An Extension of the ns-3 LTE Module to Simulate Fractional Frequency Reuse Algorithms

Piotr Gawłowicz[1] Nicola Baldo[2] Marco Miozzo[2]

[1]AGH University of Science and Technology
Kraków, Poland

[2]Centre Tecnològic de Telecomunicacions de Catalunya
Barcelona, Spain

The Workshop on ns-3, 2015

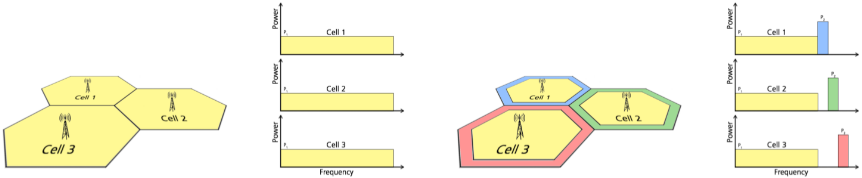
Outline

Motivation

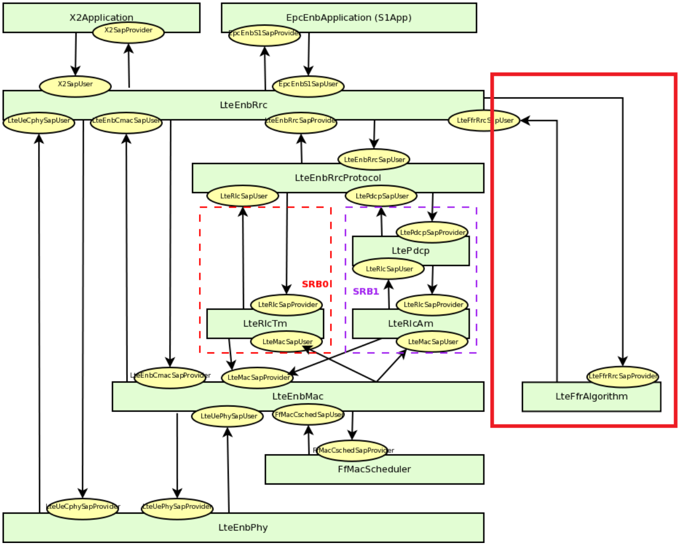
- FFR algorithms fit in the general category of Self Organized Network algorithms
- The LTE standard does not provide the design of FFR algorithms
- Design is left open for LTE equipment vendors to create their own solutions
- FFR solutions receive a significant attention in the industry and within academia
- Simulation tool is needed to implement and compare the performance of the new FFR algorithms

Frequency Reuse in cellular networks

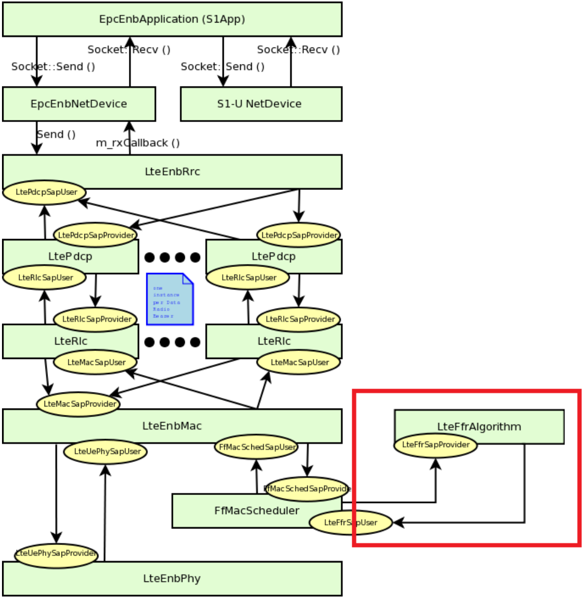
- In LTE each eNB use the same carrier frequency and system bandwidth to serve all of its users; FRF = 1
- It leads to very high throughput in cell center, but very low at the cell edge (due to high interferences)
- FFR divide available bandwidth into sub-bands with different FRF and different TX power setting
- FFR in LTE technology is possible thanks to its dynamic MAC scheduling and power control functionalities



