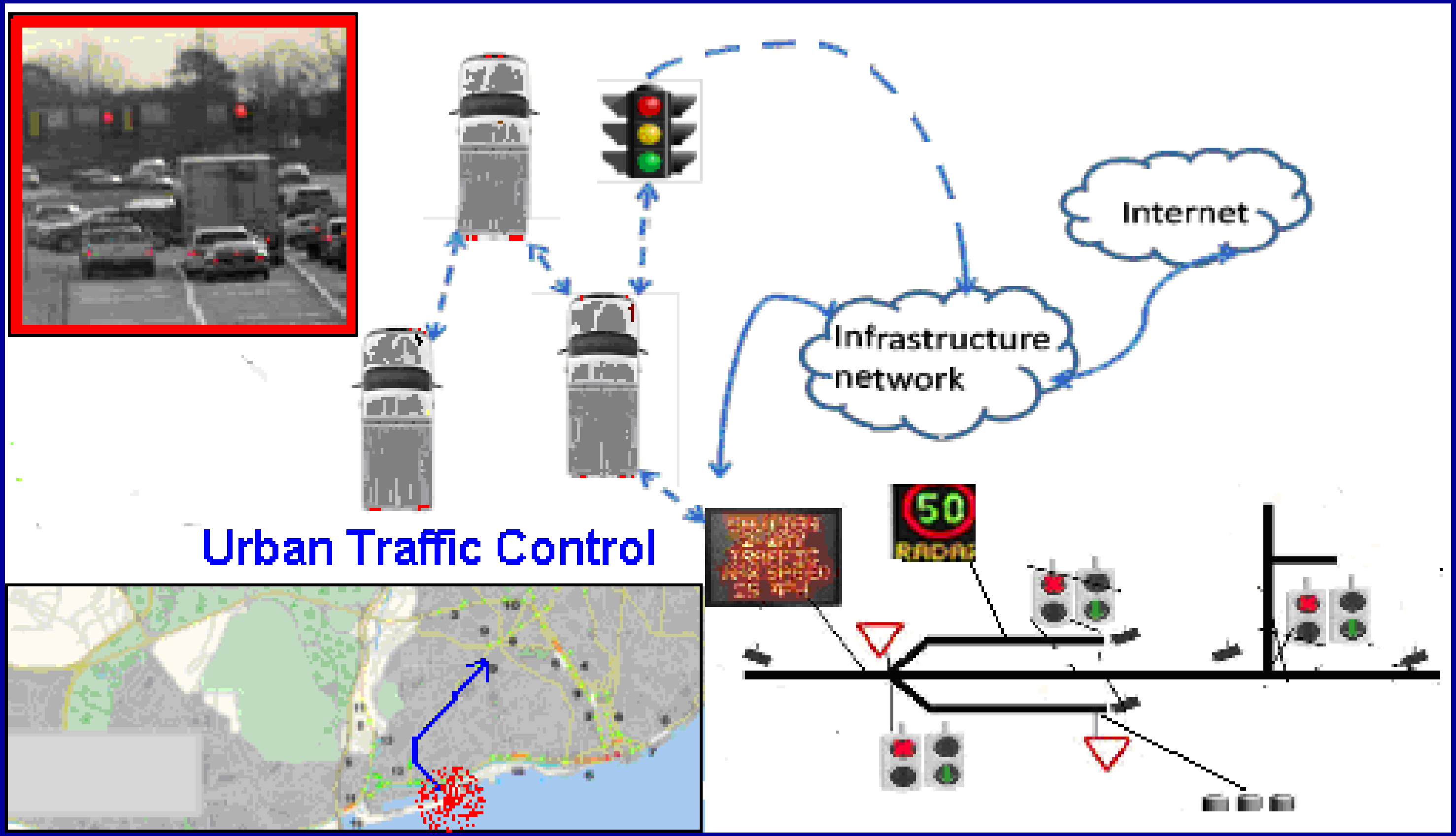
IV Work Area:

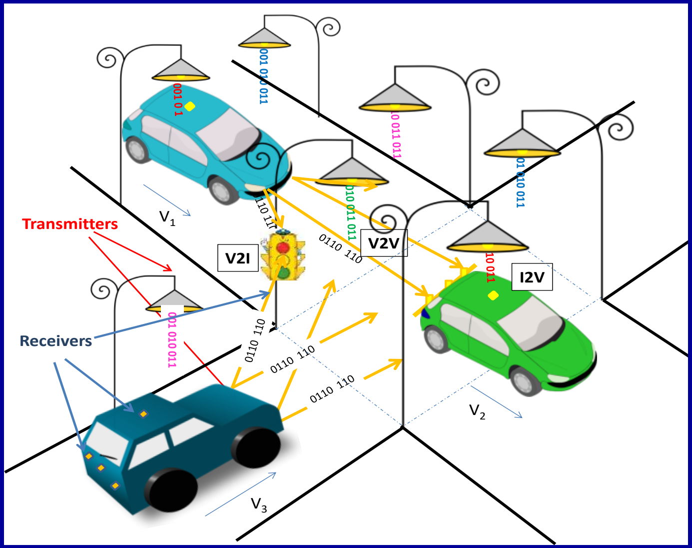
"CONNECTED CARS: ROAD TO VEHICLE COMMUNICATION THROUGH VISIBLE LIGHT"



An illustration of traffic control system of tomorrow

Motivation and Objectives

I2V, V2V, V2I optoelectronic WDM cooperative vehicular system enables direct communication between vehicles, roadside infrastructure and traffic lights control



