End-user Benefits of LTE Dual Connectivity in Heterogeneous Networks

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Introduction

› New **LTE** feature **Dual Connectivity (DC)** standardized in 3GPP Rel-12 (Nov 2014)

  - Allowing resource aggregation from two eNBs to increase the user throughput

› **Core question:** How much does the end-user gain from LTE networks with the DC feature?

  - Typical internet traffic type of today: web page downloads

› Focus of this research work:

  - Analysis and optimization of **algorithms for traffic offloading with DC**
  - DC performance evaluation in a **realistic heterogeneous network deployment**

Outline

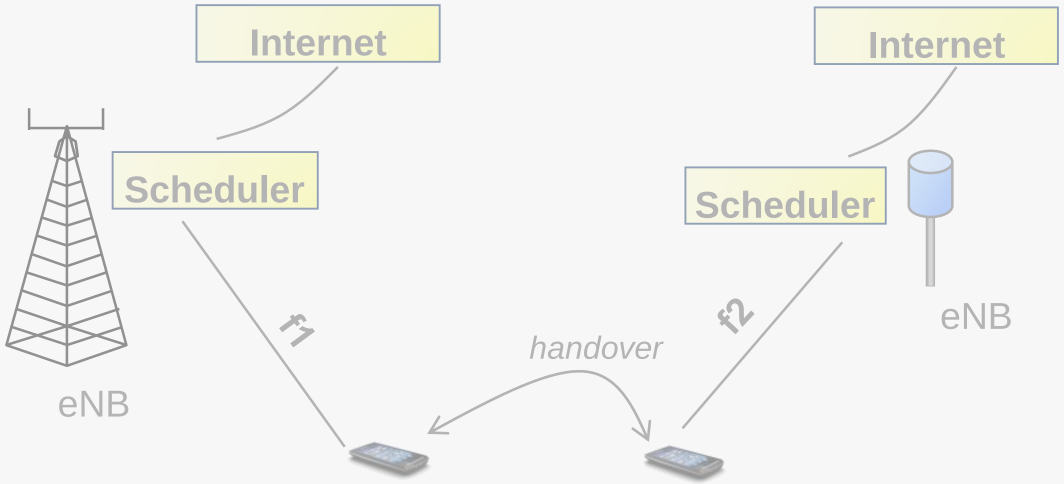
- Dual Connectivity Background
- Traffic offloading with DC
- Performance evaluation
- Conclusions

Dual Connectivity

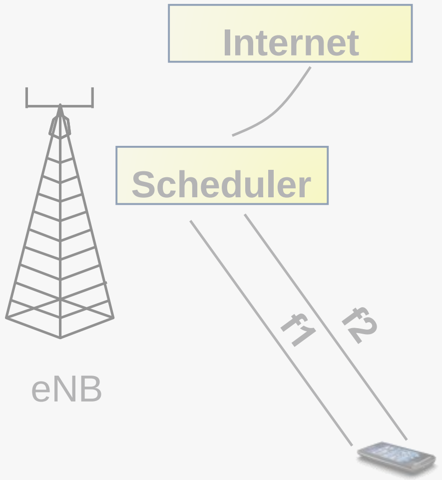
Background

LTE Architecture Options

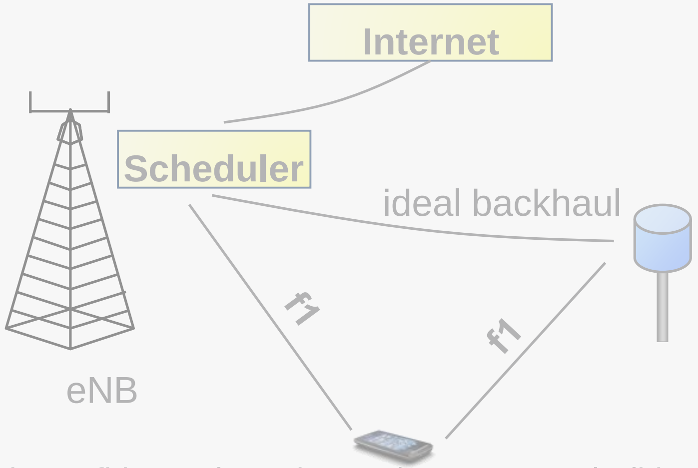
› Rel-8 LTE Baseline (Single Connectivity)



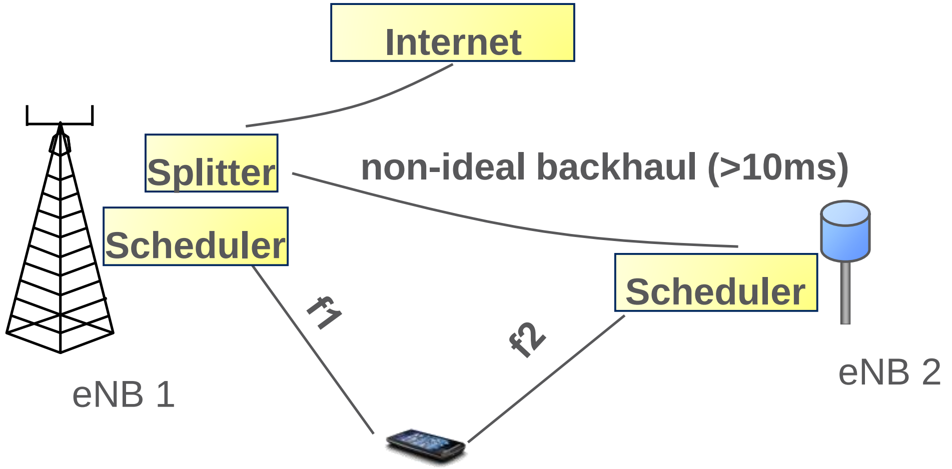
› Rel-10/11 LTE Carrier Aggregation (CA)



› Rel-11 LTE Coordinated Muti Point operation (CoMP)

