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OPENAIR5GLAB

The OpenAirInterface Application Programming Interface for Schedulers using Carrier Aggregation (FAPI 2.0)

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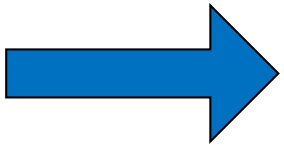
SEVENTH FRAMEWORK PROGRAMME

SOLDER

Motivation

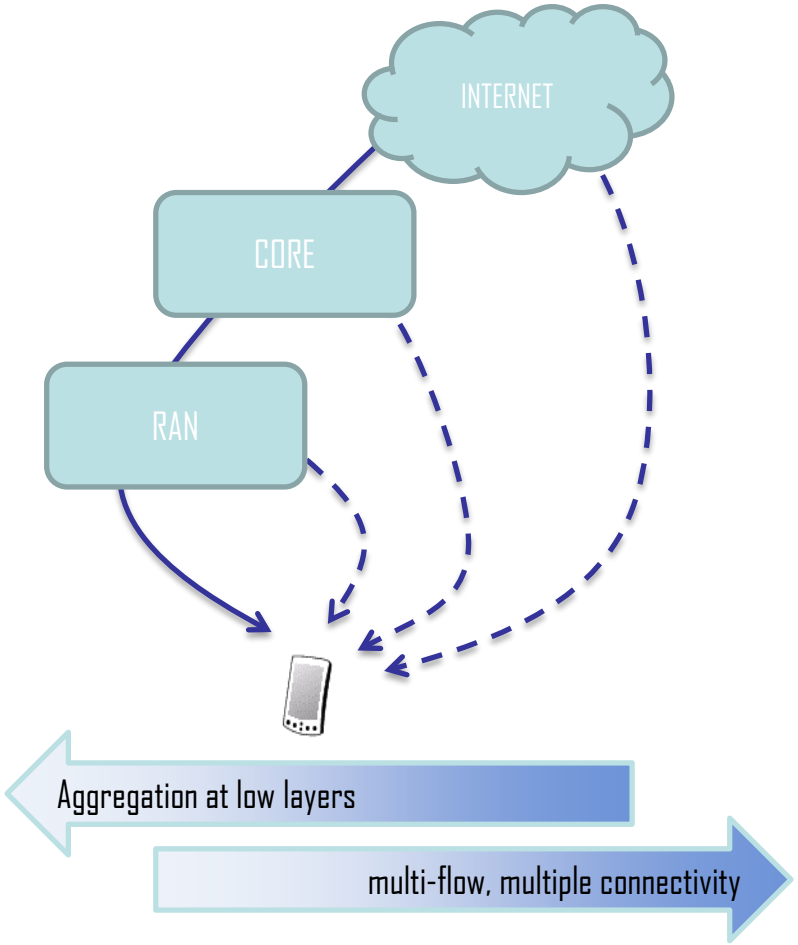
- **To supply the exponentially increasing demand for mobile broadband, more spectrum is needed**
- **Many parts of the spectrum are dedicated to specific services or technologies**
- **Aggregation of these heterogeneous spectrum and technologies allows**
  - Trunking gain (Erlang formula)
  - More efficient management
  - Flexibility and agility



SOLDER

Various types of aggregation

- **At Radio Access Network (RAN)**
  - MAC
    - LTE + LTE in licensed spectrum
    - LTE + LTE in unlicensed (LAA)
    - LTE + new radio (NR)
  - PDCP
    - LTE + WiFi (LWA)
  - IP
    - LTE + WiFi (LWIP)
- **At Core Network**
  - WiFi offload, Dual connectivity
    - LTE+Wifi
    - LTE+LTE (R.13 WI: LTE_dualC_enh)
- **At Service/Application Layer**
  - IP multi-homing
  - etc



