Università degli Studi di Padova
Dipartimento di Matematica "Tullio Levi-Civita"
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FAST MESSAGE PROPAGATION OVER IOV SCENARIOS

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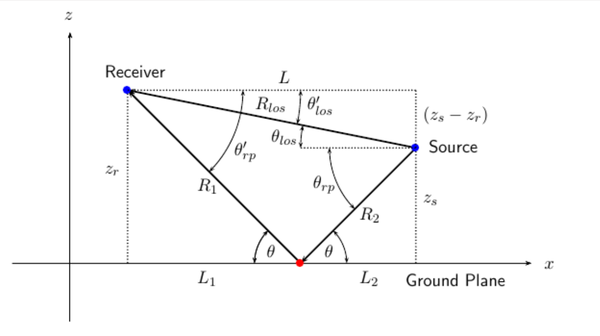
CONTENTS

CONTEXT

- Vehicular and Flying Ad-Hoc Networks (VANETs and FANETs)
- Several applications
  - Smart city management
  - Video streaming
  - Traffic control
- Focus: Emergency Message Distribution (EMD)
  - Message delivery
  - Timeliness
  - Avoid medium saturation

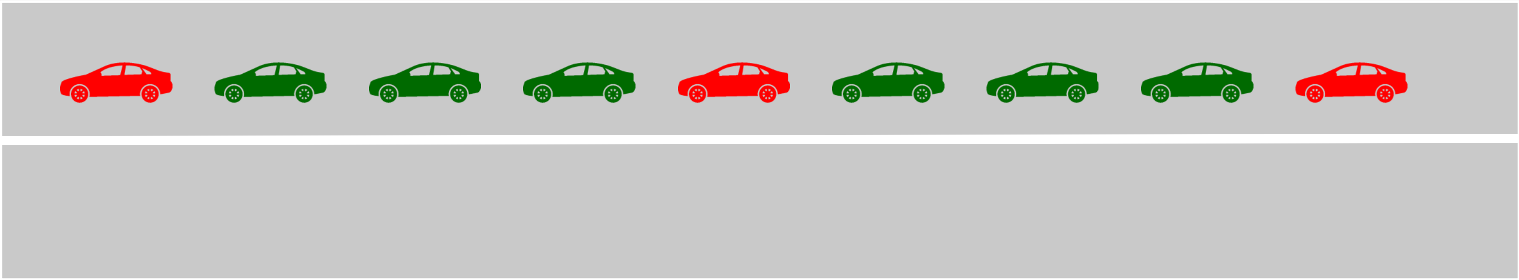
TECHNOLOGIES AND TOOLS

- Expensive large scale tests
  - Need to use simulators (ns-3)
- Additional tools and models
  - Real map data
  - Road junction modeling
- Signal propagation models
  - Two-Ray Ground
  - Obstacle shadowing (with 3D extension)



ALGORITHM CLASSIFICATION

- Multi-hop propagation
  - Farthest forwarder definition
  - Two main approaches

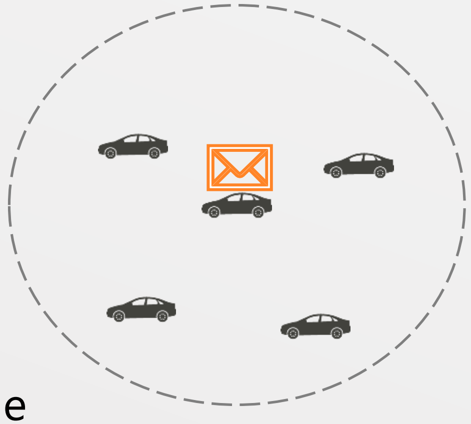


Multi-hop algorithms

Probabilistic	Deterministic
Reliability 👍	Reliability 👎
End to end delay 👎	End to end delay 👍

FAST-BROADCAST

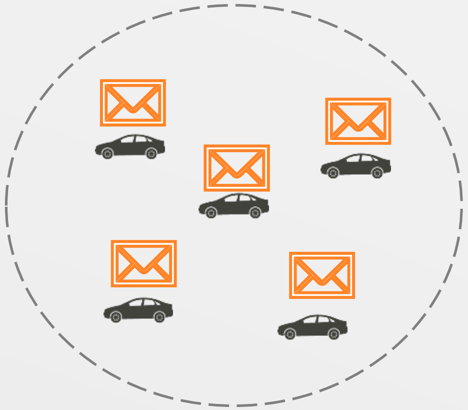
- Multi-hop **probabilistic** delay-based broadcasting protocol
- Dynamic transmission range estimation
  - No need to know it *a priori*, as often assumed in other protocols
- Estimation Phase:
  - Vehicles exchange small *Hello Messages* (beacons) to estimate their transmission range
  - **1 Hello Message** sent every *BeaconInterval* (e.g., 100ms) within each transmission range
- Broadcast Phase:



Waiting time	[0...1024]	[0...512]	[0...32]

ROFF (RObust Fast Forwarding)

- Multi-hop **deterministic** delay-based broadcasting protocol
- Estimation Phase:
  - **Each vehicle** sends a Hello Message every *BeaconInterval* (e.g., 100ms)
  - Neighborhood discovery process



- Broadcast Phase:

Priority	*3*	*2*	*1*
Waiting time	2	1	0

MY CONTRIBUTIONS

- Improvements to Fast-Broadcast
- Implementation and extension to 2D and 3D scenarios of ROFF
- Evaluation and comparison of Fast-Broadcast and ROFF through simulations
  - Urban scenarios of increasing complexity and realism
- Proposal of extension to exploit road junctions to increase message delivery ratios
  - **SJ-Fast-Broadcast** and **SJ-ROFF** (SJ=Smart Junction)

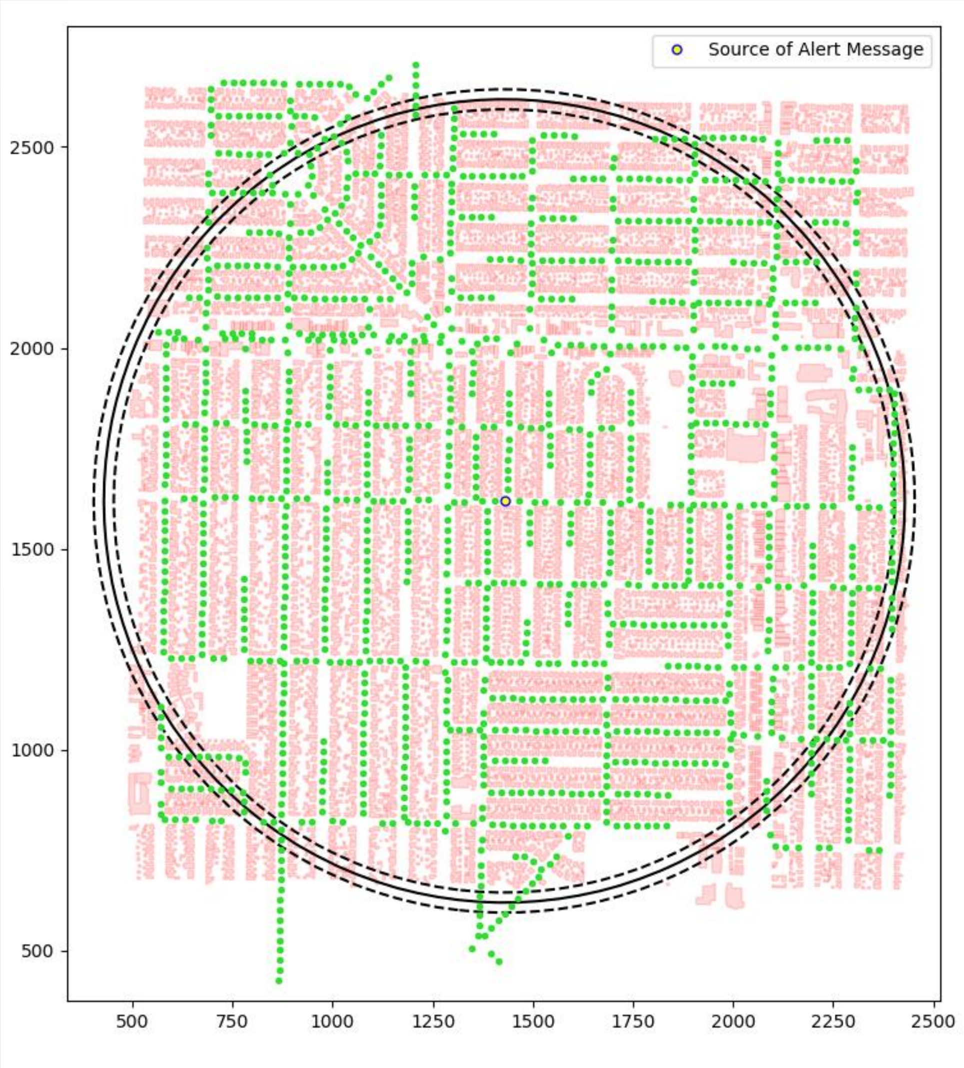
SIMULATIONS – SCENARIOS AND METRICS

- Several scenarios of increasing complexity and realism

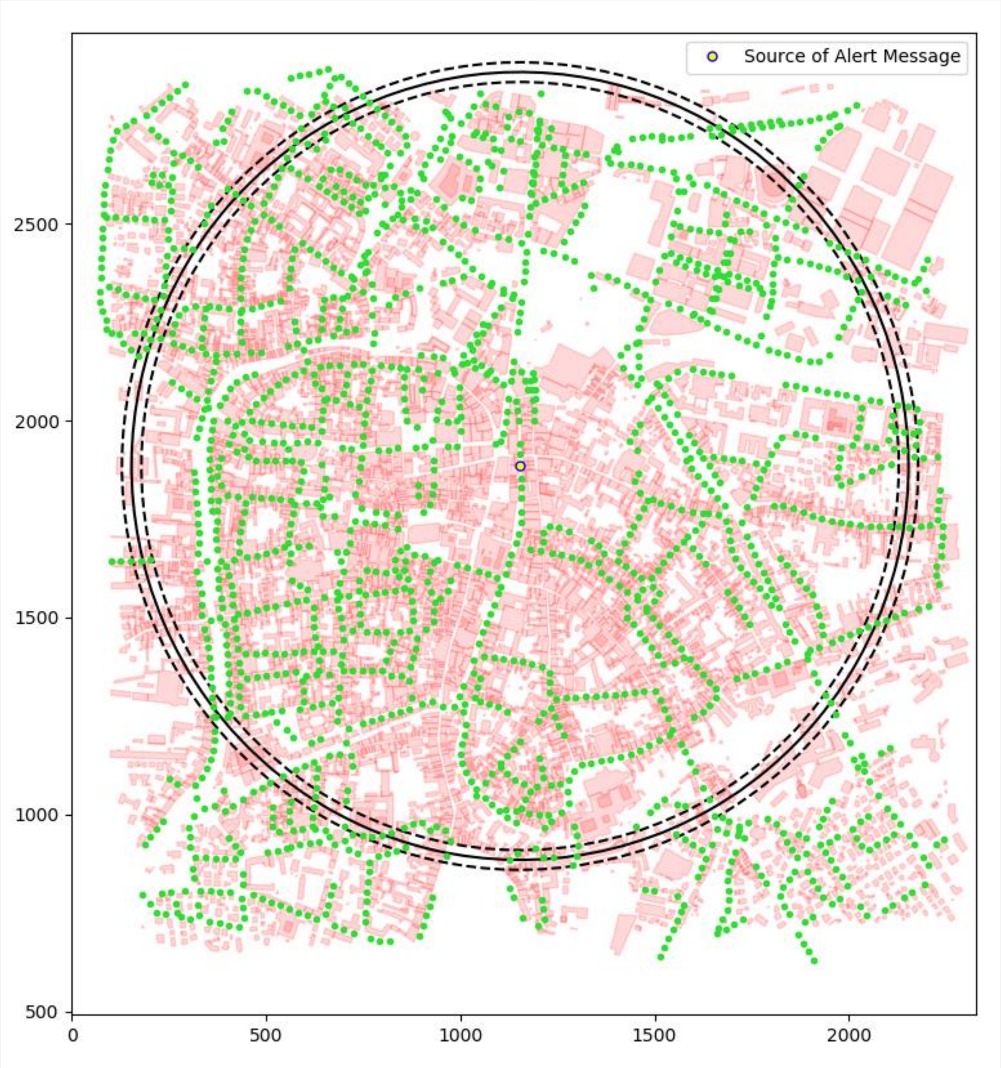
Scenario name	Type	Buildings	Drones
Platoon	1D	✗	✗
Grid	2D	✓	✗
Los Angeles	2D	✓	✗
Padua	2D	✓	✗
Los Angeles smart city	3D	✓	✓