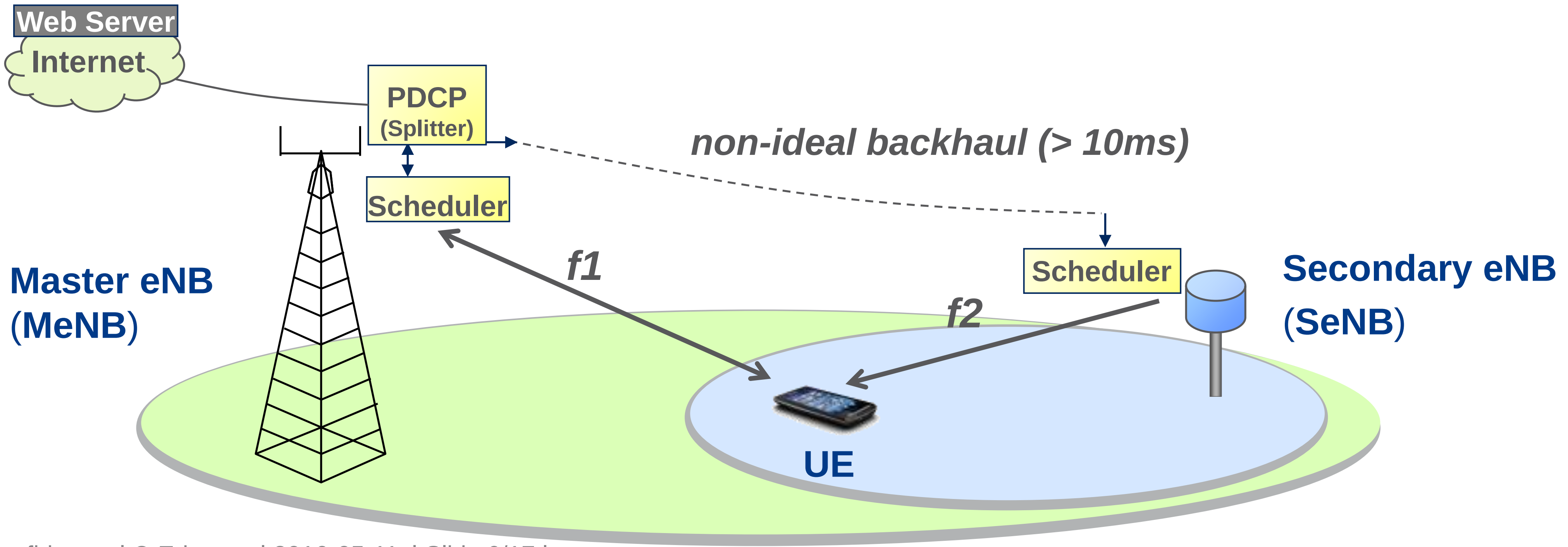


› **Rel-12 LTE Dual Connectivity (Split Bearer)**



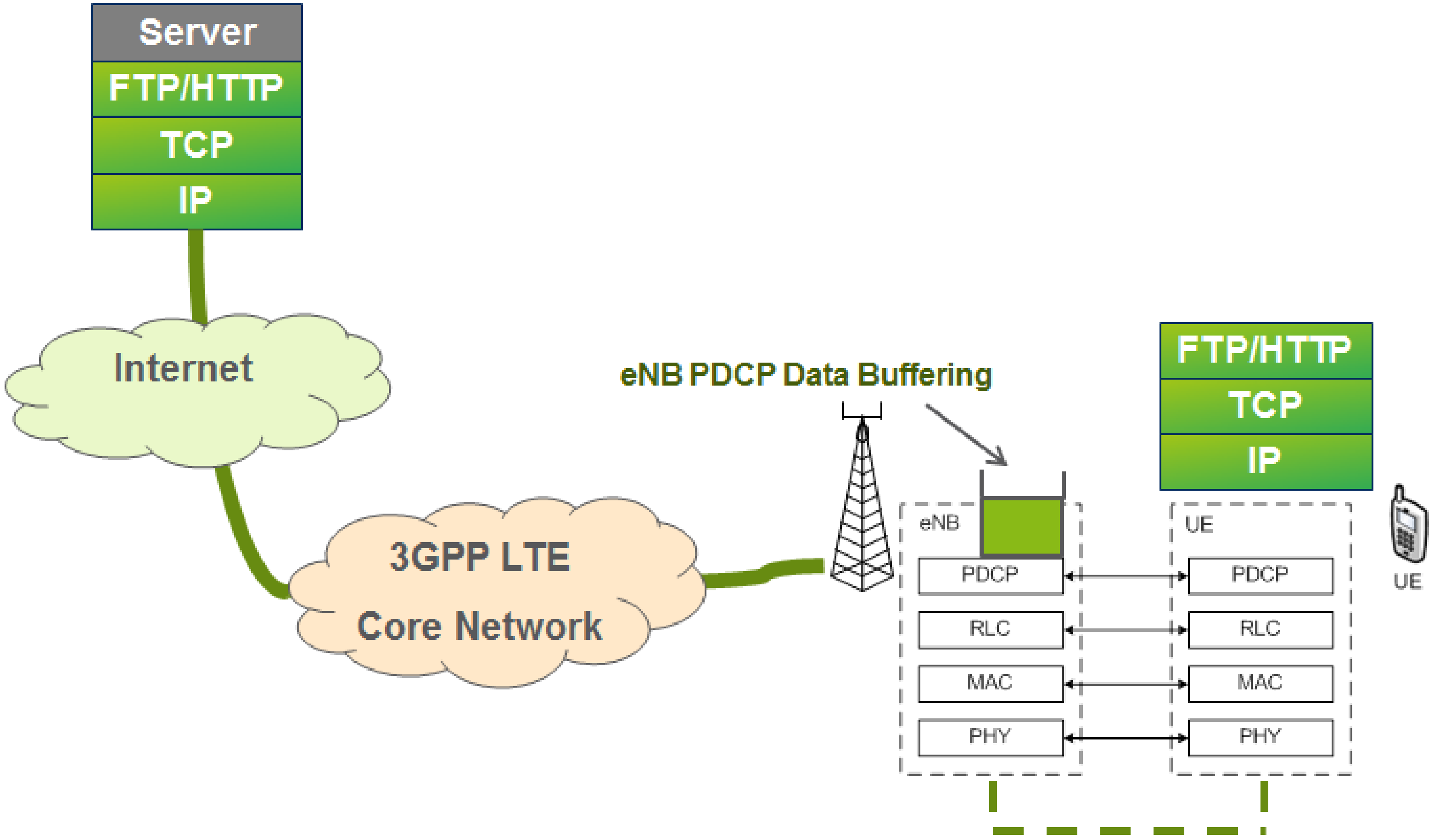
Rel-12 Dual Connectivity

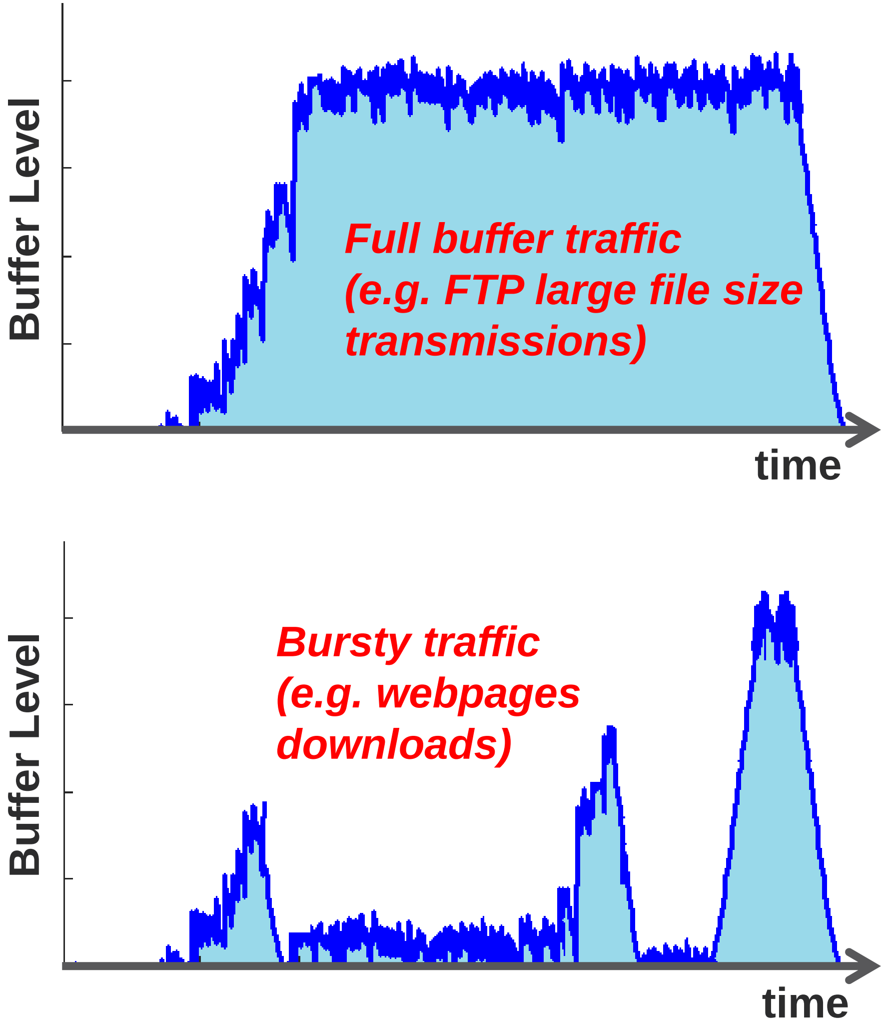
- UE aggregates radio resources from two eNBs
  - Different carrier frequencies
  - Downlink user traffic
