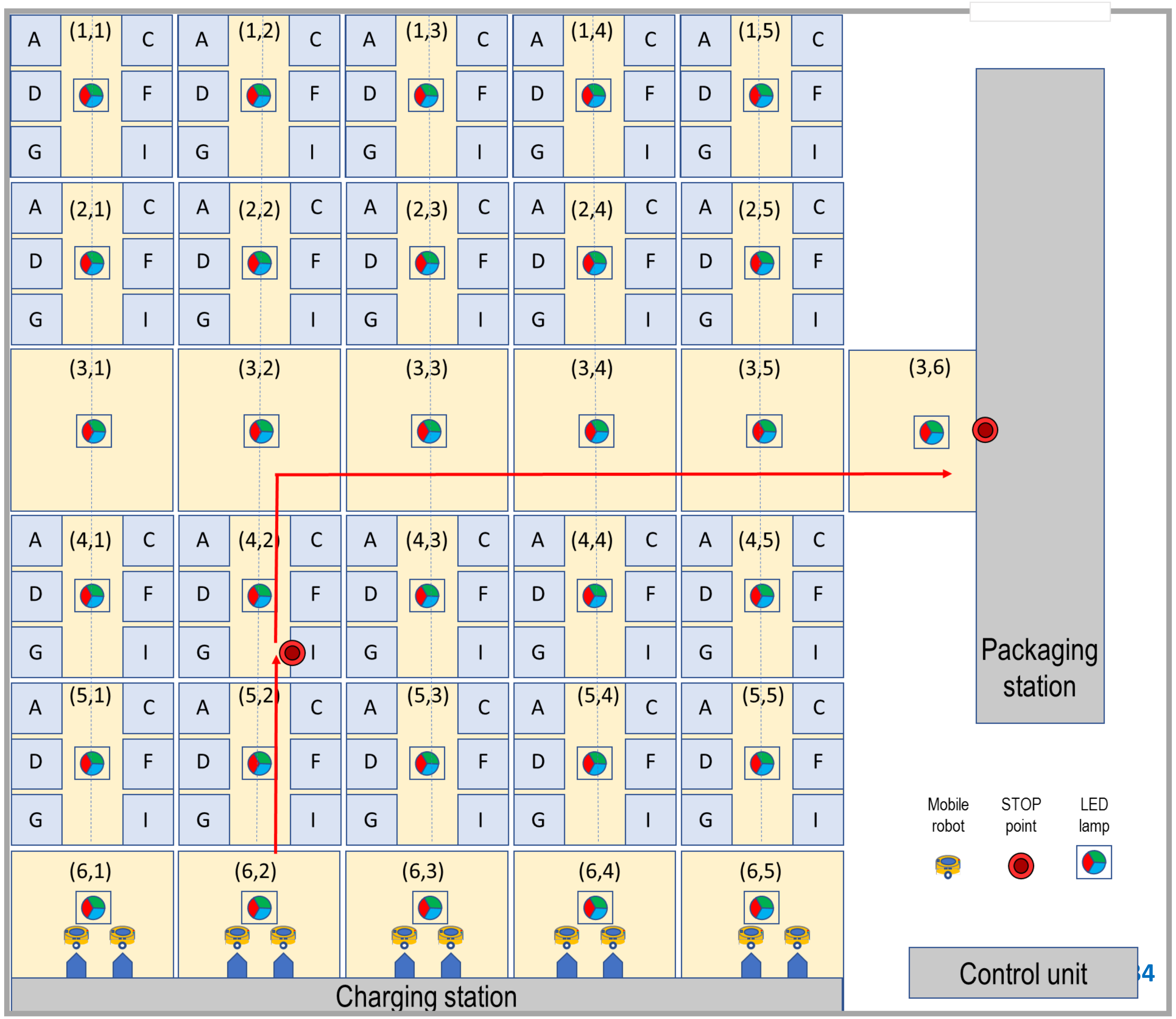
- Each luminaire for downlink transmission become a single cell, in which the optical access point (AP) is located in the ceiling and the mobile users are scattered within the overlap discs of each cells underneath (footprints).

AUTOMATED WAREHOUSE

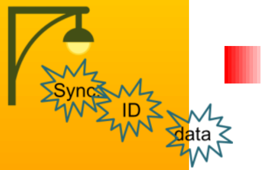
- Improve the **efficiency** of an automated warehouse which translates into direct savings
- Automated solutions can enlarge the human element in certain tasks, removing health and safety risks and limitations
- Use of **autonomous guided vehicles** to remove goods from racks of and carry them to the packaging station
- Navigation along pre-defined routes
- Use of **VLC** to support navigation and positioning of the vehicles

AUTONOMOUS GUIDED VEHICLE

- Warehouse with 5 corridors with racks on both left and right sides.
- The indoor space is lightened using LED lamps that establish the navigation cell in a squared geometry.
- In this example there are 30 LED lamps - 30 navigation cells,
- Numbering of the cells - matrix



Conclusions



- Based on ceiling landmark route instructions, we propose a dynamic indoor cooperative multi-person VLC localization and navigation system.
- The scenario of the multilevel building, the architecture of the system based on a mesh cellular hybrid structure, and the protocol of communication were established.
- Bi-directional communication between the infrastructure and the mobile receiver was analyzed.
- According to global results, the location of a mobile receiver is found in conjunction with data transmission.
- The VLC system, when applied to large building, can help to find the shortest path to a place, guiding the users on a direct, shortest path to their destinations.
- Using the dynamic LED-aided VLC navigation system, users can control their route, geotracking and navigation. The multi-person cooperative localization system detects crowded regions and alerts the user to reschedule meetings, as well as providing guidance information. With those alerts, the CM can recalculate, in real time, the best route for users requesting wayfinding services, avoiding crowded areas.

SENSORDEVICES 2022
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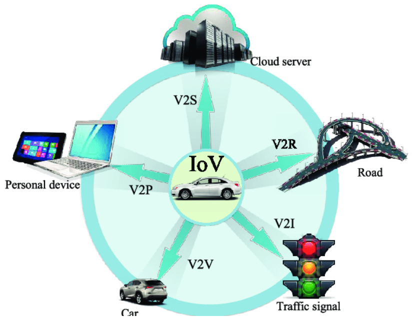
ADAPTIVE TRAFFIC CONTROL USING COOPERATIVE COMMUNICATION THROUGH VISIBLE LIGHT



