The Evolution of Direct Mode in 3GPP

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PSCR

Motivations

- **Direct Mode** communication is considered a required feature by first responders to fully transition from Land Mobile Radio (LMR) technology to Long Term Evolution (LTE).

- The 3rd Generation Partnership Project (3GPP) added support for Direct Mode in LTE by enabling device-to-device (**D2D**) communication and defining off-network Mission Critical Push-to-Talk (**MCPTT**).

- Due to internal (e.g. performance limitations) and external (e.g. market share) factors, LTE D2D has yet to be widely accessible.

- The current development of 5G New Radio (**NR**) in 3GPP offers a new opportunity to overcome those problems and fully meet first responders' required capabilities.
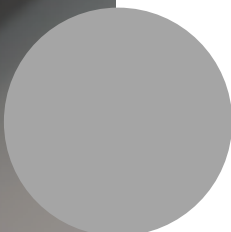
Outline

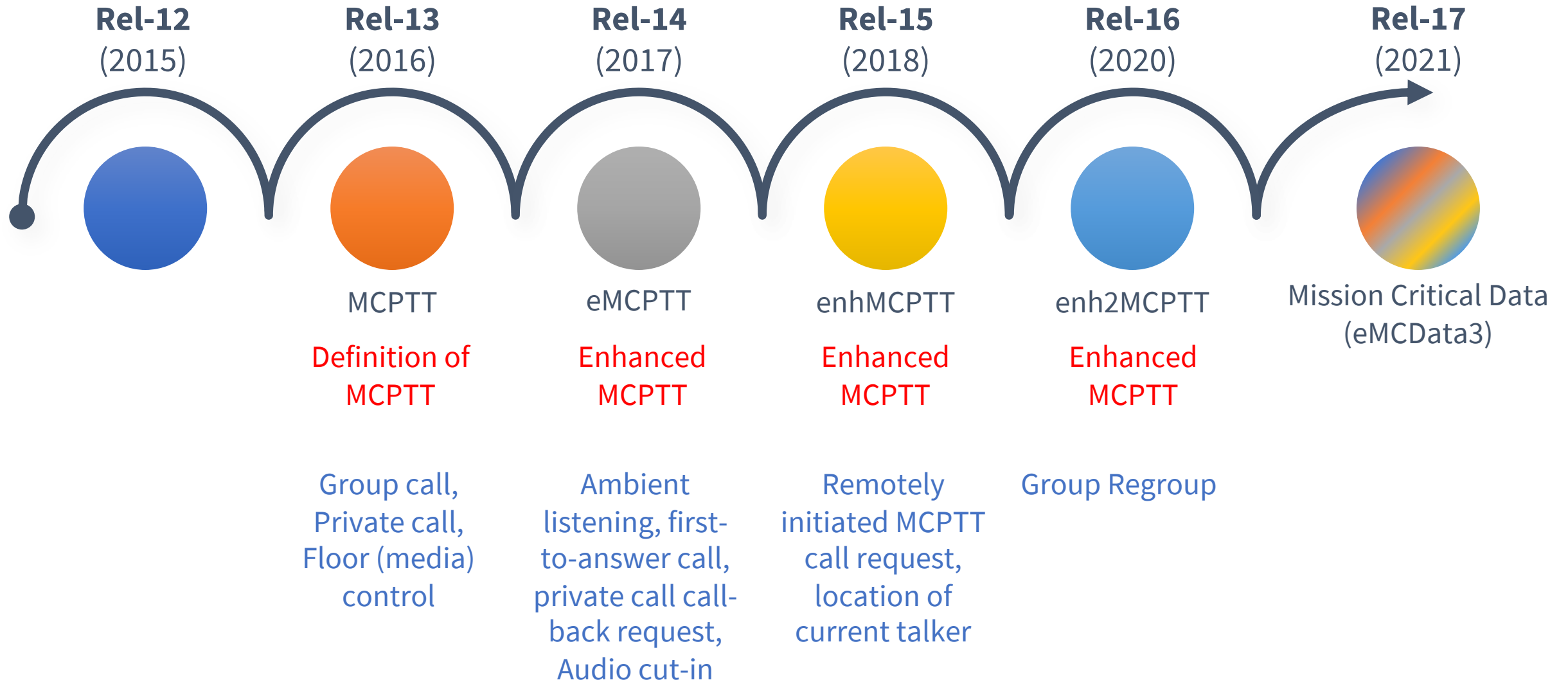**PULLING THE FUTURE FORWARD**

● **Evolution of MCPTT**

● **Evolution of D2D**

● **Intro to 5G NR and NR Vehicular-to-anything (V2X)**

Evolution of MCPTT in 3GPP

Rel-12
(2015)

Rel-13
(2016)

Rel-14
(2017)

Rel-15
(2018)

Rel-16
(2020)

Rel-17
(2021)

MCPTT

eMCPTT

enhMCPTT

enh2MCPTT

Mission Critical Data
(eMCData3)

Definition of
MCPTT

Enhanced
MCPTT

Enhanced
MCPTT

Enhanced
MCPTT

Group call,
Private call,
Floor (media)
control

Ambient
listening, first-
to-answer call,
private call call-
back request,
Audio cut-in

Remotely
initiated MCPTT
call request,
location of
current talker

Group Regroup
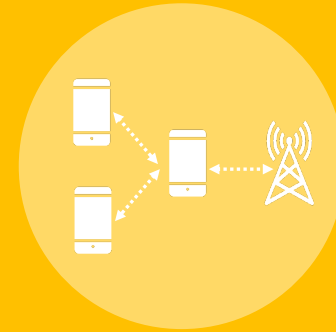
PSCR Research in Off-Network MCPTT

