Device-to-Device System for Public Safety (DDPS)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY PUBLIC SAFETY INNOVATION ACCELERATOR PROGRAM (PSIAP)

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Agenda

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Field demo

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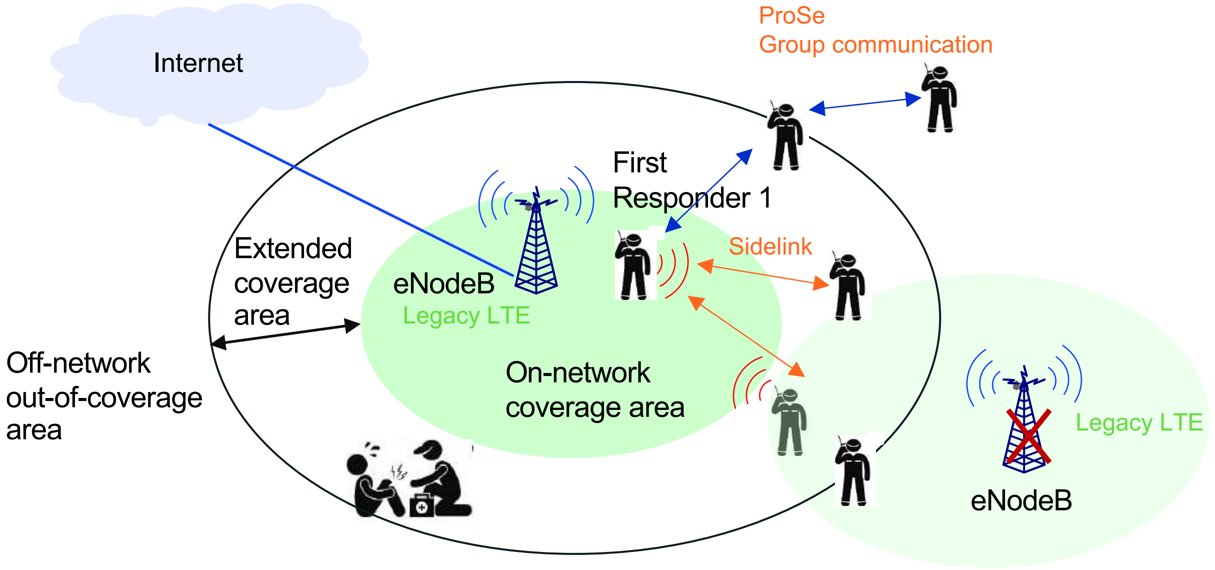
DDPS overview

DDPS team

- Perspecta Labs
  - Richard Lau (Lead)
  - Members: Stephanie Demers, Eric Becks, Heechang Kim
- EURECOM
  - Raymond Knopp (Lead)
  - Panagiotis Matzakos
  - Mohit Vyas

DDPS scenarios for first responder application

ProSe: Discovery → Sidelink data → Relay → group → multiple groups



DDPS goals are to build open source platform for ProSe:
- Supports on-net, off-net, and partial coverage
- Demo D2D 1:N (group) and 1:1 (direct) private communications
- Applications: push-to-talk, image transfer, and text message

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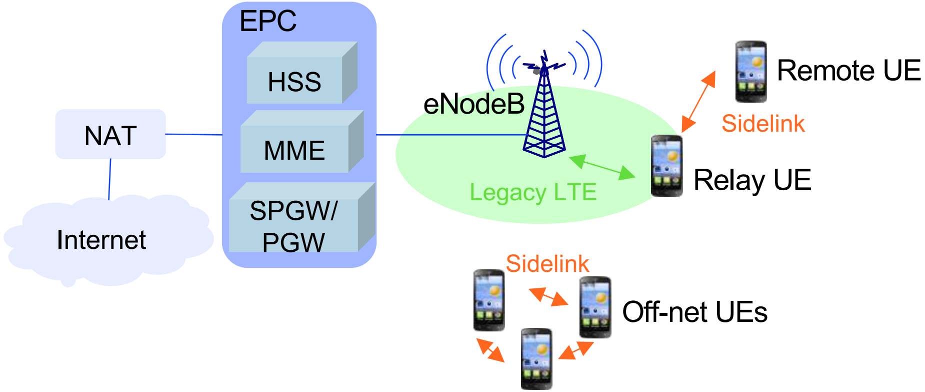
DDPS achievements (1/2)

