

# A Software Defined Vehicular Network using Cooperative Intelligent Transport System Messages

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# Motivation



# Objectives

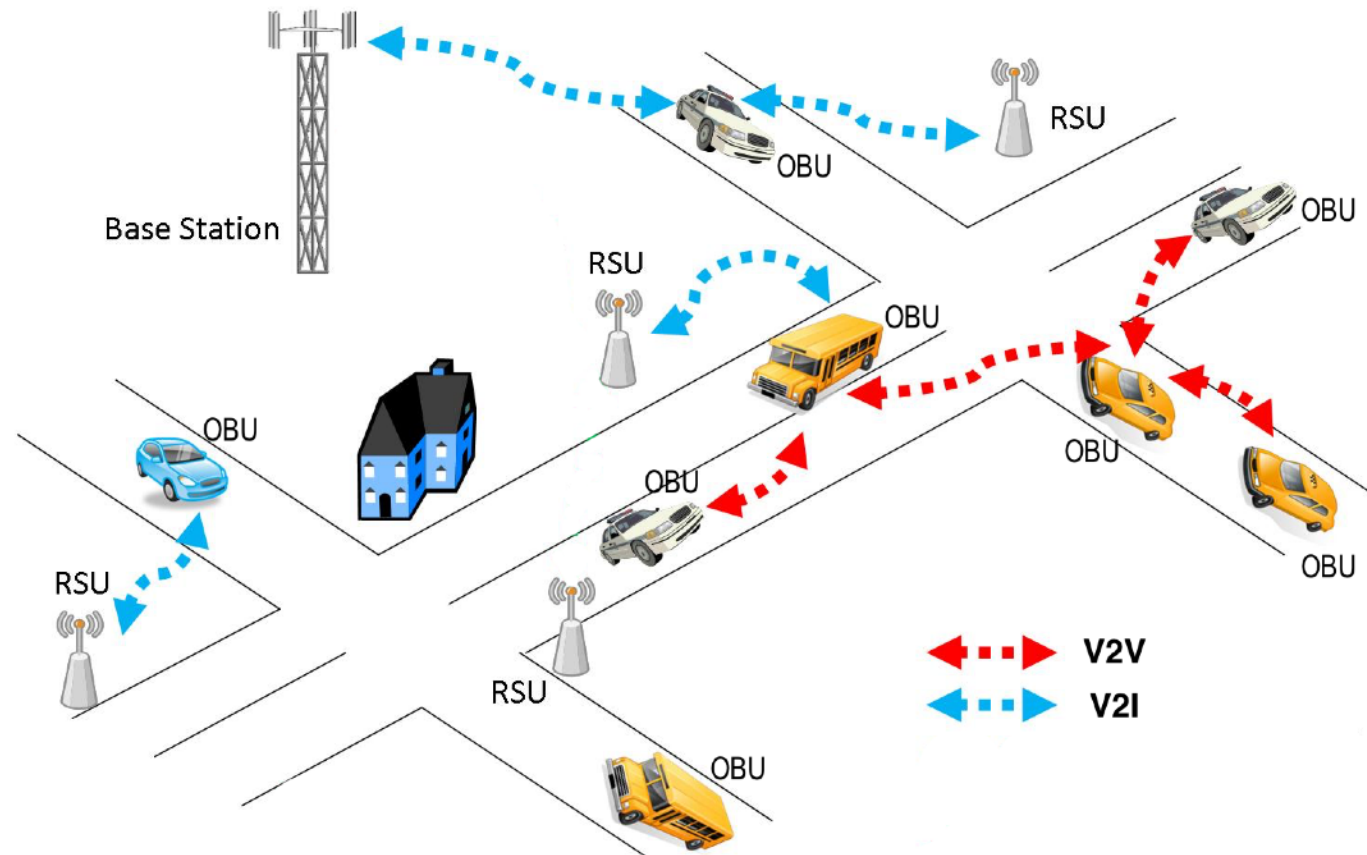
- Apply an SDN architecture in a Vehicular Environment
- Implement and deploy C-ITS messages in an SDN architecture
- Implement and deploy C-ITS messages in a Connection Manager of an OBU