  - Aggregation point at Packet Data Convergence Protocol (PDCP)
  - Any backhaul channel between eNBs



Buffering at the eNB

› Data buffering depends on traffic type



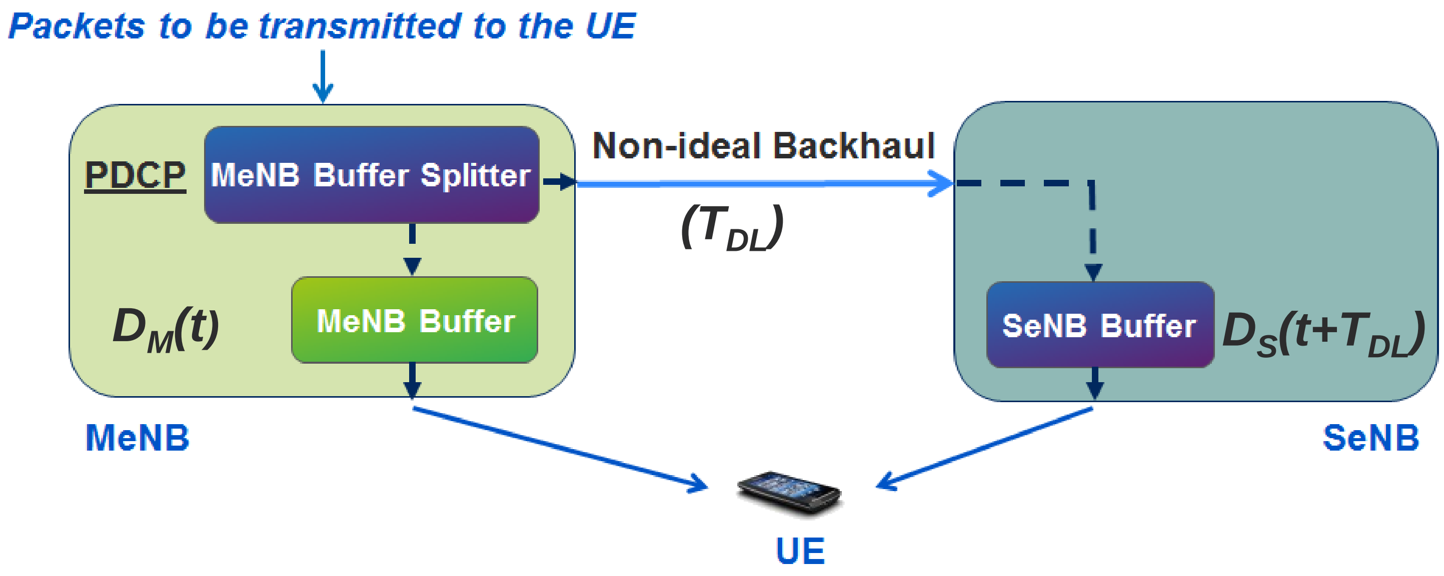


Traffic Offloading with DC

PDCP Buffer Splitting

› Transmit packets via the MeNB or via the SeNB?

