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IARIA

" VLC Connected Cooperative Driving"

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Manuel Augusto Vieira was born in Portugal. He graduated in Electronic and Telecommunication Engineering by Instituto Superior Técnico (IST) of Lisbon from the Technical University of Lisbon. In 2004, he received the Master of Science in Electronic and Computers Engineering by the Superior Technical Institute of Lisbon and in 2012 its PhD by the New University of Lisbon. The title of the thesis was ”Three transducers for one photodetector: essays for optical communication

Currently he is Assistant Professor in Electronics inside the Electronic Telecommunication and Computer Department of ISEL, Lisbon, Portugal and investigator in the M2P group of CTS-UNINOVA.

- The major research interests are related with traffic control, vehicular communications, operations management, stochastic control, optimization and discrete event dynamic systems, scheduling, inventory control, simulation infinitesimal perturbation analysis, queuing networks.
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- He was director of the traffic department of the City Hall of Lisbon for more than twenty five years. In this context he has been involved in several national and international projects, namely:
- Control between urban traffic control (GERTRUDE) and public transport vehicle location (SAEIP) systems.
- Admission Regulation of Traffic to Improve Public Transport in Urban Areas
- Requirements and options in the field of Integrated Road Safety, Information and Navigation System- IRIS.
- Microwave communications for traffic monitoring and pricing “PAMELA.
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- Mobile wireless communication networks have been experiencing enormous advances throughout its successive generations. So, at the moment its research activities are related mainly to the communication between vehicles (V2V), vehicles and infrastructures (V2I) and road infrastructure and the vehicles (I2V) using visible light (VLC).

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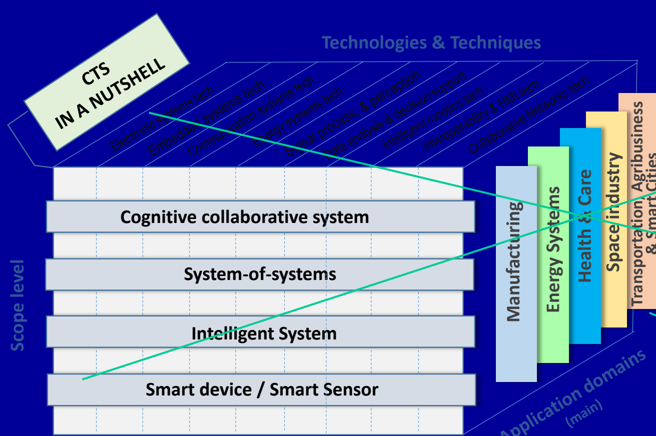


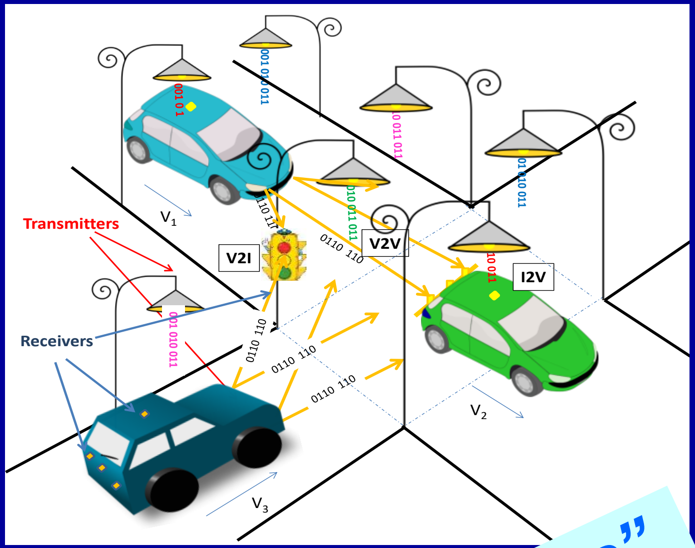
Scope:
Smart device/smart sensor

Technologies & techniques:
Electronic systems technology

Application domains:
Smart cities

Motivation and Objectives

I2V, V2V, V2I, I2V optoelectronic WDM cooperative vehicular system enables direct communication between vehicles, roadside infrastructure, traffic lights control and vulnerable road users (pedestrians, bicyclist, or wheelchair users)



"Connected vehicles" innovative concept

Paradigm shift

THE ORIGINAL IDEA:

" Bidirectional communication "

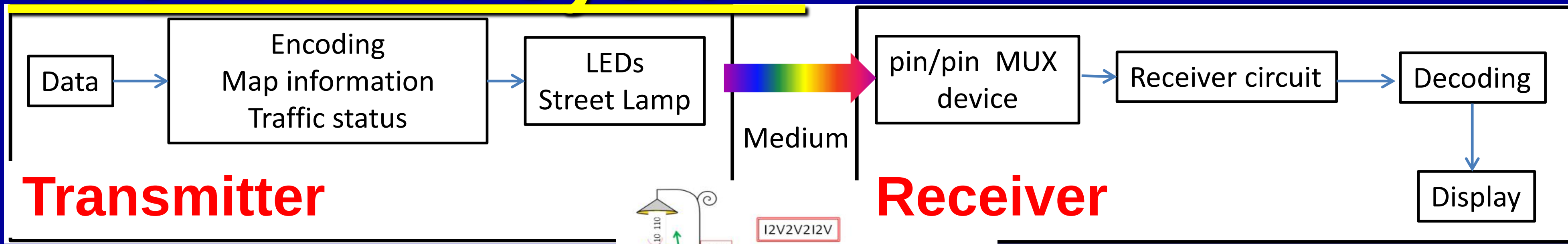
VLC transmitter that modulates the light produced by LEDs and

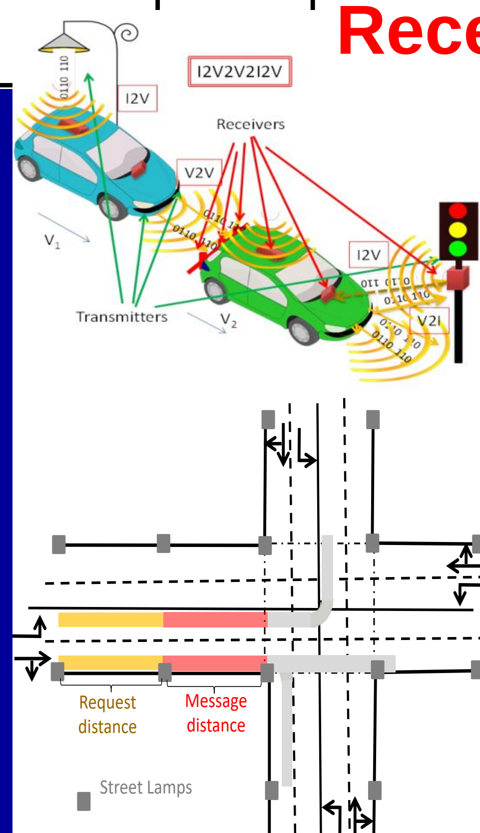
Amorphous Si/SiC transducers, allow the recovery of specific wavelengths for the transmission over WDM networks, in the visible spectrum, that could compete with conventional detection electronic devices in optical communications industry

Outline

- **State of Art:**
  VLC transmitter and Si/SiC transducers
- **Connected vehicles model**
  Transmitters and Receivers
- **I2V, V2V, V2I and I2(V, P, B) communications**
- **Cooperative VLC System**
  Evaluation and proof of concept.
- **Conclusions and future trends.**

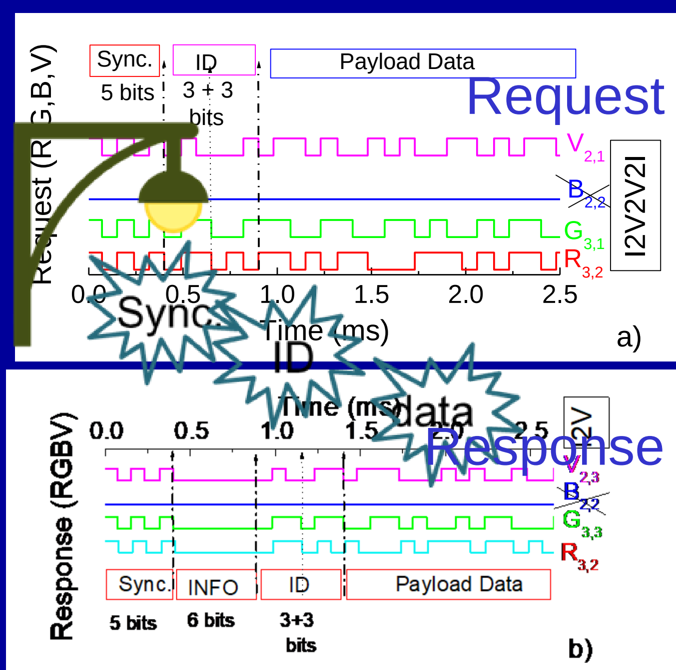
VLC I2V2V2I System

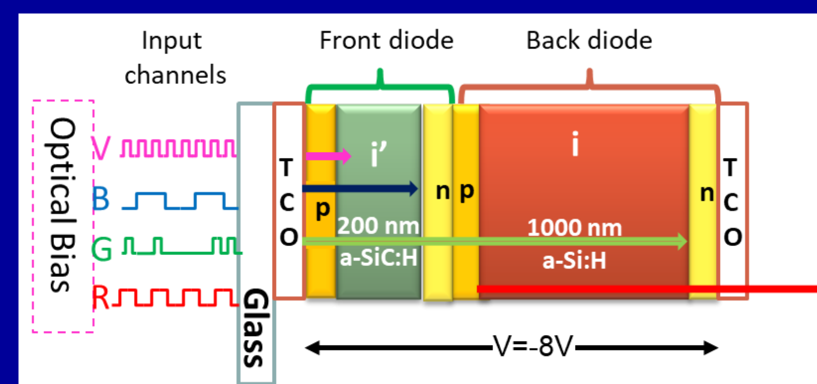




I2V : the street lamp sends a message to the SiC receiver, located at the rooftop.

