3GPP TSG RAN Meeting #70
Sitges, Spain, 7 - 10 Dec. 2015

RP-151754

Motivation for SI: Further LTE D2D Enhancement for eMBB and Wearables

Intel Corporation

Background

LTE continues evolving in Rel-14 and beyond

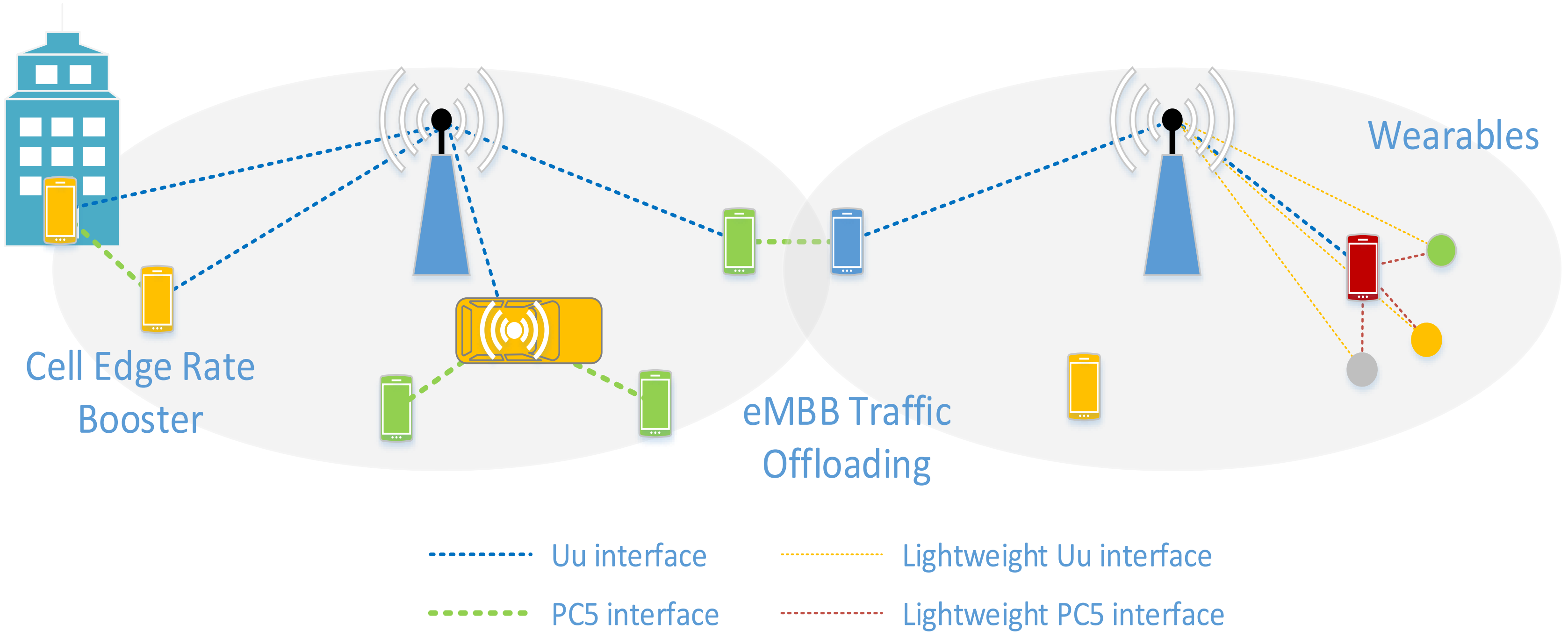
Further optimizations to continue improving MBB performance and support efficient connectivity to the new type of devices:

- eMBB: higher network spectrum efficiency, uniformed coverage and better energy efficiency
- Wearables: lower cost, better power efficiency and massive connected consumer devices

D2D relay should be further enhanced in Rel-14 in these two aspects

- D2D relay based ultra-dense network to be deployed dynamically to follow the traffic
- D2D relay based ultra-low-power connectivity to connect wearables to the network managed by the operators