This work

- **LTE-Advanced carrier aggregation (CA) is one of the key features to enable dynamic spectrum access**
- **It's also the basis for licensed assisted access (LAA) and licensed shared access (LSA)**
- **Efficiently exploiting CA is not trivial**
  - Challenges in scheduling, load balancing, dynamic carrier activation/deactivation
  - Experimentation with these techniques not possible with commercial equipment
- **OpenAirInterface is an open-source implementation of LTE-Advanced**
  - Extended with CA features and scheduler FAPI
  - Allows integration and innovation of new sharing mechanisms

OpenAirInterface today

EURECOM

NATIONAL INSTRUMENTS

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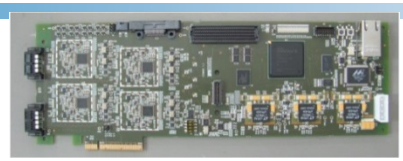
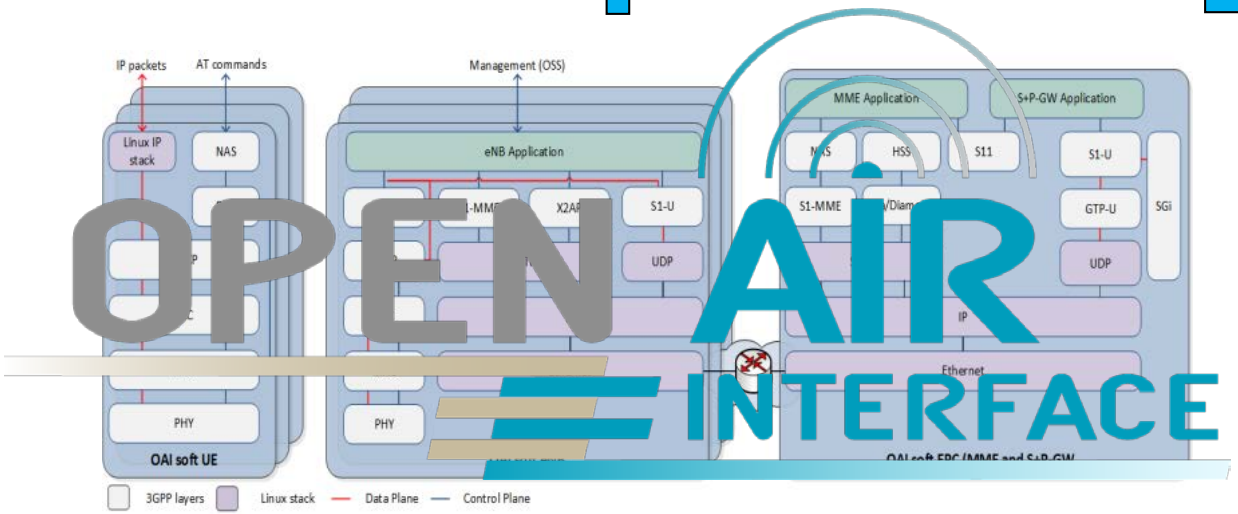


