An Ultra-Wide Overlay Cognitive Radio System for Wireless Back-hauling for Small Cells

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Outline

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- System and Modeling
- COUWBAT Physical Layer
- COUWBAT MAC Layer
- Design Considerations
- Performance Evaluation
- Conclusions

Motivation

- Wireless access technologies such as **WLAN** have recently gain **very high bitrates,** therefore **backhauling** has become the **bottleneck**
- **Cognitive Radio Networks** (CRN) in combination with **Software Defined Radios** (SDR) can be a solution for backhauling
- **PHY Layer**: Non-Contiguous OFDM (NC-OFDM) allows use of fragmented spectrum in an efficient way
- This requires an intelligent and efficient **link layer** mechanism

Contributions

- Designing a particular MAC which allows contention-free access, while providing fixed delay and high throughput.
- Integrating an in-band signaling scheme which can use different subchannels in distinct neighboring cells.
- Evaluating the performance of our MAC scheme both analytically and by means of network simulations with ns3.

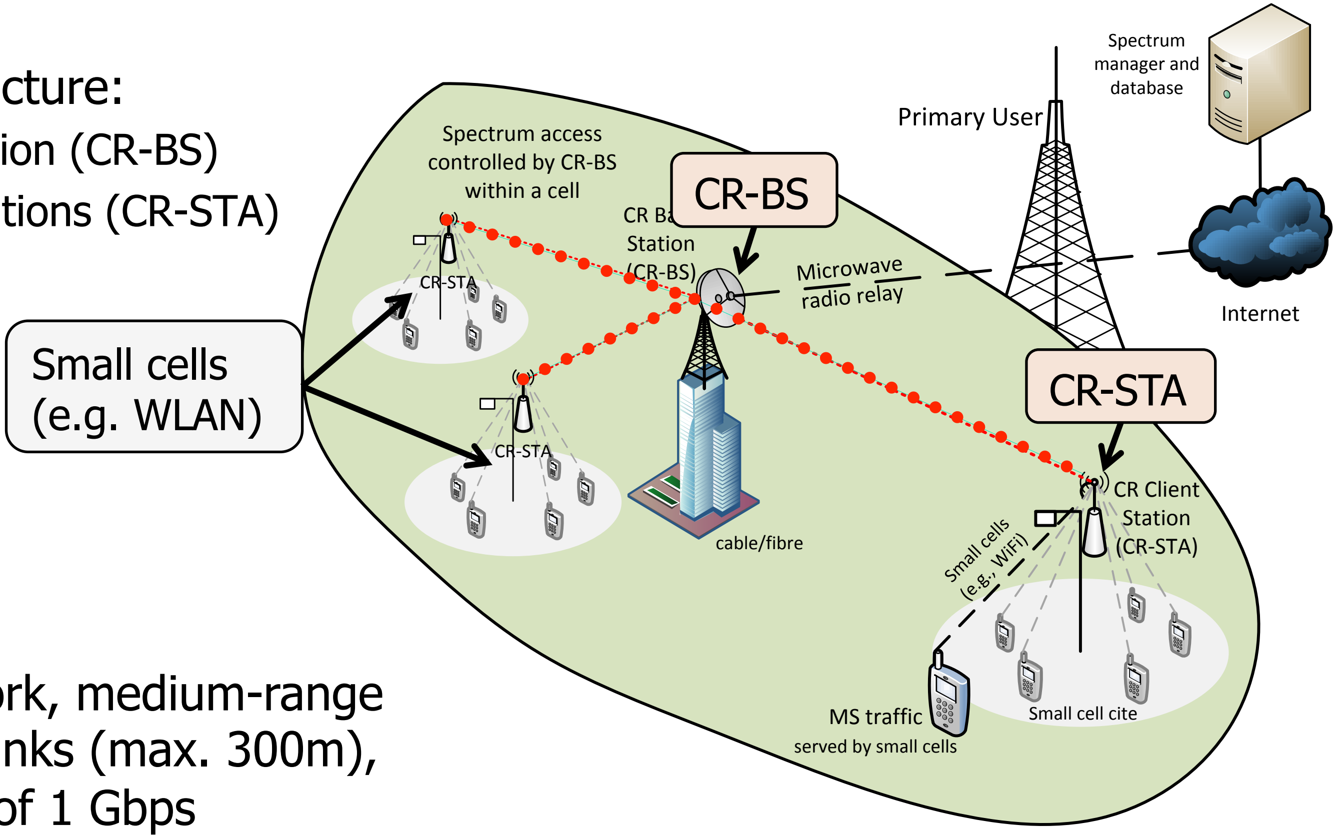
- The source code of our ns3 simulation model is available via github.

System and Modeling

COUWBAT System Model

- **Scenario**: wireless wideband overlay cognitive radio backhauling for small cells (e.g. WLAN)

- Hierarchical structure:
  - CR Base Station (CR-BS)
  - CR Client Stations (CR-STA)



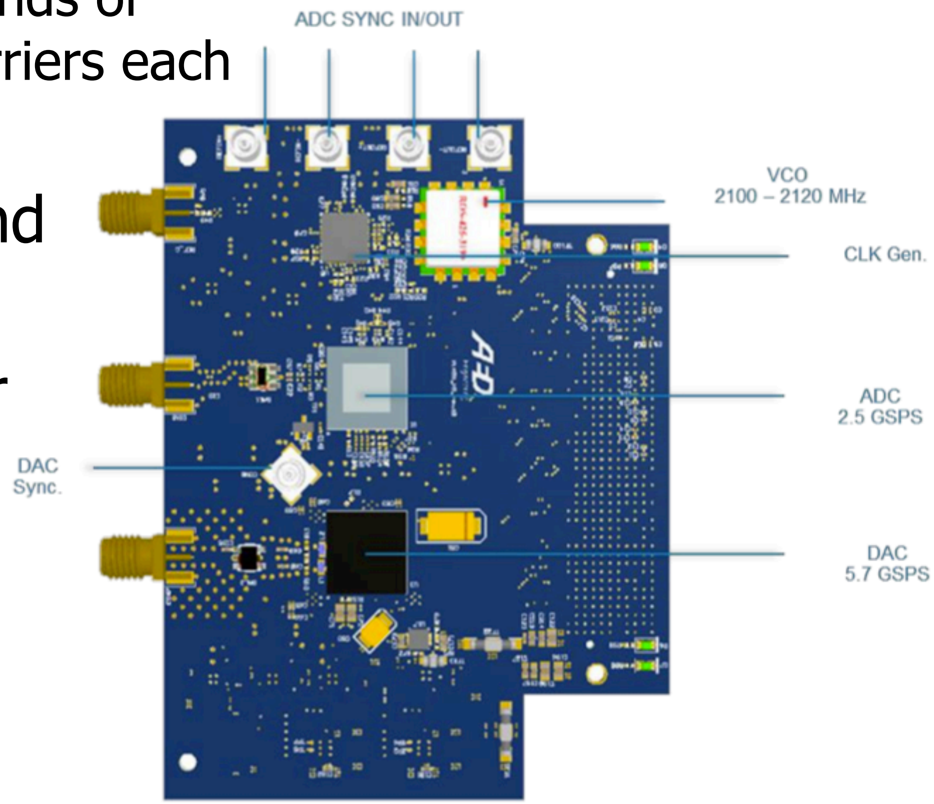
- Stationary network, medium-range communication links (max. 300m), target data rate of 1 Gbps