D2D relay use cases



Using LTE for wearable

Bluetooth LE - Low Cost & Low Energy

- State transmission: < 1 Mbps

Wi-Fi - High Data Rate

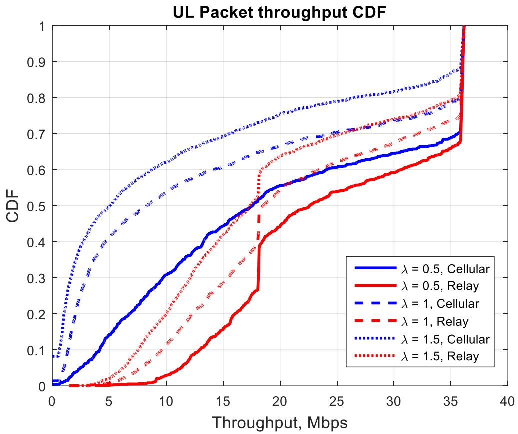
- High data rate video, voice, data

LTE Solution

- Technology competiveness
  - LTE can satisfy all design targets (low cost/low energy + various data rates + better coverage)
  - Leverage LTE technology and the economy of scale to serve IoT segments
  - Unifying the relay link with the direct link reduces the complexity and cost of IoT devices
  - Allow network control to optimize user experience, to ensure service continuity, etc.
- Enables new business opportunities to serve billion devices providing ubiquitous and seamless connectivity

- Video:
  - ✓ 720p => ~12 Mbps
  - ✓ 1080p => ~22 Mbps
- Voice/Music:
  - ✓ VoIP => 16.6 Kbps
  - ✓ Sound streaming => 64-320 Kbps
- Sensors:
  - ✓ 1-100 Kbps

D2D relay to enhance MBB

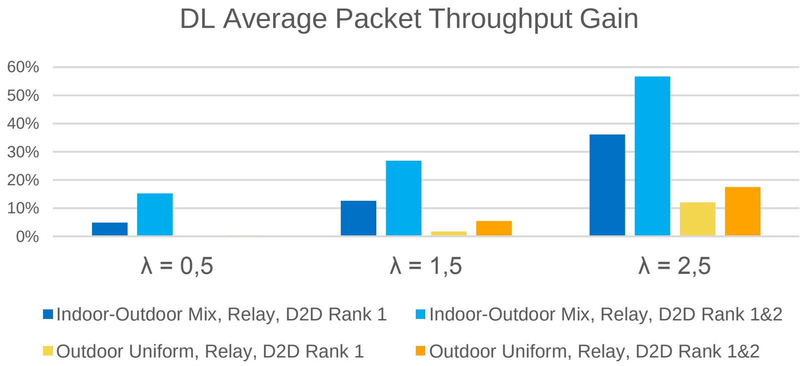


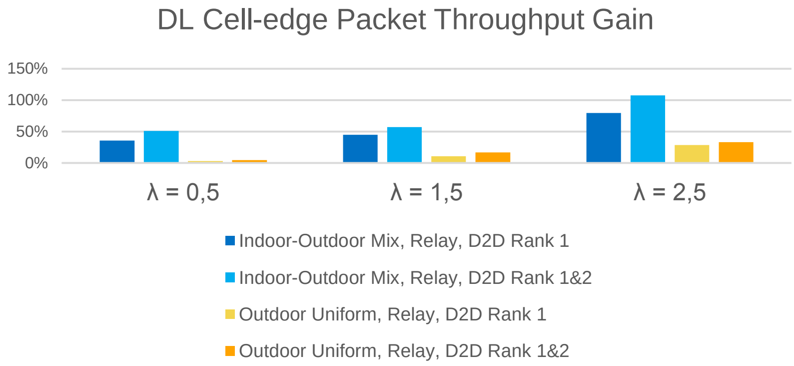
Uniformed user experience

- D2D relay to improve cell edge performance (DL or UL)

High demand to further improve area spectrum efficiency

- D2D relay allows to further exploit the densification gain





D2D relay vs LTE Rel.10 relay

Functionality	Rel-10 relay node	Relay UE (eMBB w/o coverage hole)
Relay set per cell	Small stationary set (1-4 relays at most)	Large semi-static set (amount of UEs)
NW functionality to support Relay	S1/X2 proxy functionality + S11 termination + S-GW/P-GW functionality to support relays	L2 relay data routing
Deployment	Operator (investment/maintenance is on operator)	By end user, opportunistic or operator
Access Control	Yes, via Relay	To NW: via eNB (same as normal LTE) To Relay: via discovery procedure
Relay enabling	Relay attachment + authorization by HSS	RRC connection + authorization by ProSe server
Mobility/Handover (Relay/Remote)	Relay: No, stationary Remote UE: HO procedure	Relay UE: Yes, through HO Remote UE: Fast relay/cellular path switching
Scheduling	Access Link: By Relay Backhaul Link: By eNB	By eNB (dynamic resource control is feasible)
In-band Relay Spectrum	Relay→Remote: Downlink (non-MBSFN) Remote→Relay: Uplink	Relay→Remote: Uplink Remote→ Relay: Uplink

D2D-based relay operation does NOT require upgrade at CN and can be dynamically enabled and configured under network control

Why Rel-13 eD2D is not sufficient?