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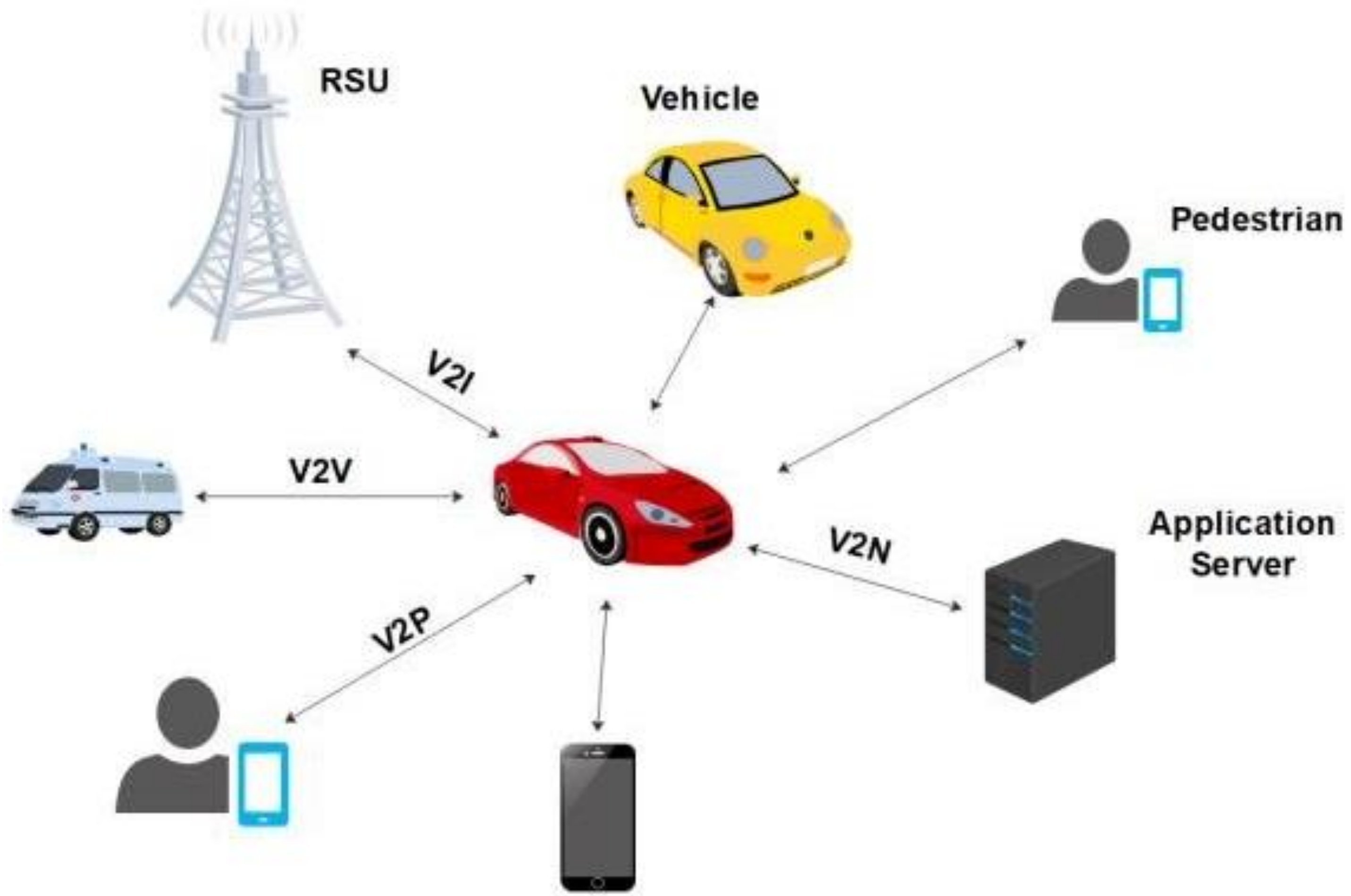
VEHICULAR COMMUNICATION SYSTEMS

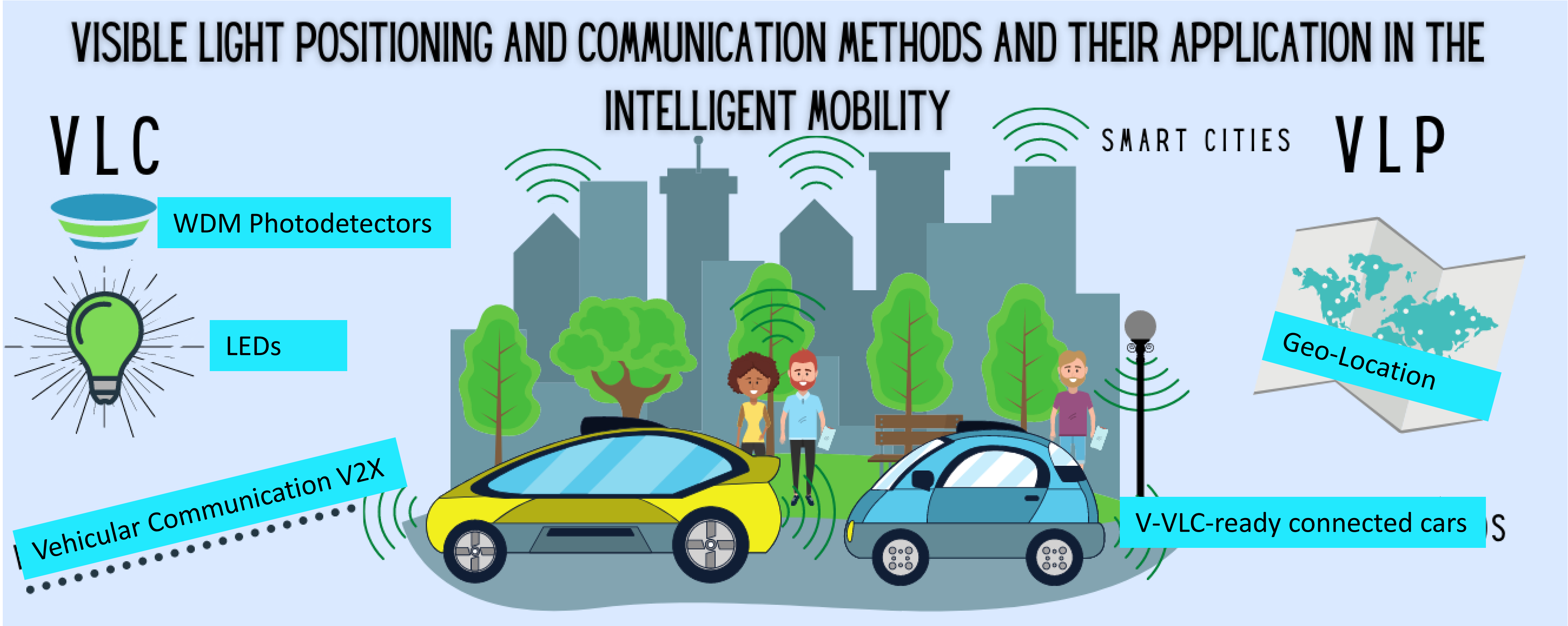


- Vehicular Communication Systems are a type of network in which vehicles and roadside units are the communicating nodes, providing each other with information, such as safety warnings and traffic information.

- Communication between fixed locations and vehicles (Infrastructure-to-Vehicle, **I2V**) between vehicles (Vehicle-to-Vehicle, **V2V**), and between vehicles and fixed locations (Vehicle-to-Infrastructure, **V2I**) is essential to transfer information in real time.

- The I2V applications focus on utilizing the traffic related infrastructure, such as traffic light or streetlight to communicate useful information.

The opportunity to optimize the operation of urban traffic network by cooperation between traffic signal control and driving behaviors.



- ✓ The traffic data collected by the current traffic control system using induction loop detector and other existing sensors is limited.
- ✓ Advancement of the wireless communication technologies and the development of the V2V and V2I systems, called Connected Vehicle (CV).
- ✓ Technical support for the development of Vehicle-to-X systems and autonomous driving industries.