Protocol Validation

Use formal verification of protocol state machines (call control, floor control, private and group call). Develop test cases
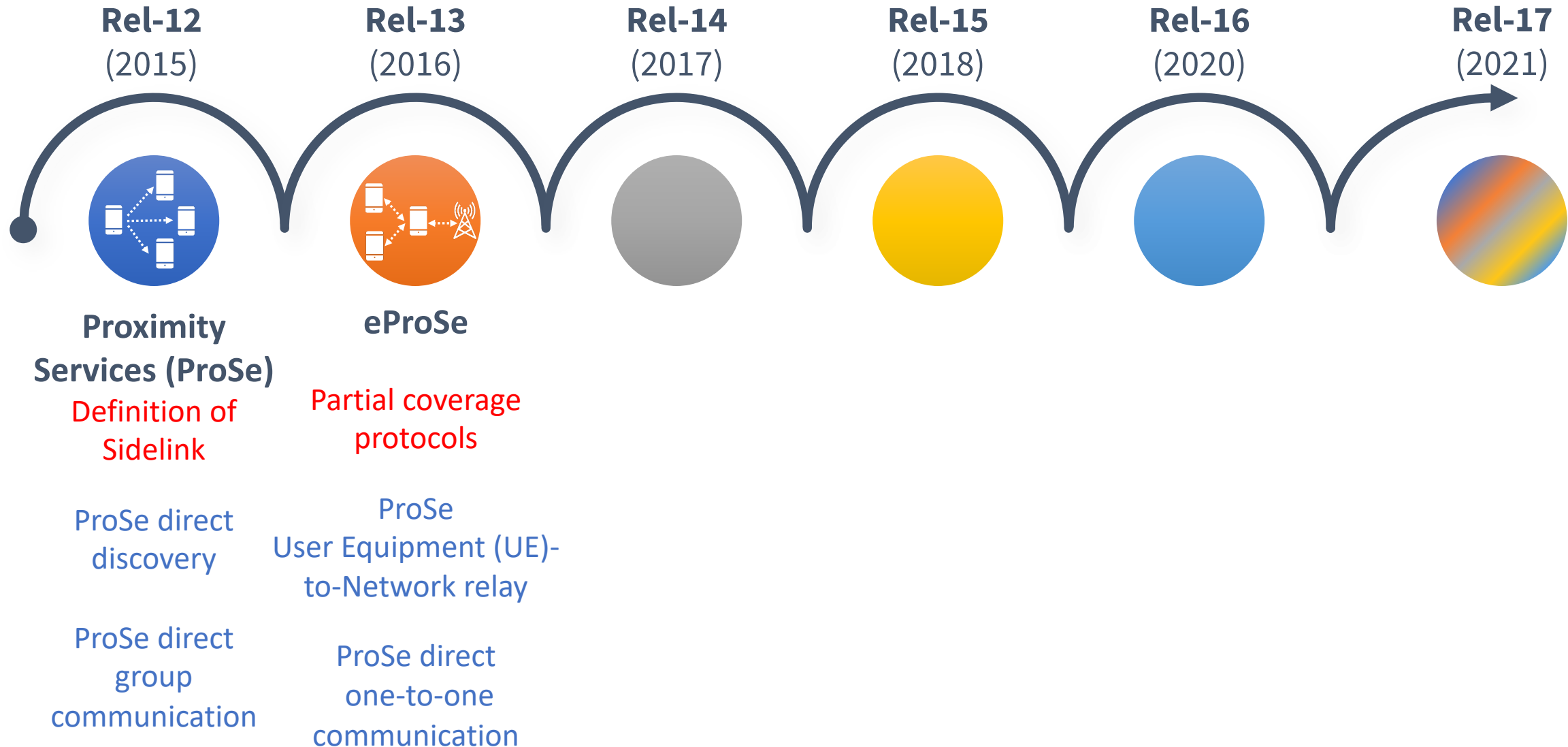
Performance Evaluation

Conduct sensitive analyses of Key Performance Indicators (KPI)s, such as access time

Contributions to 3GPP

Submitted large number of fixes across the various MCPTT releases

Evolution of D2D communication in 3GPP

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(2017)

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(2018)

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(2020)

Rel-17
(2021)

Proximity Services (ProSe)

eProSe

Definition of Sidelink

Partial coverage protocols

ProSe direct discovery

ProSe User Equipment (UE)-to-Network relay

ProSe direct group communication

ProSe direct one-to-one communication

Uses Cases for LTE D2D

Source https://www.pexels.com/photo/person-holding-space-gray-iphone-x-1440722/
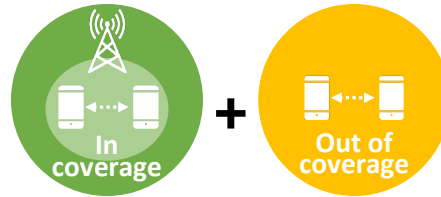
Commercial Use Cases

- Discovery services
    - Restricted discovery (e.g., social networking)
    - Open discovery (e.g., restaurant search)

- Enhanced user location services

- Dense environments (e.g., smart meters)

Public Safety Use Cases

- Group discovery

- Group communication

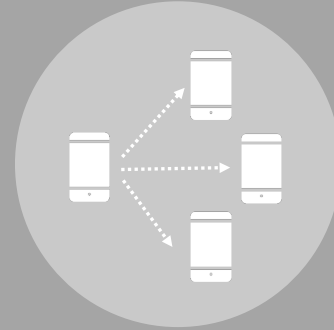- One-to-one communication

PSCR Research in LTE D2D

Synchronization

Allow devices in proximity to converge to a common configuration to be able to use D2D link

Discovery

Allow devices to detect other devices in proximity using the D2D link

Communication

Allow devices to exchange data with other devices in proximity using the D2D link

UE-to-Network Relay

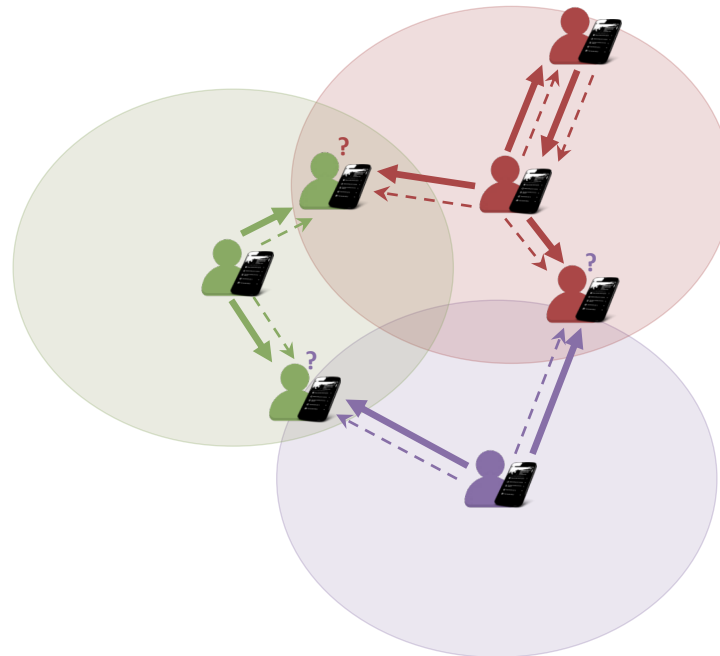Allow devices to access the network using the D2D link with another device in proximity
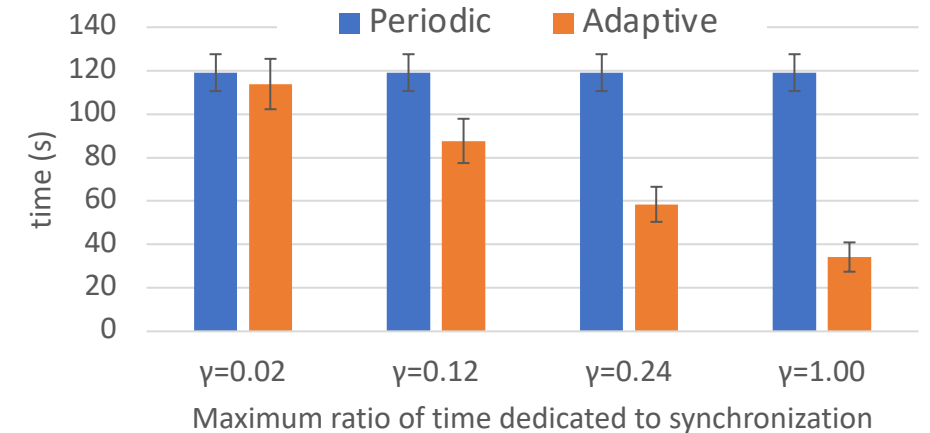
PSCR Research in LTE D2D

Evaluation of Information transmission procedure and Synchronization reference (re)selection procedure for Out-of-coverage D2D synchronization protocol