Wearable sensors (e.g. fitness, health, and wellness sensors)

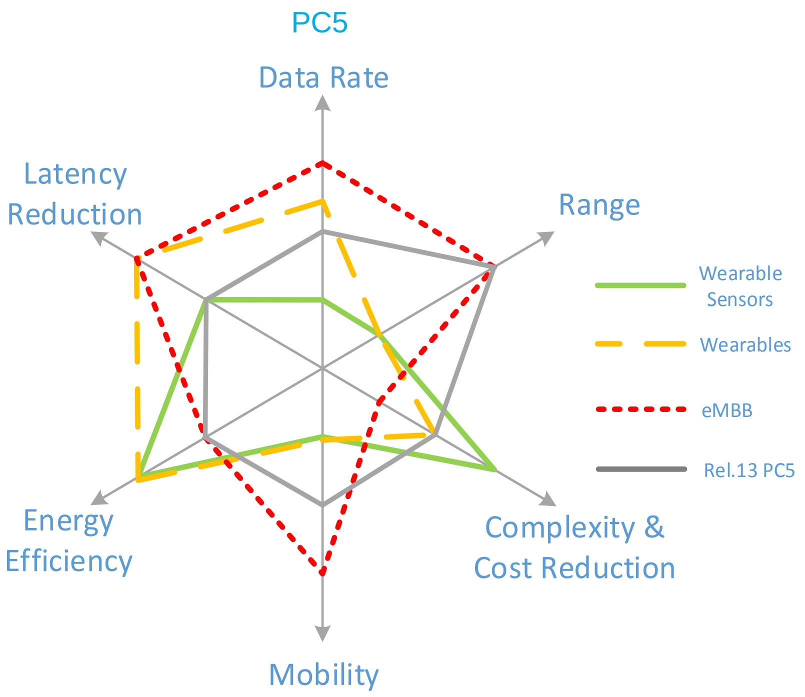
- Ultra-low-power, low-data-rate, low range, no mobility and low cost

Wearable (e.g. watch, glasses and camera)

- Ultra-low-power, high-data-rate, low range, no mobility and low latency

eMBB (e.g. hotspots, vehicular infotainment)