MOTIVATION

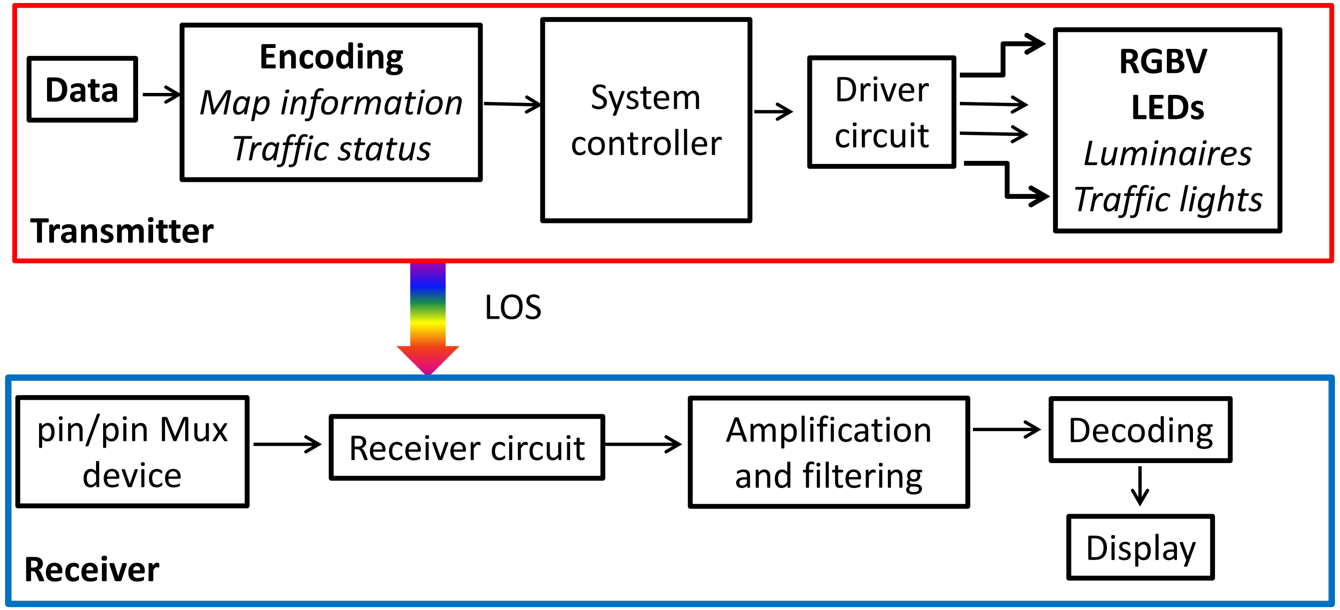
The **adaptive traffic control strategy** aims to respond to real-time traffic demand through current and predicted future traffic flow data modeling.

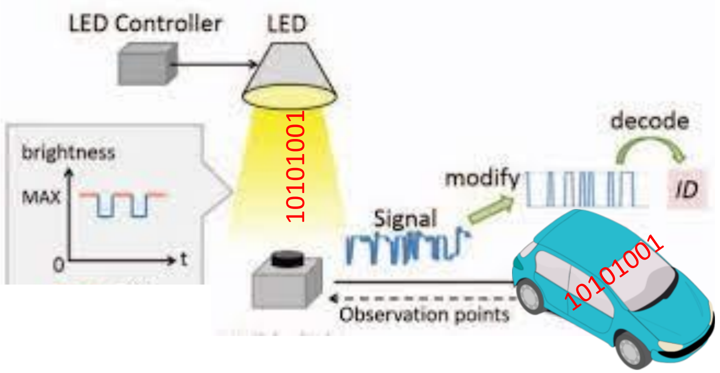
- Is it possible to implement **a reliable VLC system** using the proposed I2X vehicular visible communication model, in traffic controlled intersections?
- Using a network simulator, how can VLC be implemented in a **traffic control intersection**?
- By employing VLC at a traffic control intersection, what effects does it have on **traffic performance parameters** in an urban traffic scenario?

GOAL

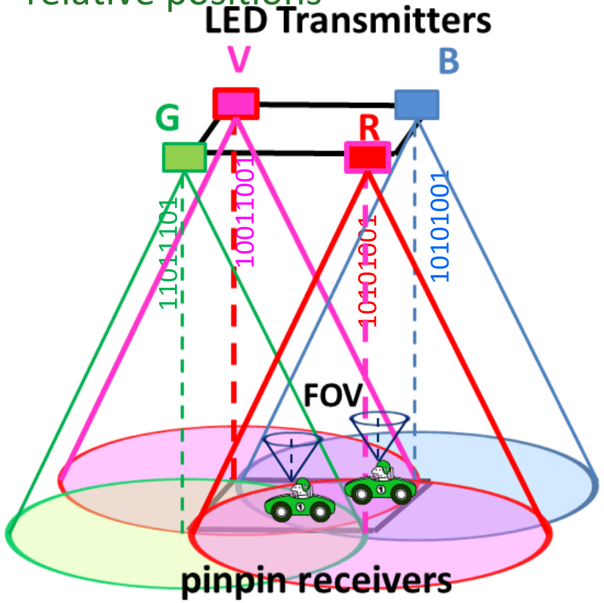
Compared with the traffic flow and occupancy information provided by the fixed coil detector, the adaptive traffic control system in V2X environment **can collect more detailed data such as vehicle position, speed, queuing length, and stopping time**.

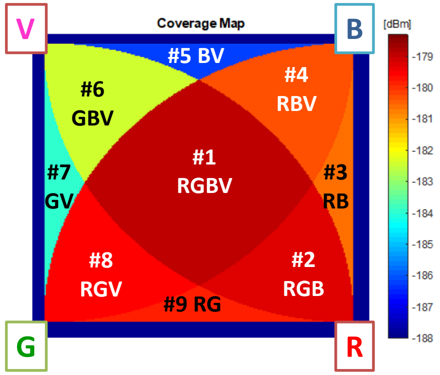
V-VLC Communication Link





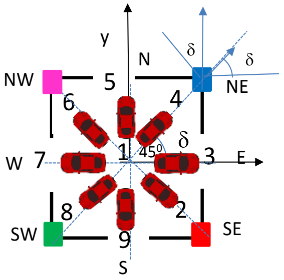
Transmitters and receivers 3D relative positions