- Metrics:
  - Coverage ↑
  - End-to-end delay ↓
  - Redundancy ↓

URBAN SCENARIOS



Los Angeles



Padua

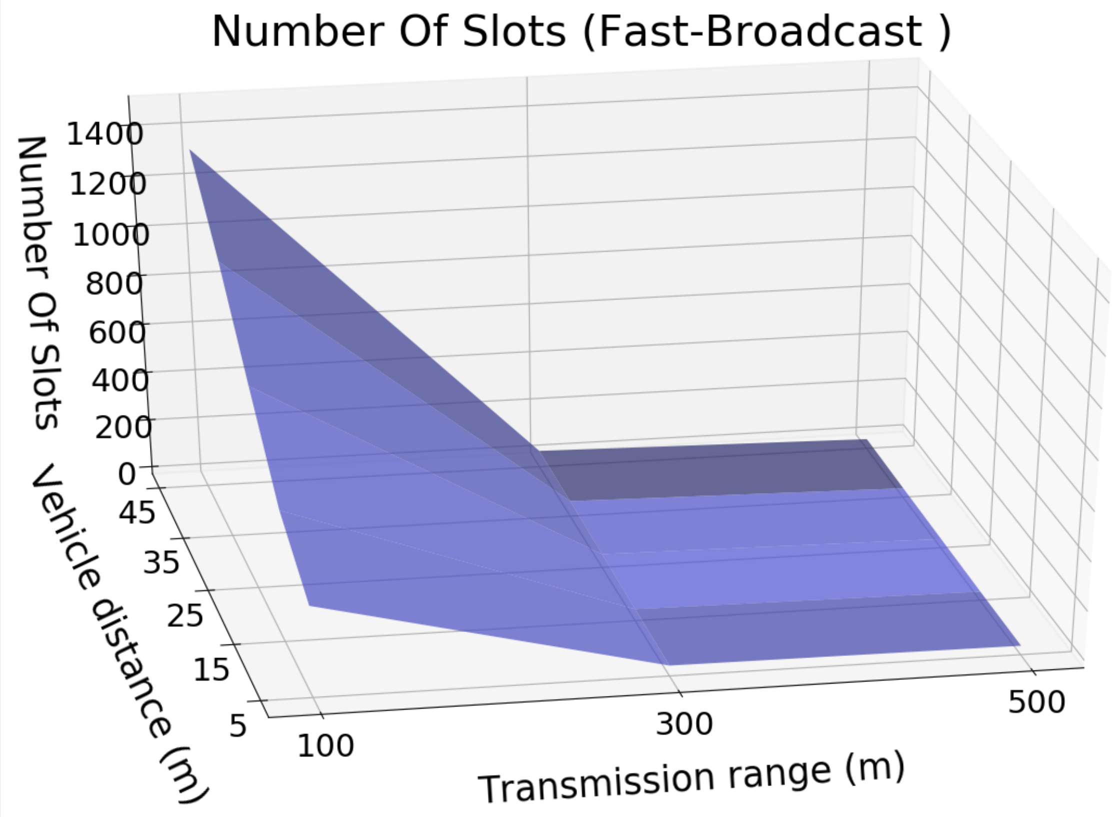
PRELIMINARY TESTS - CONFIGURATION

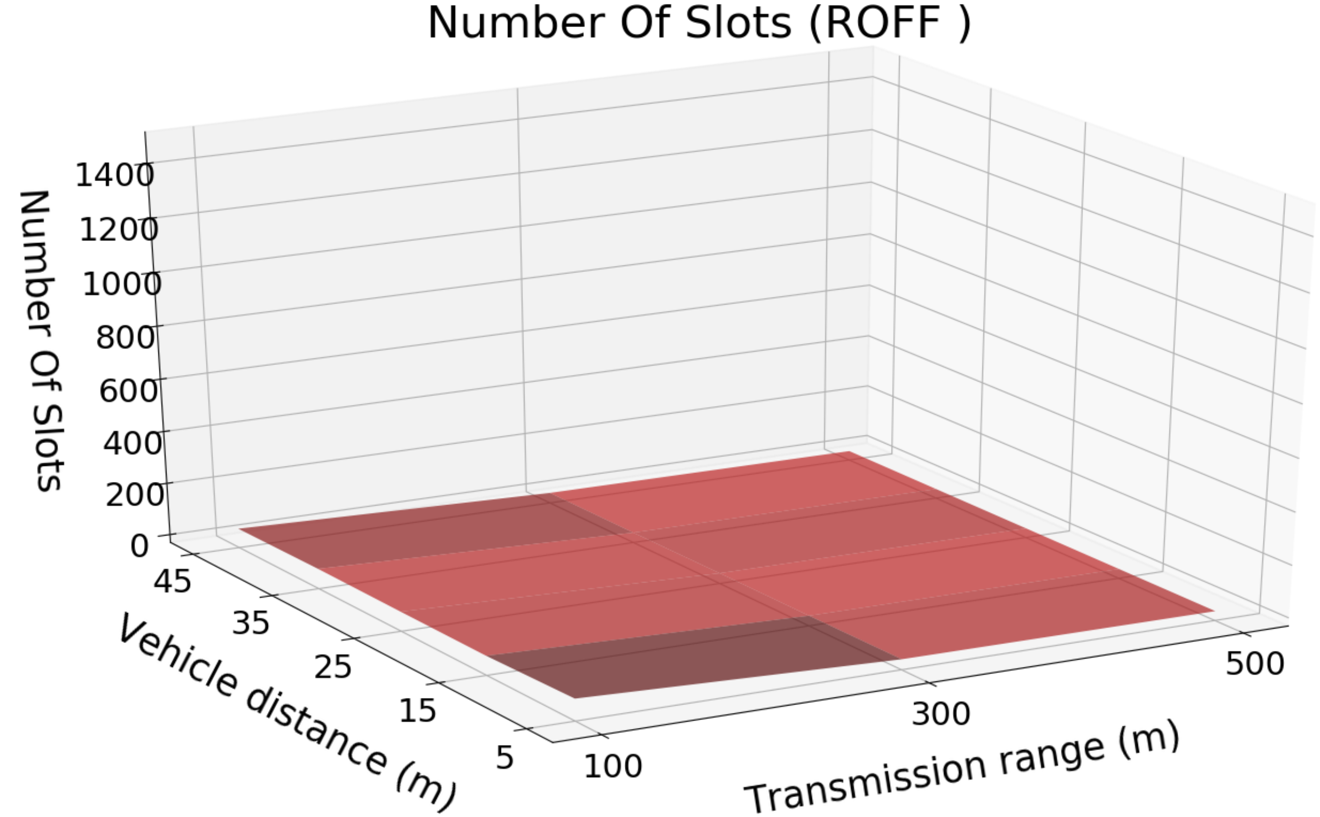
Scenario configuration	
Scenario name	Padua
Latitude N [°]	45.4171
Latitude S [°]	45.3981
Longitude W [°]	11.8654
Longitude E [°]	11.8923
Circumference radius [m]	1000
Distance between vehicles [m]	5, 15, 25, 35, 45
Number of vehicles	4975, 2856, 1775, 1318, 1072
Number of simulations	4500

Simulator configuration	
Packet payload size	100 byte
Frequency [GHz]	2.4
Channel bandwidth [MHz]	22
Transmission speed [Mbps]	11
Transmission powers [dBm]	-7.0, 4.6, 13.4
Transmission ranges [m]	100, 300, 500
Modulation	DSSS
Propagation loss model	ns3::TwoRayGround
Propagation delay model	ns3::ConstantSpeed

