

5G



Resilient Wireless Communications In Transportation Via 5G + Li-Fi

Farid Bichareh

Chief Technology Officer
IIC Smart Factory Co-Chair

Sven Schrecker

VP and Chief Architect, Cyber Security
IIC Security WG Co-Chair



Data Revolution - Explosion of Data

- Data Management/Data Centers
- Wireless Networking
- Cloud, Fog & Edge
- VR, AR and AI
- Digital ID
- Industry 4.0
- Smart Building, Smart Home and Smart City
- Mobile Connectivity
- Wireless Communication
- Intelligent Manufacturing
- Social Media

- **Connected/Autonomous Vehicle**

- Drones/Robots
- Image processing
- IoT/IIoT, etc.

By 2025:

Estimated about 150 billion “connected” devices

This can be translated to

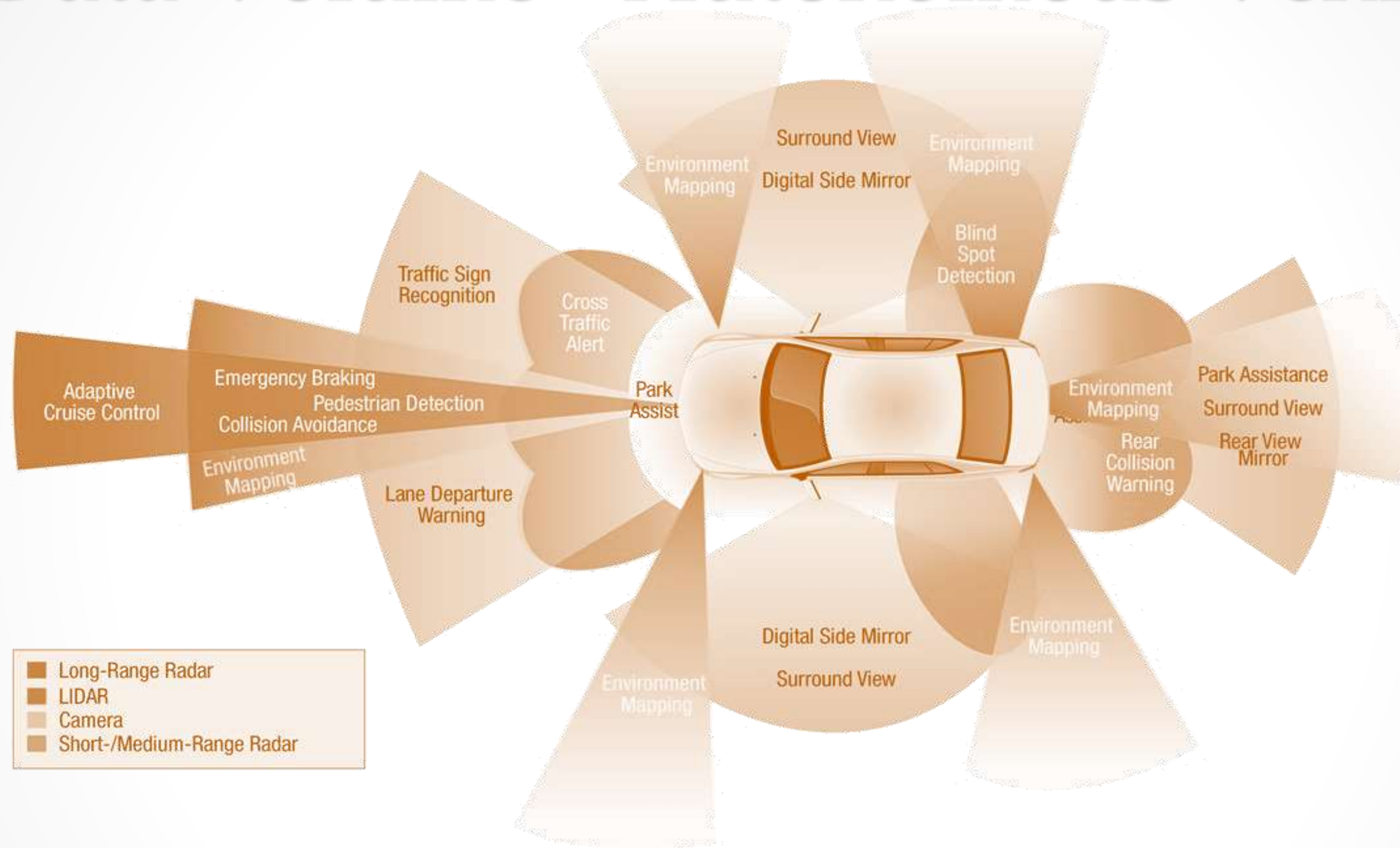
90 Zettabytes of data need to be transferred

