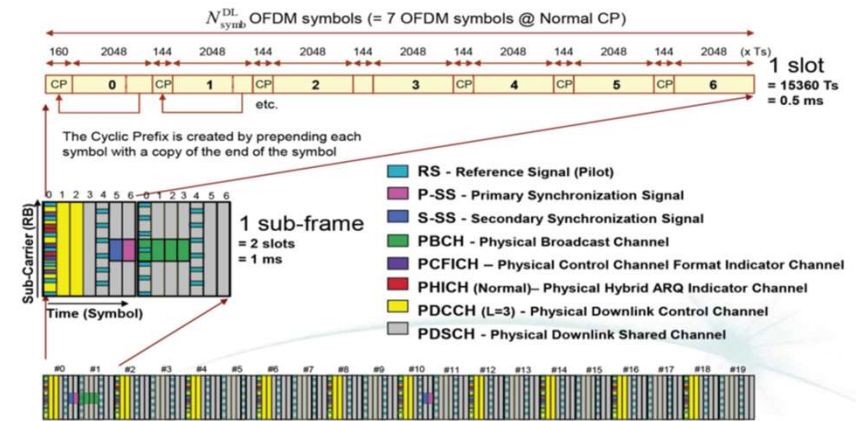
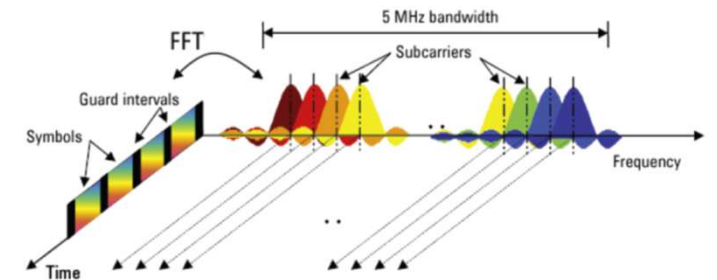
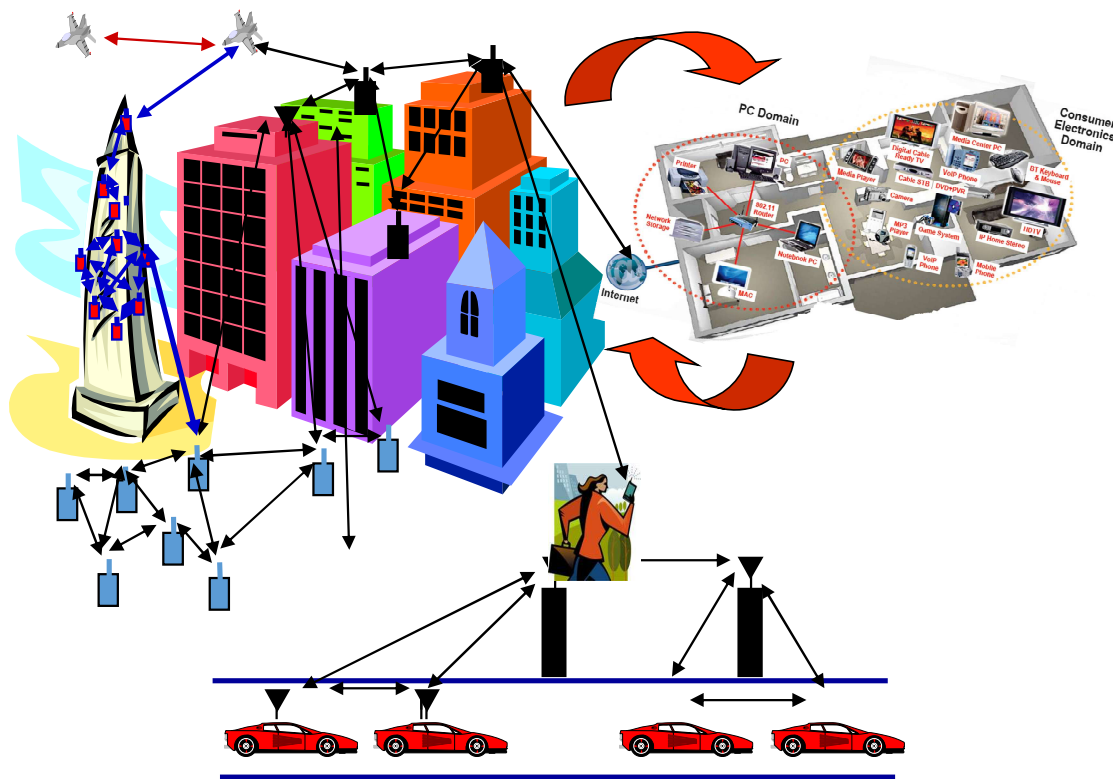