- Very-high-date-rate, seamless mobility, and low latency



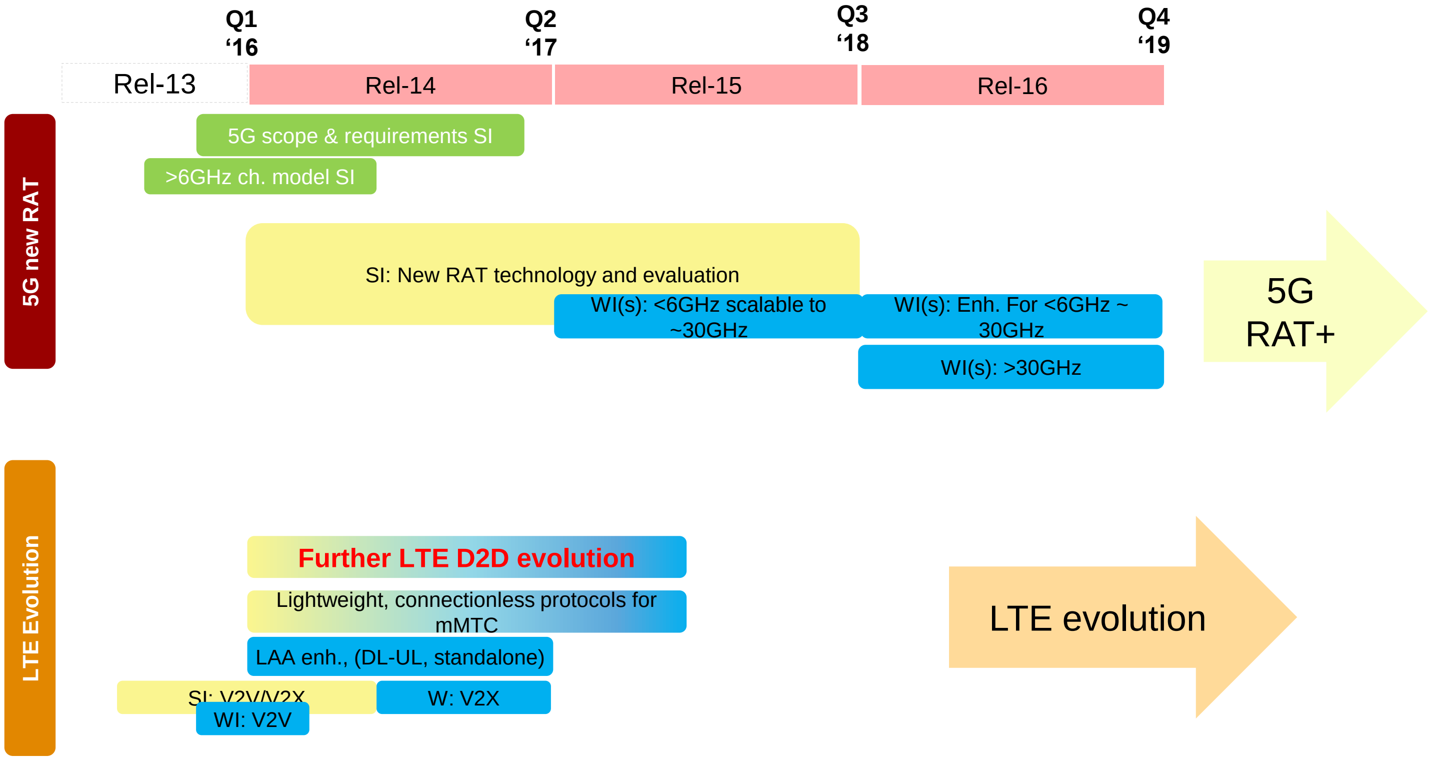
Technology gaps

Propose to study the following enhancement to PC5 in Rel-14

- Higher peak rate and spectral efficiency (for eMBB and wearables)
  - PC5 link adaptation, resource allocation, minimized conflict with cellular HARQ operation, power control over sidelink
- Allow UE to be “best connected” to maximize overall system performance (for eMBB)
  - Radio-aware relaying / measurements
  - Intelligent path selection, fast switching / data routing based on L2 relay
- Lightweight and energy efficient PC5 protocols (for wearables)
  - Master / slave operation (master UE assisted connection management, paired mobility, master UE controlled D2D resource configuration)
  - Mechanisms to improve power saving over PC5 (e.g. DRX)
  - Reduced signaling overhead during path switching with L2 relay
  - Service continuity by reducing interruption during path switching for real time service
  - Techniques to reduce device complexity and cost, e.g. support of single RX chain, narrow bandwidth operation, etc.

Low-power/low-cost Uu interface for wearables can reuse LTE-MTC and/or NB-IoT frameworks