90,000,000,000,000,000,000,000,000

Real-time data represents nearly 30% of Datasphere by 2025

CAGR of wireless traffic has been 60% during the last 10 years

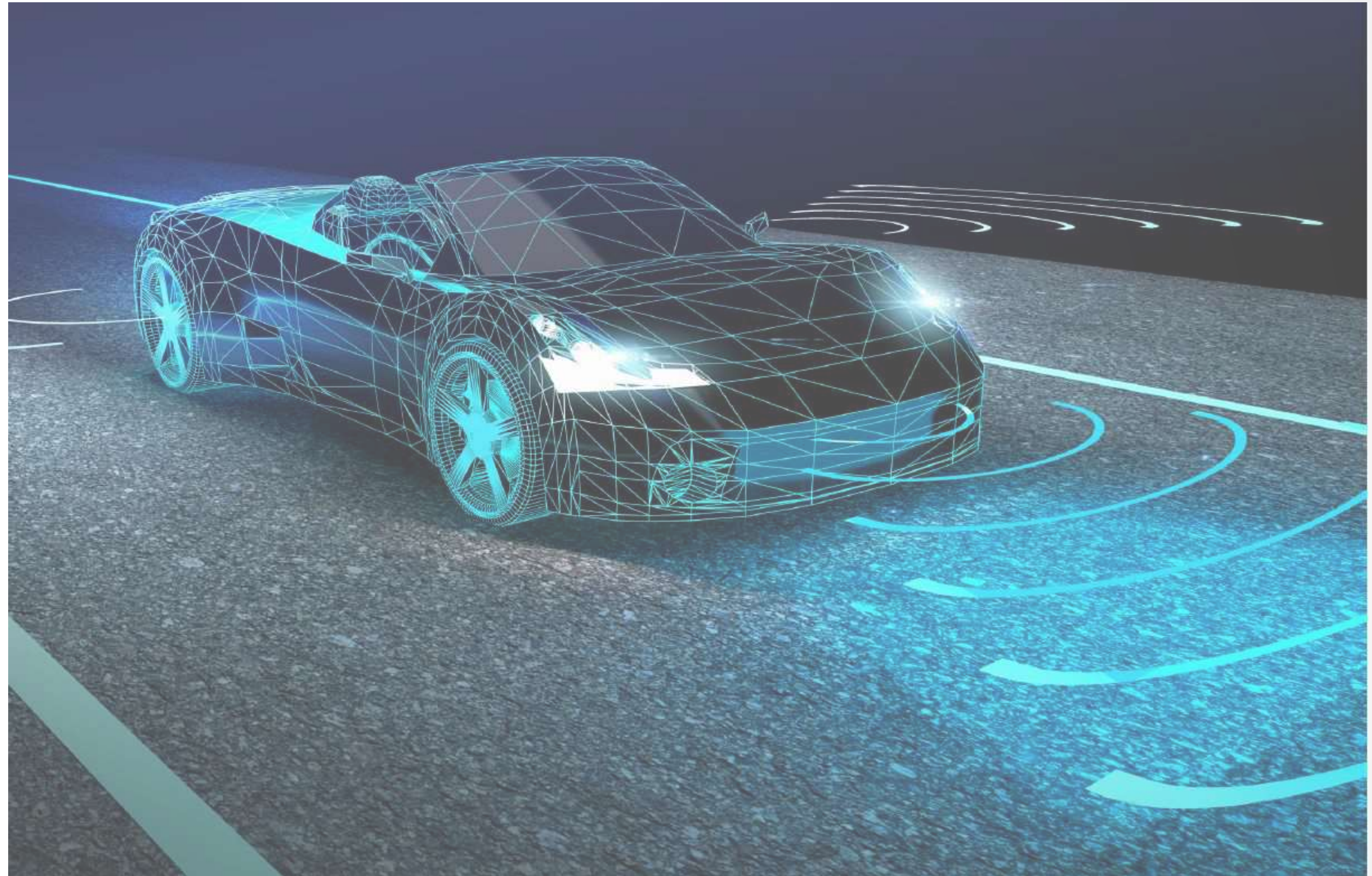
Data Volume - Autonomous Vehicle



2 Petabits or 2000 TB per week per Vehicle

Drivers of Automotive Technology Evolution

- **CASE:**
 - **C**onnected
 - **A**utonomous
 - **S**hared
 - **E**lectrified

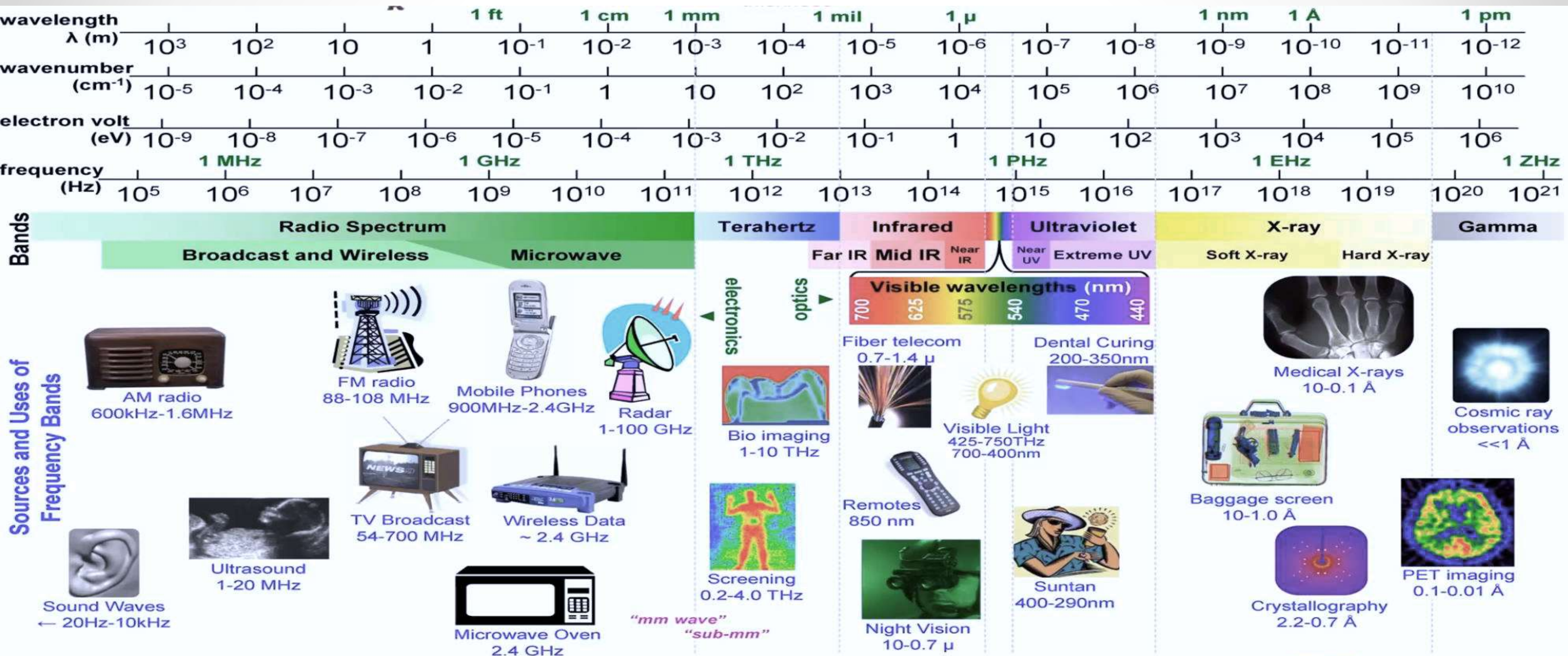


Challenges of Automotive Technology Evolution

- Reliability
- Safety
- Security
- Privacy
- Costs
- Customer Expectations



Wireless Communication



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$$\lambda = 3 \times 10^8 / \text{freq} = 1 / (\text{wn} \times 100) = 1.24 \times 10^{-6} / \text{eV}$$

SURA Southeastern Universities Research Association®

Radio Spectrum 5G

Wireless Communication

	Generation	Cell R	Comm.
Analogue to Digital •	2G (GSM)	40 Km	Voice
Small Cell concept •	3G (UMTS)	5 Km	Multimedia, internet
cm-wave •	4G (LTE)	100-200m	100 Mbps
mm-wave •	5G	20-50m	Gbps

- High infrastructure cost for the backhaul and fronthaul data links
- likelihood of line-of-sight between an interfering base station and a user terminal increases

mm-wave to **nm-wave** consequently involves Light (VLC/Li-Fi)

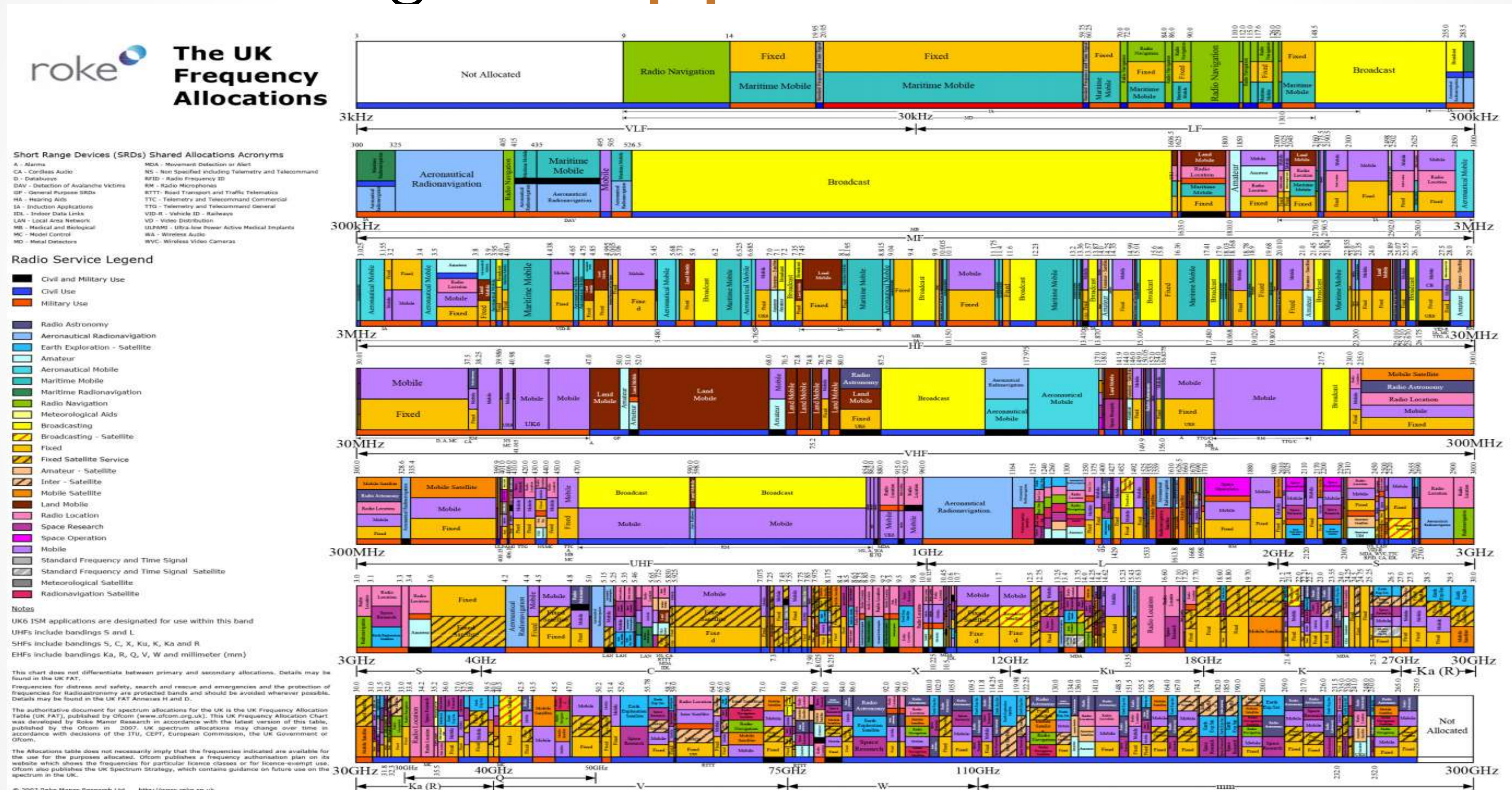
Light is part of our life and is everywhere

mmWave VS nmWave

	Spectrum	License	Safety	Power consumption	Cost
mmWave	3–300GHz	Partly free	Medium	High	High
VLC	385–790THz	Free	High	Low	Low

Interoperability Challenges - Do We?

- Do we have enough **data pipe** to transfer data?



Interoperability Challenges - Do We?

- Do we have **secure and safe** way for wireless communication?



Interoperability Challenges - Do We?

- Do we have a **scalable** solution to connect the increasing number of cars to transfer data?



Interoperability Challenges - Do We?

- Do we have **fast** wireless communication to transfer large amount of data – **real time**?



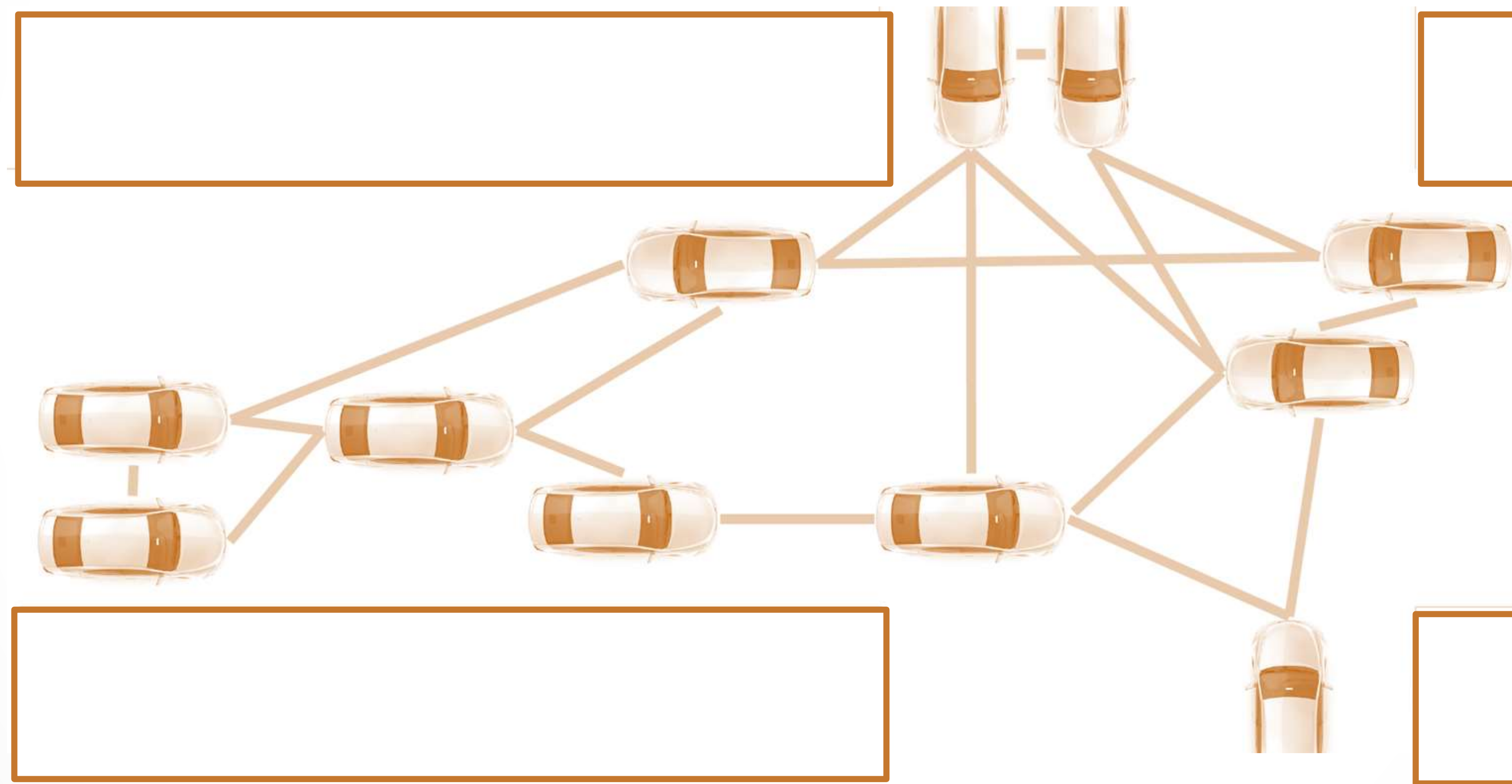
Interoperability Challenges - Do We?

- Do we have wireless communication solutions that work in all environments to connect vehicles - **EMI free – No interference?**



Interoperability Challenges - Do We?