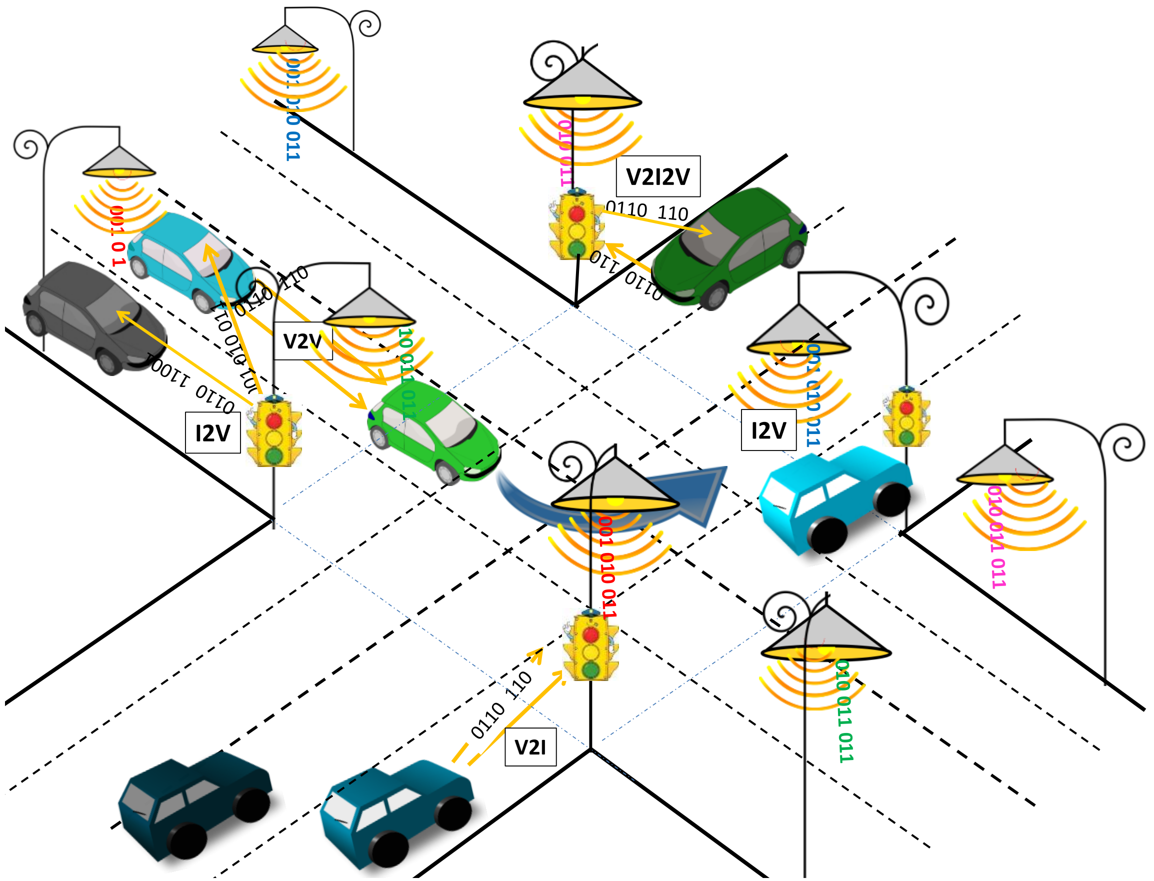
Footprint regions

Steering angles



Cooperative VLC System

Operational procedure:



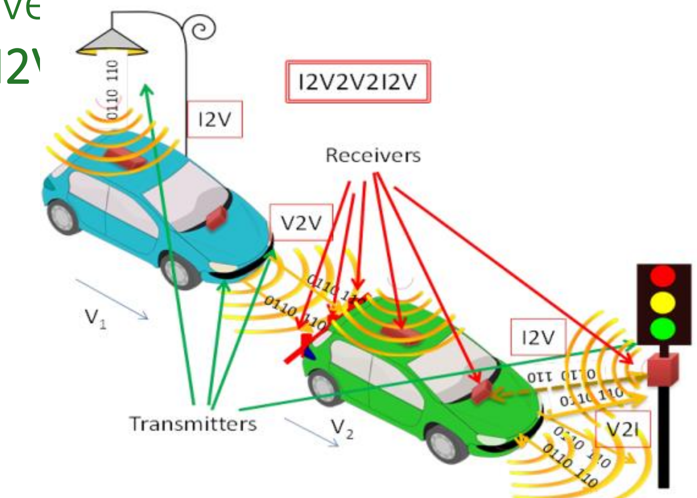
Each vehicle receives two different messages: **I2V** and **V2V** coming from the streetlight and from the follow vehicle;

Compare them and infers the **drive distance** and the **relative speed**.

Send the information to a next car **(V2V2V)** or to an infrastructure **(V2V2I)**.

Connected ve

messages (I2

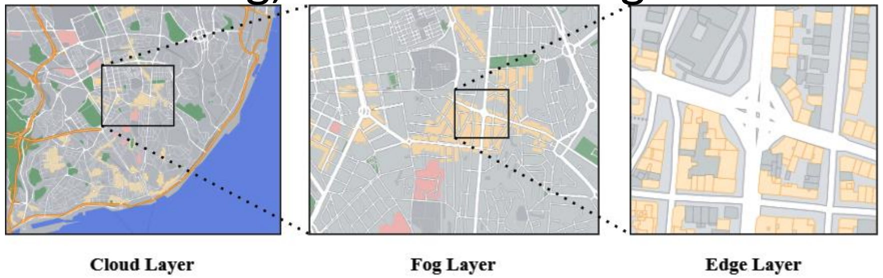


An integrated approach for optimizing the intersection

In order to verify the system operability and efficiency we have conducted an extensive set of measurements

Architecture (Edge Computing infrastructure)

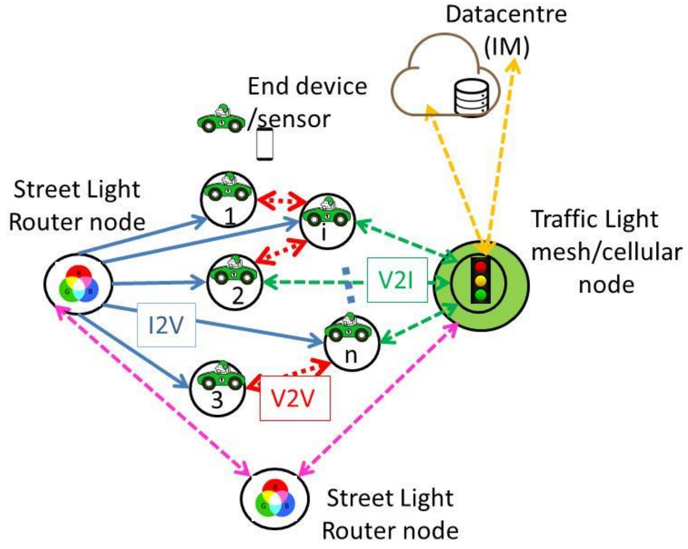
Fog/Edge computing bridges the gap between the cloud and end devices by enabling computing, storage, networking, and data management on network nodes within the close vicinity of IoT devices.