V2V2I: the information is resent to a leader vehicle or the signal controller using the headlights as transmitters (request distance)





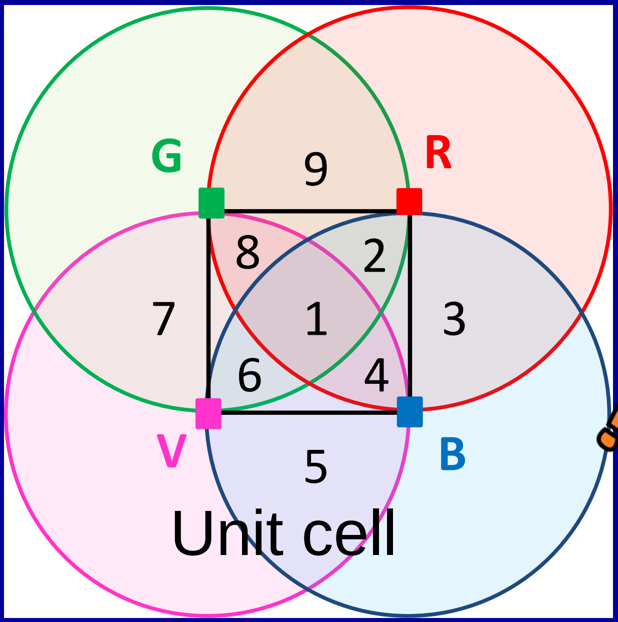
p-i'(a-SiC:H)-n/p-i(a-Si:H)-n heterostructure produced by PECVD with light filtering properties.

Frame structure representation.

The message begins with 5 synchronization bits

The rest of the frame consists of 6 ID´s bits, data bits and stop bit.

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

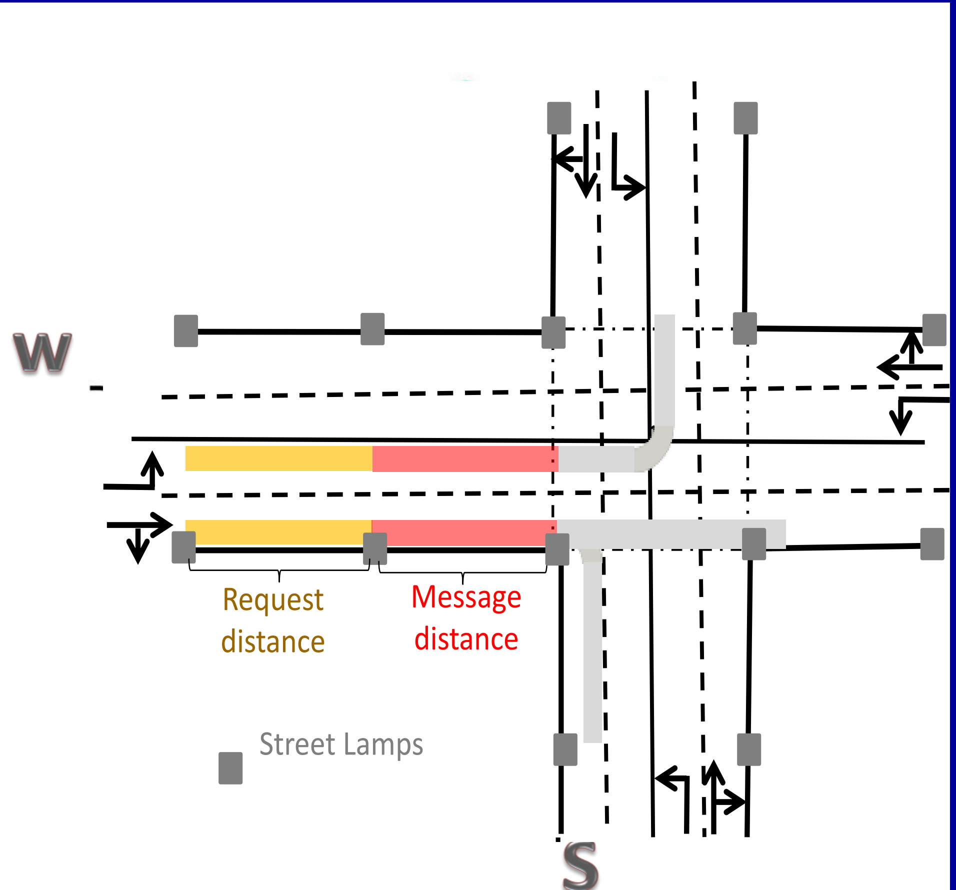
Data collected from connected vehicles provides a much more complete picture of the traffic states near an intersection

TRAJECTORY REDESIGN

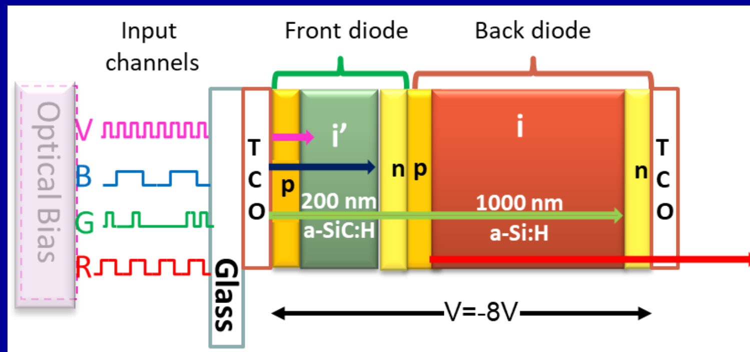
NEW CONCEPT OF REQUEST/RESPONSE

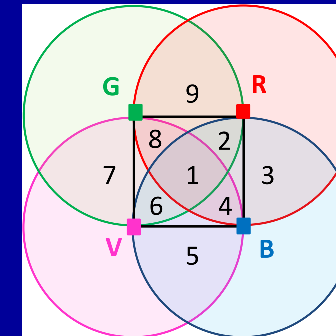
In a two-way-to-way traffic light controlled crossroad

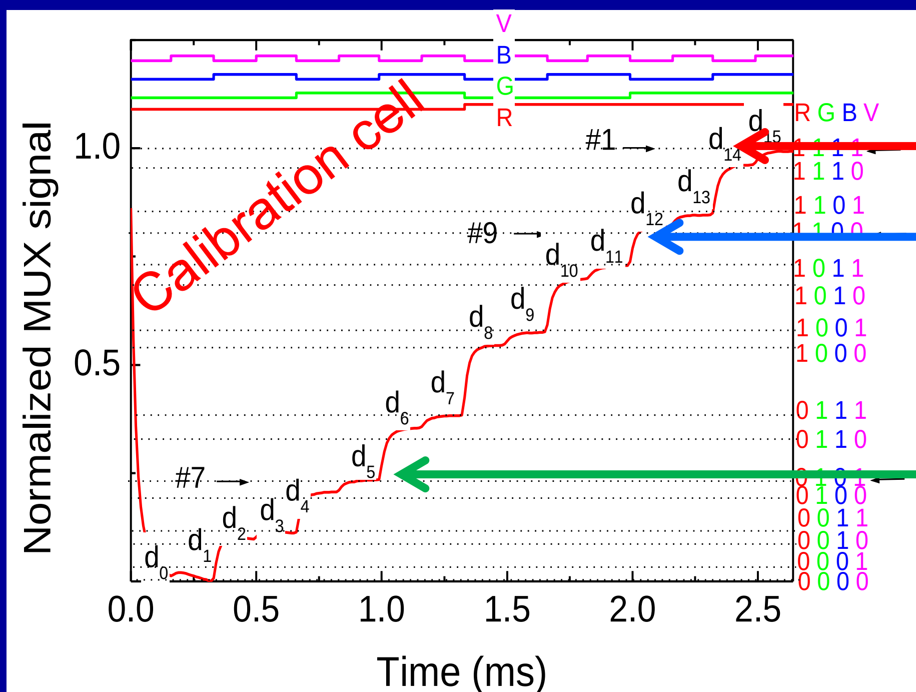
Promising benefits expected from safety and mobility improvements at the road network

