DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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Extending the ns-3 Spatial Channel Model for Vehicular Scenarios

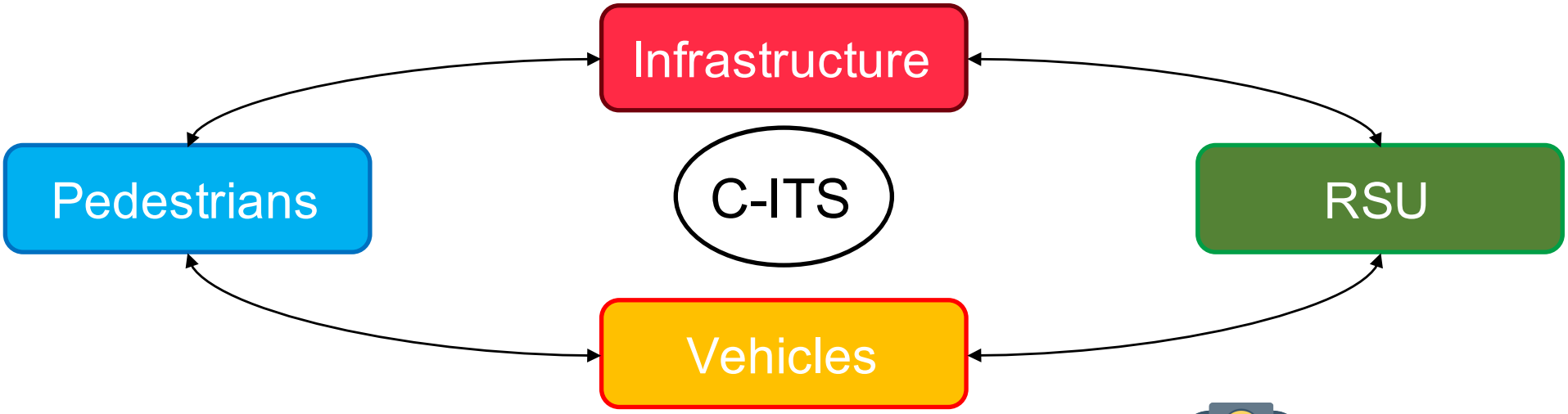
Tommaso Zugno, Matteo Drago*, Sandra Lagen°, Zoraze Ali°, Michele Zorzi**

**Dept. of Information Engineering, University of Padova, Italy*

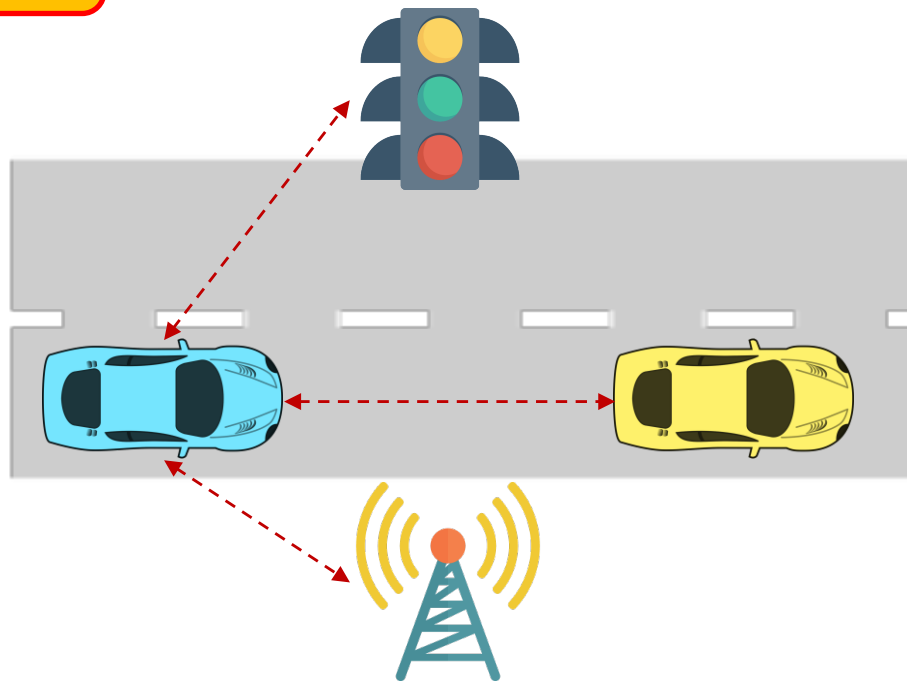
°Centre Tecnològic de Telecomunicacions de Catalunya, Barcelona, Spain

zugnotom@dei.unipd.it

Introduction

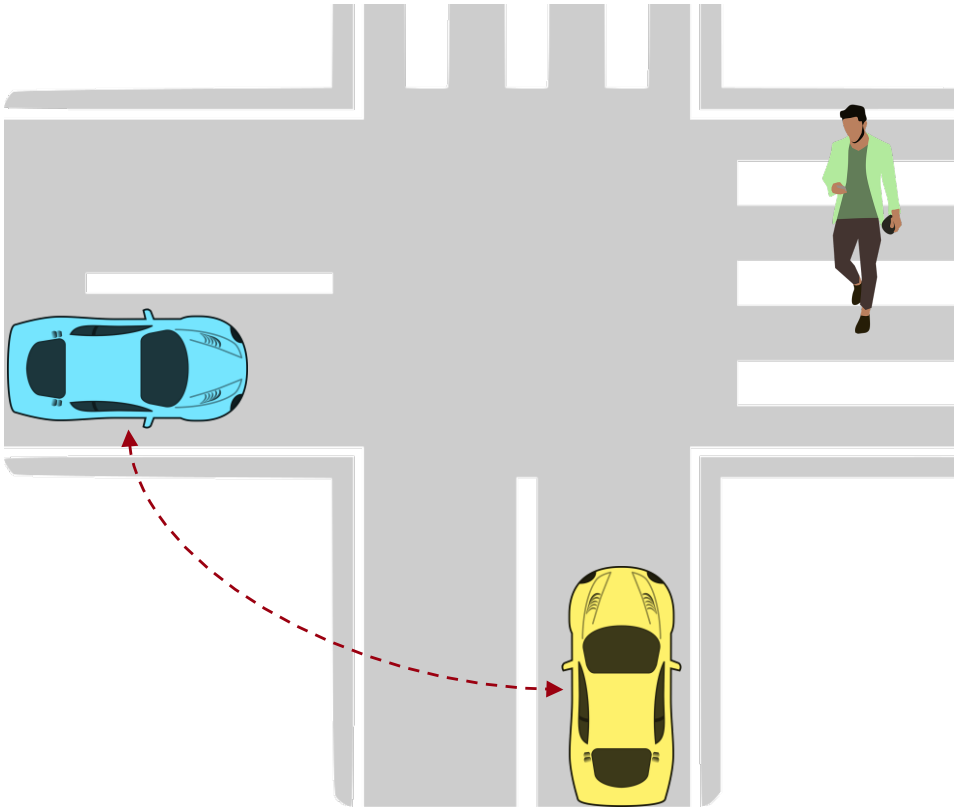


- ✓ Improve traffic safety
- ✓ Enable autonomous driving
- ✓ Reduce carbon emissions
- ✓ Reduce drivers' stress
- ✓ Save many unproductive hours