- Answer: **via the fastest path to the UE**



Transmit packet via **MeNB** if $\hat{D}_M(t) \leq \hat{D}_{S,M}(t+T_{DL}) + T_{DL}$, otherwise via **SeNB**.

$$D_M(t) = \frac{q_M^Q(t)}{\mu_M(t)}$$

$$D_S(t+T_{DL}) = \frac{q_S^Q(t+T_{DL})}{\mu_S(t+T_{DL})}$$

$D_M(t)$: Current MeNB buffering delay
$q_M^Q(t)$: Current MeNB buffer level
$\mu_M(t)$: Current MeNB throughput
$D_S(t+T_{DL})$: SeNB buffering delay at $t+T_{DL}$
$q_S^Q(t+T_{DL})$: SeNB buffer level at $t+T_{DL}$
$\mu_S(t+T_{DL})$: SeNB throughput at $t+T_{DL}$
T_{DL} : Backhaul downlink delay

Delay Compensated Buffer Splitting

› Estimation of the SeNB buffer level at the MeNB based on a fluid approximation and a recursive feedback loop

$$q_S^Q(t) = q_S^Q(t_0) + \int_{t_0}^{t} (r_{DL,M}(\tau - T_{DL}) - \mu_S(t))d\tau$$

$$\hat{q}_{S,M}^Q(t) = q_S^Q(t - T_{UL}) + \int_{t-T_{UL}}^{t} r_{DL,M}(\tau - T_{DL})d\tau - \mu_S(t - T_{UL}) * T_{UL}$$