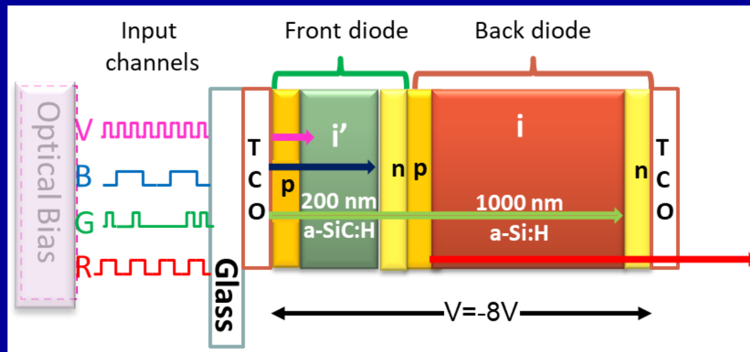
"Connected vehicles" innovative concept

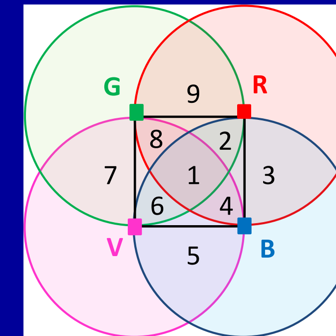
Paradigm shift

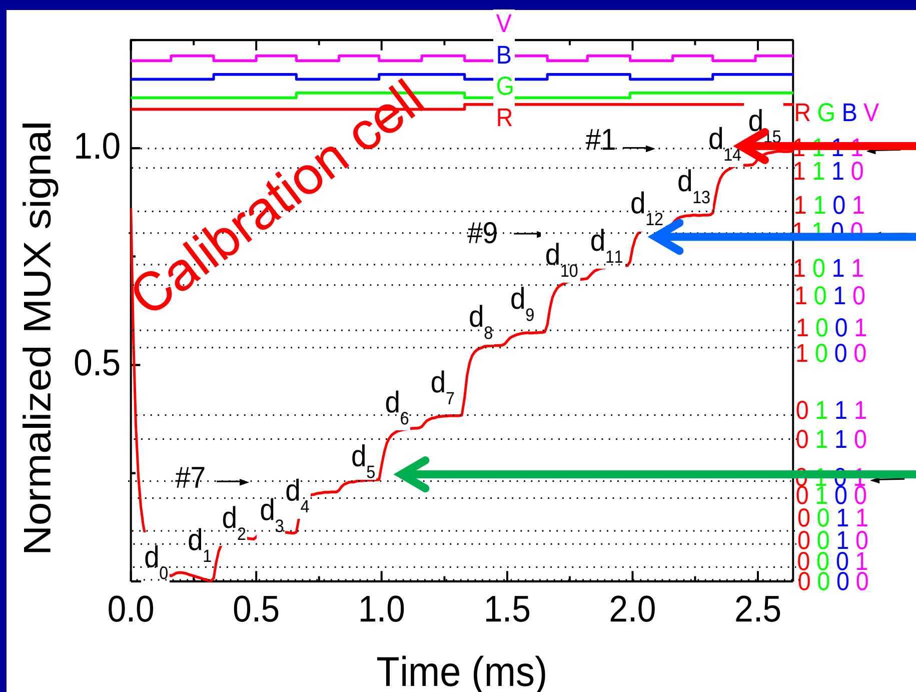
Outline

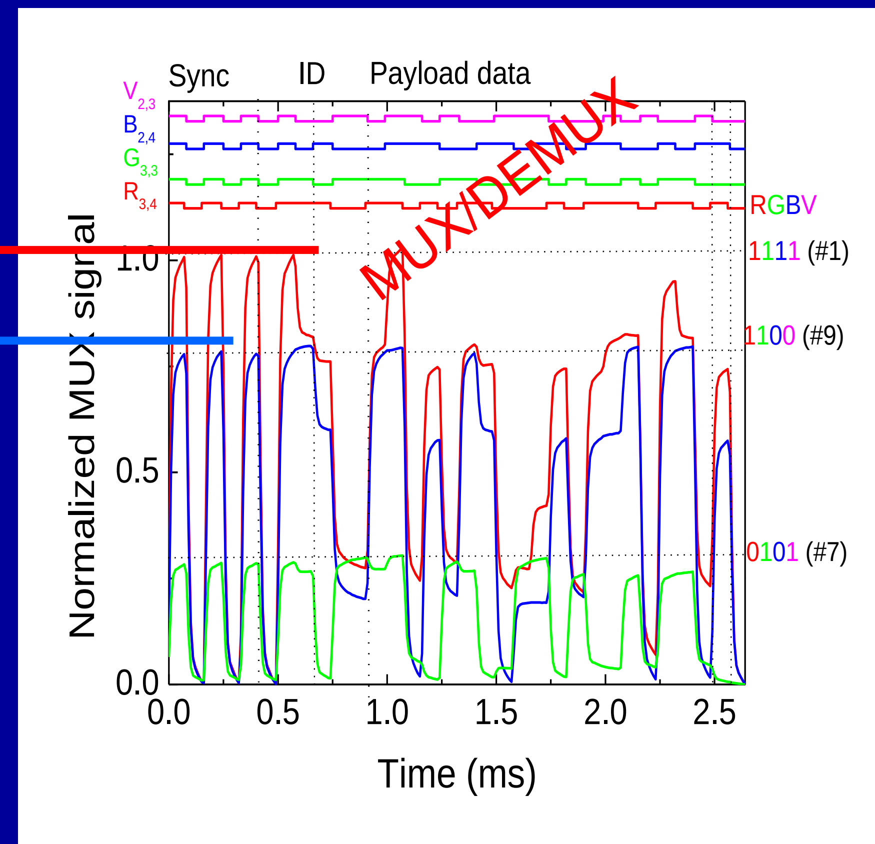
- **Connected vehicles model**
  Transmitters and Receivers
- **I2V, V2V and V2I communications**
- **Cooperative VLC System**
  Evaluation and proof of concept.
- **Conclusions and future trends.**