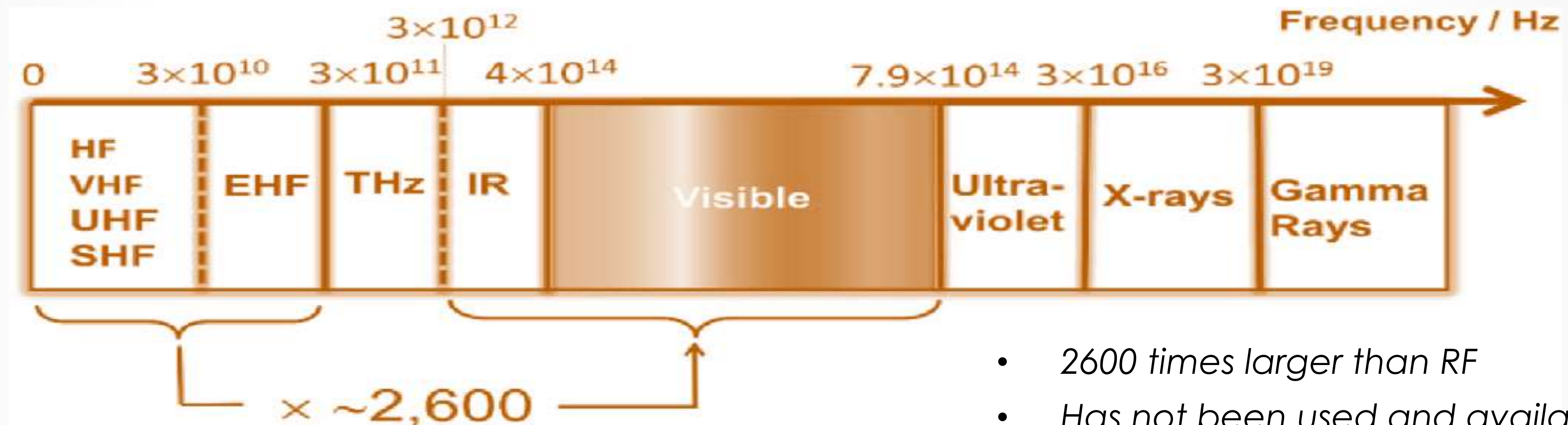
- Do we have **accurate positioning** system for vehicles?



Complimenting Wireless Communication Resources

Alternate/Complimenting Wireless Communication:

Light Spectrum



RF

0.3THz

IR and VL

780THz

- 2600 times larger than RF
- Has not been used and available
- No licensing is required, no regulation
- No EMI
- Safe for human body
- Dose not go through walls
- less energy consumption and "green"

Optical Wireless Communication-History

First LC

Voice over sunlight

Jun 3rd 1880

Graham Bell

Mors Lamp

1904

Naval

Fiber Optic

1970

1 PB/s

Infrared Communication

1978

1 Gb/s

Laser Communication

2001

400 Gb/s

Li-Fi

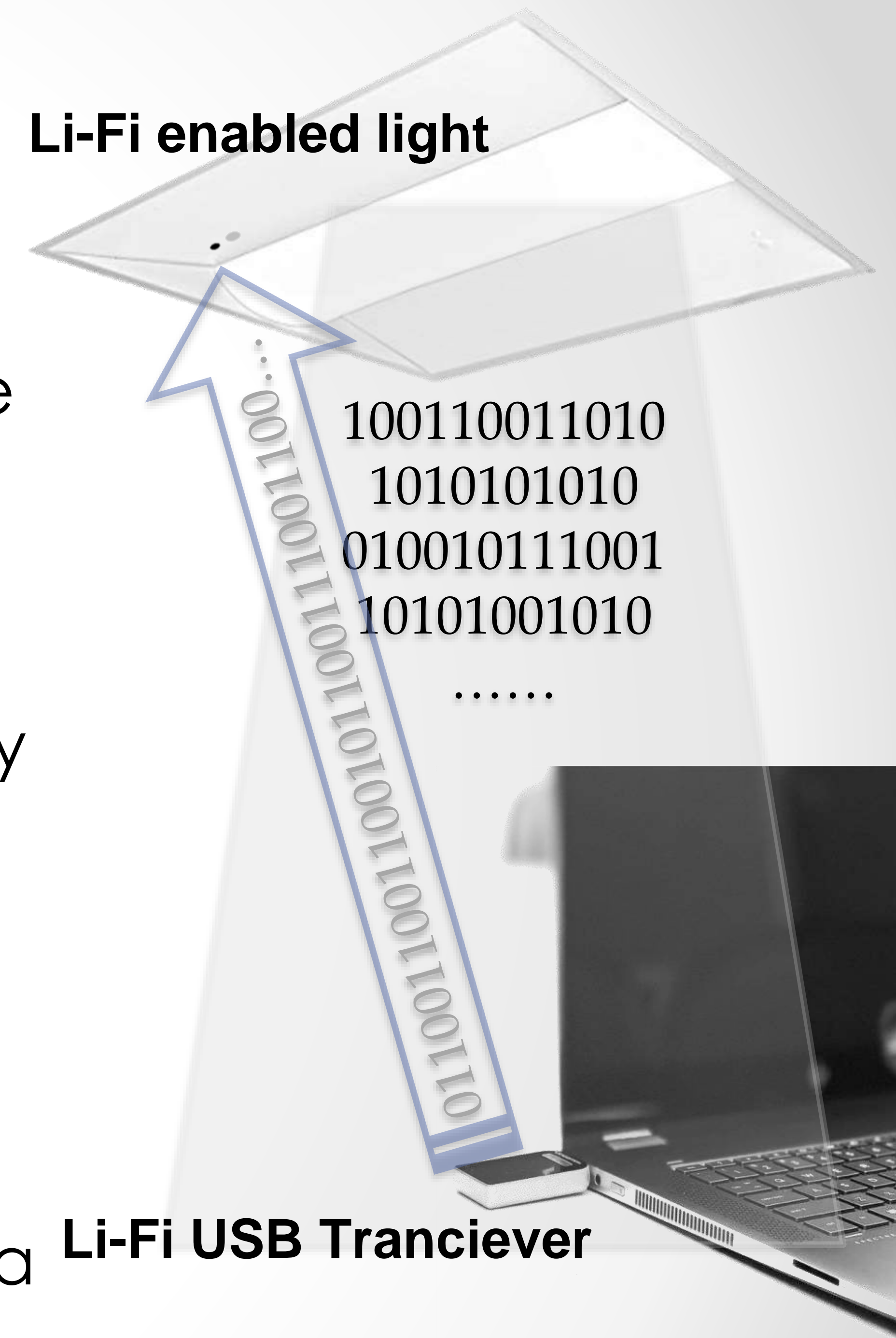
2003

224 Gb/s



What is Li-Fi?

- Li-Fi integrates the LED illumination system and communication system and transmit data through the light
- LED light will connect to the power source through a small Li-Fi modulator that controls the LED light intensity and that will form the digital signal communication with the Li-Fi transceiver.
- The mobile device or computer, through a photo diode receiver or camera, reads these digital light signals transmitted by the LED's and translate it to data



Bandwidth Issue

For example:

- **ISM RF** band in the 5.4 GHz region is about 500 MHz  **Wi-Fi**, which is becoming saturated
- **WiGig** uses the unlicensed spectrum between 57 GHz–66 GHz, a maximum bandwidth of 9 GHz.

In 5 years from now, 2024 (based on 60% CAGR)

The bandwidth demand will be

$$3,000 \times 500 \text{ MHz} = \mathbf{1.5 \text{ THz}}$$

- The entire RF spectrum is only 0.3 THz
- This means a **5 times shortfall** compared to the entire RF spectrum, and a **167 times shortfall** compared to the currently allocated bandwidth for WiGig.