# Background Concepts



# VANET – Vehicular Ad-Hoc Network



**OBU** – On Board Unit

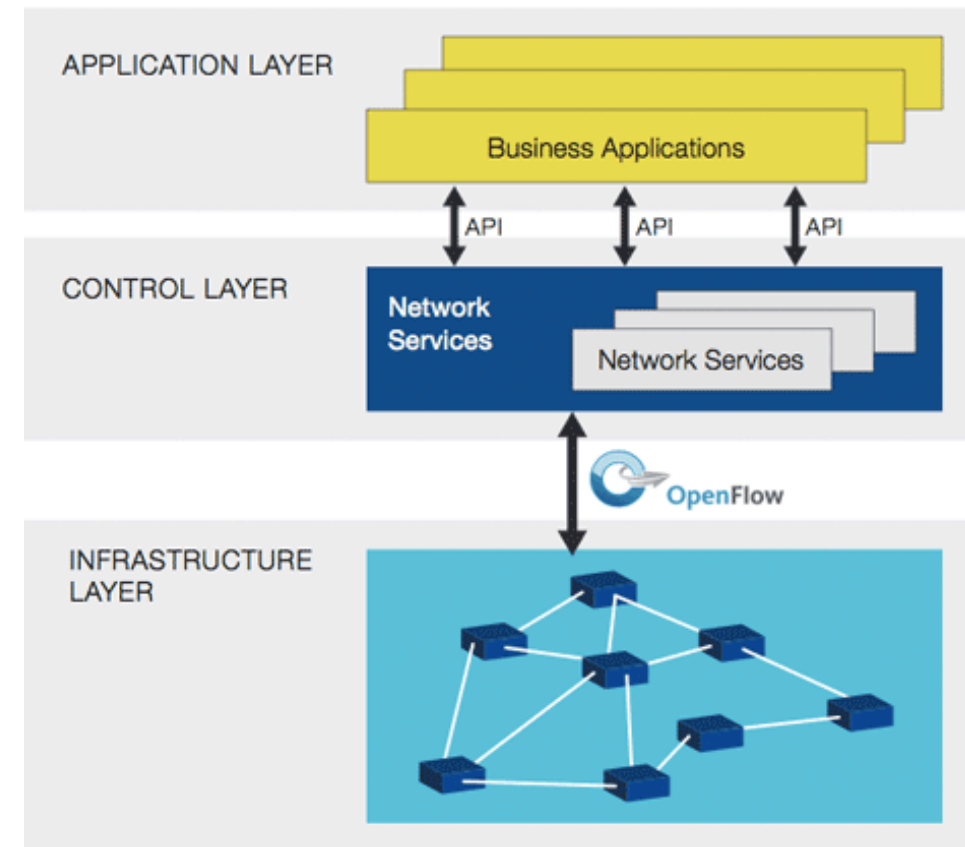
**RSU** – Road Side Unit

**V2V** – Vehicle to Vehicle

**V2I** – Vehicle to Infrastructure

# SDN – Software Defined Network

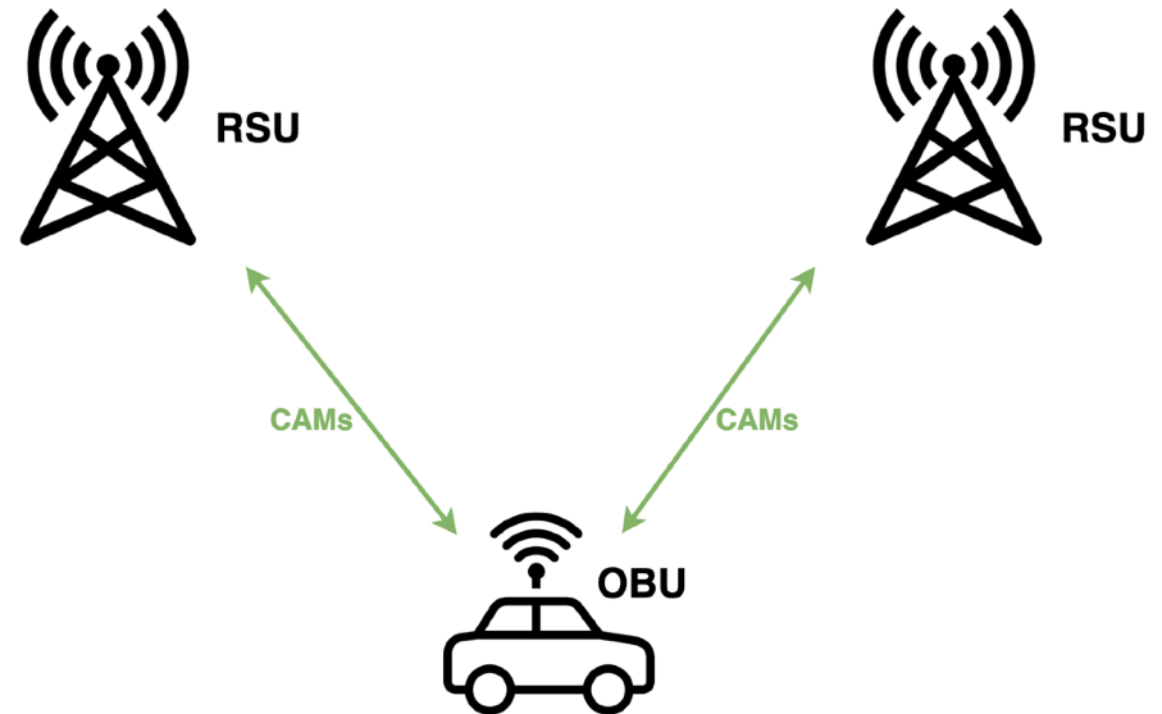
- Programmability
- Efficient Configuration
- Better Performance
- Higher Flexibility



# CAM – Cooperative Awareness Message

*(C-ITS Message)*

- Periodic
  - OBUs (10 Hz)
  - RSUs (1 Hz)
- Information
  - Location
  - Station type
  - Heading
  - Speed