COUWBAT Physical Layer

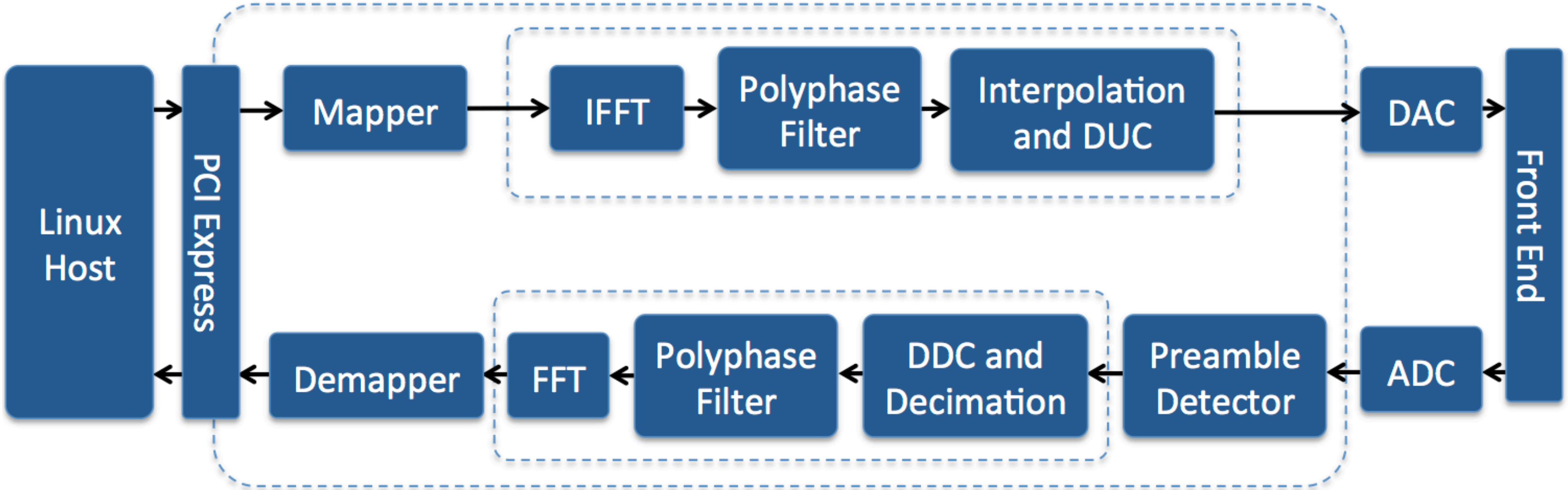
AED Engineering GmbH, Munich

General Parameters

- 3 GHz analog bandwidth
- Three transmission bands of each 1.024 GHz digital bandwidth with Direct-RF
  - Divided into two logical bands of 512 MHz with 2048 subcarriers each
- Every subcarrier can be switched separately on and off
- Different constellation per subcarrier possible
- 8192 points FFT

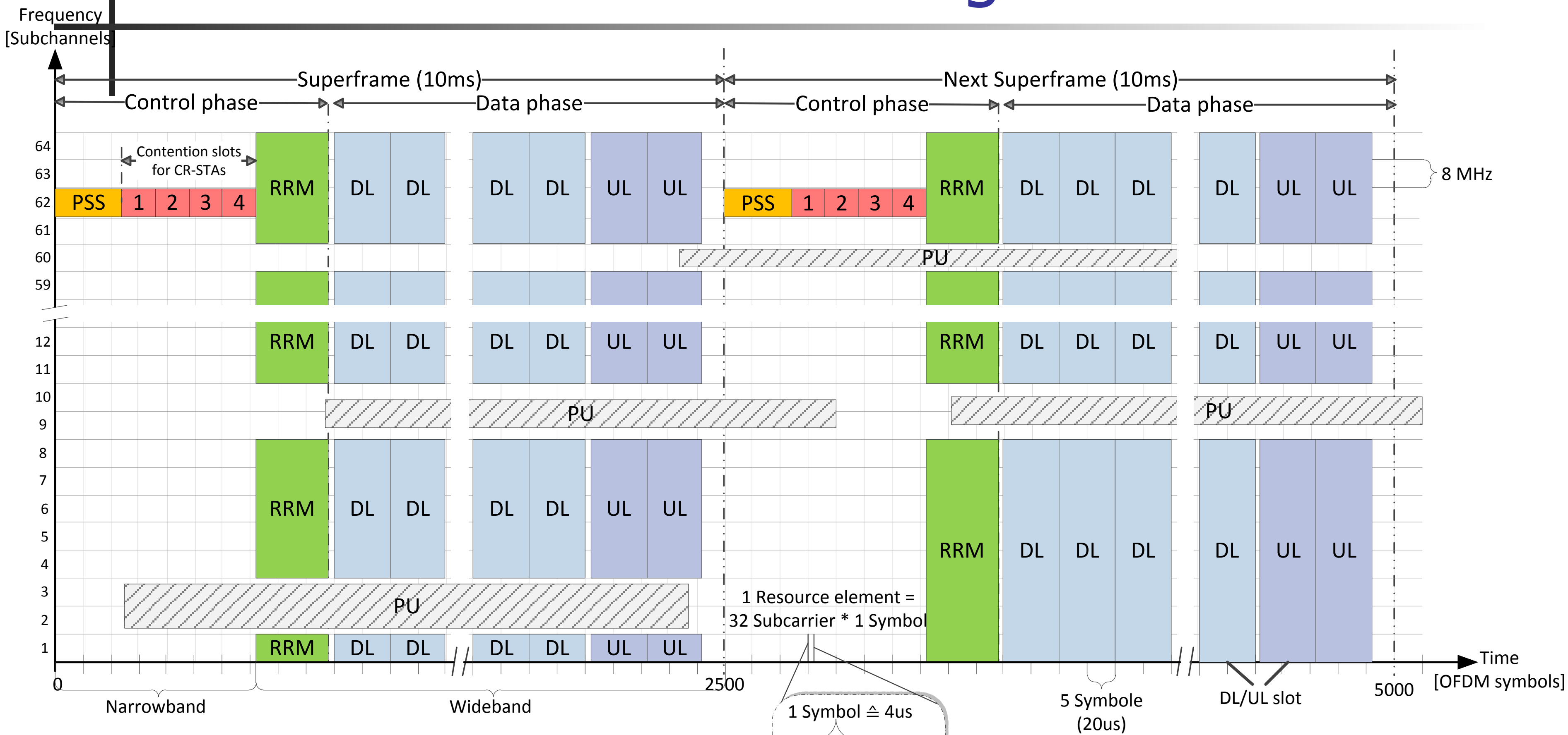


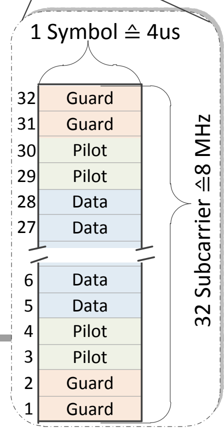
FPGA architecture



COUWBAT MAC Layer

Channelization and Framing





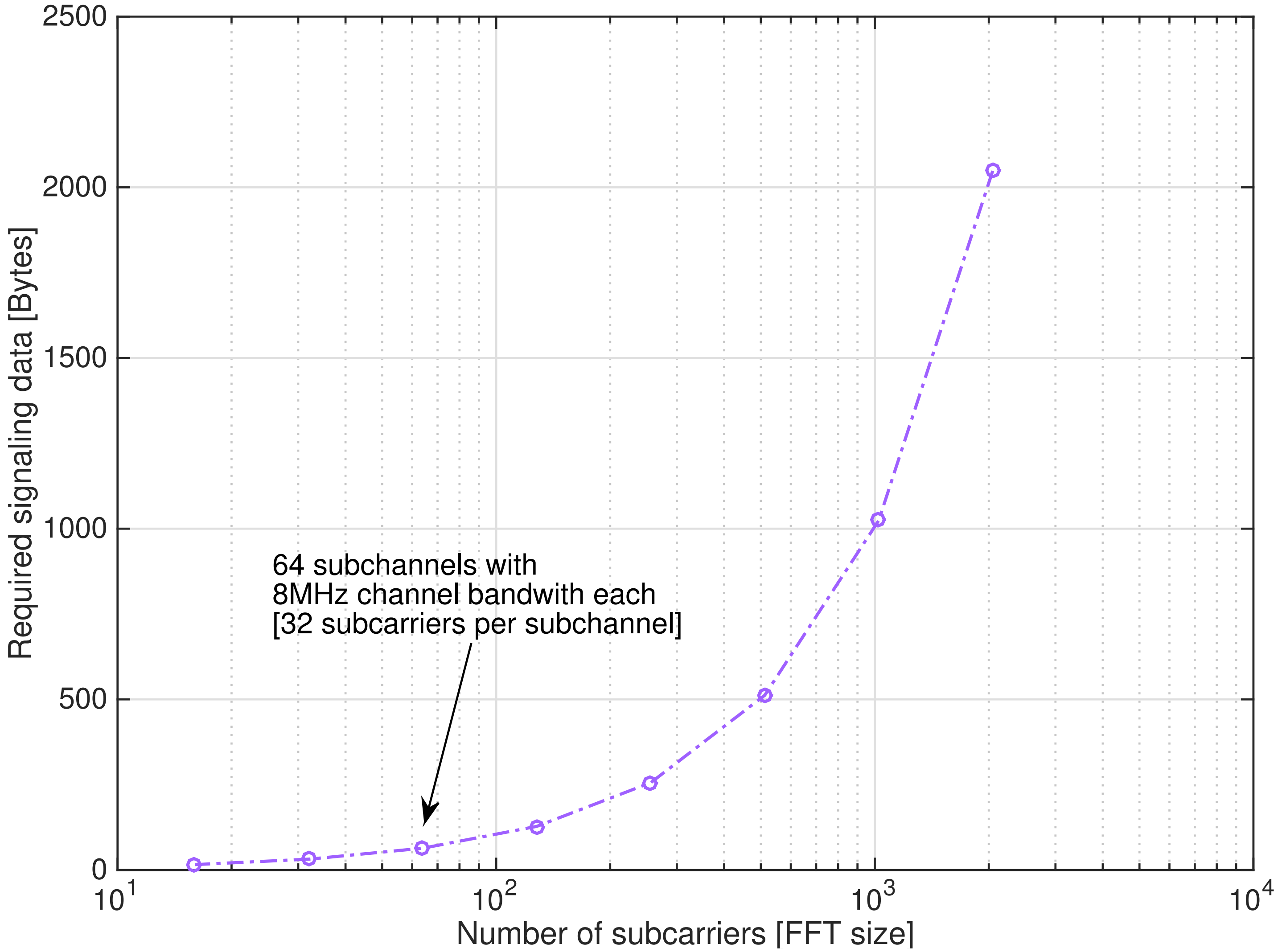
- Control phase - in-band control channel
  - Selected frequencies only….
- Data phase