$$\hat{q}_{S,M}^Q(t + T_{DL})$$

$r_{DL,M}(t)$: Downlink data rate, currently outgoing from the MeNB

$q_S^Q(t)$: Current SeNB buffer level

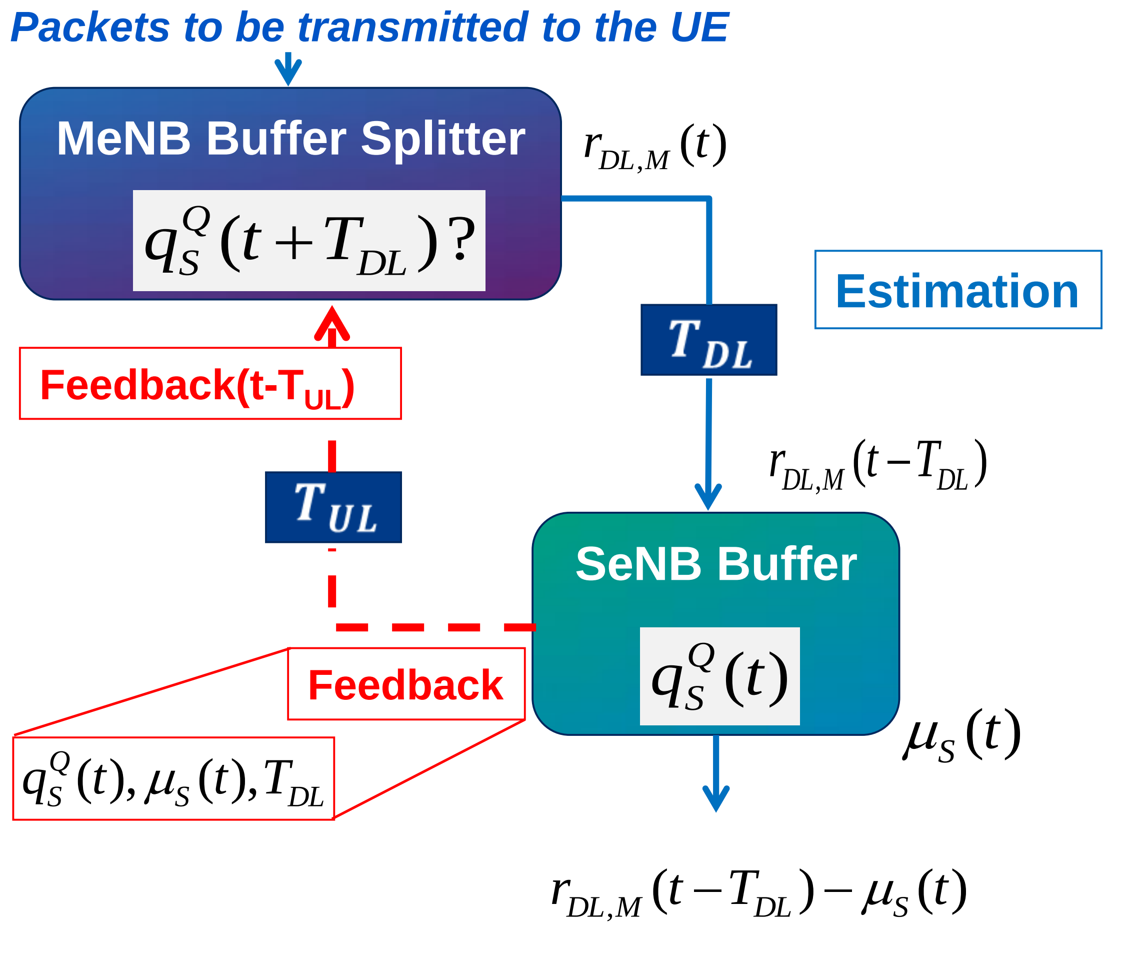
$q_S^Q(t_0)$: Initial SeNB buffer level

$\mu_S(t)$: Current SeNB throughput

T_{DL} : Backhaul downlink delay

T_{UL} : Backhaul uplink delay

$\hat{q}_{S,M}^Q$: Estimated SeNB buffer level at the MeNB