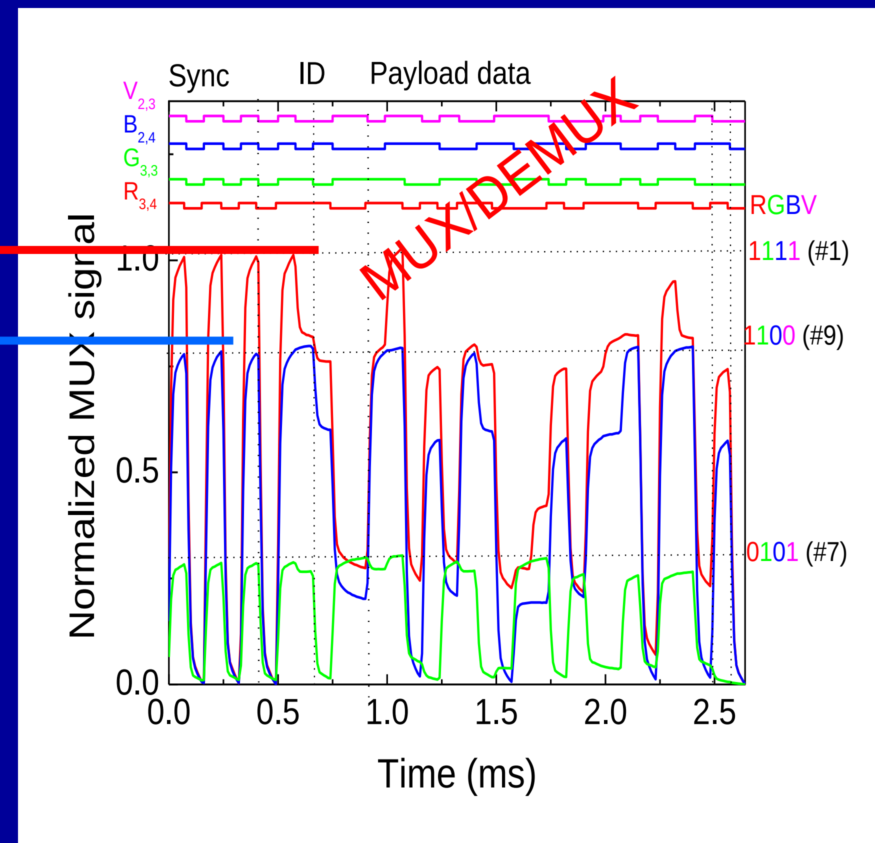


MUX/DEMUX techniques









- The output presents 2^4 ordered levels each one related with *RGBV* bit sequences

Connected Vehicles Model

Generic model

✓ cooperative vehicular and vulnerable road users communications

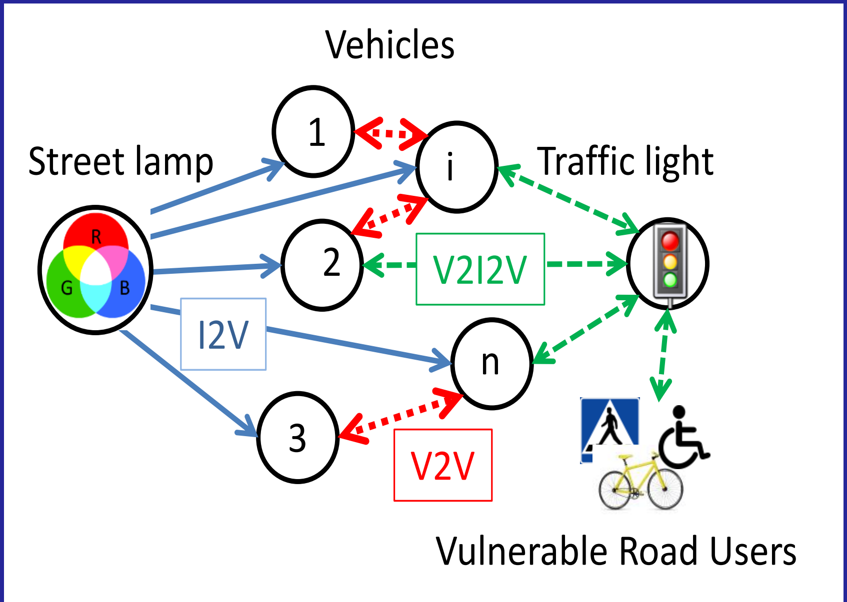
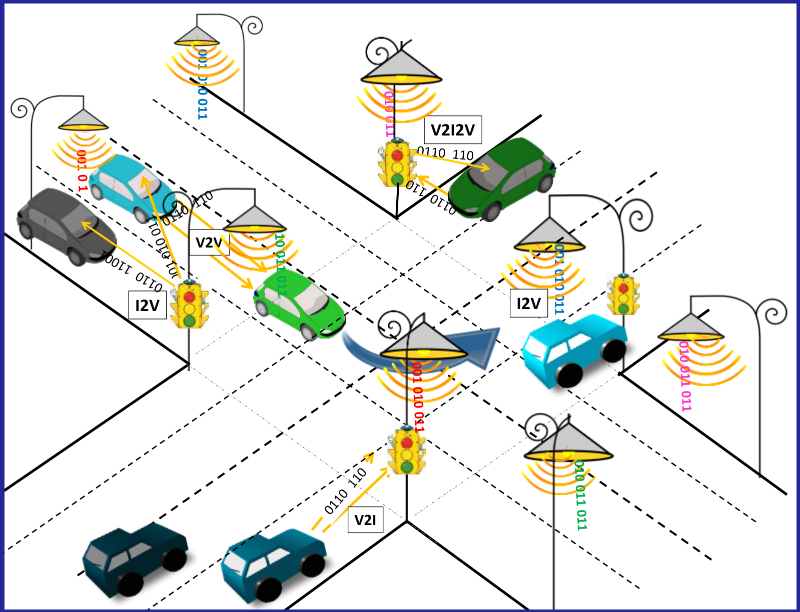


Illustration of the proposed I2V2V2I2(V,vru´s) communication scenario:

✓Connected vehicles communication in a crossroad.



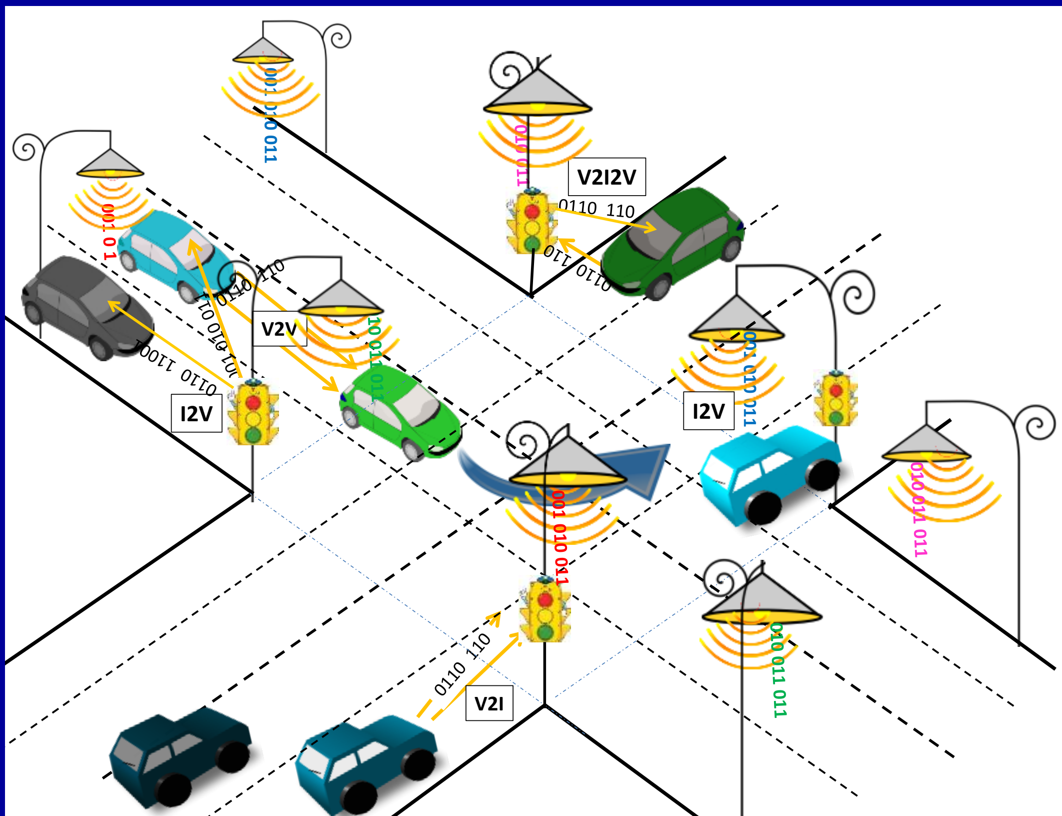
Until recently…

✓ (V2V) communication was limited to brake lights, turn signals;

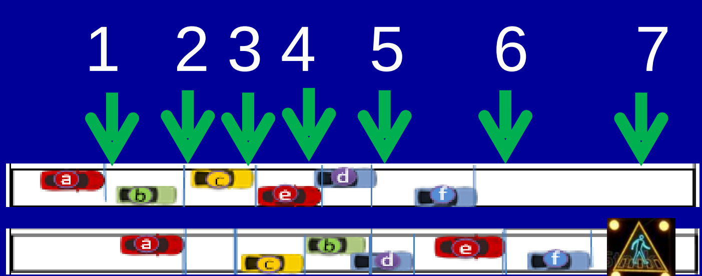
✓ (V2I) was restricted to point detection (loop detectors).