# Existing SDVN Solution





# L3 Traffic based Solution *(Reactive)*

## ■ Architecture

### – Control Plane

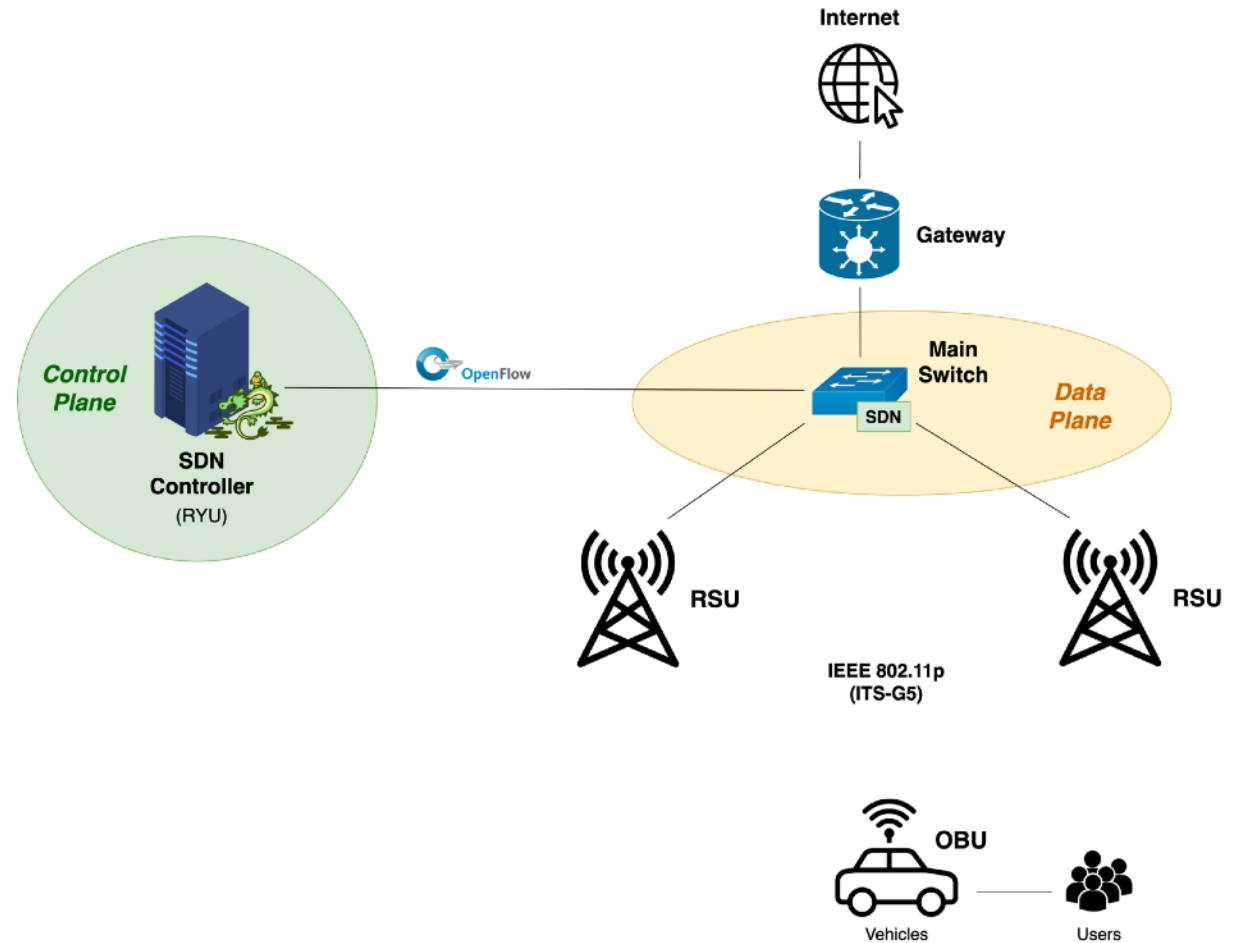
- 1 Controller

### – Data Plane

- 1 Switch

### – Controller $\rightleftharpoons$ Switch

- OpenFlow protocol



# L3 Traffic based Solution *(Reactive)*

- Limitations

- L3 uplink traffic dependent
- Handovers are only detected after they occur



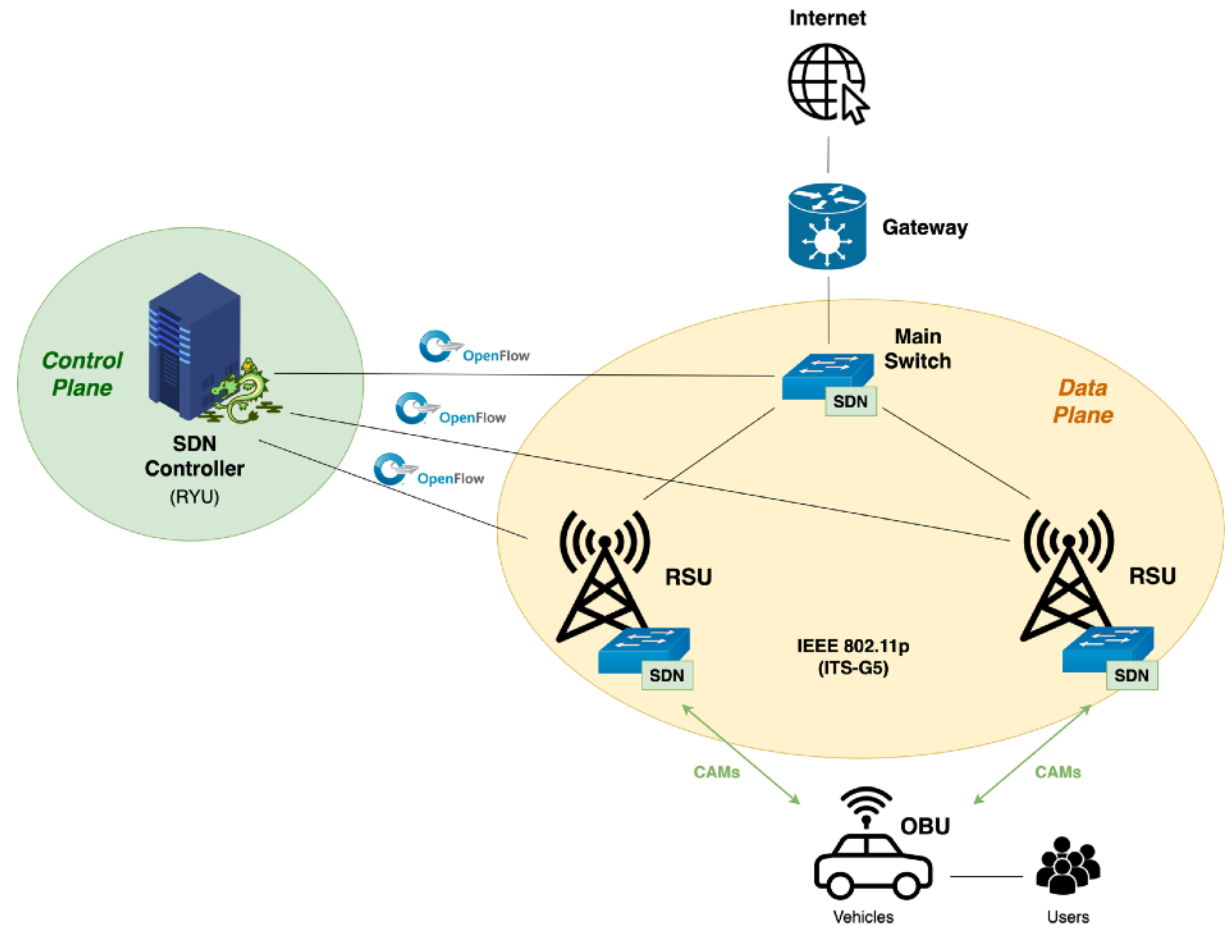
# Proposed SDVN Solution



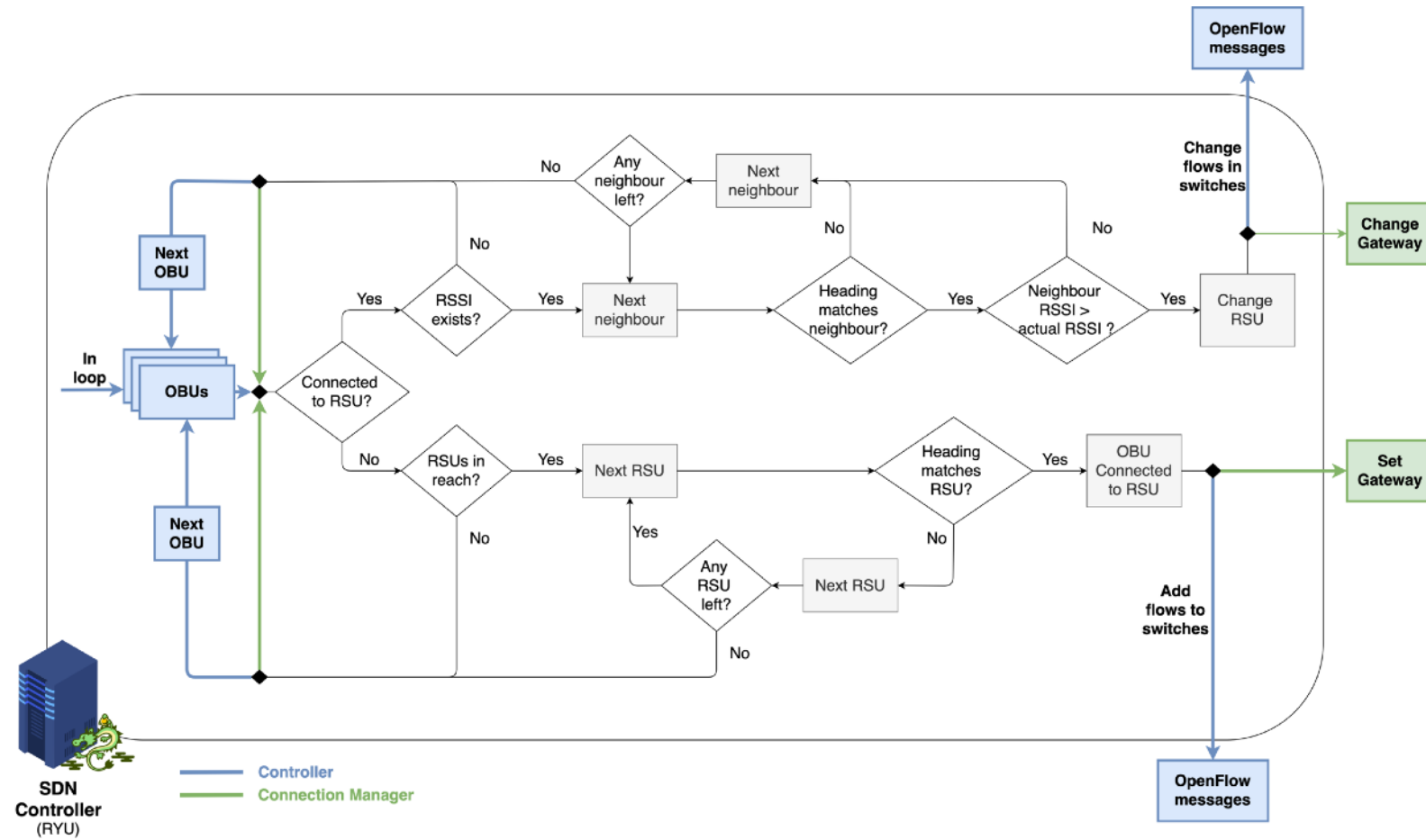
# C-ITS based Solution *(Proactive)*

## ■ Architecture

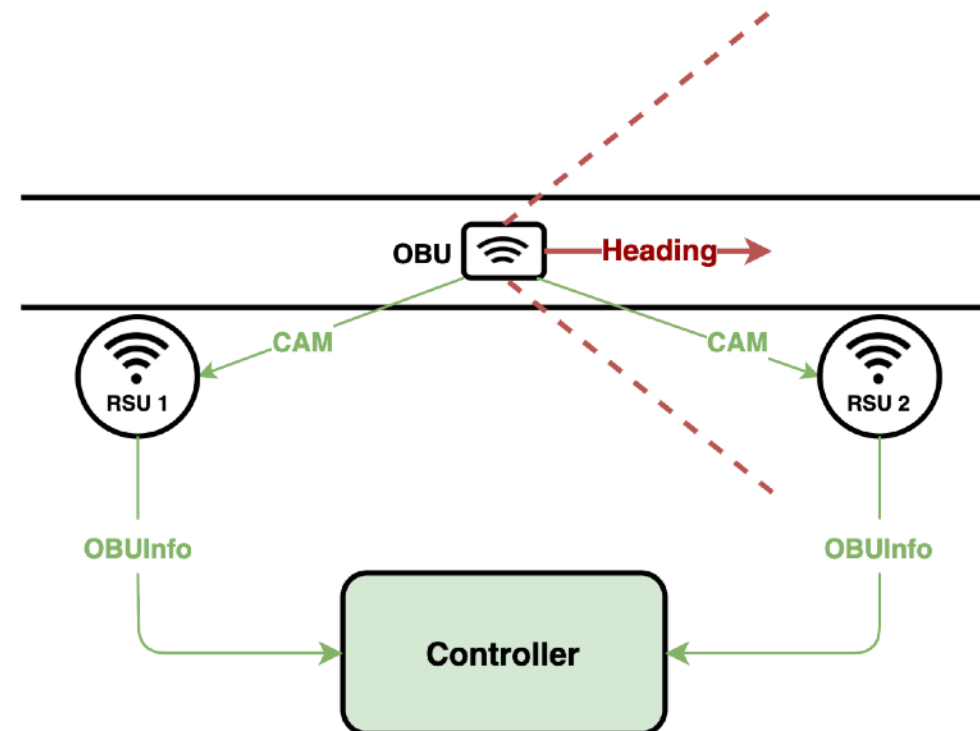
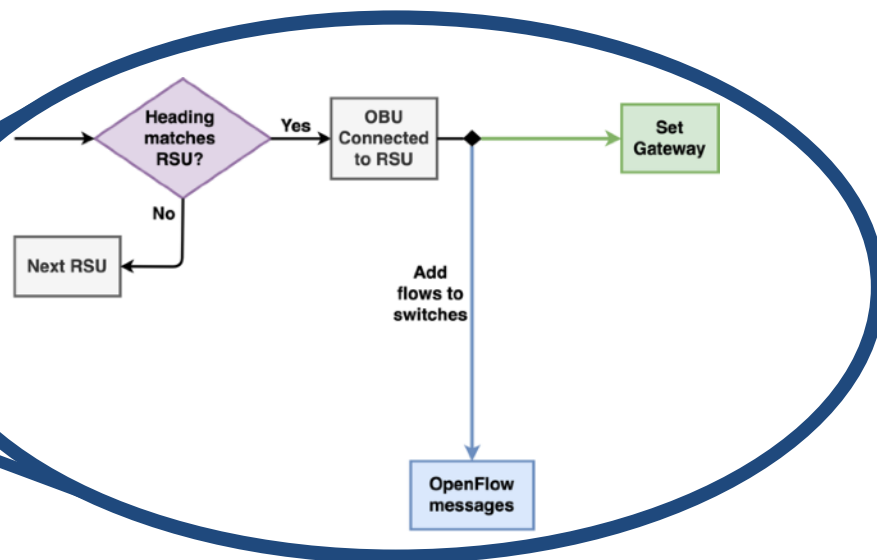
- Control Plane
  - 1 Controller
- Data Plane
  - 3 Switches
- Controller  $\Leftrightarrow$  Switches
  - OpenFlow protocol
- RSU  $\Leftrightarrow$  OBU
  - CAM messages