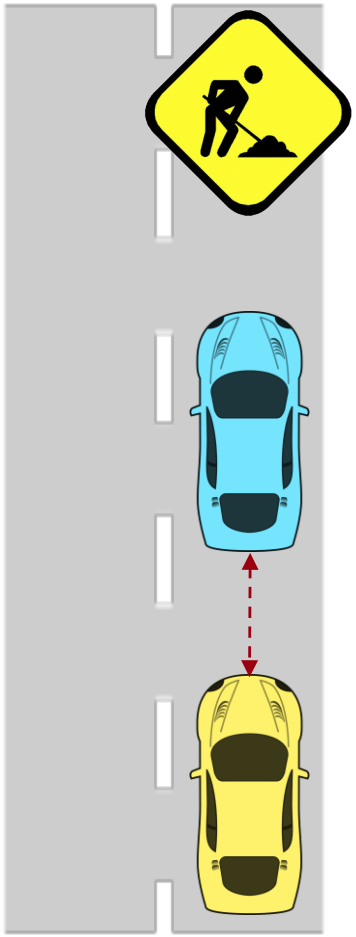
Introduction

Cooperative Perception



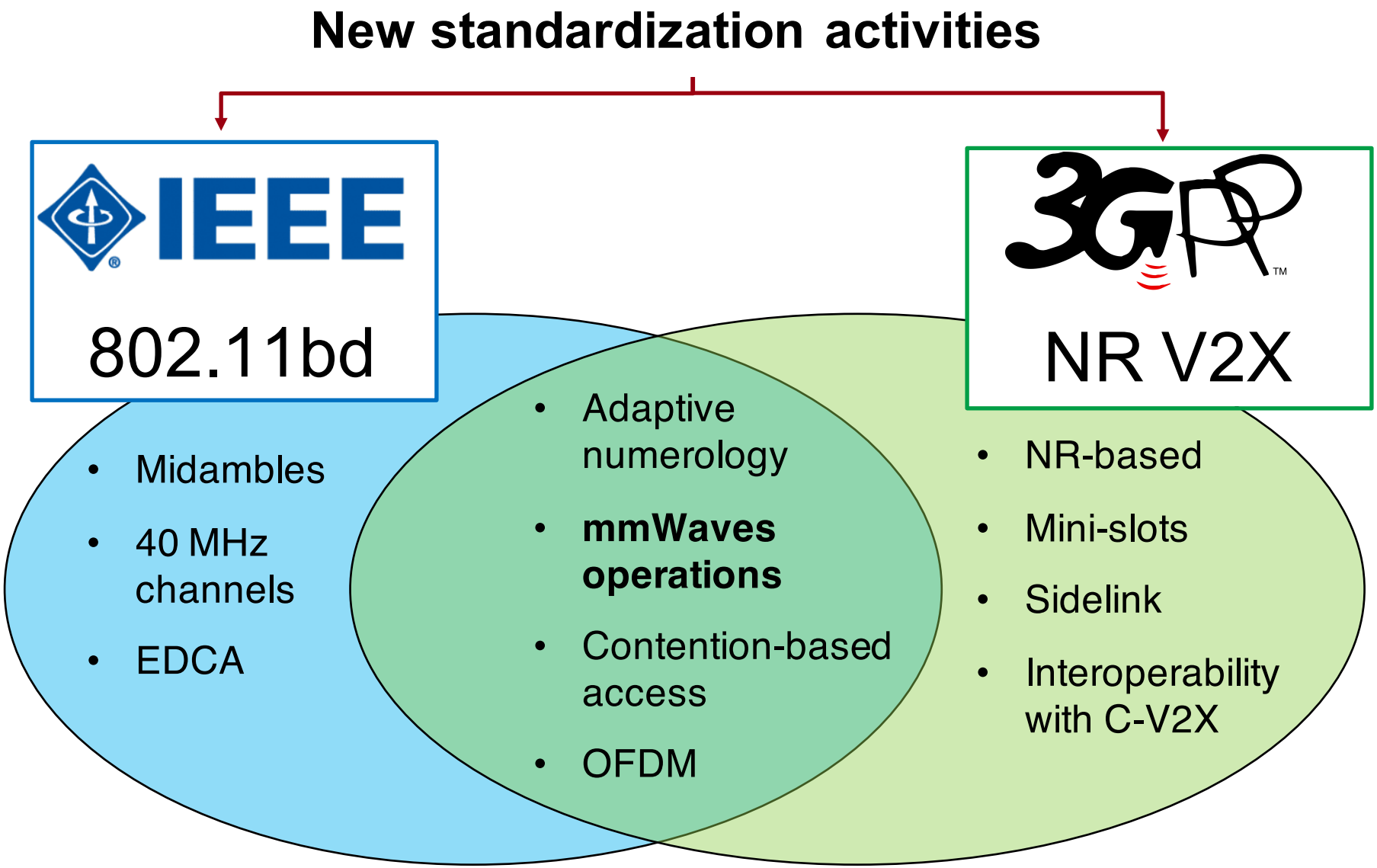
Main requirement: high throughput

Road Hazard Warning



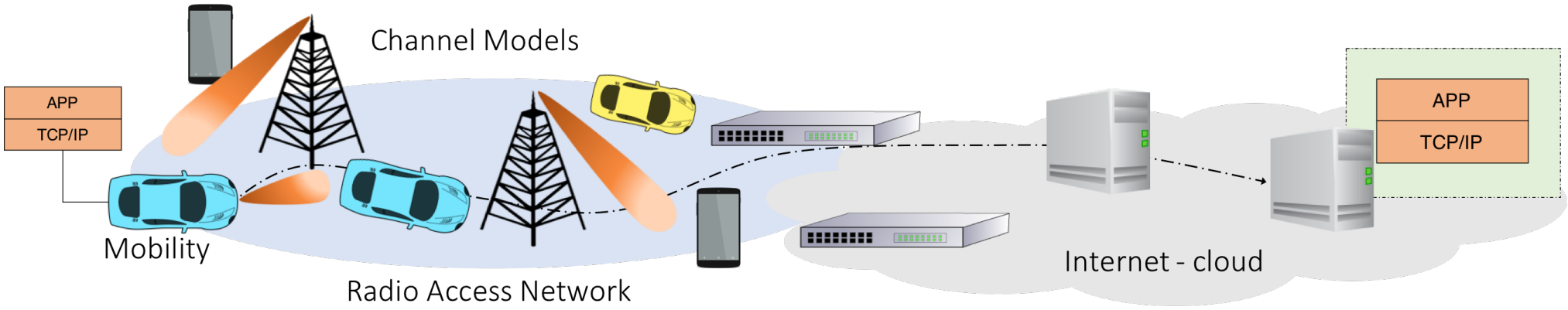
Main requirement: low latency

Introduction

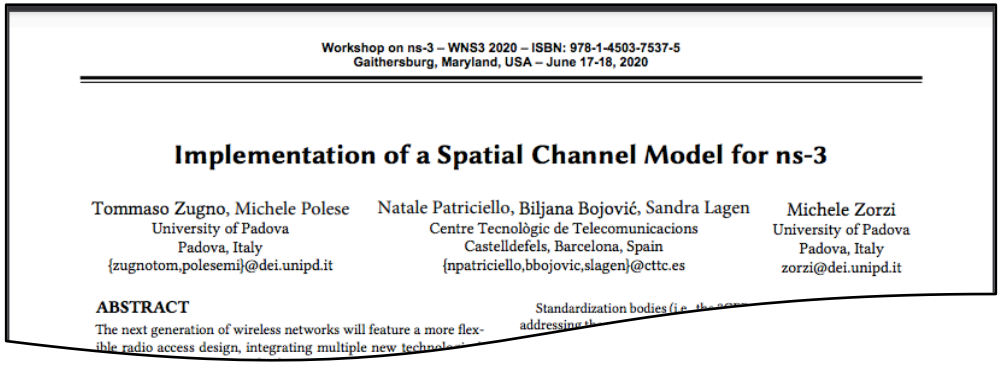


Introduction

- Simulations are a fundamental tool to evaluate the system performance without the need for a real prototype
- The overall performance depends on how signals propagate through the environment
- The modeling of the communication channel is of primary importance



ns-3 Spatial Channel Model



Workshop on ns-3 – WNS3 2020 – ISBN: 978-1-4503-7537-5
Gaithersburg, Maryland, USA – June 17-18, 2020