Lte

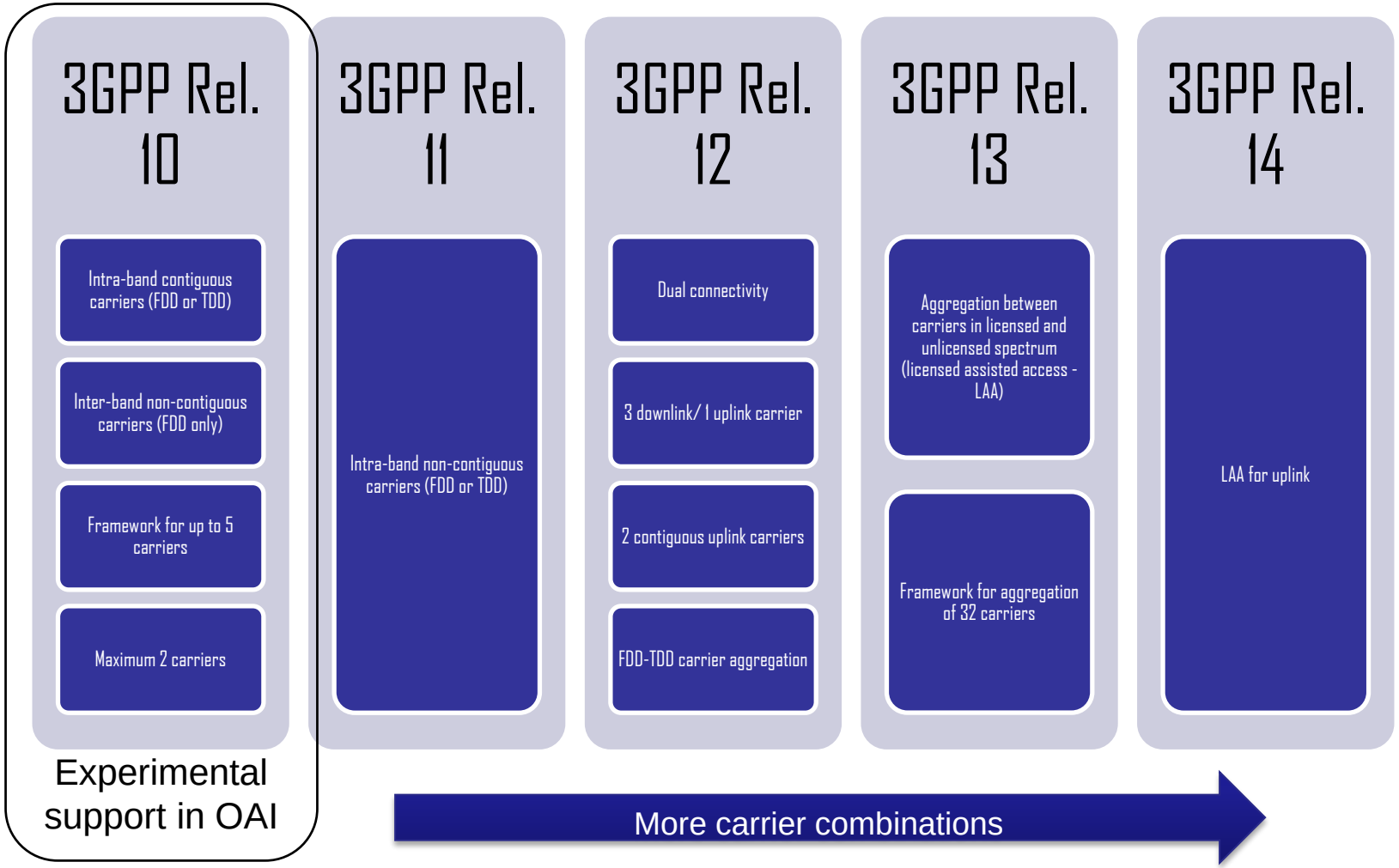


OPEN AIR INTERFACE

Introduction

- **OpenAirInterface**
  - Open-source implementation of 4G LTE/5G (UE, eNB, EPC)
  - Works with popular SDR boards (ExpressMIMO, USRP, bladeRF)
  - Allows real-time experimentation with commercial equipment
- **Objectives**
  - Bring academia closer to complex real-world systems
  - Open-source tools to ensure a common R&D and prototyping framework for rapid proof-of-concept designs
- **Other use cases**
  - Interoperability with 3rd party components (UE, eNB, EPC)
  - Matlab/Octave tools for non real-time experimentation
  - Real-time channel sounding (EMOS)
  - 802.11p Modem
  - System and unitary simulations

