Service Continuity Using UE-to-Network Relays

David Griffith and Richard Rouil

NIST/CTL/Wireless Networks Division

July 10, 2019

DISCLAIM ER

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately.

Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

*Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change

Motivations

Device to device (D2D) communication is critical when users are "out-of-coverage" from any cellular towers.

In situations where some users are still within network coverage, D2D User Equipment (UE)-to-Network relays can be leveraged to extend and maintain connectivity to users near the cell coverage area.

Partial Coverage Scenario

Network coverage may contain areas of weak/no signal, especially inside buildings or due to damaged infrastructures

D2D communication allows UEs to communicate with nearby units, but not all of them

If traffic is relayed to the network, more units can receive radio traffic
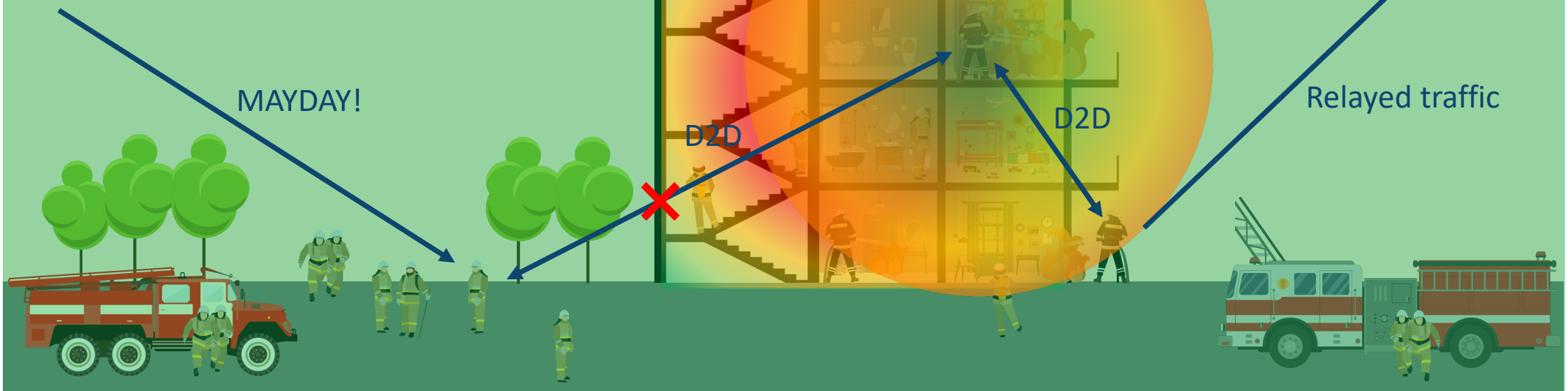
MAYDAY!

MAY DAY!

D2D

D2D

Relayed traffic

UE-to-Network Relay Functions

Relay Discovery and Selection

A UE losing connectivity with the network needs to discover the Relay UEs in proximity and select one to use

Relay Connection Establishment

The Remote UE exchanges signaling messages to establish a secure one-to-one link with the Relay UE

Relay Communication

The Relay UE performs IP-level forwarding of packets between the network and the Remote UE

How long will the process take?
What is the impact on the user experience?
What are the major factors impacting performance?
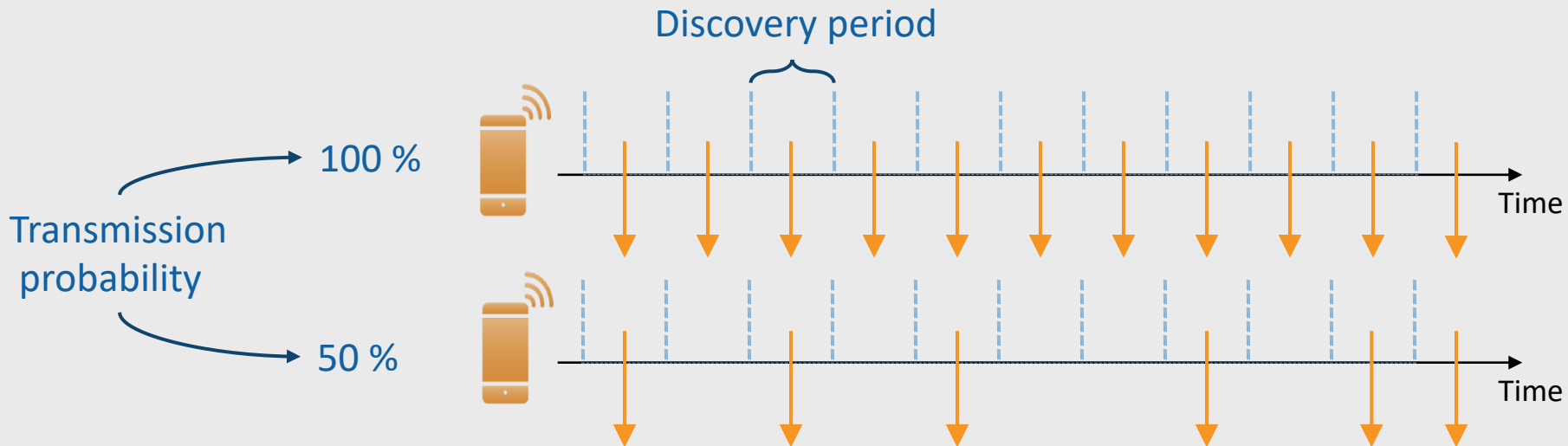
Relay Discovery and Selection

Which discovery method to use?
How many relays can be discovered?
Which relay to select?

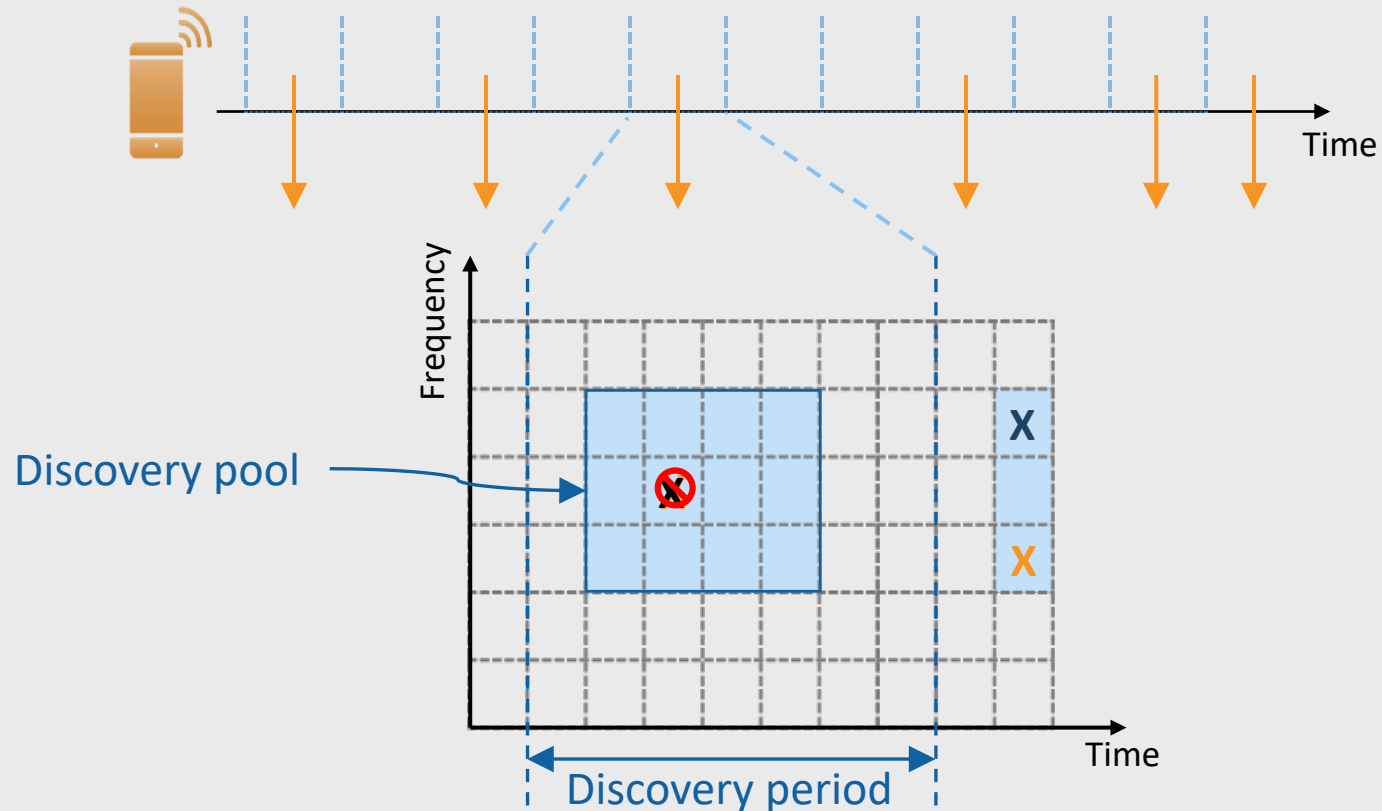# Relay Discovery and Selection

Discovery Protocol

- Discovery message transmission
  - Periodical (from 0.32 s up to 10.24 s)
  - Use transmission probability
  - Select resource randomly