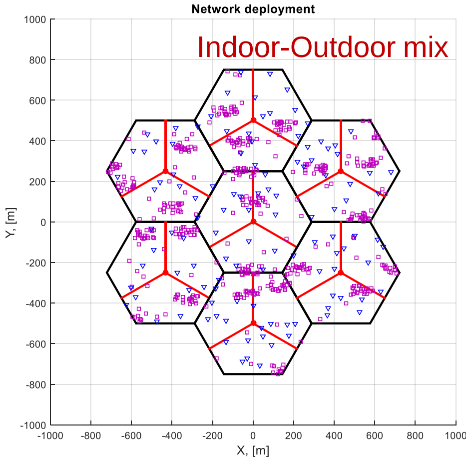
Standardization timeline

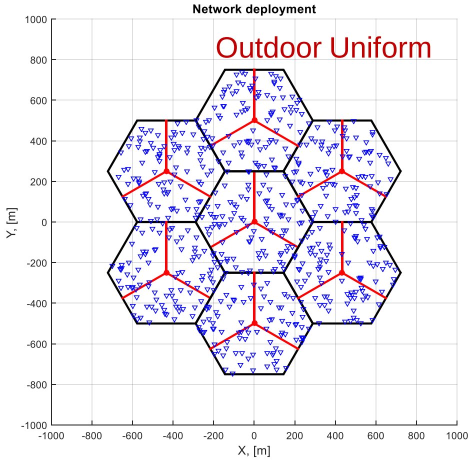


LTE eMBB Performance Analysis

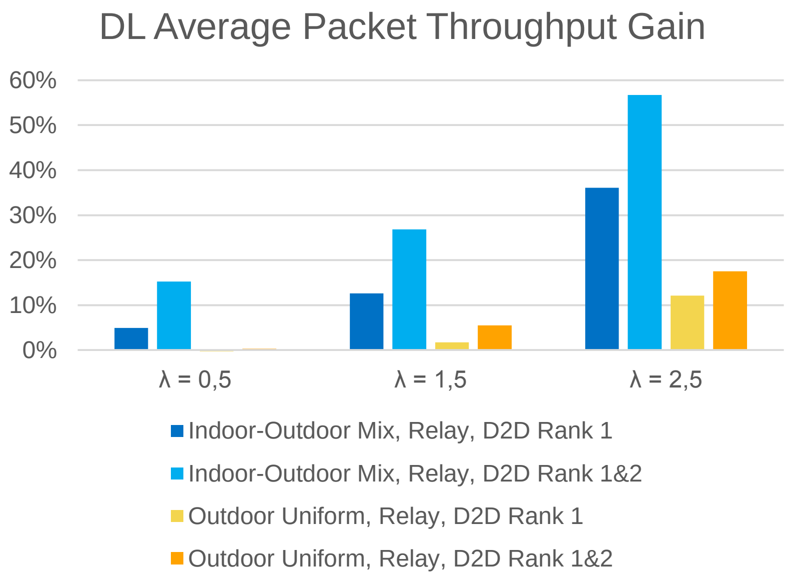
Evaluation assumptions

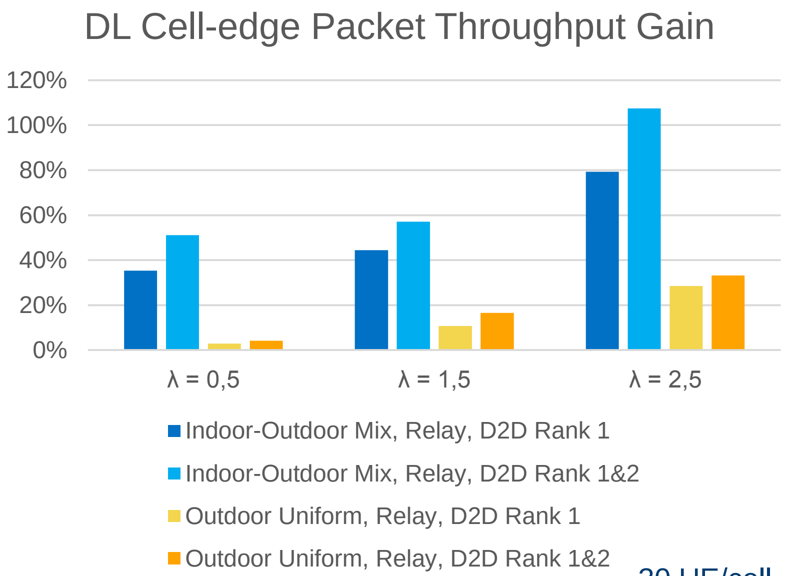
Parameter	Value/Reference/Comment	
Deployment Scenarios	Indoor-Outdoor mix D2D General Scenario 1 from 36.843 with modification: Macro-only deployment, 21 cell, 80/20 indoor-outdoor mix, clustered drop with 1 indoor hotspot building per cell	Outdoor Uniform Macro-only deployment, 21 cell, all UEs are dropped outdoor uniformly across cell
Spectrum	10MHz@2GHz, FDD	
Traffic model	FTP Model 3, 0.5 Mb file size For DL offloading λ(D) = [0.5, 1.5, 2.5], λ(U) = 0.25 if not explicitly mentioned	
Channel model (pathloss, fast fading)	3GPP TR 36.843	
Power control	eNB max power 46 dBm, UE max power 23 dBm. UL: P_0 = -76, α = 0.8 (20 dB target UL SNR) D2D: P_0 = -96, α = 0.8.	
Resource allocation	50 PRB on all layers	
Performance metric	Packet throughput: $PT = \frac{Packet\_size}{Packet\_TX\_time}$	
MIMO mode	DL: MIMO rank 1&2 adaptation. D2D: MIMO rank 1 or rank 1&2 adaptation. UL: MIMO rank 1.	