Design Considerations

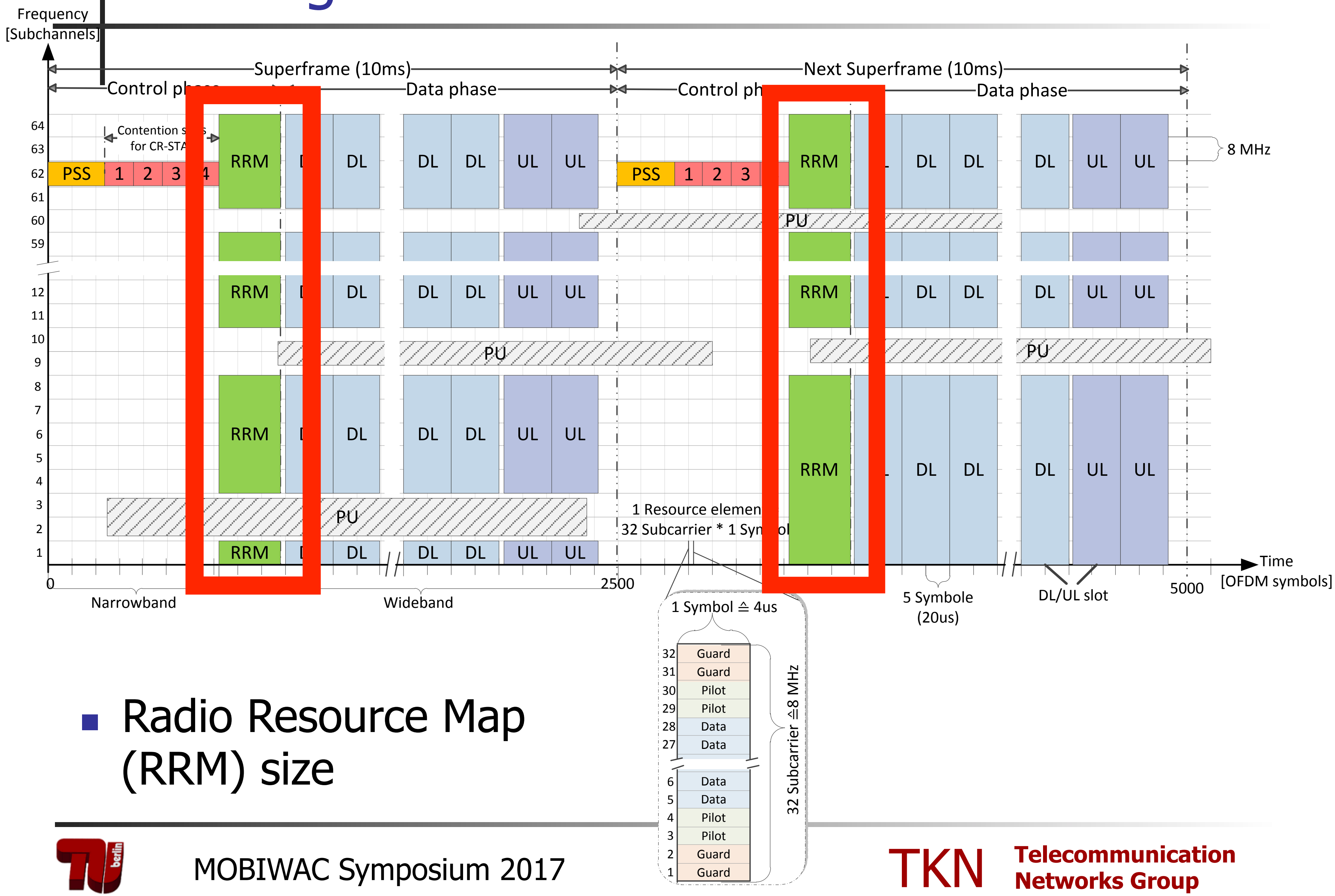
Design Considerations

- Assumption: Whole spectrum is dedicated to licensed users, but via a database available spectrum fragments for secondary usage can be requested for a given time in a given area
- Spectrum can be revoked on short notice
- Every CR-BS has low latency access to the database
- Each CR-STA is controlled by its CR-BS only