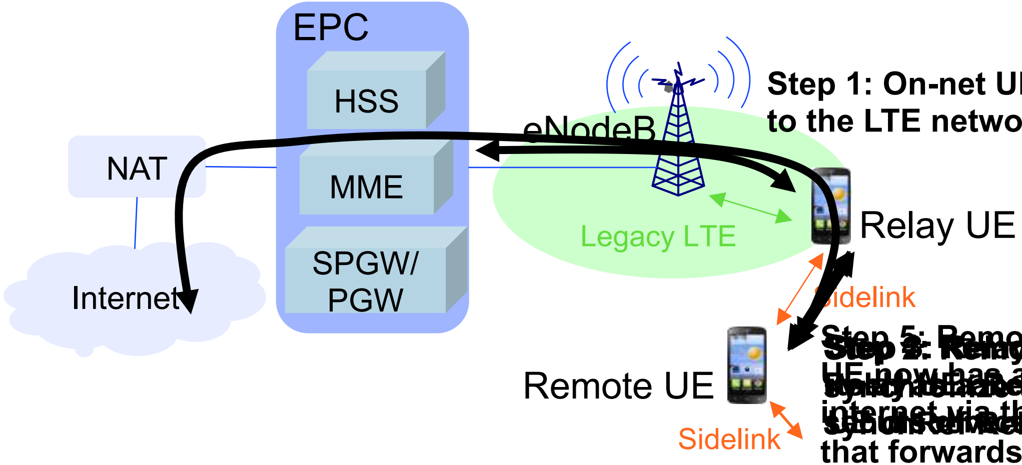
- Build a complete ProSe protocol stack in software
  - Extend OpenAirInterface™ (OAI) implementation to support D2D services on- and off-network based on 3GPP Rel-14 specifications
  - Help create an ecosystem that can ultimately lead to a small form factor platform
- Create test bed and demonstrate a full ProSe network prototype on SDR platform
- Extend OAI code to solve complex service continuity challenges
- Solve open issues related to resource allocation and time synchronization:
  - New scheduling algorithms for autonomous resource allocation to minimize collision probability.
  - Novel multi-antenna-based synchronization techniques to achieve significant improvement in UE autonomous synchronization



DDPS achievements (2/2)

- D2D software stack implementation in OAI including sidelink channel implementation with:
  - RRC: SIBs 18 and 19, and SidelinkUEInformation handling
  - PDCP: PC5-S and PC5-U traffic for Sidelink
  - MAC: SL-DCH, SL-SCH
  - PHY: PSDCH, PSSCH, PSCCH, SLSS
- Create a Technology Transfer Package
  - Merge DDPS code into the OAI main branch
  - OAI user guide for D2D implementation
  - Explore synergy with other organization of interest
    - Building the code and supporting **Off-net** sidelink scenarios : https://gitlab.eurecom.fr/oai/openairinterface5g/blob/LTE-sidelink/d2d_emulator_setup.txt
    - Additional instructions to support **On-net** sidelink scenarios: https://gitlab.eurecom.fr/oai/openairinterface5g/blob/LTE-sidelink/targets/DOCS/D2D-on-net-and-relay-setup-instructions.pdf