Dependence on system loading and D2D rank - Packet throughput gains

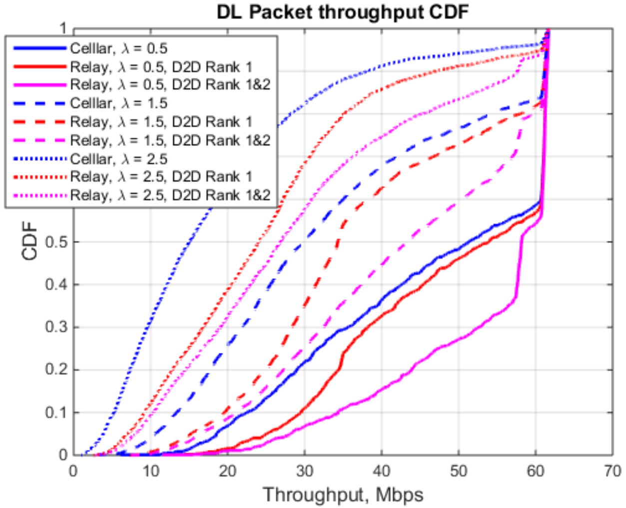




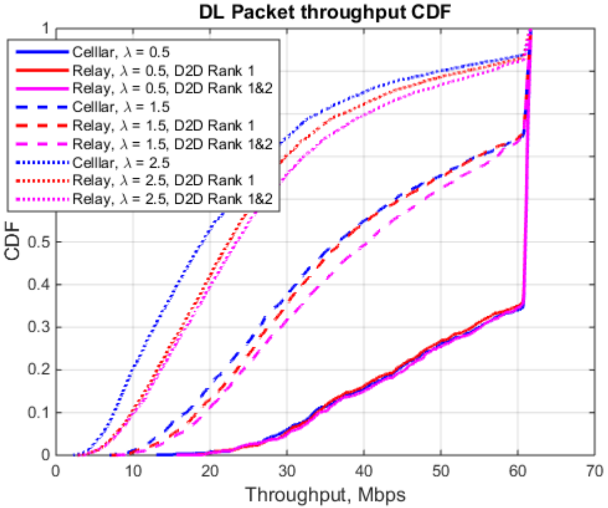
30 UE/cell

Dependence on system loading and D2D rank - Packet throughput CDFs

Indoor-Outdoor Mix

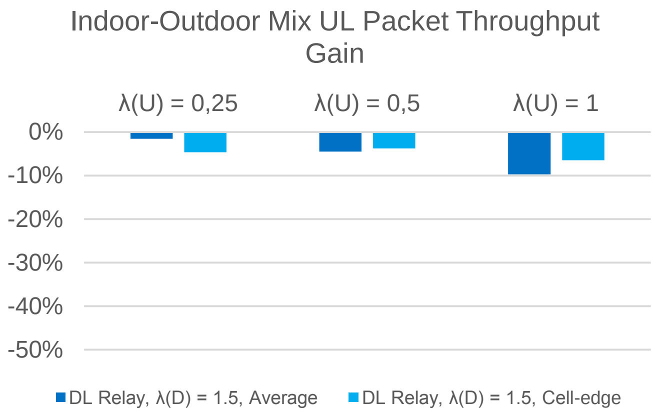


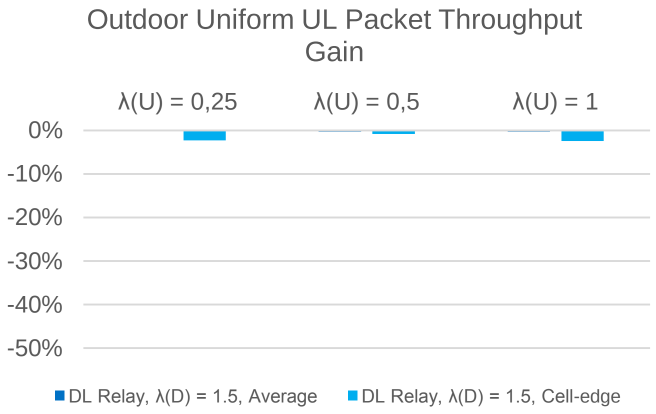
Outdoor Uniform

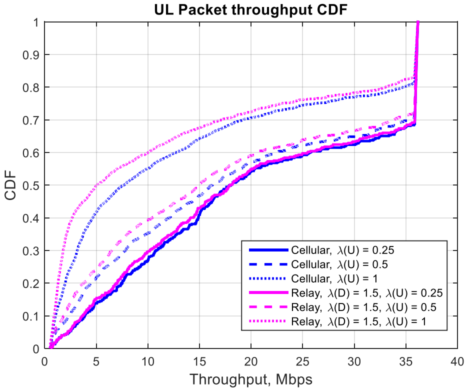


Rank 1 SL relaying provides remarkable gains especially at high DL system loading
Rank 2 SL provides additional benefit but imposes higher UE complexity
Indoor-Outdoor mix scenario is more advantageous for DL offloading due to more noise-limited nature