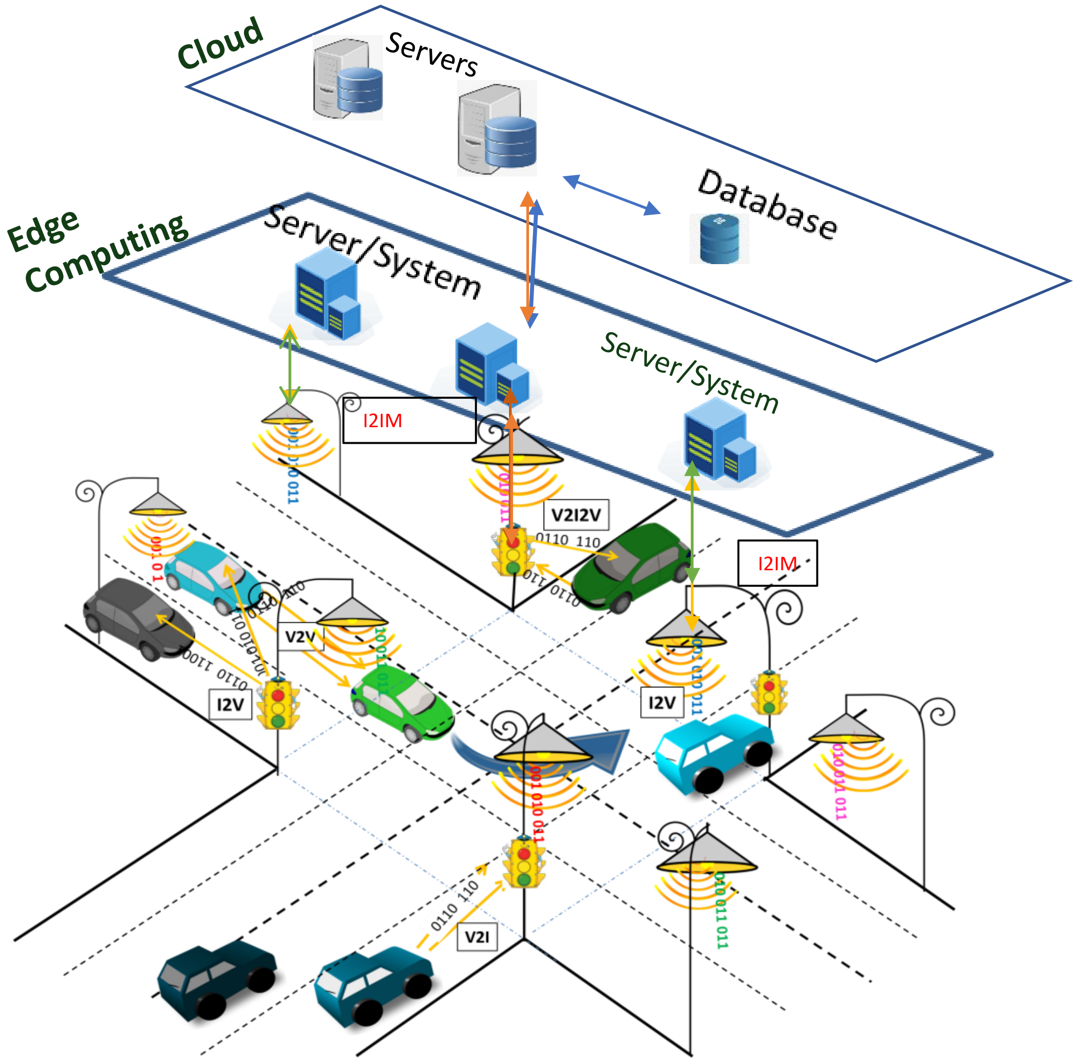


Lisbon

Streetlights two types of nodes:

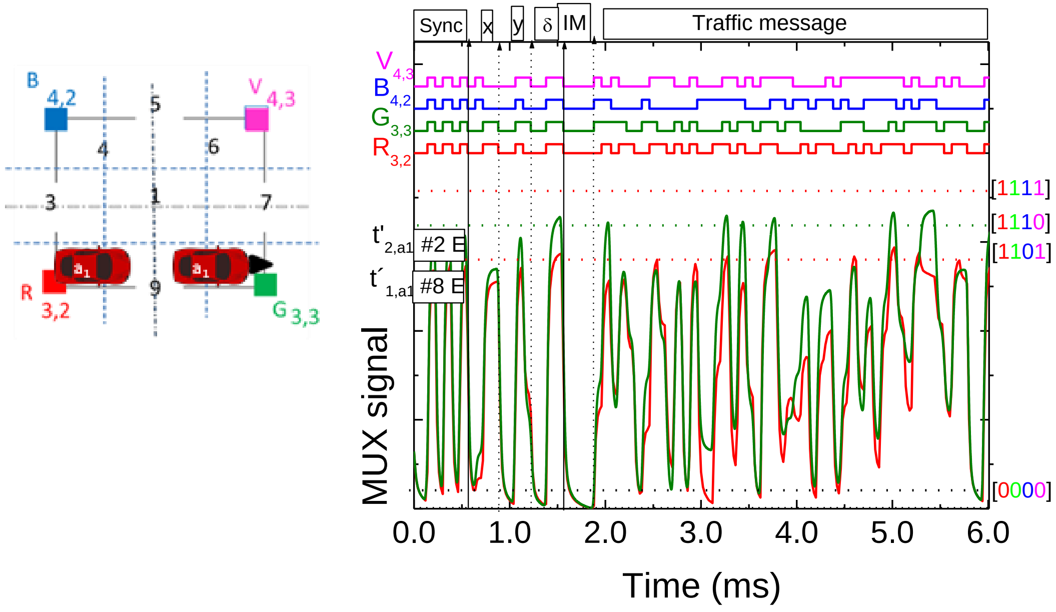
- **"mesh"** controller that connects with other nodes in its vicinity
- **"mesh/cellular"** hybrid controller that is also equipped with a modem provides IP base connectivity to the Intersection Manager (IM) services



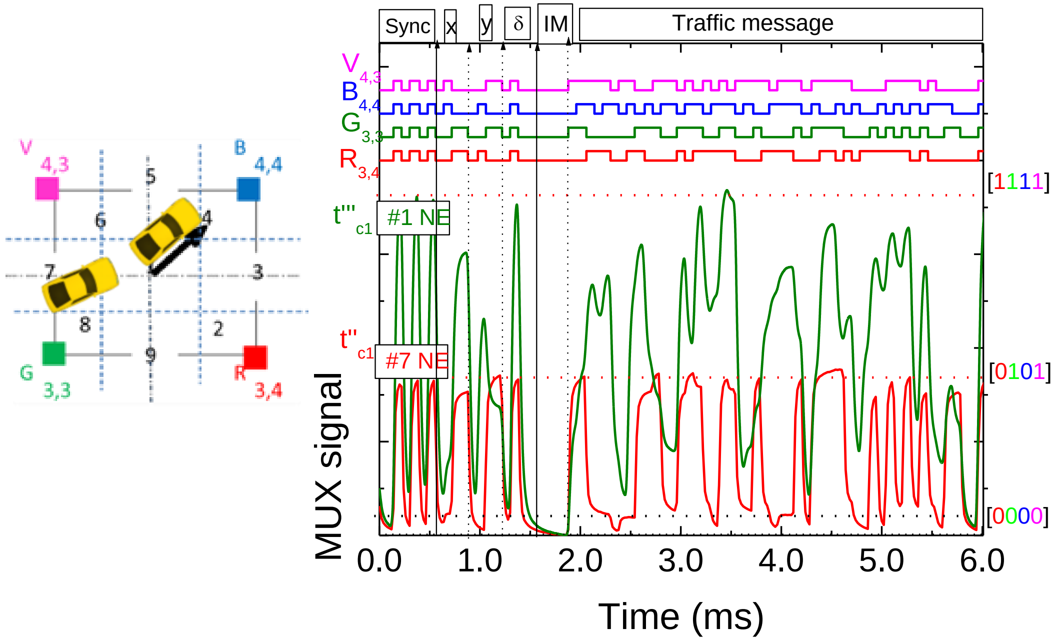


Edge Computing infrastructure. Mesh and cellular hybrid architecture.