Service continuity scenario

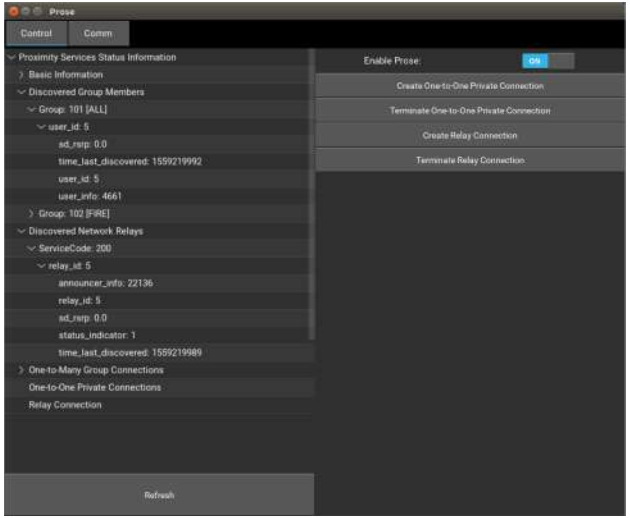


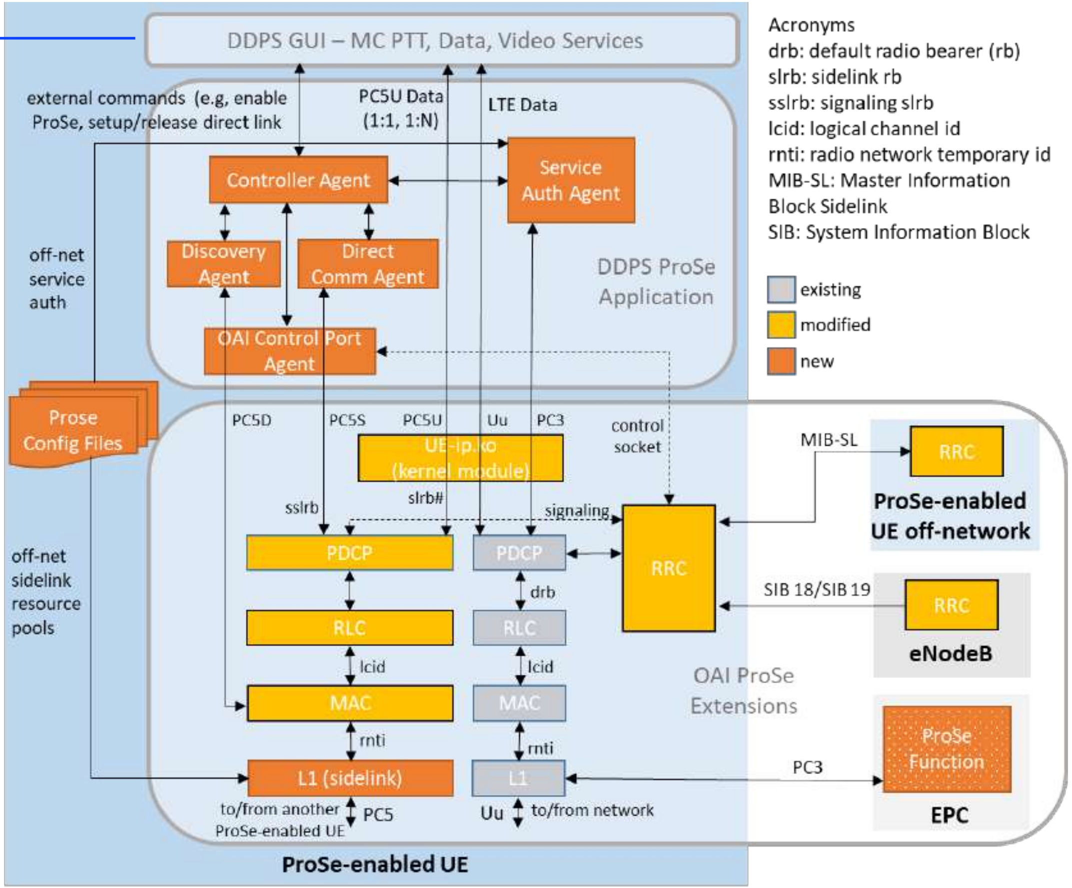
Step 1: On-net UE attaches to the LTE network

Step 5: Remote off-network UE now has access to the internet via the Relay UE that forwards its traffic

DDPS software development

DDPS software components





Acronyms
drb: default radio bearer (rb)
slrb: sidelink rb
sslrb: signaling slrb
lcid: logical channel id
rnti: radio network temporary id
MIB-SL: Master Information Block Sidelink
SIB: System Information Block

- existing
- modified
- new

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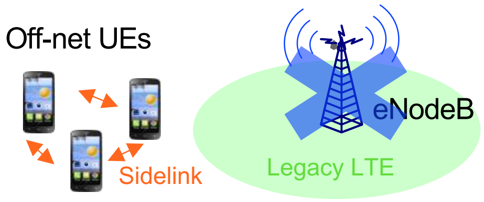
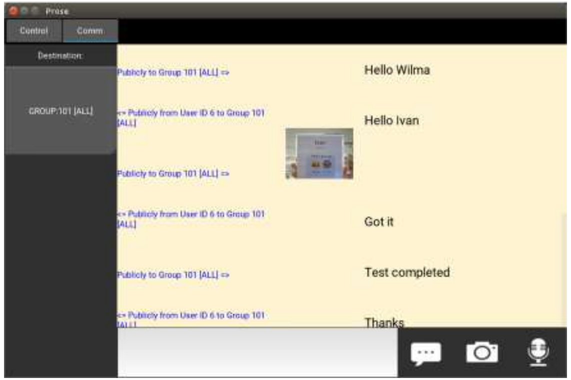
Off-network support (1/2)

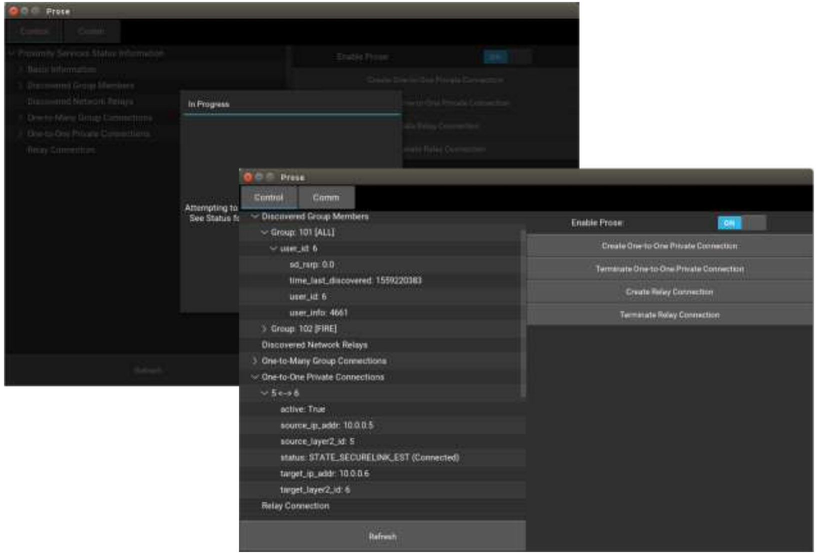
- Service authorization is done via toggle switch on the UE's GUI for ease of testing/demoing
- Synchronization
  - A SyncRef UE is manually configured as an input command argument for ease of testing/demoing
  - The SyncRef UE transmits Sidelink Synchronization Signal (SLSS) and the MasterInformationBlock-SL (MIB-SL) message on the frequency used for sidelink discovery
  - SLSS and MIB-SL for synchronization in time and frequency have been implemented, as well as the SL-BCH (Sidelink Broadcast Channel) and the Physical Sidelink Broadcast Channel (PSBCH)
- Group member discovery announcement and monitoring implemented
  - Model A Group Member Direct Discovery for Public Safety Use was implemented
  - List of discovered groups and group members are displayed on each UE's DDPS GUI