Impact on UL cellular performance

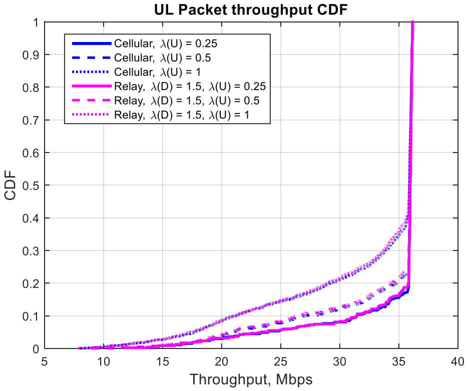






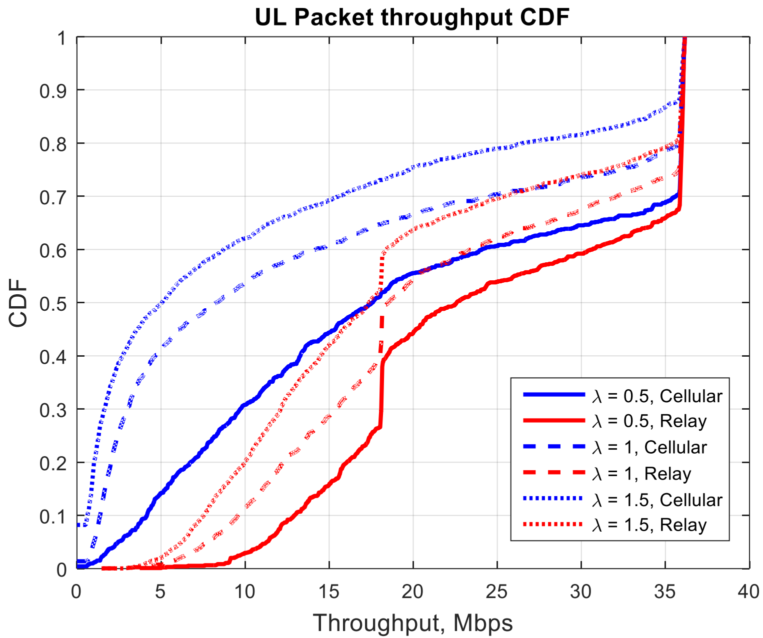
Limited impact on UL especially in outdoor scenario due to low transmission power of relays.

Network has all mechanisms to control this impact.



UL traffic offloading performance

Indoor-Outdoor Scenario



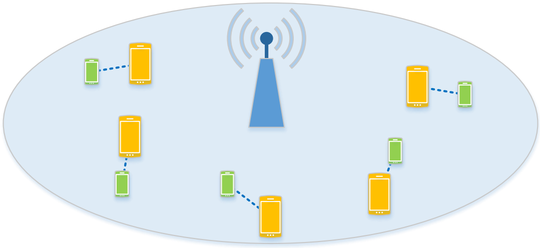
For $\lambda_{UL} > 1$, there is packet drop for the reference scenario w/o enabled D2D relaying

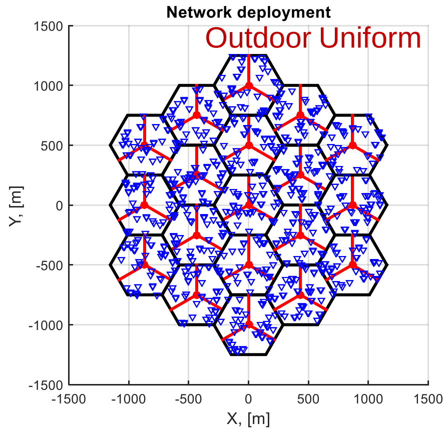
UL offloading may resolve outage in case of high UL system loading and limited coverage (observed in indoor/outdoor mix scenario)