State of art: MUX/DEMUX techniques





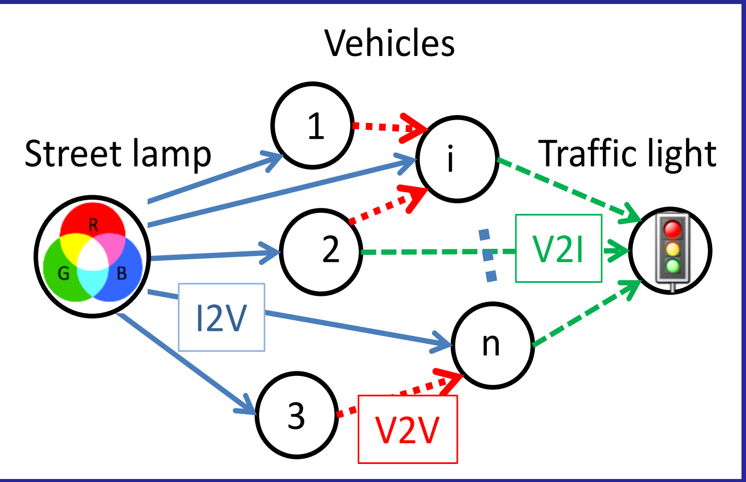


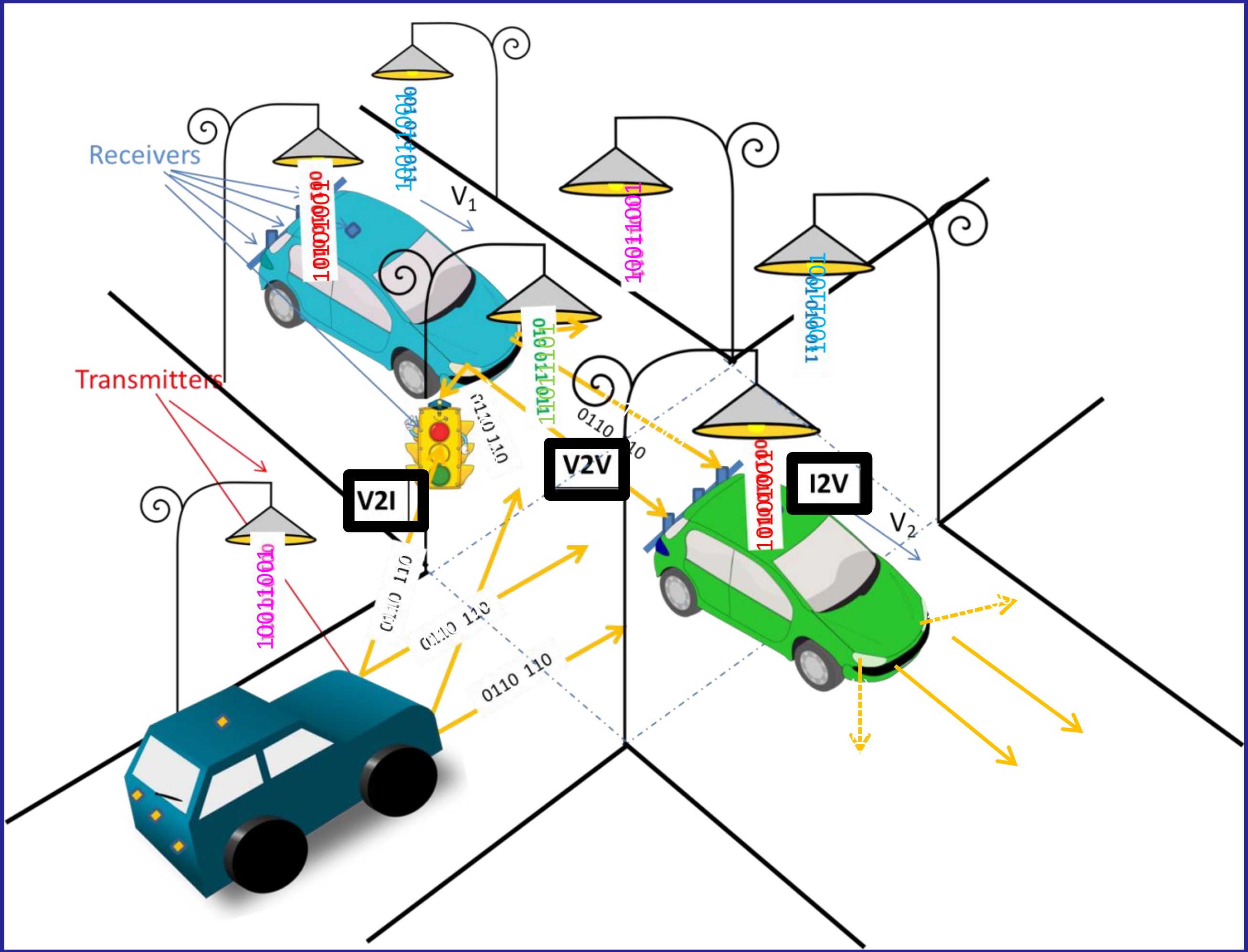


The output presents 2^4 ordered levels each one related with ***R******G******B******V*** bit sequences

Connected Vehicles Model

Generic model for cooperative vehicular communications





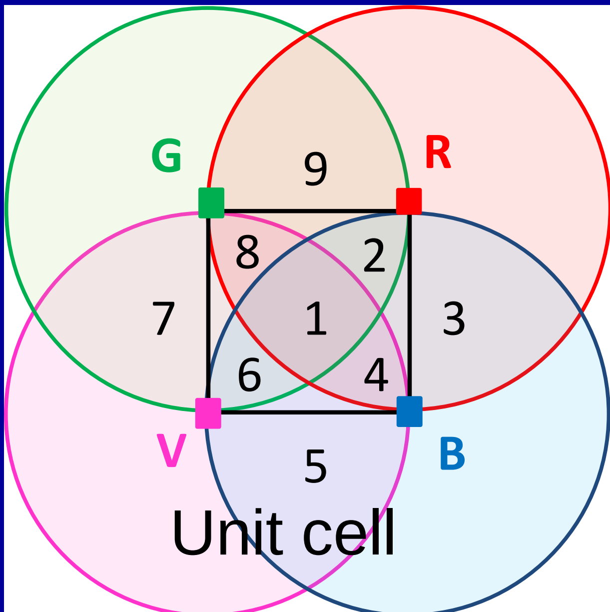
Until recently…

- ✓ (V2V) communication was limited to brake lights, turn signals;
- ✓ (V2I) was restricted to point detection (loop detectors).

Illustration of the proposed I2V2V2I communication scenario:

- ✓ Connected vehicles communication in a crossroad.

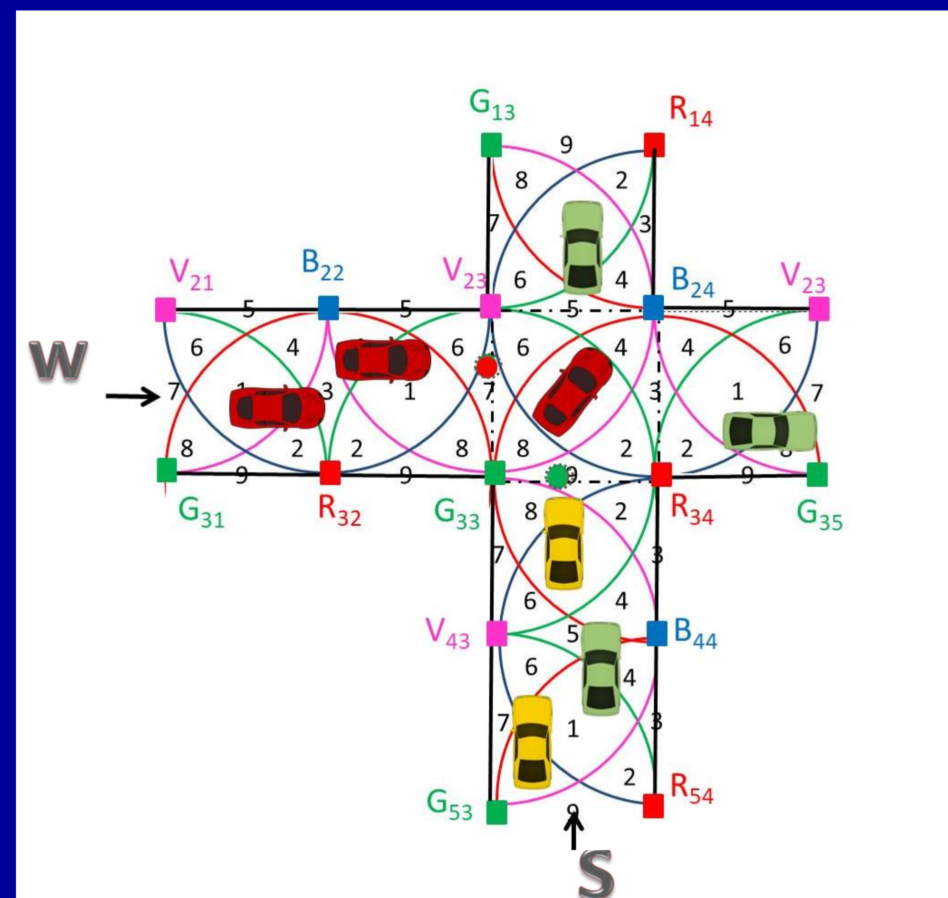
Lighting plan



Four modulated LEDs (RGBV) located at the corners of a **square grid**.

footprint regions	#1	#2	#3	#4	#5	#6	#7	#8	#9
Overlap	RGBV	RGB	RB	RBV	BV	GBV	GV	RGV	RG

Generated joint footprints

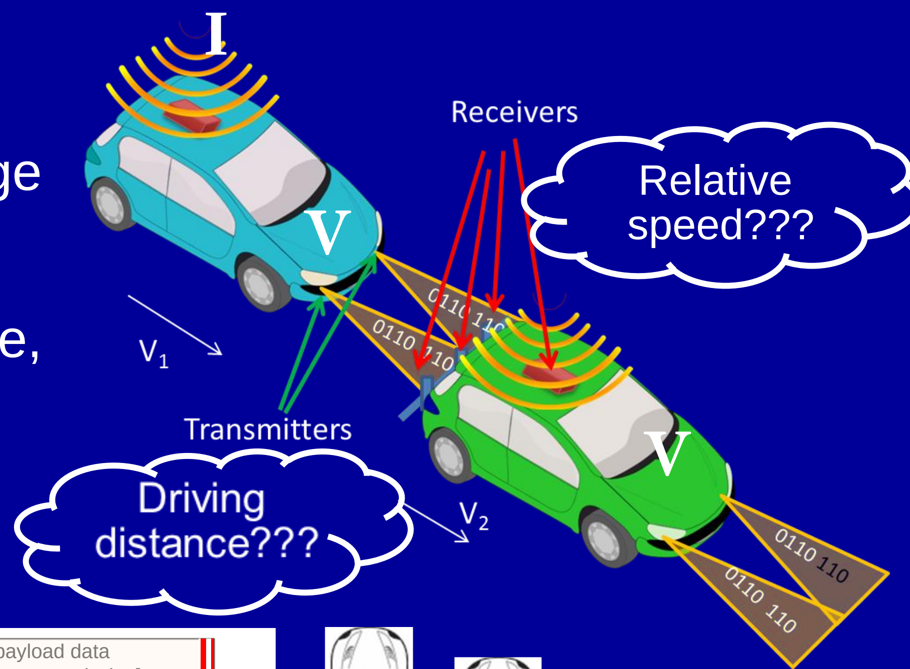


- ✓ **Promising benefits expected from safety and mobility improvements at the road network**