Signaling Overhead as Function of Subchannel Width

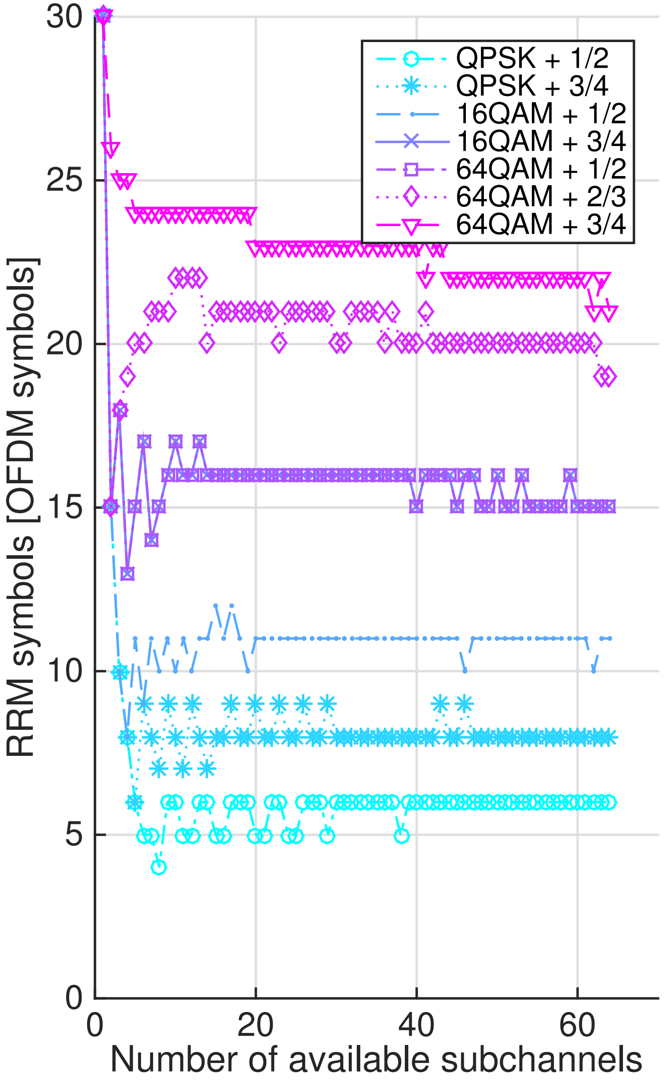


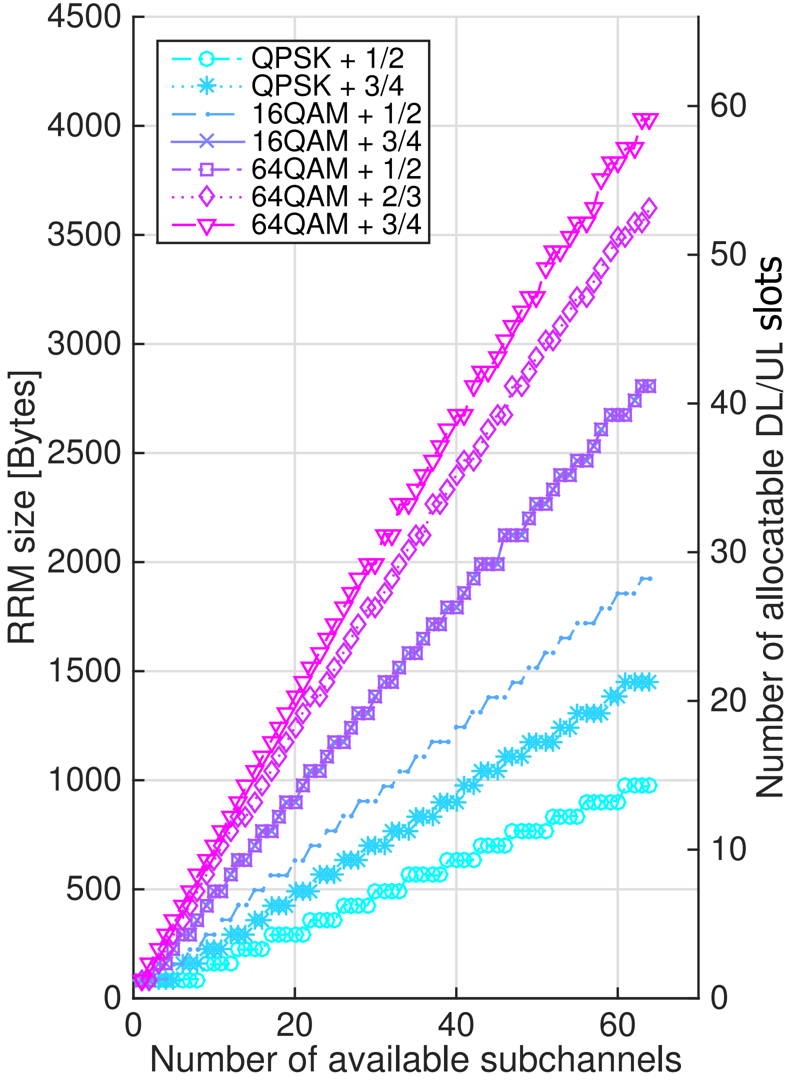
Framing – Revisited



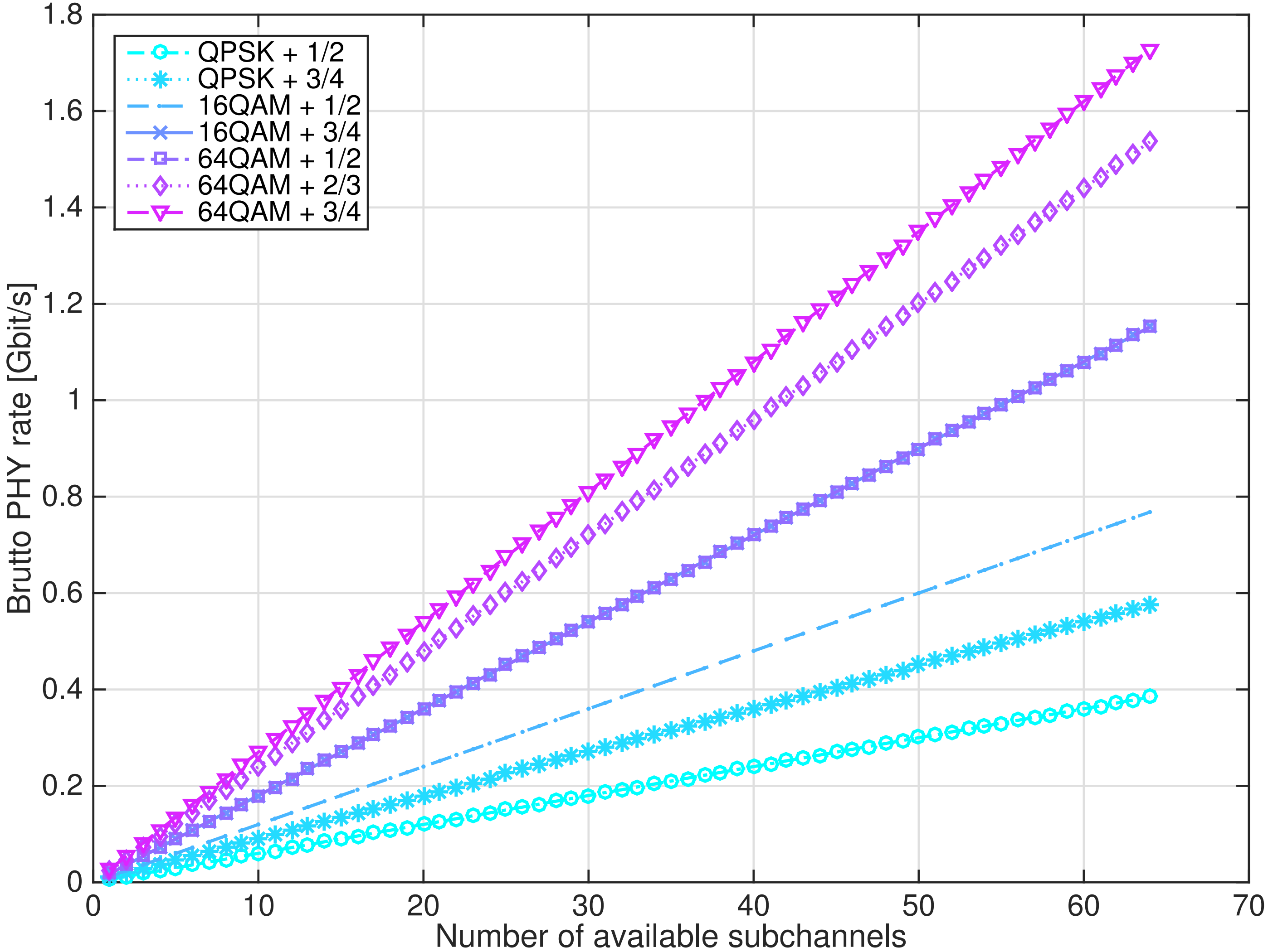
- Radio Resource Map (RRM) size

Radio Resource Map Size

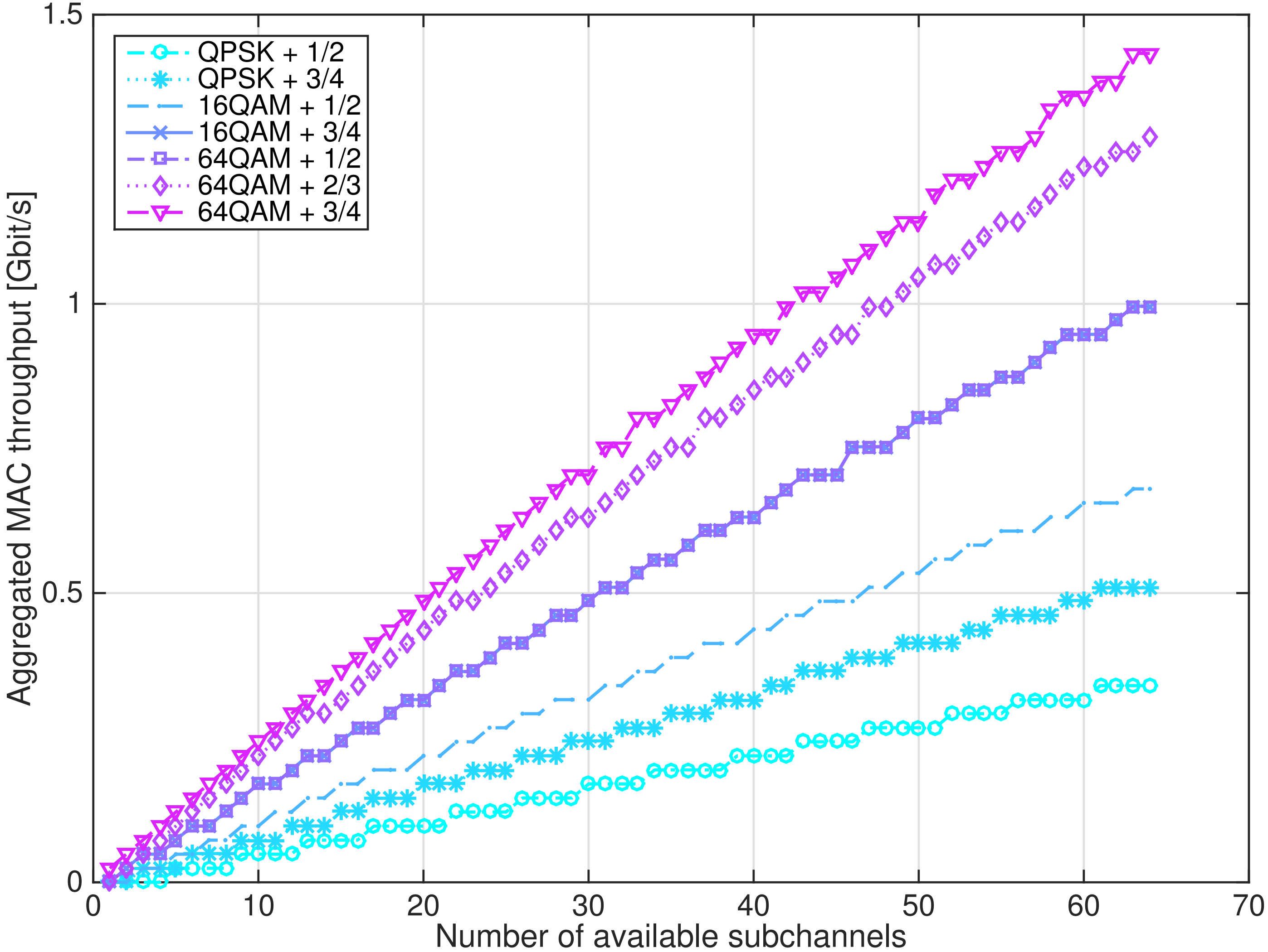