LTE Wearable Performance Analysis

Evaluation assumptions

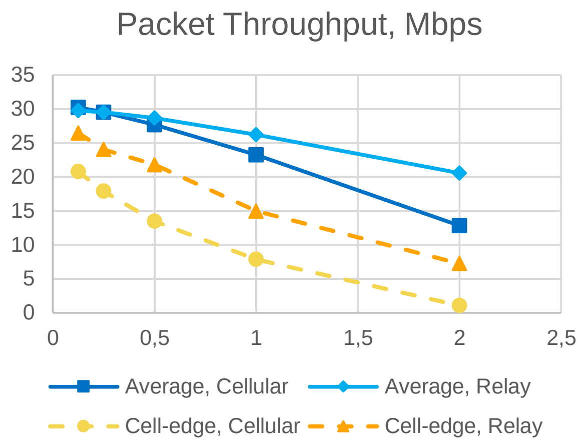
Parameter	Value/Reference/Comment
Deployment Scenarios	Homogeneous macro scenario, ISD = 500m, all UEs outdoor UE drop: 5 UE pairs per sector. Each pair is composed from a relay UE and a wearable UE. The wearable UE is dropped in [1:5]m random uniform range from the relay UE.
Spectrum	10MHz@2GHz, FDD
Traffic model	FTP Model 3, 0.5 Mb file size
Channel model	3GPP TR 36.843
Power control	eNB max power 46 dBm, UE max power 23 dBm. UL: P_0 is set to satisfy 20 dB UL SNR, α = 0.8. D2D: P_0 is set to satisfy 20 dB D2D SNR, α = 1.
Resource allocation	50 PRBs on all layers
Performance metric	Packet throughput: $PT = \frac{Packet\_size}{Packet\_TX\_time}$, Normalized Energy Efficiency: $EE_N = \frac{EE}{PT}$
Relay selection	Pre-assigned based on UE drop
Antenna configurations	Relay UE: 2 RX MTC/Wearable UE: 1 RX

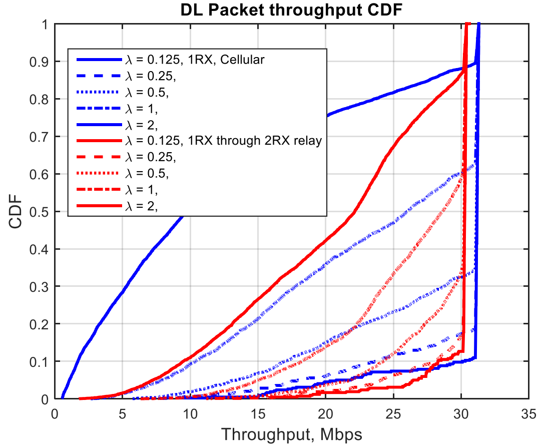




DL offloading throughput gain

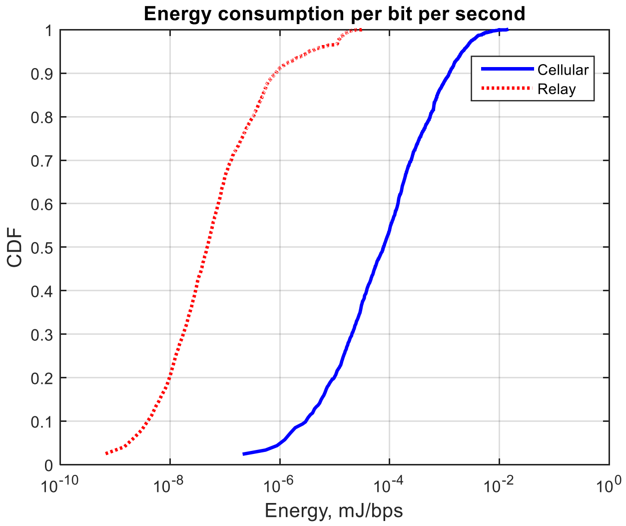
- <u>Cellular case</u>
  - wearable UEs download traffic using 1 RX antenna
- <u>Relaying case</u>
  - relay UE downloads packets with 2 RX (rank adaptation) and forwards it in SL using rank-1 towards wearable UE
- <u>Performance gains</u>
  - improved DL resource utilization in case of Rank 2 transmission and reduced overall interference load in DL (so called turbo effect)
- Note:
  - Relay and cellular scenarios have slightly different upper bounds in packet throughput due to a bit higher latency of 2-hop relay operation





UL offloading and energy efficiency

Radiated energy efficiency



- Significant savings in radiated energy for wearable UEs
- Significant saving in radiated energy normalized per packet throughput (file transfer time)

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