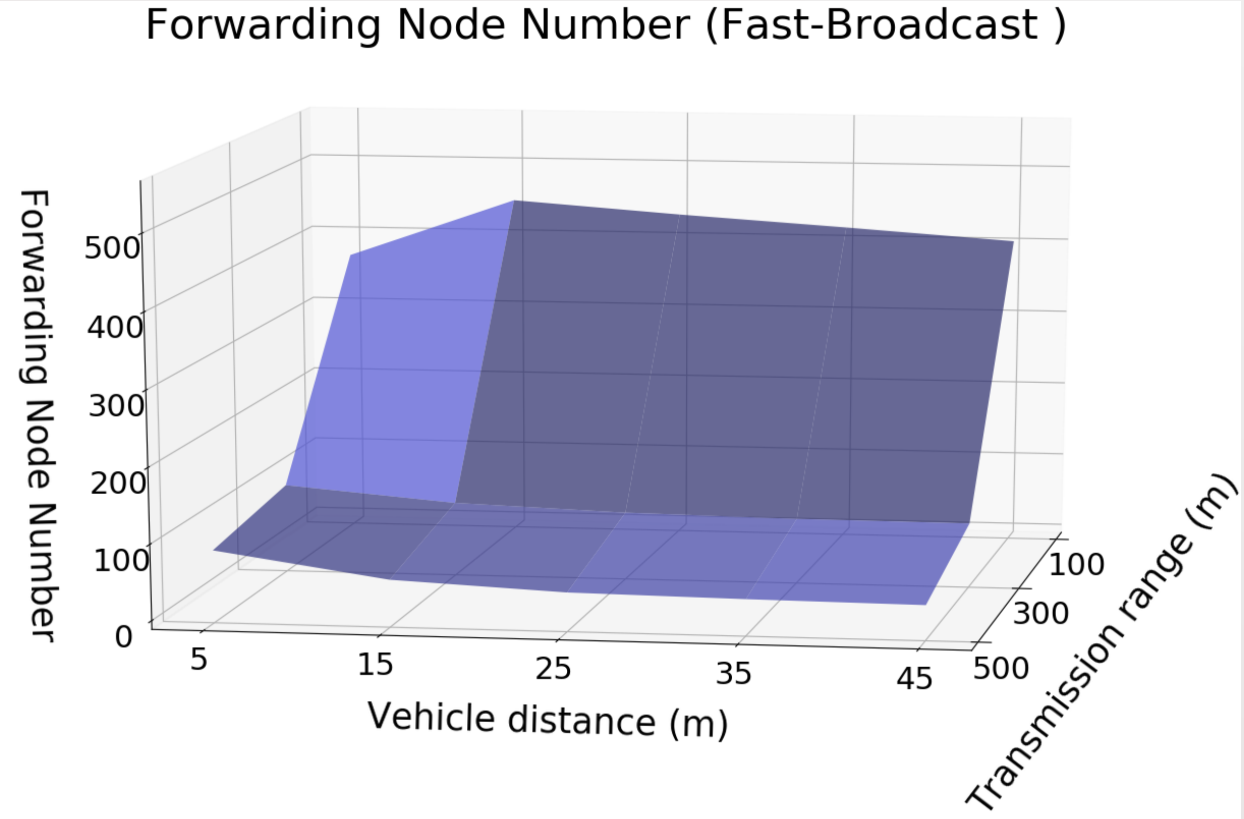
END-TO-END DELAY ↓

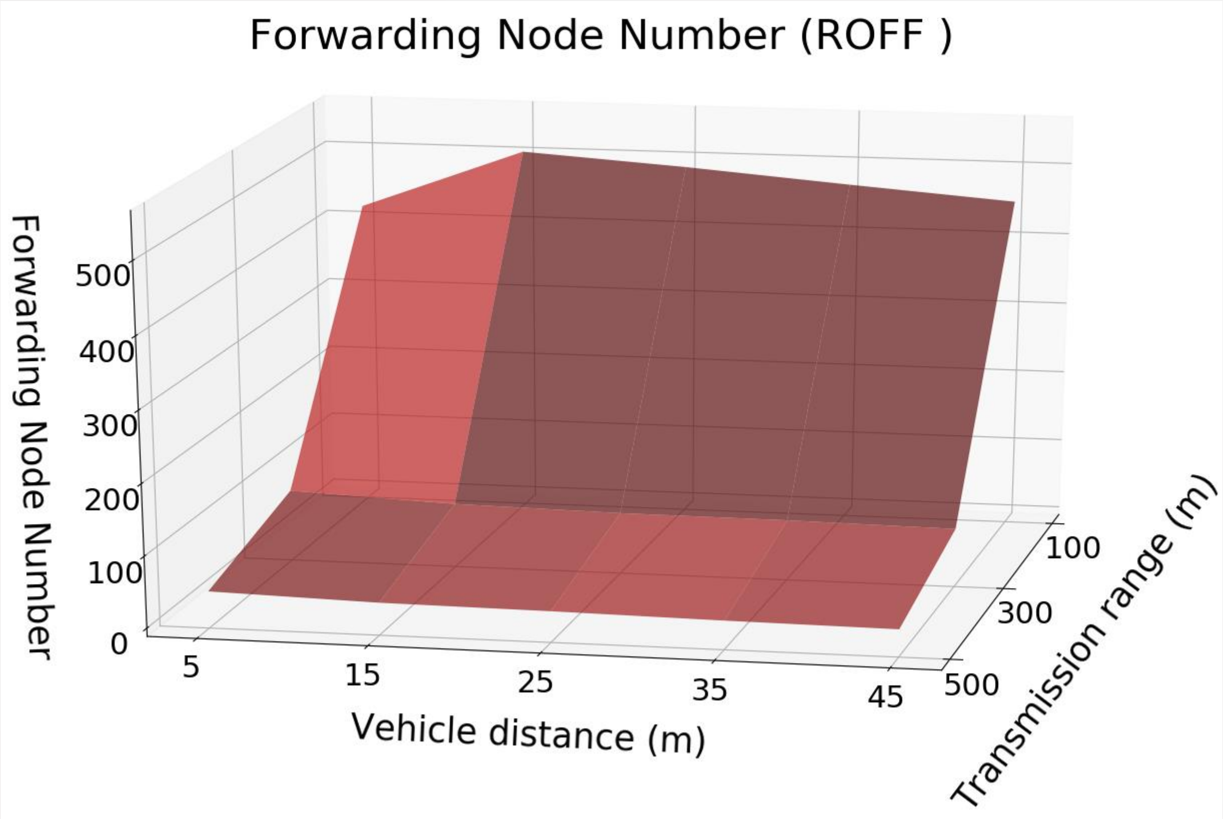
- Coverage ↑ : comparable results
- End-to-end delay ↓ :





REDUNDANCY ↓


Forwarding Node Number (Fast-Broadcast)
Forwarding Node Number
0
100
200
300
400
500
5
15
25
35
45
Vehicle distance (m)
100
300
500
Transmission range (m)

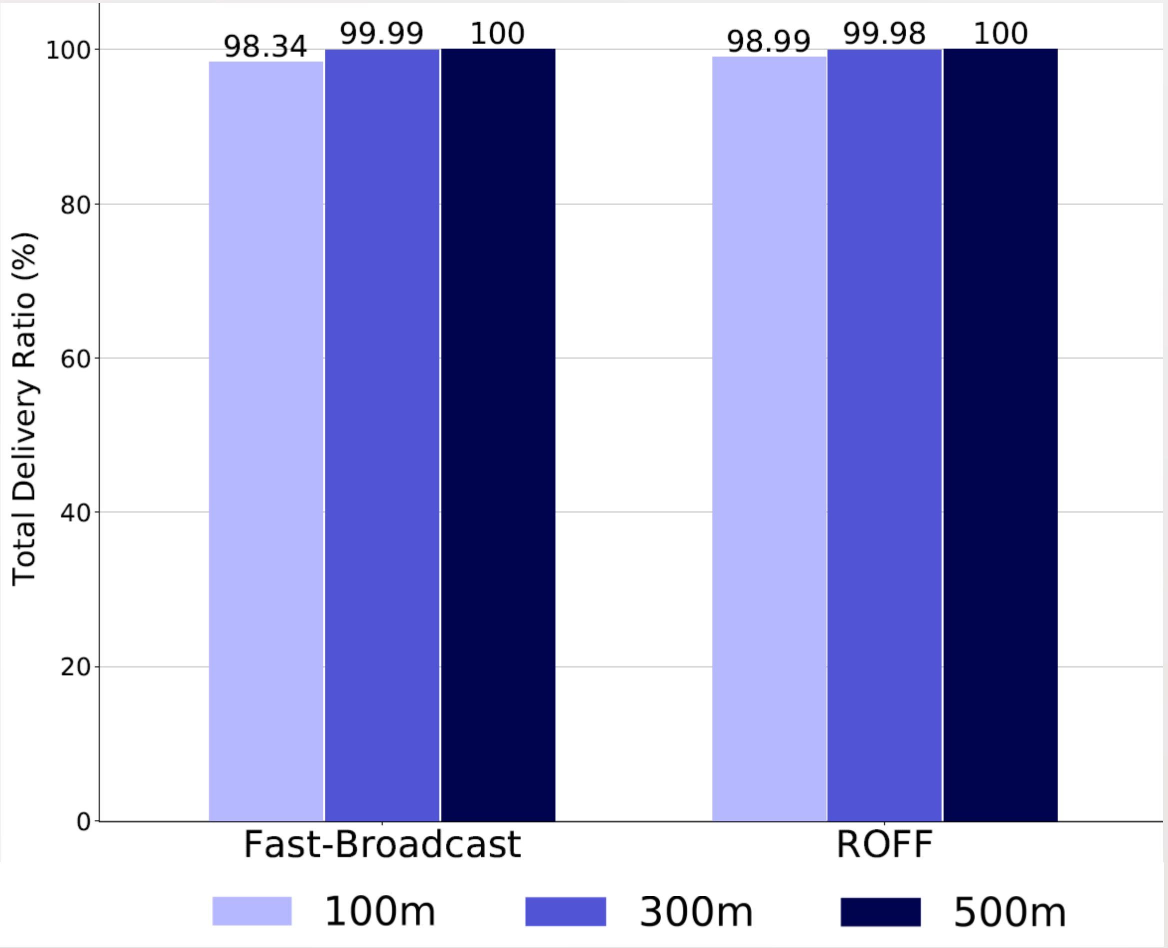

Forwarding Node Number (ROFF)
Forwarding Node Number
0
100
200
300
400
500
5
15
25
35
45
Vehicle distance (m)
100
300
500
Transmission range (m)

PADUA WITH BUILDINGS

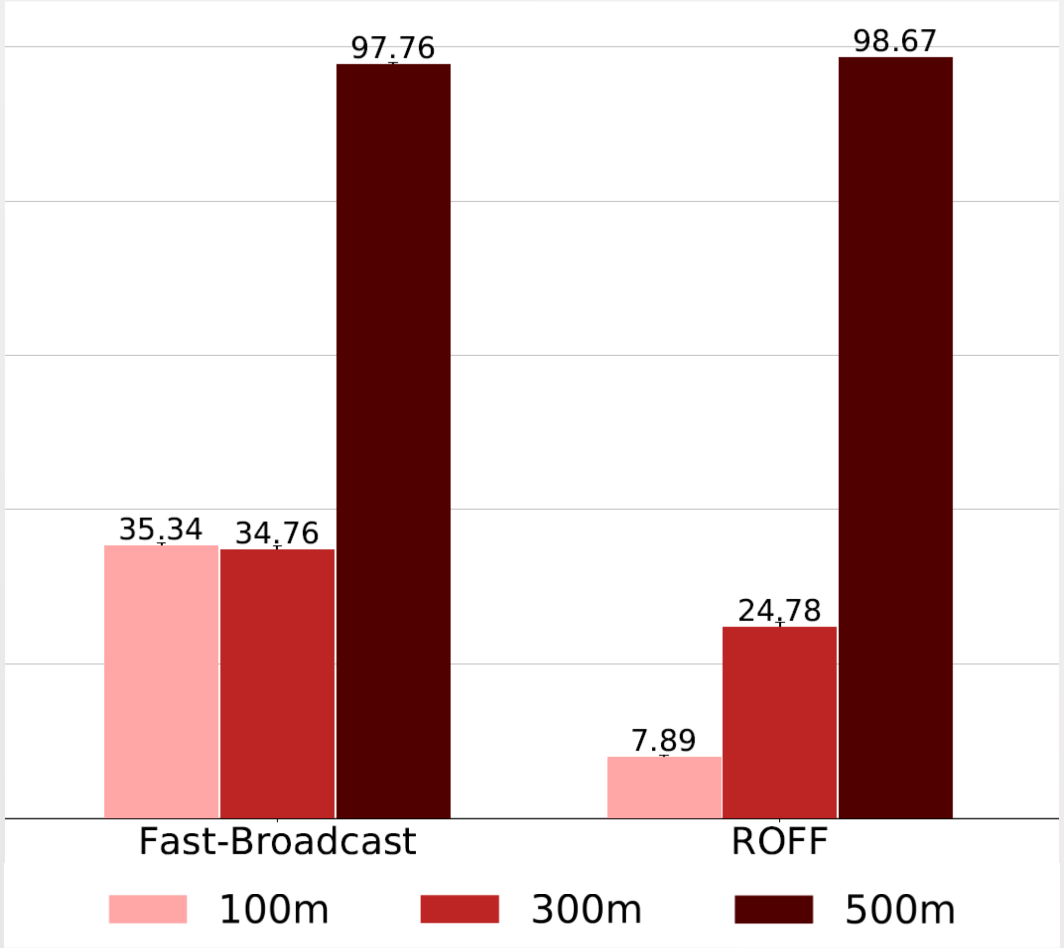
Scenario configuration	
Scenario name	Padua
Latitude N [°]	45.4171
Latitude S [°]	45.3981
Longitude W [°]	11.8654
Longitude E [°]	11.8923
Circumference radius [m]	1000
Distance between vehicles [m]	25
Number of vehicles	1775
Number of buildings	**6322**
Number of simulations	4500