IEE 2620: System Aspects in Communications

Professor Muhammad Mahtab Alam

Lecture 15

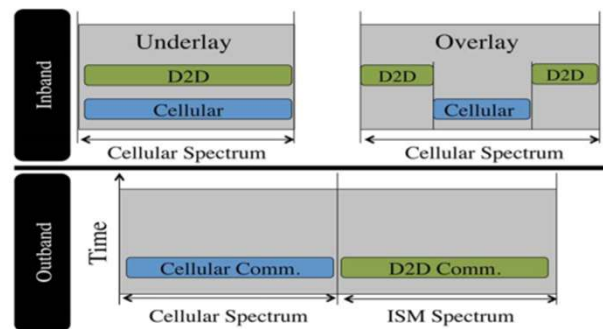


Outline

- Brief follow-up from last lecture
- Cooperative Communication (Continues ..)
- Device to Device (D2D) Communication
 - D2D Scenarios
 - Peer Discovery
 - Resource Allocation
- Summary

Device to Device Communication Modes

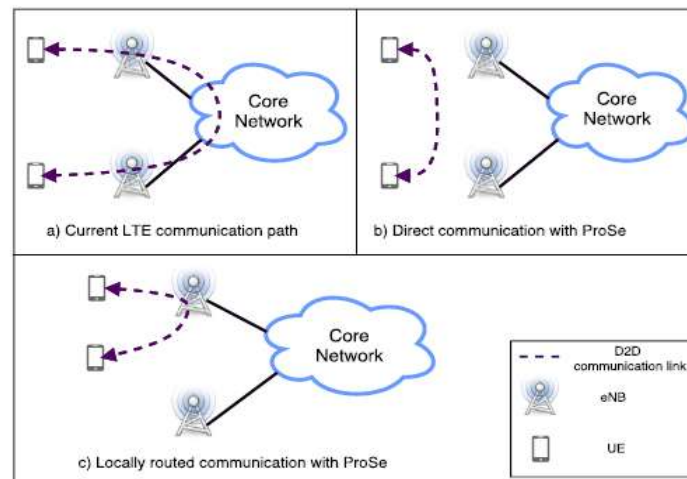
- D2D permits fast communication between nearby devices through **in-band and out-band modes** (illustrated in Figure).
 - In **in-band mode**, a D2D pair share the spectrum of the cellular users in an overlay (**base-station assisted**) and **underlay** (**not base-station assisted**) fashion
 - Whereas, in the out-band scheme, D2D users switch to unlicensed bands (e.g. ISM band)



- **Out-band** D2D communication faces challenges in coordinating the communication over two different bands because usually D2D communication happens on a second radio interface (e.g., WiFi Direct, LTE Direct and Bluetooth).

Proximity Services

- Proximity services include features to **discover devices** in physical proximity and enable an optimized communication between them.
- Proximity services **offer two functions**: the **network-assisted** discovery of users in a close proximity and the facilitation of direct communication between such users with or without supervision from the network
- Proximity services also **extend normal network coverage area**. If a User Equipment is outside the cellular coverage, it can, through another UE, relay its traffic to a base station (eNodeB) or to a different UE.