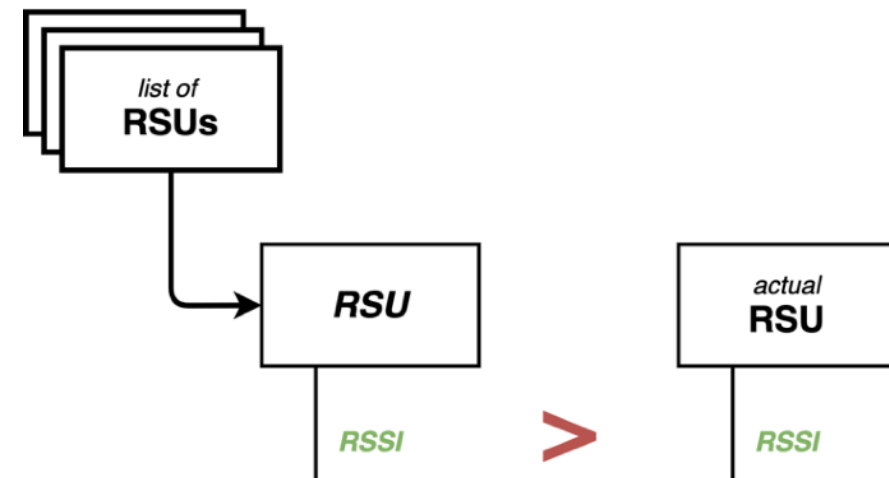
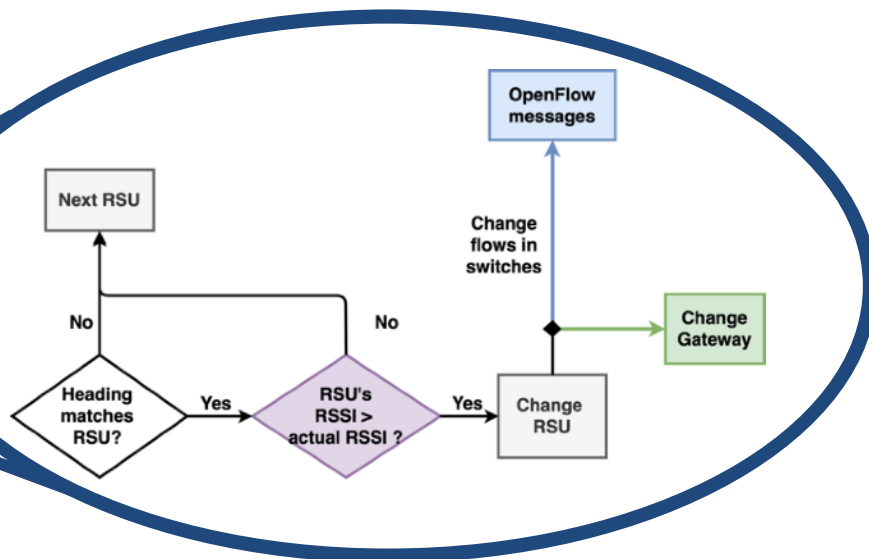
# C-ITS based Solution *(Proactive)*