Off-network support (2/2)

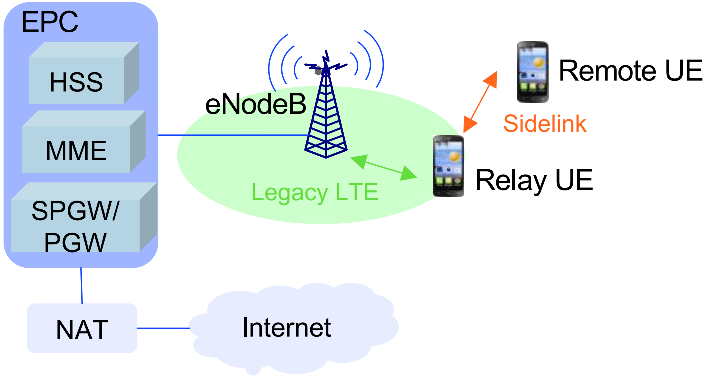
- One-to-many group communication
  - A discovered group can be selected on the UE's DDPS GUI to start a 1:N communication with the members of that group over Sidelink Traffic Channel (STCH)
- One-to-one direct communication
  - A discovered group member can be selected on the UE's DDPS GUI and a direct secure link can be established with that group member over the PC5 control plane
  - Once is a secure direct link is established, exchange of traffic over STCH is possible
  - The direct link can be released when not needed anymore

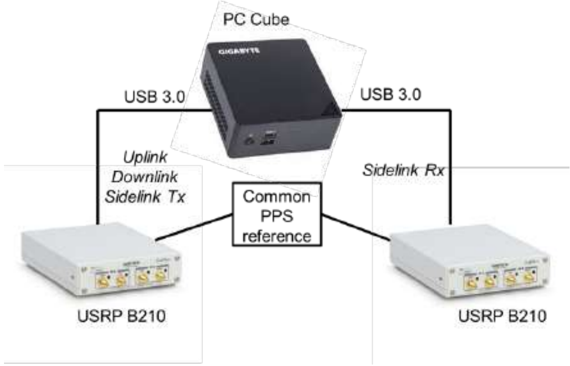




UE-to-network relay operation support (1/2)

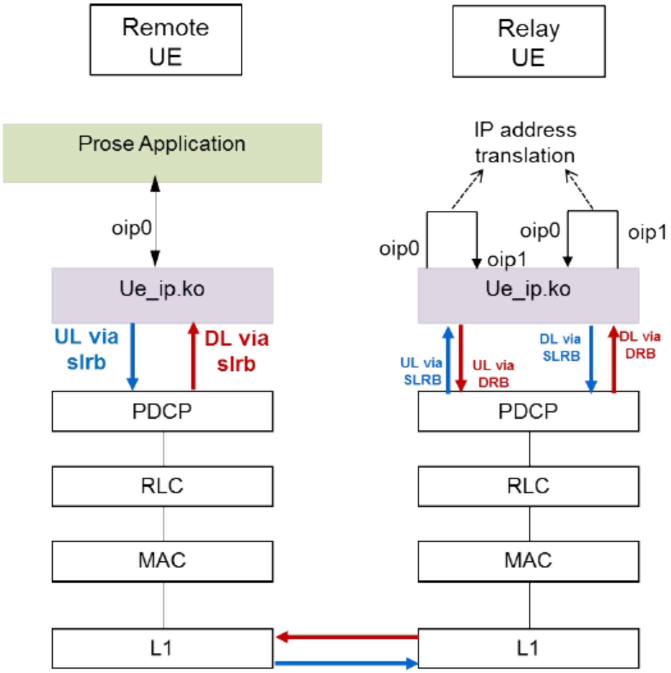
- System information broadcast (SIB)
  - eNodeB was extended to broadcast SIB18 (sidelink comm related resource config info) and SIB19 (sidelink discovery related resource configuration info)
- Relay UE discovery announcement and remote UE monitoring
  - Model A UE-to-Network Relay Discovery procedure was implemented
  - List of discovered relay UEs are displayed on each remote UE's DDPS GUI
- Simultaneous support of LTE and sidelink in Relay UE
  - Two separate USRB B210s are connected to the PC where the relay UE resides. First USRP is used for LTE UL/DL and sidelink tx. Second USRP is used for the sidelink rx





UE-to-network relay operation support (2/2)