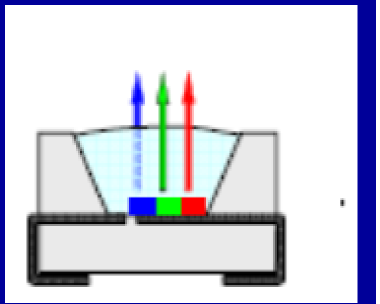
I2V2V system design

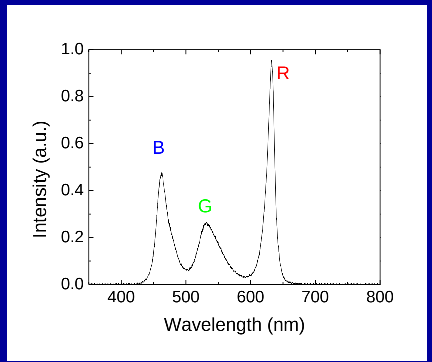
I2V : the street lamp (transmitter) sends a message to the SiC receiver, located at the rooftop.

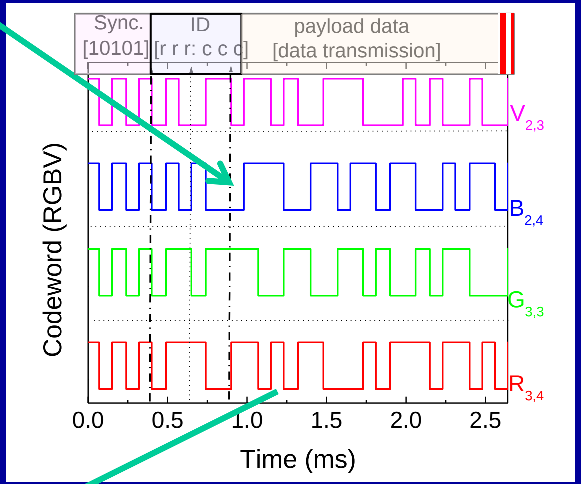
V2V: the information is resent to a leader vehicle, using the headlights as transmitters, .

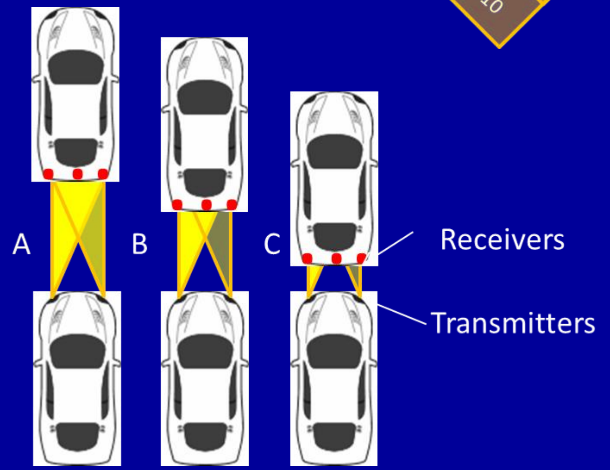


Transmitter RGB-LED

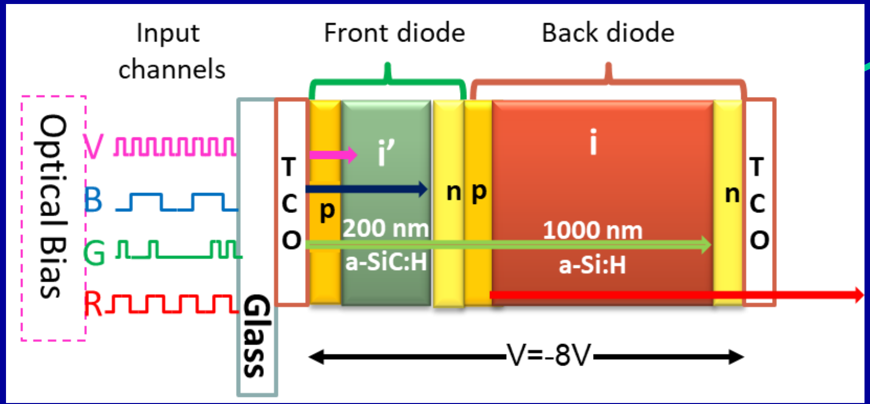








Receiver SiC pinpin



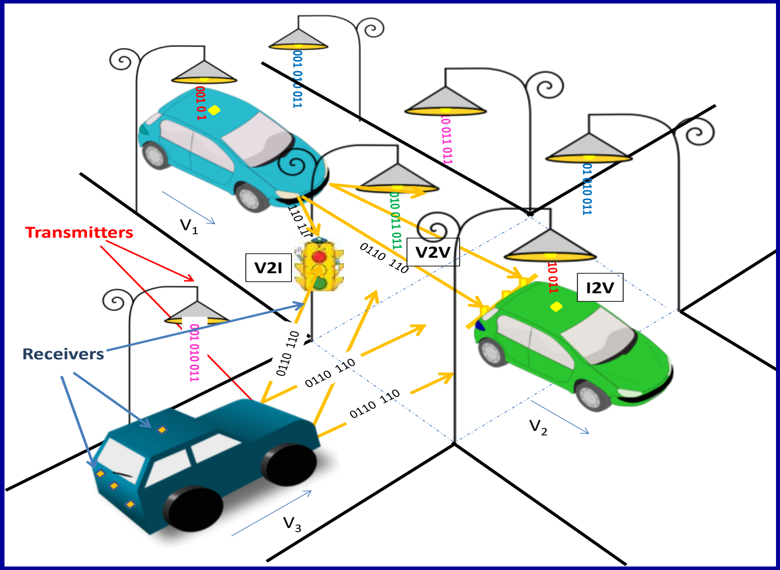
Representation of the I2V2V communication (working principle for the prototype)

The structure of the frame is a classical one

The message begins with 5 synchronization bits
The rest of the frame consists of 6 ID´s bits, data bits and stop bit.