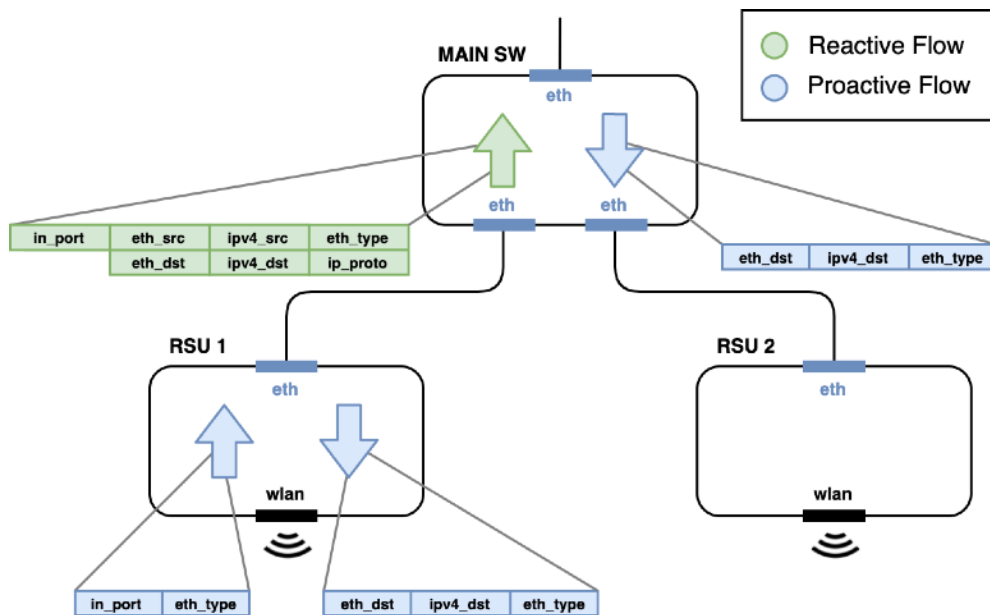
# C-ITS based Solution *(Proactive)*



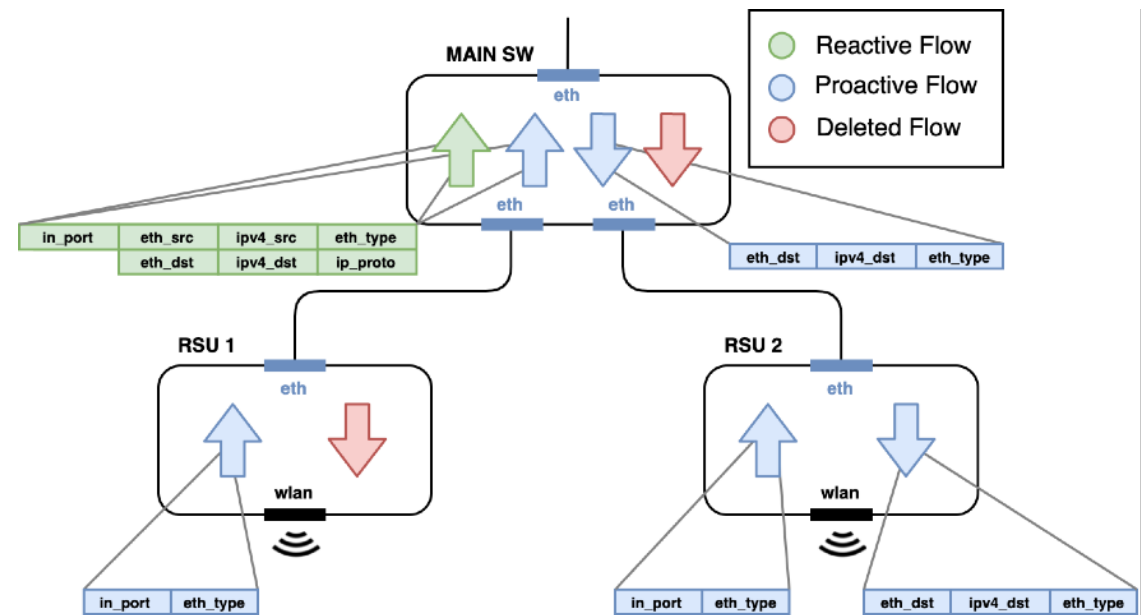
# C-ITS based Solution *(Proactive)*



# C-ITS based Solution *(Proactive)*



*No previous link*



*Previous link*



# Laboratory Environment



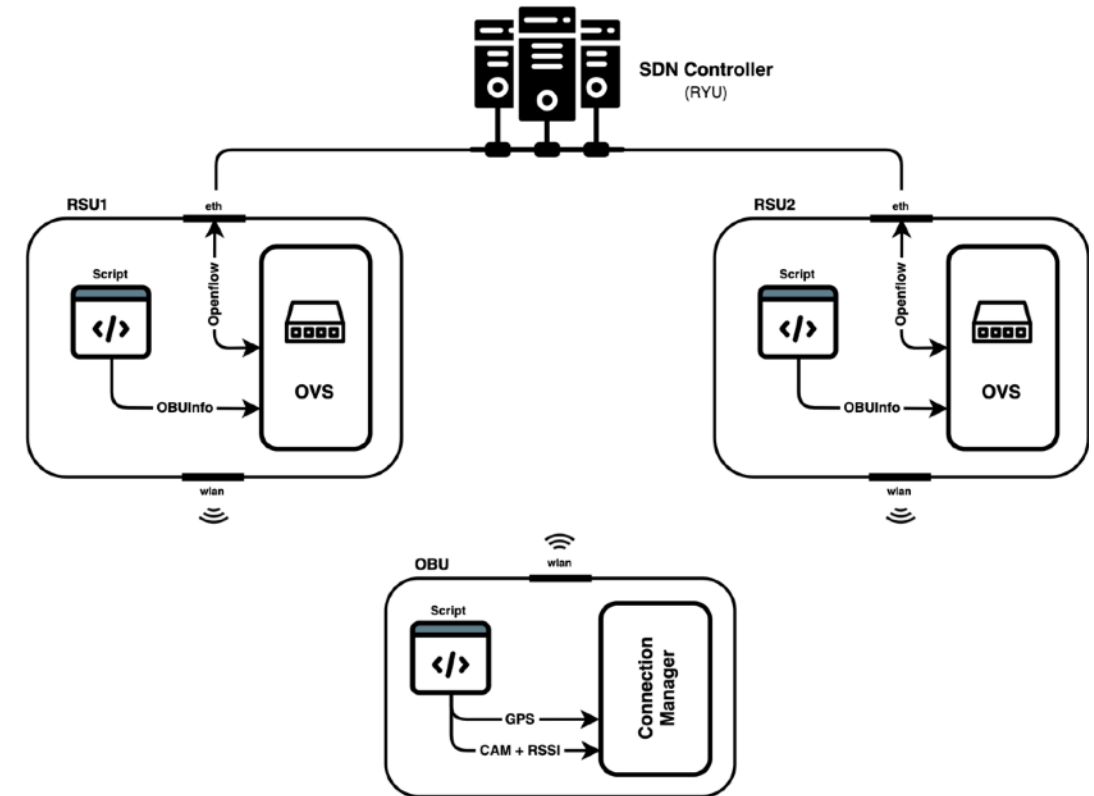
# Setup & Emulation scripts



1 Main SW  
+  
3 RSUs (SWs)



OBU

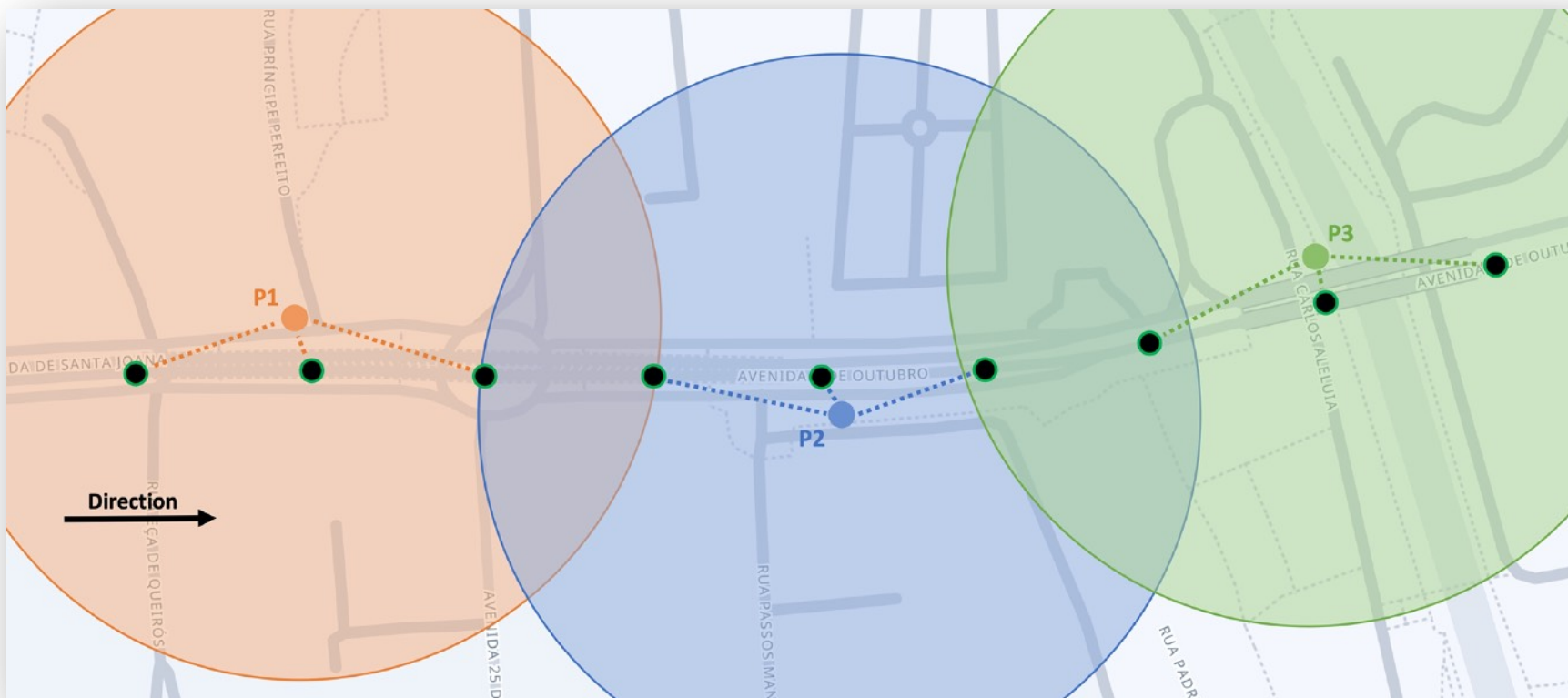


Emulated Info:

- Location
- Heading
- RSSI

# Scenario 1

*Smooth transition of CAMs between RSUs*



# Functional tests - Scenario 1

*Smooth transition of CAMs between RSUs*

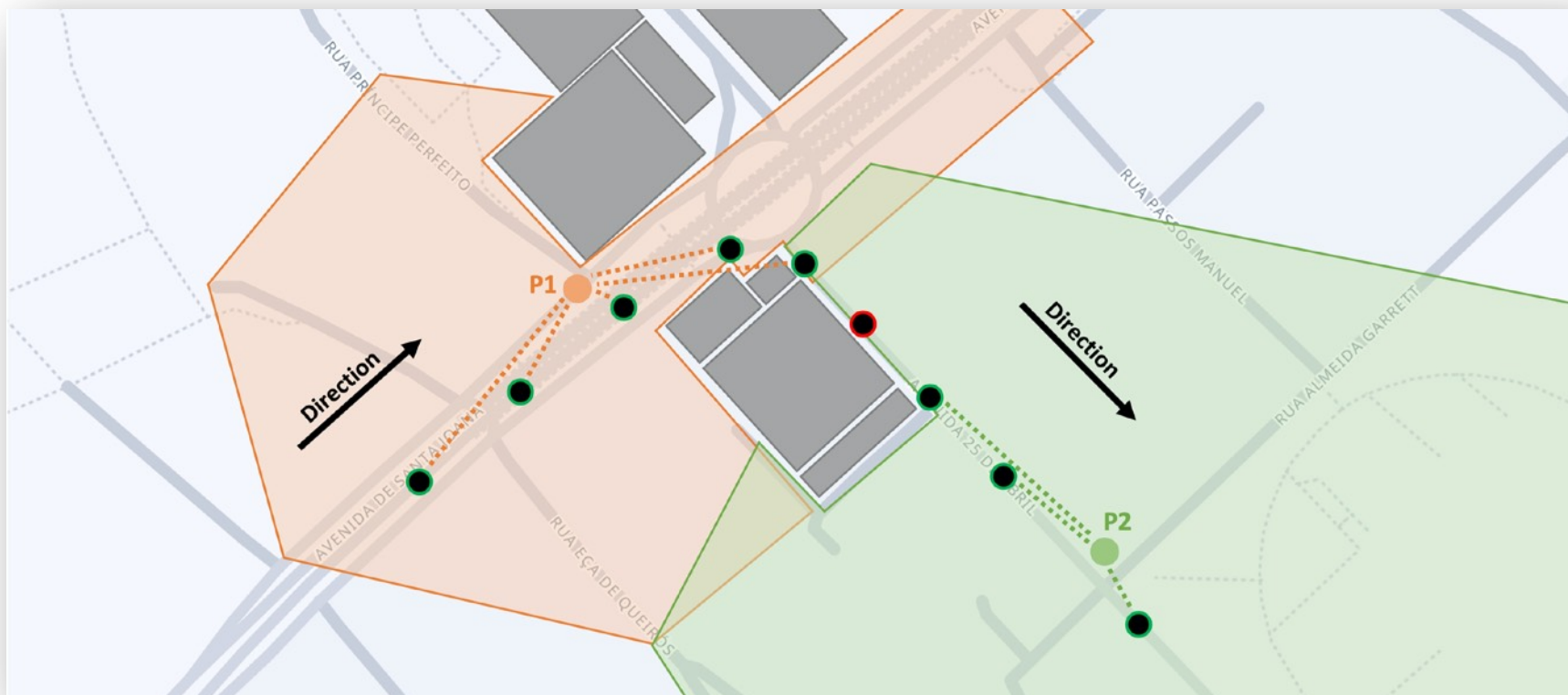


Time	0(s)	6(s)	12(s)	18(s)	24(s)	30(s)	36(s)	42(s)	48(s)
P1's RSSI (dBm)	-60	-50	-60	-70	-	-	-	-	-
P2's RSSI (dBm)	-	-	-70	-60	-50	-60	-70	-	-
P3's RSSI (dBm)	-	-	-	-	-	-70	-60	-50	-60
Direction	45°	45°	45°	45°	45°	45°	45°	45°	45°
Connected to	P1	P1	P1	P2*	P2	P2	P3*	P3	P3
Connectivity	yes	yes	yes	yes	yes	yes	yes	yes	yes

**Conclusions:** Handovers at 18s and 36s due to higher RSSI of neighbour RSU.

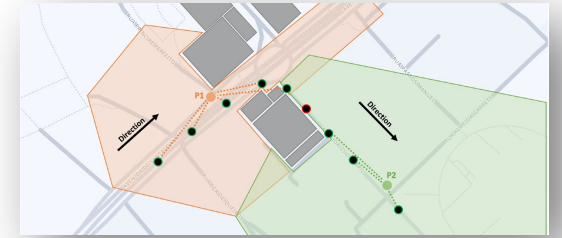
# Scenario 2

*Uneven transition of CAMs between RSUs*



# Functional tests - Scenario 2

*Uneven transition of CAMs between RSUs*



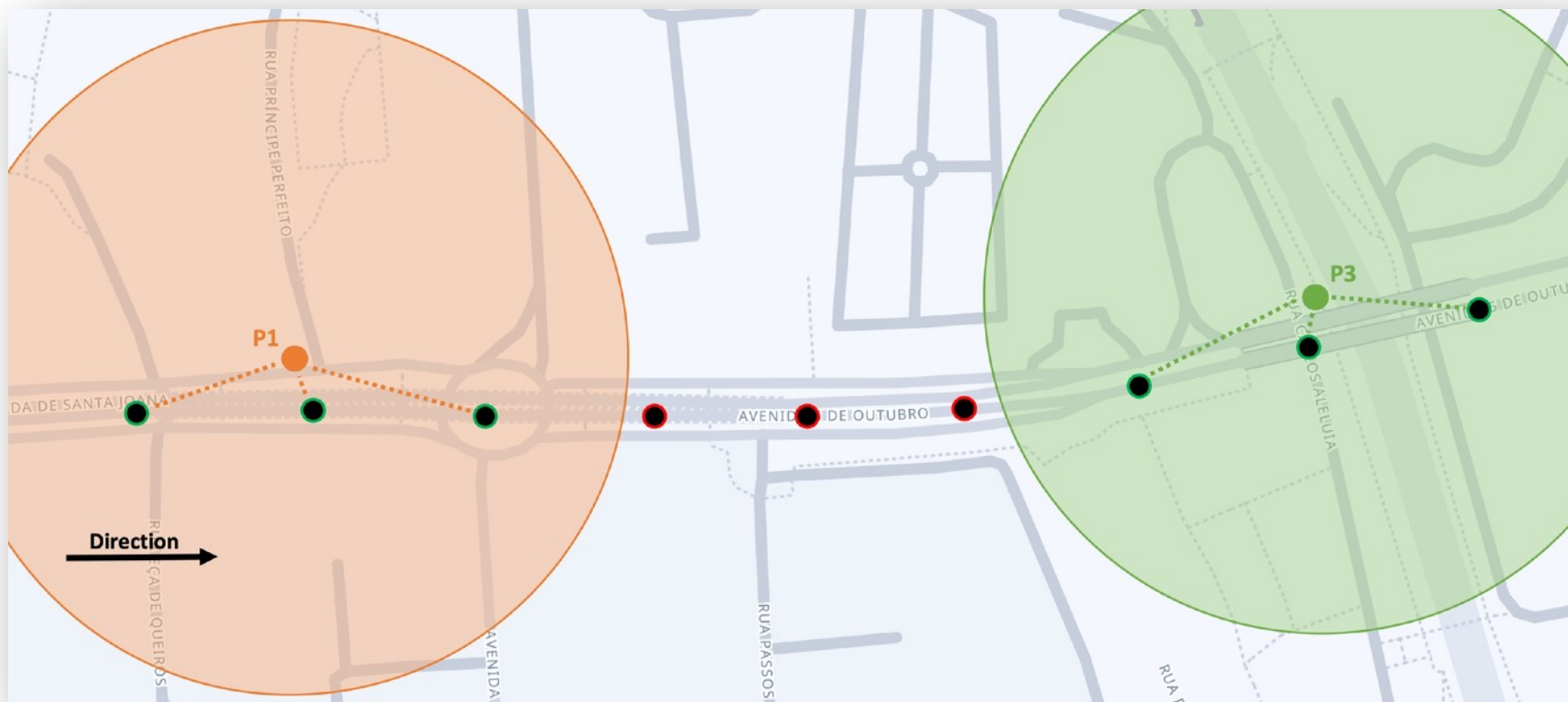
Time	0(s)	6(s)	12(s)	18(s)	24(s)	30(s)	36(s)	42(s)	48(s)
P1's RSSI (dBm)	-70	-60	-50	-55	-60	-	-	-	-
P2's RSSI (dBm)	-	-	-	-	-80	-70	-60	-55	-50
Direction	45°	45°	45°	45°	90°	135°	135°	135°	135°
Connected to	P1	P1	P1	P1	P1	P1	P2*	P2	P2
Connectivity	yes	yes	yes	yes	yes	no	yes	yes	yes

