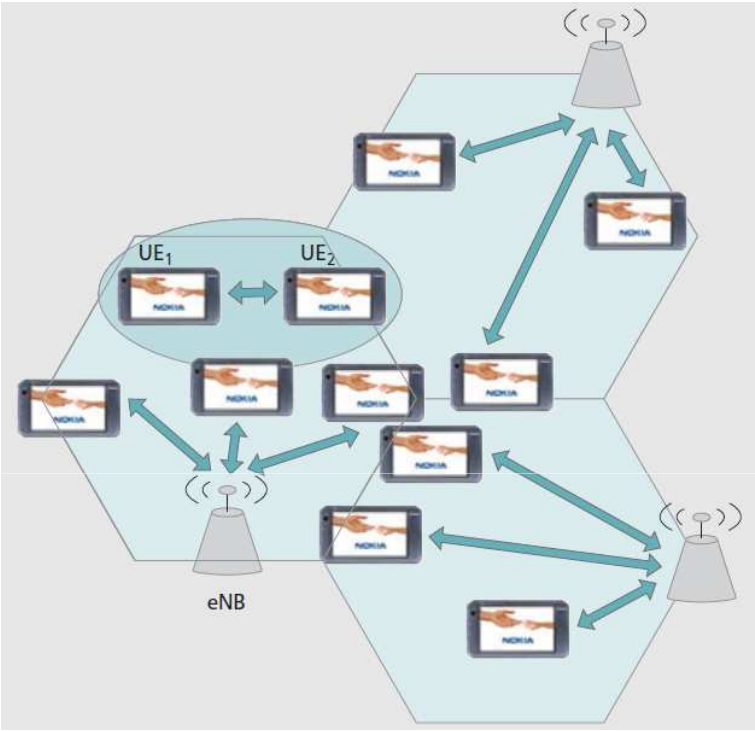
Device-to-Device Communication in LTE

PhuongBang Nguyen

02/2011

What is D2D?



- UEs communicate directly with each other.
- D2D connections remain controlled by the base stations.

Why D2D?

- Traditionally, all communications between mobile devices are relayed by the base station.
- Intuitively, there could potentially be many benefits when two mobile devices in “close” proximity to each other communicates directly or communicates in D2D mode.
- These benefits could include but are not limited to better throughput, lower power, and shorter delay between the two devices. The system as a whole can also benefit from D2D in terms of less relay load for the base stations, better channel resource reuse, etc.

Research Directions

1. Establish a working model of the wireless network under D2D and an associated network simulation environment that are both realistic, and tractable.
2. Examine system benefits when a subset of devices are in D2D mode. Investigate trade-offs and possibly formulate optimization problems related to different conditions to put a pair of device in D2D mode.
3. Consider possible resource reuse schemes. For example, the same radio resources can potentially be reassigned to different users in a different geographical region within the same cell.
4. Establish D2D management protocols. These protocols will determine when and how the communication between a pair of devices is switched from the traditional mode to D2D mode and vice versa.
5. Establish the set of channel parameters required for successful D2D communications.

RUNE Simulation Environment

Starting with RUNE Matlab code, the followings are available:

- Cell layout with base stations with omni or directional (3-sector) antenna patterns
- Channel assignments for base stations with reuse
- Mobile device movements, call assignments, handoff and terminations
- Log-normal shadow fading and distance-dependent loss
- Path gain calculation from all base stations to all mobiles
- Carrier strength and co-channel interference calculation for uplink/downlink

D2D Simulation Environment

Additional features required for D2D:

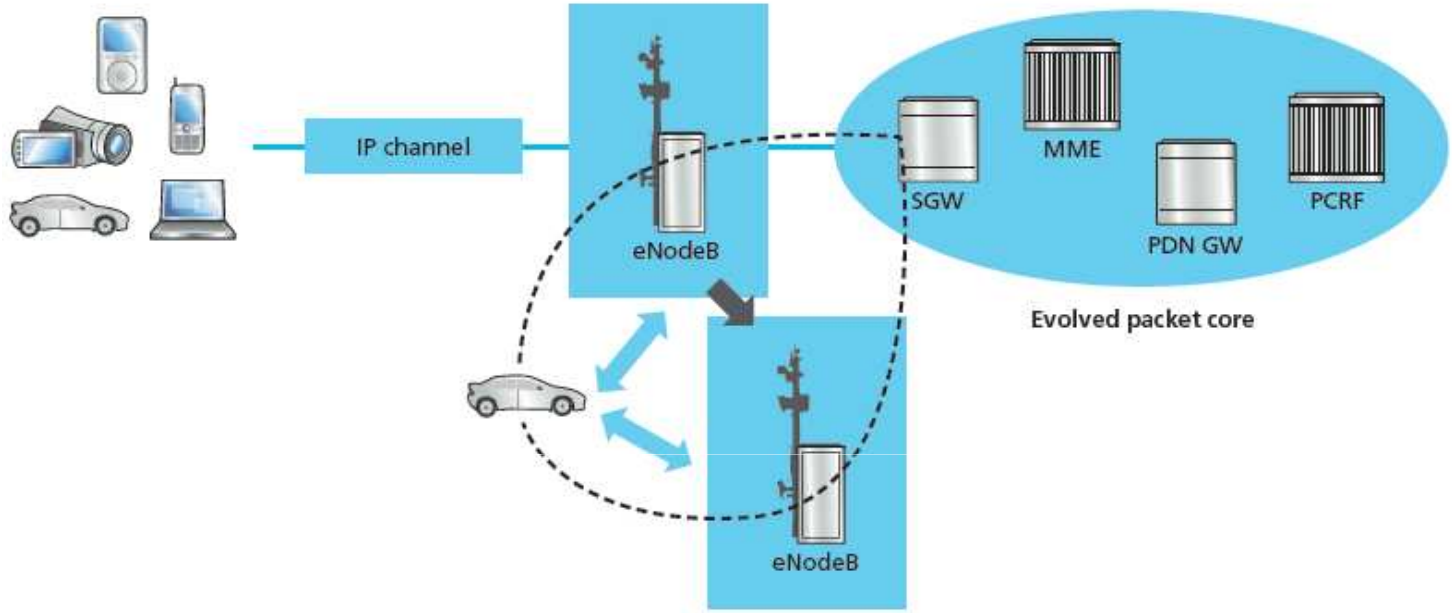
- Fading modeling and path loss between mobile devices
- Path gain calculation between mobile devices.
- Interference modeling for D2D resource reuse: to/from base stations and to/from other non-D2D devices for uplink and downlink.
- Device mode switching between cellular and D2D (in addition to assign, handoff and terminate).
- C/I calculation for D2D devices
- System performance with D2D

