

- The 3rd Generation Partnership Program (3GPP) introduced Device to Device (D2D) Proximity Services (ProSe) in release 12
- ProSe enabled devices to exchange information directly, i.e., without traversing the eNB
- ProSe allows the operation in both LTE uplink and public safety specific spectrum
- Out-of-coverage UEs can autonomously operate in public safety scenarios
- Three D2D functionalities defined under ProSe service
 1. Direct communication
 2. Direct discovery
 3. Synchronization

- Network simulation is a vital tool for researching network performance
- It bridges the gap between conducting mathematical analysis and network experiments
- Ns-3 is a powerful tool that by one measure (academic citations) is already the leading packet simulation tool for LTE-based network simulations
- We are intensively collaborating with the National Institute of Standards and Technologies (NIST), the University of Washington and the broader PSCR community to further develop ns-3 as an **accessible, sustainable, and usable** packet simulator for PSCR research.

ns-3 LTE protocol stack and architecture enhancements

UE

EpcUeNas

Direct communication

- Management of sidelink bearers
- Transmission of packets when out-of-coverage

Direct communication	Direct discovery	Synchronization
<ul style="list-style-type: none"> Creation of sidelink bearers Reception and processing of SIB18 message Transmission of SidelinkUeInformation message 	<ul style="list-style-type: none"> Creation and removal of discovery application Reception and processing of SIB19 messages Filtering of discovery messages 	<ul style="list-style-type: none"> UE synchronization status tracking Transmission of MIB-SL SyncRef selection procedure

LtePdcp

Direct communication

- Extension of logical channel identifier

LteRlc

Direct communication

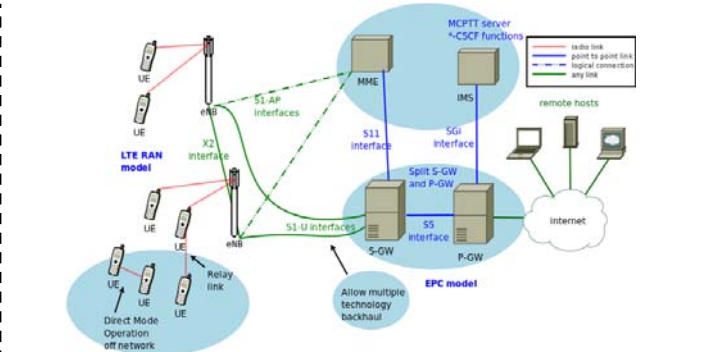
- Extension of bearer identifier

Direct communication	Direct discovery	Synchronization
<ul style="list-style-type: none"> Allocation and scheduling of the traffic (Mode2) Coordination of the sidelink transmission (Mode 1 and 2) 	<ul style="list-style-type: none"> Creation and scheduling of discovery messages 	<ul style="list-style-type: none"> Timing information update upon synchronization

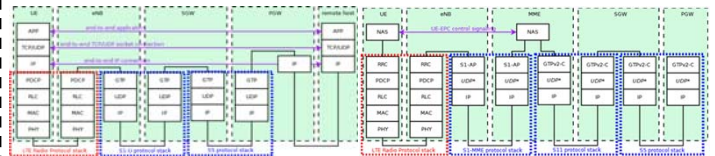
Direct communication	Direct discovery	Synchronization
<ul style="list-style-type: none"> Sidelink TX and RX in uplink RX SCI messages RX PSSCH as per received SCI message 	<ul style="list-style-type: none"> RX of discovery messages 	<ul style="list-style-type: none"> Support for half duplex mode TX and RX of SLSS Control S-RSRP measurement and report process Updating frame/subframe number upon synchronization

- Advanced interference calculation for sidelink transmissions
- Implementation of new error models for all the sidelink physical channel

ns-3 LTE EPC model enhancements



- More flexible network configurations
- Start to support on-network modes of MCPTT



ns-3 LTE sidelink tested scenarios

Description	UE A	UE B	Direct communication	Direct discovery	Synchronization	Example
Out-of-coverage	Out-of-coverage	Out-of-coverage	Yes RA = Mode 2	Yes RA = Type 1	Yes Autonomous synchronization	
In-coverage single cell	In-coverage	In-coverage	Yes RA = Mode 1 RA = Mode 2	Yes RA = Type 1	Yes Network synchronization	

RA = Resource scheduling

eNB

eNB

EpcEnbApplication

EpcEnbNetDevice	S1-U NetDevice
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Direct communication	Direct discovery	Synchronization
<ul style="list-style-type: none"> TX SIB18 TX RrcConnectionReconfiguration message Processing of SidelinkUeInformation 	<ul style="list-style-type: none"> TX SIB19 	

LtePdcp

LteRlc

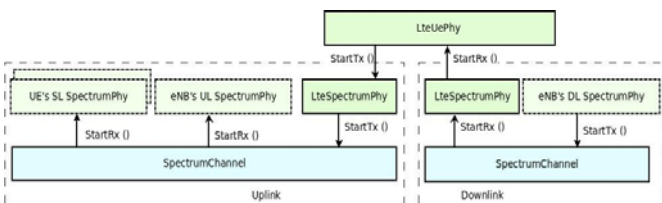
LteEnbMac

Direct communication

- Rx SL-BSR (**Mode 1**)
- Resource scheduling (**Mode 1**)

LteEnbPhy

New PHY and channel model architecture for the UE



Model validation (out-of-coverage scenario)

ProSe Communication

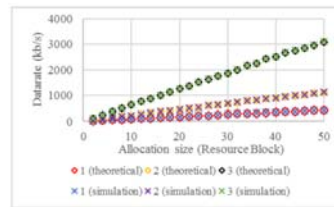


Fig.2 PSSCH data rate validation

Configuration	SL Period (ms)	PSSCH Duration (ms)	KTRP	MCS
1	40	8	2	10
2	80	8	4	12
3	320	40	8	15

Table.1 Simulation parameters for PSSCH

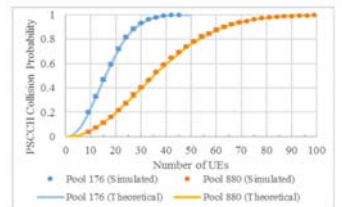


Fig.1 PSSCH resource collision validation

$$rate = \frac{tbSize \times \left[\frac{period - PSSCH \times KTRP}{8 \times NHARQ} \right]}{period}$$

$$P_{Collision} = 1 - \left(\frac{NPSSCH}{n_{UE}} \right)^{n_{UE}} \times \frac{n_{UE}!}{NPSSCH^{n_{UE}}}$$

ProSe Discovery

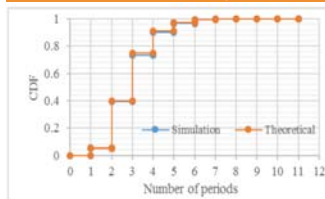


Fig.3 Number of discovery periods needed for one UE to discover all other UEs in the group

ProSe Synchronization

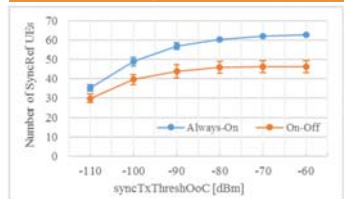


Fig.4 Number of SyncRef UEs after 450 SyncRef selection cycles