Cooperative VLC System Evaluation

Generalized view of the architecture



7 different scenarios:



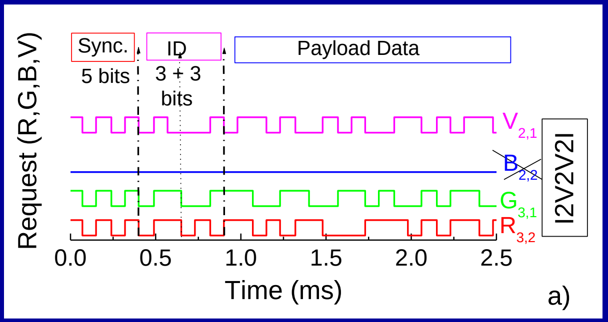
Operational procedure:

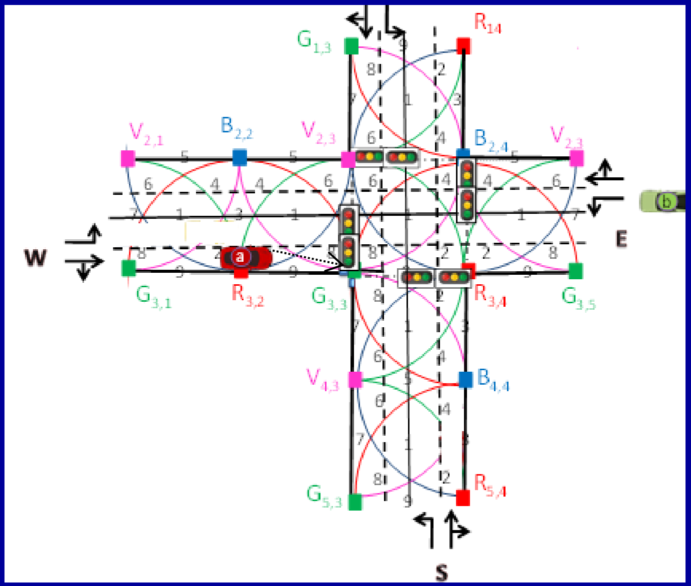
- Each vehicle receives two different messages:
  I2V and **V2V** coming from the streetlight and from the follow vehicle;
- Compare them and infers the **drive distance** and the **relative speed**.
- Send the information to a next car (V2V2V) or to an infrastructure (V2V2I).
- Connected vehicles receive response messages (I2V).

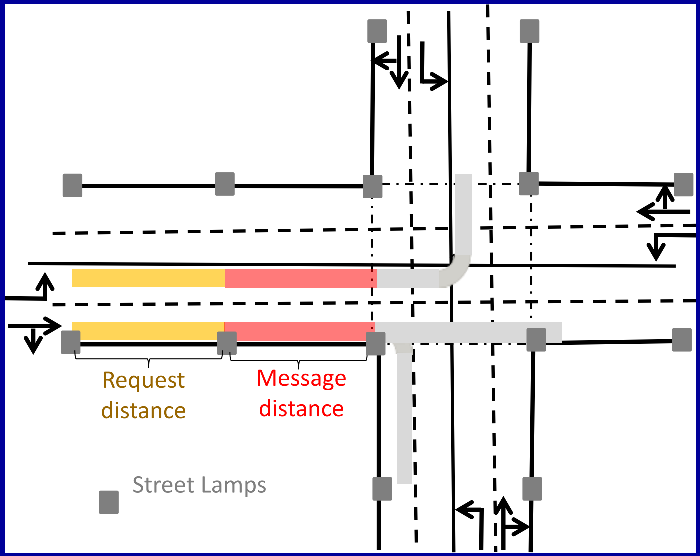
In order to verify the system operability and efficiency we have conducted an extensive set of measurements

Scenario 1: I2V2I

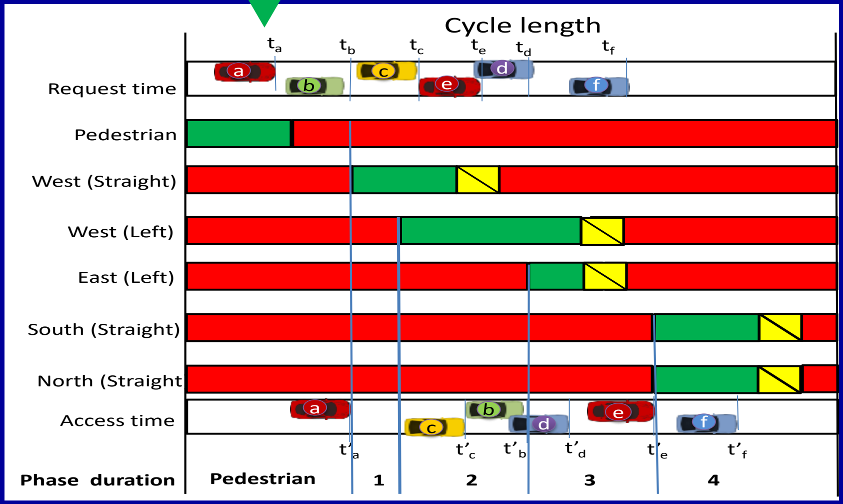
- Vehicle "a" send the request message to the infrastructure (V2I) and inform the signal controller that this vehicle desires service (often called "demand" for service).