Relay Discovery and Selection

Discovery Protocol

- Performance constraints / potential problems
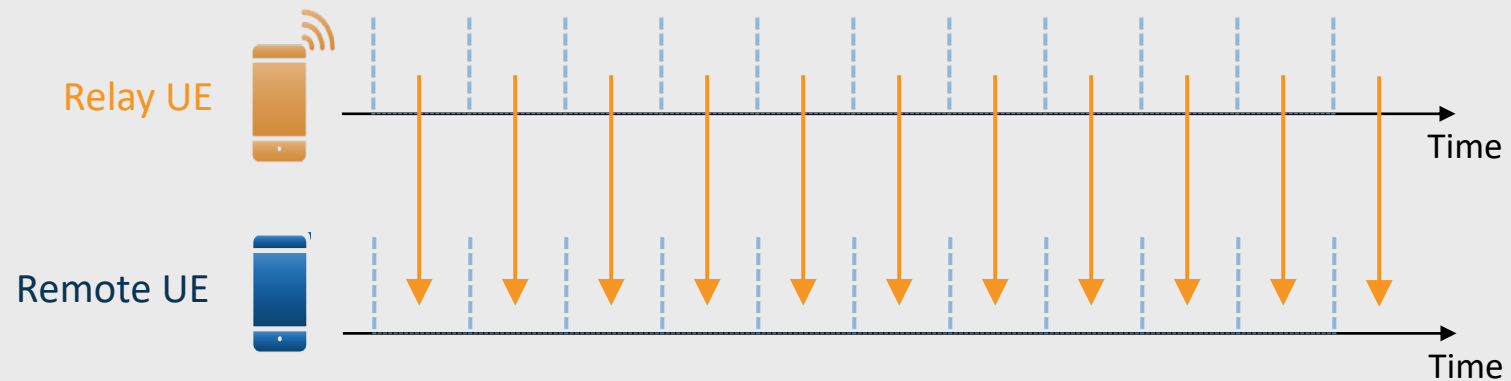 - Collisions
  - Half-duplex
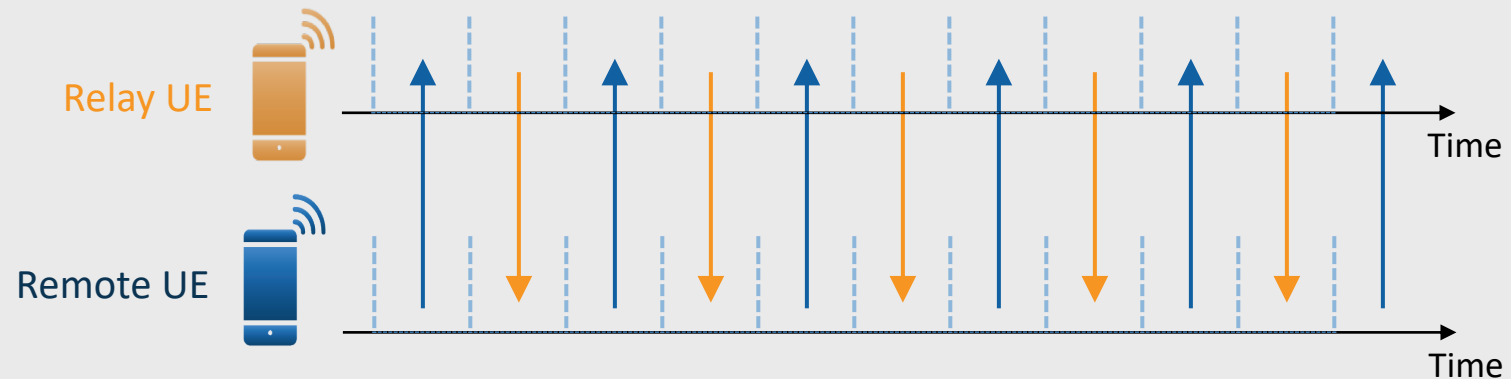
Relay Discovery and Selection

Relay Discovery and Selection
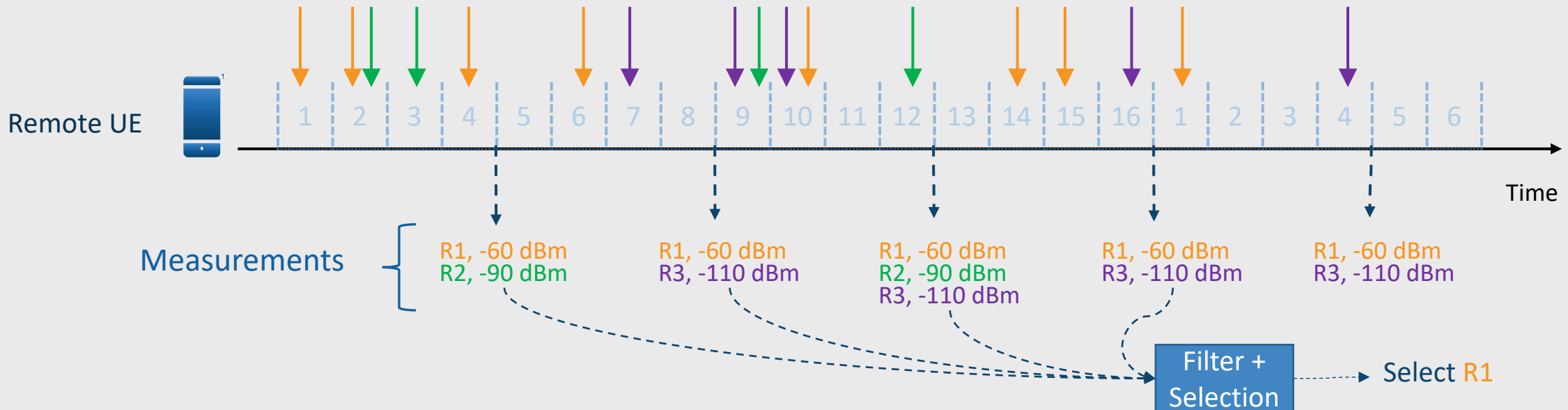
- Discovery Models

Model A : Relay Announcement

Relay UE

Time

Remote UE

Time

Model B : Relay Solicitation (Remote UE) - Relay Response (Relay UE)

Relay UE

Time

Remote UE

Time

9

Relay Discovery and Selection
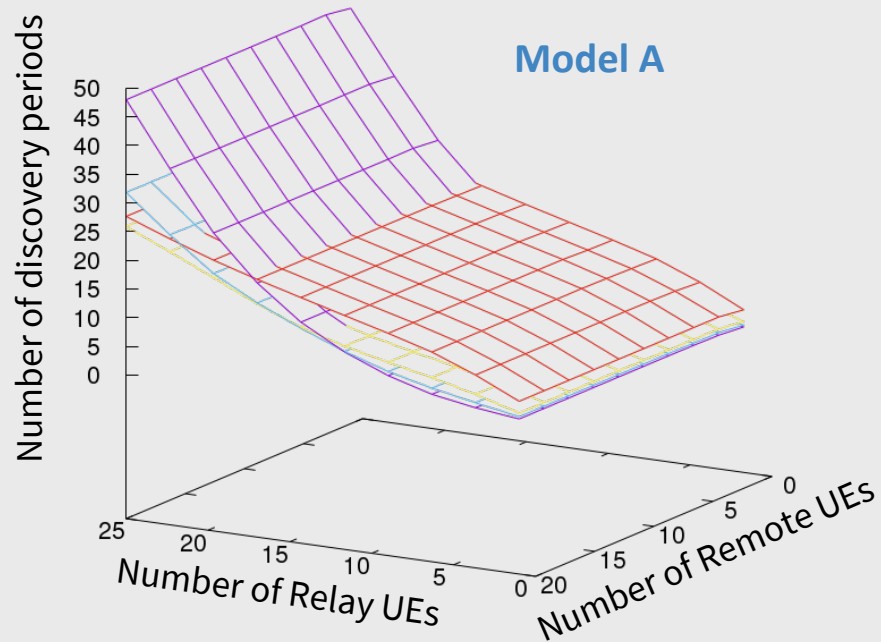
Relay Discovery and Selection

- Relay Selection
  - Search for candidate relay UEs every discovery period
  - Measurement of the candidate relays every 4 discovery periods
 - Evaluation of the candidate relays within 16 discovery periods