D2D Communication As an Underlay to LTE Advanced Networks

Reviewed by PhuongBang Nguyen

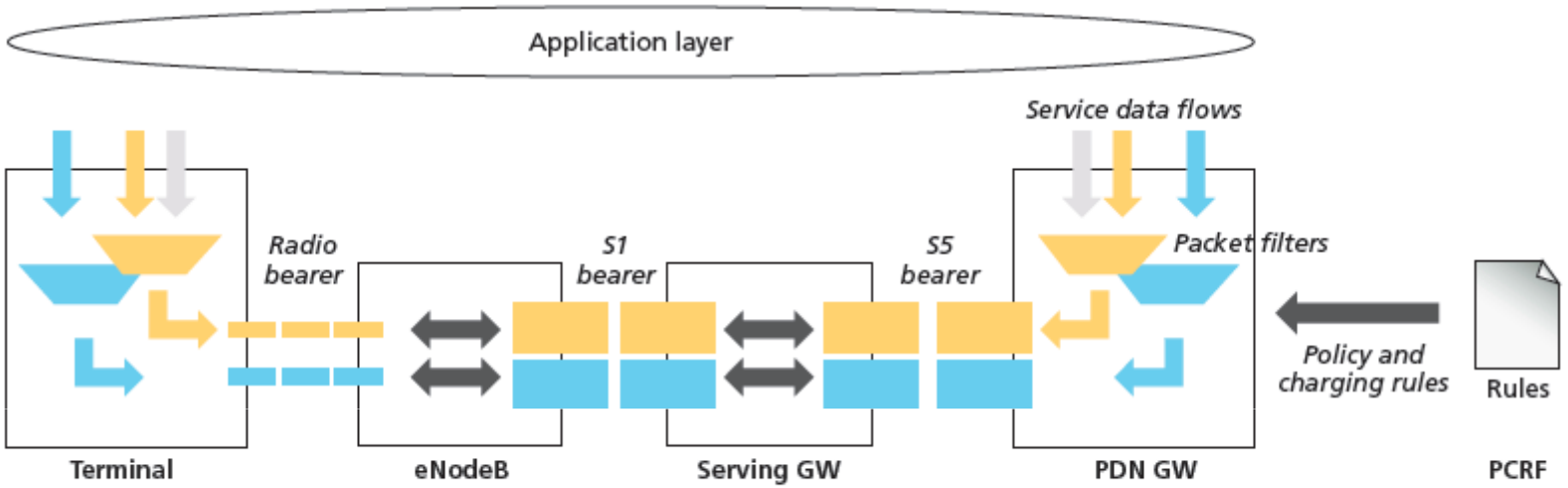
Nov 2010

LTE Network Overview (EPC)



- The Evolved Packet Core provides mobile core functionality that, in previous mobile generations (2G, 3G), has been realized through two separate sub-domains: circuit-switched (CS) for voice and packet-switched(PS) for data.

LTE End-to-End Datapath



- A datapath between a UE and a PDN, has three segments:
  - Radio bearer between UE and eNodeB
  - Data bearer between eNodeB and SGW (S1 bearer)
  - Data bearer between SGW and PGW (S5 bearer)

Benefits of D2D

- Operation on licensed band (D2D) guarantees interference environment, easier for service provider to plan access and investment than an uncoordinated environment such as WLAN.
- Base stations (eNBs in LTE) remain in control of the resources and transmitted power for D2D UEs. Resource can still be assigned to D2D in dense network, whereas cognitive radios will fail to find white spaces to jump in.
- D2D is transparent to users. The base station detects the access to local server and routes the connection automatically. Bluetooth requires pairing, WLAN requires connection setup to access points. Unlicensed spectrum may not be available.

Method 1: Identifying D2D Traffic, Setting up D2D Bearers

- In SAE architecture, the gateway is aware of the global IP addresses. It routes packets to correct eNBs serving the destination UEs.
- If source and destination addresses belong to the same eNB, the gateway earmarks the traffic to indicate a potential D2D communication.
- The eNB requests the involved UEs to make the tradeoff measurements between cellular and D2D communications and sets up a D2D bearer if necessary.
- D2D can be set up for UEs served by neighboring eNBs as well.
- SAE bearer (between UEs and the gateway) remains active to allow connection the internet.

Method 2: D2D Setup Using Dedicated SAE Signaling

- Avoid the overhead of IP header processing for D2D detection.
- Use a special URI to indicate a D2D session requests.
- Initiating UE sends session setup request to MME via the control plane instead of user plane.
- MME receives the requests and hand them to the SIP handler, which detects if the UEs are served by the same eNB or two neighboring eNBs. This makes use of the tracking area augmented with the D2D URIs.
- The eNBs will then be contacted to set up a D2D bearer if possible.
- The eNBs send confirmation back to MME.