Convergence Time

- Characterization of the convergence time as a function of protocol parameters

- Report potential synchronization problems and proposals for optimization

Synchronization

Allow devices in proximity to converge to a common configuration to be able to use D2D link
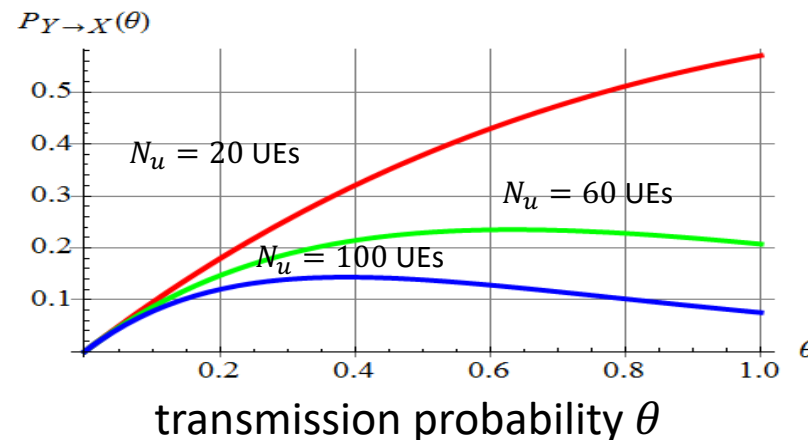
PSCR Research in LTE D2D

Discovery

Allow devices to detect other devices in proximity using the D2D link
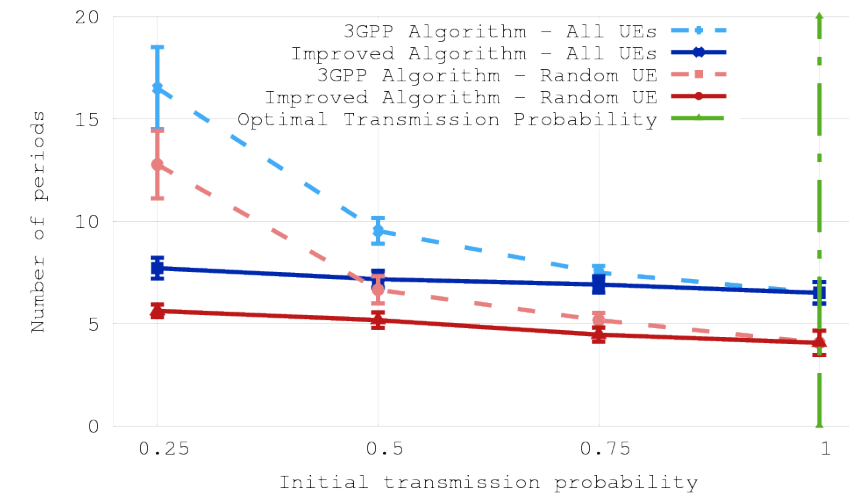
Developed KPIs to characterize the performance of group discovery
- Distribution of the time required to finish the group discovery
- Upper bounds for the number of UEs in a discovery group

Example of probability that a discovery message from UE Y reaches UE X

$P_{Y \to X}(\theta)$

$N_u = 20$ UEs

$N_u = 60$ UEs

$N_u = 100$ UEs

transmission probability θ

Group size: 10 UEs

Number of periods

Initial transmission probability

3GPP Algorithm – All UEs
Improved Algorithm – All UEs
3GPP Algorithm – Random UE
Improved Algorithm – Random UE
Optimal Transmission Probability

Developed optimizations of the discovery protocol considering
- Protocol parameters (e.g., transmission probability)
- Changes on the group size
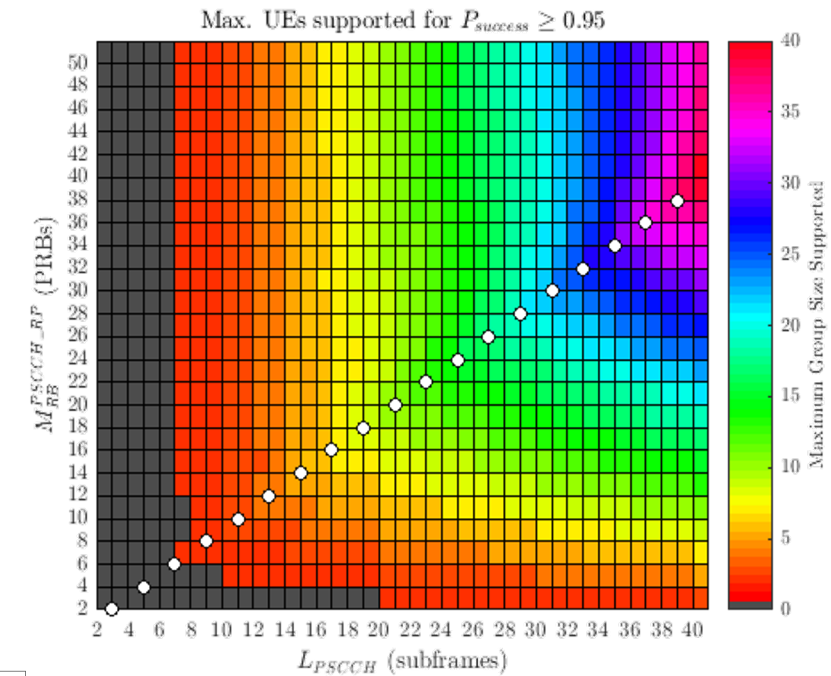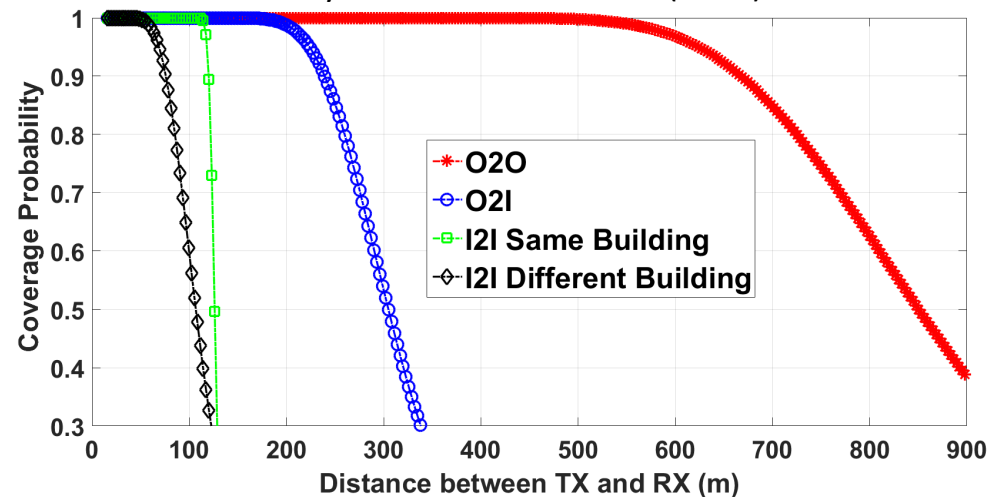
PSCR Research in LTE D2D
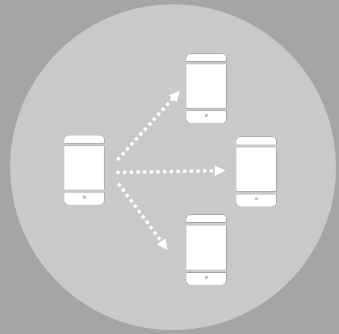
Evaluate factors impacting coverage and capacity of D2D group communication