Evolution of LTE Carrier Aggregation



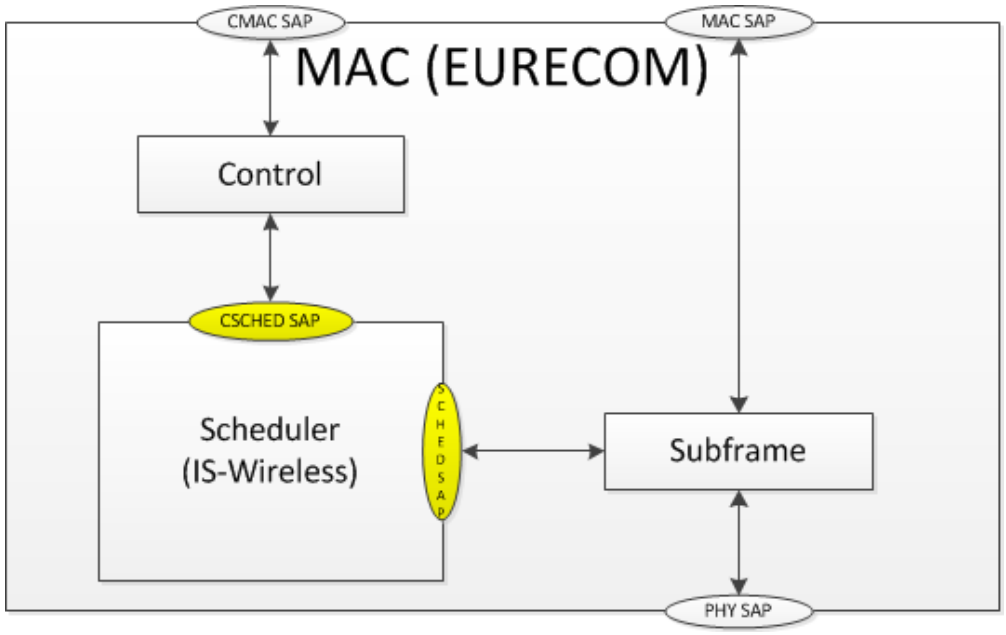
Release 10 carrier aggregation features in OAI*

- **2 DL carriers, 1 UL carrier**
  - Feedback (ACK/NACK & CQI) for both DL carriers on UL carrier
- **UE can connect on either carrier**
- **RRC (re-)configuration of secondary component carrier (SCC)**
- **Dynamic activation and de-activation of SCC through MAC signaling**
- **Simple round-robin scheduler**
  - No load balancing or fairness

* Available from gitlab.eurecom.fr/oai/openairinterface5g, branch feature-15-carrier-aggregation

The Femto Application Program Interface (FAPI)

- "LTE MAC Scheduler Interface Specification v1.11" published by the Femto Forum (now Small Cell Forum) in 2010
- Extended in SOLDER project for carrier aggregation (FAPI-2.0)
- Scheduler resides in its own linked library
  - Can also be closed source thanks to the OAI public license
- Implemented in OAI
  - Available from gitlab.eurecom.fr/oai/openairinterface5g, branch feature-31-ff-scheduler-api



IS-Wireless scheduler overview

Algorithm/ Component	Round Robin	Proportional Fair	LTE eNB Scheduler
Channel conditions	No	Yes	Yes
Historical throughput	No	Yes	Yes
Packet delay	No	No	Yes
Queue length	No	No	Yes
GBR/non-GBR traffic	No	No	Yes
Carrier Aggregation*	No	No	Yes
Wrong CQI correction	No	No	Yes
FAPI 2.0 support	Yes	No	Yes

IS Wireless scheduler operation

- **Step 1: High-level user prioritization and preparation**
  - Decision on whether to use additional carriers
  - Correction of real-life UE imperfections (wrong CQI reporting)
- **Step 2: Best resource selection**