Cooperative VLC System Evaluation

Generalized view of the architecture



Operational procedure:

Each vehicle receives two different messages:

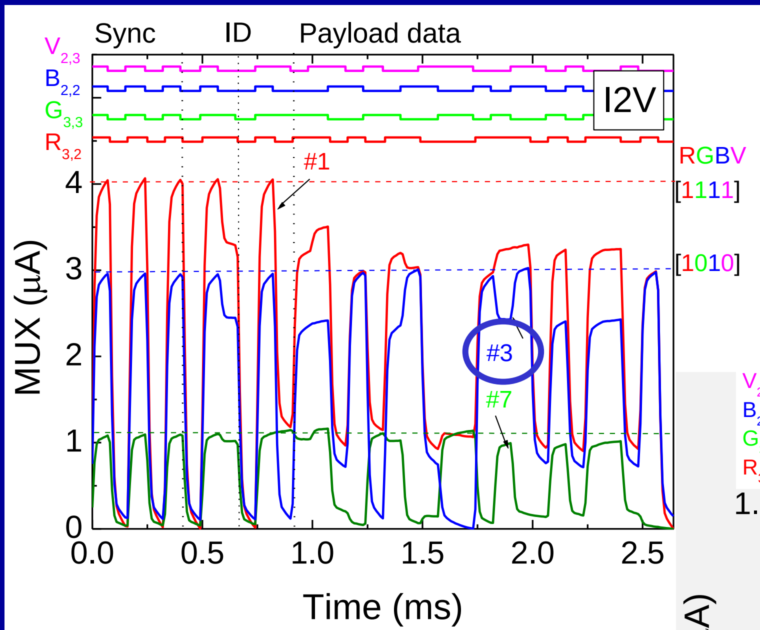
- **I2V** and **V2V** coming from the streetlight and from the follow vehicle;
- Compare them and infers the **drive distance** and the **relative speed**.
- Send the information to a next car (**V2V2V**) or to an infrastructure (**V2V2I**).

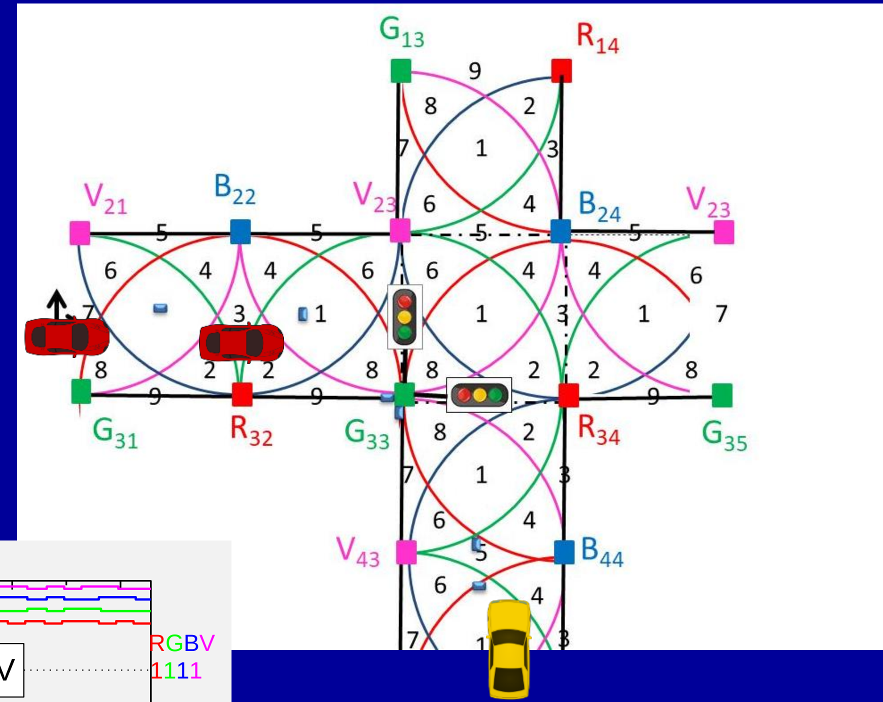
Three different scenarios:

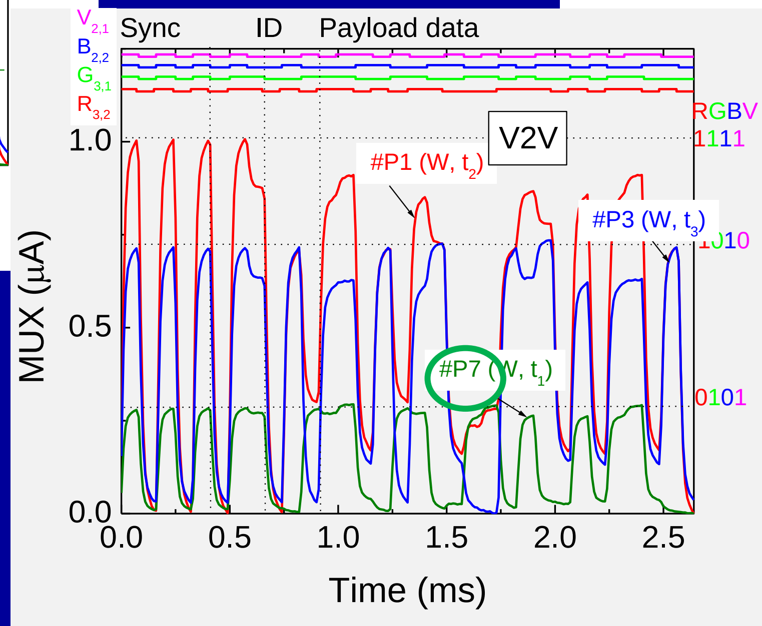
Scenario 1 I 2 V 2 V 2 I
Scenario 2 I 2 V 2 I
Scenario 3 I 2 V 2 V 2 I

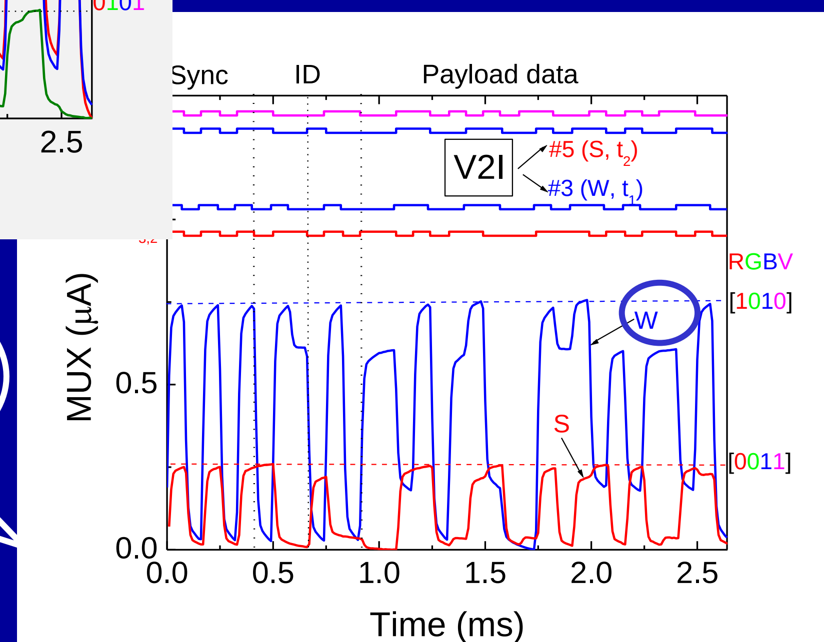
In order to verify the system operability and efficiency we have conducted an extensive set of measurements