Remote UE

Measurements

R1, -60 dBm
R2, -90 dBm

R1, -60 dBm
R3, -110 dBm

R1, -60 dBm
R2, -90 dBm
R3, -110 dBm

R1, -60 dBm
R3, -110 dBm

R1, -60 dBm
R3, -110 dBm

Filter + Selection

Select R1

Time

Relay Discovery and Selection

Discovery Time

Number of discovery periods needed for All Remote UEs to discover all Relay UEs

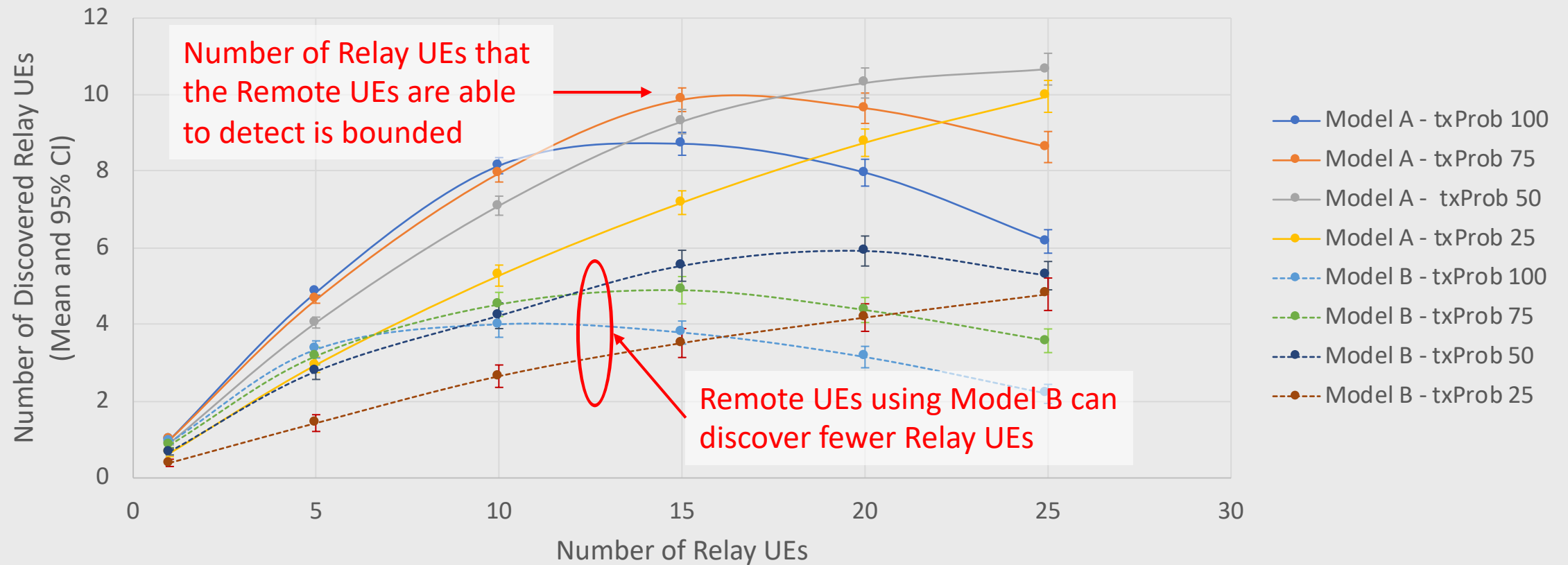- Only the number of Relay UEs affects the discovery time.
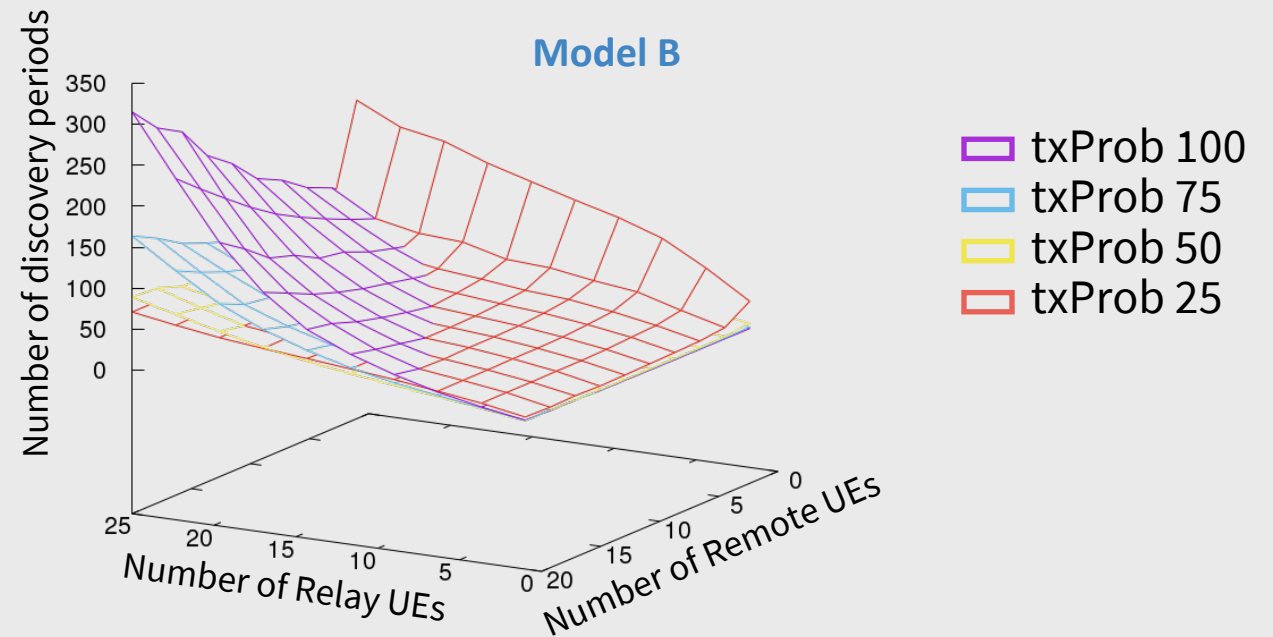
- Both the number of Relay UEs and number of Remote UEs affect the discovery time

Relay Discovery and Selection

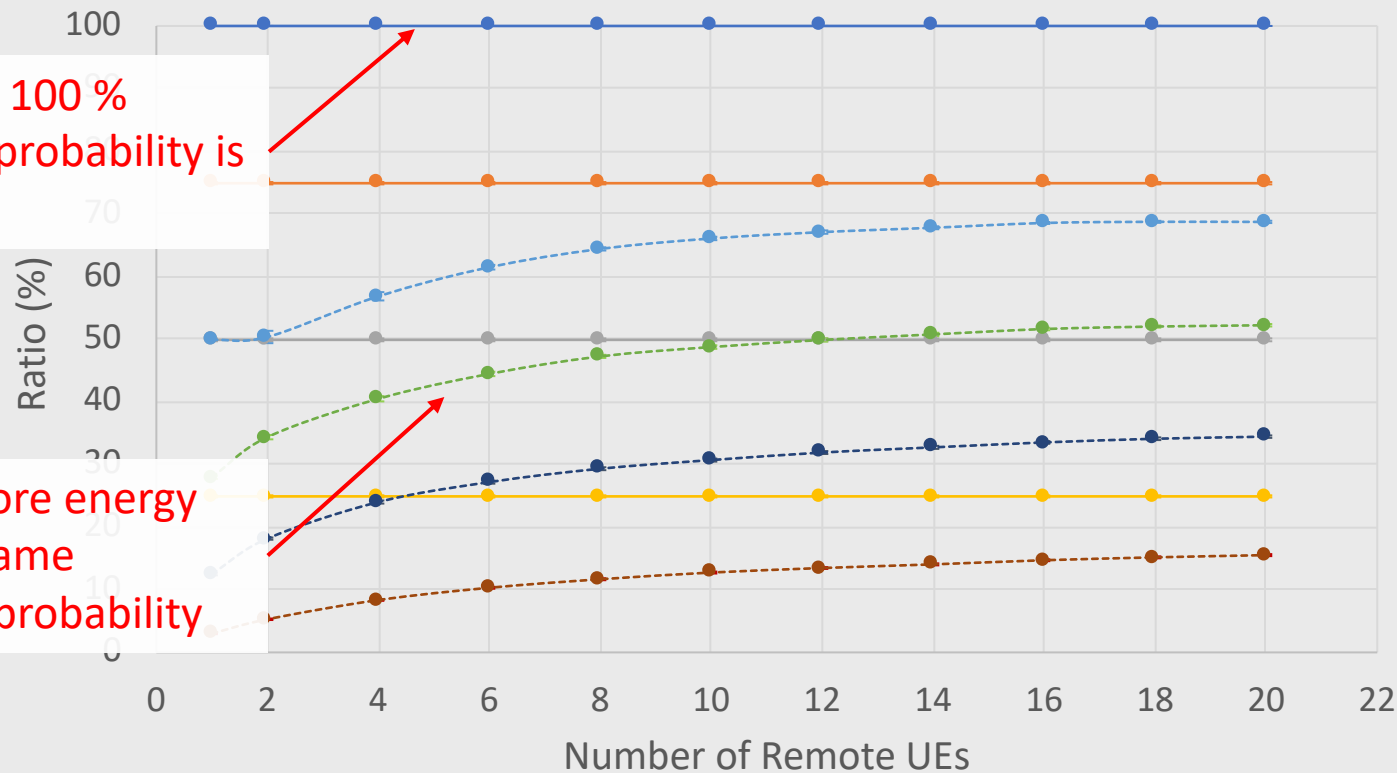## Impact of Discovery on the Relay Selection

Average Number of discovered Relays UEs in a measurement period (4 discovery periods) with 10 Remote UEs present

Relay Discovery and Selection

Discovery Model Comparison

Relative number of transmitted discovery messages by the Relay UEs

Model A with 100 % transmission probability is the worst

Model B is more energy efficient for same transmission probability

Legend:
- Model A - txProb 100
- Model A - txProb 75
- Model A - txProb 50
- Model A - txProb 25
- Model B - txProb 100
- Model B - txProb 75
- Model B - txProb 50
- Model B - txProb 25

Y-axis: Ratio (%)
X-axis: Number of Remote UEs

Relay Discovery and Selection

Selection Algorithm

- Relay discovery affects the choices available to the Remote UEs

- Enhancing information available during the discovery allows to better selection
  - Load
  - Battery level
  - Achievable data rate
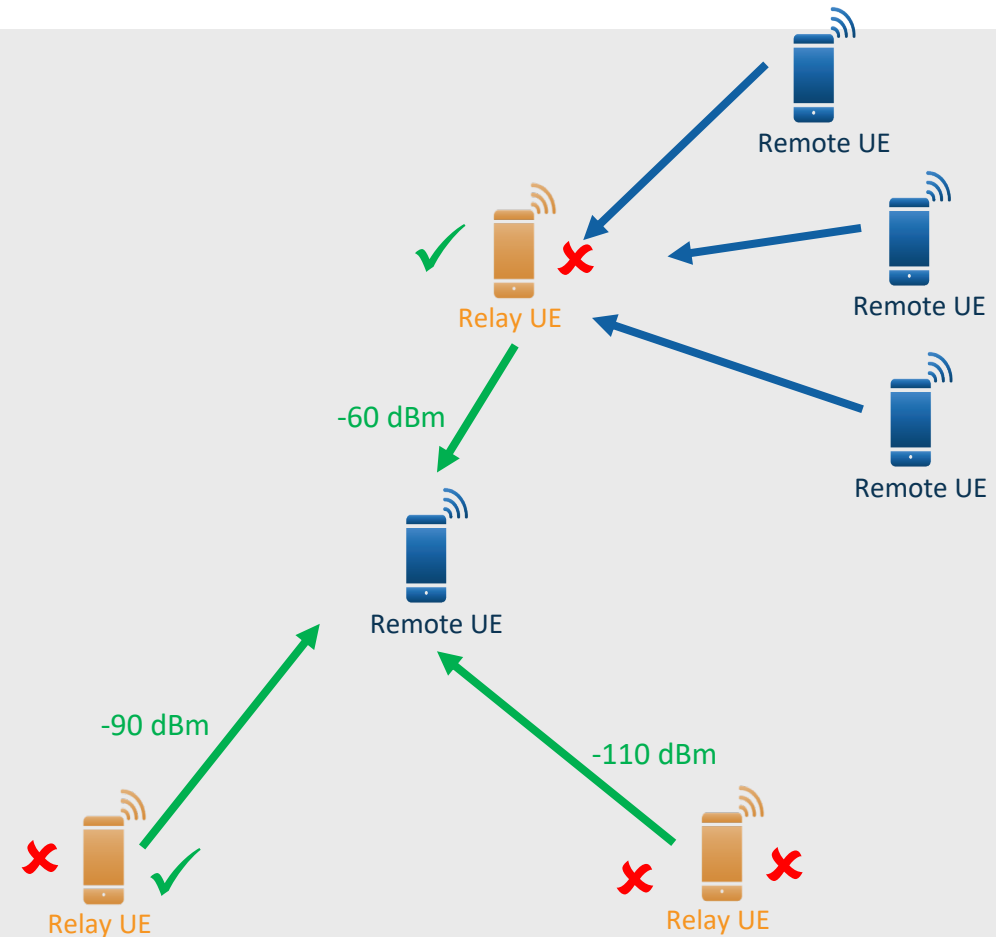
UE-to-Network Relay Functions

Relay Discovery and Selection

A UE losing connectivity with the network needs to discover the Relay UEs in proximity and select one to use