DC Performance Evaluation

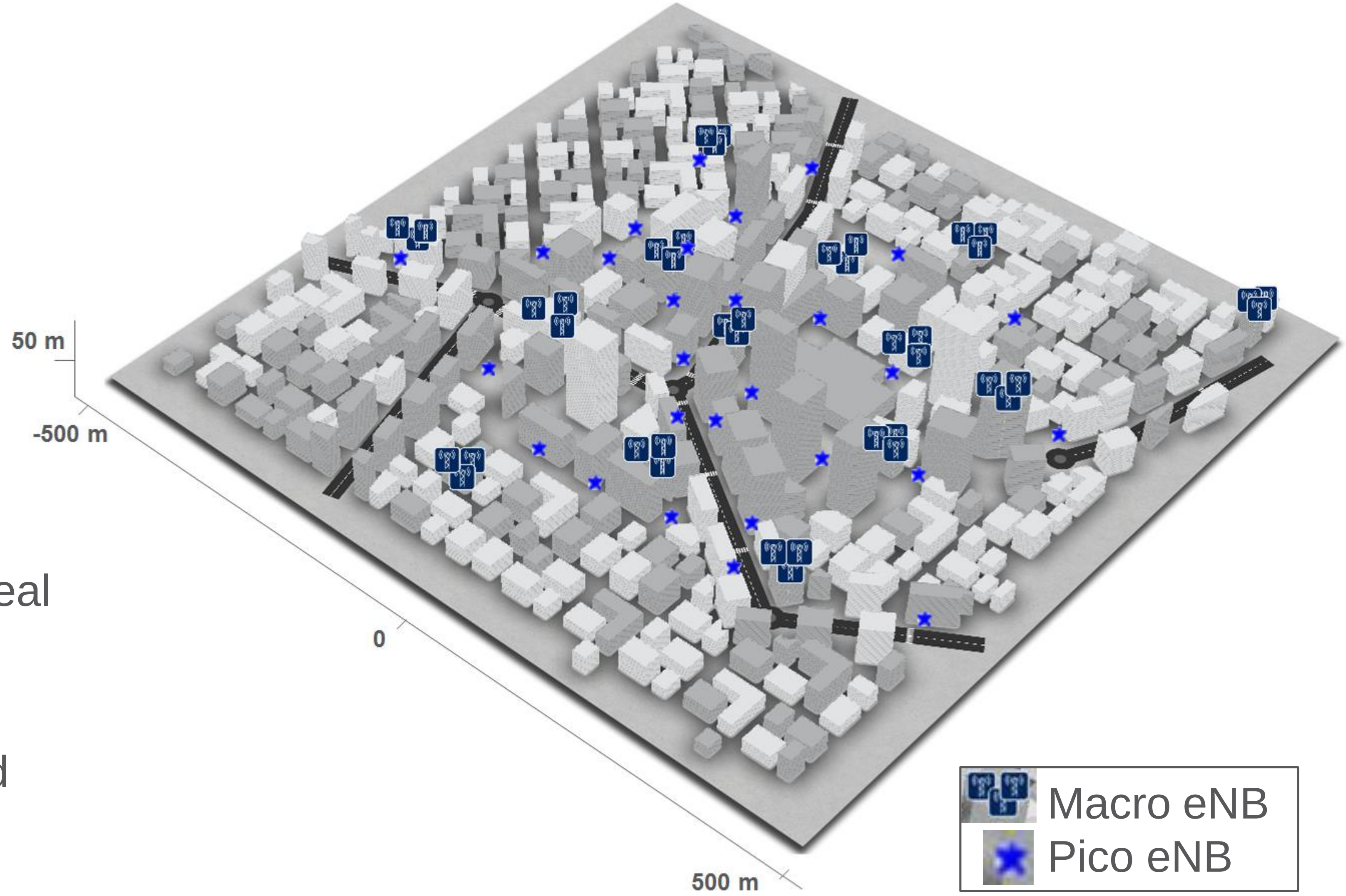
LTE System Simulator

- Asian city inspired by Tokyo/Seoul
  - Population: 10000 users/km2
  - Indoor user probability: 90%

- Heterogeneous network deployment
  - Two 10 MHz carriers
  - Macro eNB @900MHz
  - Pico eNB @2GHz

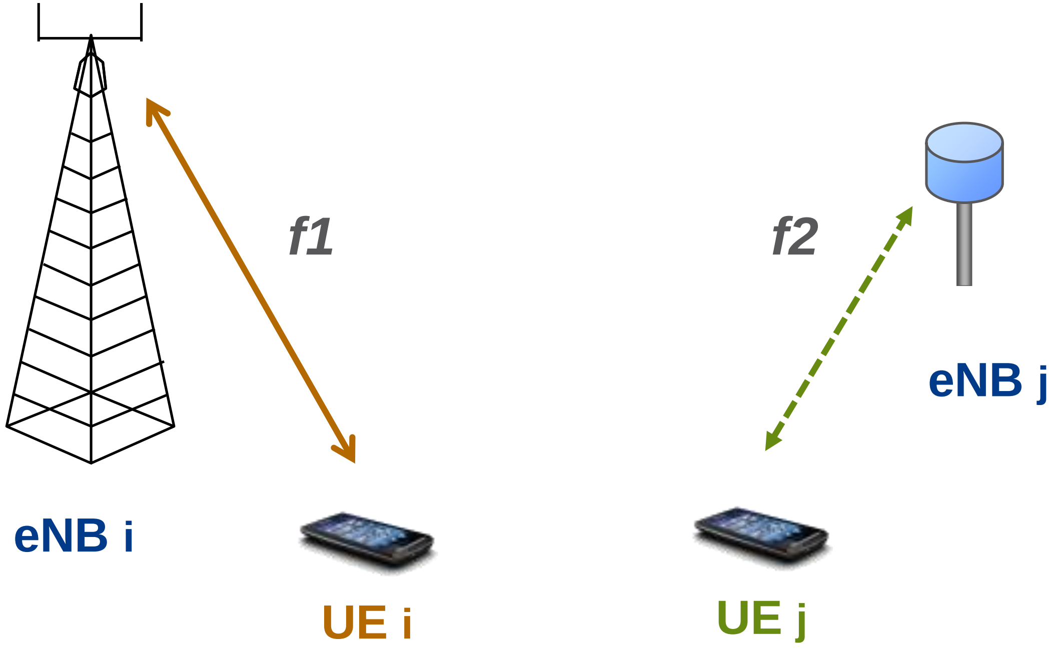
- Propagation model well tuned from real measurements