Characterize the performance of
- Control – Physical Sidelink Control Channel (PSCCH)
- Data – Physical Sidelink Shared Channel (PSSCH)

Communication

Allow devices to exchange data with other devices in proximity using the D2D link

Impact of Buildings
With Modulation and Coding Scheme (MCS) 10 and 2 Physical Resource Blocks (PRBs)

Max. UEs supported for $P_{success} \geq 0.95$

Guidelines for pre-deployment configuration
- Resource pool configuration
- Scheduling

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PSCR Research in LTE D2D

UE-to-Network Relay

Allow devices to access the network using the D2D link with another device in proximity

Evaluate factors impacting performance including:

- UE-to-Network Relay discovery and selection
- One-to-one direct communication link establishment
- End-to-end communication via Relay UE

Discovery Time: Model B

Impact of T4100 timer value
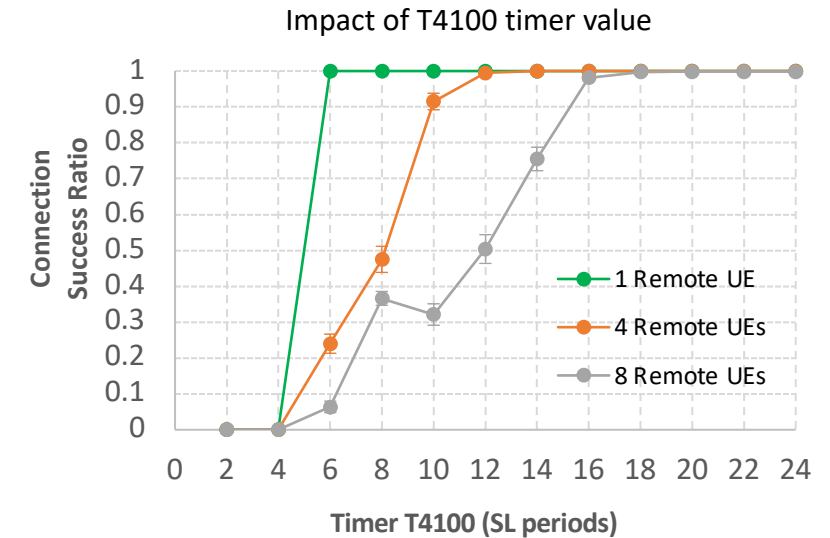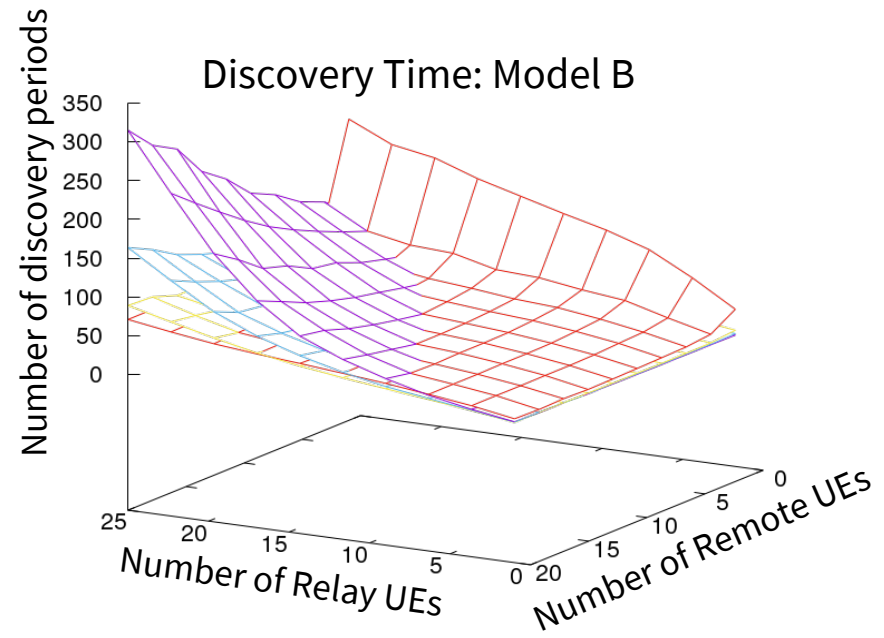
Guidelines for:
- Resource allocation
- Scheduling
- Timer configuration
- Service activation
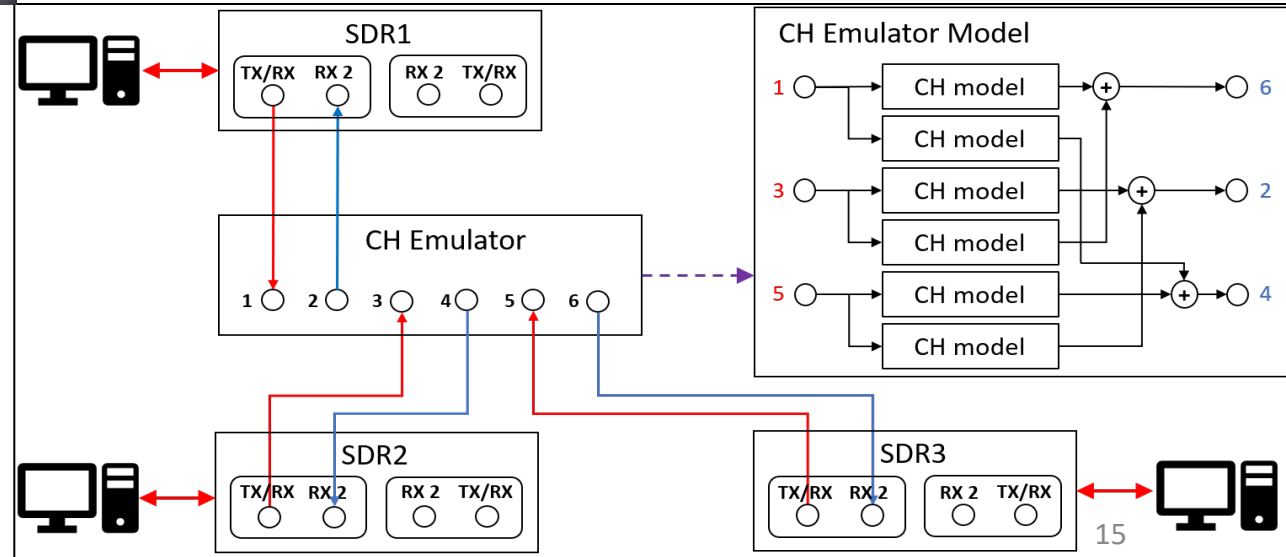
On-going LTE D2D Activities