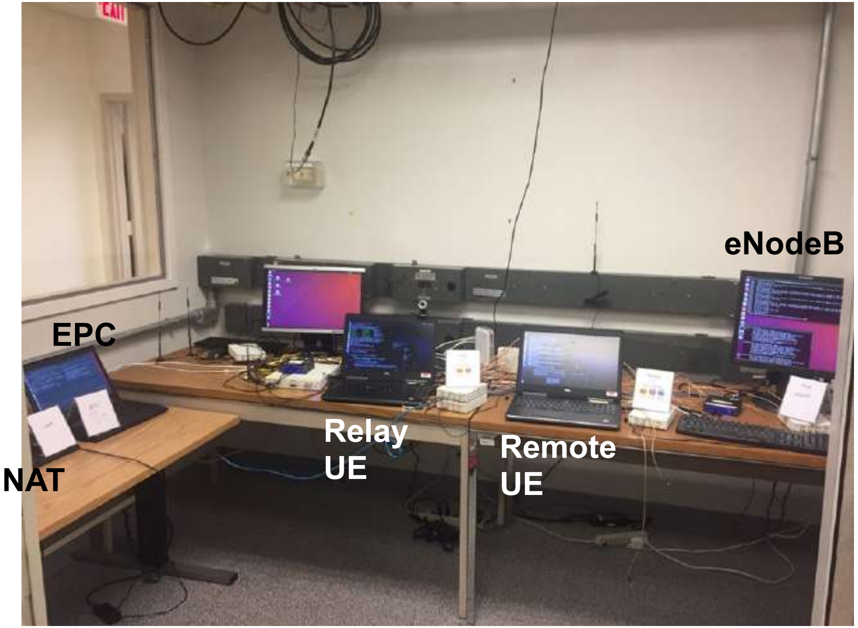
- Link setup/release between relay and remote UE
  - A discovered relay UE can be selected on the remote UE's DDPS GUI and a direct secure link can be established with that relay
- Routing extension to support traffic relaying
  - At the relay UE, UL traffic is forwarded from sidelink (oip0) to LTE (oip1) interface based on ip table rules and ue_ip.ko driver extensions. UL traffic is also masked with the oip1 IP address of the relay UE as source IP and transferred to the core network using the relay existing PDN connection.
  - At the relay UE, DL traffic is received at the oip1 interface of the relay UE and recognized as remote UE traffic based on the applied NAT routing rule. Then, it is forwarded to the sidelink interface (oip0) with the original IP address of the remote UE and eventually received at the remote UE.



DDPS demonstration

Indoor RF service continuity testbed

- Indoor RF testbed includes
  - eNodeB connected to a USRP and two antennas
  - UE-to-network relay UE
  - Off-network UE that acts as a remote UE connected to one USRP and two antennas to transmit and receive over the sidelink channel
  - On-network UE that acts as relay UE and attaches to the eNodeB and serves as the source synchRef for the remote UE. It has two USRPs and three antennas to communicate over LTE UL/DL and transmit and receive over sidelink
  - One laptop is used for the EPC (HSS, MME, and S/PGW), which is wired to the eNodeB. The EPC is also connected to a NAT machine



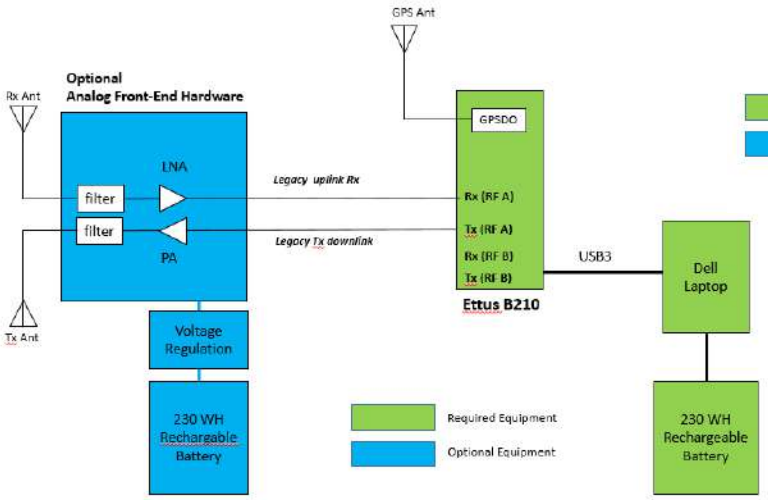
- Used to test and demo successfully the service continuity scenario