Implementation of a Spatial Channel Model for ns-3

Tommaso Zugno, Michele Polese
University of Padova
Padova, Italy
{zugnotom,polesemi}@dei.unipd.it

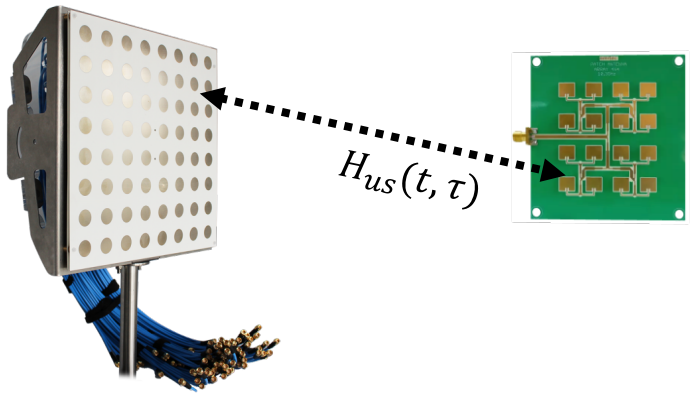
Natale Patriciello, Biljana Bojović, Sandra Lagen
Centre Tecnològic de Telecomunicacions
Castelldefels, Barcelona, Spain
{npatriciello,bbojovic,slagen}@cttc.es

Michele Zorzi
University of Padova
Padova, Italy
zorzi@dei.unipd.it

ABSTRACT

The next generation of wireless networks will feature a more flex-
ible radio access design, integrating multiple new technol
addressing th
Standardization bodies (i.e., the 3GPP

- ✓ Stochastic Spatial Channel Model (SCM) based on 3GPP TR 38.901
- ✓ Wide frequency range, 0.5 to 100 GHz
- ✓ Different propagation environments
- ✓ Support to multiple antennas



ns-3 Spatial Channel Model

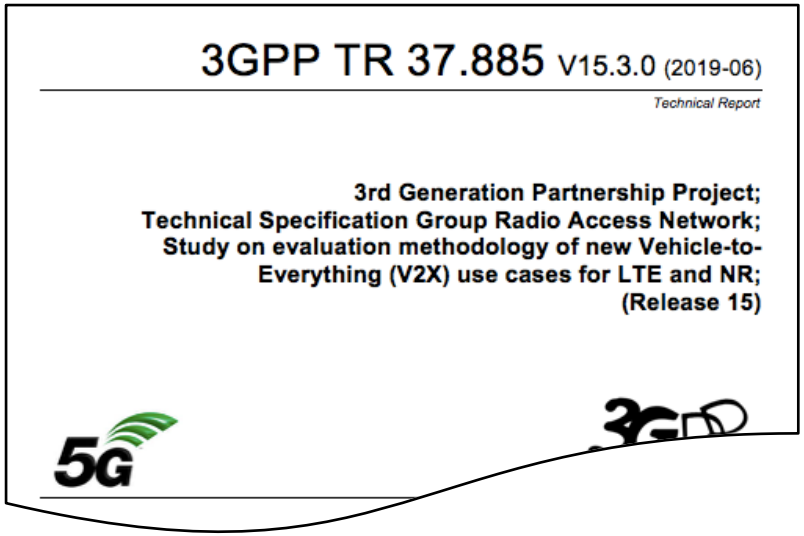
Main limitations:

- ✘ supports mobility at a single end of the link
  - ➥ not suitable for the simulation of Vehicle-to-Vehicle (V2V) communications
- ✘ supports “traditional” propagation scenarios
  - ➥ not able to characterize communication between antennas mounted on vehicles

Need for new channel models

3GPP V2X Channel Model

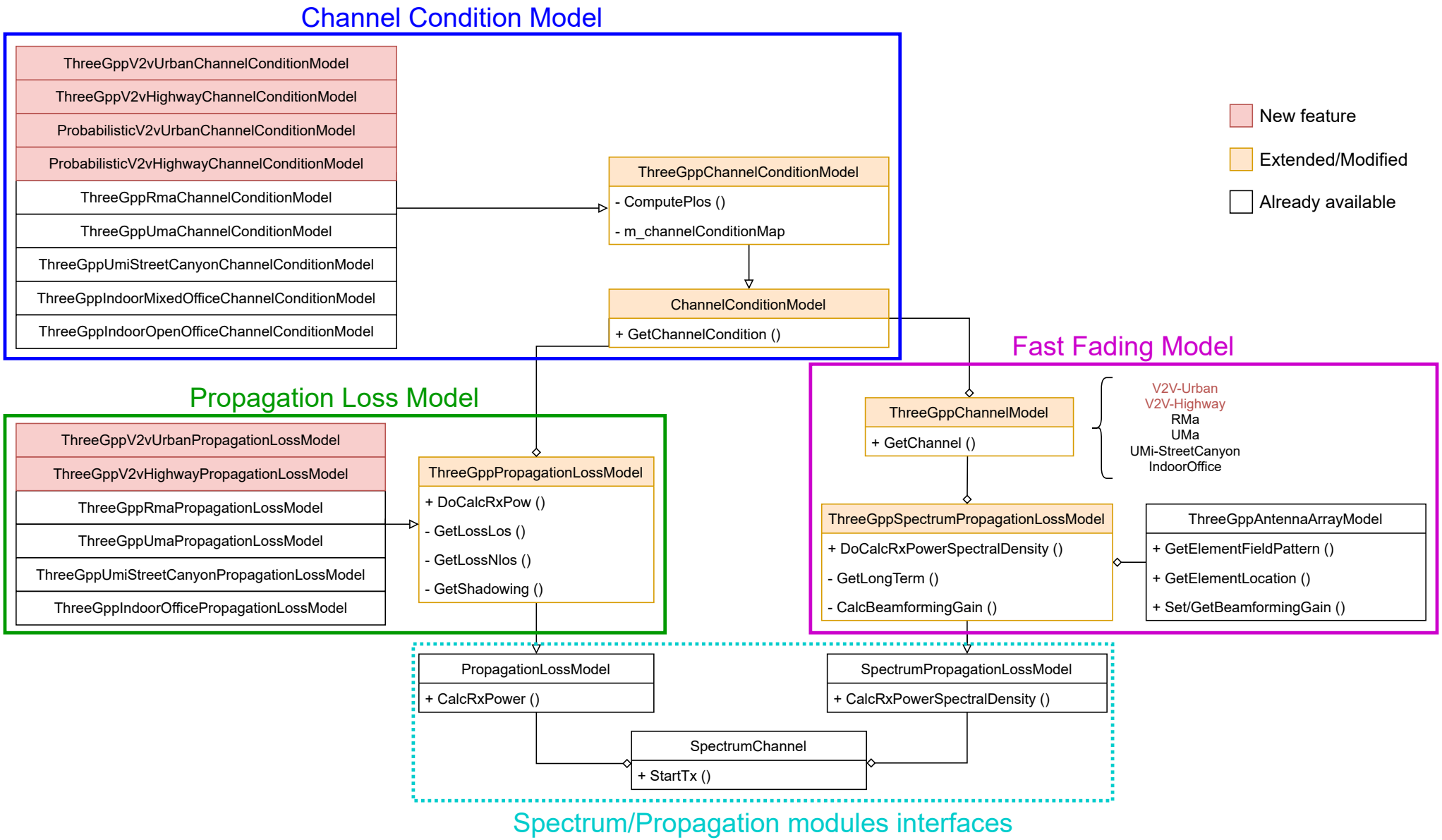
- Extension of TR 38.901
- New features:
  - mobility of both end terminals
  - modeling of vehicular blockages
  - additional Doppler component
  - new propagation scenarios