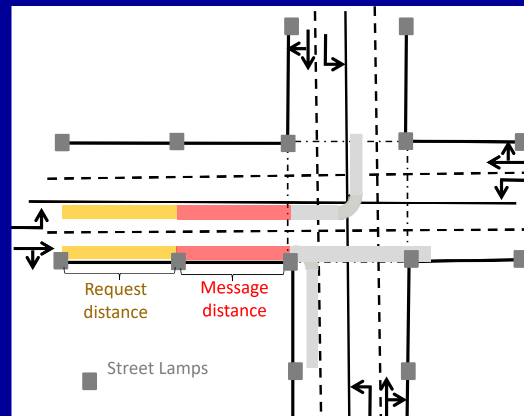


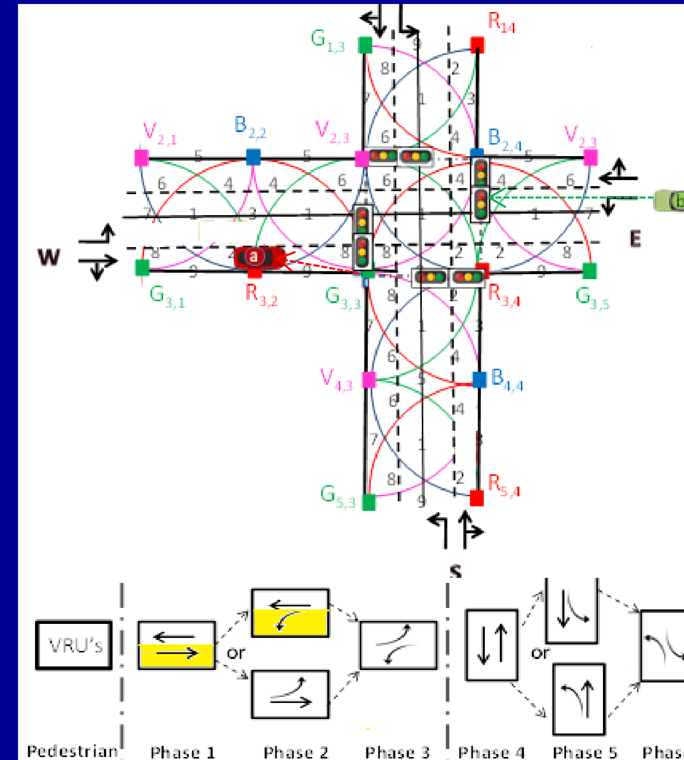
Phasing of traffic flows



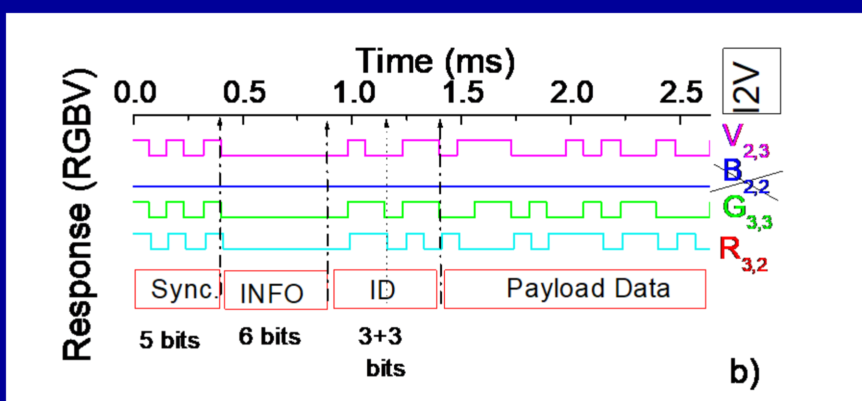
Scenario 2: I2V2I2V

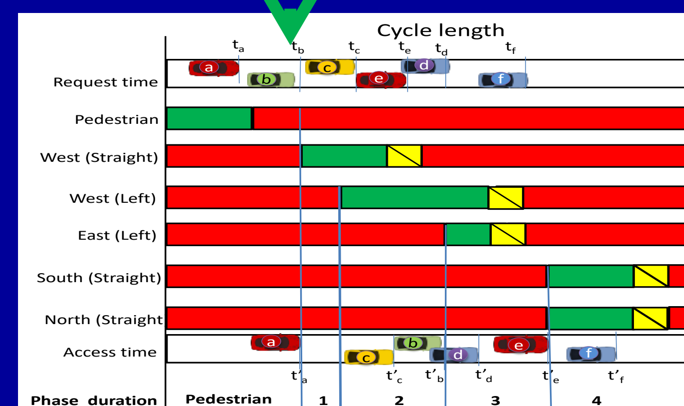
- Vehicles “b” send the request message to the infrastructure (V2I) and inform the signal controller that this vehicle desires service





Phasing of traffic flows



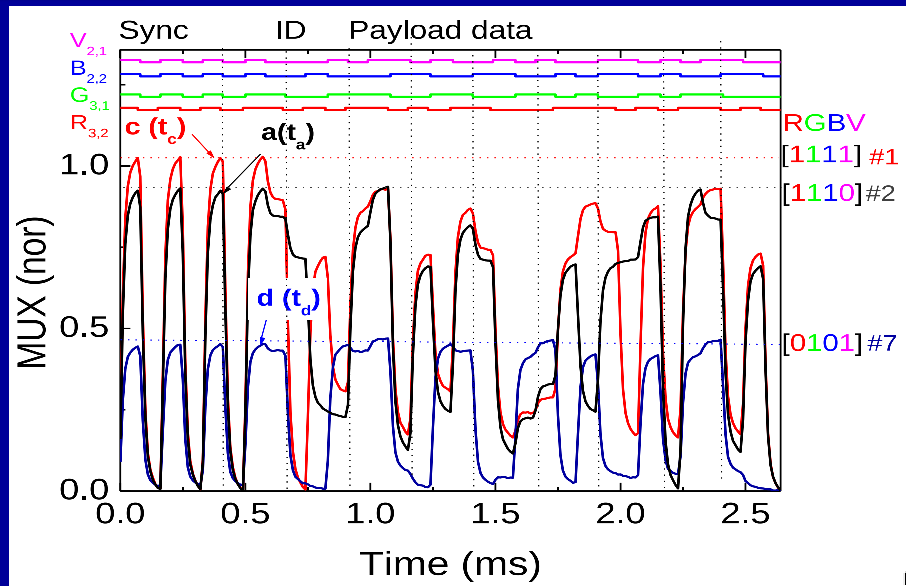


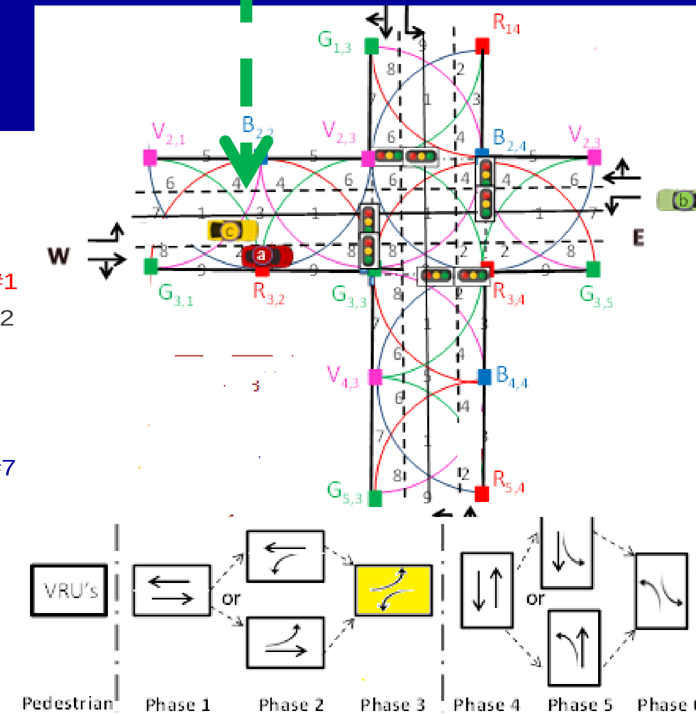
Responding permission (I2V) to vehicle “a” to cross the intersection

Scenario 3:

Request times:
Position of the vehicles
"a", "c" from the W flow

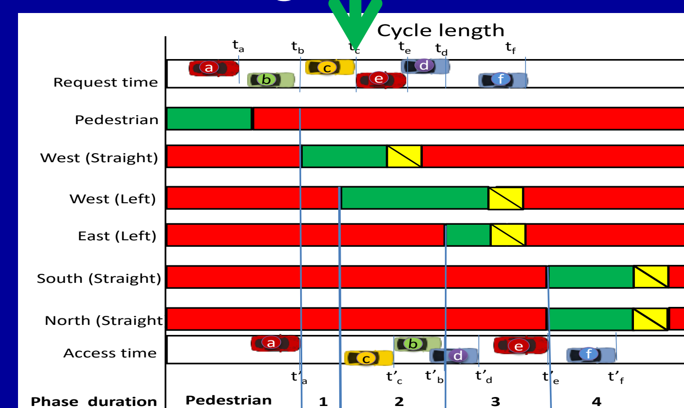
- Vehicle "a" at t_a #2($R_{3,2}$ $G_{3,1}$ $B_{2,2}$)
- Vehicle "c" at t_c #1($R_{3,2}$ $G_{3,1}$ $B_{2,2}$ $V_{2,1}$)





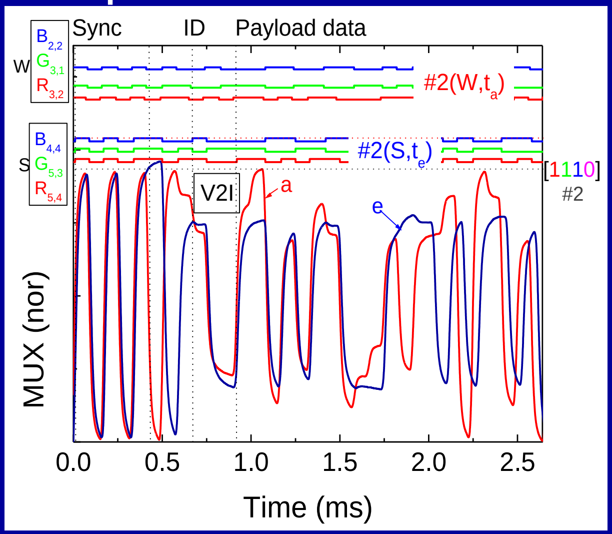
- Vehicle "c" sends the request message to the infrastructure (V2I) and informs the signal controller that this vehicle demand for service.