**Conclusions:** Handover at 36s due to timeout being exceeded.



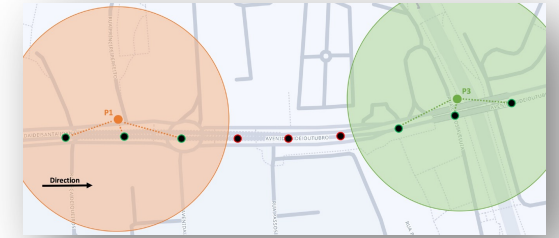
# Scenario 3

*Loss of CAMs reception*



# Functional tests - Scenario 3

## *Loss of CAMs reception*



Time	0(s)	6(s)	12(s)	18(s)	24(s)	30(s)	36(s)	42(s)	48(s)
P1's RSSI (dBm)	-60	-50	-60	-70	-	-	-	-	-
P3's RSSI (dBm)	-	-	-	-	-	-70	-60	-50	-60
Direction	45°	45°	45°	45°	45°	45°	45°	45°	45°
Connected to	P1	P1	P1	P1	P1	P3*	P3	P3	P3
Connectivity	yes	yes	yes	yes	no	yes	yes	yes	yes

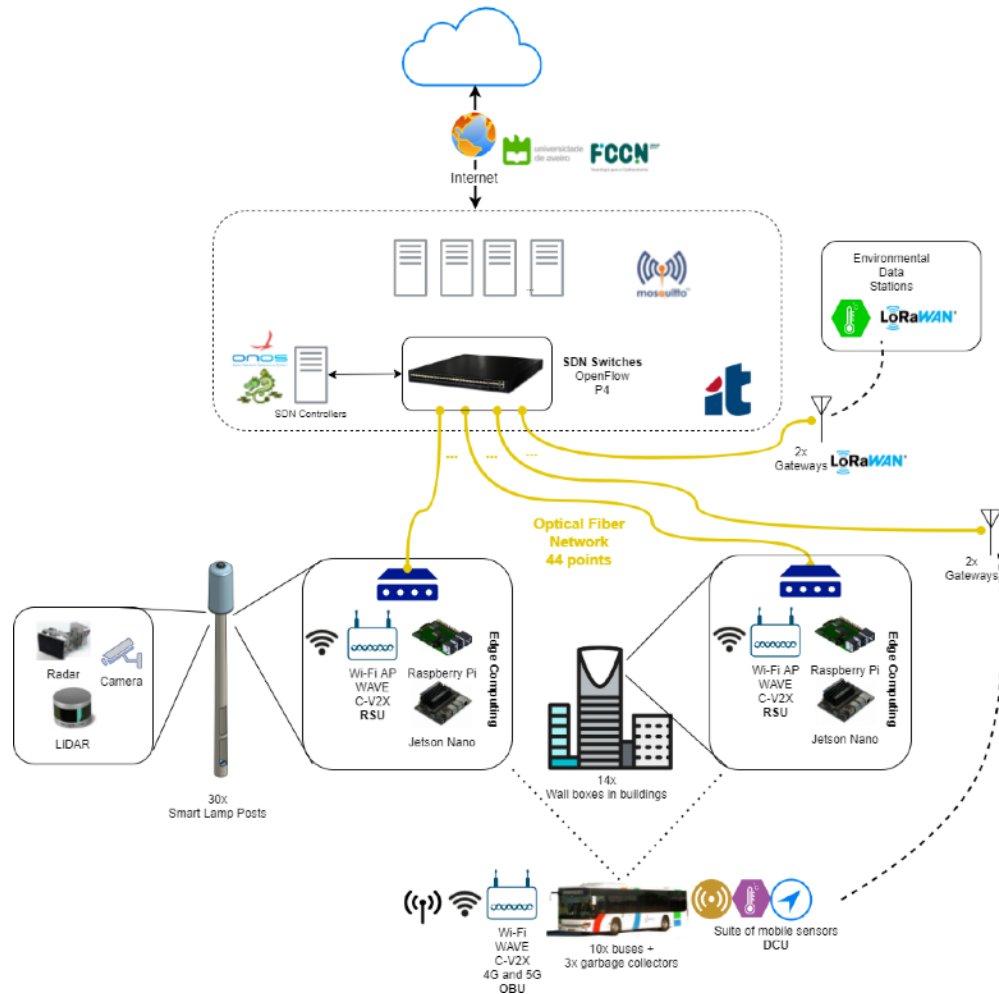
**Conclusions:** Handover at 30s due to timeout being exceeded.



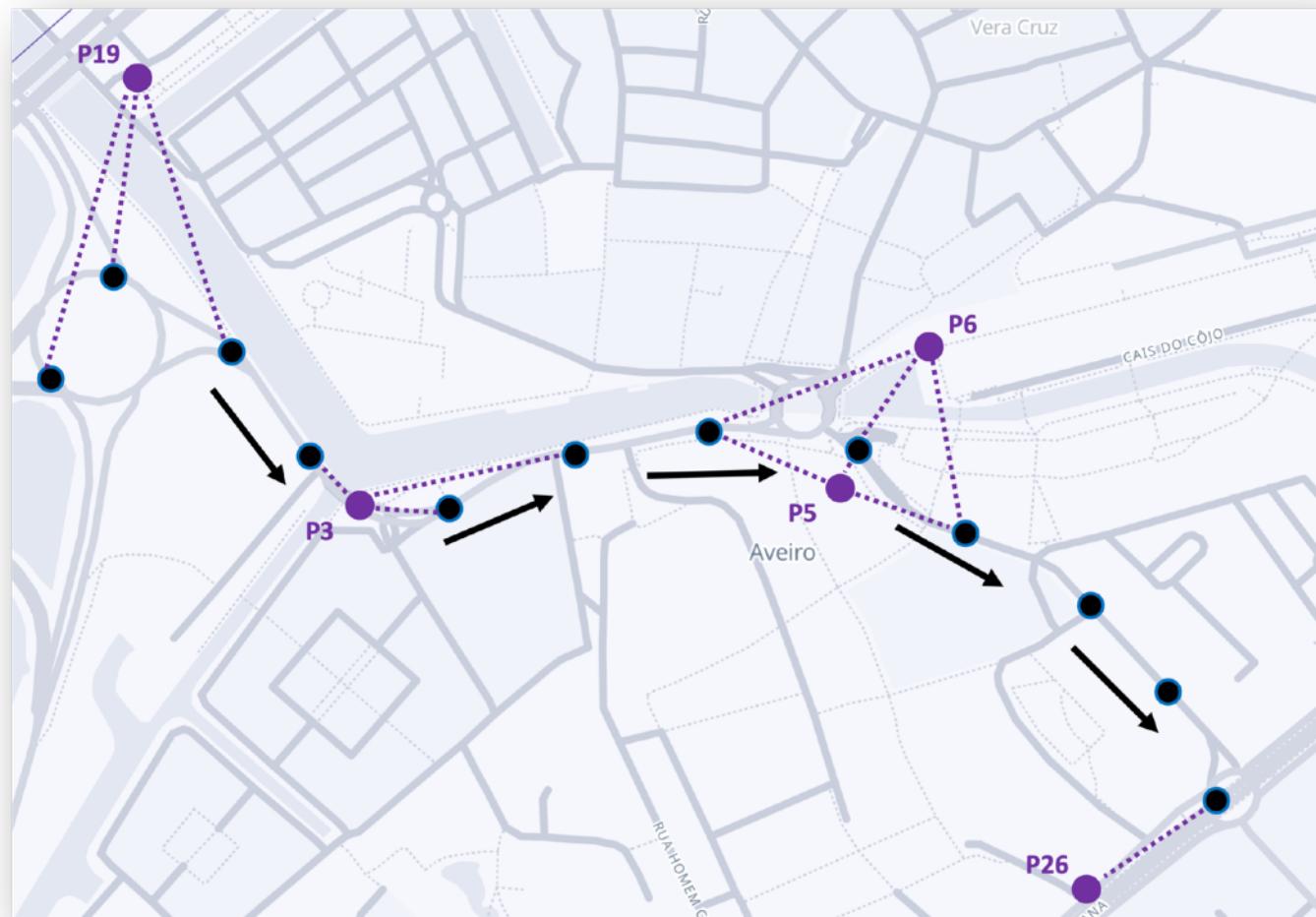
# City Environment (Aveiro)