Modeling enhancements

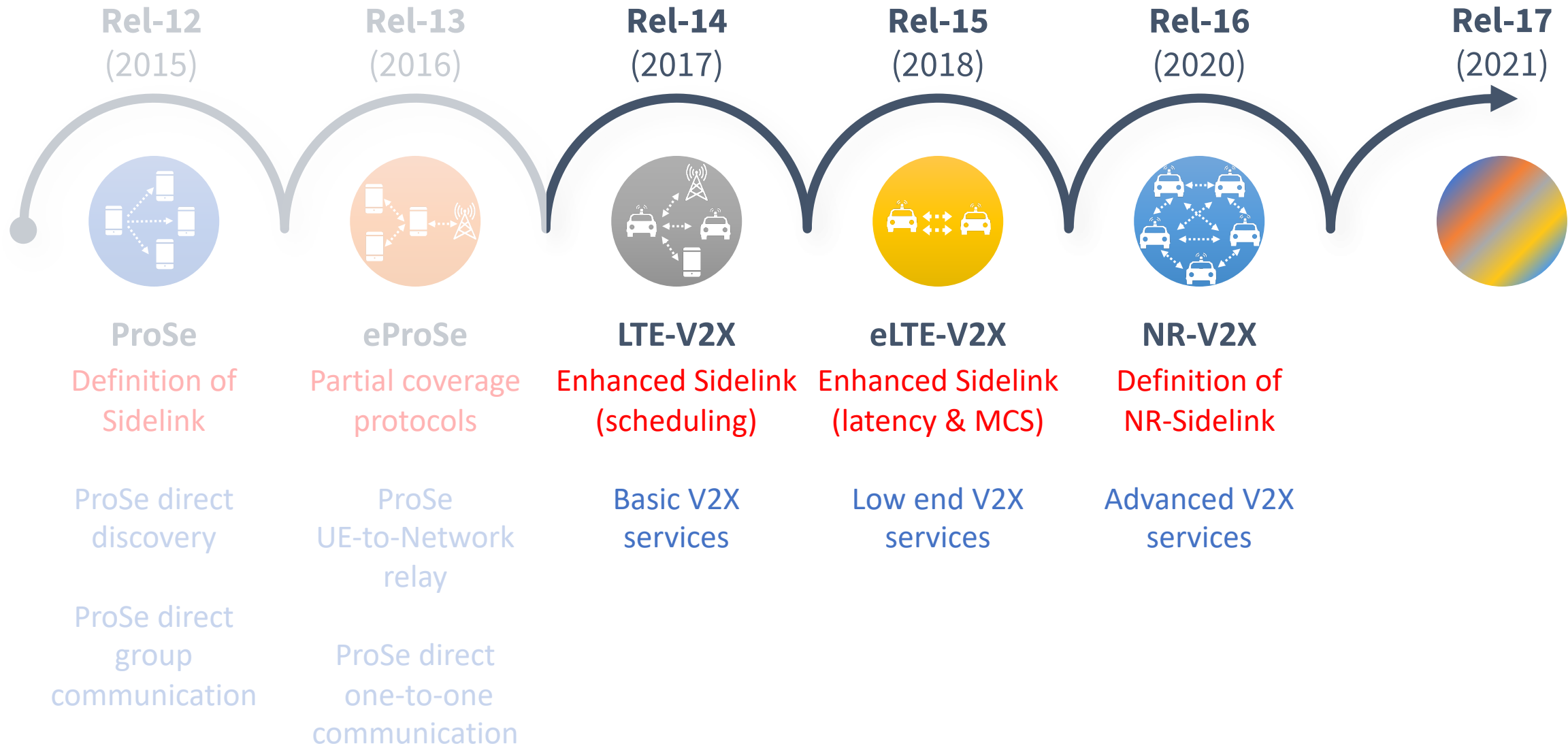Leverage Open Air Interface (OAI) D2D code, developed under Public Safety Innovation Accelerator Program (PSIAP) award to Perspecta Labs, to conduct testing/comparison of physical channel block error rate (BLER) using Software Defined Radios testbed.

Audio Quality/Intelligibility

Evaluate the effect of interference and distance on an Adaptive Multi-Rate Wideband (AMR-WB) audio going through a D2D link.

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(2020)

Rel-17
(2021)

ProSe

Definition of
Sidelink

ProSe direct
discovery

ProSe direct
group
communication

eProSe

Partial coverage
protocols

ProSe
UE-to-Network
relay

ProSe direct
one-to-one
communication

LTE-V2X

Enhanced Sidelink
(scheduling)

Basic V2X
services

eLTE-V2X

Enhanced Sidelink
(latency & MCS)

Low end V2X
services

NR-V2X

Definition of
NR-Sidelink

Advanced V2X
services

V2X Use Cases For 3GPP Technology

LTE V2X (TR 22.885)

27 use cases defined that fall into one of the following categories:
- Road safety (e.g., wrong way driving warning)
- Mutual vehicle awareness (e.g., forward collision warning)
- Other vehicle related application (e.g., automated parking system)
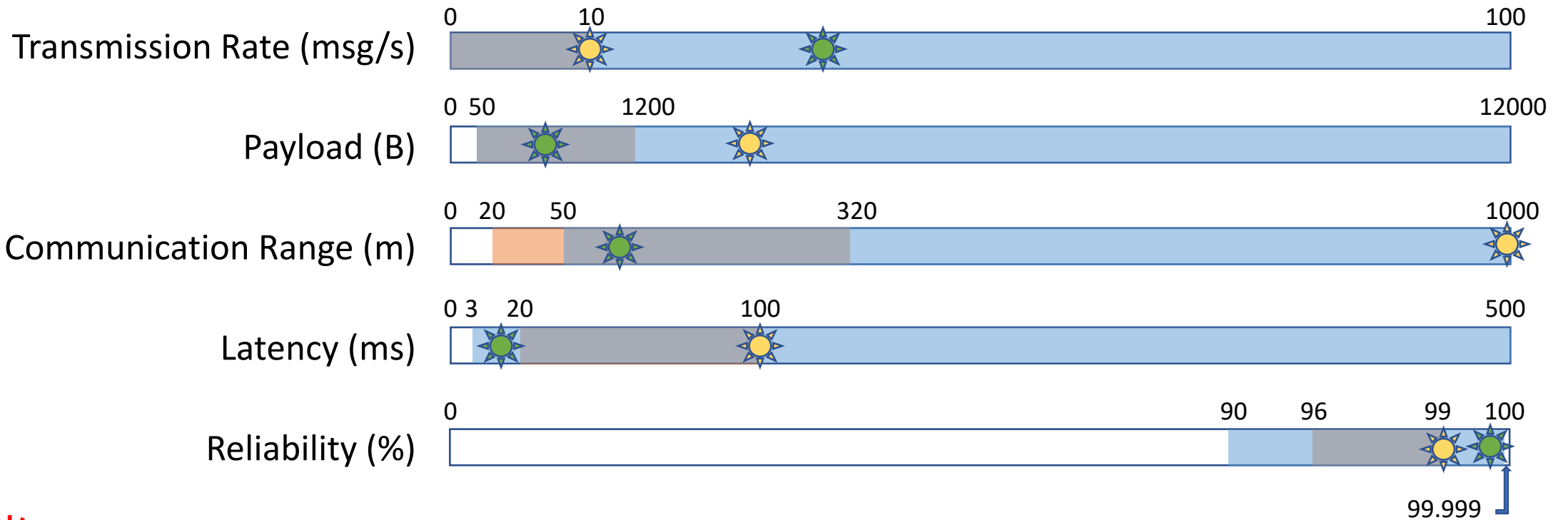
NR V2X (TR 22.886)