Phasing of traffic flows

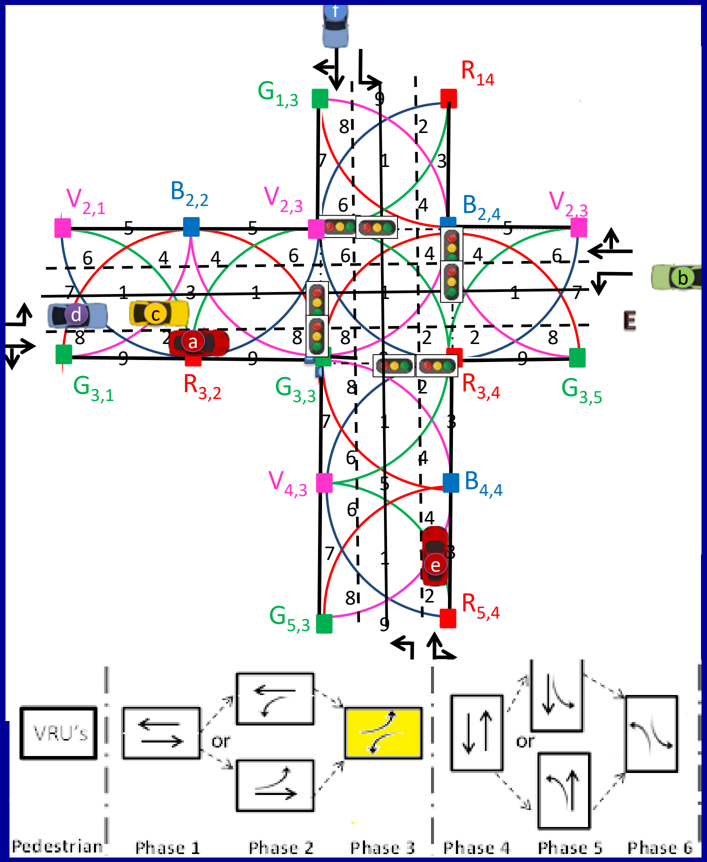


Scenario 4:

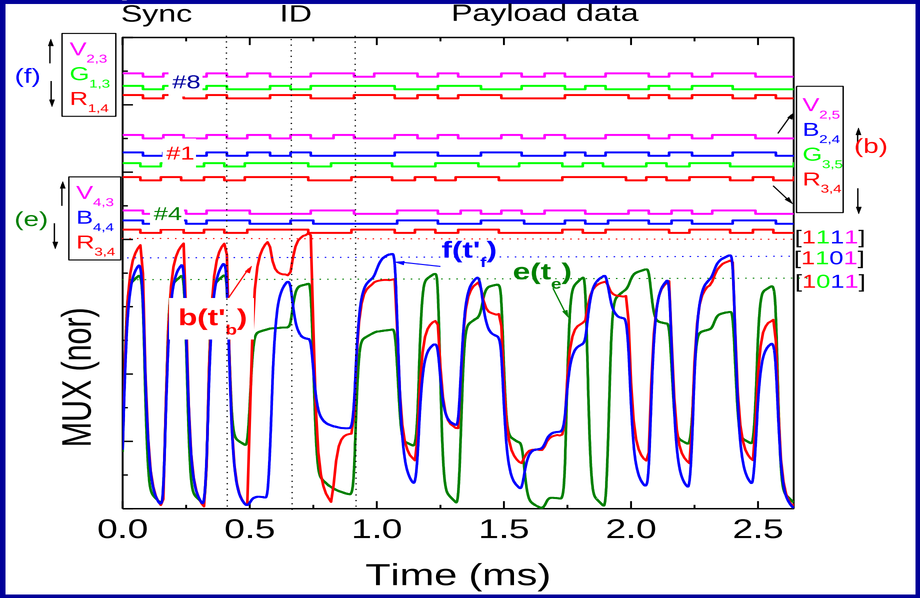
Request times:

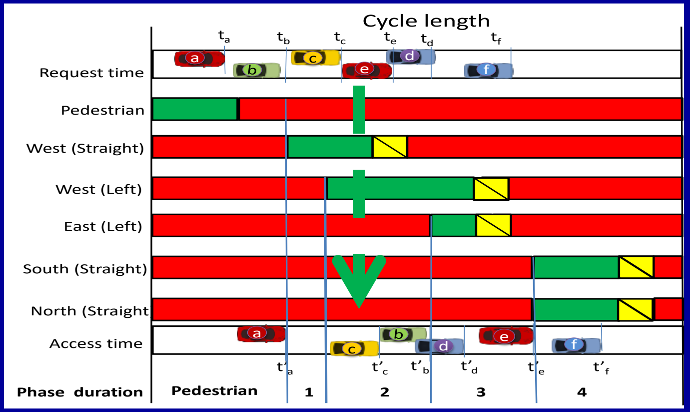


- t_e
  Vehicle "e" S #2 ($R_{5,4}$ $G_{5,3}$ $B_{4,4}$)
- t_a
  Vehicle "a" W #2 ($R_{3,2}$ $G_{3,1}$ $B_{2,2}$)



Response times

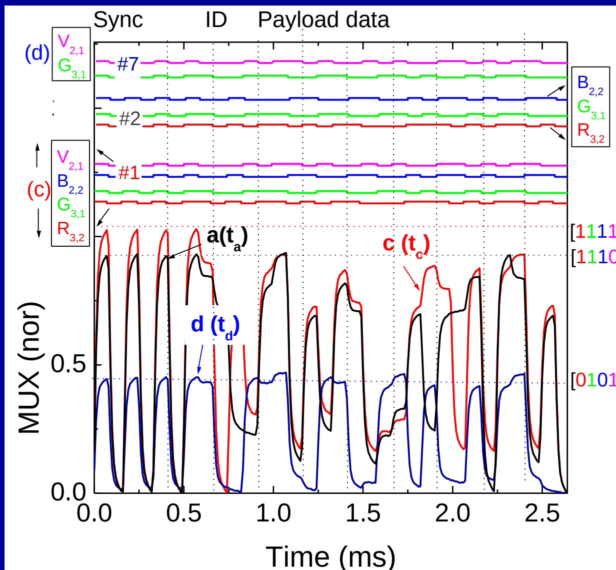




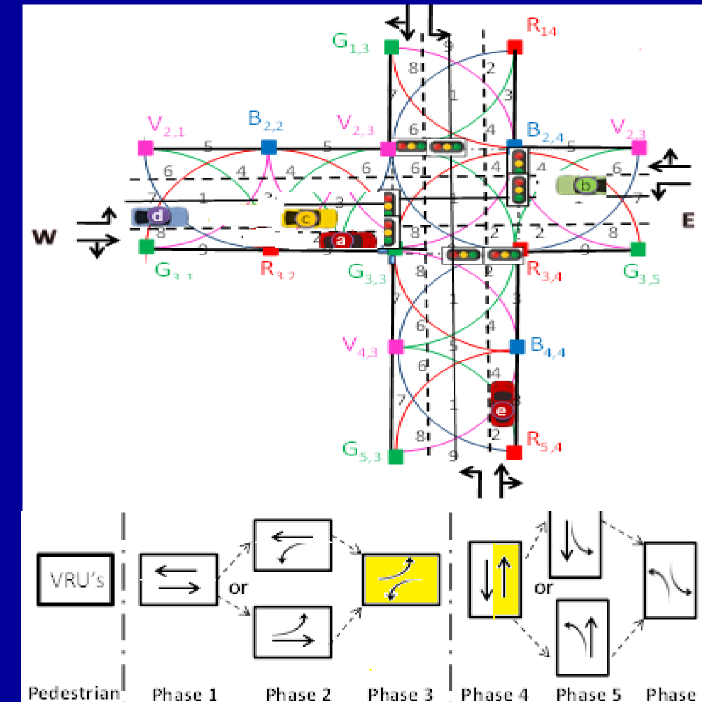
t'_b Vehicle "b" #1 ($R_{3,4}$ $G_{3,5}$ $B_{2,4}$ $V_{2,5}$)
t'_f Vehicle "f" #8 ($R_{1,4}$ $G_{1,3}$ $V_{2,3}$)

Responding permission to vehicle "b" and "c" to cross the intersection

Scenario 5:



$t_a<t_c<t_d$.

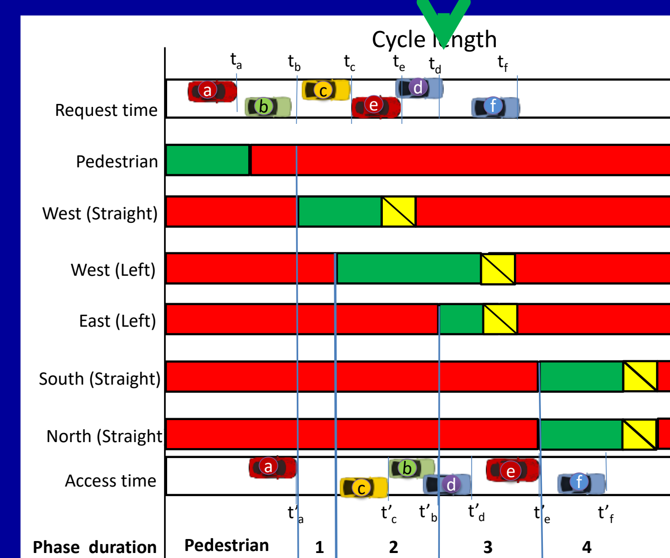


- Vehicles "d" send the request message to the infrastructure (V2I) and "demands" for service.