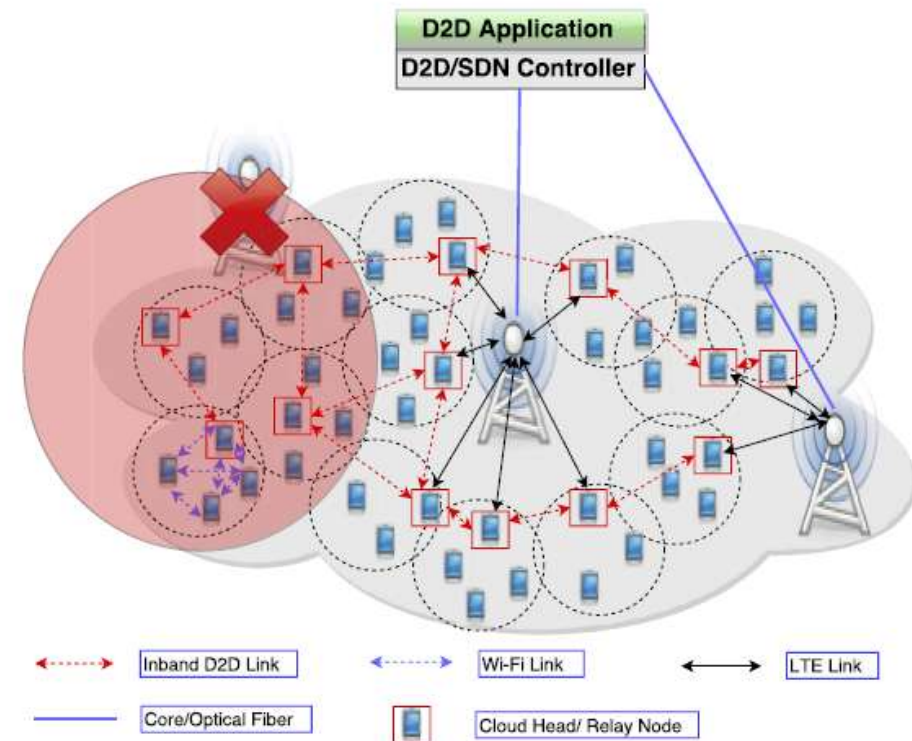


Public Safety Scenario (1/3)

- The mobile communication infrastructure (fixed base-stations) is only **partially available**. In this case, the important questions are:
 - i) **how to establish a connectivity** among the devices which are not covered through the infrastructure?
 - ii) while connecting these devices through D2D communication modes, **how to ensure a harmonized solution** i.e., maintaining as low transmission power as possible to minimize the mutual interference among D2D devices and cross interference with those which are already connected to the cellular infrastructure.
- The mobile communication infrastructure is completely unavailable or damaged or destroyed. In this case, D2D communication will take place in the out-band mode.

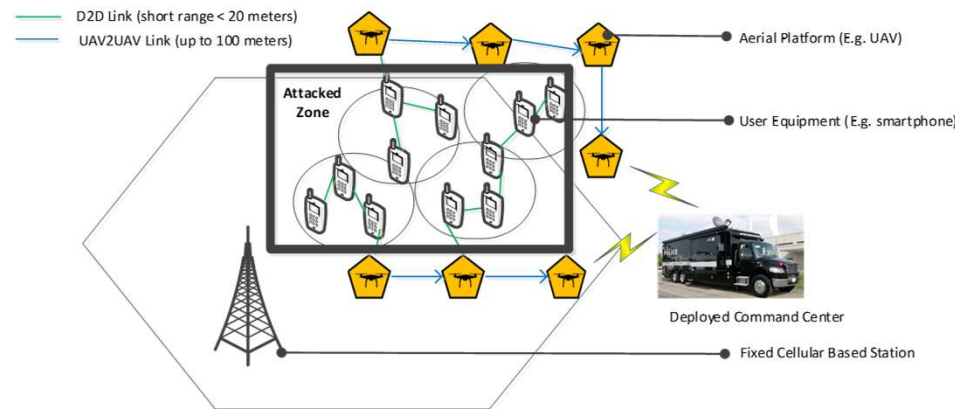
Public Safety Scenario (2/3)

- Figure presents a scenario where one of the base stations is collapsed, highlighted by red circle, due to a natural disaster.
 - The mobile devices make a **relay network to reach the nearest UEs inside the coverage area**. The devices marked with a red boundary in figure act as relay to carry the information of out of coverage devices to the other part of the network.
- There are two cases:
 - i) **due to several resource requests from UEs**, the network could be congested,
 - ii) **due to the disaster several devices try to get connected** to the working eNB, resulting in congestion.
- In case of disaster all out-of-coverage UEs try to reach the nearest base station using relay network. This flood of traffic from out-of-coverage area of the network results in the congestion in other parts of the network due to the scarce resources available at the BS.



Public Safety Scenario (3/3)

- The above scenarios will assist in acquiring precise information about the emergency situation as stated above and add **advanced services** such as positioning of devices inside the emergency area.
- Therefore, it is important to deploy a mobile and portable command center, **onboard Aerial Platforms (AP) or unmanned aerial vehicles (UAVs)** near the disaster site to provide reliable network connectivity and, possibly to increase positioning accuracy in the OS-A devices.