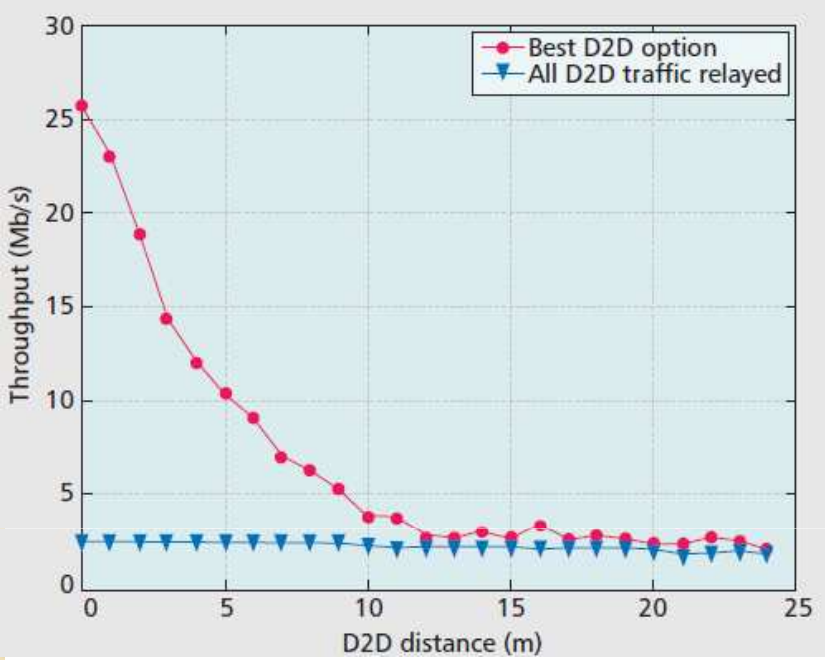
Interference Management

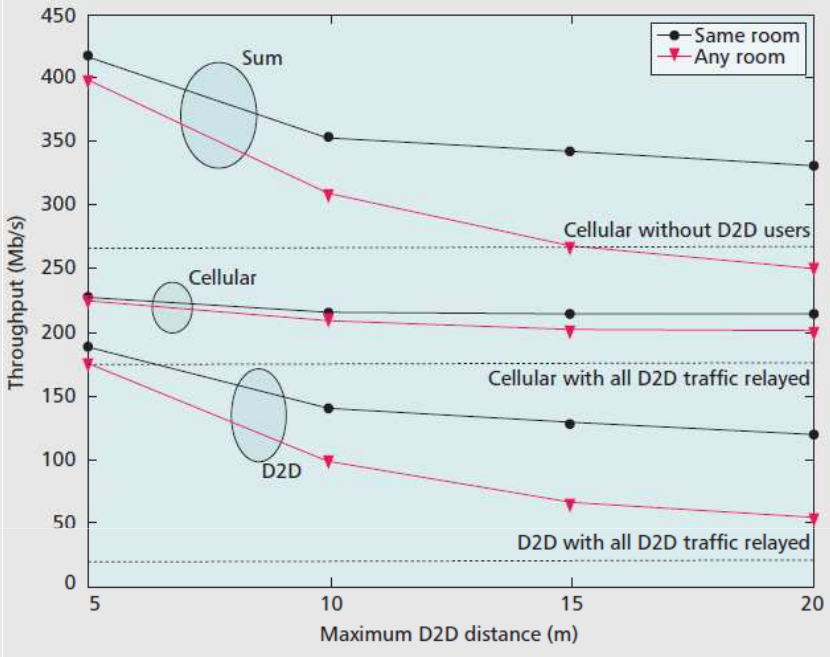
- Dedicated OFDMA resources are assigned to D2D connections when possible.
- eNBs can adjust transmitter power of D2D UEs.
- During uplink period, a D2D transmitter that reuses the cellular resources reduces its power by a backoff value. Other cellular transmitters may be required to boost the transmitting power to maintain the uplink SINR.
- During downlink period, transmitted power of D2D UEs can also be reduced when there is a degradation in cellular connections.
- eNBs should schedule resource sharing for D2D connections and cellular connections that are well isolated in propagation conditions (indoor D2D and outdoor cellular connections).

Simulation Network Modeling

- Cellular users are uniformly distributed (20 users/cell average).
- 10 D2D pairs are added per cell.
- Uplink D2D with shared resources has 10 dB power backoff.
- Downlink D2D with shared resources transmits at -5 dBm. D2D with no sharing transmits at 3 dBm.
- D2D pairs that "potentially" share uplink/downlink resources are chosen randomly (which 5 of the 10 will share uplink/downlink).
- For each timeslot, a D2D pair can communicate using either dedicated resources, base station relay, or shared resource with cellular users. This decision is based on the highest projected throughput. D2D terminals measure link quality for dedicated/shared resources and feed it back to the base station.

Simulation Results





- With D2D, total throughput of (D2D plus cellular) increases 65% comparing to the case where all D2D traffic is relayed.
- Throughput of cellular users decreases 35% (compared to no D2D user case) when all the D2D traffic is relayed.
- D2D benefits a lot more when the D2D pairs are within the same room.

References

- "**Introduction to Evolved Packet Core**", Alcatel-Lucent.
- "**Device-to-Device Communication as an Underlay to LTE-Advanced Networks**", Klaus Doppler, Mika Rinne, Carl Wijting, Cássio B. Ribeiro, and Klaus Hugl, Nokia Research Center, IEEE Communications Magazine, December 2009