3GPP TR 37.885 V15.3.0 (2019-06)

Technical Report

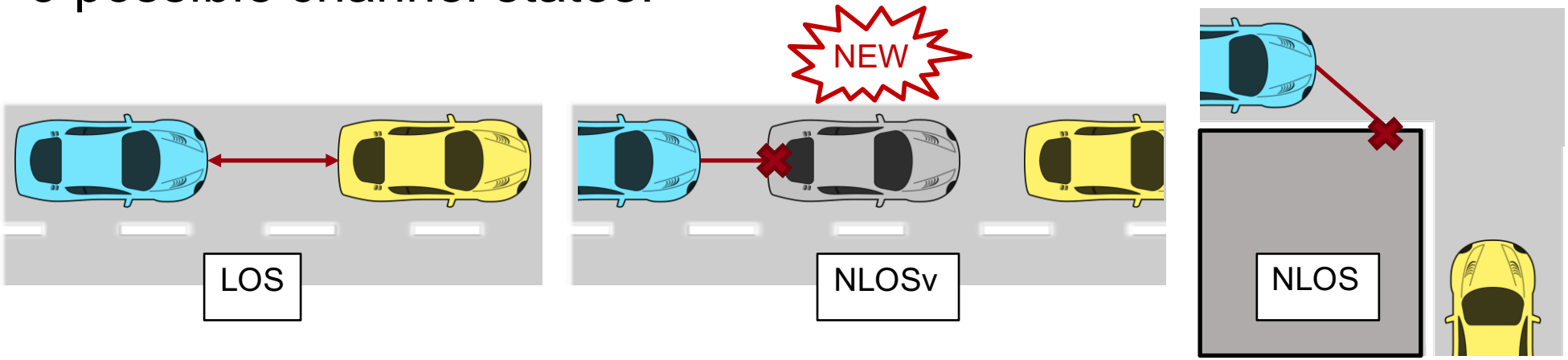
3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on evaluation methodology of new Vehicle-to-Everything (V2X) use cases for LTE and NR;
(Release 15)

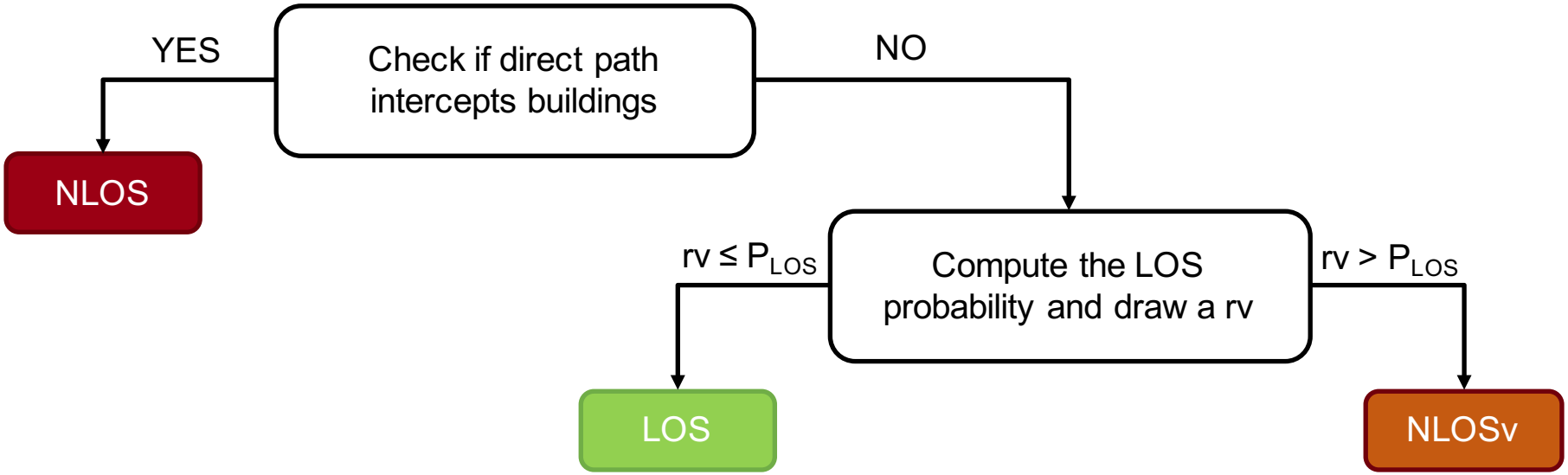
ns-3 implementation



Channel Condition Model

3 possible channel states:



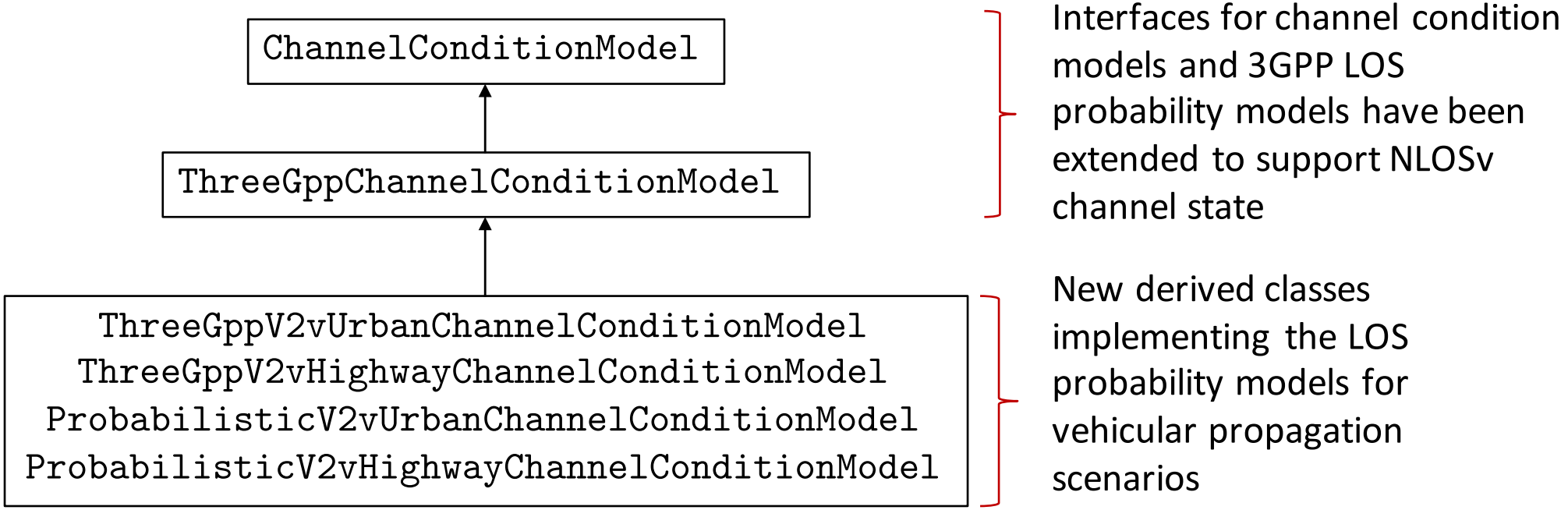


Channel Condition Model

LOS probability models:

	V2V-Urban	*V2V-Highway*
P_{LOS}	$\min\{1, 1.05 \times \exp(-0.0114 \times d)\}$	$\begin{cases} \min\{1, 2.1013 \times 10^{-6} \times d^2 - 0.002 \times d + 1.0193\} & d \leq 475m \\ \max\{0, 0.54 - 0.001 \times (d - 475)\} & d > 475m \end{cases}$
P_{NLOS_v}	$1 - P_{LOS}$	$1 - P_{LOS}$

ns-3 implementation:



Propagation Loss Model

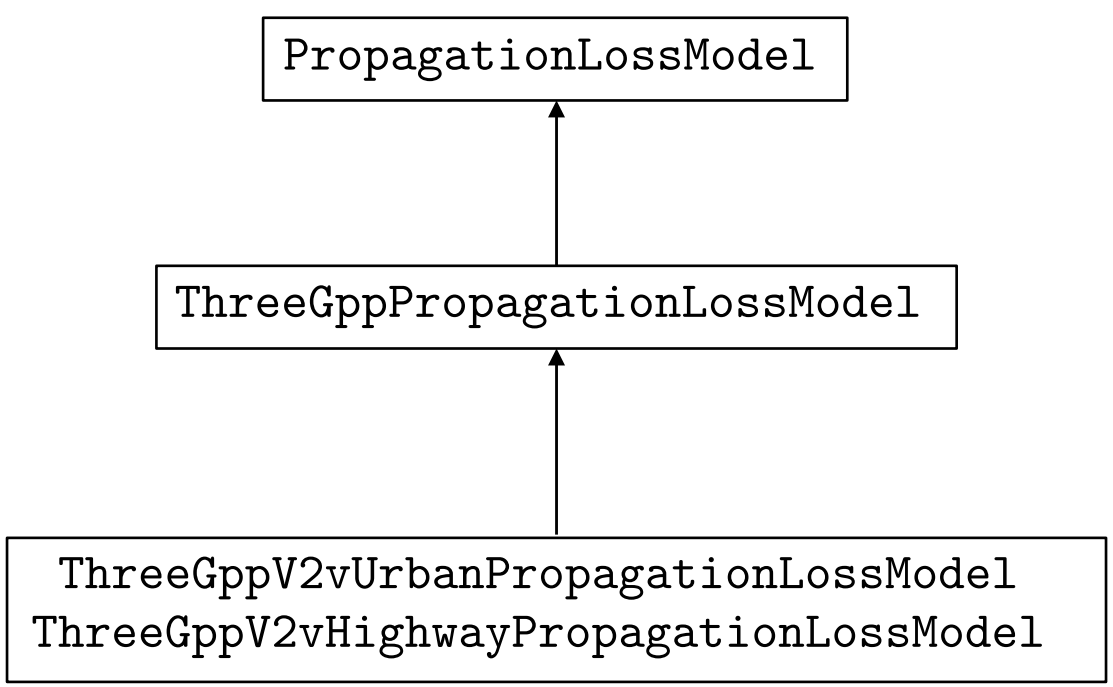
$$PL = A\ log_{10}(d) + B + C\ log_{10}(f_C) + SF + B_v$$

Propagation Loss — Pathloss — Shadowing — Vehicular blockage

- B_v is a log normal random variable
  - added only in NLOSv conditions
  - distribution depends on the blocker's height
  - 2 vehicle types: cars and trucks
  - blocker's height is randomly determined depending on the percentage of trucks in the scenario

Propagation Loss Model

ns-3 implementation:



Interface provided by the propagation module

Base class for the 3GPP propagation loss models

Derived classes implementing the models for vehicular propagation scenarios.
The attribute `PercType3Vehicles` specifies the percentage of trucks in the scenario.

Fast Fading Model

- Stochastic model based on 3GPP TR 38.901
- New parameters for vehicular scenarios
- Additional Doppler component to account for scattering in high mobility environments

ns-3 implementation

- Modification of `ThreeGppChannelModel` to include the parameters for V2V-Urban and V2V-Highway scenarios
- Modification of `ThreeGppSpectrumPropagationLossModel` to include the new Doppler component