From a capacity point of view is more efficient, if vehicle "d" is given access before vehicle "e", slotting and maintaining a safe distance from one another

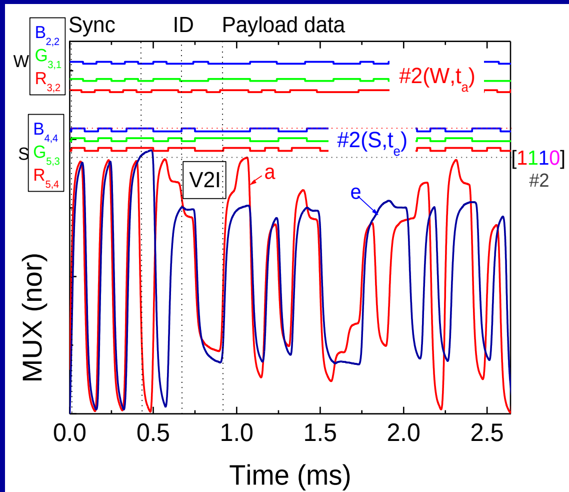
Responding permission to cross the intersection vehicle "d"

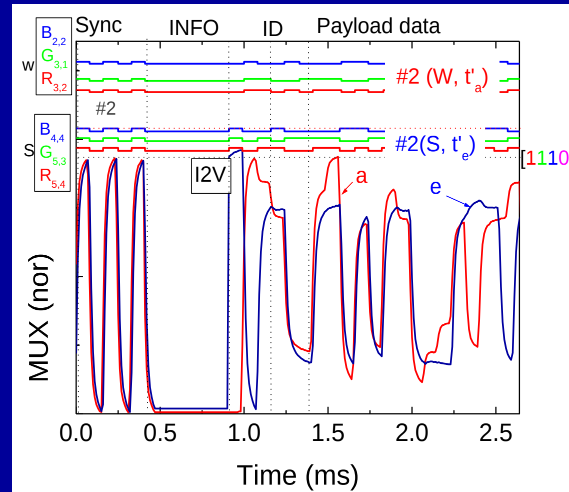
Phasing of traffic flows

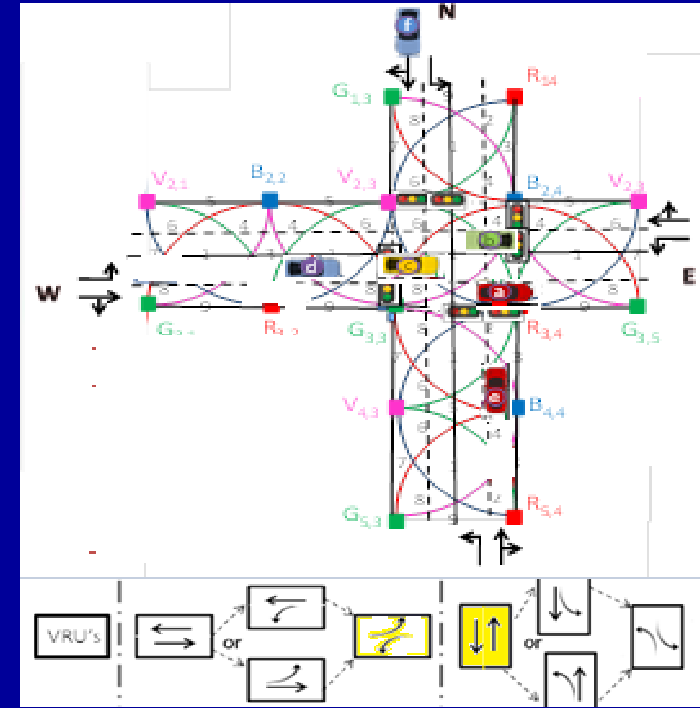


Scenario 6:

Request t_a t_e /Response times t'_a t'_e



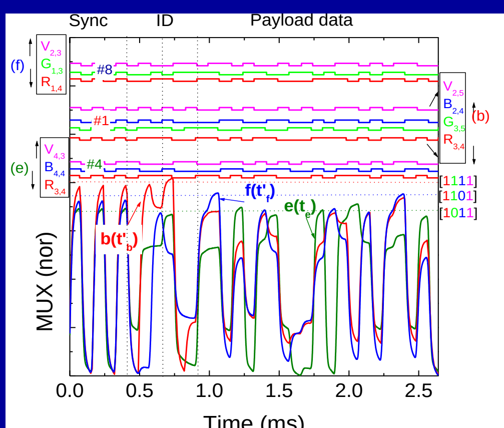




Vehicle "*a*": W #2 ($R_{3,2}$, $G_{3,1}$ and $B_{2,2}$)

Vehicle "*e*": S #2 ($R_{5,4}$, $G_{5,3}$ and $B_{4,4}$)

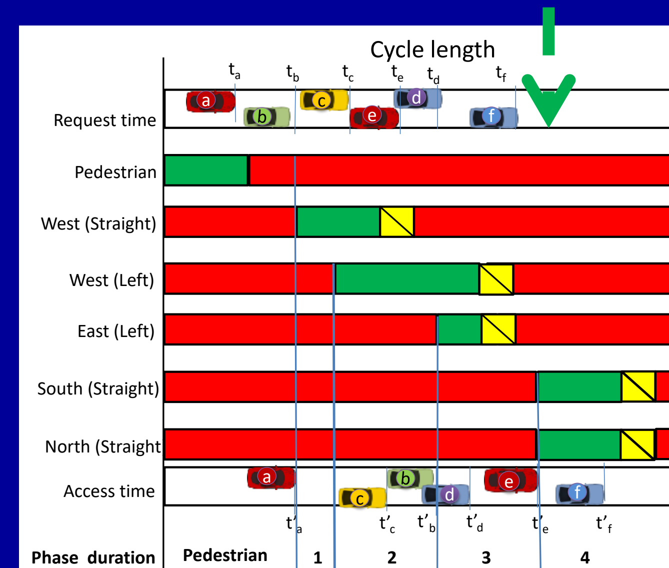
Phasing of traffic flows



Response times t'_e , t'_b and t'_f

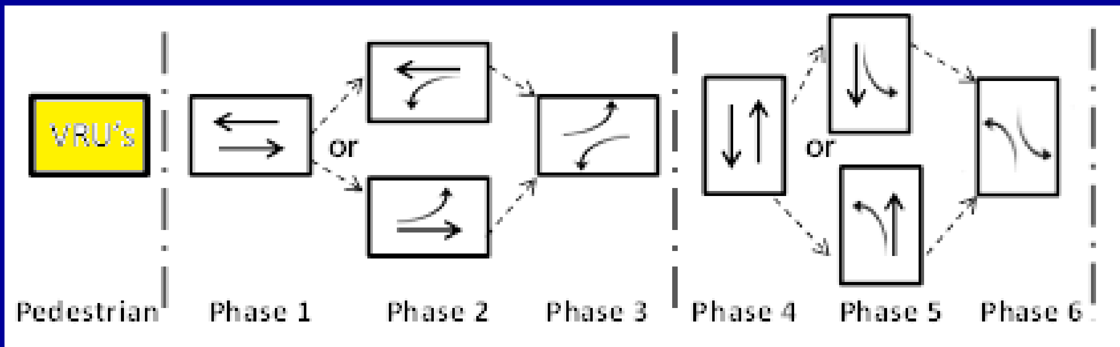
$t_a < t_b < t_c$

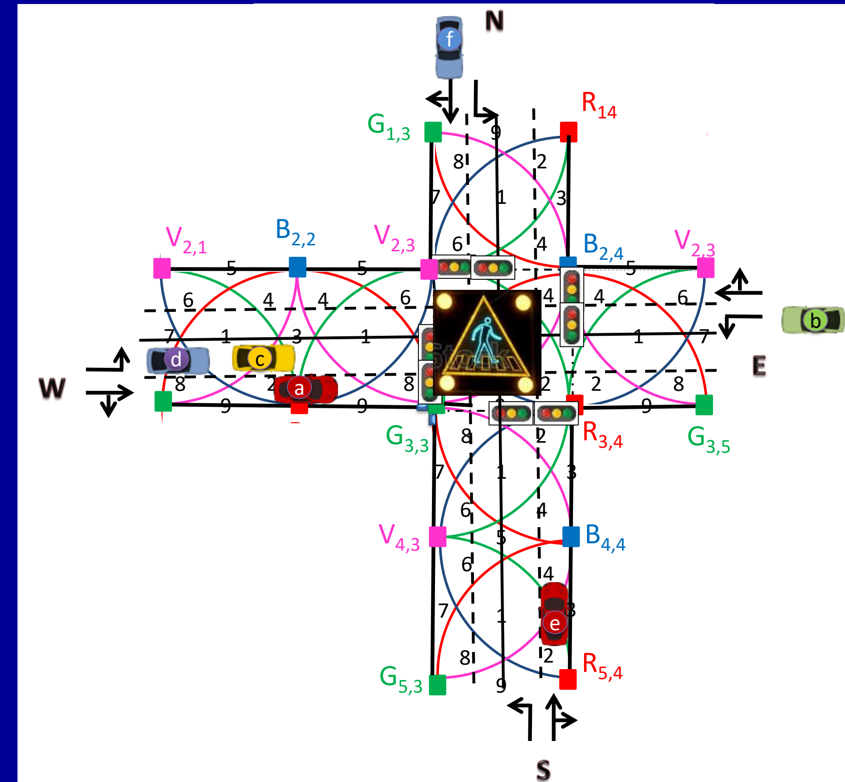
$t'_e < t'_f$.