Simulator configuration	
Packet payload size	100 byte
Frequency [GHz]	2.4
Channel bandwidth [MHz]	22
Transmission speed [Mbps]	11
Transmission powers [dBm]	-7.0, 4.6, 13.4
Transmission ranges [m]	100, 300, 500
Modulation	DSSS
Propagation loss model	ns3::TwoRayGround
Propagation delay model	ns3::ConstantSpeed
Shadowing model	**ns3::ObstacleShadowing**

PADUA WITH BUILDINGS – COVERAGE ↑



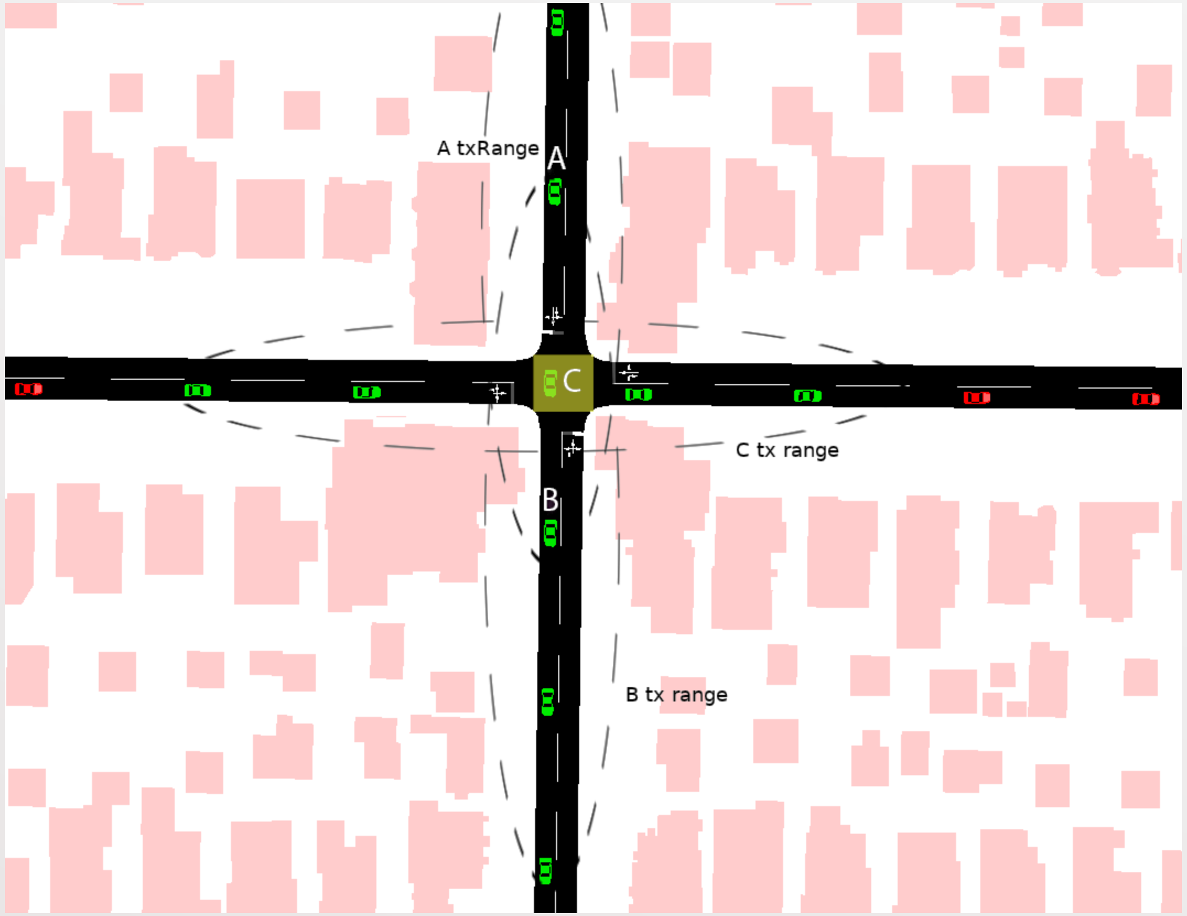
Without buildings



With buildings

EXPLOITING JUNCTIONS – EXAMPLE

Without junction model



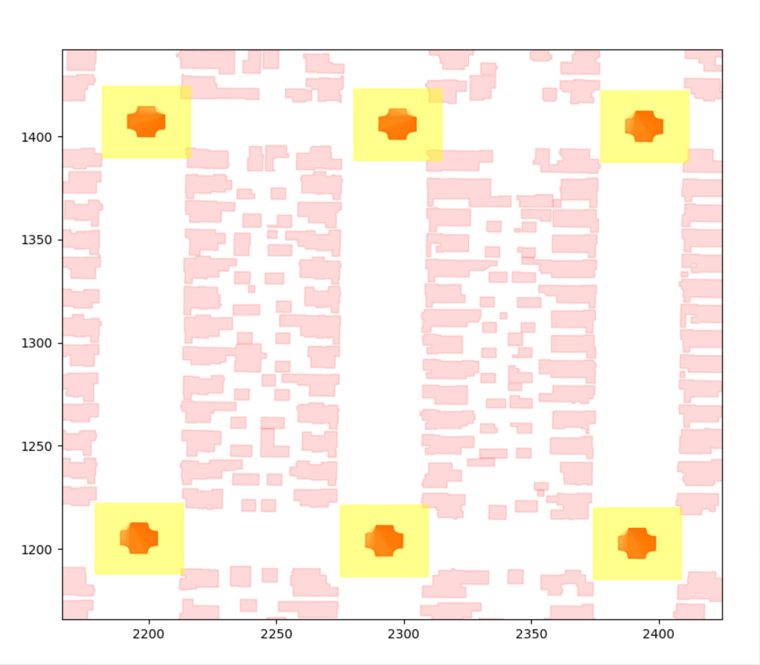
With junction model

JUNCTION MODEL

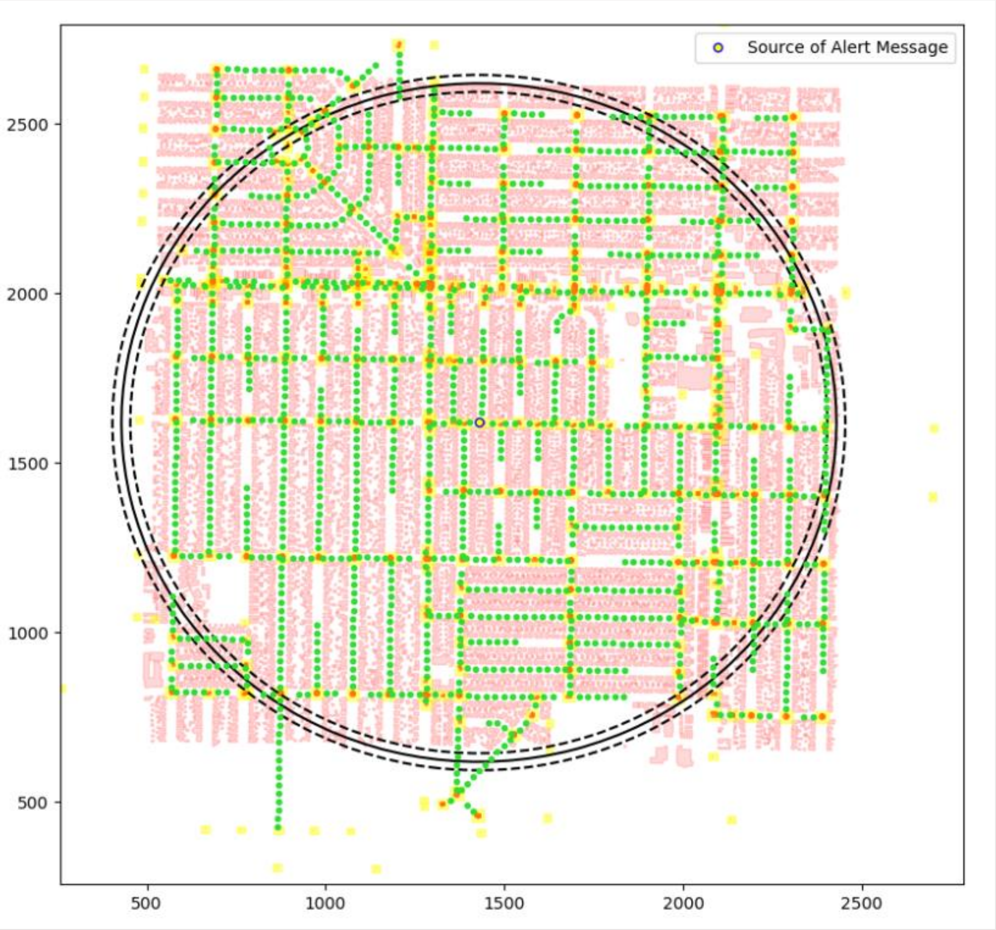
- Aim: exploit vehicles located within junctions to improve coverage
- Identification of junctions via OSM/SUMO tools

```
<junction id="1101896841" type="right_before_left" x="1261.31" y="2430.73"
incLanes="94925123#0_0 -94925123#1_0" intLanes=":1101896841_0_0 :1101896841_1_0
:1101896841_2_0 :1101896841_3_0 :1101896841_4_0 :1101896841_5_0"
shape="1262.20,2433.25 1263.07,2432.75 1262.80,2431.98 1262.85,2431.66 1263.03,
2431.39 1263.32,2431.17 1263.73,2430.99 1263.11,2429.09 1259.38,2430.19 1259.87,
2432.13 1260.78,2432.09 1261.18,2432.22 1261.56,2432.46 1261.90,2432.81">
```