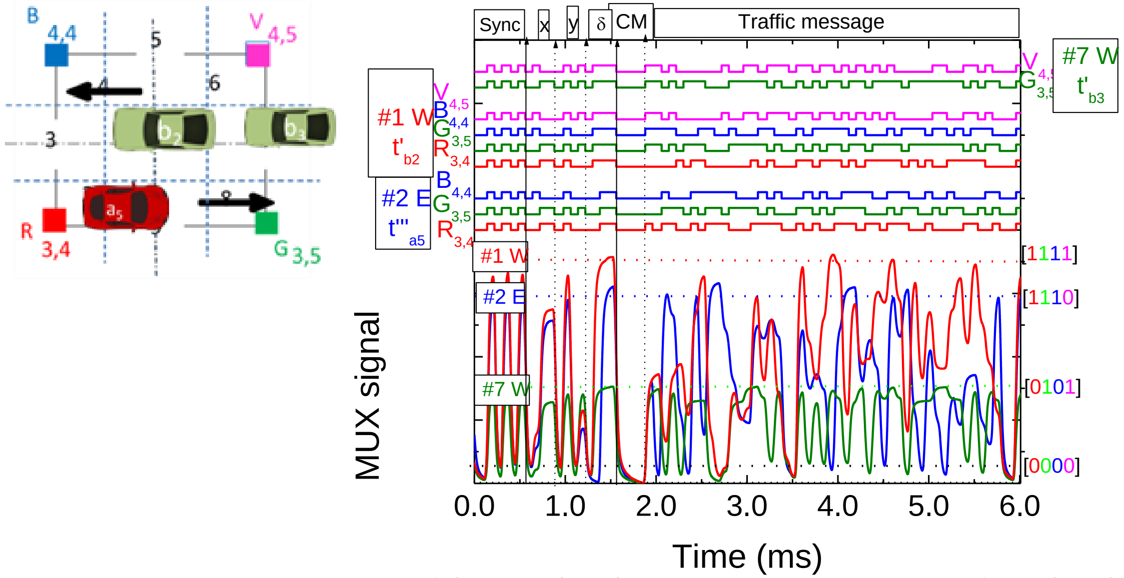
Adaptive Traffic Control (V-VLC evaluation)



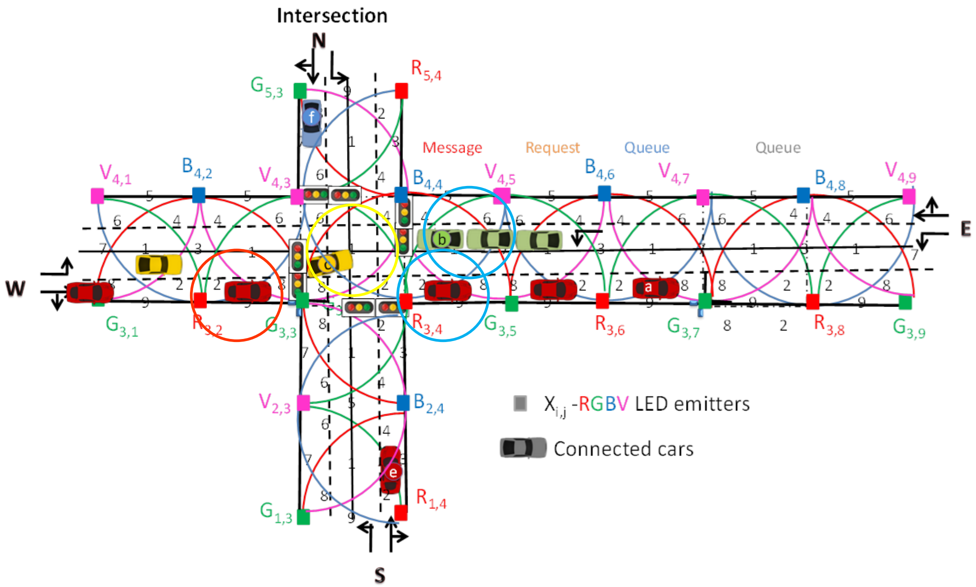
Messages received by a_1, poses #8E, #2E



Messages received by c_1, poses #7NE, #1NE



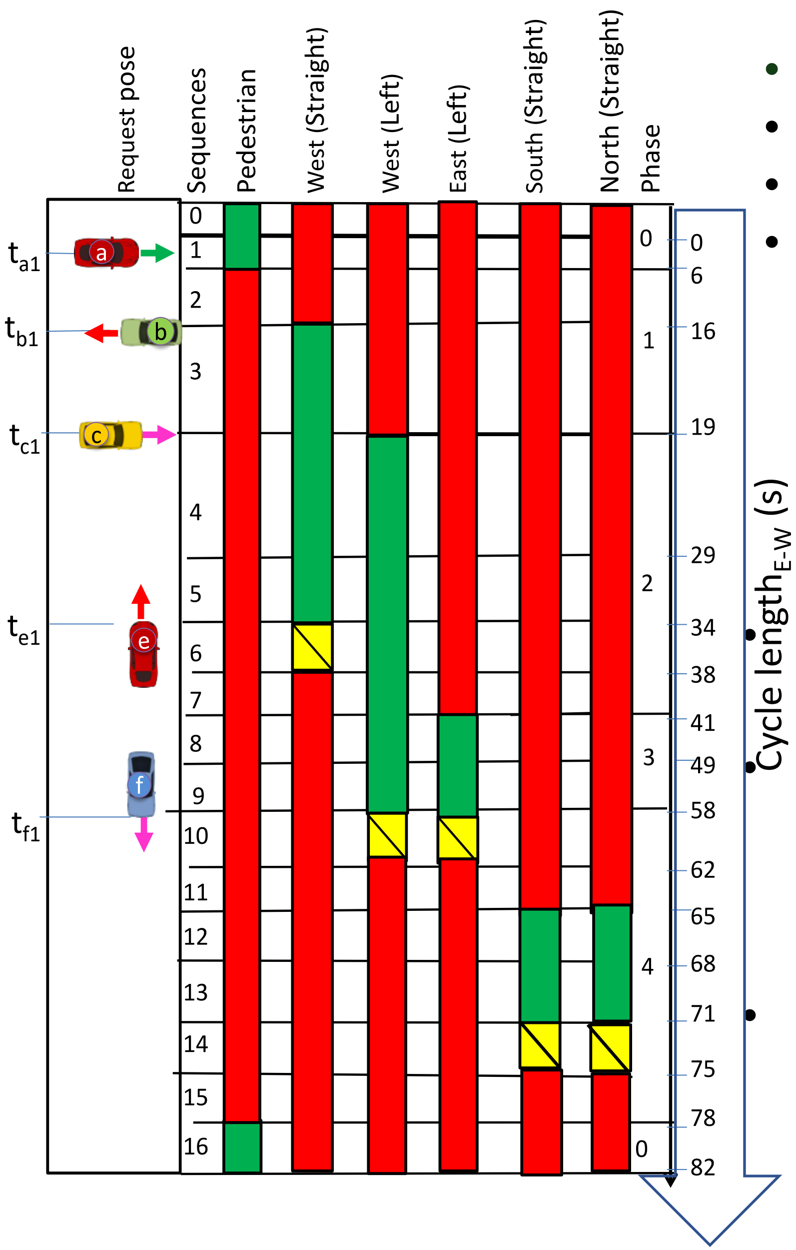
Messages received by Vehicle a_5, pose #2E, and Vehicle b_2 poses #7W and, b_3 at #1W.