- Vehicles Platooning
- Advanced Driving
- Extended Sensors
- Remote Driving
- Vehicle quality of service support
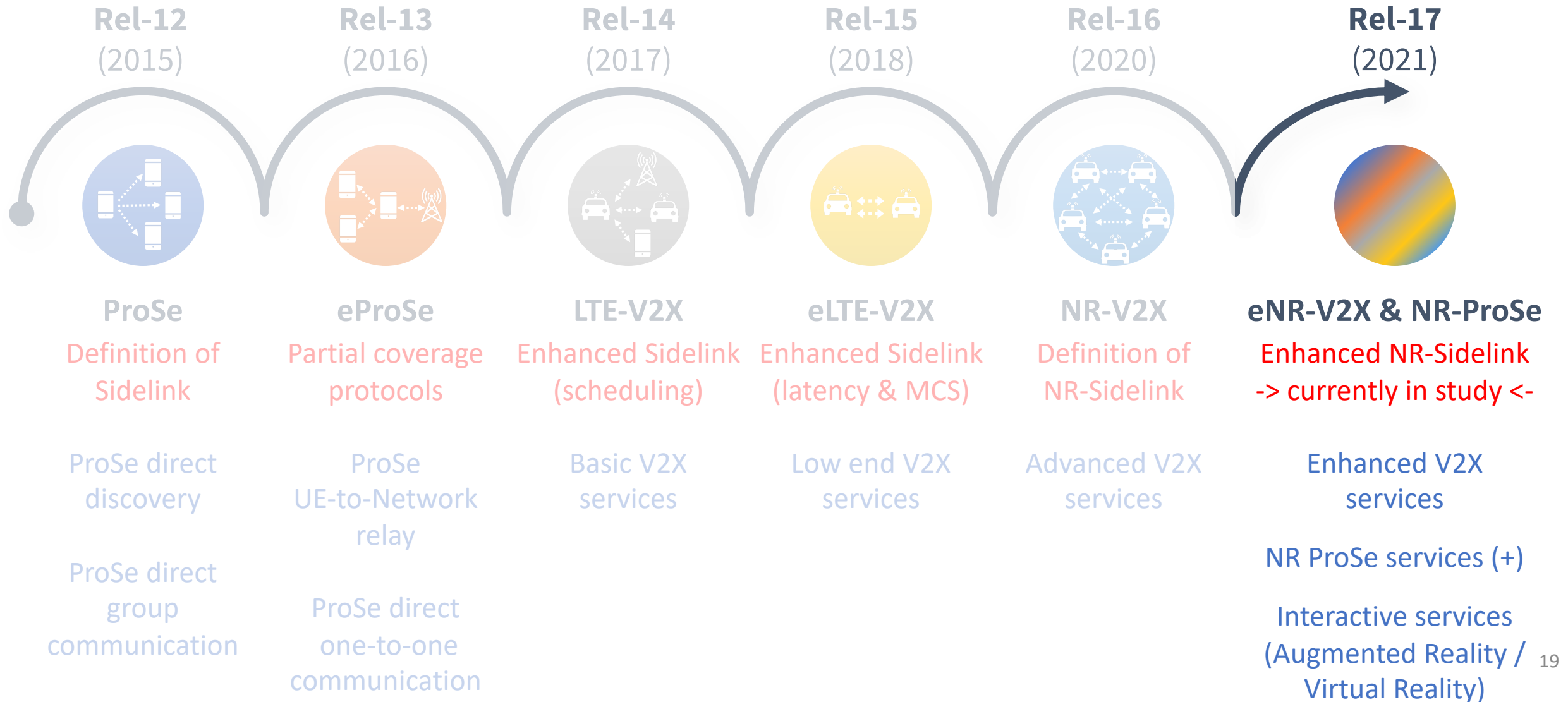
V2X Performance Requirements

LTE V2X
NR V2X

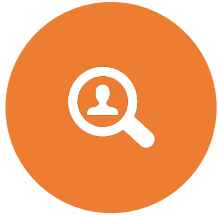☀ Sensor (low automation)
☀ Platooning (high automation)

Transmission Rate (msg/s)
0   10   100

Payload (B)
0 50   1200   12000

Minimum Communication Range (m)
0 20   50   320   1000

Latency (ms)
0 3   20   100   500

Reliability (%)
0   90   96   99 100
                                            99.999

💡 NR V2X appears to be a great candidate for supporting Direct Mode

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ProSe

Definition of
Sidelink

ProSe direct
discovery

ProSe direct
group
communication

eProSe

Partial coverage
protocols

ProSe
UE-to-Network
relay

ProSe direct
one-to-one
communication

LTE-V2X

Enhanced Sidelink
(scheduling)

Basic V2X
services

eLTE-V2X

Enhanced Sidelink
(latency & MCS)

Low end V2X
services

NR-V2X

Definition of
NR-Sidelink

Advanced V2X
services

eNR-V2X & NR-ProSe

Enhanced NR-Sidelink
-> currently in study <-

Enhanced V2X
services

NR ProSe services (+)

Interactive services
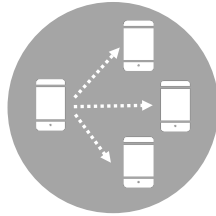(Augmented Reality /
Virtual Reality)

PS Direct Mode Features Under Study in Release 17

ProSe Discovery

Application and group member discovery between devices in proximity

ProSe Communication
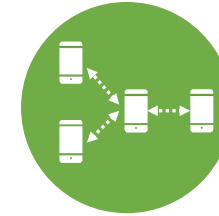
One-to-one and one-to-many communication

Support end-to-end Quality of Service (QoS)

UE-to-Network Relay

Indirect access to the network via another device

Support end-to-end QoS, service continuity, and simultaneous relay connections

UE-to-UE Relay

Communication with a device via another device

Support end-to-end QoS, and service continuity

NR Sidelink + NR V2X

Introduction to 5G NR and NR V2X

How to achieve high performance D2D communication

5G NR Capabilities and Target Performance

Wide range of use cases by enhancing 3 key capabilities:

Enhanced Mobile Broadband (eMBB)
High capacity and peak data rates

Ultra-Reliable and Low Latency Communication (URLLC)

Massive Machine Type Communication (MMTC)
High connection density and low data rates

Associated performance targets include:

Data rates
Peak: Downlink (DL) = 20 Gb/s, Uplink (UL) = 10 Gb/s
Cell Edge: DL = 100 Mb/s, UL = 50 Mb/s
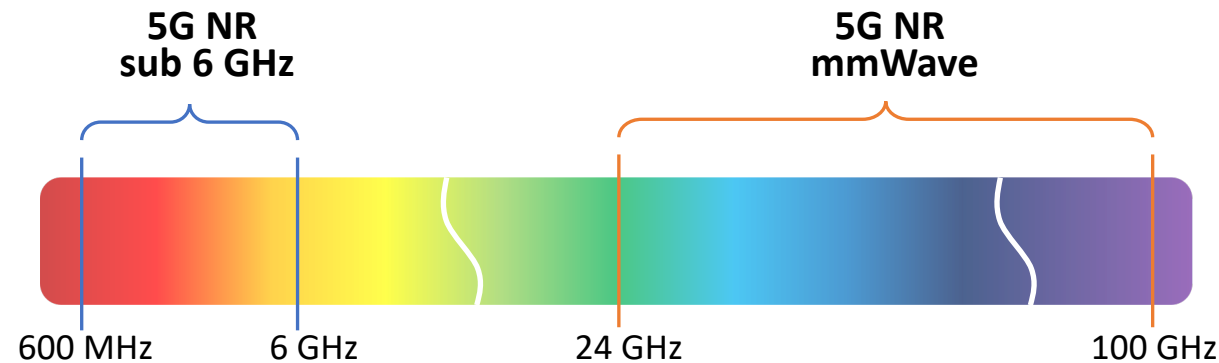**Cell throughput up to 10 Mb/s/m²**