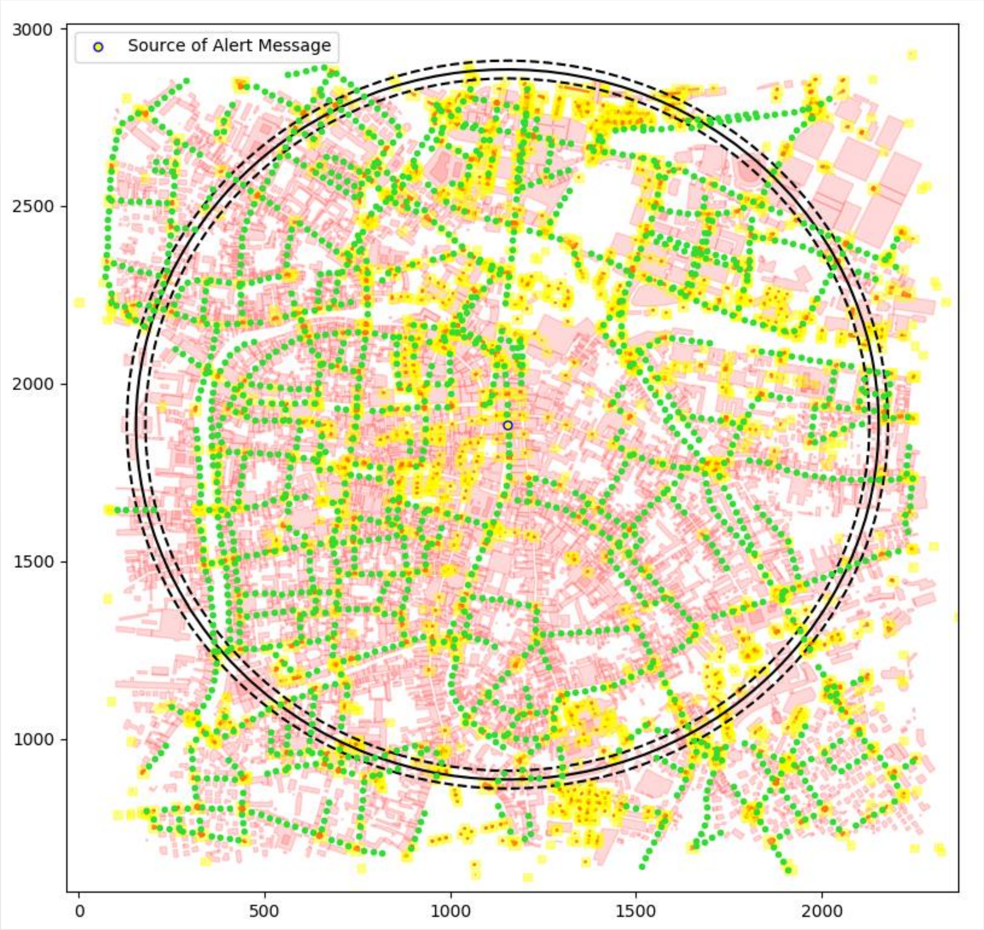
- 20x20m bounding box to extend the polygon
- Vehicles within a junction participate in a **second contention**
- Extension applicable both to Fast-Broadcast and ROFF
    - SJ-Fast-Broadcast and SJ-ROFF



JUNCTION MODEL - SCENARIOS



Los Angeles



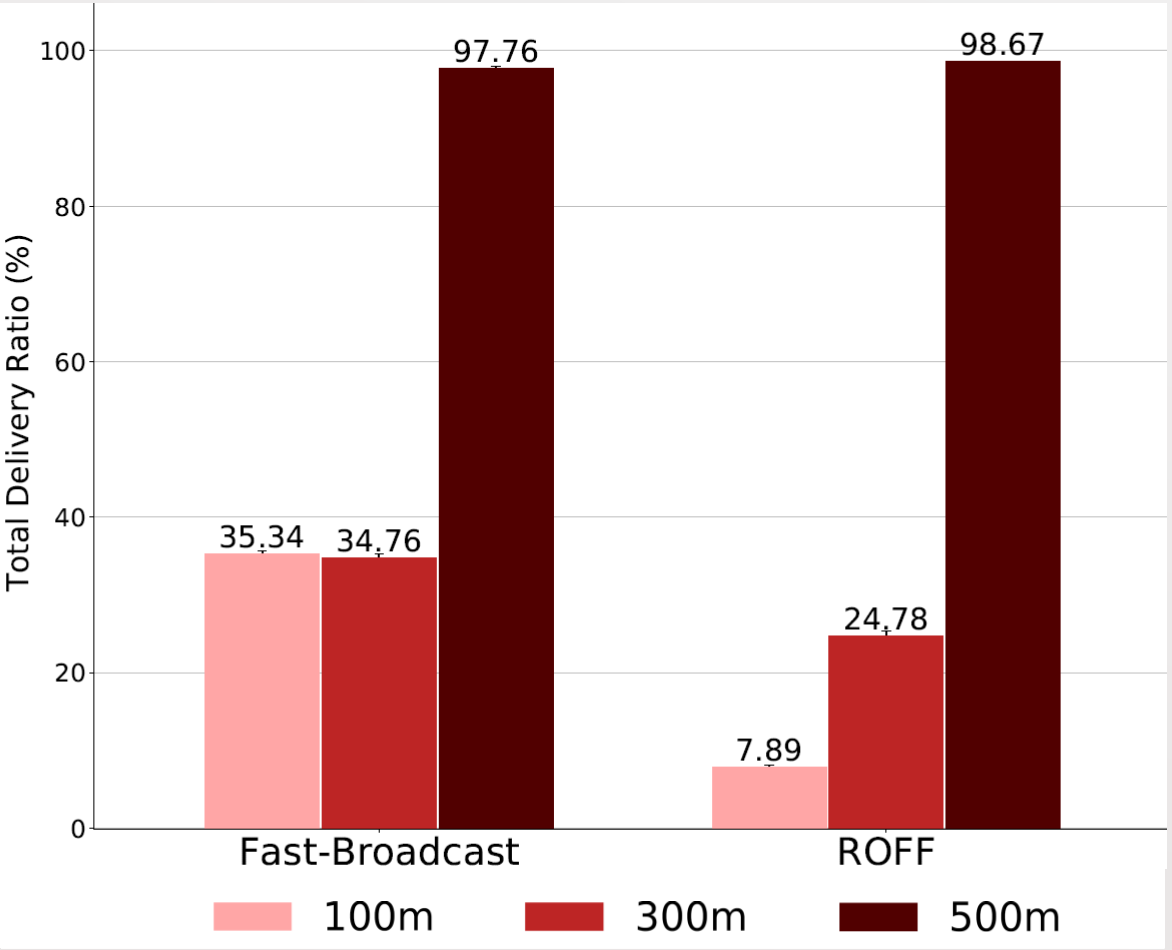
Padua

PADUA WITH JUNCTIONS

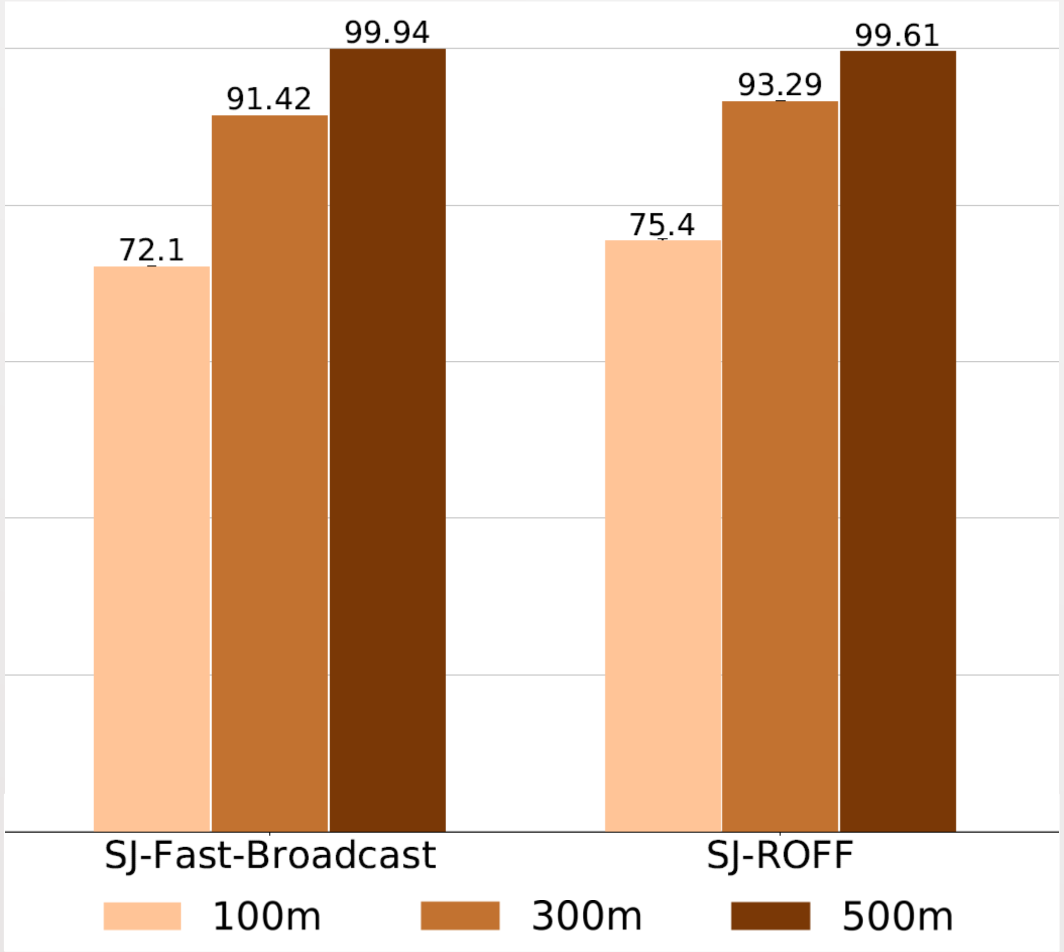
Scenario configuration	
Scenario name	Padua
Latitude N [°]	45.4171
Latitude S [°]	45.3981
Longitude W [°]	11.8654
Longitude E [°]	11.8923
Circumference radius [m]	1000
Distance between vehicles [m]	25
Number of vehicles	1775
Number of buildings	6322
Number of junctions	**3231**
Number of simulations	4500

Simulator configuration	
Packet payload size	100 byte
Frequency [GHz]	2.4
Channel bandwidth [MHz]	22
Transmission speed [Mbps]	11
Transmission powers [dBm]	-7.0, 4.6, 13.4
Transmission ranges [m]	100, 300, 500
Modulation	DSSS
Propagation loss model	ns3::TwoRayGround
Propagation delay model	ns3::ConstantSpeed
Shadowing model	ns3::ObstacleShadowing