# Aveiro Tech City Living Lab



# Scenario

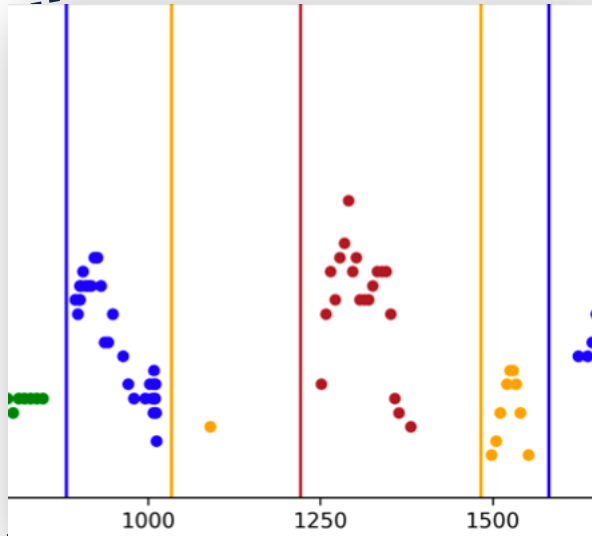
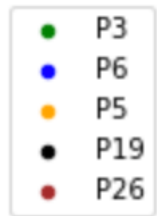


# City Results

*Application tests*

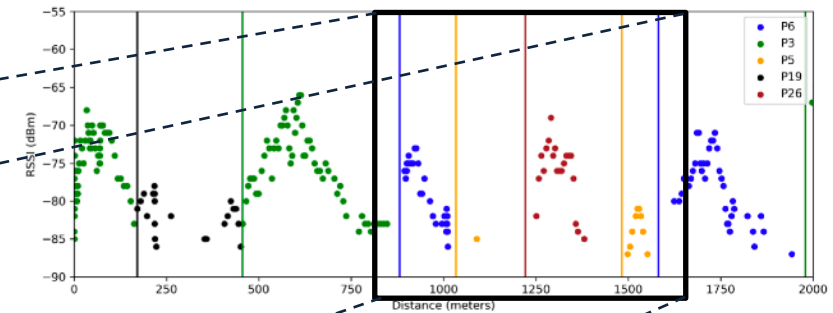


# Application tests (*RSSI*)

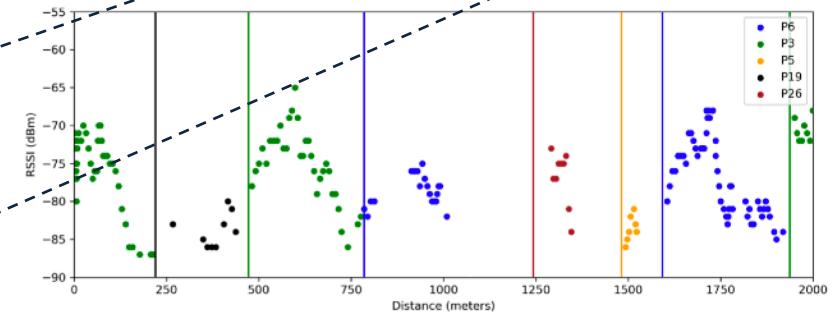


*Proactive*

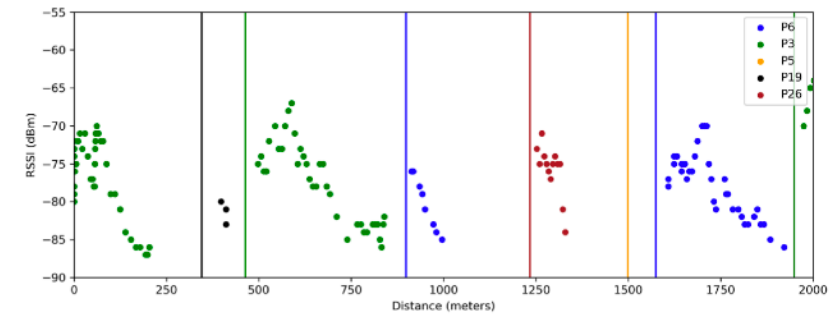
**Conclusions:** The proactive version makes handovers through all the RSUs, which shows the high responsiveness of the solution



(a) Proactive

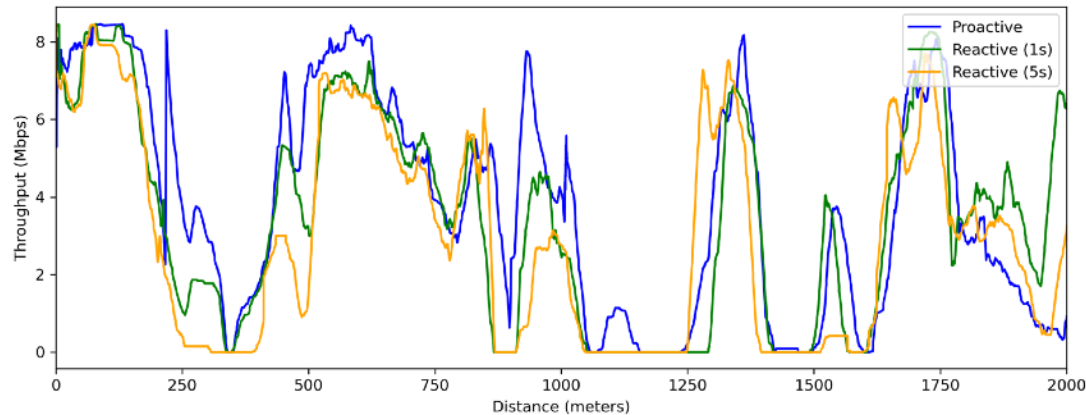


(b) Reactive (1s)

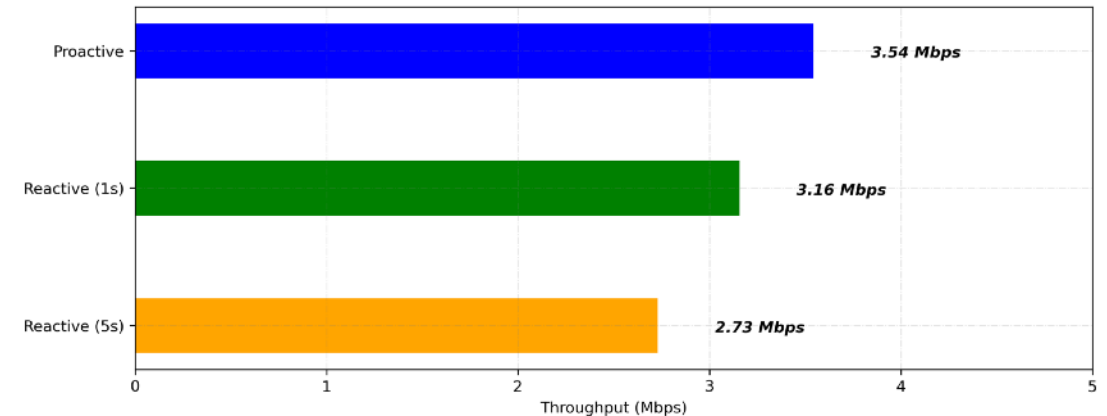


(c) Reactive (5s)

# Application tests *(Throughput)*



Proactive	Reactive (1s)	Reactive (5s)
68,69%	62,37%	56,01%



**Conclusions:** The proactive version obtained the longest period of connectivity with the infrastructure and the highest average throughput, which demonstrates the great importance of traffic frequency (CAMs)

# Conclusions and Future Work



# Conclusions

- Combine the use of C-ITS messages with an SDVN architecture
- Increase in connectivity time and higher average throughput, which translates into a better user experience
- Possibility of initiating L3 communication with a specific OBU even if there is no L3 uplink traffic
- Viability of the solution outside a laboratory environment





# Future work

- Increase the number of SDN-capable entities
- Integration of new communication technologies
- Mobility path prediction



# Thank you!