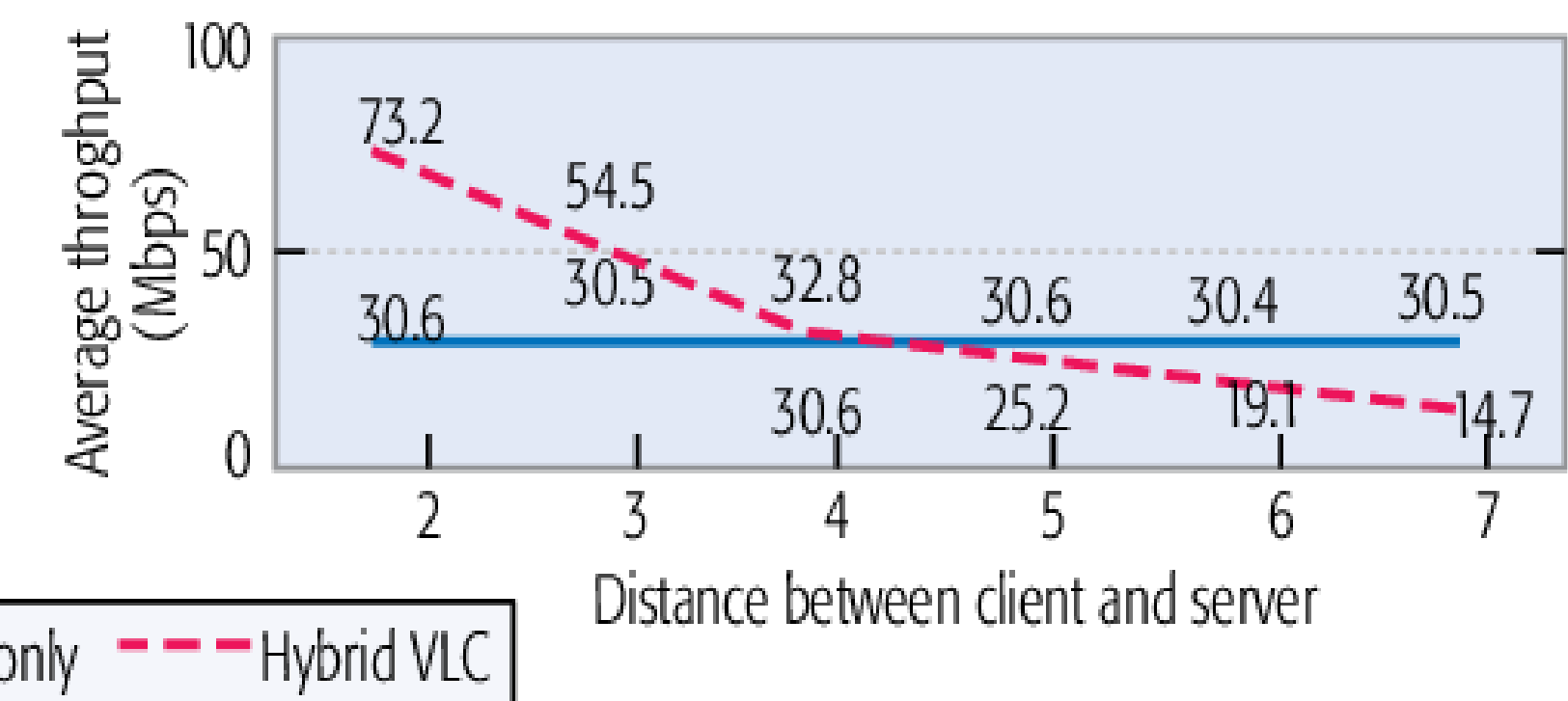
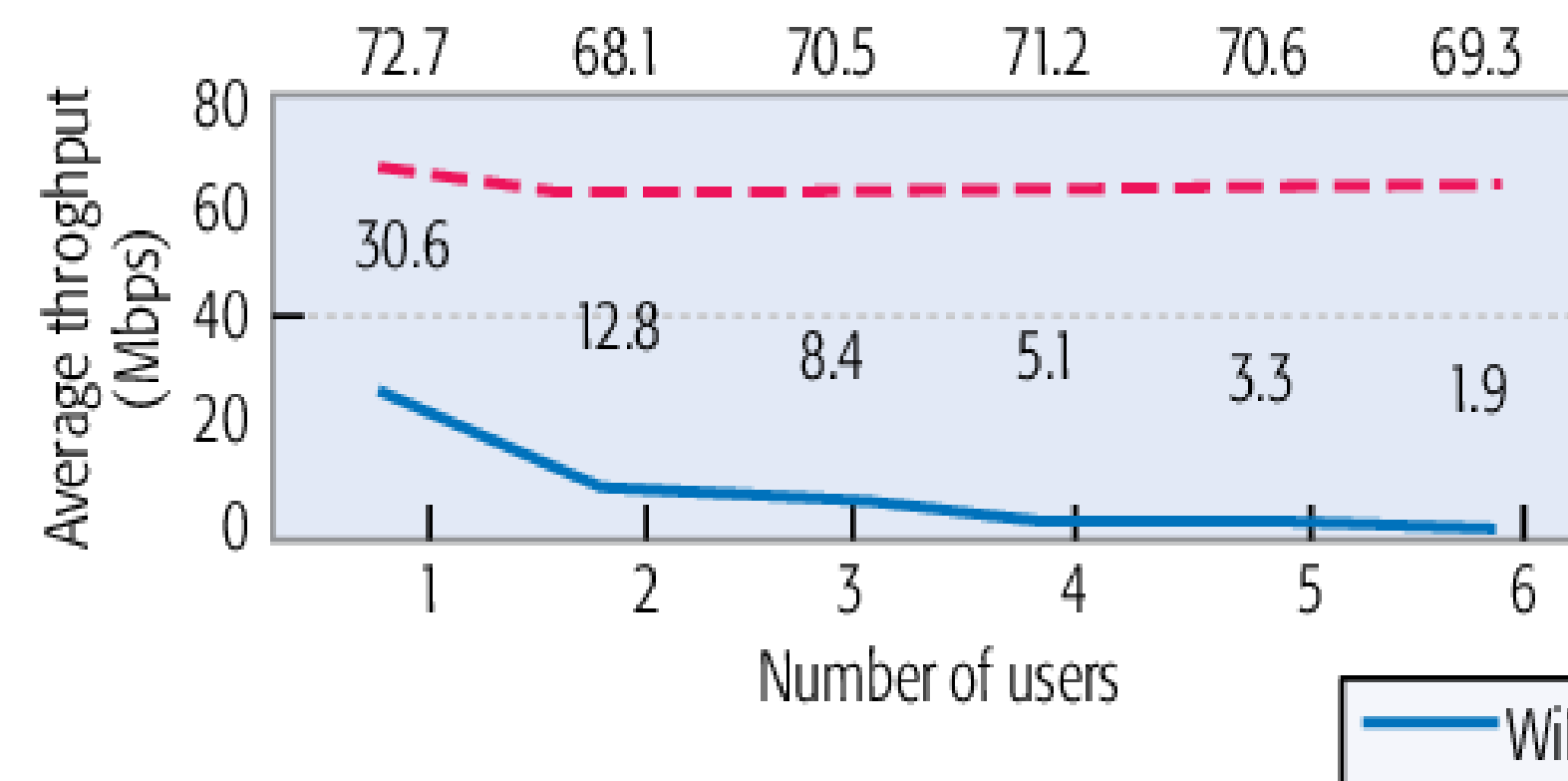
In comparison, the 1.5 THz of bandwidth is only 0.2% of the entire IR and visible light spectrum

Li-Fi Interoperability - Advantages

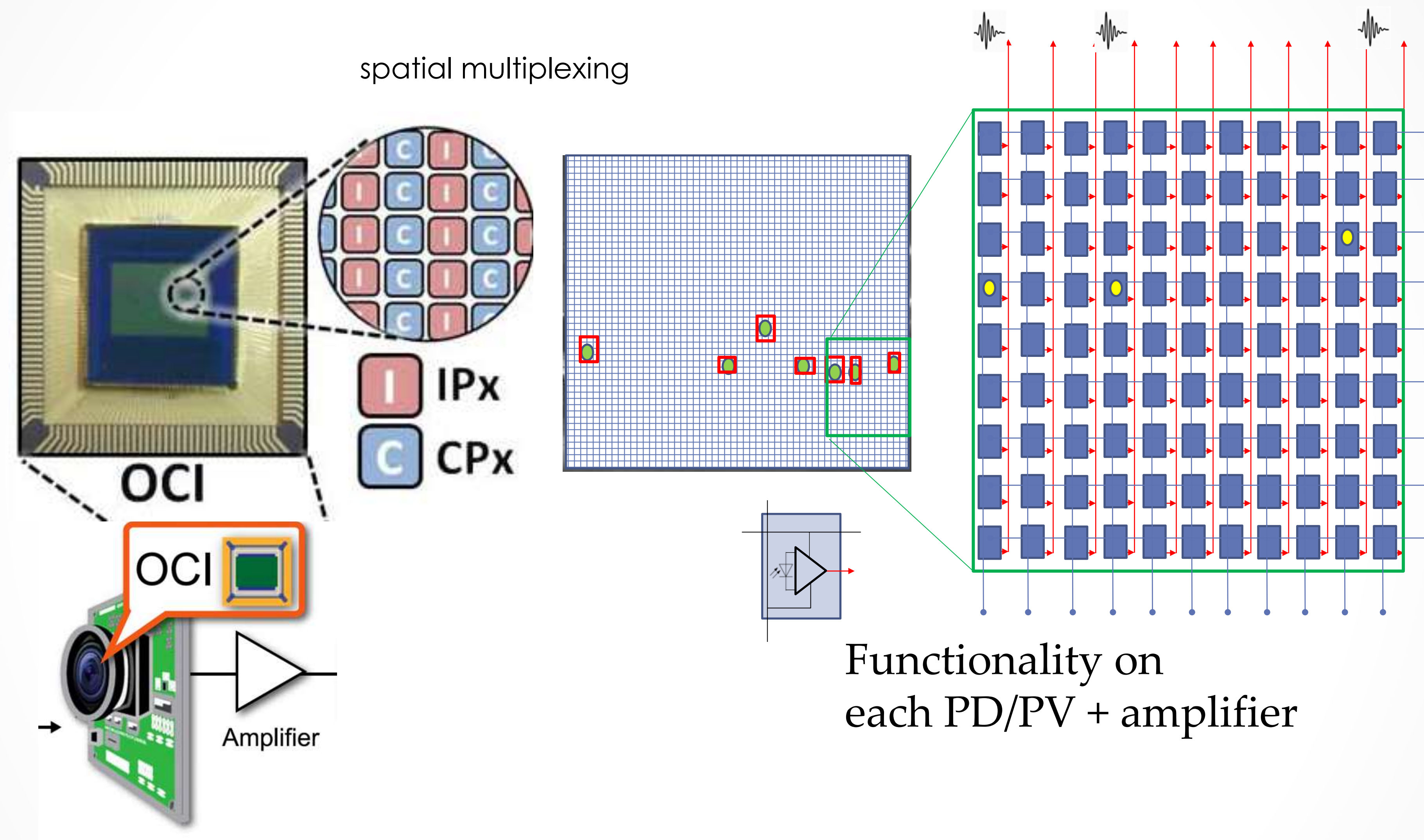
- Lights are everywhere : Cars, Streets and roads, buildings, ...
- Provides accurate relative positioning – combining with communication
- <1ms Latency , Less power consumption
- Works through interference of sunlight conditions (or other light sources)
- Lights can be dimmed to imperceptible level by humans (**eU-OFDM, ToV**)
- Lights flickers can not be seen by, or have effect on the human eye
- Bidirectional - provides uplink and downlink
- Not only a Line-of-Sight (LoS) technology, but also a non-LoS
- Mobility, hand-off, multi user, co-channeling interface
- Intelligent and balanced coexistence with RF communication (Wi-Fi, 5G,...) – **DDS**
- EMI-free, high speed, secure, low latency, license-free, not in use, “green”, safe, ...

Li-Fi Interoperability – Challenges

- What happens if the transceiver (receiver) is saturated?
- What happens when the transceiver (receiver) is shadowed or completely blocked?
- What if the distance between the light source and receiver is far ?
- What if the light source is not bright enough?
- Restricted to development of hardware (LED, PD, etc.)
- Backhaul networking based on light
- Adoption: Integrability into devices
- Standardizing vs productizing
-