PADUA WITH JUNCTIONS – COVERAGE ↑

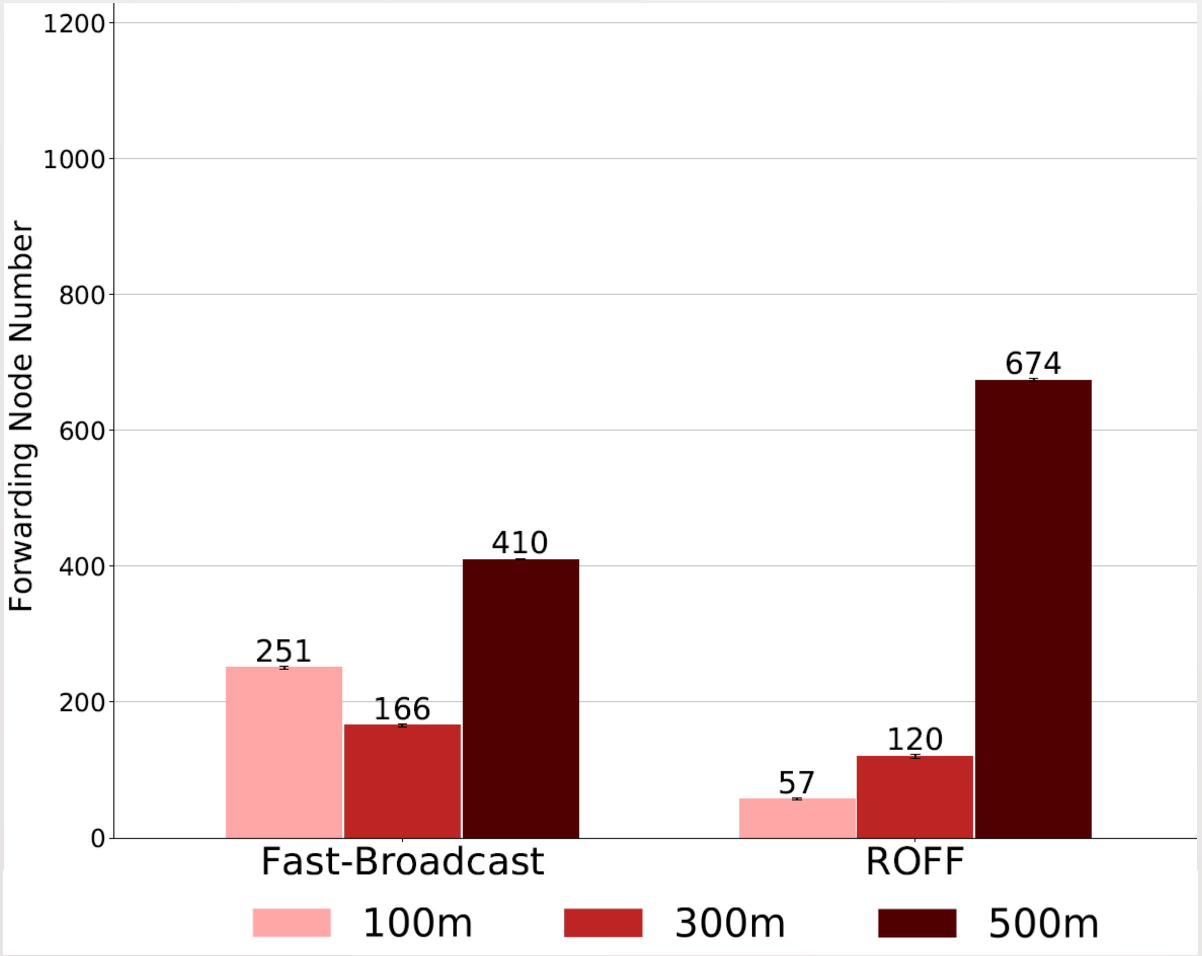


Without smart junction

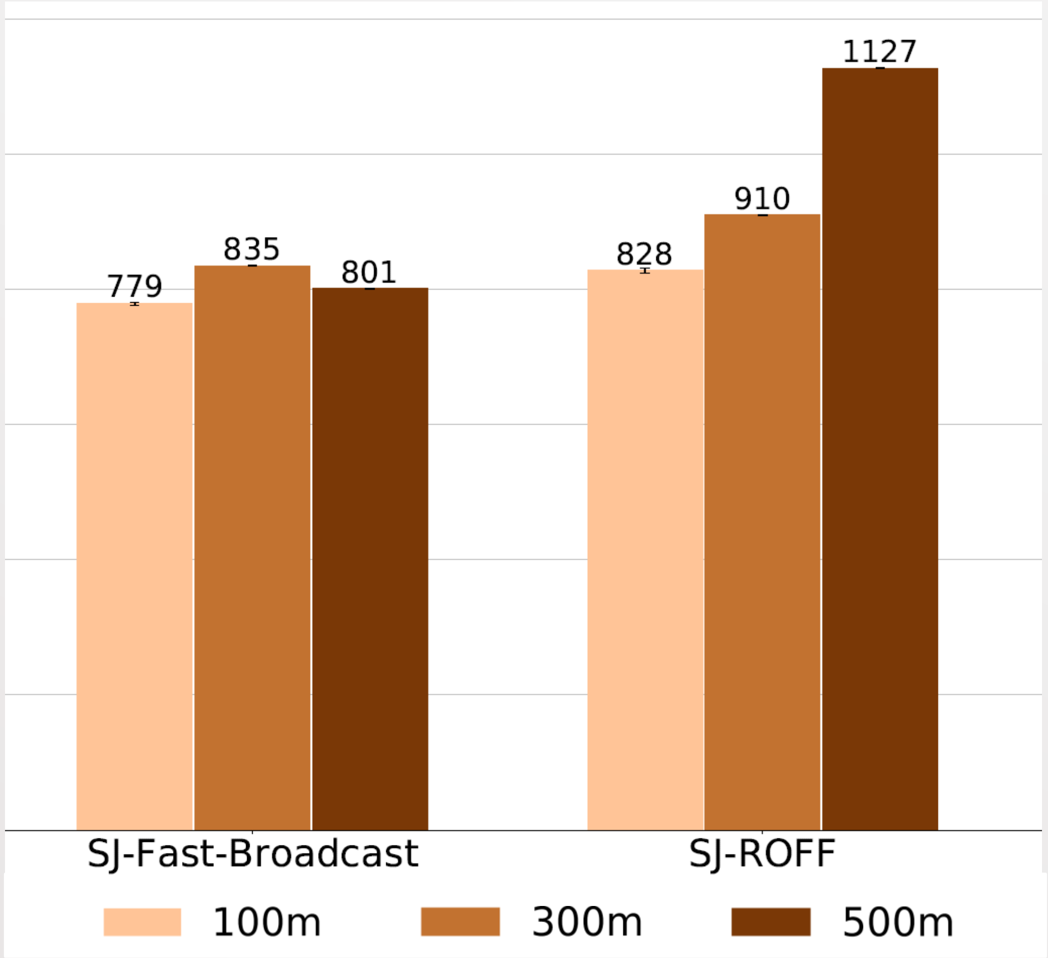


With smart junction

PADUA WITH JUNCTIONS – REDUNDANCY ↓



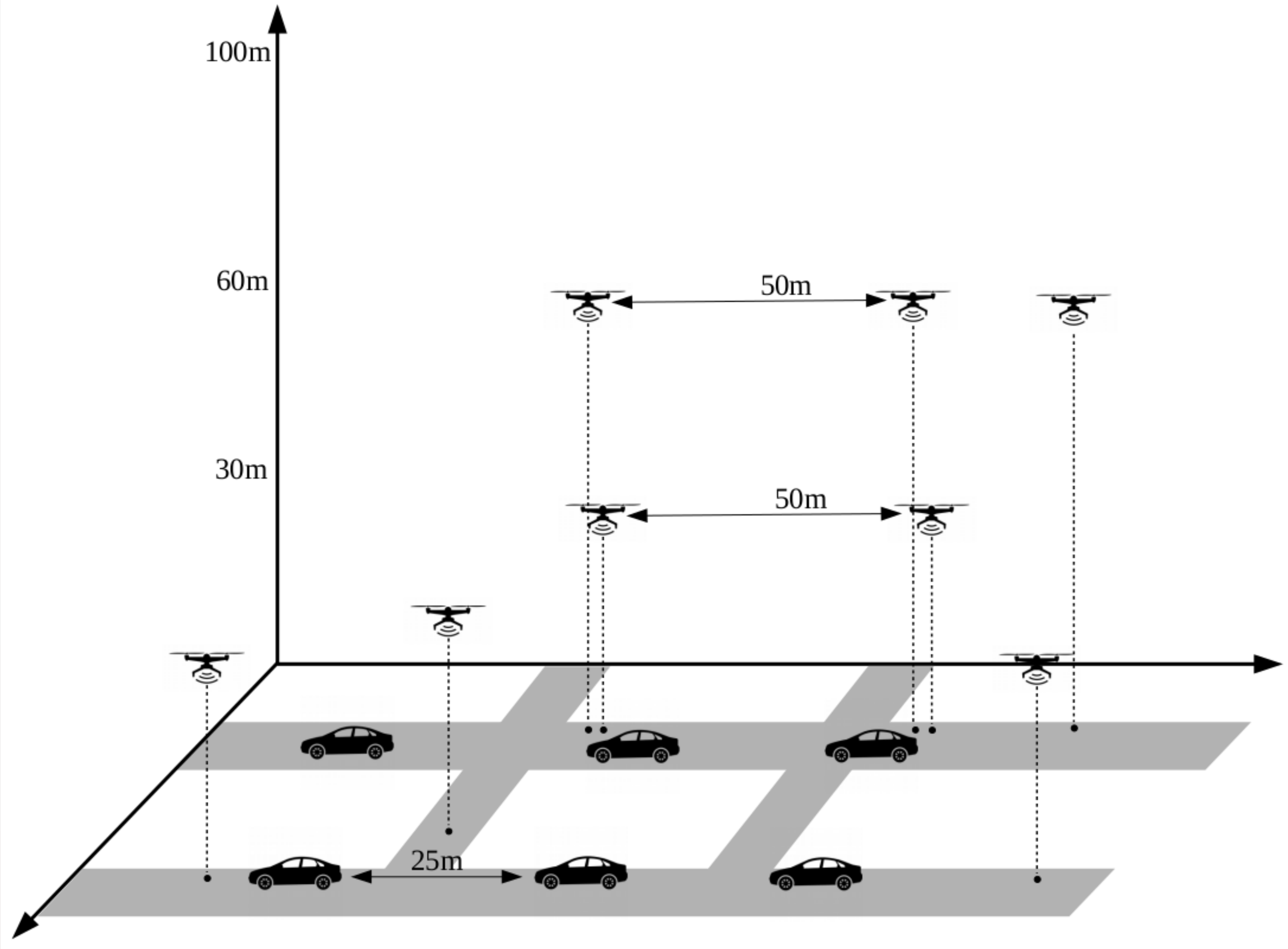
Without smart junction



With smart junction

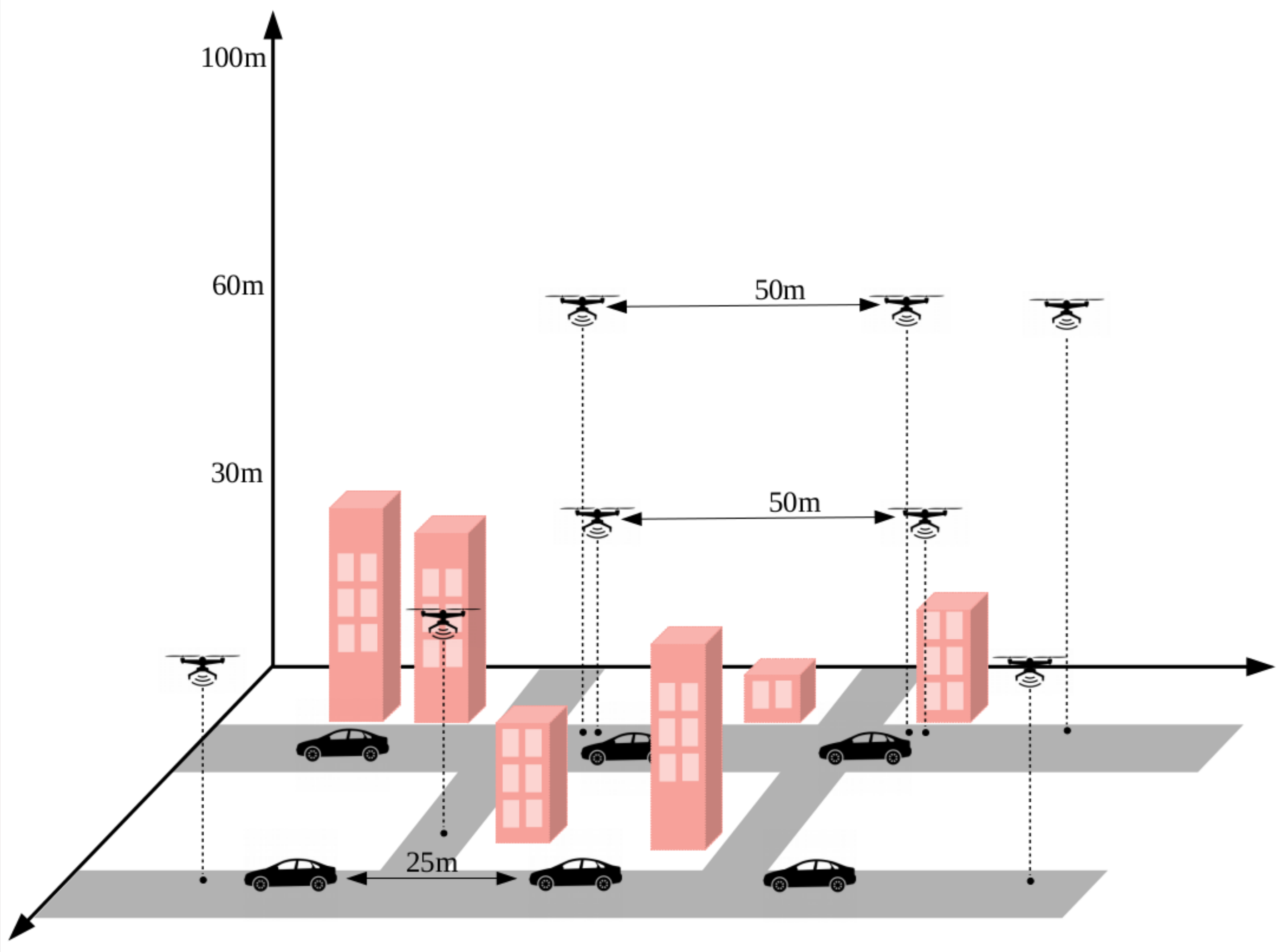
L.A. SMART CITY SCENARIO

- Vehicular + drones mixed scenario
  - Message propagation in 3D
- Different buildings configurations
  - **No buildings**