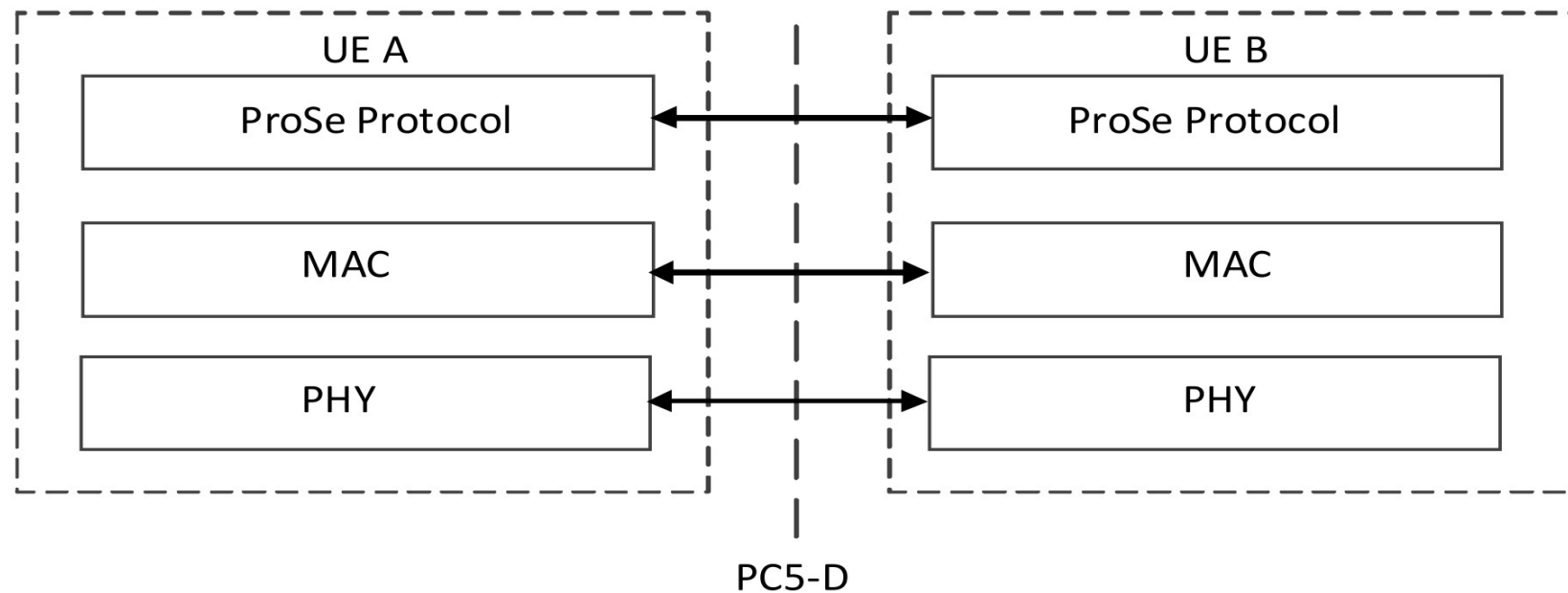
Public Safety Use Cases and Scenarios

- **Little or no coverage:** Used when there is attenuation due to the local environment, the mobility of the users, or a simple lack of coverage
- **Fall Back:** Used when there has been a complete network failure in an area that would typically have coverage
- **Extra Capacity:** Used to provide extra capacity to manage some incidents
- **Local Communication Requirement:** This is used in scenarios where there is no need to connect back to a control room or dispatch. Solutions for PS ProSe shall support the following scenarios:
 - Device to device E-UTRA Communication for Public Safety ProSe-enabled UEs is needed among within network coverage UEs, outside network coverage UEs and a mixture of UEs within and outside Network coverage.

Comparison between D2D and other wireless Technologies

Feature Name	D2D	Wi-Fi Direct	Bluetooth5.0
Standardization	3GPP Release12	802.11	Bluetooth SIG
Frequency band	Licensed band and unlicensed band	2.4 GHz, 5GHz	2.4-2.485GHz
Max transmission distance	500 m	200m	300m
Quality of service	Qos guarantees	No Qos guarantees	No Qos guarantees
Max data rate	5-10 Gbps	250Mbps	48Mbps
Device discovery	BS coordination	ID broadcast and embed soft access point	Manual pairing
Uniformity of service provision	Yes	No	No
Application	Public safety, Content sharing, Local advertising, Cellular relay	Content sharing, Group gaming, Device connection	OBject EXchange, Peripherals connection

PC5 interface for sidelink discovery



D2D Discovery

- The process of peer discovery should be efficient, so that D2D links are discovered and established quickly, it is also important for ensuring optimum throughput, efficiency and resource allocation within the system.
- Researchers are working on different Techniques for peer Discovery. Peer discovery techniques can be **restricted discovery and open discovery**.
- From the perspective of the network, device discovery can be controlled by the base-station either tightly or lightly.