Scenario 1: I2V2V2I









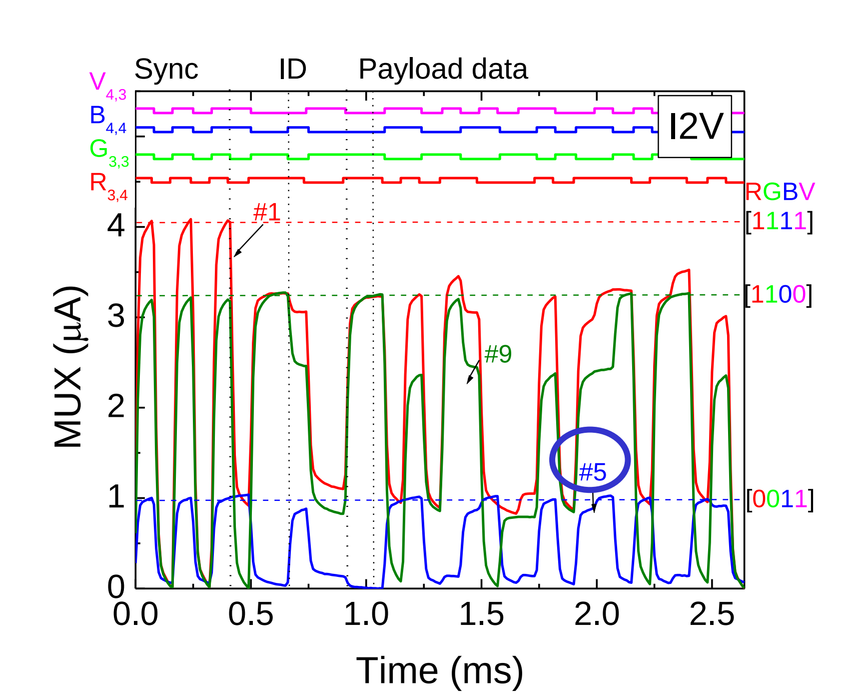
- Vehicle 1 sends the request message to the infrastructure (V2I) and informs the signal controller that this vehicle desires service (often called “demand” for service).

Request time: t_1

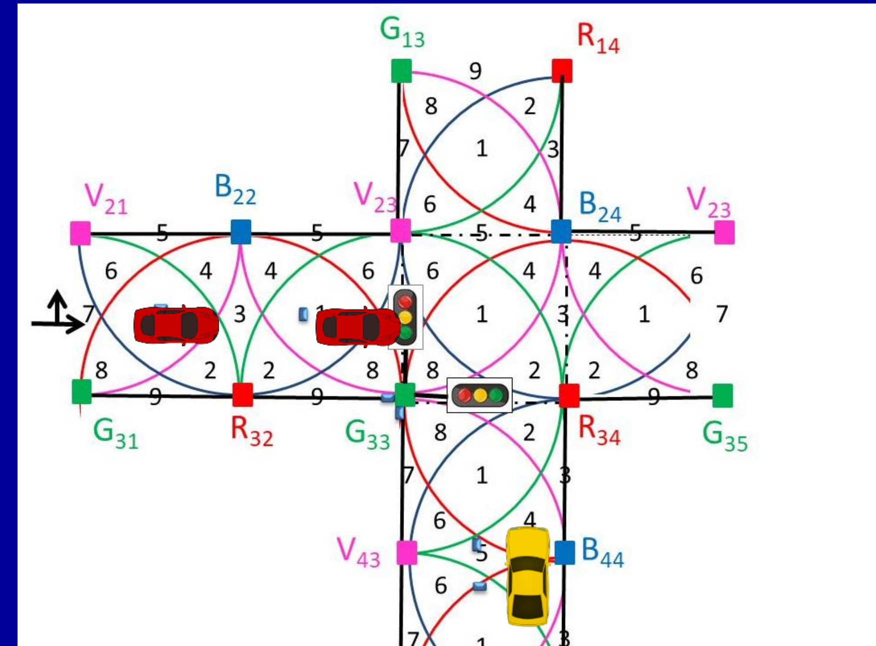
Δt=…. Δv=….

- ✓ Data collected from connected vehicles provides a much more complete picture of the traffic states near an intersection

Scenario 2: I2V2I



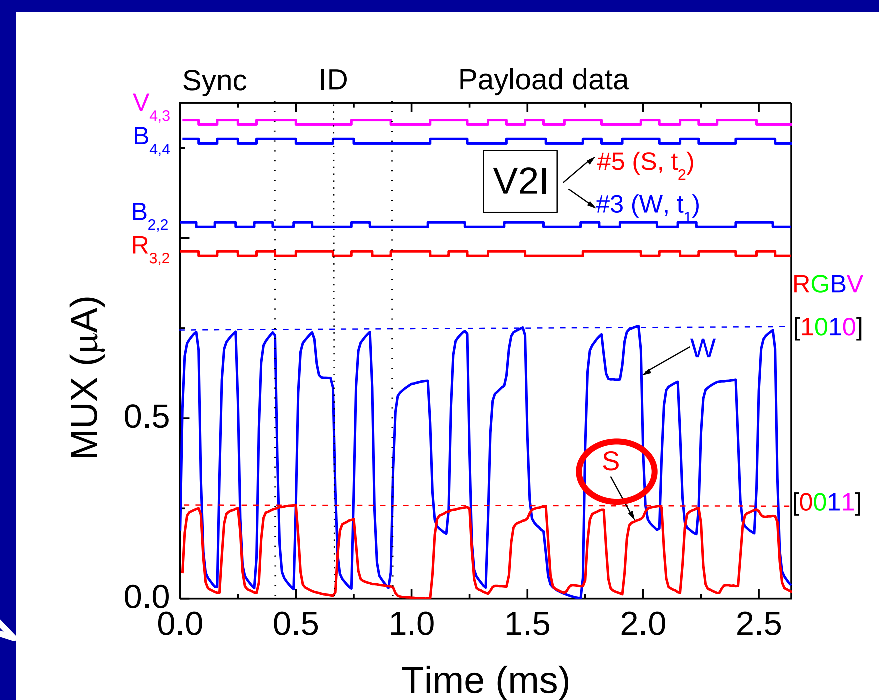
·I2V MUX signal received by a rooftop receiver moving in the S direction when the vehicle 2 is located #5



- Vehicle 2 sends the request message to the infrastructure (V2I)) and informs the signal controller that this vehicle desires service.