Example

New example available in ns-3:
`examples/channel-models/three-gpp-v2v-channel`

- shows how the proposed model can be used to extract SNR and propagation loss

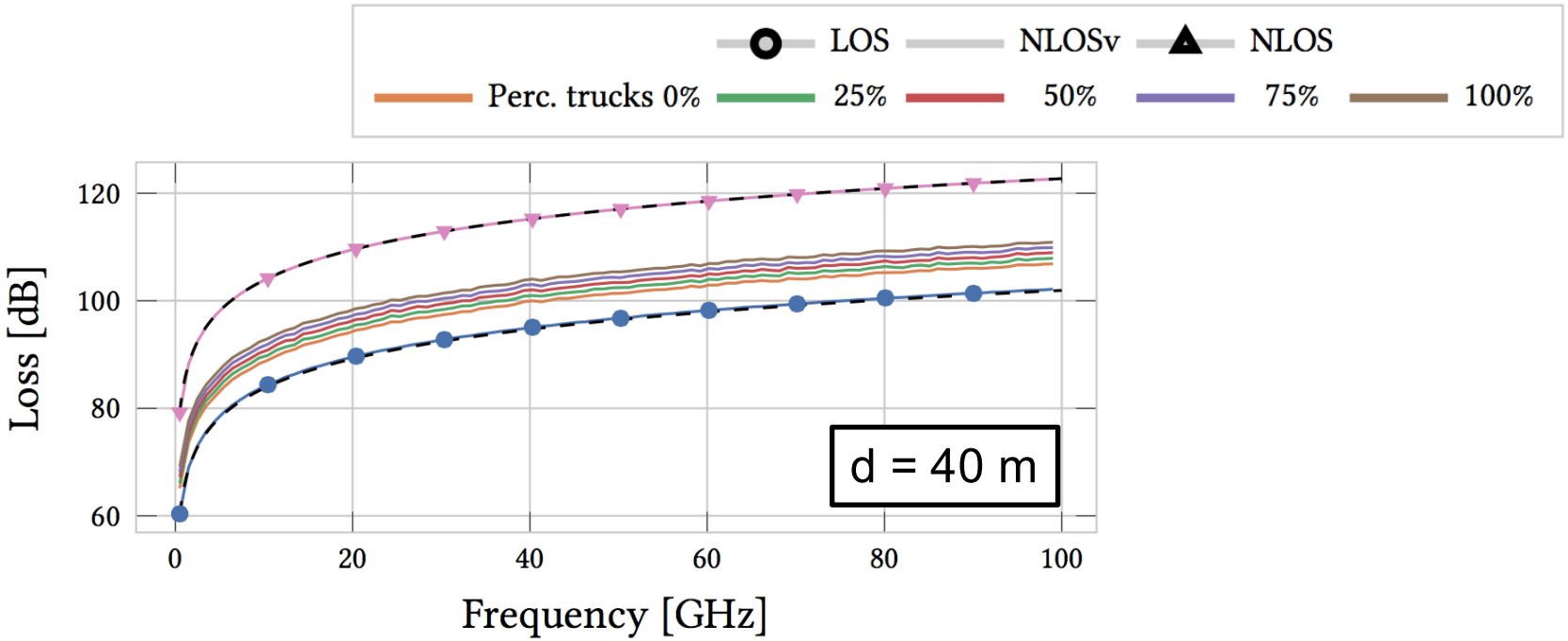
Transmitter parameters

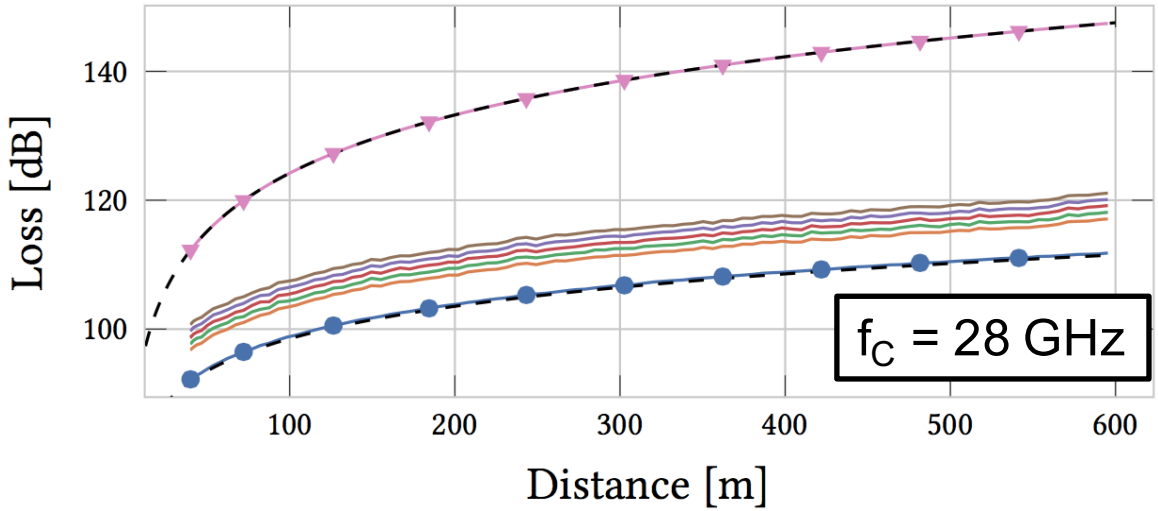
- height: 1.7 m
- tx power: 30 dBm

Receiver parameters

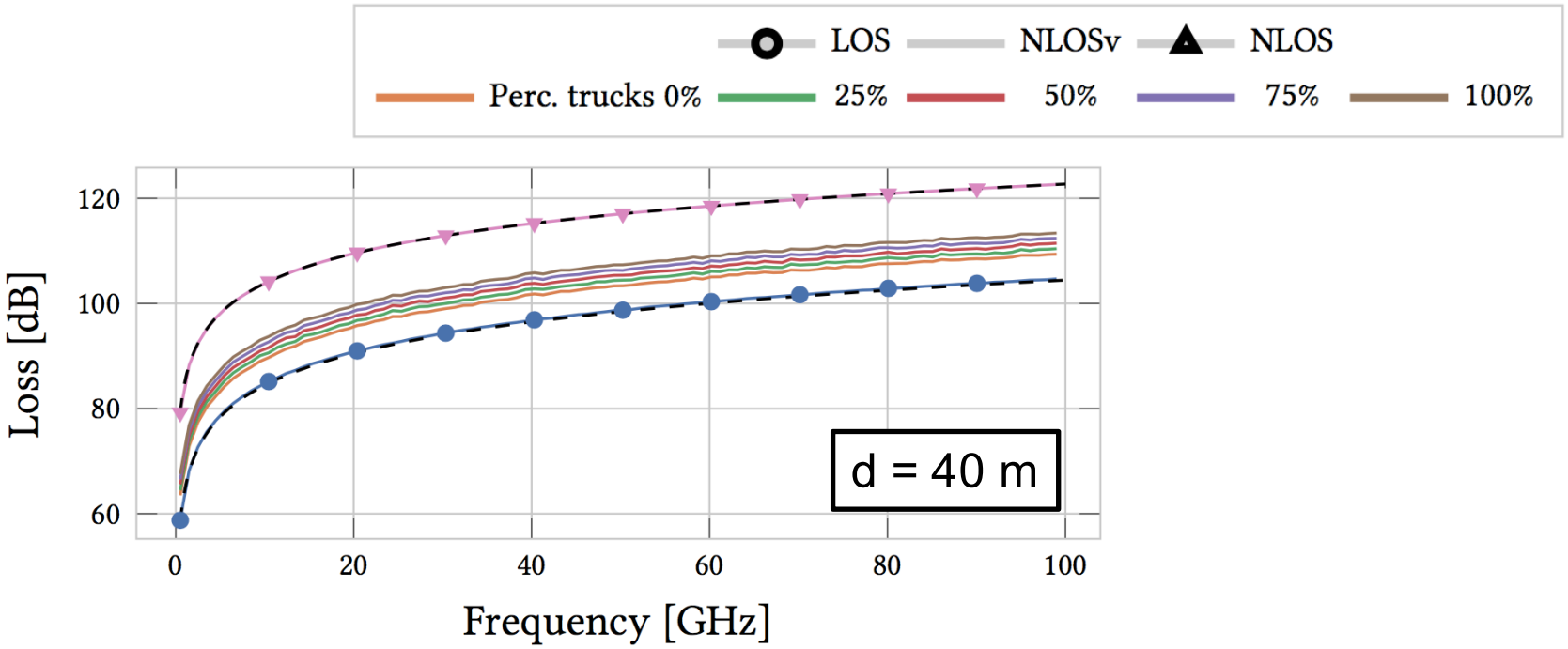
- height: 1.5 m
- noise figure: 9 dB

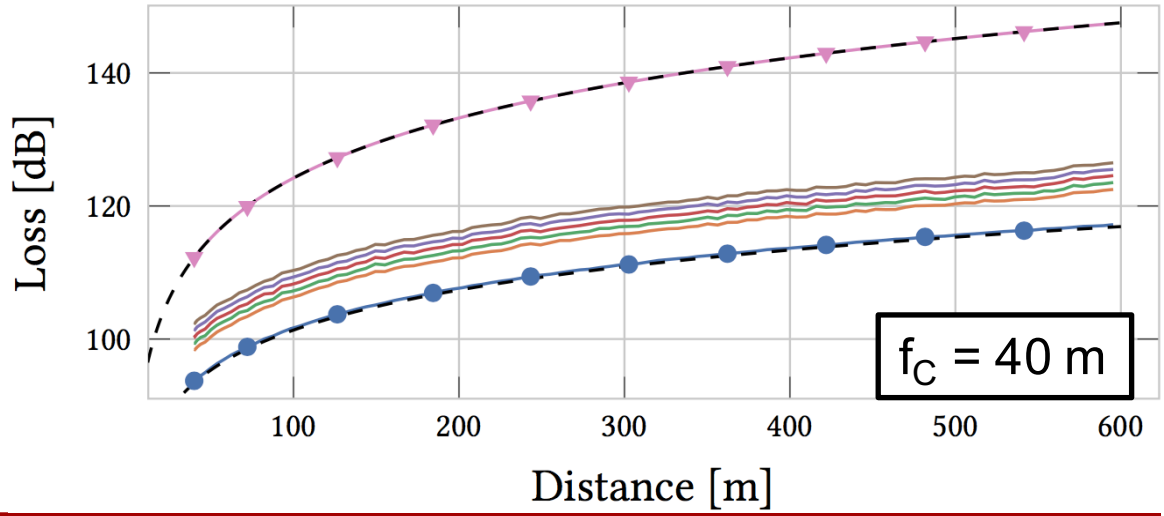
Average Propagation Loss for V2V-Urban



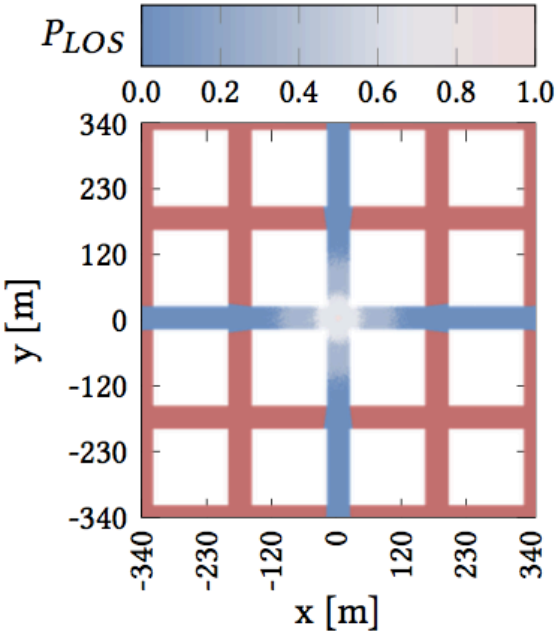


Average Propagation Loss for V2V-Highway

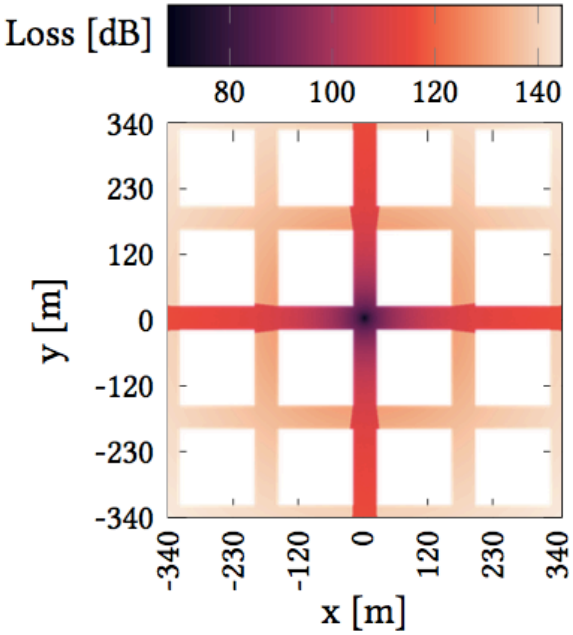