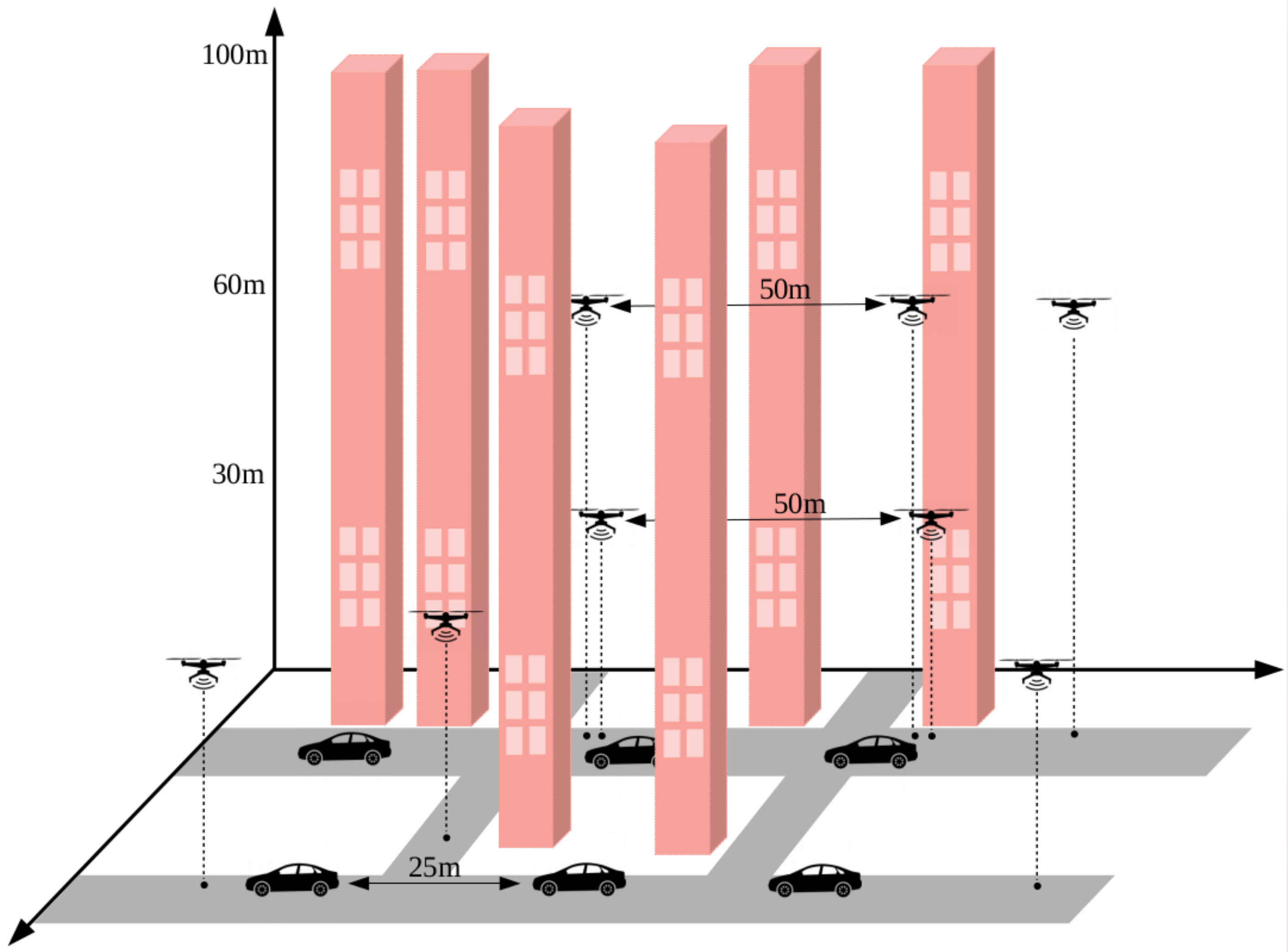
L.A. SMART CITY SCENARIO

- Vehicular + drones mixed scenario
  - Message propagation in 3D
- Different buildings configurations
  - No buildings
  - **Buildings with real heights**

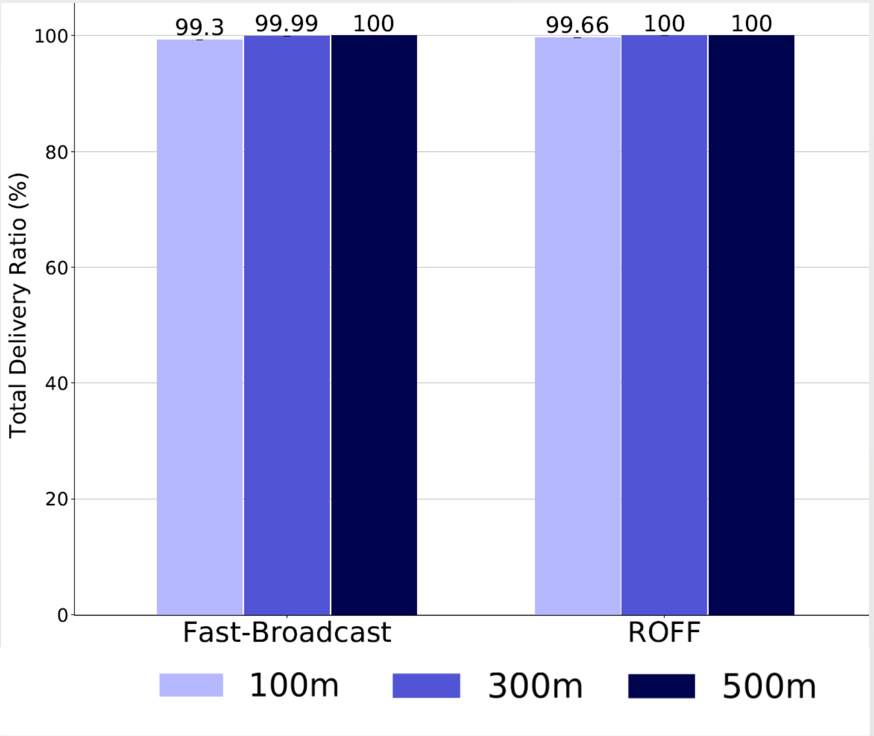


L.A. SMART CITY SCENARIO

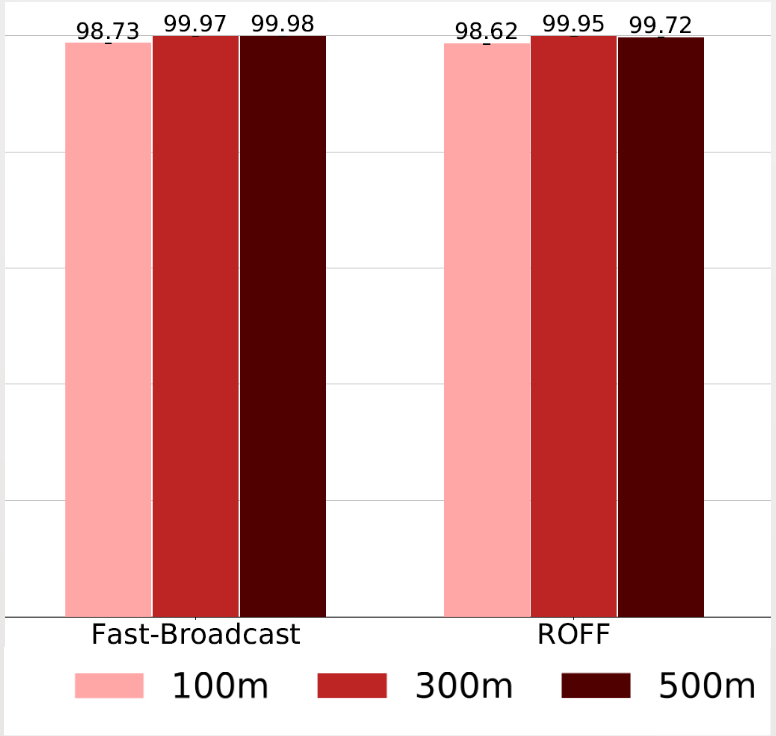
- Vehicular + drones mixed scenario
  - Message propagation in 3D
- Different buildings configurations
  - No buildings
  - Buildings with real heights
  - **Very tall buildings**