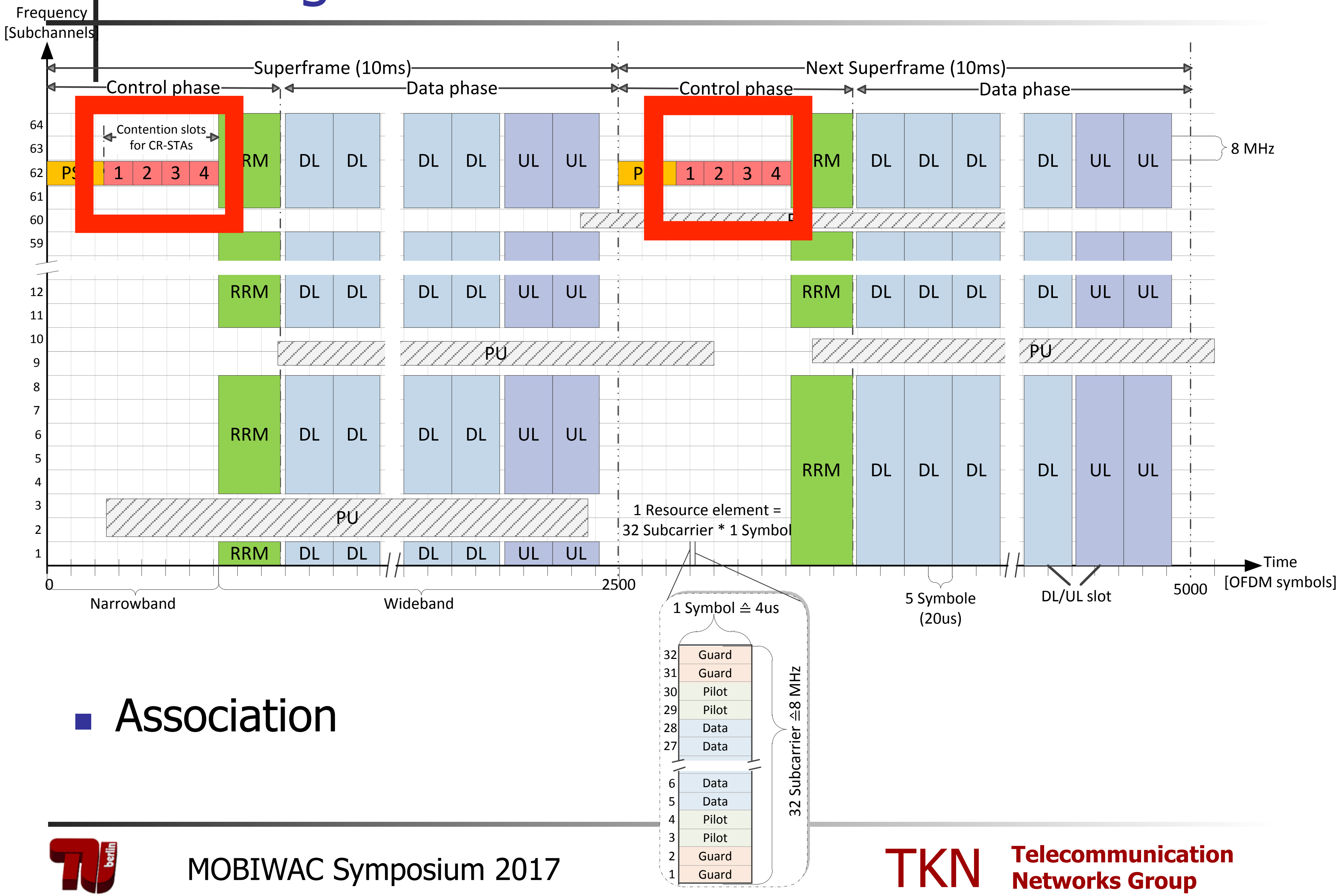
Brutto PHY Rate



MAC Rate

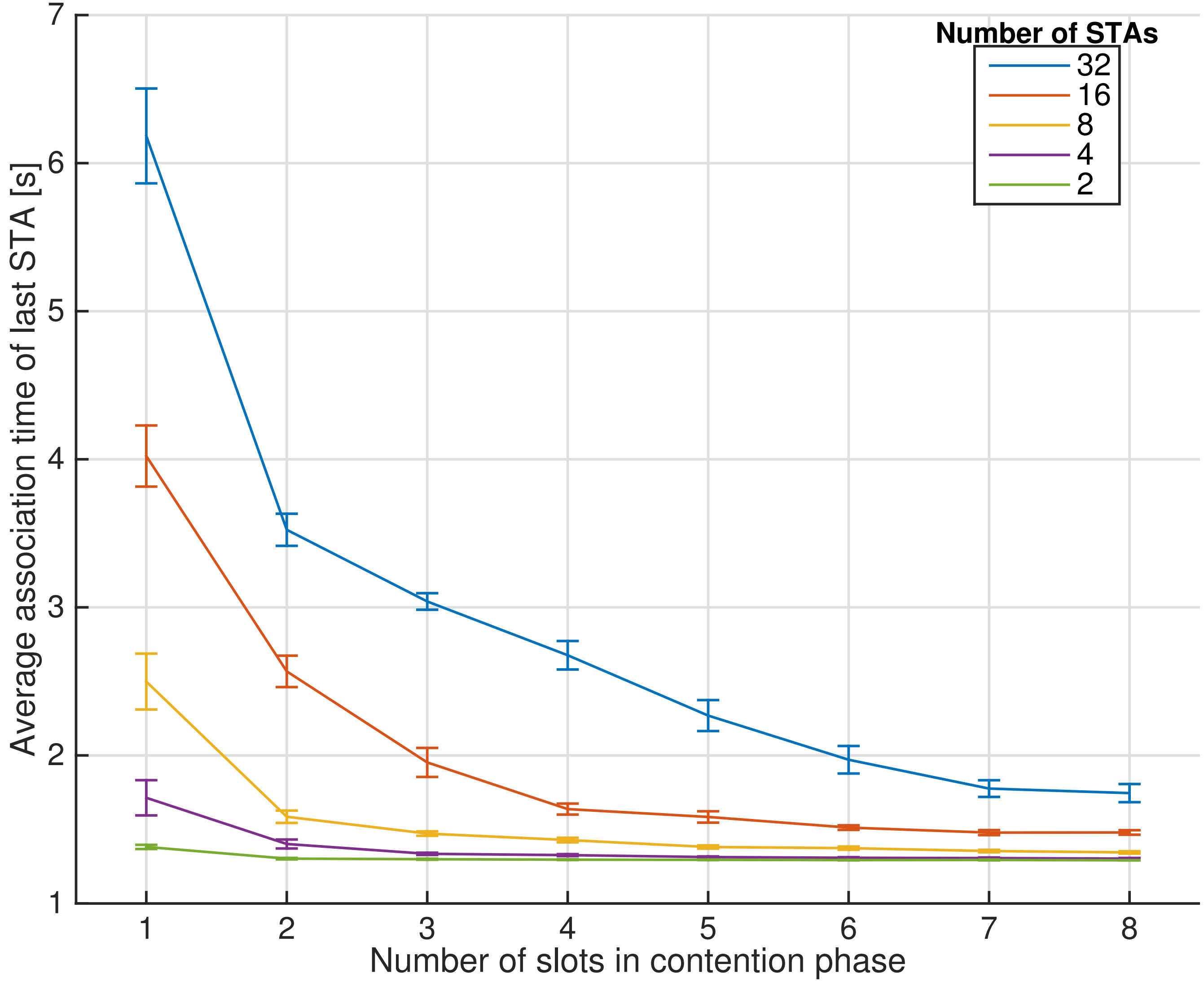

QPSK + 1/2
QPSK + 3/4
16QAM + 1/2
16QAM + 3/4
64QAM + 1/2
64QAM + 2/3
64QAM + 3/4
Aggregated MAC throughput [Gbit/s]
Number of available subchannels
0
0.5
1
1.5
0
10
20
30
40
50
60
70