Radio access network latency less than 1 ms

Connection density up to 1 M devices/km²

5G NR Flexible Architecture

- Wide range of spectrum: sub 6 GHz and mmWave frequencies

5G NR sub 6 GHz

5G NR mmWave

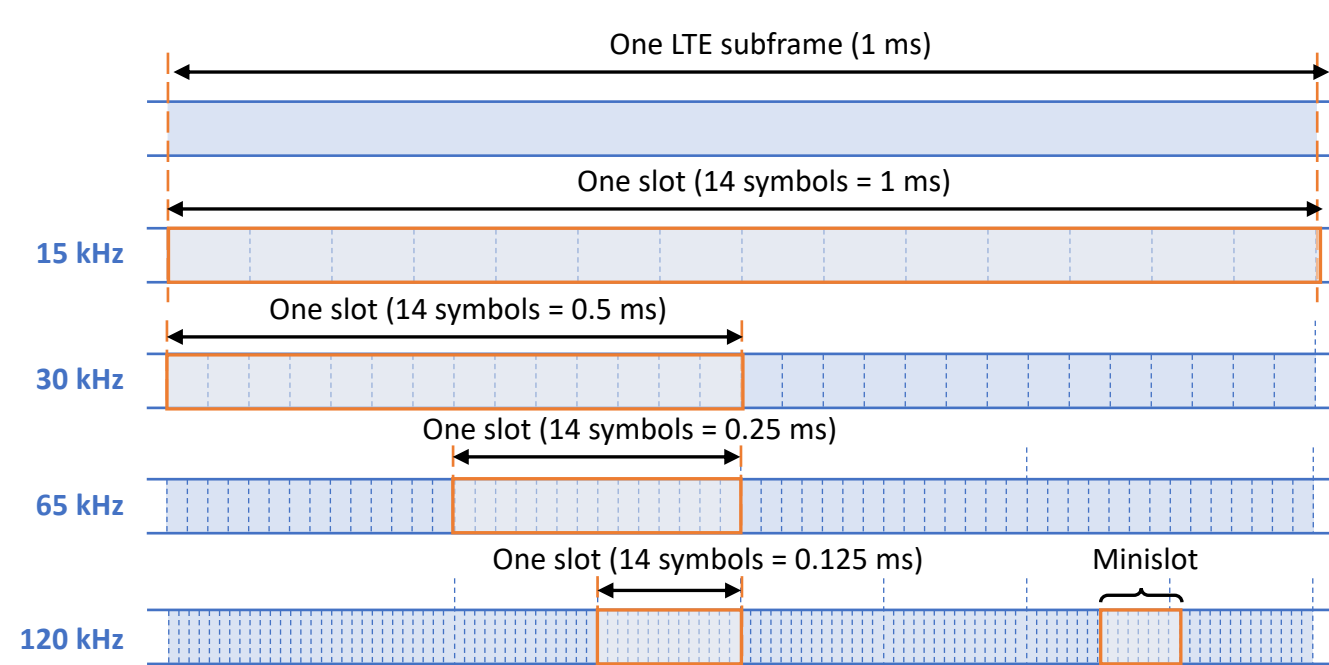600 MHz   6 GHz   24 GHz   100 GHz

- Scalable Orthogonal Frequency Division Multiplexing (OFDM)-based air interface (numerology)
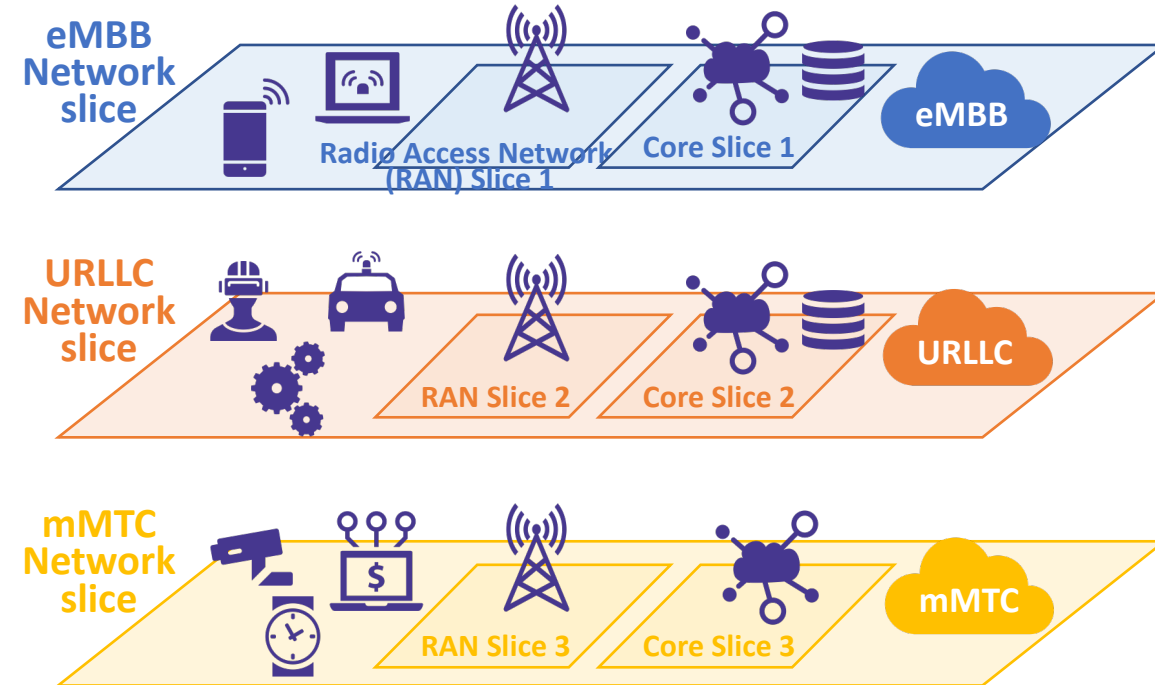- Wideband carrier support

- Advanced channel coding
- Massive Multiple Input Multiple Output (MIMO)

# 5G NR Flexible Architecture

- Radio resource allocation

One LTE subframe (1 ms)

One slot (14 symbols = 1 ms)

15 kHz

One slot (14 symbols = 0.5 ms)

30 kHz

One slot (14 symbols = 0.25 ms)

65 kHz

One slot (14 symbols = 0.125 ms)