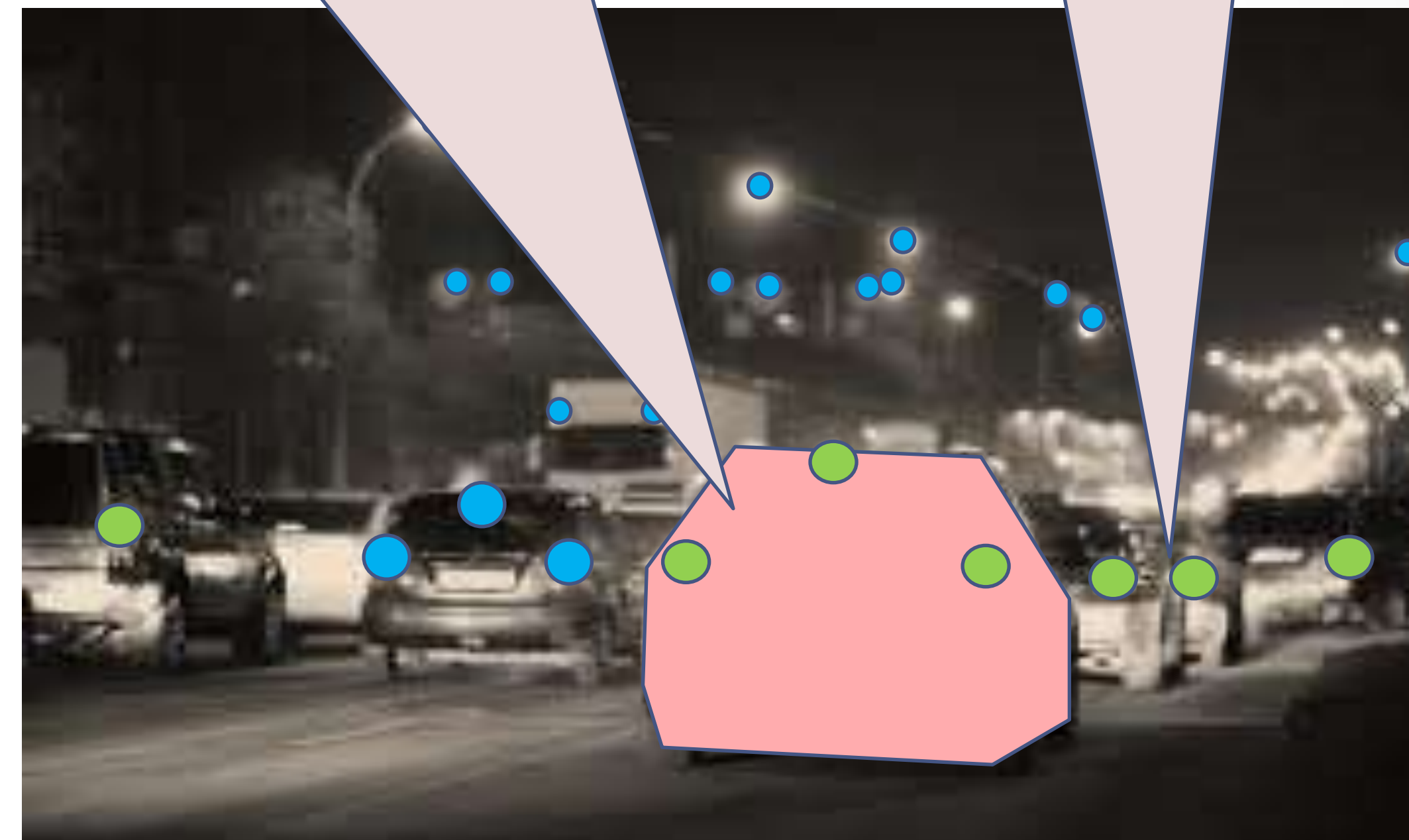
Li-Fi: Hybrid Technology



Approach

Lights from a vehicle
It is possible to determine the direction with several images

Lights from the same vehicle
It is possible to determine the distance with one single image

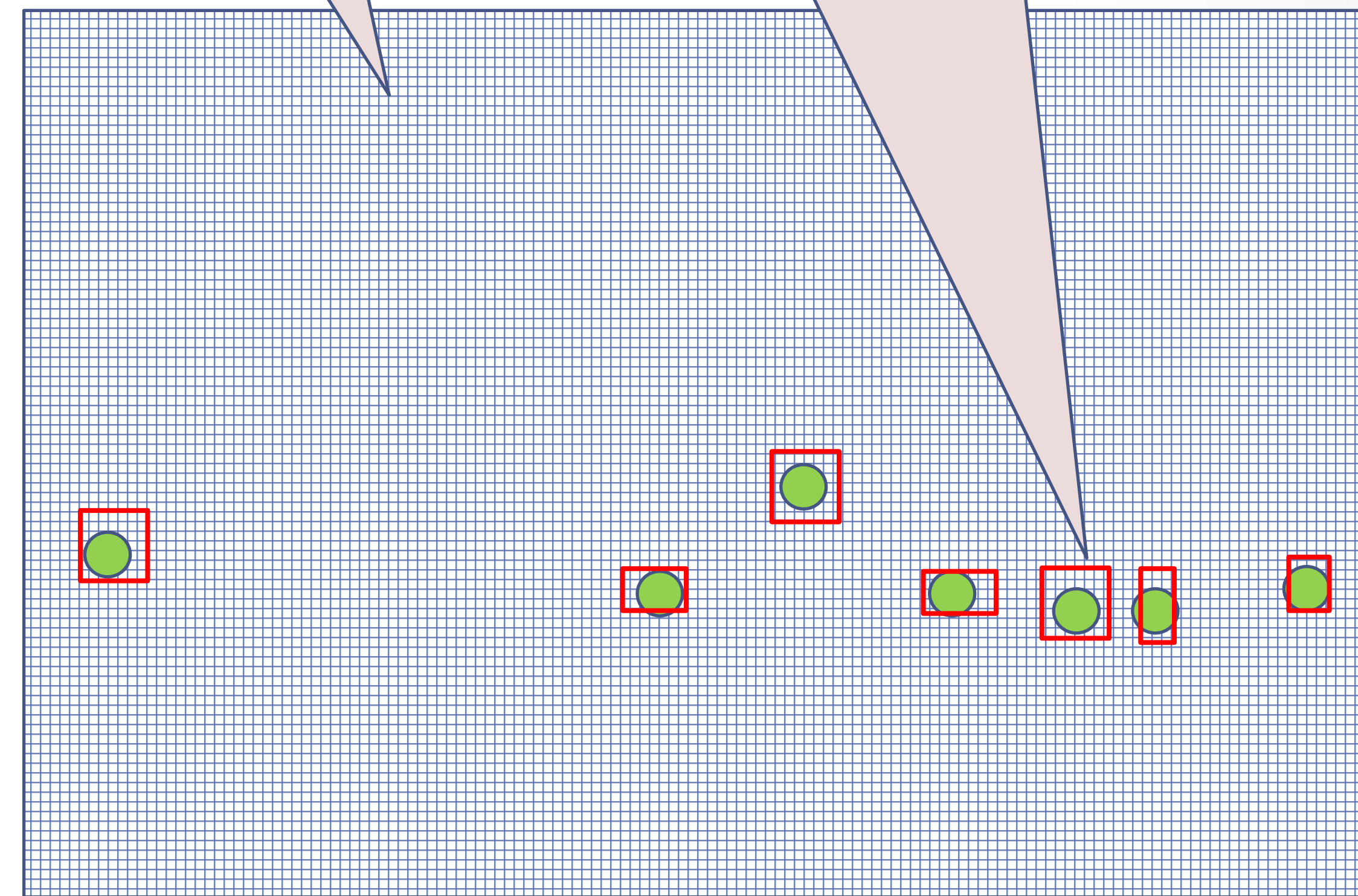


- Light with no data
- Light with data

Approach

Array of
photodiodes

Set of photodiodes related with the
decoding of a light



● Light with data

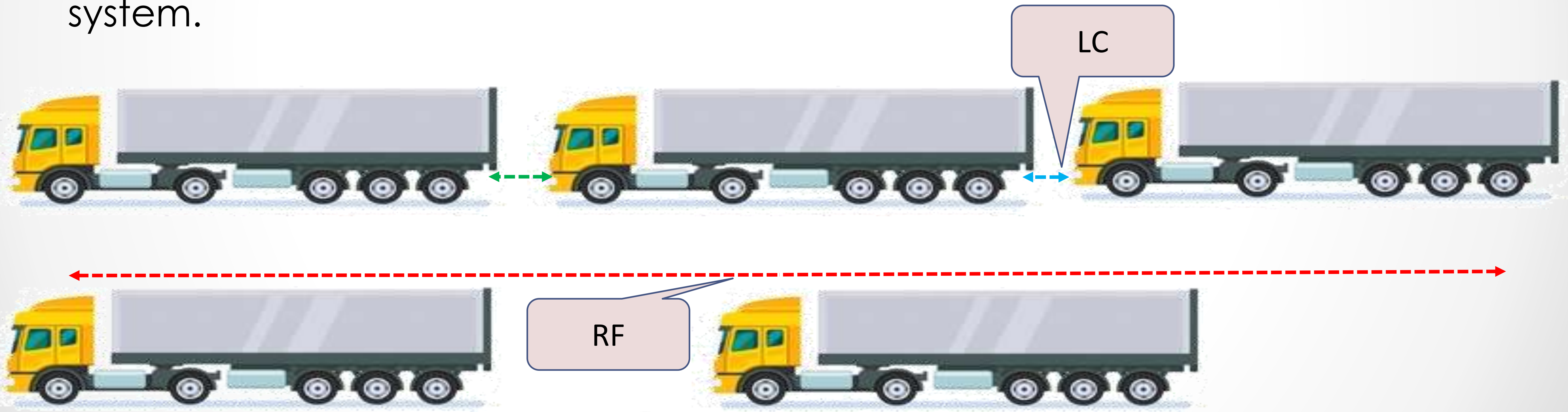
5G and Li-Fi

- Usage of Li-Fi

- o Can combine communication with location

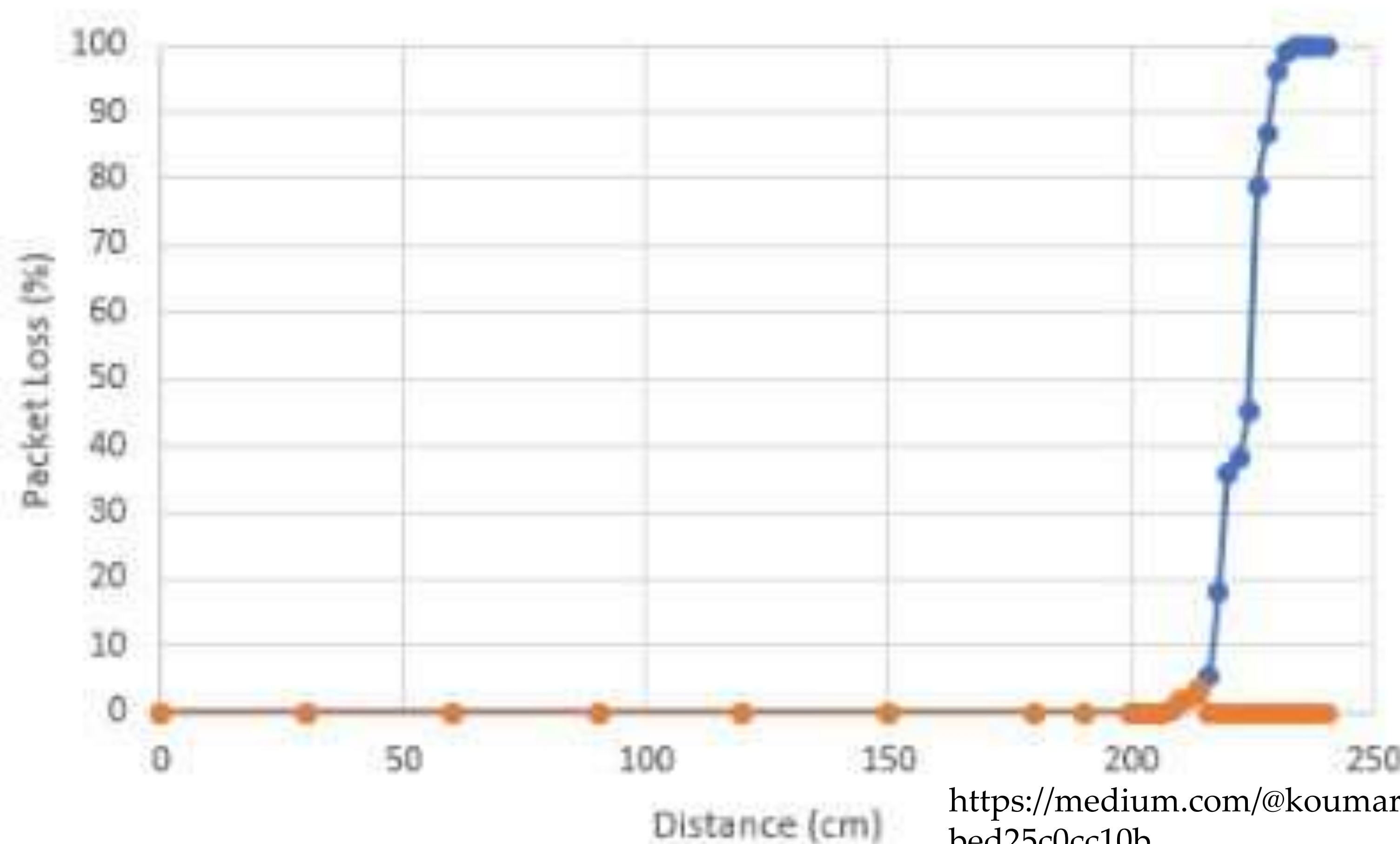


- o When combined with radiofrequency messages results in a very flexible system.