Relay Connection Establishment

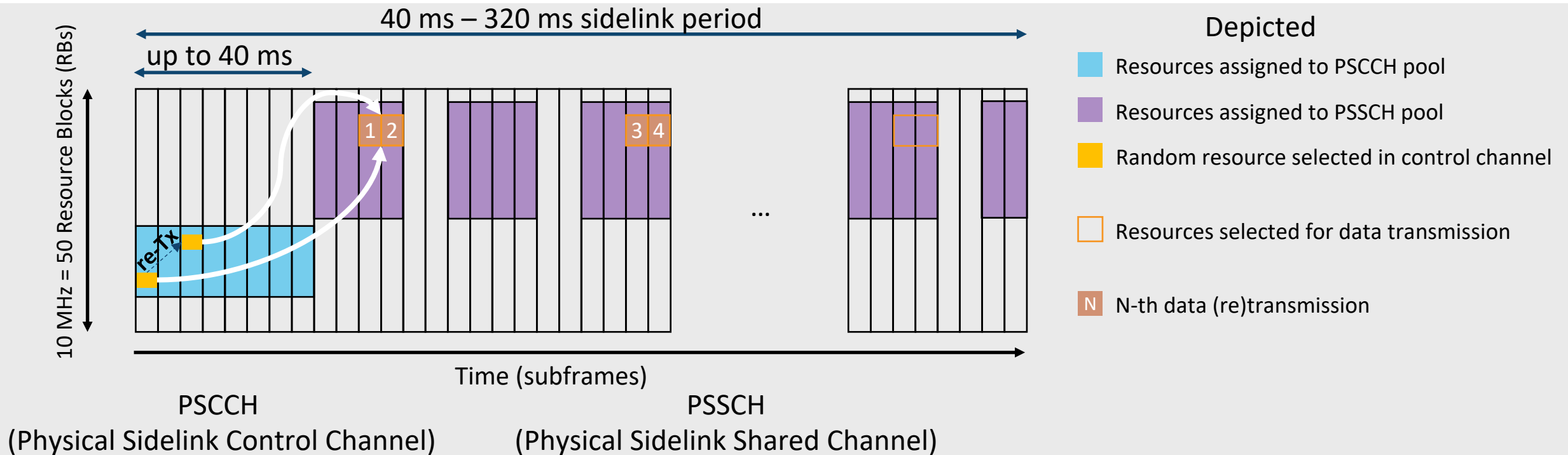The Remote UE exchanges signaling messages to establish a secure one-to-one link with the Relay UE

Relay Communication

The Relay UE performs IP-level forwarding of packets between the network and the Remote UE

Use the sidelink communication protocol to exchange signaling messages and data

Communication Over Sidelink
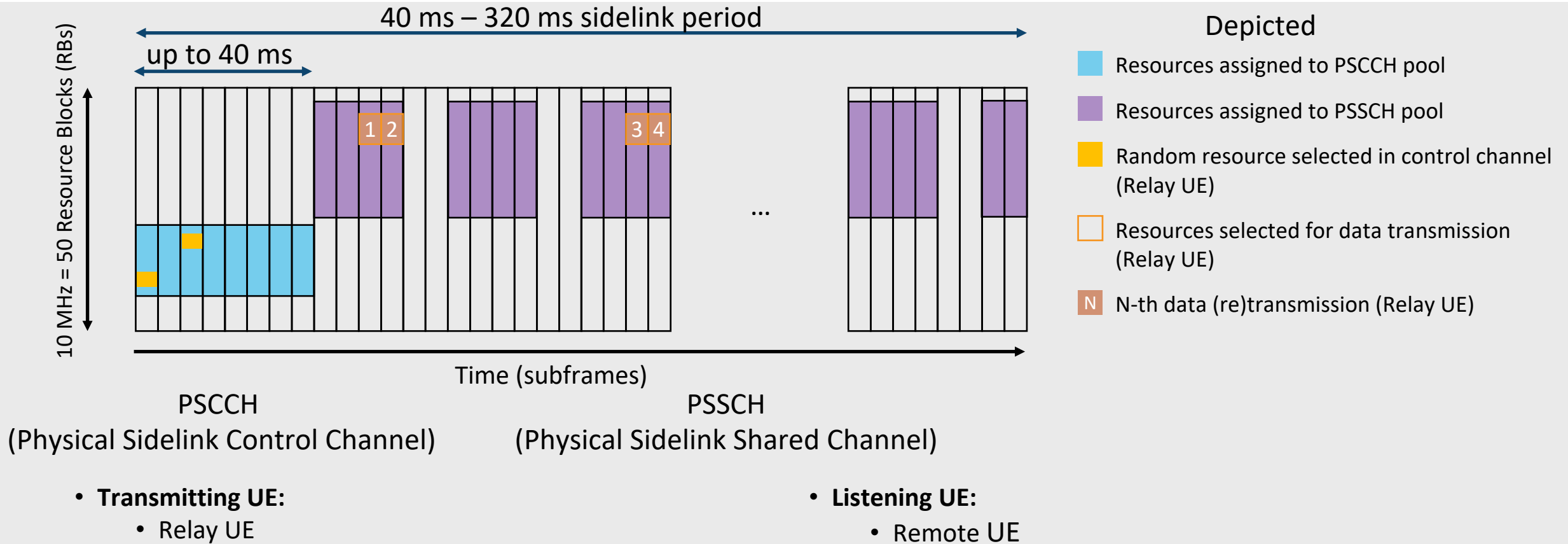
Basic Operation

- **Transmitting UE:**
  - Selects a **random resource** in the PSCCH pool to send a Control Information Message, indicating where and how the data will be transmitted in the PSSCH.

- **Listening UE:**
  - Each UE listens to the control channel to learn whether other UEs are going to transmit and what resources they will use
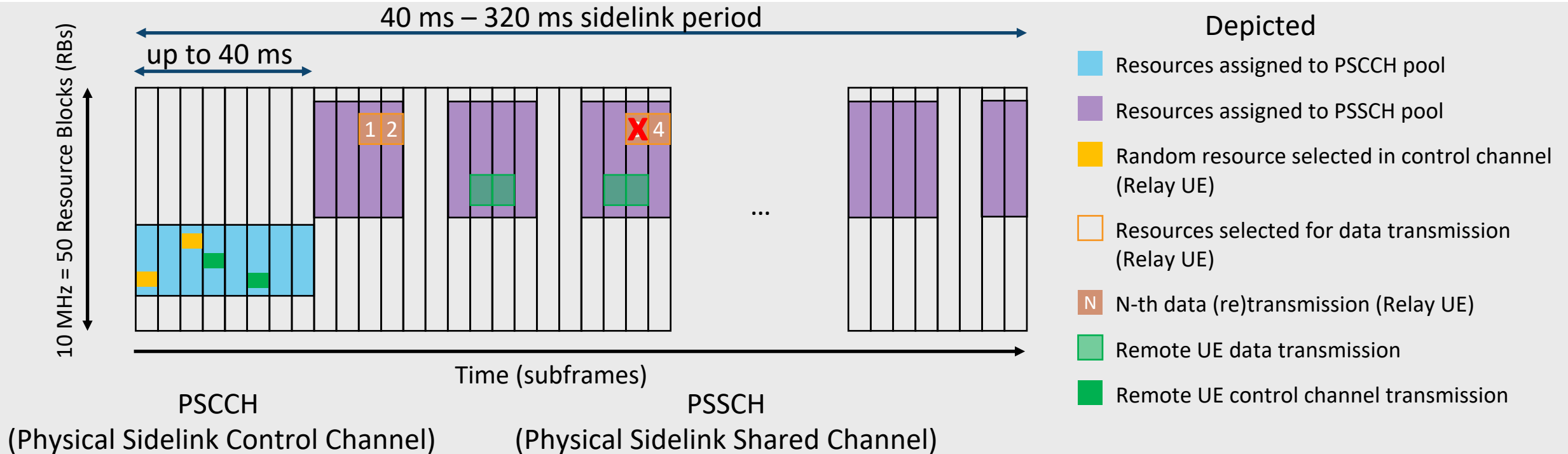
Communication Over Sidelink

Consider a Relay UE to Remote UE Transmission

Depicted
- 🟦 Resources assigned to PSCCH pool
- 🟪 Resources assigned to PSSCH pool
- 🟧 Random resource selected in control channel (Relay UE)
- ⬜ Resources selected for data transmission (Relay UE)
- N N-th data (re)transmission (Relay UE)

40 ms – 320 ms sidelink period

up to 40 ms

10 MHz = 50 Resource Blocks (RBs)

Time (subframes)

PSCCH
(Physical Sidelink Control Channel)

PSSCH
(Physical Sidelink Shared Channel)

- **Transmitting UE:**
  - Relay UE

- **Listening UE:**
  - Remote UE

What factors can affect the successful reception of the transmissions?
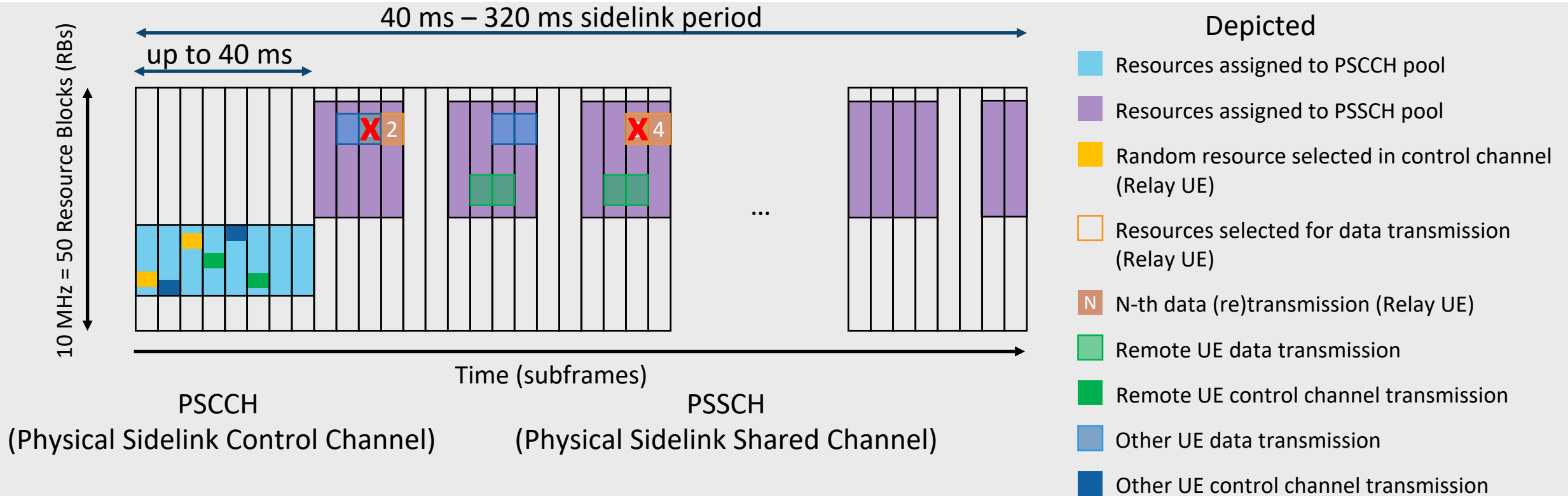
Communication Over Sidelink