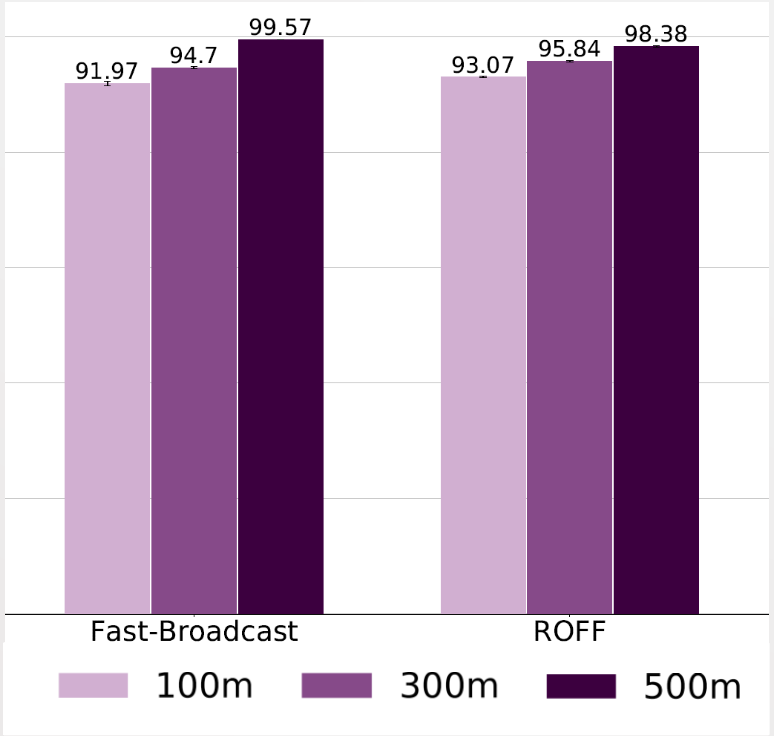
LOS ANGELES – COVERAGE ↑



Without buildings



Real height buildings



Very tall buildings

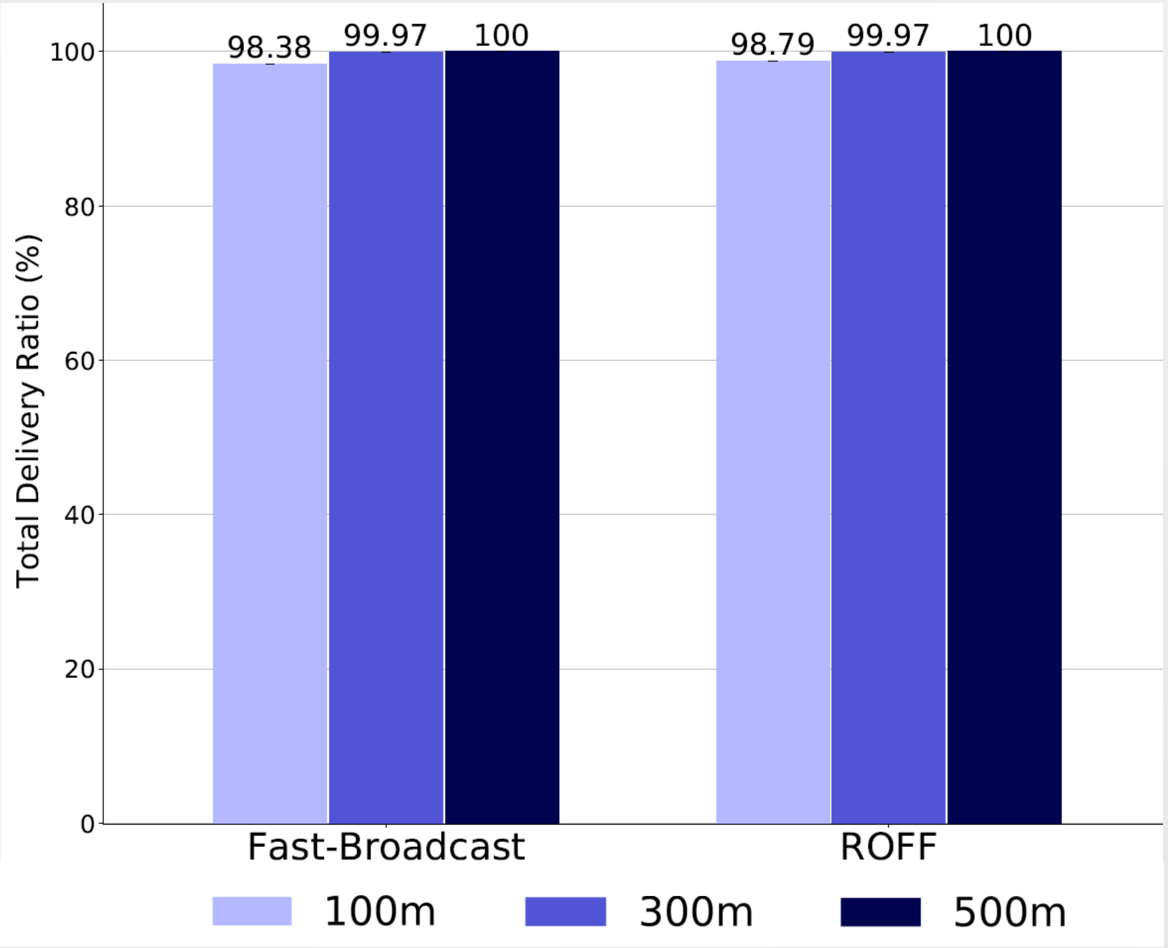
CONCLUSION

- ROFF introduces a much smaller end-to-end delay than Fast-Broadcast
  - Greater redundancy
  - Determinism and collisions
  - High number of Hello Messages
- SJ-Fast-Broadcast and SJ-ROFF improve coverage greatly
  - At the cost of more retransmissions
- The algorithms work well even in mixed 3D scenarios
- *C.E. Palazzi, J. Gottardo, A. Bujari, D. Ronzani, "Message Dissemination in Urban IoV", IEEE/ACM DS-RT 2019: 23rd International Symposium on Distributed Simulation and Real Time Applications , Cosenza, Italy, Oct 2019 (submitted)*
- Working on full publication

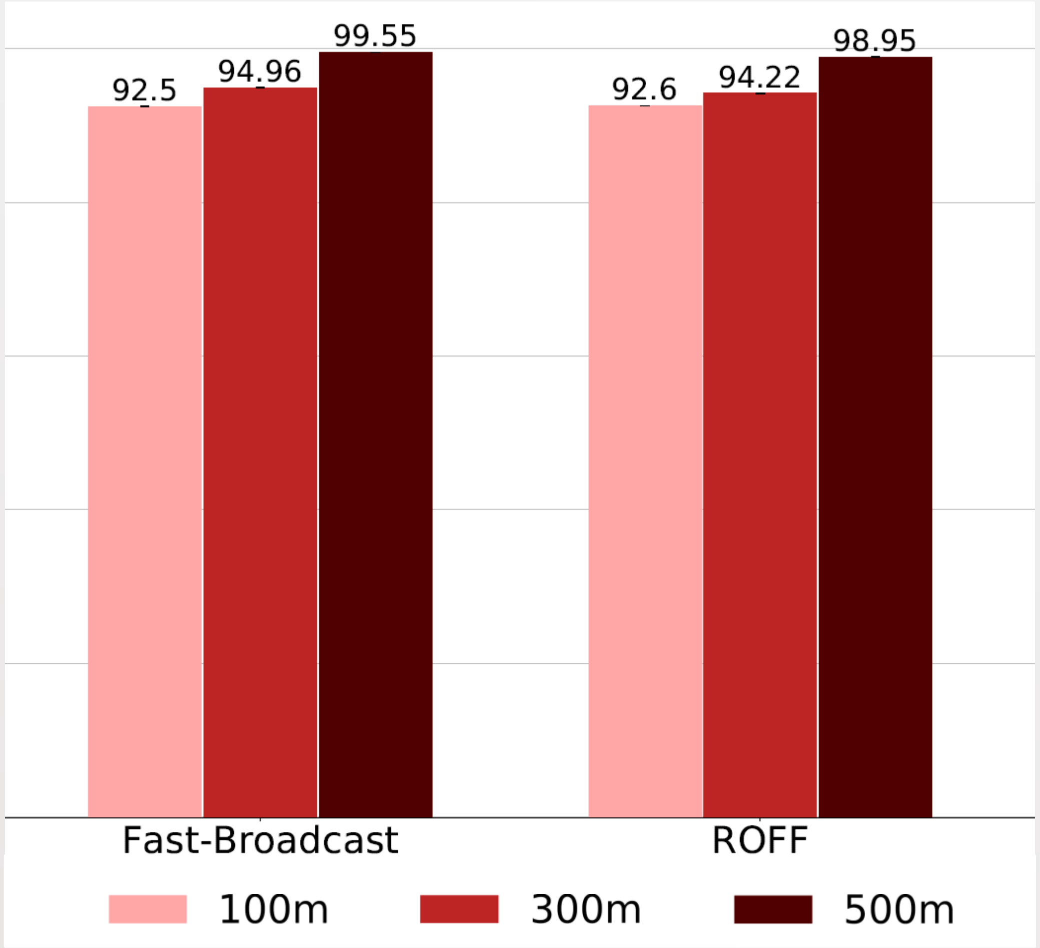
FUTURE WORK

- Dynamic lower and upper bounds for Fast-Broadcast's waiting time calculation
  - Based on vehicle density
- Junction identification backup mode
  - Reliance on GPS
  - Compute angle between received messages to identify vehicles within junctions
- Evaluation in more widespread FANETs

L.A. WITH BUILDINGS – COVERAGE ↑



Without buildings



With buildings

FORGING ATTACK – END TO END DELAY ↓