# A Long Term Evolution (LTE) Device-to-Device module for ns-3

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## ABSTRACT
In this paper, we provide an overview of our on-going implementation of a 3rd Generation Partnership Program (3GPP) Proximity Services (ProSe) module in ns-3 to enable the performance evaluation of device-to-device (D2D) discovery and communication in Long Term Evolution (LTE) networks.

## CCS Concepts
**• Networks → Network performance evaluation • Networks → Network types → Mobile networks.**

## Keywords
3GPP; Long Term Evolution; Device-to-Device communication; network modeling; ns-3.

## 1. INTRODUCTION
Device-to-device (D2D) communication is a common feature in technologies such as Bluetooth and WiFi. However, this is a fairly new concept for 3GPP where historically access to the radio resources has been controlled by the network. If the network is not available, the devices are not able to communicate. With Release 12 and the introduction of ProSe [1], 3GPP provides the ability for User Equipments (UEs) to discover each other and, in some cases, communicate with each other without eNodeB intervention. The discovery service provided by ProSe responds to the increasing use of social media where users want to know what is happening around them. Some of the use cases include advertisement broadcast in shopping malls or notifications of nearby people with similar interests. While discovery is available to all UEs when the network supports it, direct communication is currently restricted to Public Safety users, which have identified this feature as critical in order to fully transition to LTE. Furthermore, D2D communication has been identified as one of the enablers for 5G communications [2] indicating that further research is needed in that domain and that the current restrictions may have to be removed. The rest of this document provides an overview of the ProSe module implementation followed by validation results, open issues and future work.

## 2. IMPLEMENTATION
Our ProSe module is extending the ns-3 LTE model [3] by adding UE to UE communication capabilities. In 3GPP specifications, the term sidelink refers to the D2D communication in contrast to downlink and uplink communication between the eNodeB and the UE.

### 2.1 Architecture
In our implementation, the structure of the LTE UE nodes, shown in Figure 1, has not been changed. However, the extension involved some modifications at all levels of the LTE protocol stack, from the Non Access Stratum (NAS) down to the physical layer. The main design alteration, shown in Figure 2, was the addition of a new instance of the *SpectrumPhy* class in the UE in order to allow the reception of packets sent by other UEs on the uplink channel.