Half Duplex Constraint

- The Remote UE transmits on the sidelink on overlapping resources in time
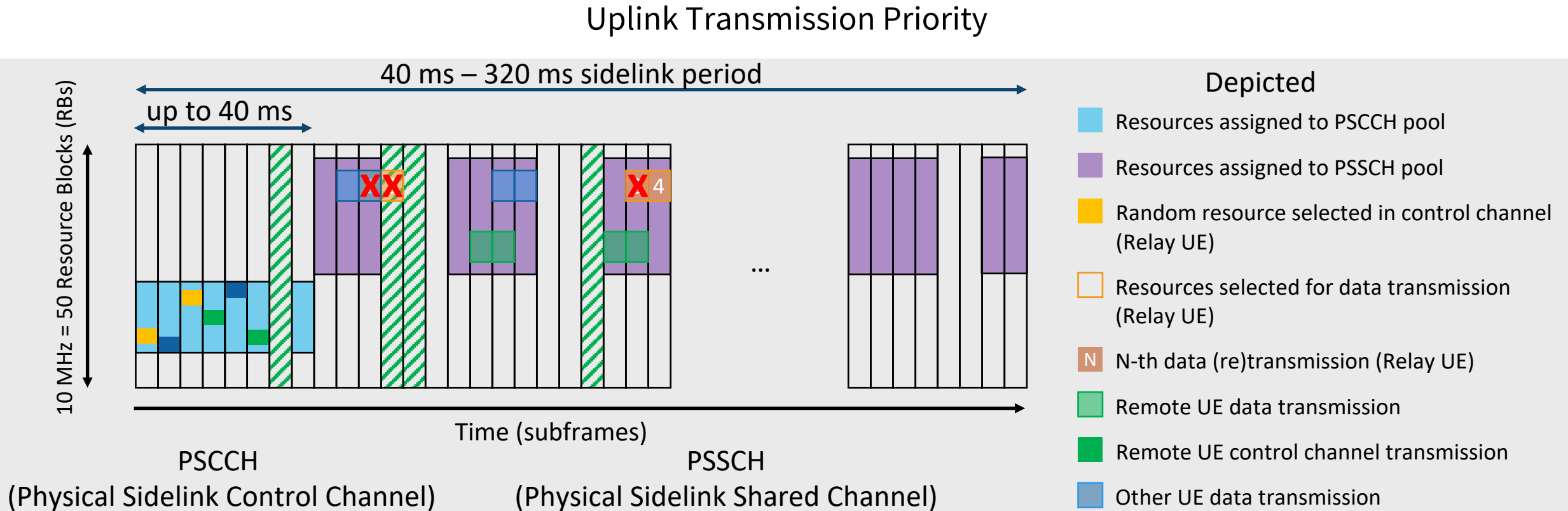   → Miss transmissions from the Relay UE

Communication Over Sidelink

Collisions and Interference

- Another UE selects overlapping resources in time and frequency
  - ➔ Remote UE is not able to decode the transmission

Communication Over Sidelink

Uplink Transmission Priority

PSCCH
(Physical Sidelink Control Channel)

PSSCH
(Physical Sidelink Shared Channel)

- The Relay UE transmits on the uplink on overlapping resources in time
  - ➜ Must drop transmissions to the Remote UE

Communication Over Sidelink
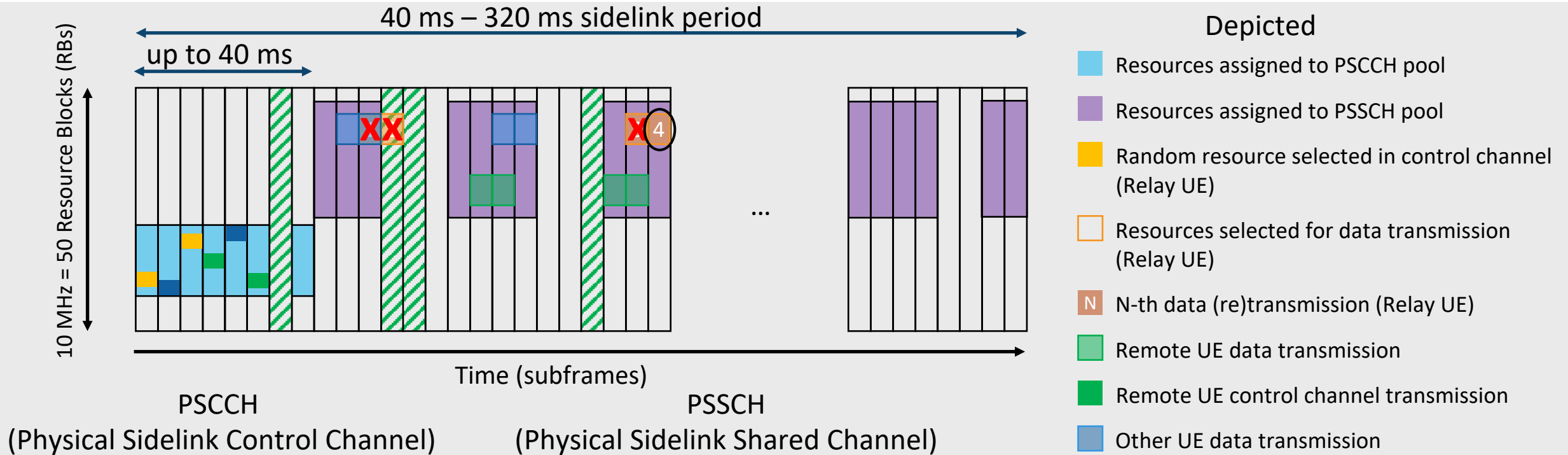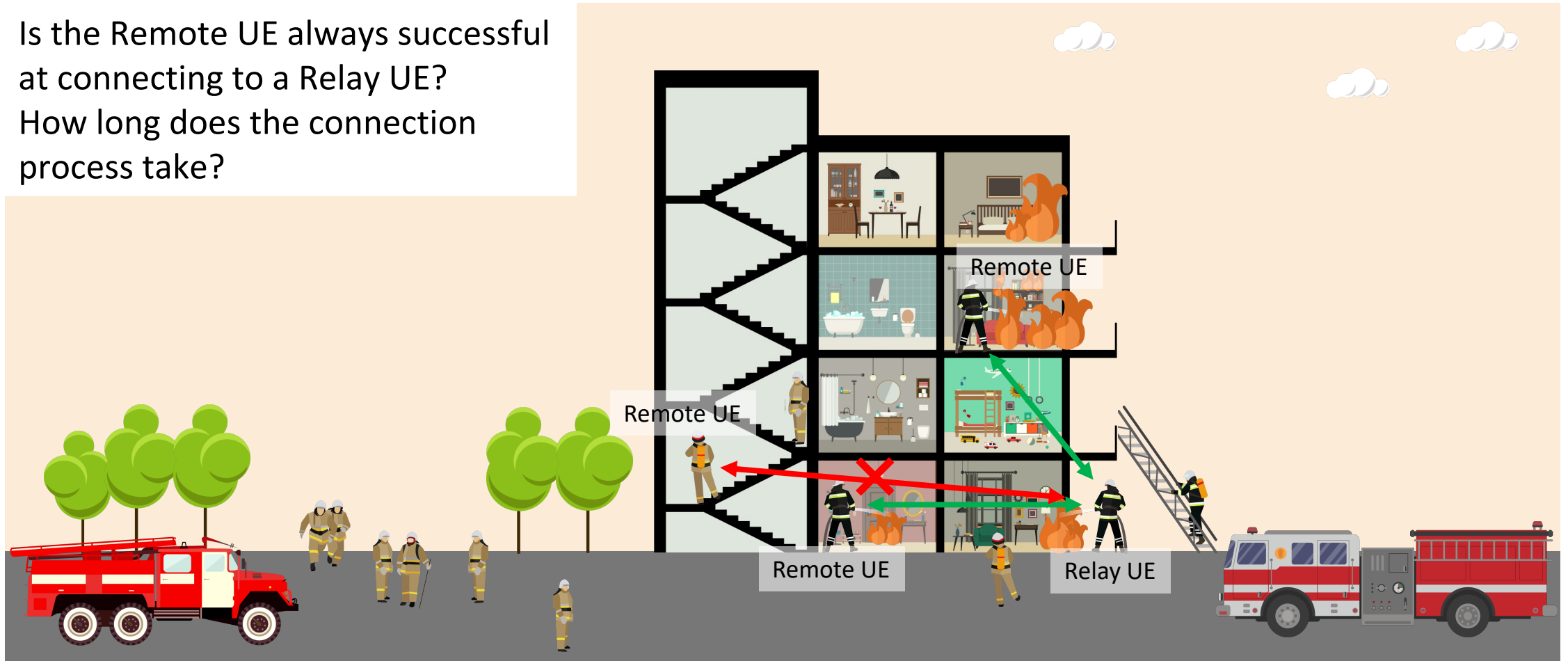
Relay Connection Establishment

Is the Remote UE always successful at connecting to a Relay UE?
How long does the connection process take?