Framing – Revisited

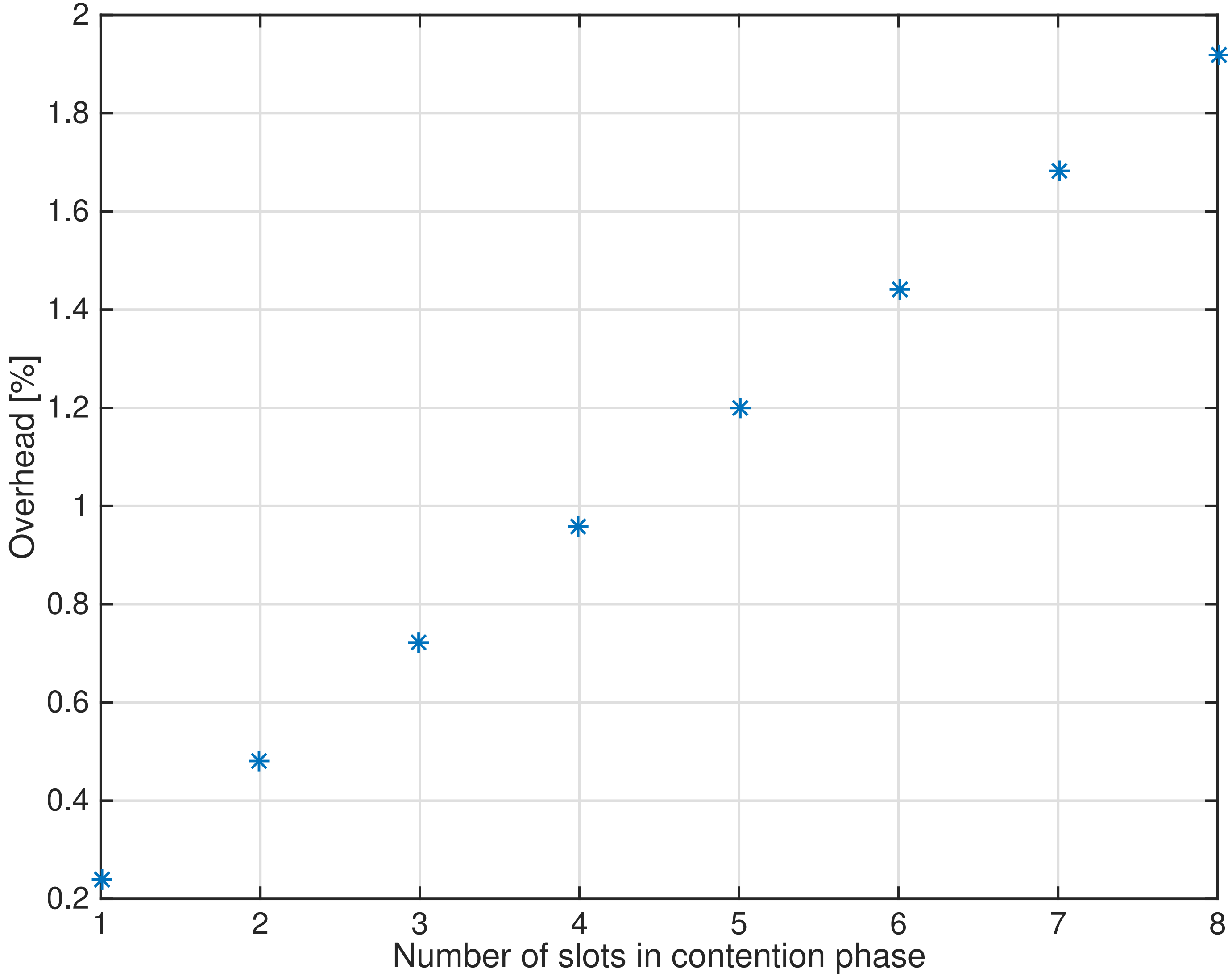


- Association

Association Phase



Scanning Phase

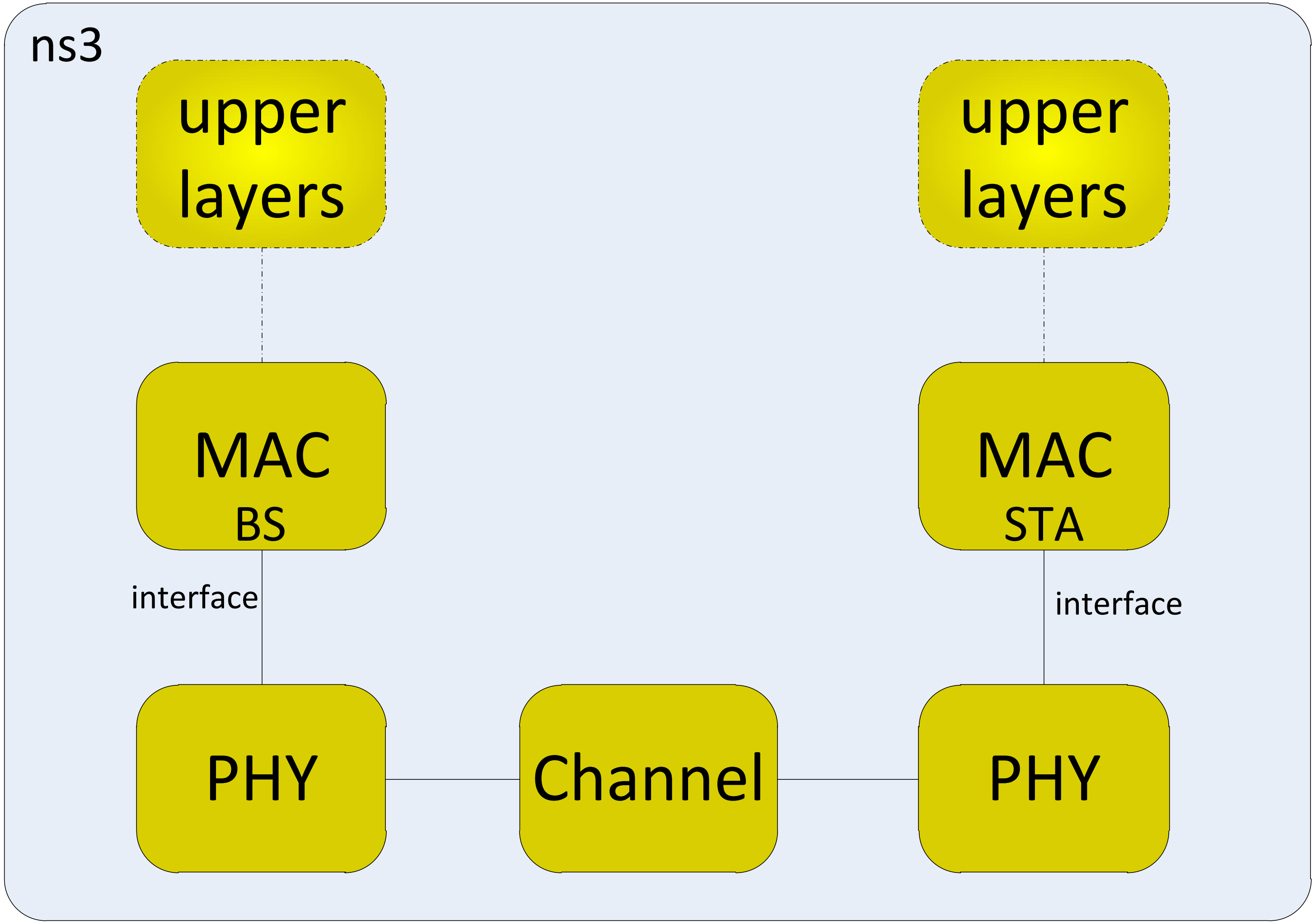


Performance Evaluation

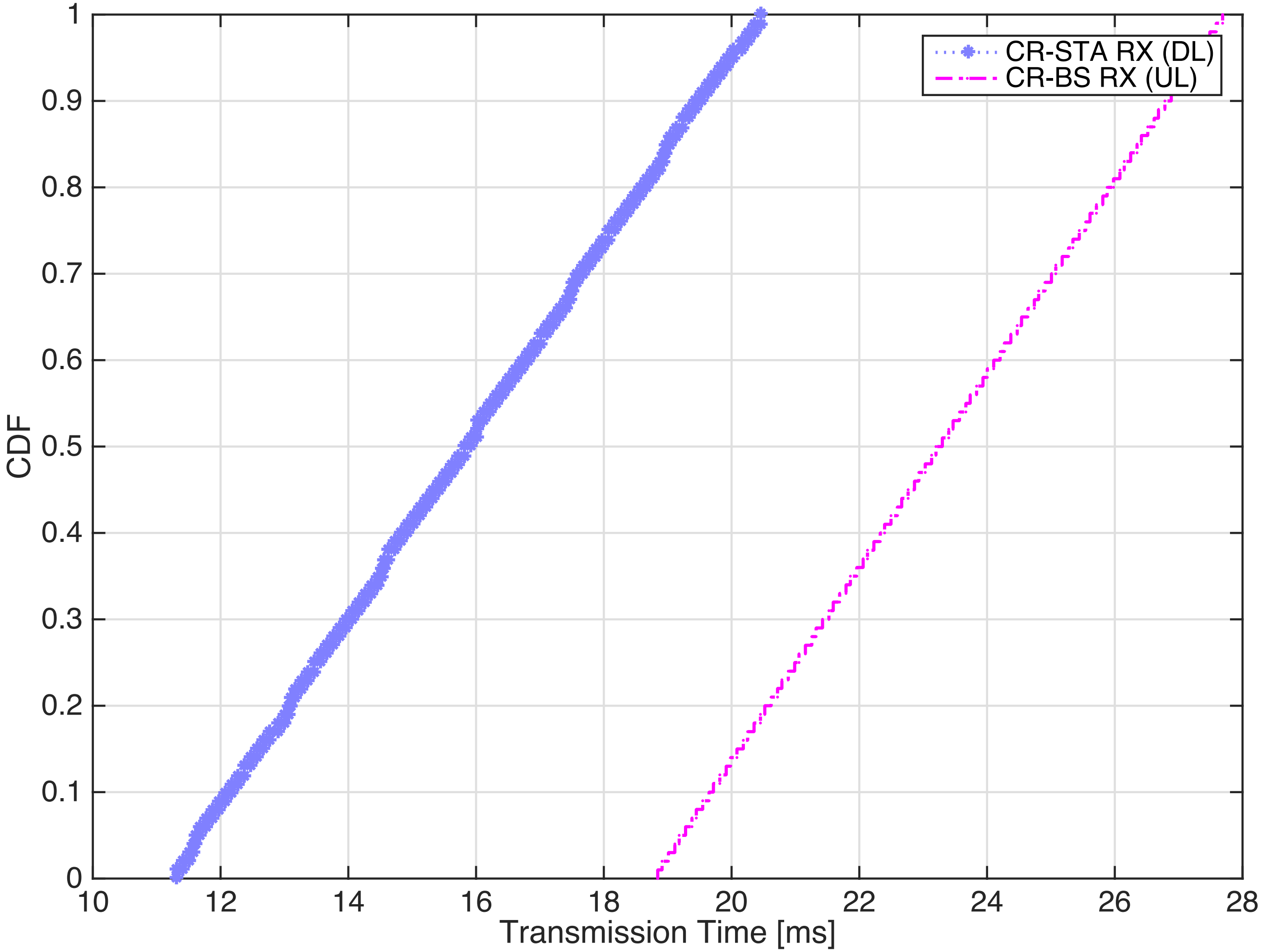
NS3 Simulation Model

- 1 CR-BS, n CR-STA
- Placement: random and fixed
  - Height: CR-BS 30m, CR-STA 6m
- Bandwidth 512MHz (2048 subcarrier)
  - 64 subchannel, 32 subcarrier each
- Okumura Propagation Model (small city, urban environment) and Nakagami Fading Model
  - Both per subchannel
- Transmit power 17dBm
- 7 MCS (QPSK 1/2,3/4; 16-QAM 1/2,3/4; 64-QAM 1/2,2/3,3/4)
- Trace-based PU, but not interfering (database)