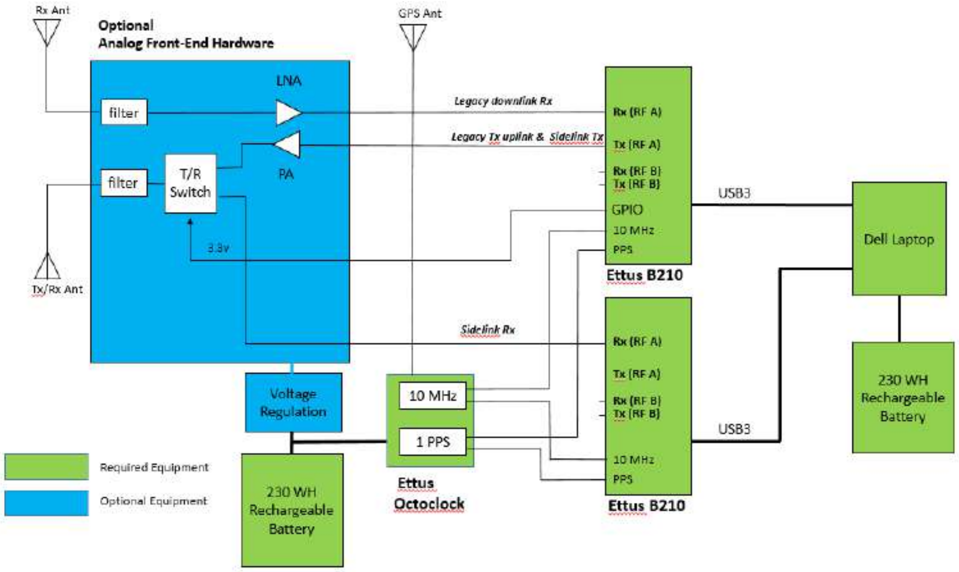
Outdoor RF testbed

- Three carts are used for the eNodeB, relay UE, and remote UE respectively
- Each cart consists of the following components:
  - A tub cart, 36” high x 35” wide x 18” deep on 5” locking wheels.
  - SDR electronics, consisting of a laptop computer, one or two B210 SDR transceivers, with optional National Instruments Octoclock and/or analog front end electronics.
  - An (steel) plate for magnetic mount antennas, accommodating two antennas (Wilson 311125 magnetic mount antennas) and a GPS antenna.
  - One or more rechargeable Lithium batteries for “portable” operation
- Used to field demo off-network D2D operation

Schematics

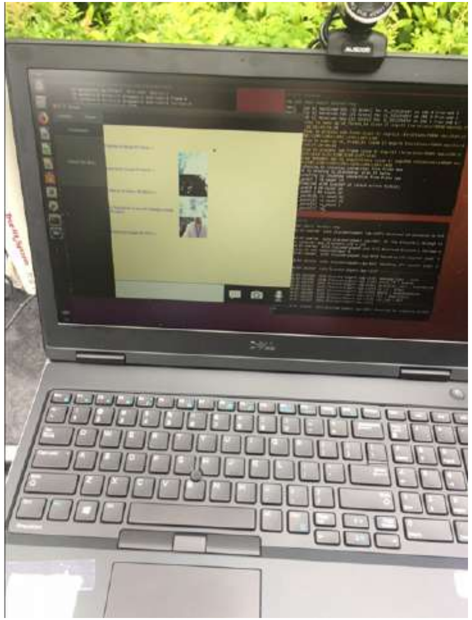
Remote UE and eNodeB Schematic





Relay UE Schematic

Outdoor field demo



Most images sent were received perfectly

At 20 meters distance, one image was received distorted

- 50 PRBs, 0dBm transmit power, sidelink Band 14 used
- Distance between off-net UEs: 5, 10, 15, and 20 meters

Outdoor field demo

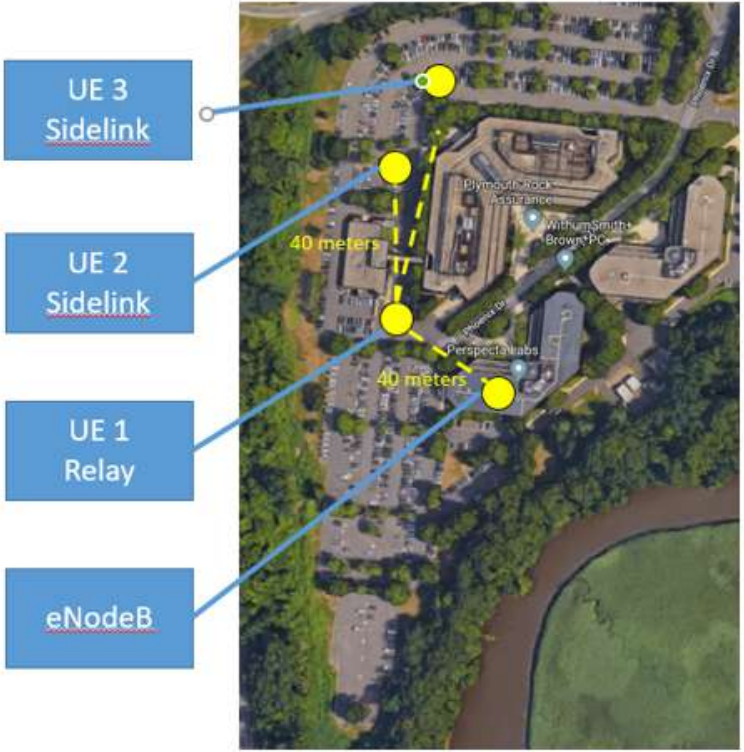
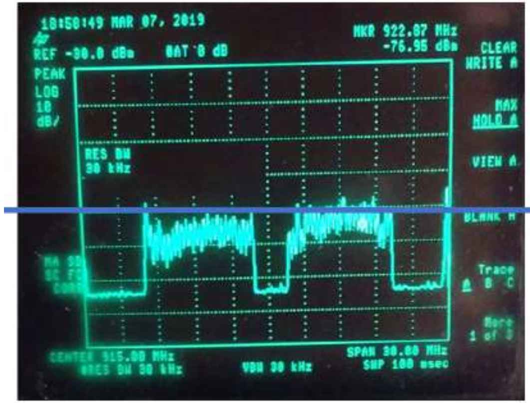