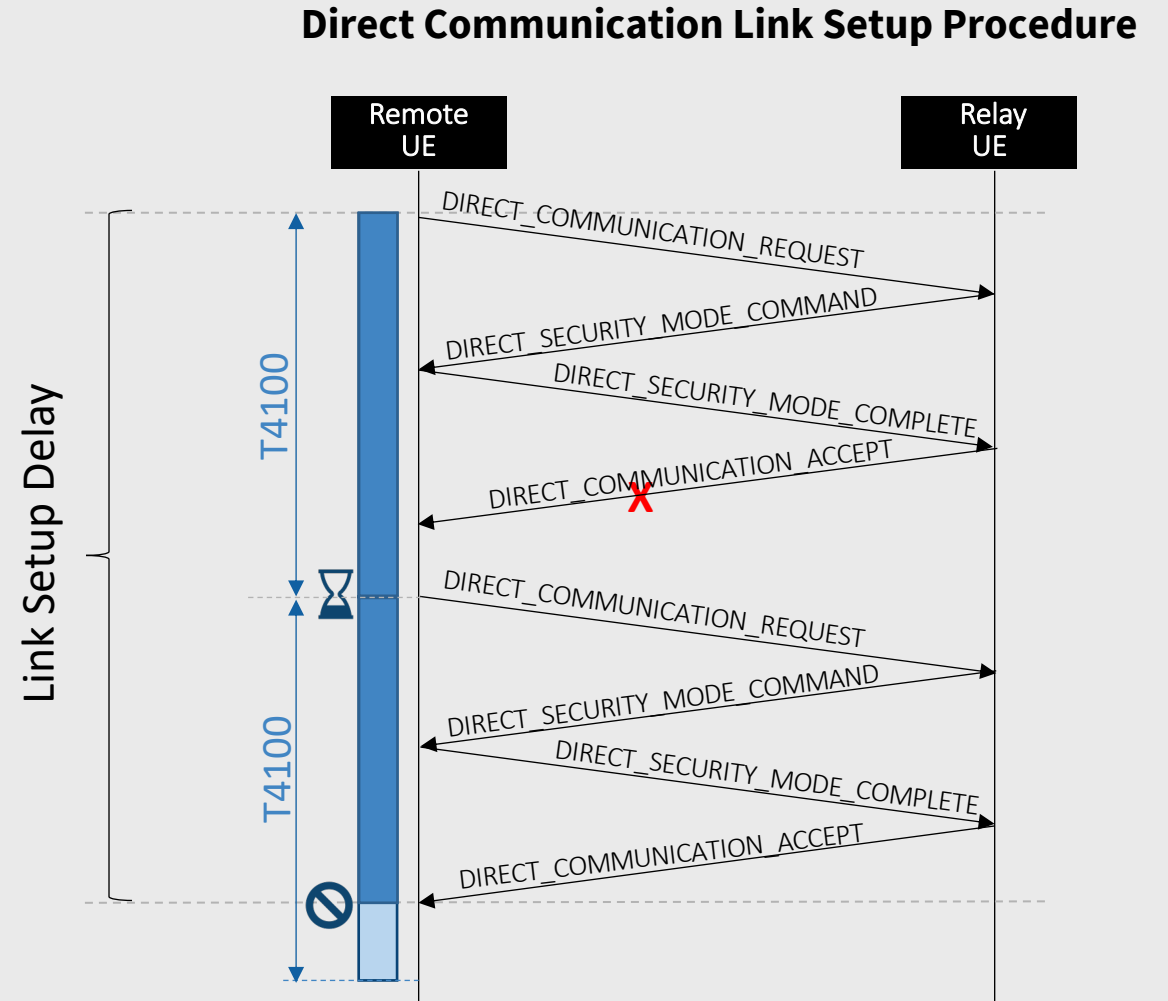Remote UE

Remote UE

Remote UE

Relay UE

Relay Connection Establishment
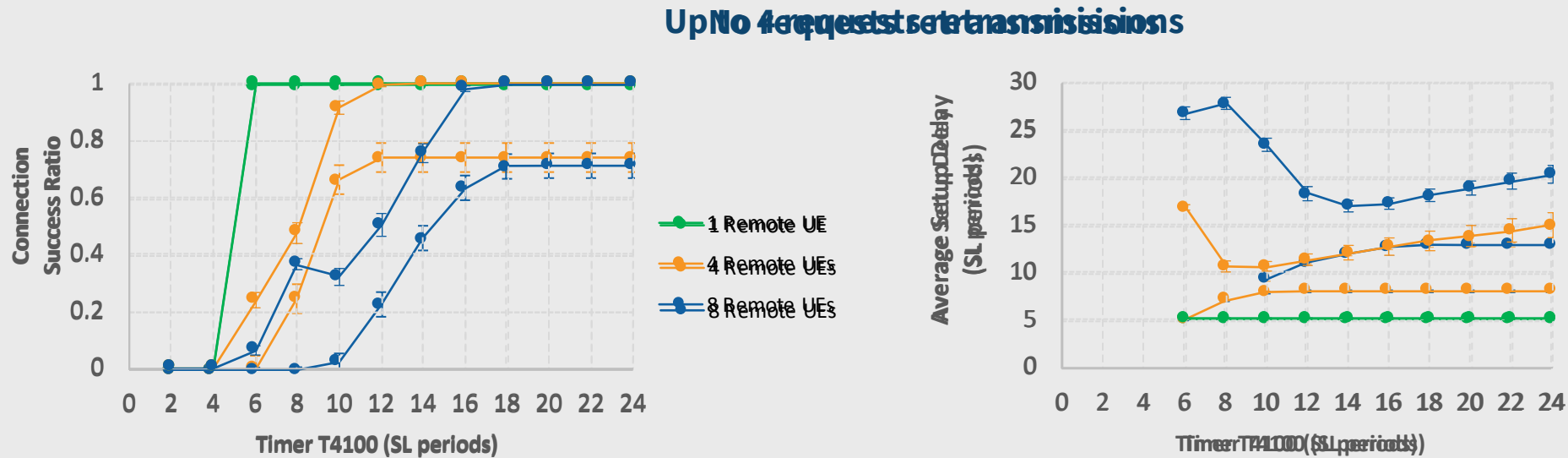
Connection Time

- Direct Communication Link Setup requires signalling between the Remote UE and the Relay UE

- If messages are lost, recovery mechanisms are available based on the following parameters:
  - Duration of Direct Communication Request retransmission timer (T4100)
  - Maximum number of Direct Communication Request retransmissions upon expiration of T4100

➔ How to configure those parameters?

Direct Communication Link Setup Procedure

Remote UE — Relay UE

DIRECT_COMMUNICATION_REQUEST
DIRECT_SECURITY_MODE_COMMAND
DIRECT_SECURITY_MODE_COMPLETE
DIRECT_COMMUNICATION_ACCEPT ✗

DIRECT_COMMUNICATION_REQUEST
DIRECT_SECURITY_MODE_COMMAND
DIRECT_SECURITY_MODE_COMPLETE
DIRECT_COMMUNICATION_ACCEPT

T4100
T4100

Link Setup Delay

Relay Connection Establishment

Impact of T4100 and Number of Retransmissions

- The configuration of timer T4100 depends on the number of Remote UEs the Relay UE is communicating with in the Sidelink
- Retransmissions increase reliability but also latency
- ➜ Deployment must be considered when configuring protocols

Relay Connection Establishment

Impact of Uplink Occupancy

4 Remote UEs and T4100 = 16 SL periods

**Results with UL traffic and no scheduling coordination between UL and SL**
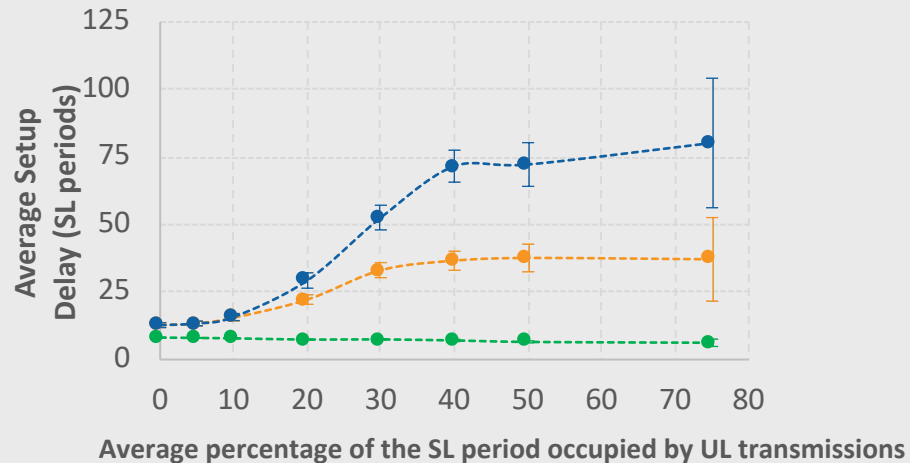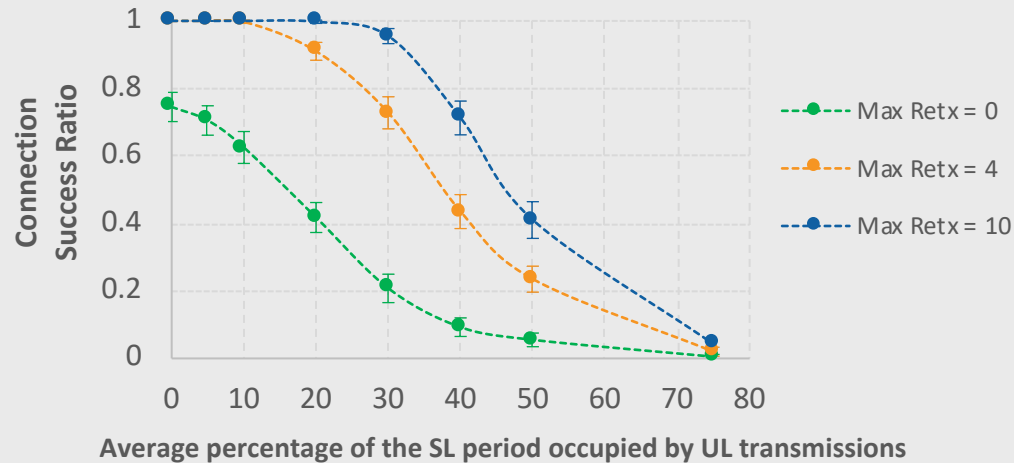
Connection time	SL period length	
	0.04 s	0.32 s
Number of periods — 10	0.40 s	3.20 s
25	1.00 s	8.00 s
50	2.00 s	16.00 s
75	3.00 s	24.00 s

- Frequent uplink transmissions lower the sidelink connection reliability
- Increasing the number of retransmission can mitigate the loss but cause significant delays
- ➜ Coordination between uplink and sidelink resource allocation is needed

Relay Communication

What are the effects on application performance?
Will the user experience be affected?