5G and Li-Fi SDN

- Enabling seamless transfer from radio frequency to Li-Fi via SDN
- Leverage Li-Fi until packet loss is detected, and switch to radio frequency



<https://medium.com/@koumaras/sdn-based-wifi-vlc-coupled-5g-system-bed25c0cc10b>

V2X – IIC Automotive Security Testbed

LHP, AASA

IIC, Aicas

NI Week 2018

IoT SWC 2018

Computex 2019

Hannover Messe 2019

IoT World 2019

NI Week 2019

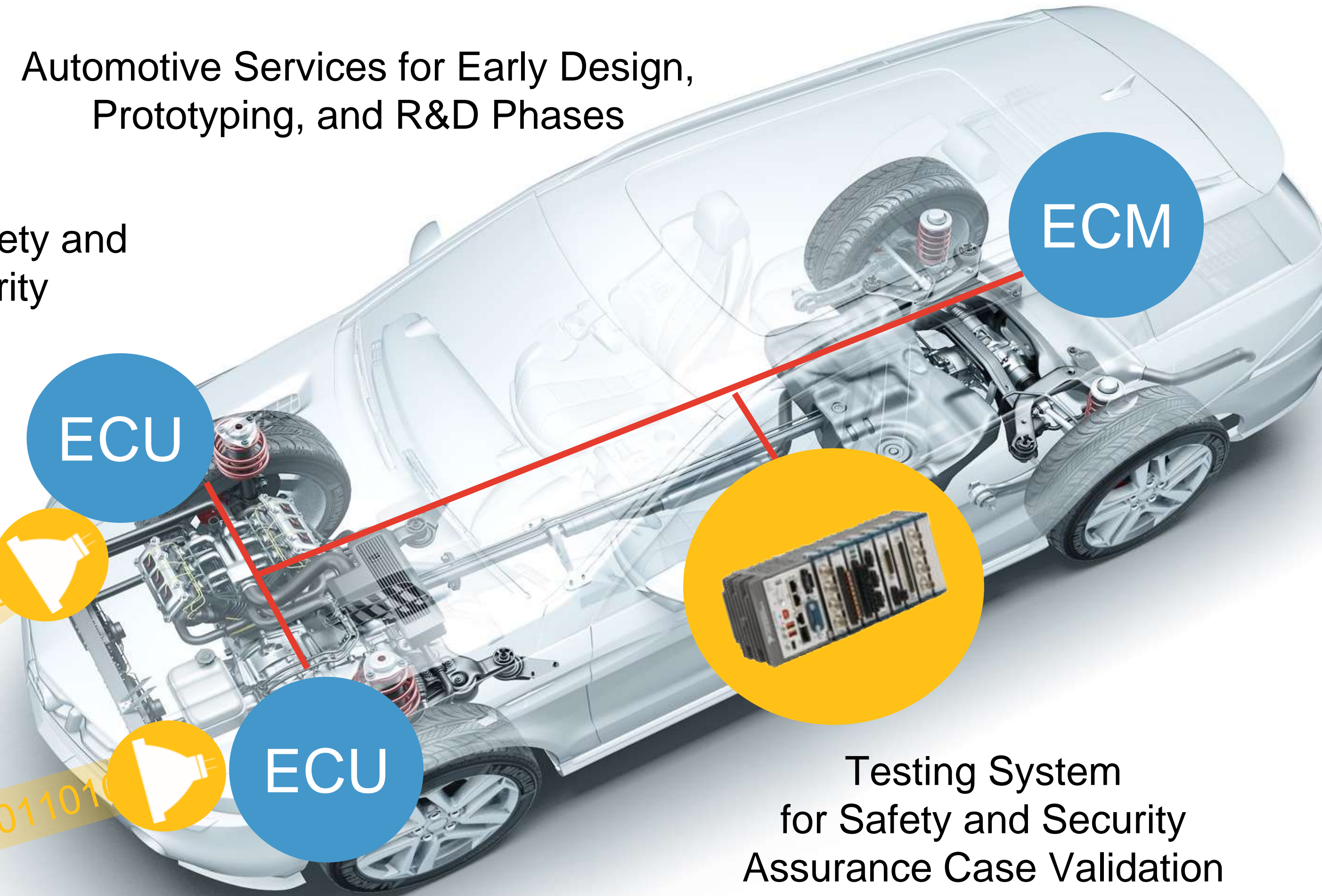
IoT SWC 2019

Intra-vehicle communications network
security testing on encrypted CAN Bus

Automotive Services for Early Design,
Prototyping, and R&D Phases

Automotive Safety and
Cybersecurity

Augmented Reality
Visualization using VLC by
AASA – 01LightComm



Testing System
for Safety and Security
Assurance Case Validation



Cloud-enabled validation
and certification capabilities

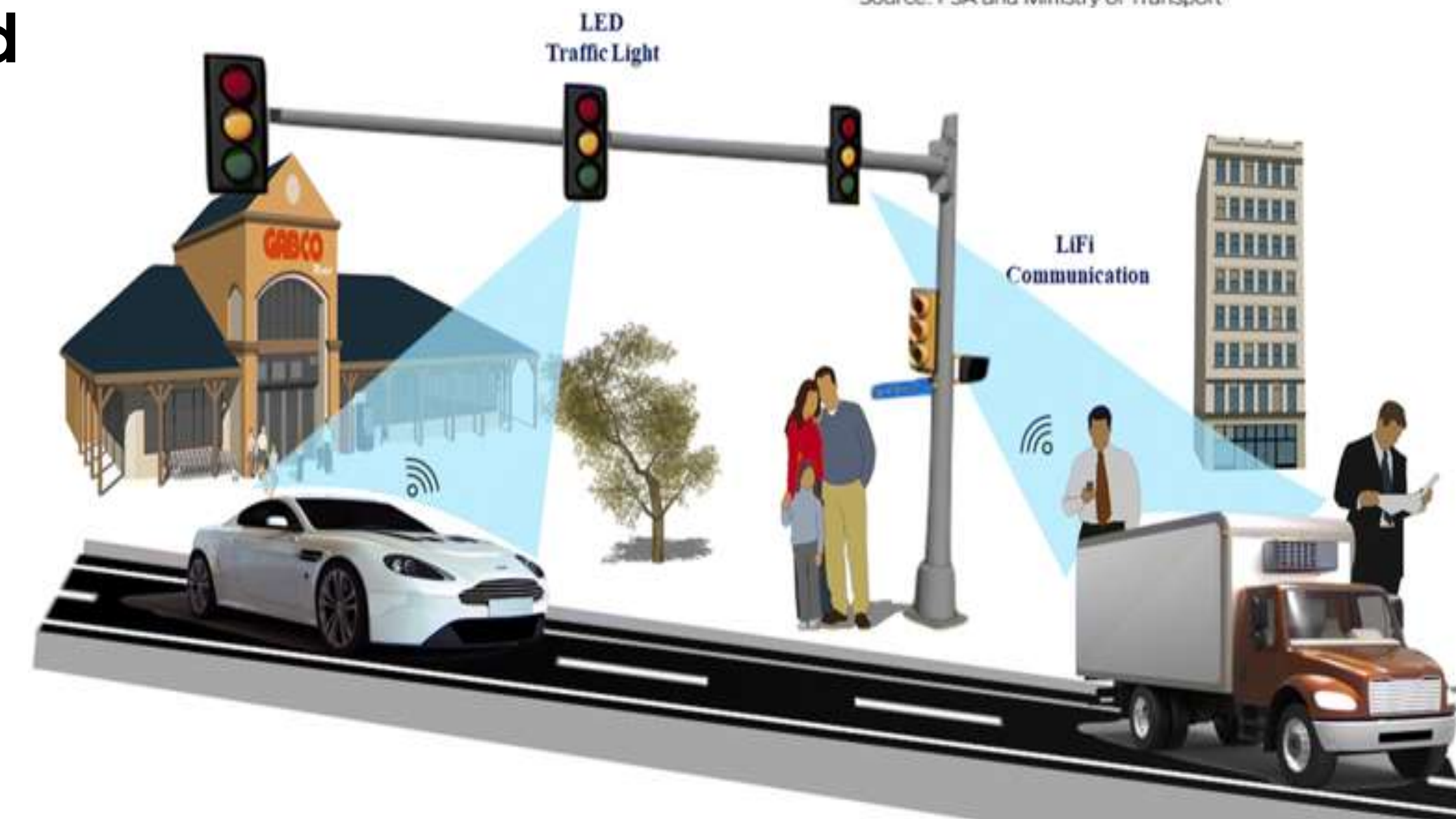
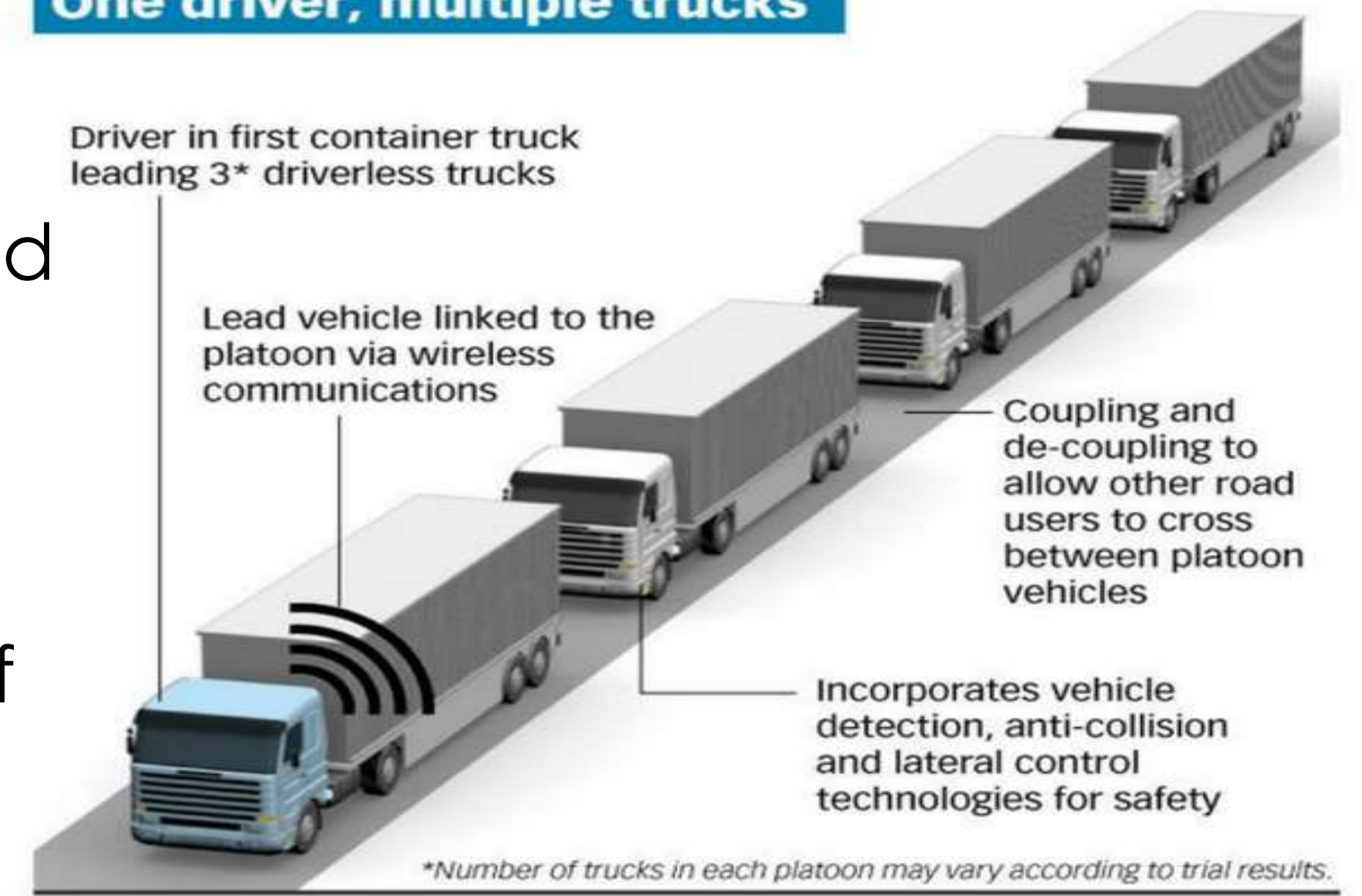