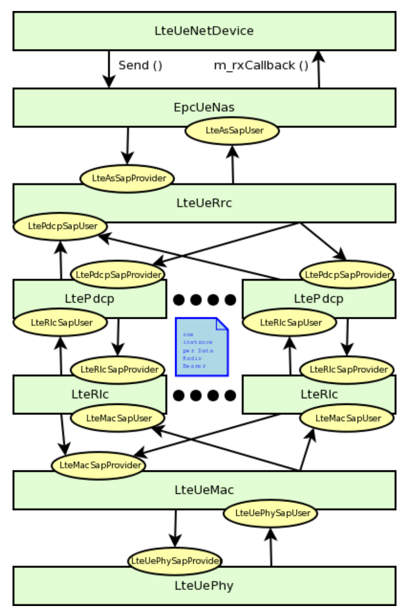


**Figure 1: LTE radio protocol stack architecture for the UE on the data plane**

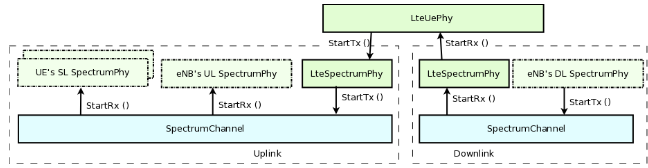


**Figure 2: New PHY and channel model architecture for the UE**

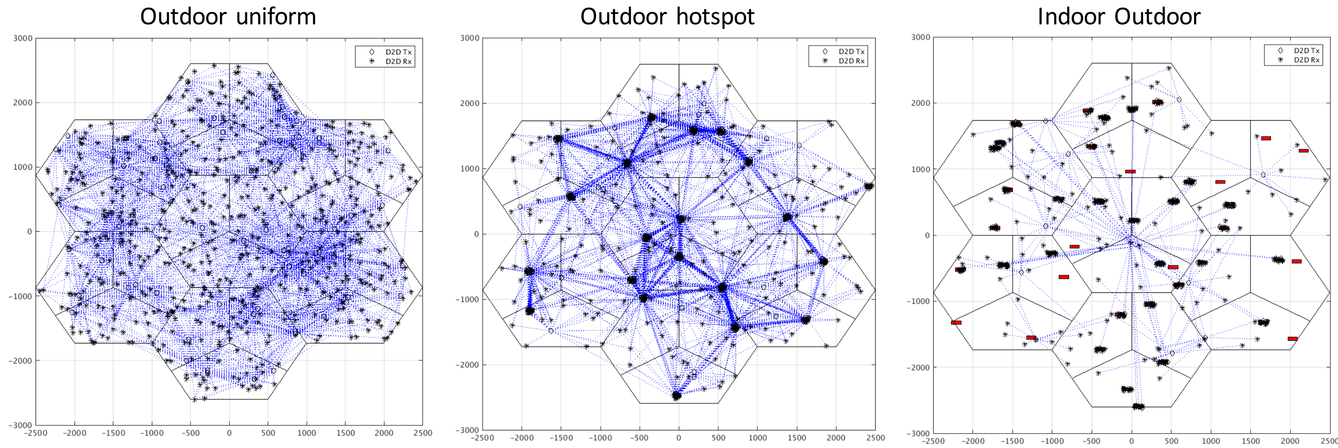


**Figure 3: Topologies used for model validation**

## 2.2 Summary of modifications

### *2.2.1 Radio Resource Control (RRC) Protocol*

The RRC layer provides signaling between the eNodeB and the UE to perform attachment and setup radio bearers. Extensions to the protocol have been made so the UE can indicate its interest in performing D2D when in coverage of an eNodeB. It also stores the preconfigured radio resources when the UEs are out of coverage.

### *2.2.2 Packet Data Convergence Protocol (PDCP) and Radio Link Control (RLC) Protocol*

The sidelink radio bearers use the Unacknowledged Mode (UM) transmission mode that is already available in ns-3. However, the identifier for the logical channels has been extended to include the source L2 ID and destination L2 ID that identifies the transmitter UE and the group to which the packets must be delivered.

### *2.2.3 Medium Access Control (MAC) Protocol*

The MAC protocol responsible for allocating radio resources had to be modified at both the eNodeB and the UE. The changes include the processing of sidelink Buffer Status Request (BSR) to indicate how much D2D traffic needs to be transmitted and the schedulers to handle the new type of resource allocations. The concept of scheduling algorithm is new to the UE implementation as it normally just follows the information provided by the eNodeB at each subframe. With D2D, the UE has to decide how to allocate resources when it is out of coverage or when it is in coverage but the allocation mode is UE selected. The initial scheduler implementation provides a static allocation, with the same number of resource blocks and subframes used in each sidelink period, that is configurable from the scenario.

### *2.2.4 Physical Layer Protocol*

The physical layer was extended to support additional physical channels such as the Physical Sidelink Discovery Channel (PSDCH) to send and receive discovery messages, Physical Sidelink Control Channel (PSCCH) to carry the allocation information, and Physical Sidelink Shared Channel (PSSCH) to carry the D2D data. The model also supports scanning and transmission of sidelink synchronization messages so UEs can detect and synchronize with each other. Finally, a half-duplex constraint has also been added so UEs cannot send and receive uplink/sidelink transmissions as the same time.

### *2.2.5 Propagation and Error Modeling*

Several D2D propagation models have been implemented as specified by 3GPP [4] to model outdoor to outdoor, outdoor to indoor, and indoor to indoor environments. A new error model was introduced to handle interference from multiple sources on the same resource blocks and to properly characterize uplink modulations.