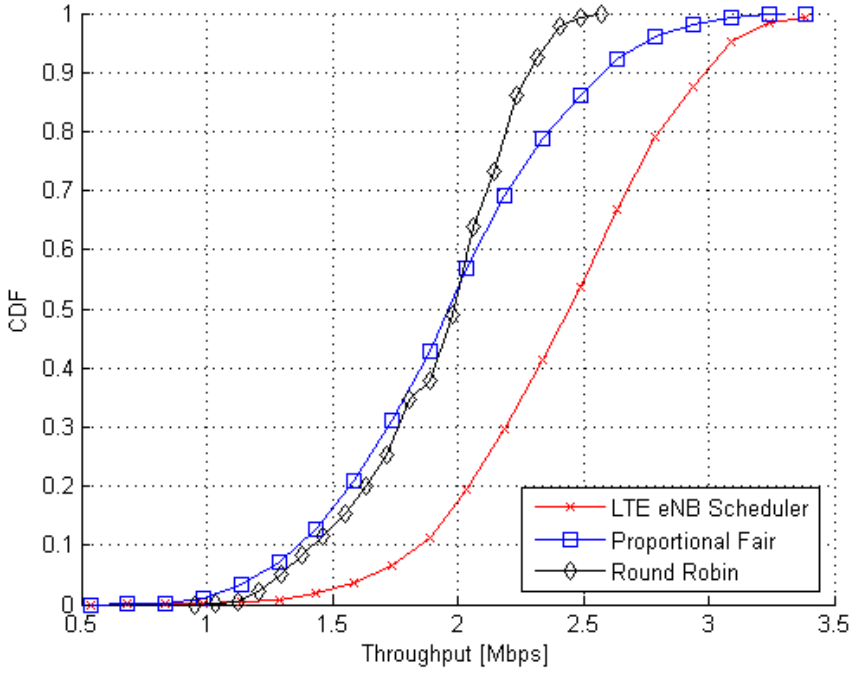
$$P_i^{(n)} = (1 + w_1 \cdot p_{CQI_i}^{(n)}) \cdot (1 + w_2 \cdot p_{delay}^{(n)}) \cdot (1 + w_3 \cdot p_{historical}^{(n)}) \cdot (1 + w_4 \cdot p_{queue}^{(n)}) \quad (1)$$

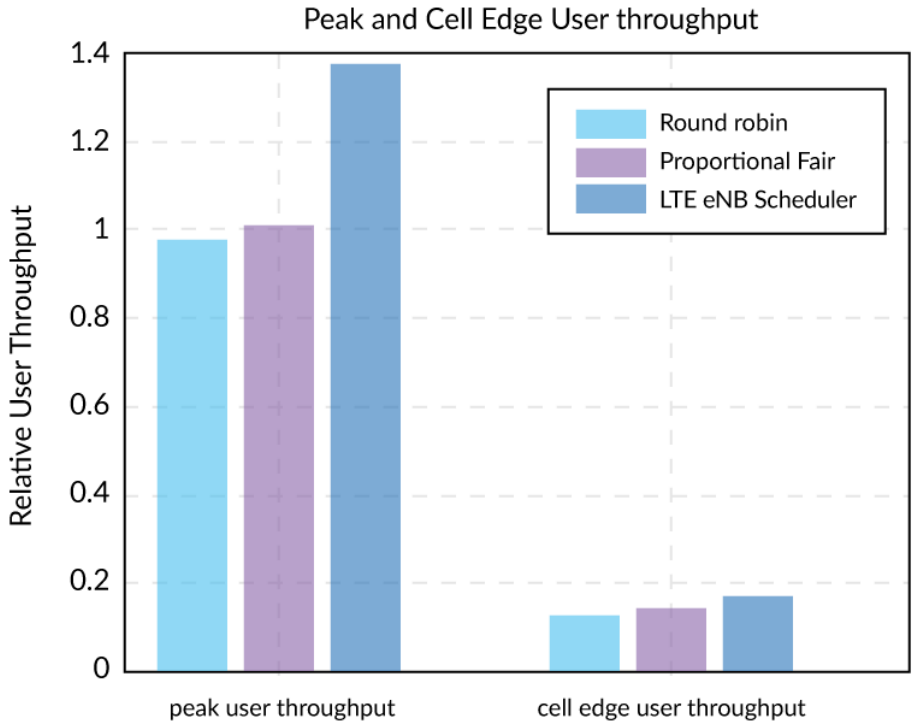
Weights for parameterization

$P_i^{(n)}$ – priority for n-th user for i-th PRB
$p_{CQI_i}^{(n)}$ – n-th user's channel quality in i-th PRB
$p_{delay}^{(n)}$ – n-th user's packet delay priority
$p_{historical}^{(n)}$ – n-th user's historical throughput priority
$p_{queue}^{(n)}$ – n-th user's queue size priority