Downlink Traffic

Relayed Traffic
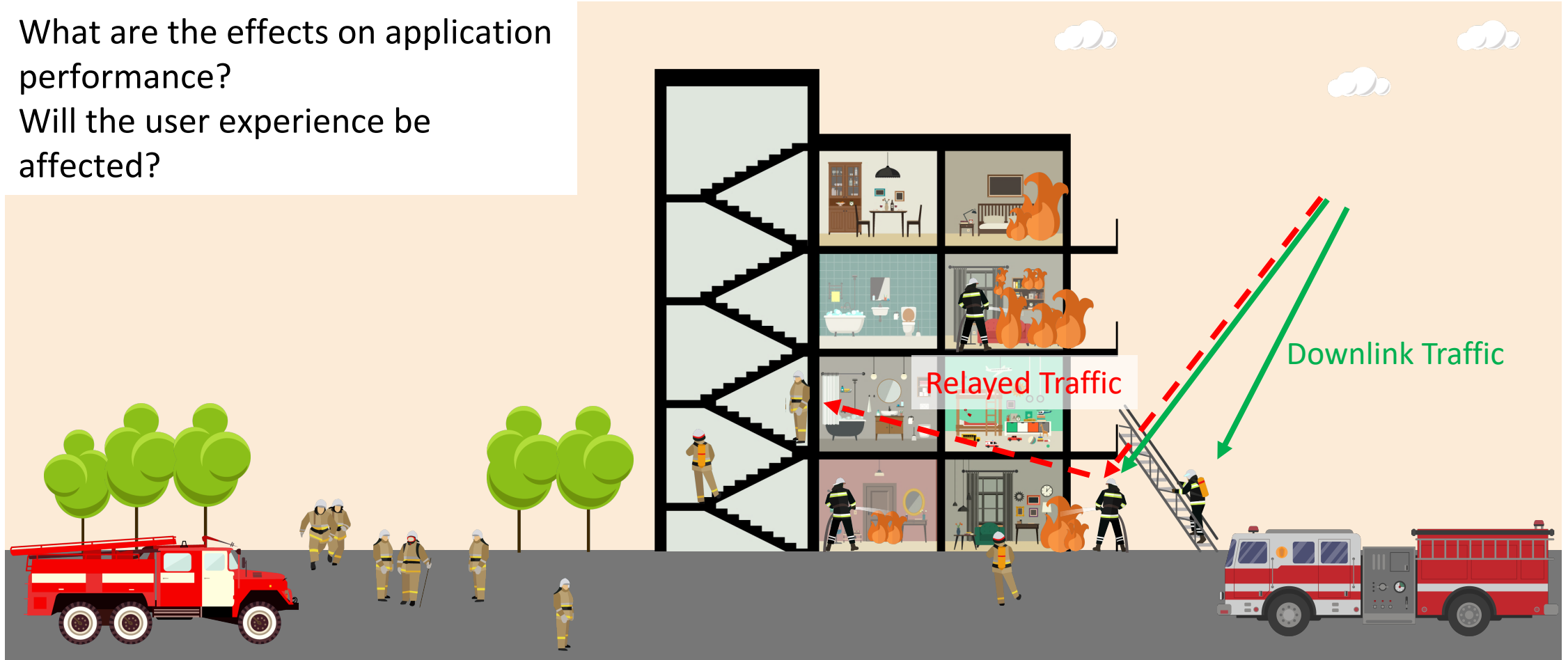
Relay Communication

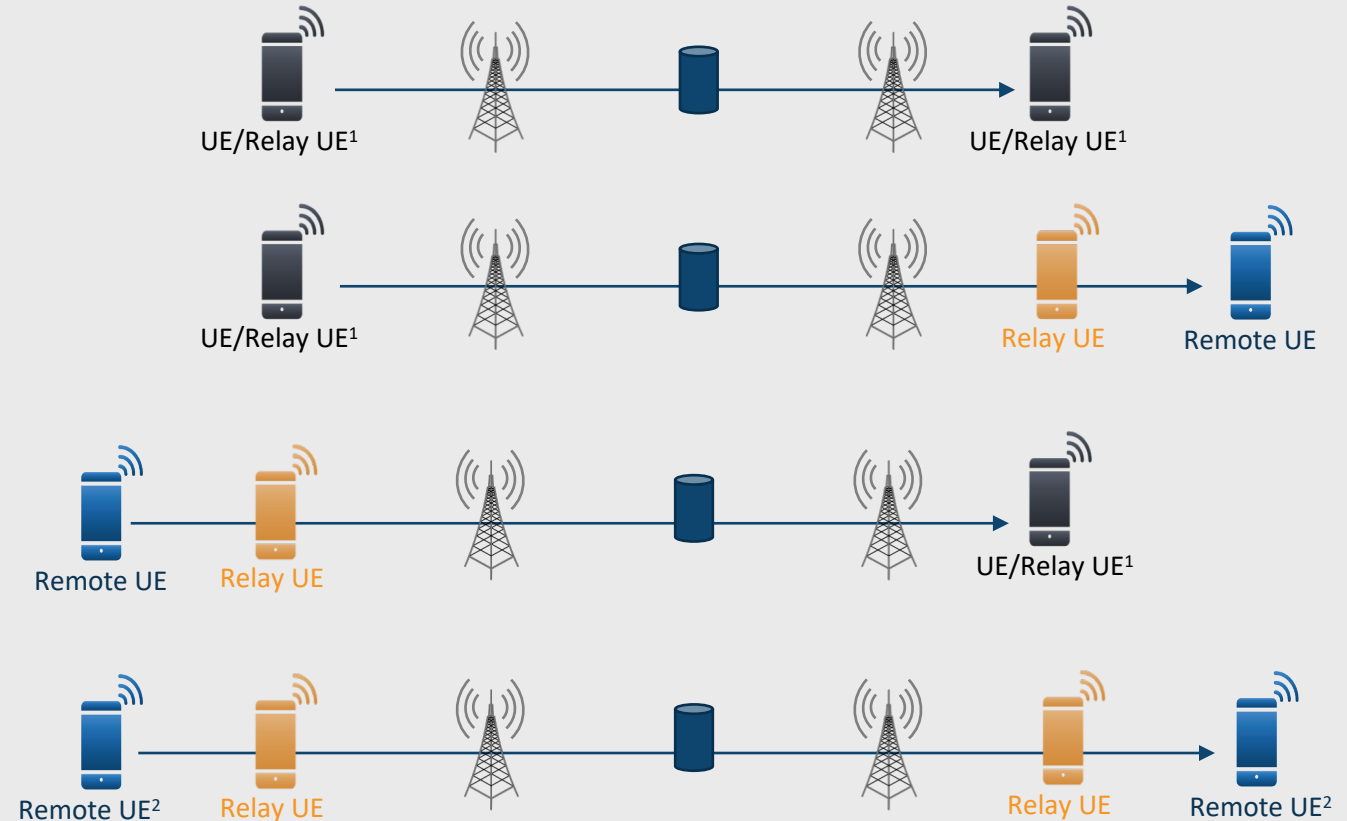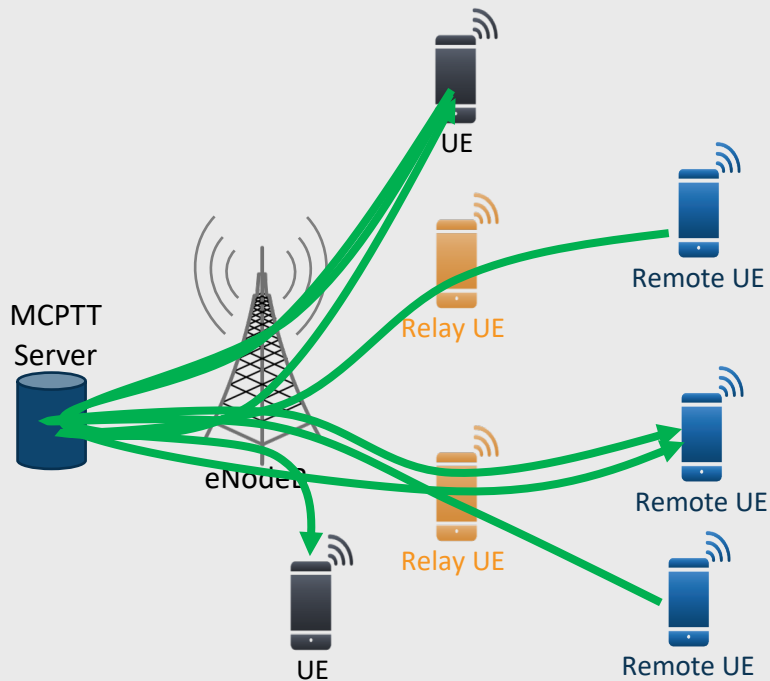Mission Critical Push-to-Talk (MCPTT) Performance Requirements

- 3GPP defines performance requirements for on network (TS 22.179)
  - **MCPTT Access time** (KPI 1) **less than 300 ms** for 95 % of all MCPTT Request.
  - **End-to-end MCPTT Access time** (KPI 2) **less than 1000 ms**
    - For users under coverage of the same network when the MCPTT Group call has not been established prior to the initiation of the MCPTT Request.
  - **Mouth-to-ear latency** (KPI 3) that is **less than 300 ms** for 95 % of all voice bursts.
  - Assumes negligible backhaul delay, max 70 % load, no transcoding

➜Can the same requirements be met when connected to a UE-to-Network relay?