control, configuration, and
measurement

Autonomous Connected Vehicle - Platooning

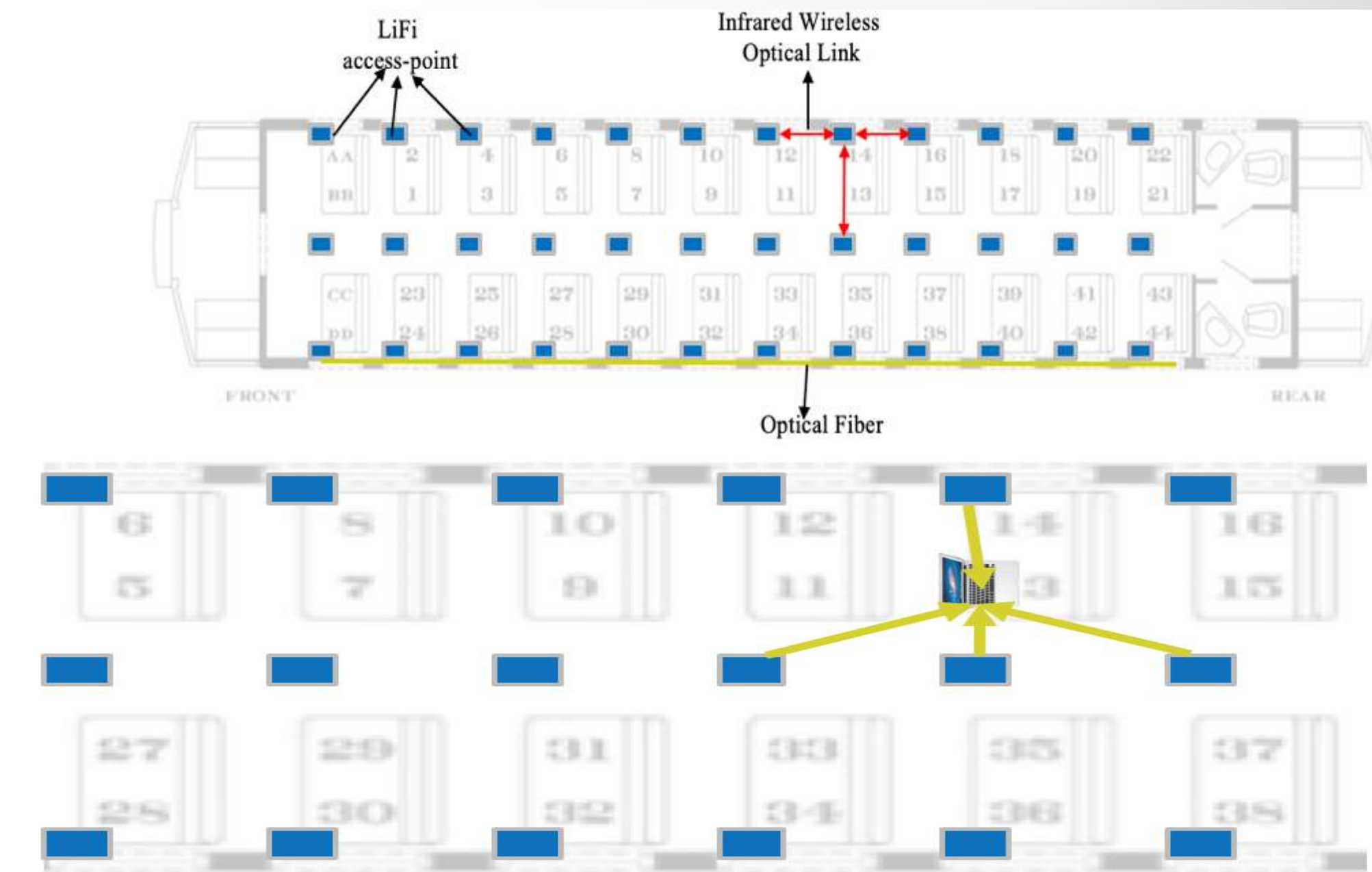
- V2X communication using balanced channeling between 5G and Li-Fi
- Using hybrid receiver technology of PC matrix and OC
- Balanced connectivity between different channels and in case of droppage – reliable connectivity : DDS
- The goal is to achieve real adoption of **Autonomous Connected Vehicles** concept and **Platooning** to achieve better, safer, smoother and smarter transportation
- Collaboration between: Autonomous Vehicle developer, Li-Fi technology developer, 5G technology provider

One driver, multiple trucks



Li-Fi - Hyperloop

- Each Li-Fi access-point uses an imaging sensor to monitor the line-of-sight (LOS) path to the users it serves
- In case of loosing LOS from a user to a LiFi AP, the system uses another LiFi AP that has LOS
- If there is no LiFi AP with LOS, the system will use the most efficient non-LOS path to transfer data to
- Laser is used for C2C and C2T
- The distance between two capsules is larger than 10 miles (~25 miles at the maximum speed)
- For a minimum 25 Mb/s bandwidth per user, the uplink and downlink to a capsule should be at least 1 Gb/s
- No EMI interference and jamming



Underwater Optical Wireless Communication

- Navigation signal transmission to underwater robots from an onshore / offshore base (i.e. from a ship)
- Transmission rate: ≥ 100 Mbit/s (Ultimate goal: \geq several hundred Mbps)
- Transmission distance: ≥ 100 m
- Embeddable system device size and weight in underwater robots; its size is less than 1x1x1 m
- UOWCT is installed to robots working at an offshore wind farm built on Japan's Pacific coast
- Water depth: \leq approx. 200 m
- Underwater visibility: approx. 1 m



Autonomous Lift Truck/AGV/Drone/Robot



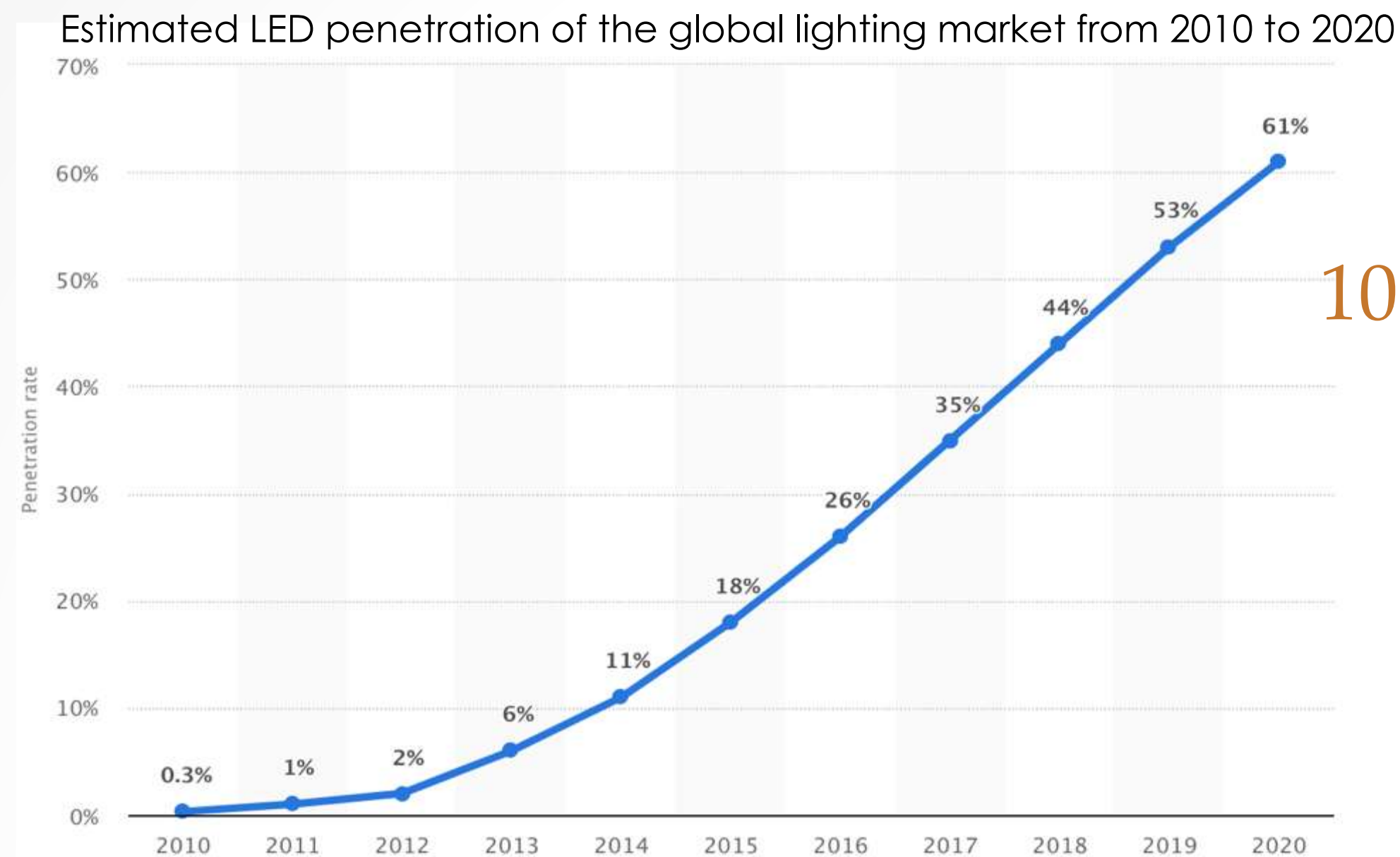
- Achieve **Smart Factory** concept
- Cooperation with a Lift Truck manufacturer and autonomous technology provider
- Provides real time 3D indoor positioning/navigation with +/- 2cm accuracy and 3 degree orientation
- OCC based, low rate data communication
- Prototype has been developed and ready with real time navigation for VLC enabled AGV concept
- Forming a technical team to develop a pilot
- Based on the Pilot achievements, phase to phase adoption of the smart factory will be planned