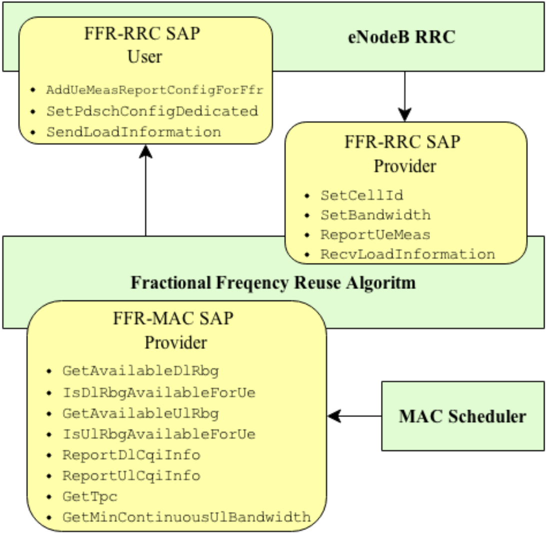
FFR implementation — Control Plane



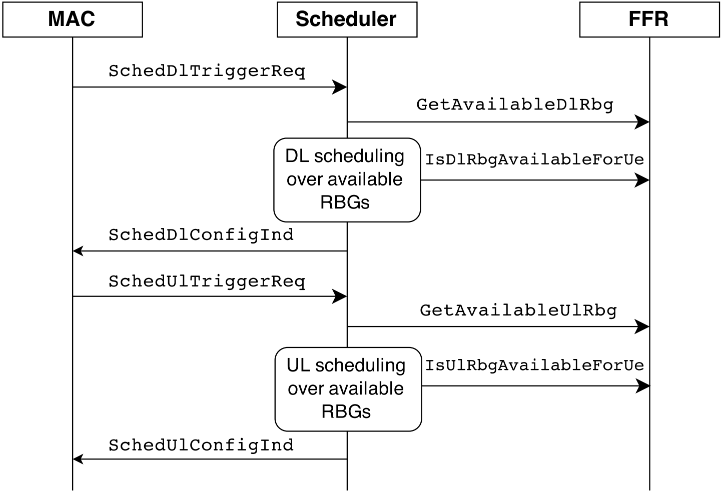
FFR implementation — Data Plane



FFR implementation — API



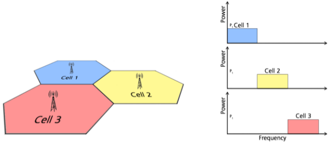
FFR implementation — Scheduling

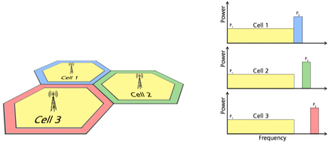


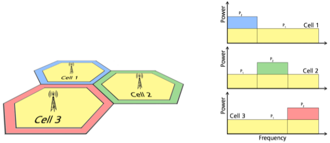
MAC schedulers supporting FFR: PF, PSS, CQA, TD-TBFQ and FD-TBFQ

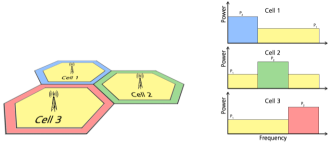
Implemented FFR algorithms

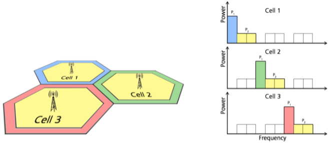
- Full Frequency Reuse (*no-op*)
- Hard Frequency Reuse
- Strict Frequency Reuse
- Soft Frequency Reuse (two versions)
- Soft Fractional Frequency Reuse
- Enhanced Fractional Frequency Reuse
- Distributed Frequency Reuse Scheme











Manual configuration

- FFR algorithm type needs to be specified in `LteHelper`
- Default algorithm: *no-op*
- Each algorithm provides different set of attributes, that have to be configured by user
- Default configuration for each FFR algorithm is provided (the same for each cell)

Automatic configuration

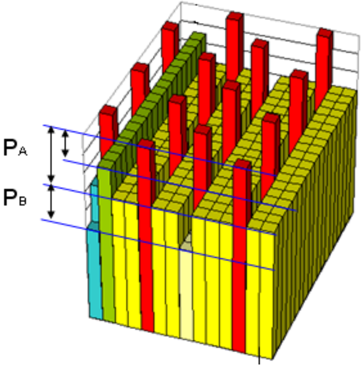
- *Manual* configuration is quite complex
- *Automatic* solution was implemented to avoid problems with sub-bands configuration
- User needs to set only `FrCellTypeId`, which can take value of {1,2,3}
- *Note*: only sub-bands will be automatically configured; in most cases, this is enough to perform a meaningful simulation