- LTE protocol stack explicitly modeled
  - DC PDCP buffer splitting

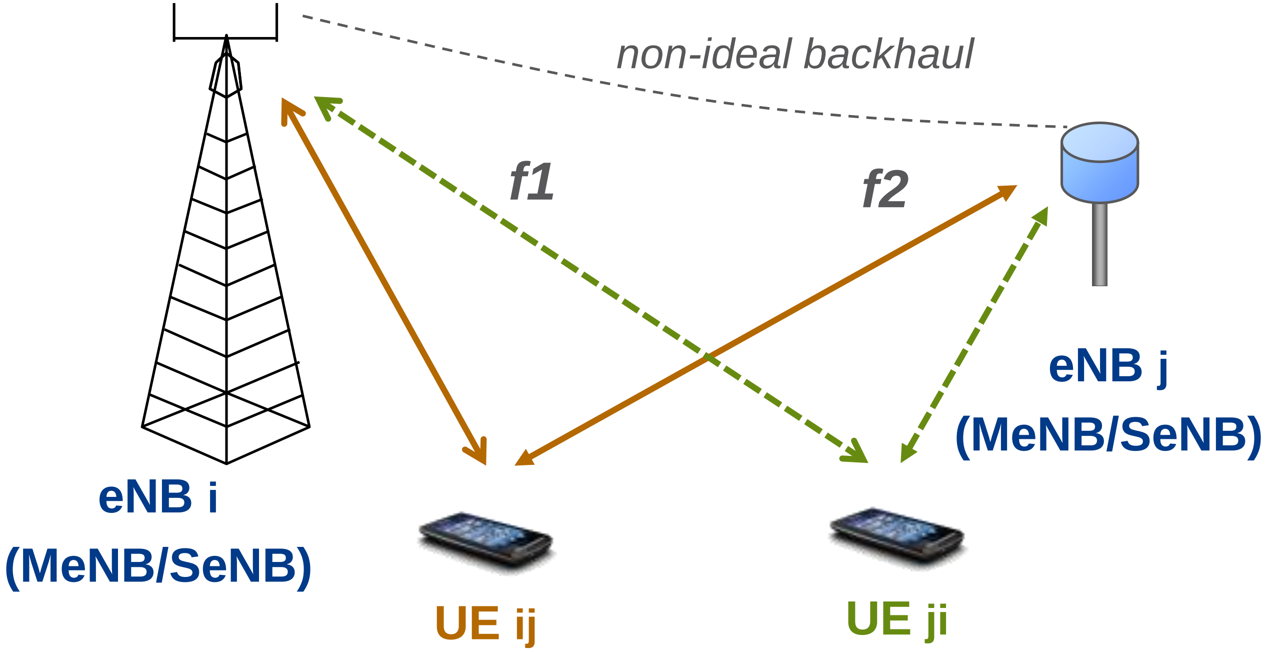


Performance Comparison

› **LTE architectures:** LTE Baseline and LTE Dual Connectivity



<u>**Rel-8 LTE Baseline: Single Connectivity**</u>

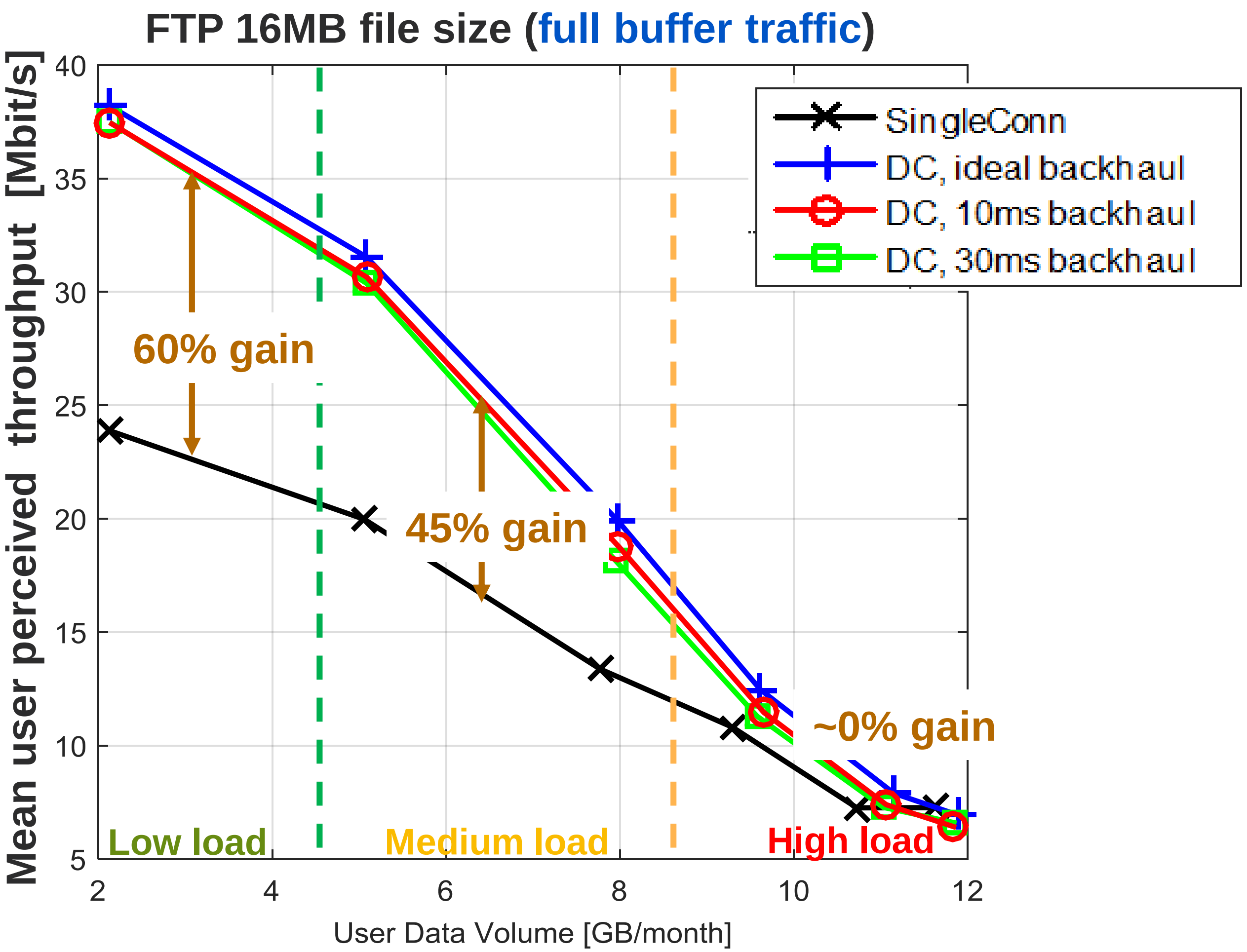


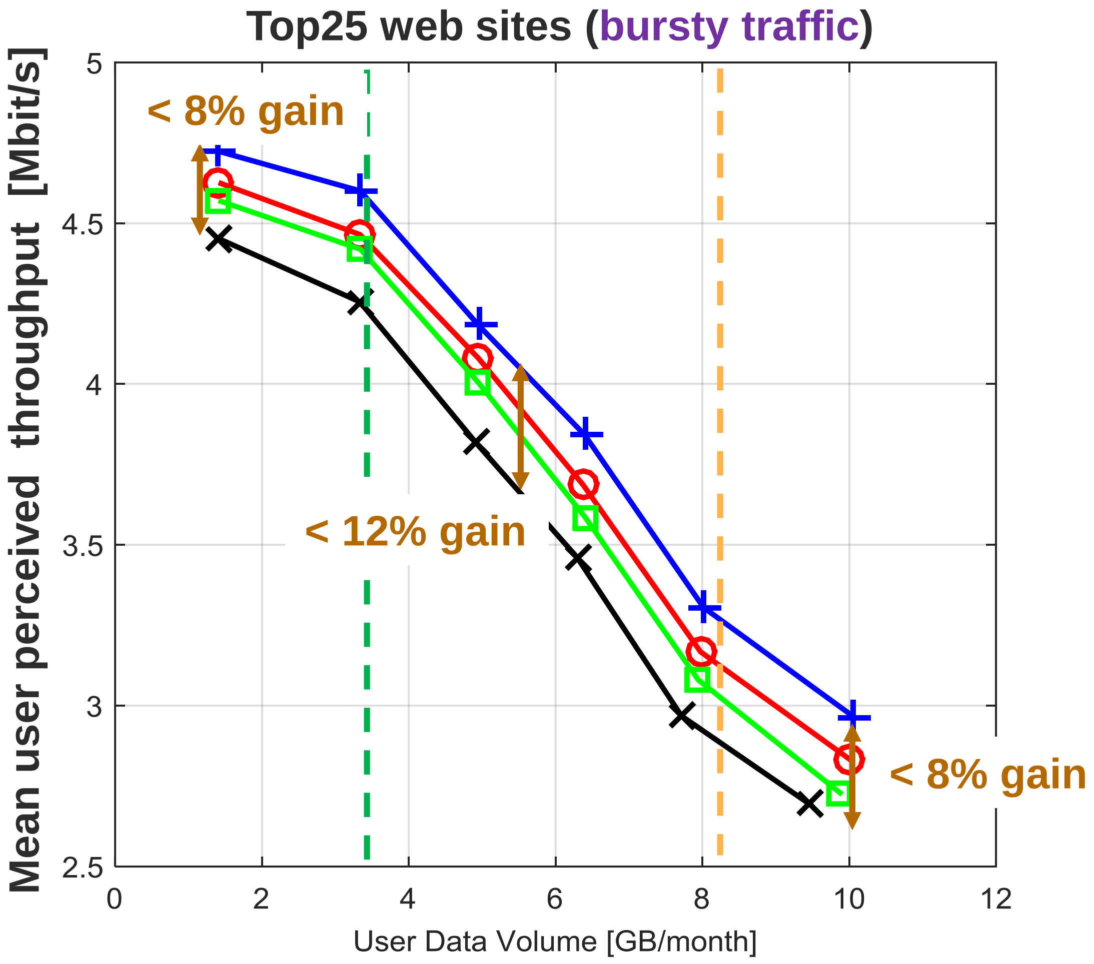
<u>**Rel-12 LTE Dual Connectivity (DC)**</u>