Major Business Impact

Lighting

Longevity of LEDs



100% - 2025
2030

Smart Lighting
Lighting Control
Human centric
Need more product, services,...

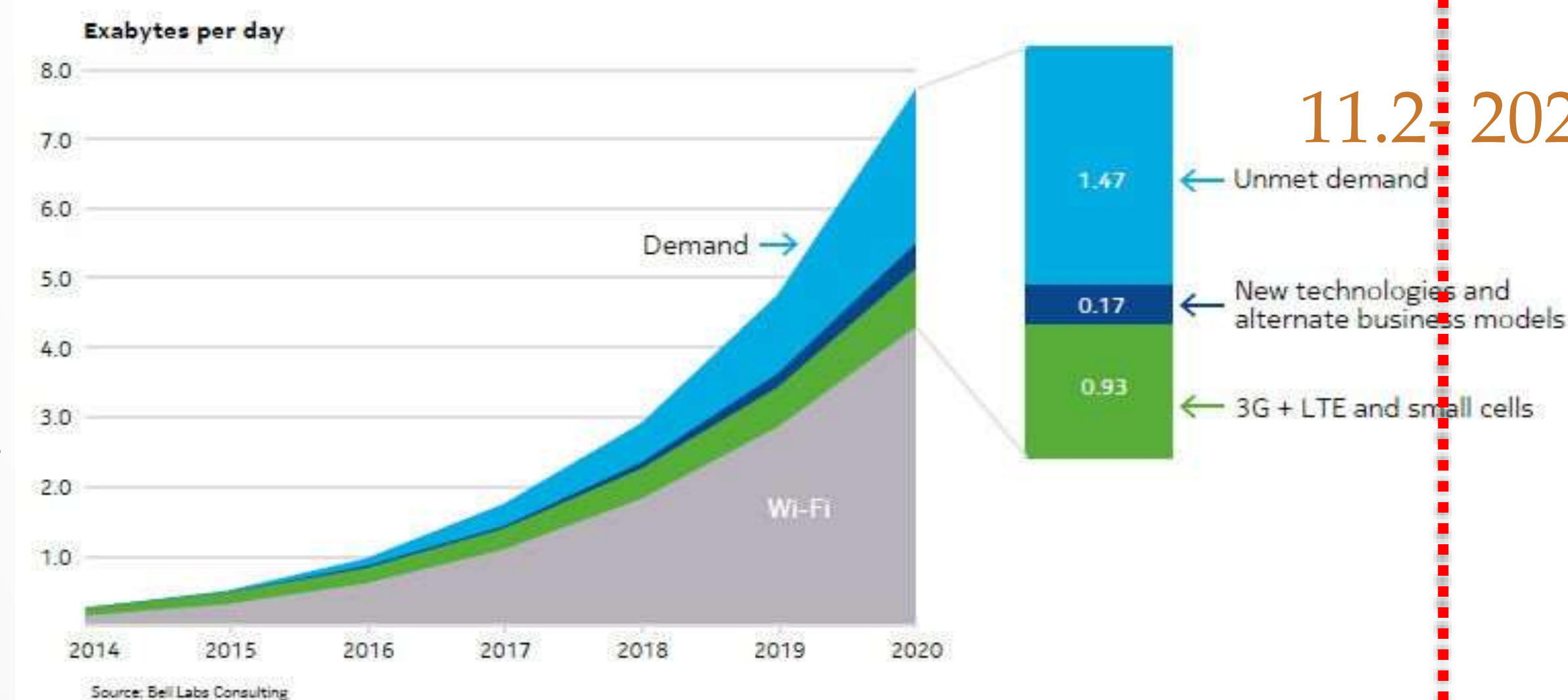
IoT Enabled Lighting
Li-Fi Enabled Lighting - LEL



Li-Fi Connectivity – Li-Fi/Wi-Fi Router

Wireless communication

Wireless demand



Historical and predicted demand/supply for wireless data

11.2 - 2025

Need more resources
IoT/IIoT
M2M
Cloud
Mobile devices



AASA Inc - 01LightComm
Lifi@aasainc.com
+1-703-444-6170

Business Impact

- In the future, Li-Fi / 5G drivers will be combined with LED drivers and provide OS for Lighting/Communication (Light Chip)

Impact on the lighting electronics industry such as light driver manufacturer

- In the future Li-Fi will have (Power over Ethernet) PoE in place (Green field : 50% reduction on power cable usage and 25% on service work)

Impact on the cabling manufacturer and service companies

- Data and communication technologies need to be insured

Impact on the insurance companies

- Privacy and Security of the the Data we are transferring is highly important

Impact on regulations, legislations (governments) and insurance companies

THANK YOU!



QUESTIONS

Looking forward to meet you at “Testbed Area”, Cyber Security V2X demo

Sven Schrecker

VP and Chief Architect, Cyber Security
LHP Engineering Solutions

Farid Bichareh

Chief Technology Officer
IIC Smart Factory Co-Chair

Fbichareh@aasainc.com

Tweeter: @faridMBi

Instagram : @faridMB



AASA Inc - 01LightComm
Lifi@aasainc.com
+1-703-444-6170

5G Multi-layer Architecture

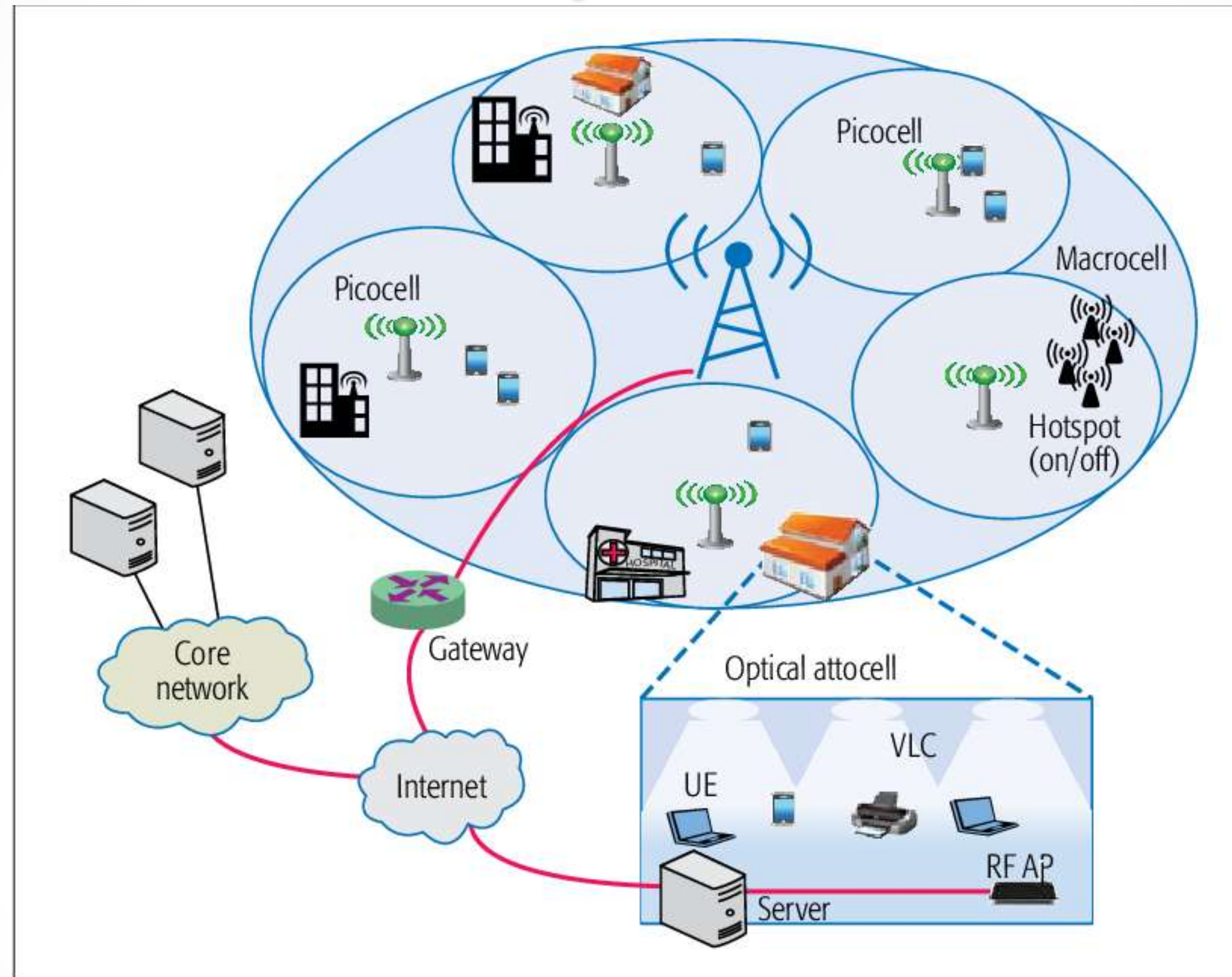


FIGURE 2. A multi-layer 5G cellular architecture.