Relay Communication

Communication Paths

Scenarios with group communication

MCPTT Server

eNodeB

UE

Relay UE

Remote UE

Relay UE

Remote UE

UE

Remote UE

UE/Relay UE[1]

UE/Relay UE[1]

UE/Relay UE[1]

Relay UE

Remote UE

Remote UE

Relay UE

UE/Relay UE[1]

Remote UE[2]

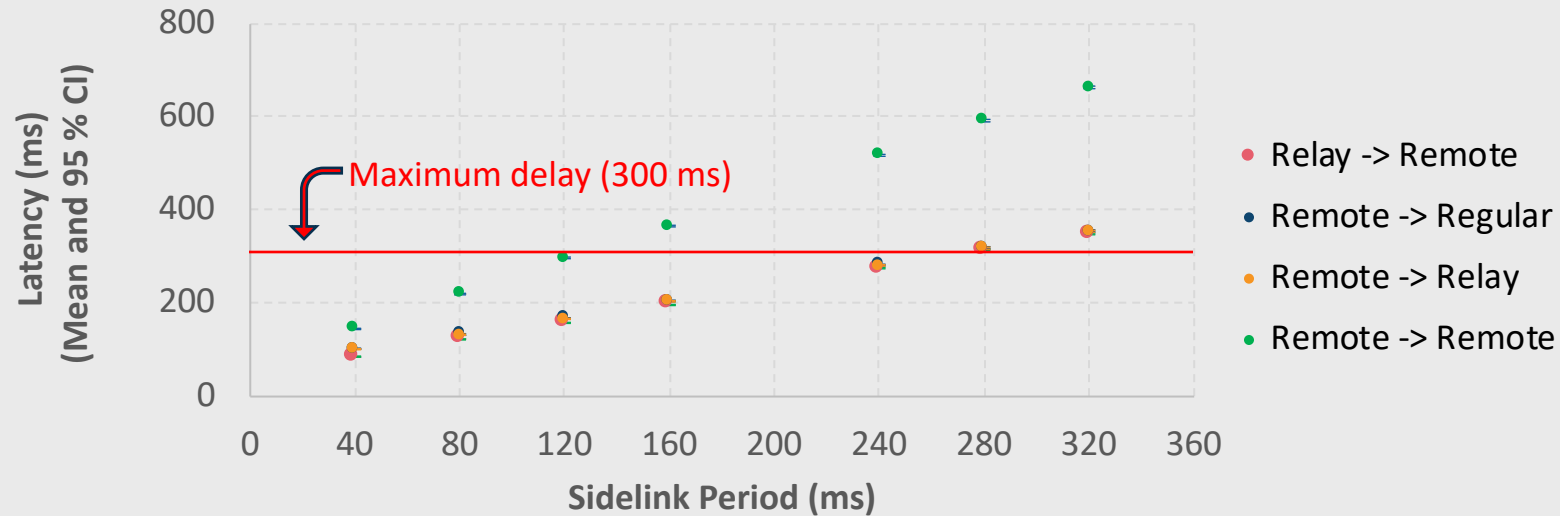Relay UE

Relay UE

Remote UE[2]

[1]While relay UEs are in coverage, delays to/from a relay UE might differ from that of a non-relay UE
[2]Performance will change whether the transmitter and receiver remote UEs are connected to the same relay or not

Relay Communication

Impact of Sidelink Period on Mouth-to-Ear Latency

- Performance results shown are for a network where only the media traffic is carried (no other load on the network)

- When a Remote UE is involved, the higher the sidelink period, the larger the latency

➔ Sidelink period configuration must be configured considering end-to-end packet delay requirements
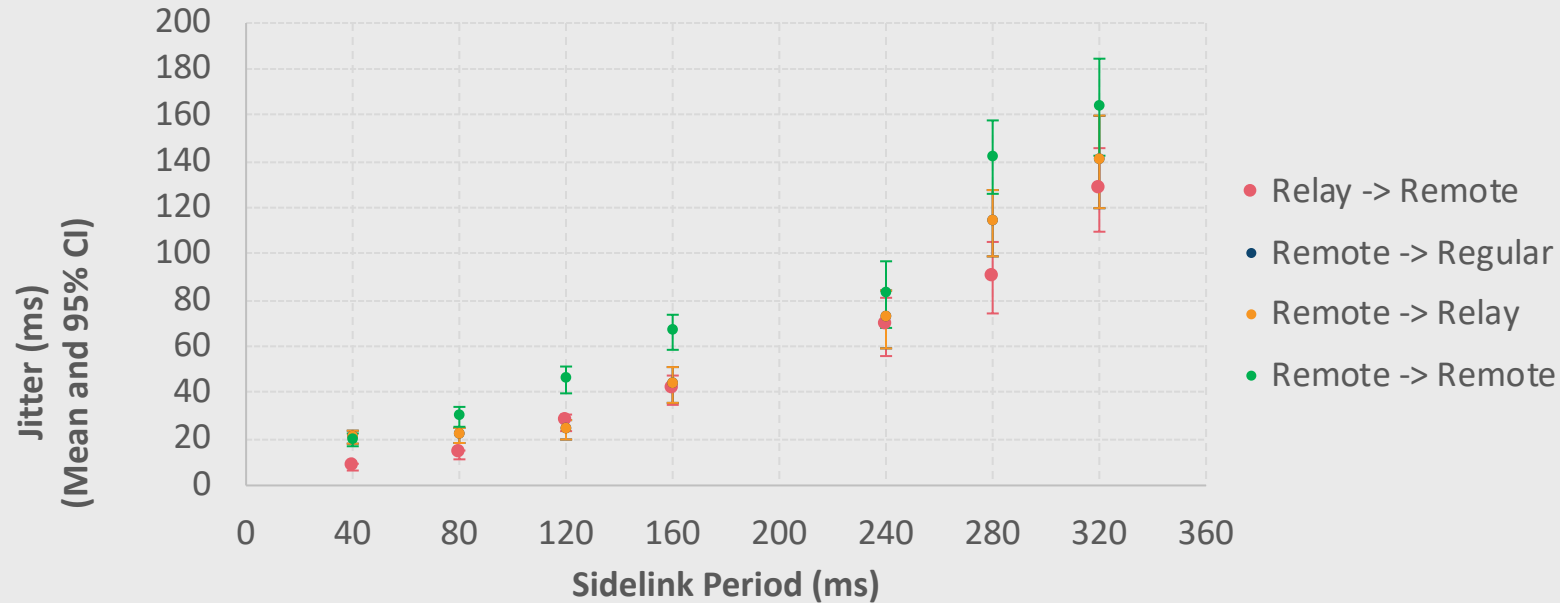
Relay Communication

Impact of Sidelink Period on Packet Loss

- Loss for Relay UE to Remote UE traffic under the threshold

- Excessive packet loss is observed when the transmitter is a Remote UE

➔ Sidelink period duration does not have a significant effect on the packet loss

➔ Coordination between uplink and sidelink resource allocation is needed

Relay Communication

Impact of Sidelink Period on Packet Jitter

- Jitter is higher for Remote UE to Remote UE communication since sidelink is used twice

➔ Sidelink period duration has a direct impact on the packet jitter
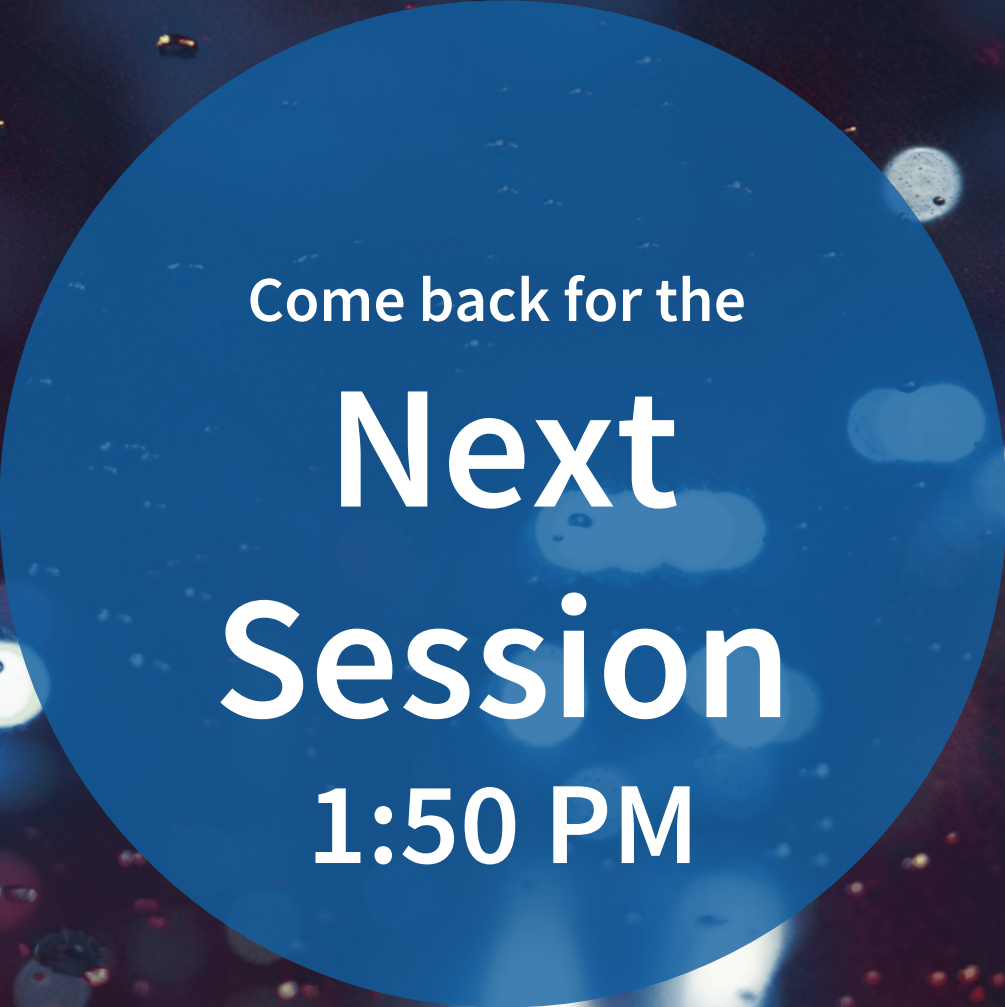
UE-to-Network Relays

Lessons Learned

- UE-to-Network relays can help maintain connectivity for UEs losing coverage while in proximity of other UEs that are still in coverage
- Preliminary results show that performance are sensitive to several factors including:
  - Number of devices that can act as Relay UEs
  - Number of devices communicating with the Relay UEs
  - Sidelink configuration
  - Traffic load
- Users may notice some service degradation under certain conditions compared to on-network
- Our work will provide guidelines to configure the resources allocated to D2D and the protocol configurations to ensure proper operations

UE-to-Network Relays

Areas for Future Investigation

- Relay activation
  - Algorithms to detect when/where a relay might be needed
- Interference mitigation
  - Reduce collisions between uplink and sidelink
- Impact on energy consumption
  - Quantify additional energy cost to the relay nodes
- Protocol configuration
  - Guidelines for configuring timers and maximum number of retransmissions (i.e., keep alive, failure recovery)

THANK YOU

Come back for the

Next Session

1:50 PM