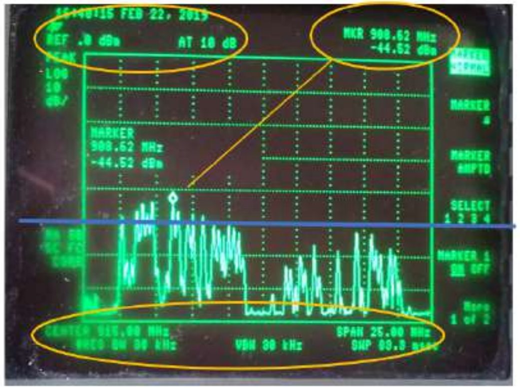
Figure 25: Proposed Service Continuity Test Area

Measured 915 MHz ISM band occupancy



Indoors, 8 dB roof to lab coax loss
Mar 7 2019 18:58

-70 + 8 = -62 dBm
Expected Interference Level
Measured in lab



Feb 22, 2019

Outdoors
Vertical Polarization
Butler Building
Ground Level

-50 dBm
Interference Level
Measured at
Antenna output

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Estimated operational distance – ISM interference environment

PRBs, Subcarriers, BW	Power Amplifier, 16 dBm	Power Amplifier, 23 dBm
25, 300, 5 MHz P.1411 distance (meters)	53.3 dB path loss 25 meters	60.3 dB path loss 40 meters
50, 600, 10 MHz P.1411 distance (meters)	50.2 dB path loss 20 meters	57.2 dB path loss 34 meters

The above calculation is: Transmit Subcarrier Power (dBm) - -62 dBm Receiver Subcarrier Power = Allowable Path Loss (dBm)

Conclusion

Conclusion

- Despite standardization, there is no mature LTE D2D when cellular communication fails
- DDPS is an effort to facilitate the development of an LTE D2D ecosystem based on ProSe
- The key DDPS technologies include building a complete ProSe stack for Mission Critical Voice by extending the OAI implementation and solving key related problems
- DDPS testbed demonstrates feasibility of ProSe for first responder applications
- Challenges
  - Synchronization, resource allocation, service continuity
  - Testbed implementation, frequency agility including Band 14 and ISM band
  - Current SDR platform sufficient for demo of ProSe, but more computationally powerful platform and smaller form factor hardware are needed for deployment

Thank you

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Come back for the

Next Session

4:20 PM

Backup material

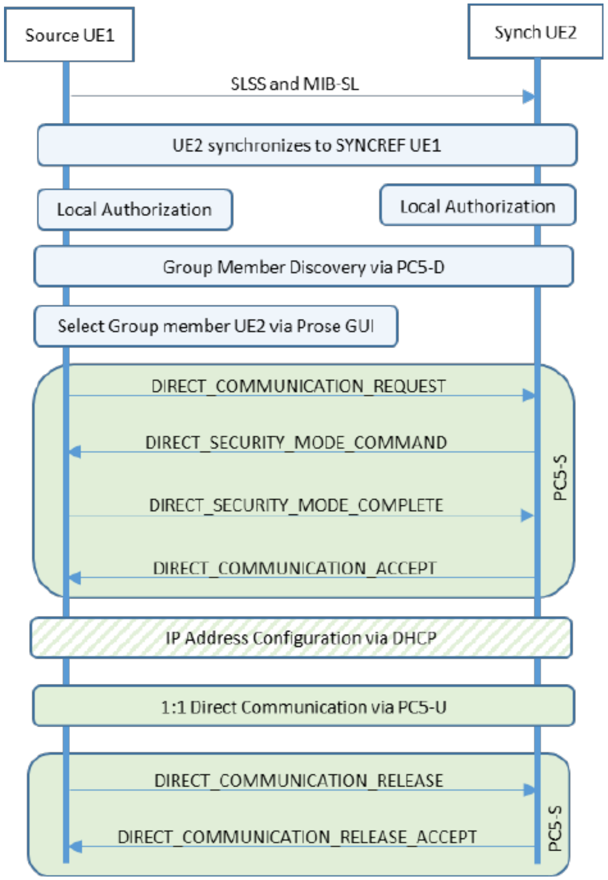
DDPS achievements – details (1/2)