$t_{a1}<t_{b1}<t_{a2}<t_{b2}<t_{a3}<t_{c1}<t_{b3}<t_e<t_{a4}<t_{c2}<t_{a5}<t_f$.

Dynamic Traffic Signal Phasing

The objective is to maximize the traffic flow through the intersection over time.



- Cycle length **5** phases divided in **16** time sequences.
- The pedestrian phase contains the *"0"*, the *"1"* and the *"16"* sequences.
- The cycle's top synchronism starts with sequences *"1"*.
- The first, second, third, and fourth phases contain sequences between *"2)"* and *"15"* and control traffic flow.

The matrix of states (durations of the states for a given cycle) allows to view, enter, or modify the division of an intersection into states.

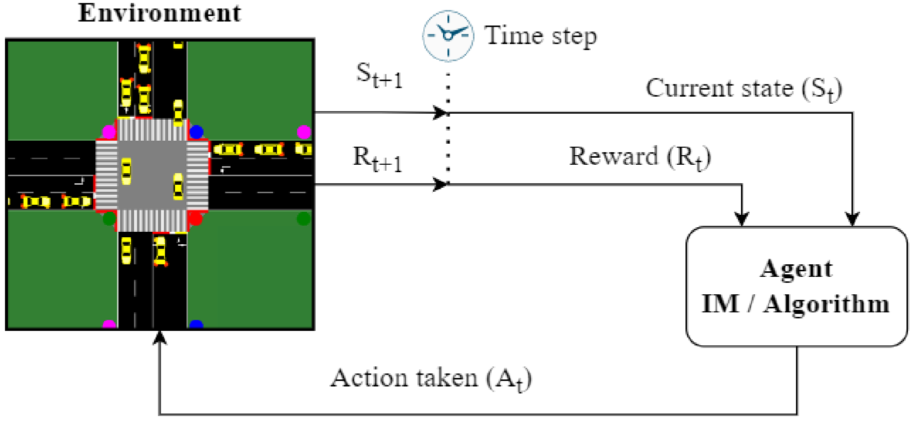
- Each element represents the lighting state.
- Columns represent the duration of the states from cycle minimum [fluid traffic] to cycle maximum [dense traffic].
- For a medium traffic scenario, three cycles (N-S , W-E straight or left).

Sequences	Low-traffic scenario (s)	N-S medium traffic scenario (s)	E-W medium traffic scenario (Left) (s)	E-W medium traffic scenario (Straight) (s)	High traffic scenario (s)	Fixed time (s)
0	9	3	3	3	3	
1	0	6	6	6	6	
2						10
3						3
4	0	8	7	10	12	
5						5
6						4
7						3
8	3	3	8	8	10	
9	3	3	9	9	8	
10						4
11						3
12	3	6	3	3	7	
13	3	8	3	3	9	
14						4
15						3
16	0	4	4	4	6	
Cycle lenght	**60**	**80**	**82**	**85**	**100**	**39**

✓ **Medium E-W scenario, the IM extends the green to accommodate all the a_i followers and the the arriving c_i**

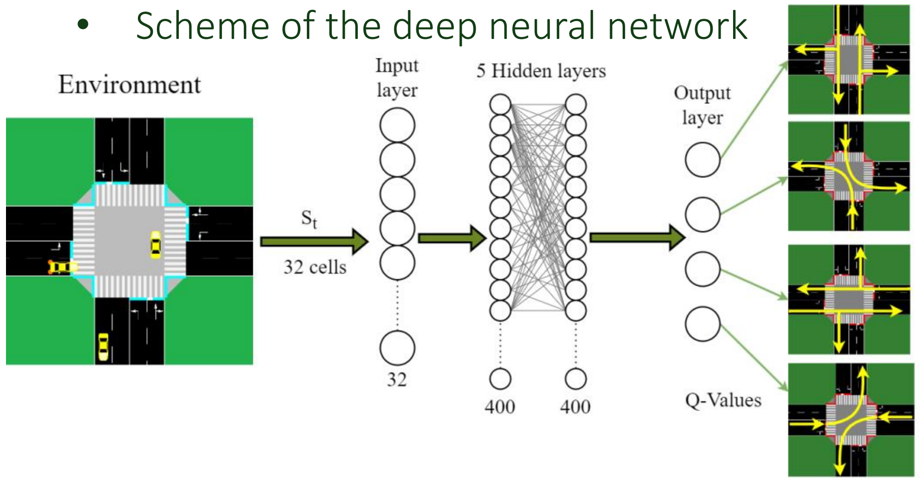
Intelligent control CV systems (simulation)

The simulations were **agent-based** and they have been carried out in a tool for **S**imulation of **U**rban **MO**bility (SUMO).



SUMO controls the traffic lights according to the decisions of the learning agent, describes the overall traffic flow and defines the reward to the actions carried out by the traffic lights control agent.

- Scheme of the deep neural network



The agent must decide how to explore new states while simultaneously maximizing its total reward in order to create the best possible policy.

Maximize the traffic flow through the intersection over time minimizing the accumulated total waiting time in each arm:

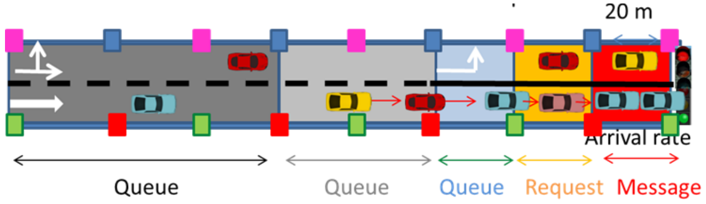
$$aTw_t = \sum_{xi=1}^{n}(awt)_{xi,t}$$

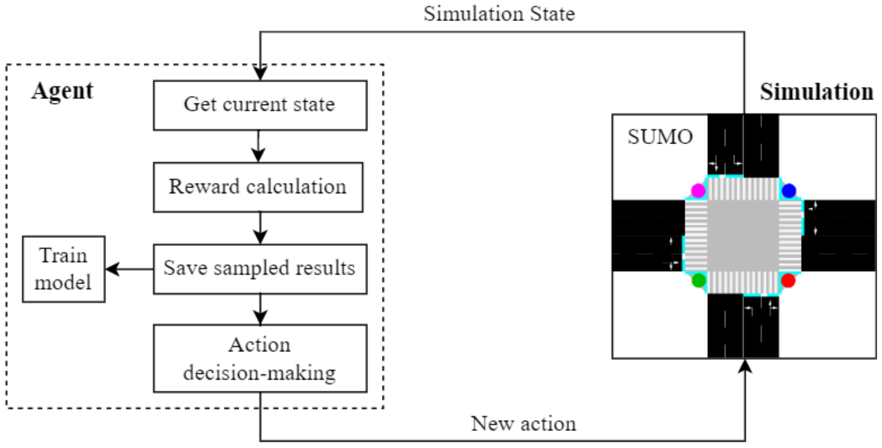
$$r_t = aTw_t - aTw_{(t-1)}$$

r_t

<0 

>0 





- Agent's workflow

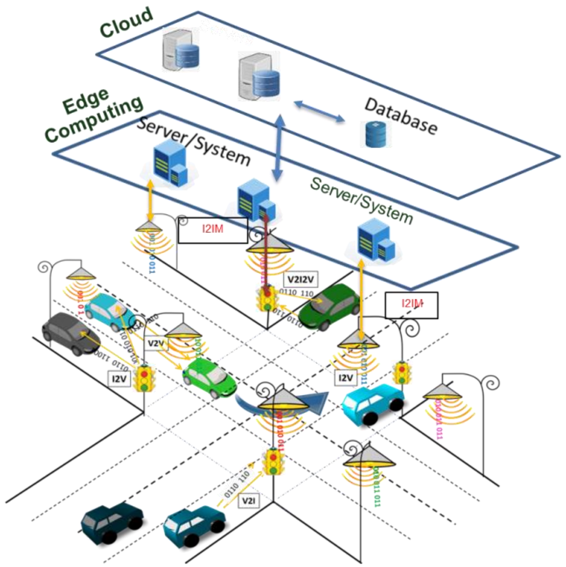
Simulation0410.mp4

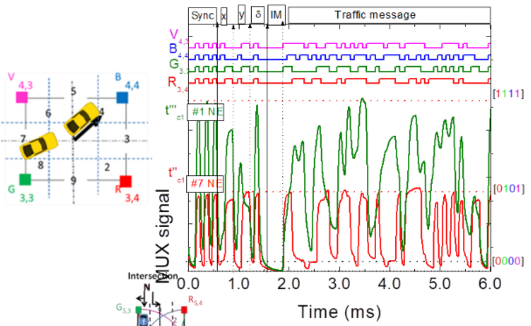
v<0.1 m/s a queue alert is generated.

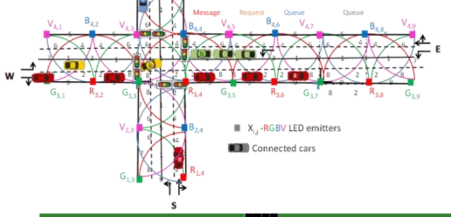
Conclusions

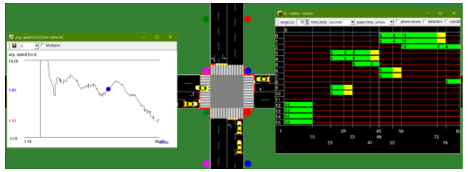
- V-VLC-ready optimizes urban traffic network operation by integrating traffic signal control and driving behavior.
- For managing intersections, the adaptive traffic control system uses a queue/request/response approach.
- An architecture, scenario, environment, and hybrid mesh/cellular network configuration were developed and proposed.
- The adaptive traffic control in a V2X environment can collect more detailed data, such as vehicle position, speed, queue length, and stopping time, than the traffic flow and occupancy information provided by fixed coil detectors.
- The traffic light phase is adjusted to the traffic scenario and the duration of the traffic light is changed dynamically which reduces travel times and unnecessary waiting for the green phase, leading to optimized traffic flow.
- The introduction of VLC between connected vehicles and the infrastructure allows the direct monitoring of critical points that are related to the queue formation and dissipation, relative speed thresholds and inter-vehicle spacing increasing the safety.

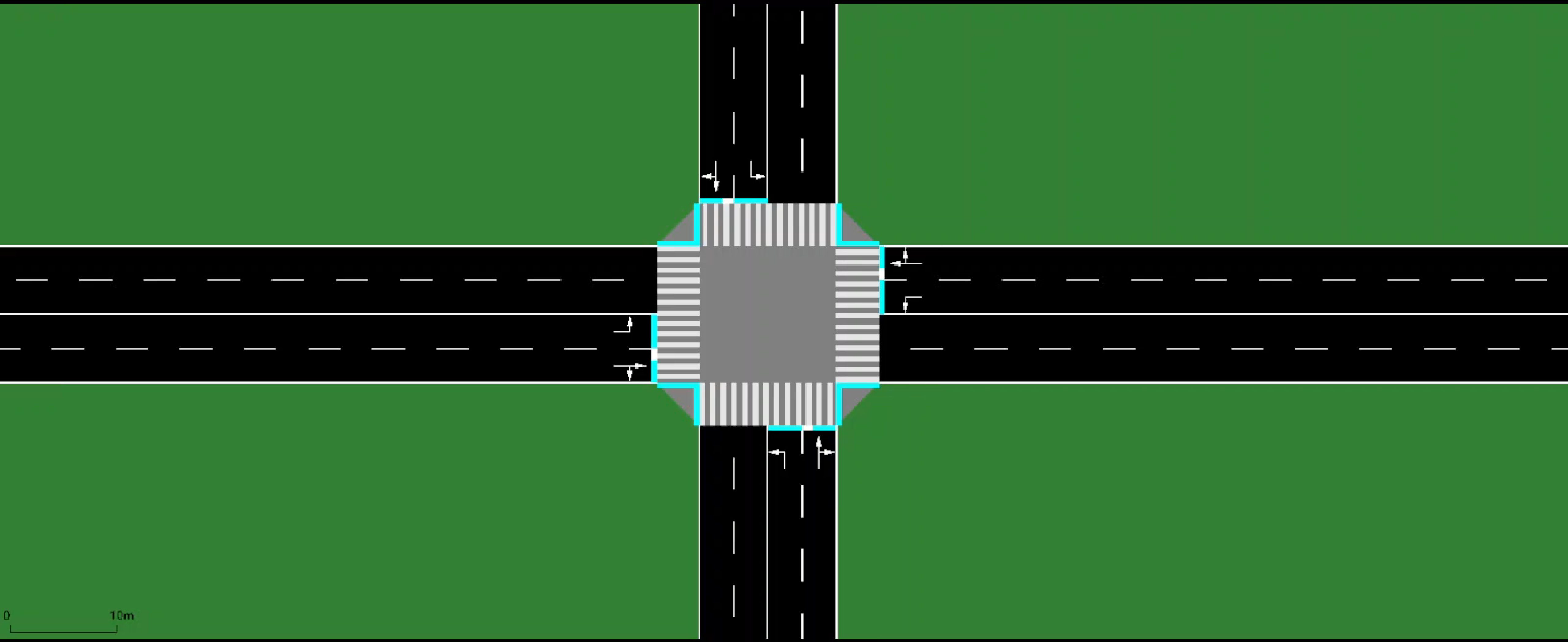
THANK YOU FOR YOUR ATTENTION










0
10m