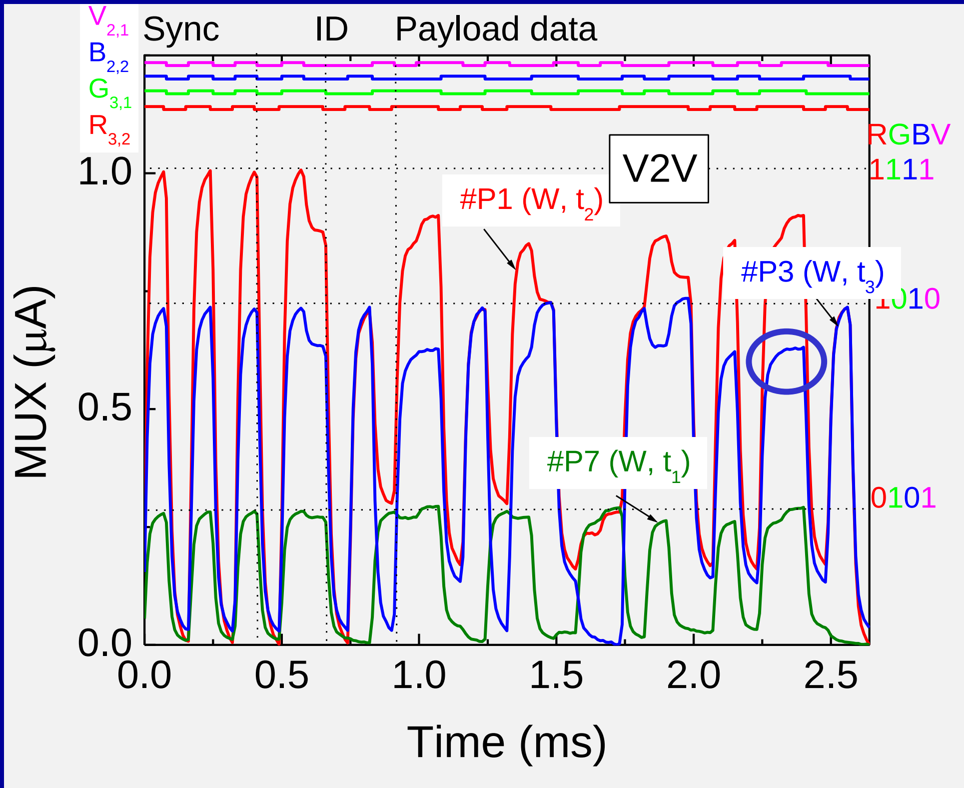
Request time: t_2

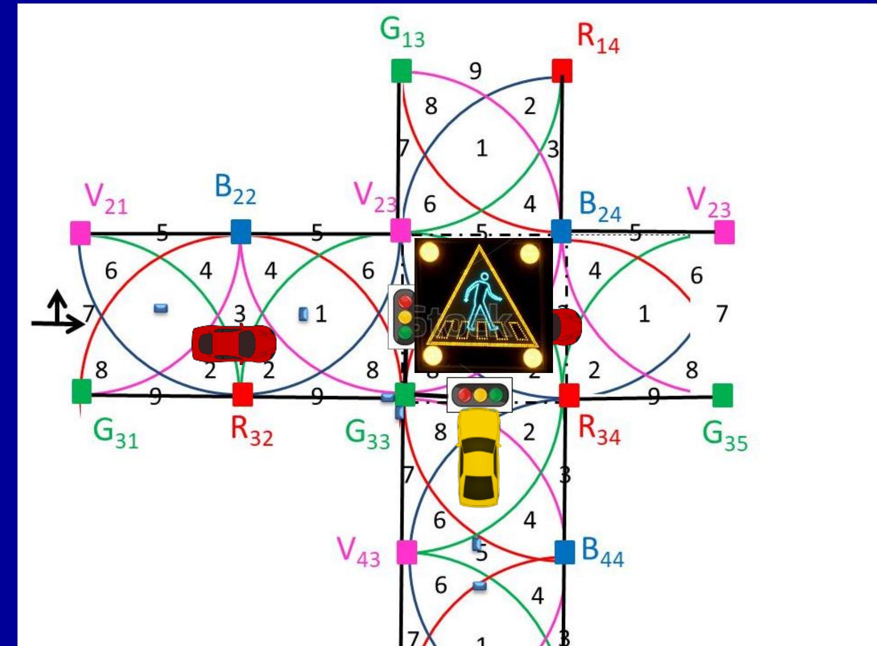
$\Delta t=\ldots.$ $\Delta v=\ldots.$



·V2I communication from vehicle 2 to the infrastructure

Scenario 3: I2V2V2I



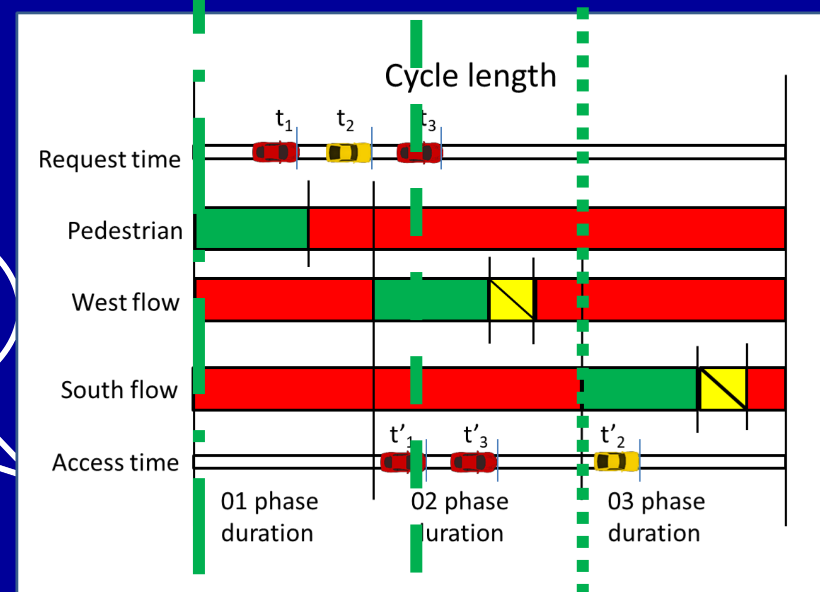


Pedestrian-only stage (01 phase) two single-lane road phases

- Vehicle 3 sends the request message to the infrastructure (V2I) and to the leader (V2V)

Request time: t_3

$\Delta t = \ldots$ $\Delta v = \ldots$

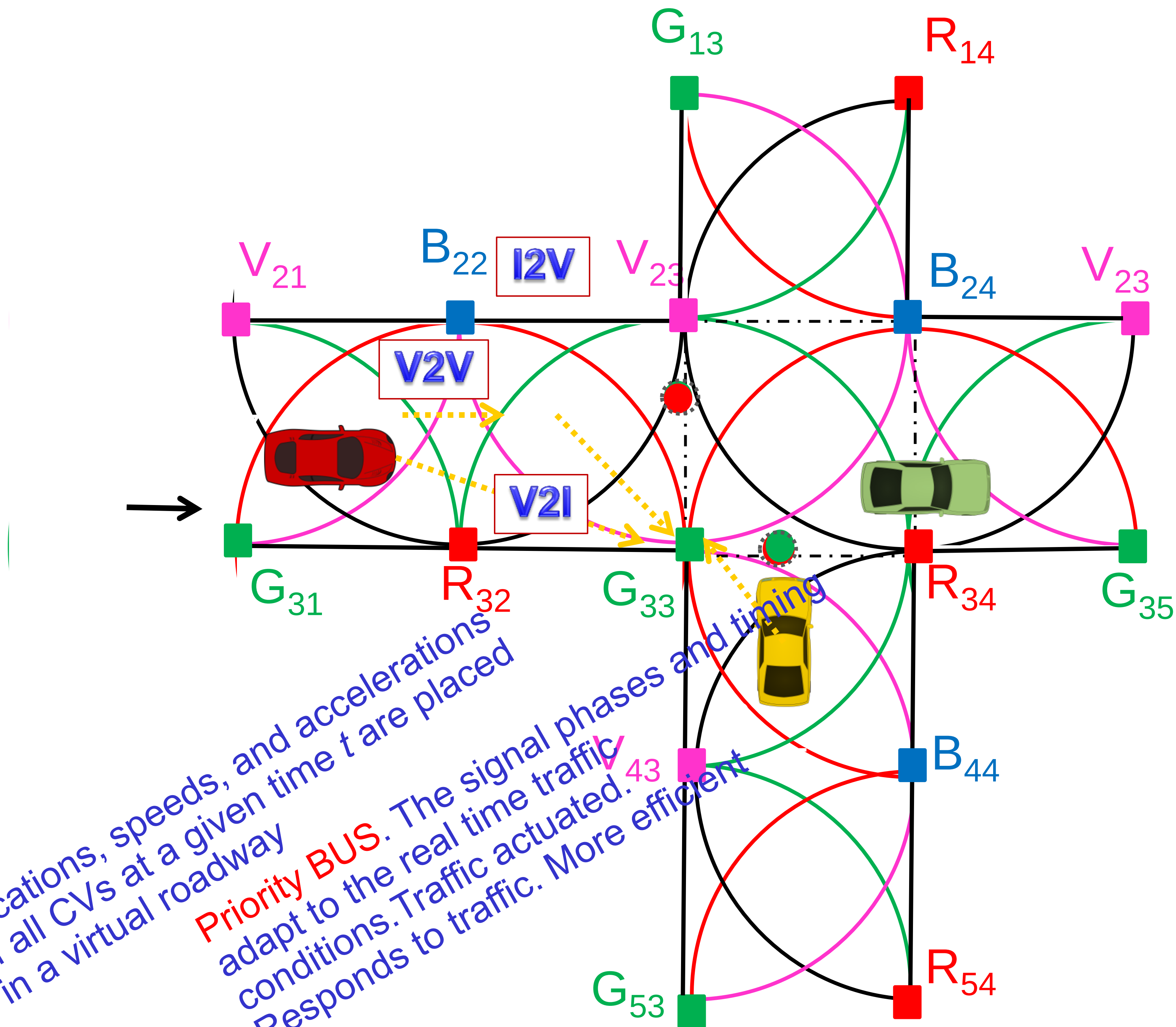


Phasing of traffic flows

Vehicle's intersection access time is defined as the time at which the head of the vehicle enters the intersection area