Minislot

120 kHz

Increased granularity (minislots)

eMBB Network slice

Radio Access Network (RAN) Slice 1

Core Slice 1

eMBB

URLLC Network slice

RAN Slice 2

Core Slice 2

URLLC

mMTC Network slice

RAN Slice 3

Core Slice 3

mMTC

Increased resource partitioning

5G NR Flexible Architecture

- Modular deployment
  - Software based (network virtualization)
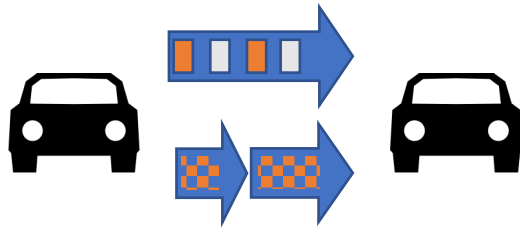 - Incremental (non-standalone, standalone)
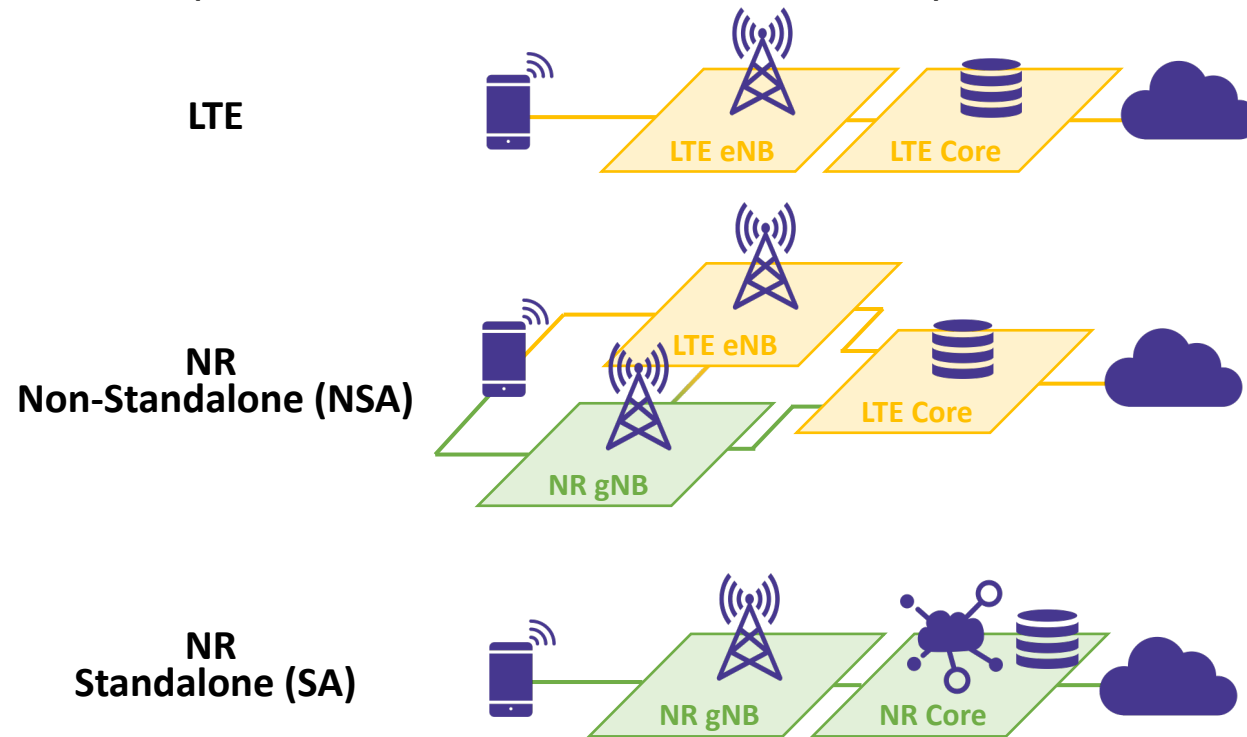
5G NR V2X Enhancements

- Besides benefiting from the improvements brought by 5G NR, NR V2X also includes several enhancements and new capabilities compared to its LTE counterpart, including:
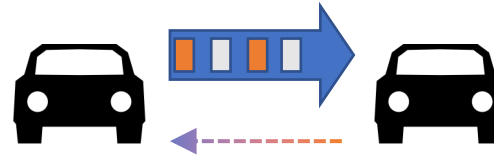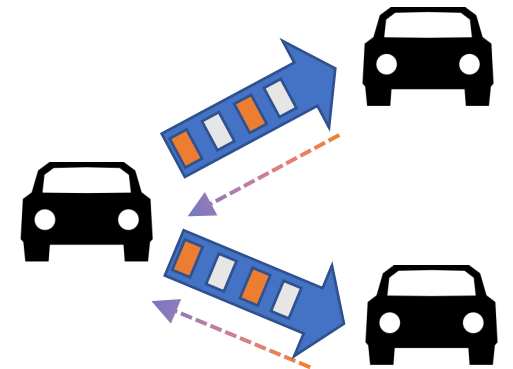

Sensing
Similar to LTE V2X

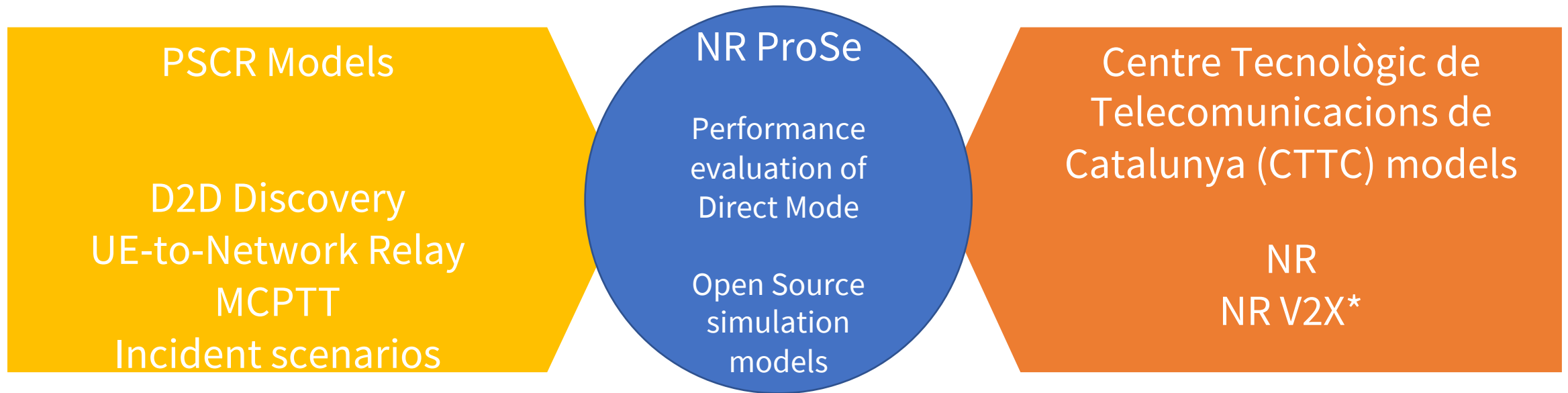**Scheduling**
Semi-persistent
Per-packet

Feedback
Channel State Information
PSSCH ACK/NACK
Hybrid Automatic Repeat
Request (HARQ)-ACK

Multicast
Connectionless
Distance-based

Current NR Modeling Effort

PSCR Models

D2D Discovery
UE-to-Network Relay
MCPTT
Incident scenarios

NR ProSe

Performance evaluation of Direct Mode

Open Source simulation models

Centre Tecnològic de Telecomunicacions de Catalunya (CTTC) models

NR
NR V2X*

* Under development via NIST Measurement Science and Engineering (MSE) Research Grant

Conclusion

- PSCR continues to support First Responder's need for reliable Direct Mode in 3GPP

- LTE ProSe allowed First Responders to maintain connection while out of coverage, but NR V2X is a promising solution to achieve high performance

- PSCR will leverage the research conducted over the past few years and partners to enable faster evaluation of the proposed solutions in NR ProSe

COME SOLVE WITH US

Contact Us

richard.rouil@nist.gov

https://www.nist.gov/programs-projects/public-safety-communications

https://github.com/usnistgov/psc-ns3

THANK YOU

#PSCR2020

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