- **Step 3: Final resource allocation**
  - Based on constraints of LTE framing

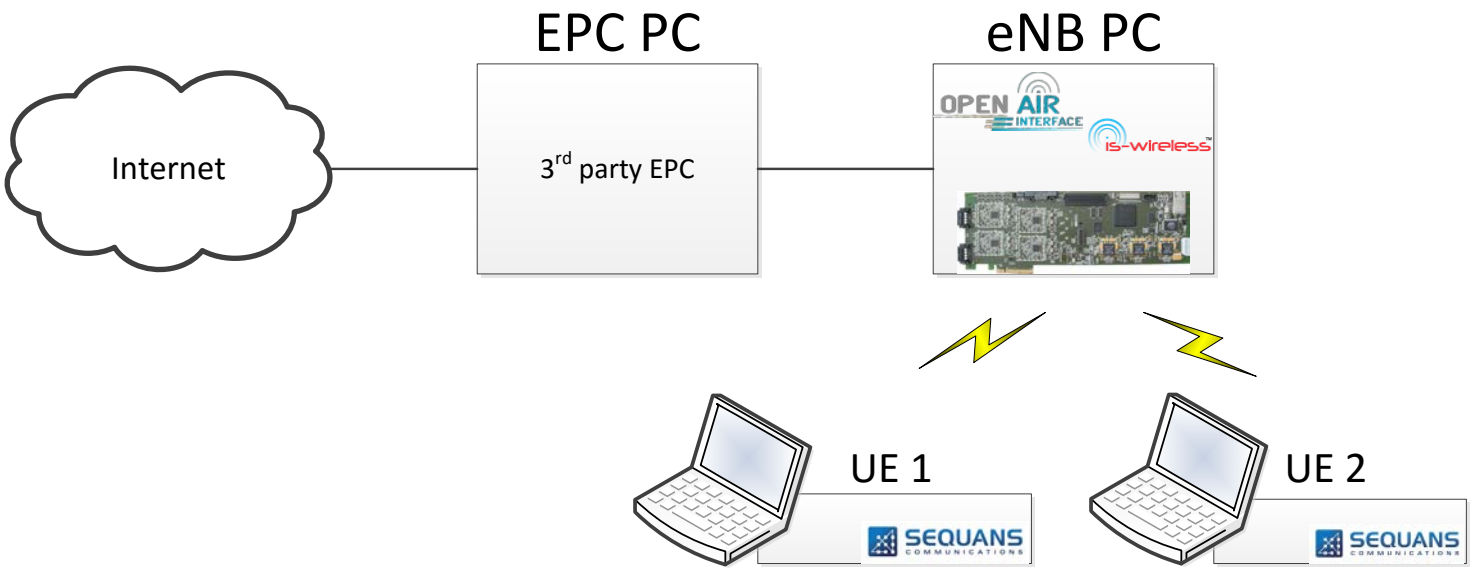
Simulation results





- Throughput results obtained with LTE MAC Lab
- See http://is-wireless.com/lte-enb-scheduler/ for details