ProSe Direct Discovery Overview

ProSe Direct Discovery is defined as the process that detects and identifies another UE in proximity using E-UTRA or WLAN direct radio signals.

There are two types of ProSe Direct Discovery: open and restricted.

Open Discovery: where there is no explicit permission that is needed from the UE being discovered,

Restricted discovery: only takes place with explicit permission from the UE that is being discovered.

Two models for ProSe Direct Discovery exist.

Model A ("I am here")

Model B ("who is there?" / "are you there?")

ProSe Direct Discovery Models

- **Model A ("I am here")**

- Announcing UE:** The UE announces certain information that could be used by UEs in proximity that have permission to discover.

- **Monitoring UE:** The UE that monitors certain information of interest in proximity of announcing UEs.

Both open and restricted discovery types are supported by Model A.

- **Model B ("who is there?" / "are you there?")**

- Discoverer UE:** The UE transmits a request containing certain information about what it is interested to discover.

- **Discoveree UE:** The UE that receives the request message can respond with some information related to the discoverer's request.

The Public Safety discovery is considered restricted. The monitoring UE/discoverer UE needs to have authorization to perform discovery of the appropriate service(s)

Direct Discovery for Public Safety use

The following functions for public safety direct discovery are supported:

- UE-to-Network Relay Discovery.

It involves the use of pre-provisioned parameters to first discover a UE-to-Network Relay, and a subsequent communication link establishment

- Determination is needed regarding within the ProSe Communication which user(s) are in ProSe Communication range at any given time (shortly referred to as "Group Member Discovery").

Group Member Discovery is a form of restricted discovery type in that only users that are affiliated with each other are able to discover each other (e.g. only users sharing the same Discovery Group ID).

Both Model A and Model B discovery are supported.

Key performance indicators

- **user throughput:** average data rate during connection time.
- **Latency:** This measures the connection establishment time in D2D situations
- **The Signal to Interference Plus Noise Ratio:** SINR is defined as the power of a certain signal of interest divided by the sum of the interference power (from all the other interfering signals) and the power of some background noise
- **Energy consumption:** This measures the gain energy consumption between a D2D connection

SINR Calculations

- One of the main parameters that can Devices or BS can make resource allocations according to it is signal to interference plus noise ratio.

$$\text{SINR} = P / I + N$$

- Example for SINR Calculation:

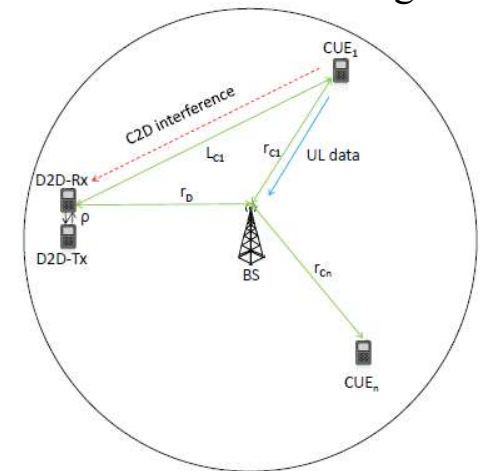
- a single cell environment,
- base station is located in the cell center
- one D2D pair
- N cellular users

- the distance between the CUE_i and D2D-Rx is given as

$$L_{Ci} = \sqrt{(r_{Ci}^2 + r_D^2 - 2r_{Ci}r_D \cos \theta_i)}$$

- r_{Ci} = distance between cellular user equipments and base station
- r_D = distance between D2D – Rx and base station
- $\theta_i = [0, 2\pi]$

SINR Calculation in single Cell



SINR Calculations

- received signal at the D2D-Rx:
 - $y_i = h_D \sqrt{P_D} \rho^{-\alpha} x_D + h_{Ci} \sqrt{P_{Ci}} L_{Ci}^{-\alpha} x_{Ci} + \eta_0$
- h_D = Fading Coefficient in D2D link
- h_{Ci} = fading coefficient in CUE interference link to D2D Rx
- P_D, P_{Ci} = are transmit power of D2D – TX and CUE
- X_D, X_{Ci} = are both signals of D2D – TX and CUE signal to BS
- α = path loss exponent
- $P_D \rho^{-\alpha}$ = received power at D2D-Rx for D2D link
- $P_{Ci} L_{Ci}^{-\alpha}$ = received power at D2D-Rx for C2D interference link
- η_0 = AWGN

SINR: $\gamma_{D_i} = \frac{|h_D|^2 P_D \rho^{-\alpha}}{|h_{C_i}|^2 P_{C_i} L_{C_i}^{-\alpha} + N_0}$