From a capacity point of view is more efficient, if Vehicle 3 is given access before Vehicle 2

Virtual road network: I2V2V2I



Horizon 2020 Transport virtual info day

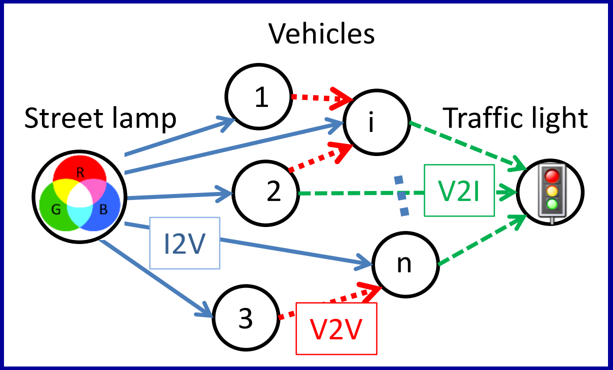
Horizon 2020
Transport virtual info day

The event will present the following 2019 calls for funding making available a total of nearly €355 million

Mobility for Growth
Automated Road Transport
Green Vehicles
Next Generation Batteries

Conclusions

- Light-activated pi'n/pin a-SiC:H devices combines the demultiplexing operation with the simultaneous photodetection and self amplification.

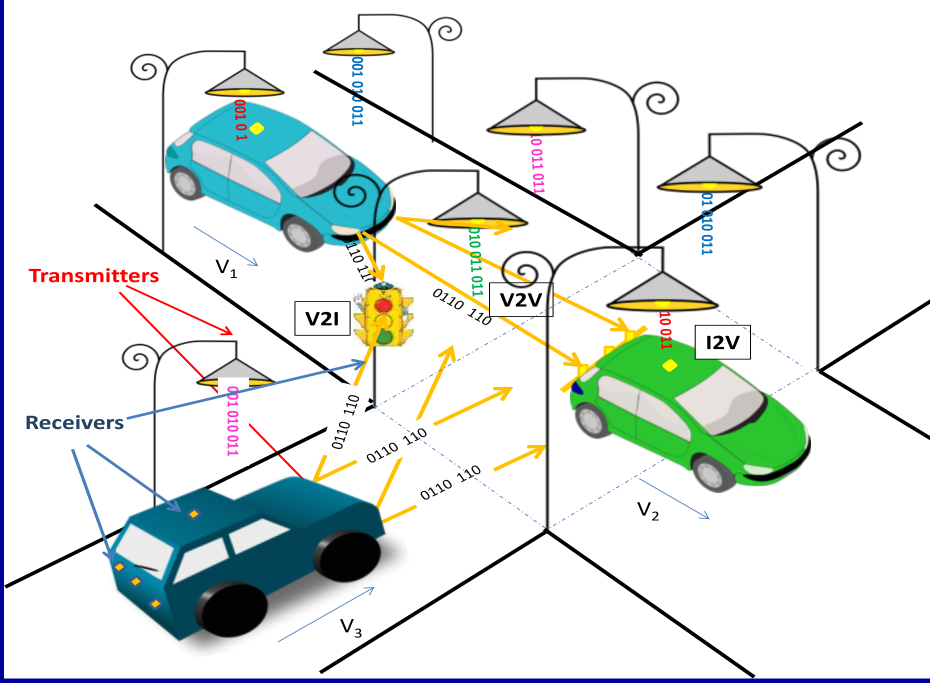


- Connected vehicles information from the network (I2V), vehicular interaction (V2V) and infrastructure (V2I) is analyzed.

- A generic model of cooperative transmissions for vehicular communications services is established.

- The experimental results, confirmed that the proposed cooperative VLC architecture is **appropriate** for the **control and management of a traffic** light controlled crossroad network.

- **Two-level optimization**: phase sequence and duration.



THANK YOU FOR YOUR ATTENTION

Optical communications strategies
Future research directions

Examples of visualizations of urban dynamics

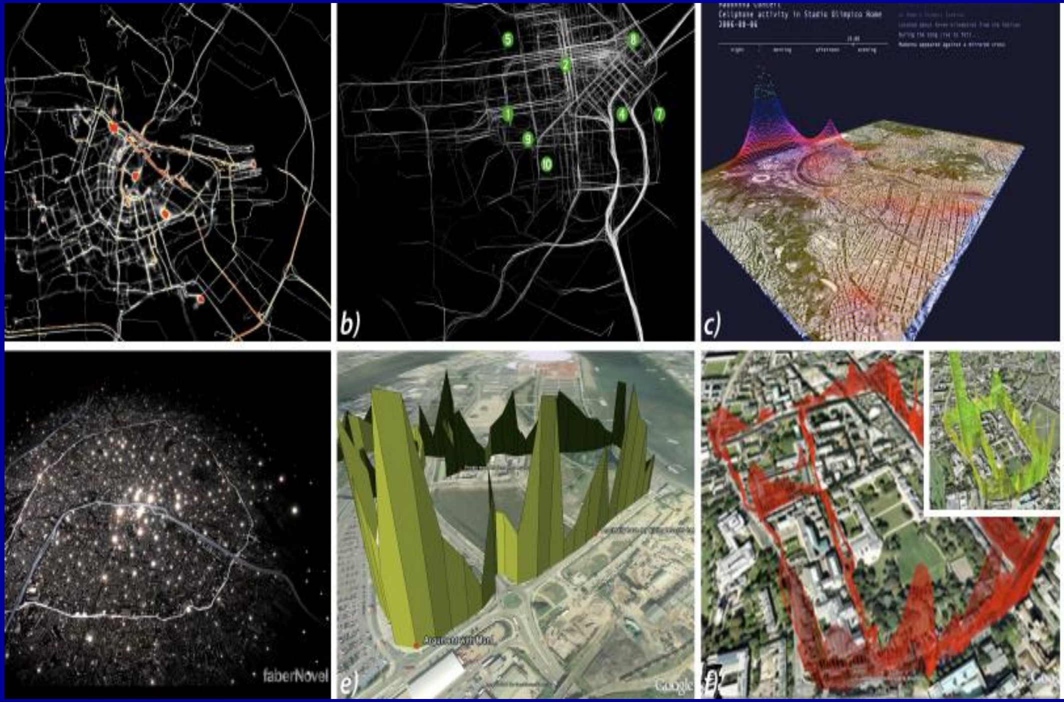
DI

The Heartbeat of a smarter Society

The place for

- **innovation strateg**
- **product developm**
- **continued growth**

even in difficult times



-Representation of traffic flows **a) b)**
-Aggregated data from cell phones during two special event **c) d)**