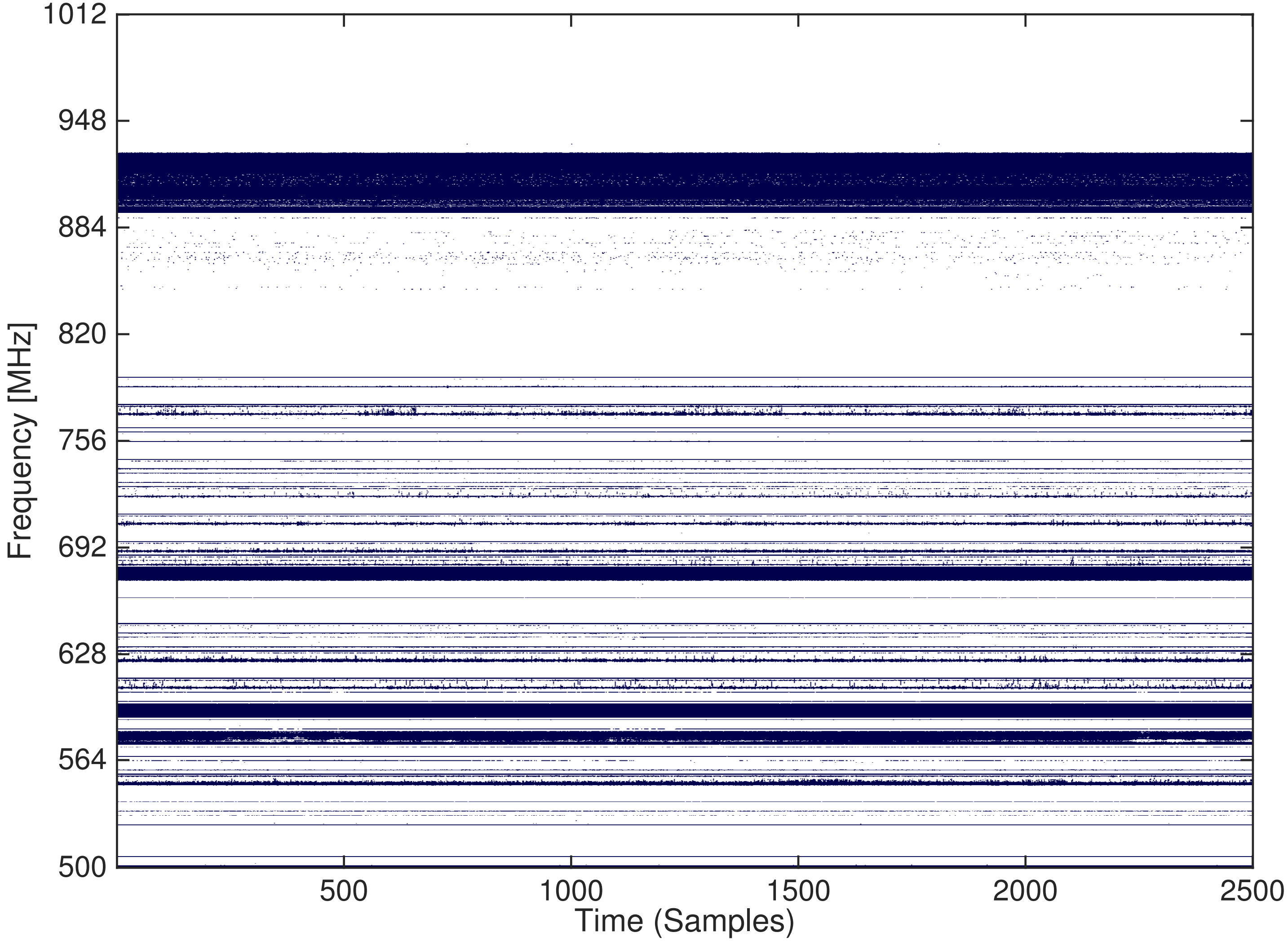
NS3 Topology



UDP End-to-End Delay

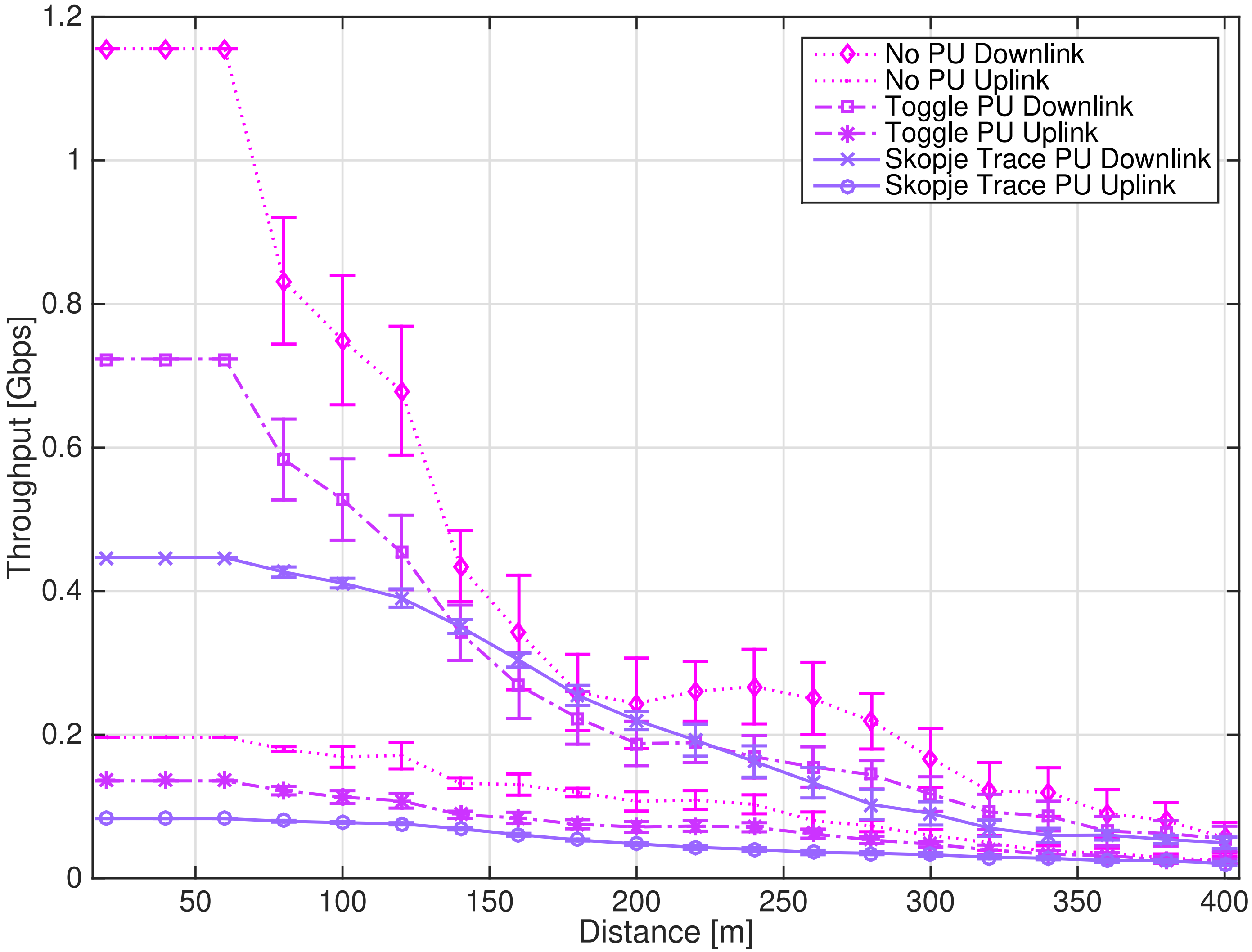


Spectrum Snapshot – Skopje Trace

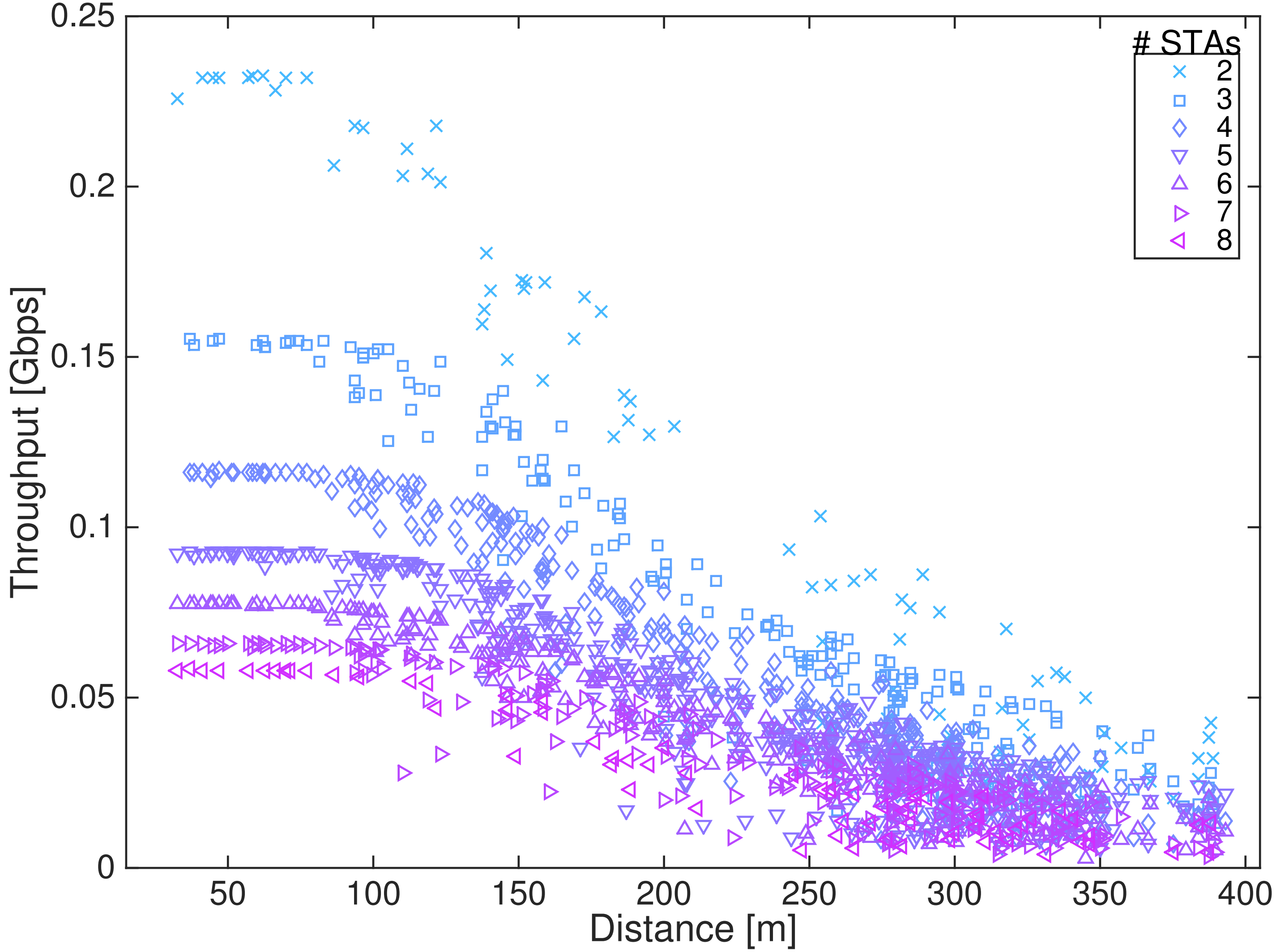


[8] A. Palaios et al. "Two days of European Spectrum: Preliminary analysis of concurrent spectrum use in seven European sites in GSM and ISM bands." IEEE ICC 2013

MAC level throughput w/o PU



Skopje Trace/ Uplink/ Multiple Stations



Conclusions

Conclusions

- Proposed the COgnitive Ultra-Wide BAckhaul Transmission system, which allows flexible usage of a very wide range of non-continuous, allocatable spectrum
- Designed a flexible Cognitive MAC, which allows fast adaptation on spectrum changes, while protecting primary users
- Evaluated the design analytically, as well as by a self-deployed ns3 model
- Integration/Test on real hardware was due to certain difficulties not possible (no stable synchronization between boards) – nevertheless, a demonstrator was set up

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Thank you.

Acknowledgement

This work has been supported by the COUWBAT project of the German Federal Ministry of Education and Research (BMBF 16KIS0029) and the European Union's Horizon 2020 research and innovation program under grant agreement No 645274 (WiSHFUL project)

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