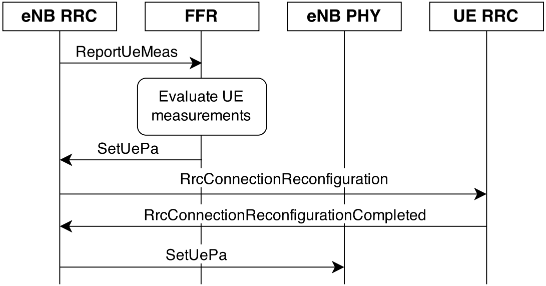
Configuration example

```
lteHelper->SetFfrAlgorithmType ("ns3::LteFrSoftAlgorithm");

#Option 1: Manual Configuration:
lteHelper->SetFfrAlgorithmAttribute("DlEdgeSubBandOffset", UintegerValue (8));
lteHelper->SetFfrAlgorithmAttribute ("DlEdgeSubBandwidth", UintegerValue (8));
lteHelper->SetFfrAlgorithmAttribute ("UlEdgeSubBandOffset", UintegerValue (8));
lteHelper->SetFfrAlgorithmAttribute ("UlEdgeSubBandwidth", UintegerValue (8));

#Option 2: Automatic Configuration:
lteHelper->SetFfrAlgorithmAttribute("FrCellTypeId", UintegerValue(2));

lteHelper->SetFfrAlgorithmAttribute ("AllowCenterUeUseEdgeSubBand", BooleanValue(false));
lteHelper->SetFfrAlgorithmAttribute ("RsrqThreshold", UintegerValue(20));
lteHelper->SetFfrAlgorithmAttribute ("CenterPowerOffset", UintegerValue (LteRrcSap::
     PdschConfigDedicated::dB0));
lteHelper->SetFfrAlgorithmAttribute ("EdgePowerOffset", UintegerValue (LteRrcSap::
     PdschConfigDedicated::dB3));
```

Downlink Power Control

- DPC is essential for FFR algorithms
- Requirements in 3GPP, TS 36.213 Physical Layer Procedures
- Only P_A values implemented
- DPC mechanism is partially embedded in FFR algorithms implementation





Source: www.sharetechnote.com

Uplink Power Control

- UPC allows to adjust the transmission power, thus reduce interferences and power consumption
- Requirements in 3GPP, TS 36.213 Physical Layer Procedures
- New class `LteUePowerControl` is responsible for computing and updating the power levels of UL channels (PUSCH and SRS)
- Two UPC mechanisms implemented:
  - Open Loop
  - Closed Loop (with two modes: Absolute and Accumulation)
- Several attributes available
- Trace sources for collection of TX power uplink channels
- FFR algorithm in eNB is responsible for determining the proper values of TPC commands for each UE

Testing

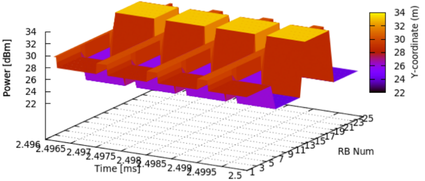
New test suites:

- *lte-frequency-reuse*
  - three test cases types suitable for different FFR algorithms
  - test vector comprises configurations for all FFR algorithms
  - each FFR algorithm is tested with all the schedulers which support FFR
  - tests pass if the UE is served in DL and UL using the RBs and power levels expected for the FR algorithm being tested
- *lte-downlink-power-control*
  - test case for `SpectrumValue` creation (PHY layer)
  - test case to check power level difference between PDCCH and PDSCH
  - test case for *RRC Reconfiguration*
- *lte-uplink-power-control*
  - test case for UPC with Open Loop
  - test case for UPC with Closed Loop in Absolute mode
  - test case for UPC with Closed Loop in Accumulation mode

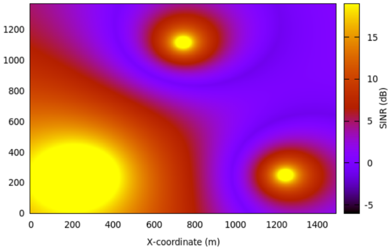
Examples

- Two examples are provided to show basic FFR algorithms functionalities:
  - *lena-frequency-reuse*
  - *lena-distributed-reuse*
- `RadioEnvironmentMapHelper` was extended to be able to generate radio environment map on a per RB basis
- *lena-dual-stripe* example now supports FFR algorithms; `LteHexGridEnbTopologyHelper` extended

Visualization



Spectrum Analyzer trace; Soft FFR



REM for RB 1; Soft FR

Summary

Outcome:

- FFR API and 7 algorithms are available
- Power Control in DL and UL are implemented
- Test and examples are provided
- Documentation can be found on project official webpage
- The code was merged to official ns-3 repository and is available from version 3.21
- The project was funded by the Google Summer of Code 2014 program

Future work:

- Compare performance of implemented FFR algorithms
- More advanced mechanism for UPC

GSoC experience

- Thanks to Nicola and Marco for mentorship
- Opportunity to see how open source community works
- Good communication (telco, mail) = fruitful cooperation
- Perfect organization: proposal, weekly reports and code reviews

Thank you