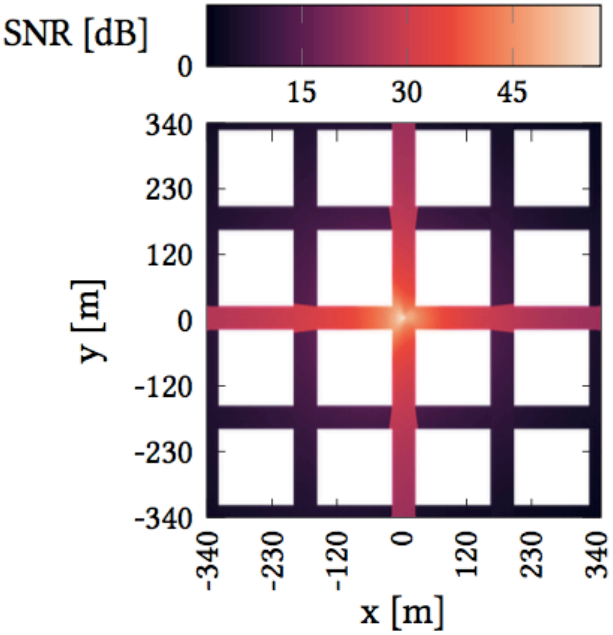
Low-level metrics for V2V-Urban



(a) LOS Probability

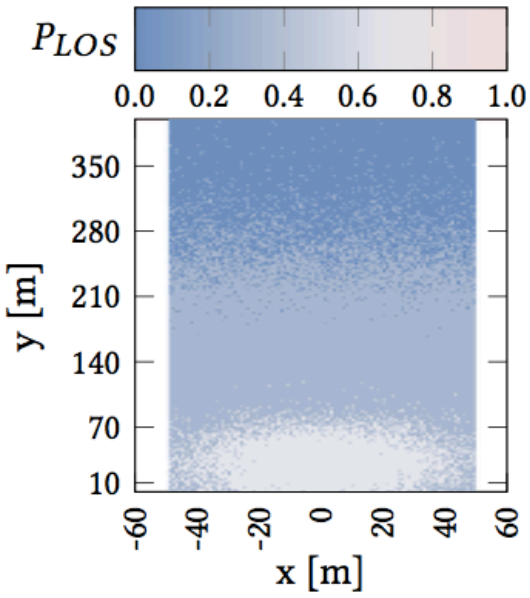


(b) Propagation Loss

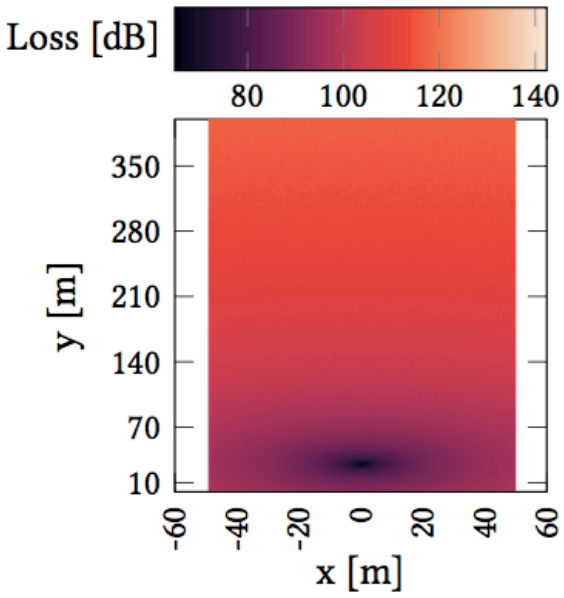


(c) SNR

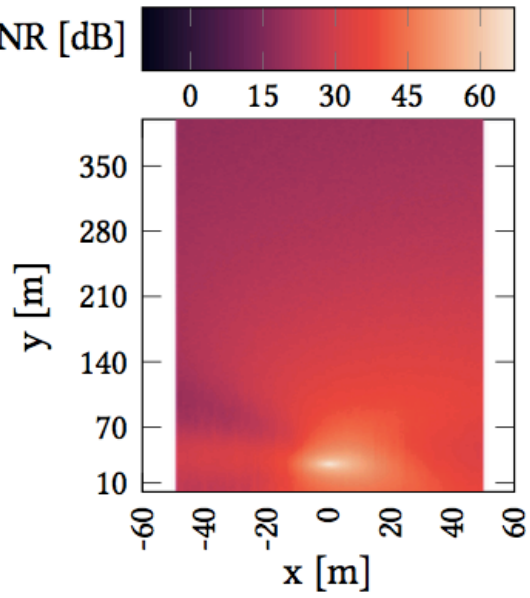
Low-level metrics for V2V-Highway



(a) LOS Probability



(b) Propagation Loss



(c) SNR

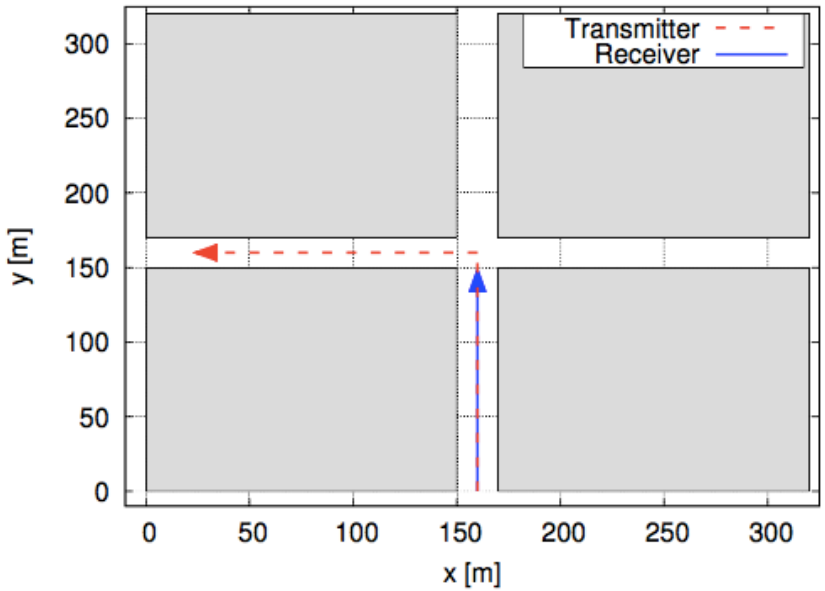
Full Stack Example

Full stack example with MilliCar*

- ns-3 module for the simulation of V2V communications based on the 3GPP NR V2X standard

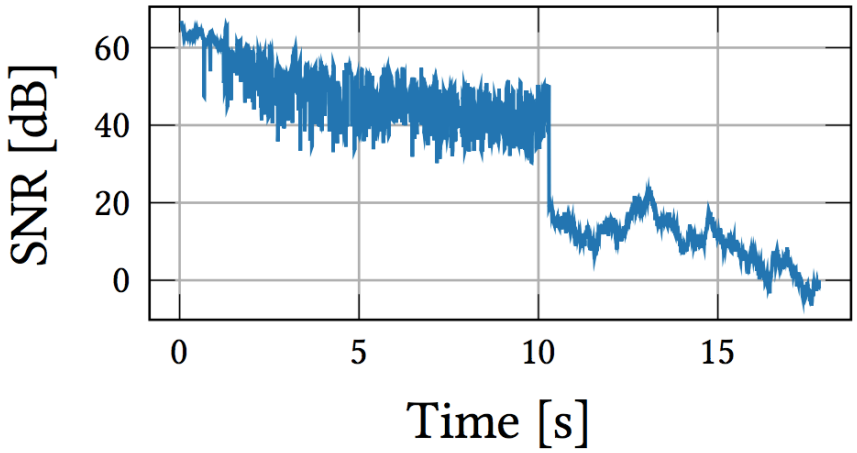
Simulation parameters:

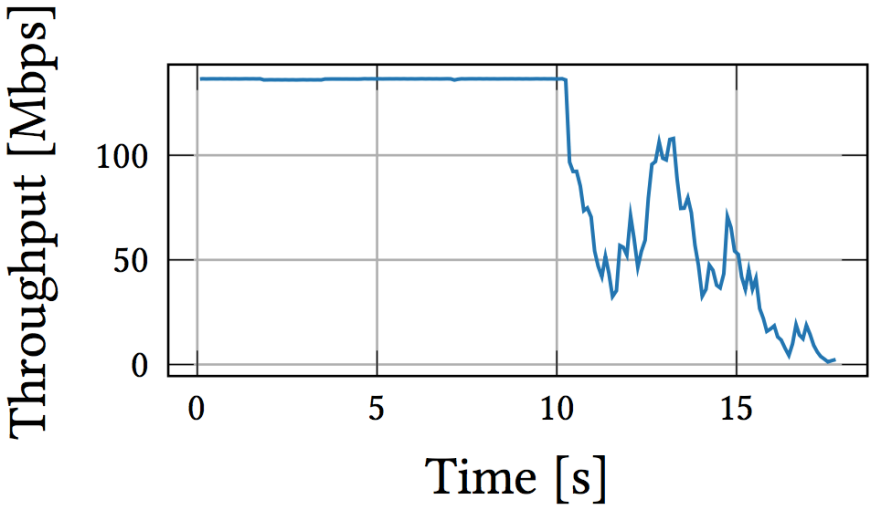