Responding permission to cross the intersection vehicles "e" and "f"

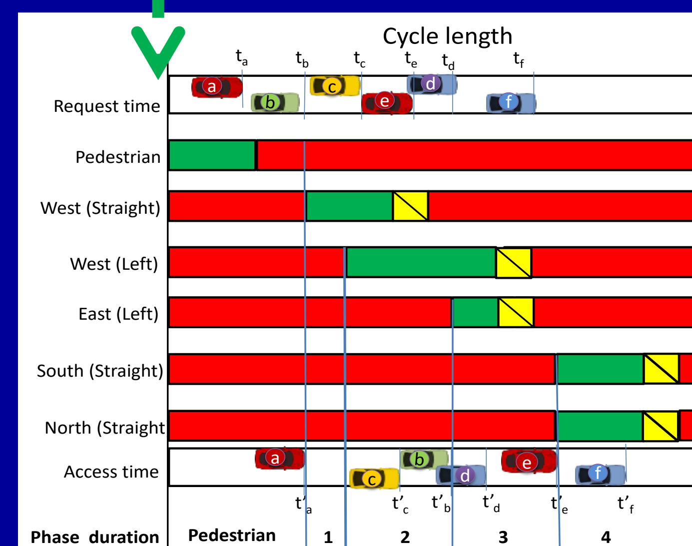
Scenario 7:





Exclusive Pedestrian Phasing

When vehicles will be stopped on all approaches to an intersection while pedestrians are given a WALK indication



I2V2V2I2vru´s communication allows direct monitoring:

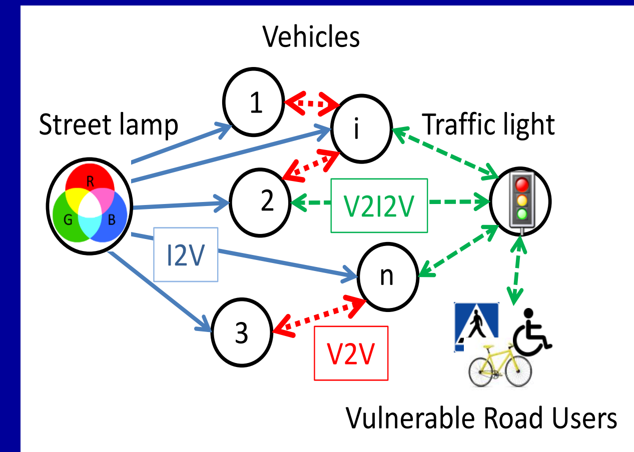
- Vulnerable road user crossing requests
- Controller message to nomadic road user´s devices

Conclusions

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

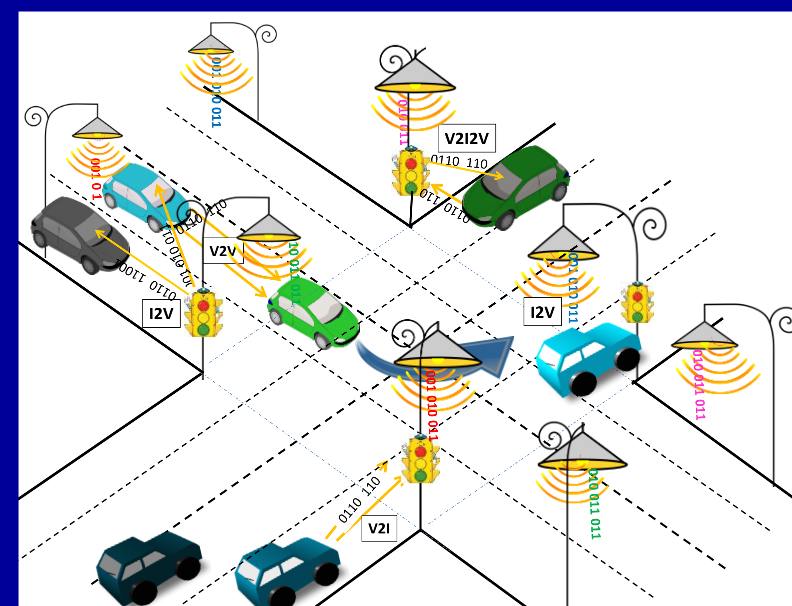
- Connected vehicles information from the network (I2V), vehicular interaction (V2V) and infrastructure (V2I) and (I2V) is analyzed.

- 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 **two-way-two-way** crossroad network.

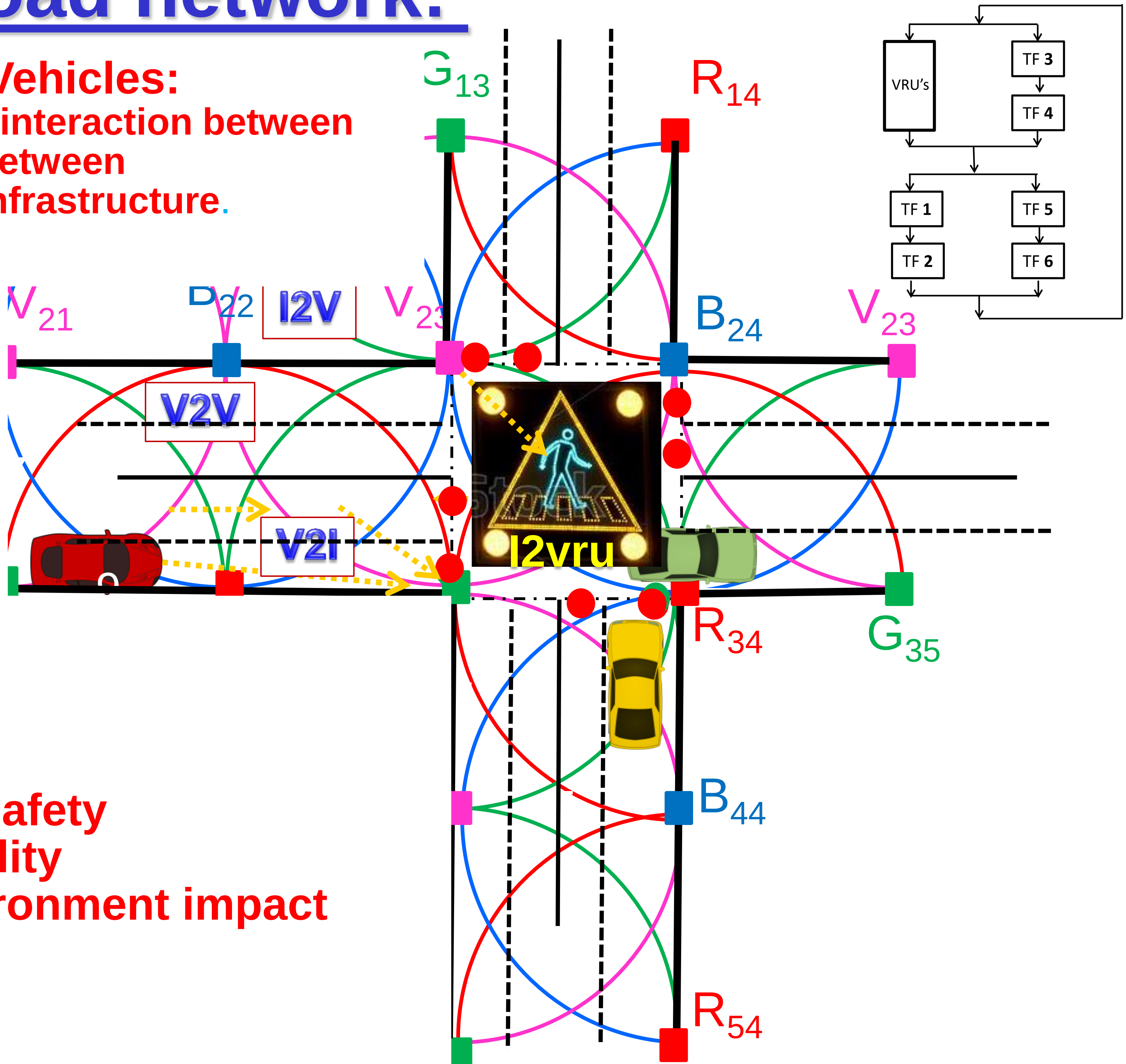
- **Two-level optimization**: "Redesign phasing" and duration.



THANK YOU FOR YOUR ATTENTION

Virtual road network:

Connected Vehicles:
provide better interaction between vehicles and between vehicles and infrastructure.



- **Increased Safety**
- **Better Mobility**
- **Lower Environment impact**