- Backhaul delays: 0ms (ideal), 10ms, 30ms

Performance Evaluation

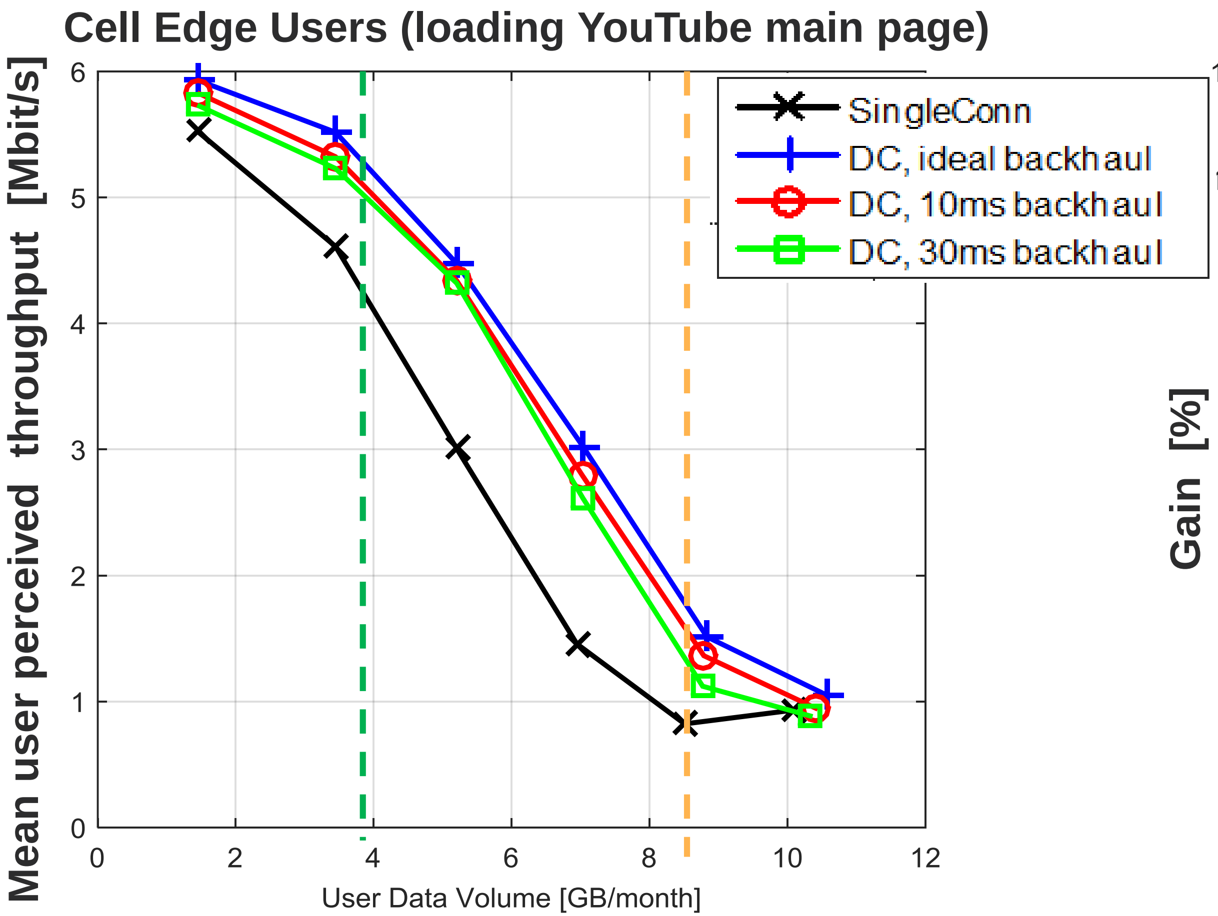
- Full buffer traffic → High buffering → High potential benefits of DC
- Bursty traffic → less buffering → lower DC benefits

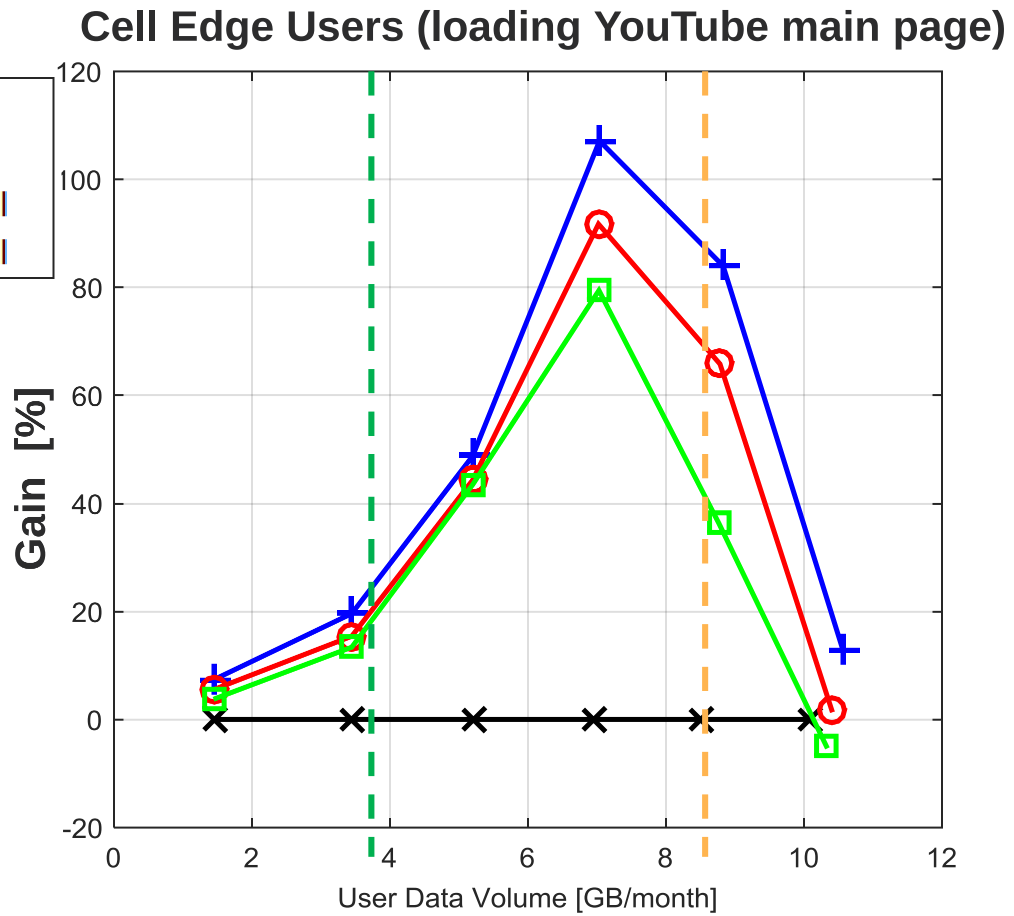




Performance Evaluation

- The cell edge user experience is significantly improved with DC for bursty traffic
  - **Low Loads** → low buffering → low DC benefits
  - **Medium Loads** → more buffering → gains by aggregating resources
  - **High Loads** → lower throughput, more buffering → No gains with DC, all resources being used in both eNBs





CONCLUSIONS

- The end-user performance improves with LTE DC by offloading traffic from loaded eNBs buffers.
- In full buffer traffic conditions (large file transfers), DC provides high gains for the end-users.
- In bursty traffic, especially for the worst users in the system, DC enables to significantly reduce the webpage download times.
- DC can be considered as a valuable feature to achieve the system capacity that will be demanded within the next years (2021 forecast).

Thank you for your attention