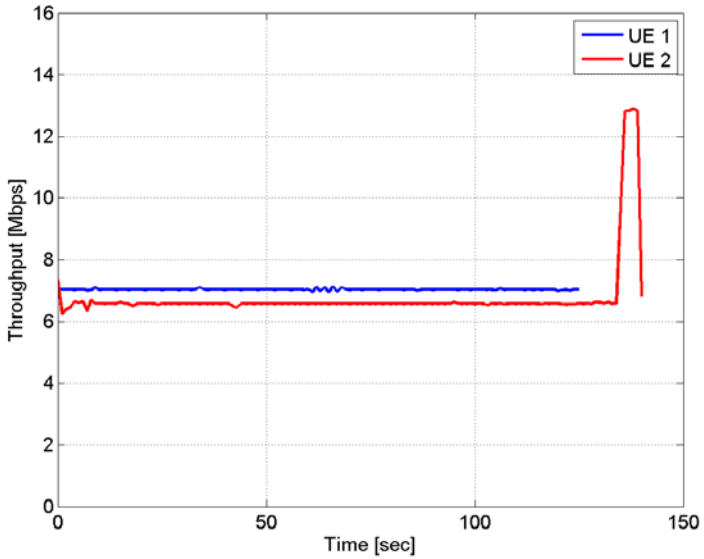
Demo setup

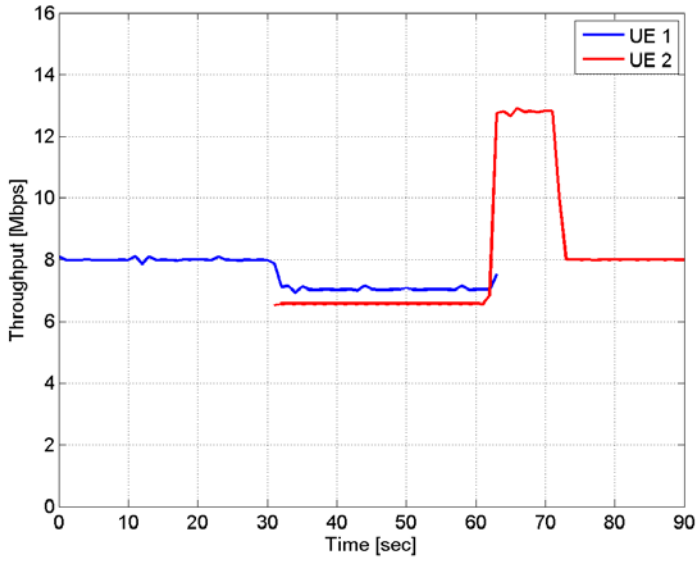


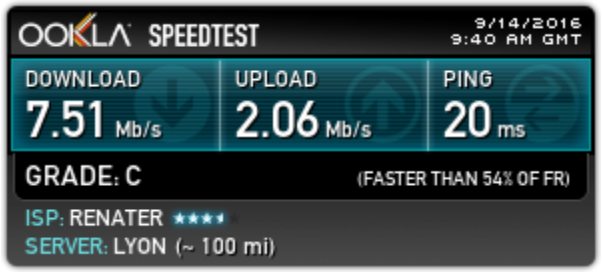
Case	No. UEs	No. CCs	Traffic	Scenario
1a	1,	1,	UDP traffic (16Mbps),	static (eNB and UE in same room)
1b	1,	1,	TCP traffic	static (eNB and UE in same room)
2a	2,	1,	UDP traffic (8Mbps per UE simultaneously),	static (eNB and UEs in same room)
2b	2,	1,	UDP traffic (8Mbps per UE time shifted),	static (eNB and UEs in same room)
2c	2,	1,	TCP traffic simultaneously	static (eNB and UEs in same room)

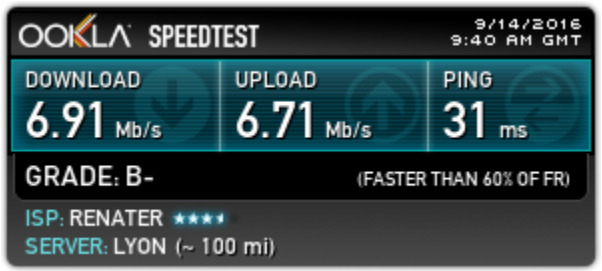
Real-time results

	UE1	UE2
RSRP	-90.19dBm	-107.76dBm
CINR	19.22dB	15.47dB









Conclusions

- **Scheduling remains a challenge, especially for new use cases like LAA, LSA, ASA, etc.**
- **OpenAirInterface has been extended with support for**
  - Carrier aggregation
  - FAPI-2.0 for scheduler
- **Novel proportional fair scheduler with support for CA and QoS**
- **Initial real-time results with OpenAirInterface**
- **Future work**
  - Finalization of carrier aggregation support in FAPI-2.0
  - Extension to LAA

Thank you!

www.openairinterface.org