- D2D software stack implementation in OAI including sidelink channel implementation with:
  - RRC: SIBs 18 and 19, and SidelinkUEInformation handling
  - PDCP: PC5-S and PC5-U traffic for Sidelink
  - MAC: SL-DCH, SL-SCH
  - PHY: PSDCH, PSSCH, PSCCH, SLSS
- Sidelink synchronization between off-network UEs and between Relay and Remote UEs
- Relay UE support with 2 USRPs (USRP1: LTE UL/DL + sidelink Tx; USRP 2: sidelink Rx)
- Group members and UE-to-Network relay discovery announcement and monitoring
- Group members registration and authentication
- Creation/Rrelease of direct link between off-net UEs and between Relay and Remote UEs
- D2D 1:N (group) comm and 1:1 (direct) private comm and traffic exchange over group and direct link via GUI, including push-to-talk, image transfer, and text message
- Tested and demoed over cabled and wireless testbed indoor and outdoor

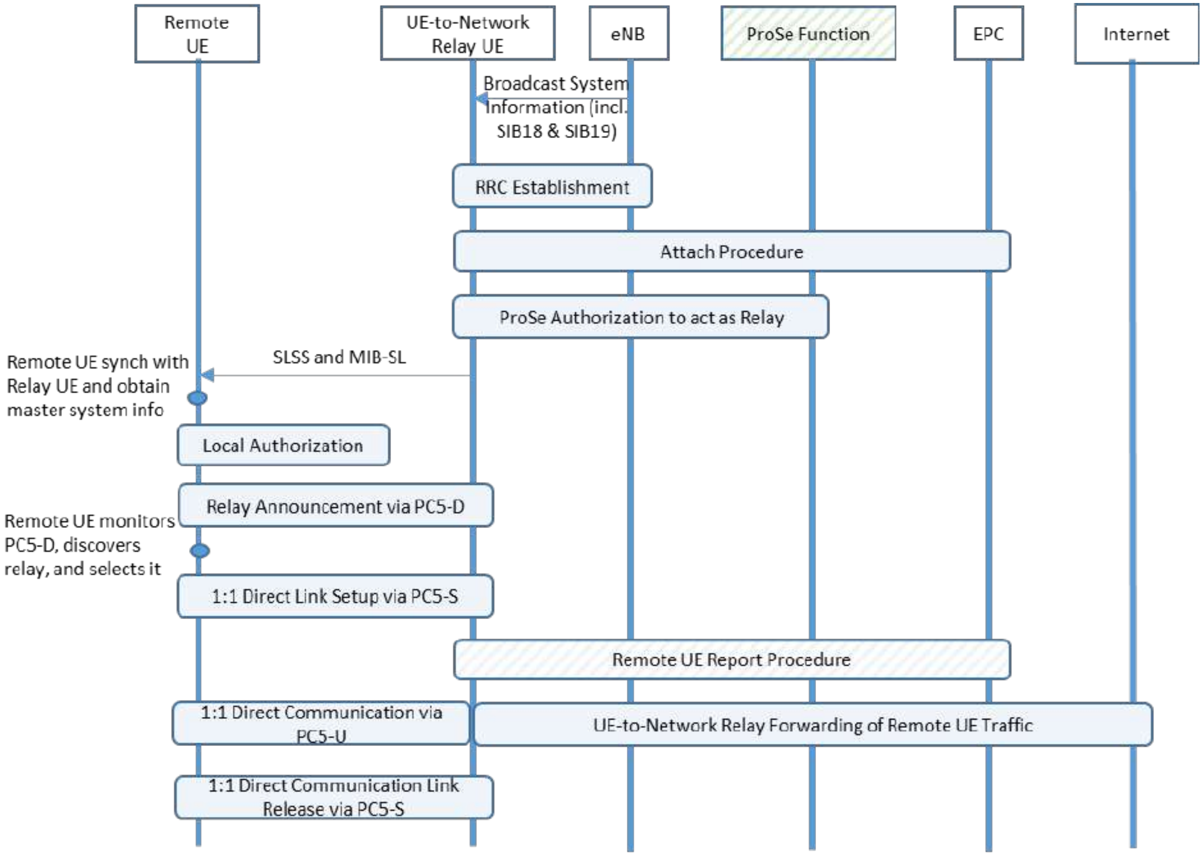
DDPS achievements details (2/2)

- Synchronization study
  - Simulated the VL “Array-Assisted Cross-Ambiguity Function (AACAF)” synchronization algorithm on MatLab for D2D indoor and outdoor environments
  - Compared the performance of multiple synchronization search algorithms including three variants of AACAF and four variants of direct correlation detector, under the variables of frequency offset, Gaussian noise, and pedestrian multipath channel conditions
  - Showed feasibility with respect to stringent SNR and frequency offset
- Resource management study
  - Investigated methods for reducing collision rates for off-net D2D operations
  - Proposed new algorithms and compared performance with the baseline 3GPP D2D resource assignment procedure.
  - Studied two variants of the resource assignment algorithm. Both achieved an improvement of ~25% reduction in collision rate. Further study will compare implementation complexity.

Off-network call flow



Service continuity Ccall flow



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OAI RAN and CN additional extensions (in progress)