# 3. VALIDATION

A critical step for the adoption of a new model is to compare the results obtained using well defined scenarios. This section describes the performance evaluation of the sidelink shared (data) channel and shows that our results are within range of other models documented in [4].

## 3.1 Modeling assumptions

The assumptions contained in Table 1 were used to perform the evaluation of the sidelink shared channel.

**Table 1: Simulation parameters**

| Parameter | Value |
|---|---|
| Transmission BW (RBs) | 2.0 |
| Packet size including CRC (bits) | 328.0 |
| Modulation and Coding Scheme | QPSK |
| Coding | Turbo |
| Number of symbols/Transmissions | 12.0 |
| Tx Power (dBm) | 23.0 |
| Num HARQ transmissions | 4.0 |
| Frequency Diversity (across transmissions) | Yes [per period] |
| Time Diversity (across transmissions) | Yes [per period] |
| Number of TX/cell | 3.0 |
| RSRP threshold (dBm) | -112.0 |
| Traffic | On/off Voice over IP (VoIP) |

## 3.2 Topologies

The validation scenarios are based on a 19 macro-cell topology. The UEs are deployed following one of three options: in outdoor uniform, all UEs are uniformly and randomly deployed within each sector; in outdoor hotspot, some of the UEs are concentrated in random locations; finally, for indoor outdoor, buildings are randomly placed in the topology and UEs are deployed either indoor or outdoor. Random transmitters are selected throughout the topology and receiver UEs are associated to the transmitters if the RSRP is above the preconfigured threshold. For legibility, Figure 3 illustrates those deployments for a 7 macro-cell deployment.

## 3.3 Simulation results

In this section we present the performance results obtained with our model side by side with the results provided in [4]. The first performance metric used is the fraction of successful VoIP links, which is defined by a link with less than 2 % packet loss. As shown in Figure 4, our results are comparable to the other companies.

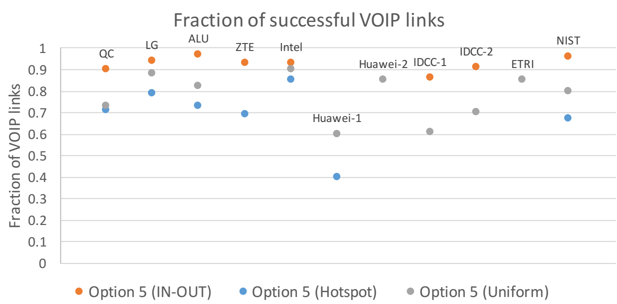


**Figure 4: Fraction of successful VOIP links for various deployments**

The second metric is the number of successful links per transmitter. As with the fraction of successful links, Figure 5 shows that our results are in the same range as the other companies.

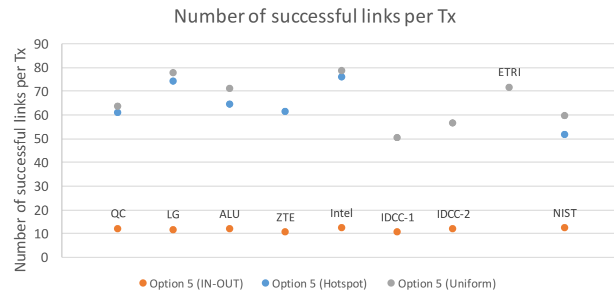


**Figure 5: Number of successful links per transmitter for various deployments**

# 4. OPEN ISSUES

Among the model limitations, we can mention the lack of idle mode in the default LTE implementation. Workarounds had to be made to simulate the out of network scenarios. In addition, we would like to create an UE scheduler interface as currently done in the eNodeB so that researchers can easily test their own algorithms. Finally, traces will need to be extended to support the D2D packet transmissions.

# 5. CONCLUSION AND FUTURE WORK

In this extended abstract, we presented an overview of the extensions made to the ns-3 LTE implementation to support D2D discovery and communication. The model presented is under active development and several new features may be added such as UE-to-network relay or priority queues, which are features added in 3GPP Release 13.

# 6. REFERENCES


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