- Data rate: 137 Mbps
- Carrier frequency: 28 GHz
- Bandwidth: 100 MHz
- Channel scenario: V2V-Urban
- Tx speed: 60 km/h
- Rx speed: 30 km/h

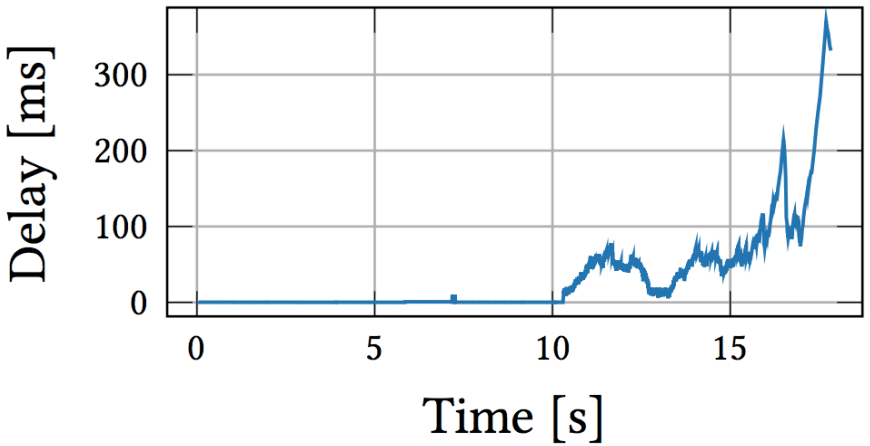


* https://github.com/signetlabdei/millicar

Full Stack Example







Conclusions

- We presented an extension of the ns-3 SCM for vehicular scenarios
- This model enables full-stack simulations of vehicular communication technologies
- We provide low-level and system-level examples to illustrate the usage and effectivity of this model
- Already available in ns-3 (starting from release 33)

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