

Closed Loop Control Scheduling in Multihop Cellular Networks

VDE/ITG Workshop Contribution

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12.02.2009

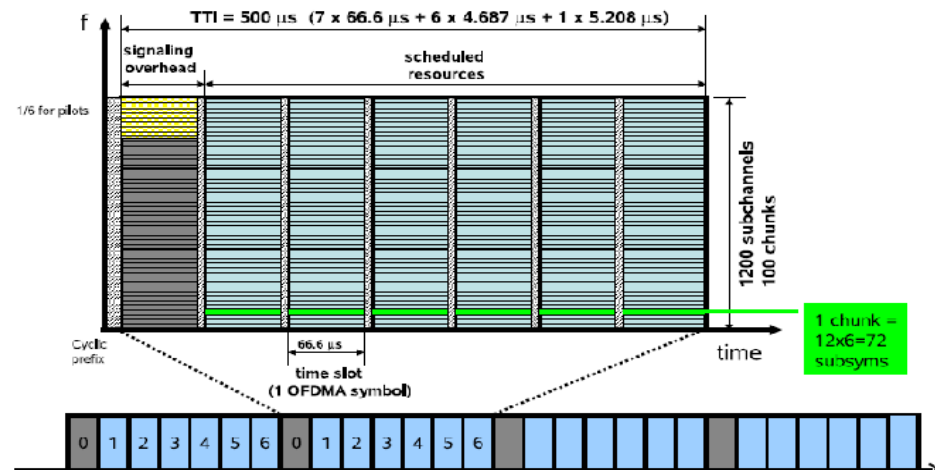
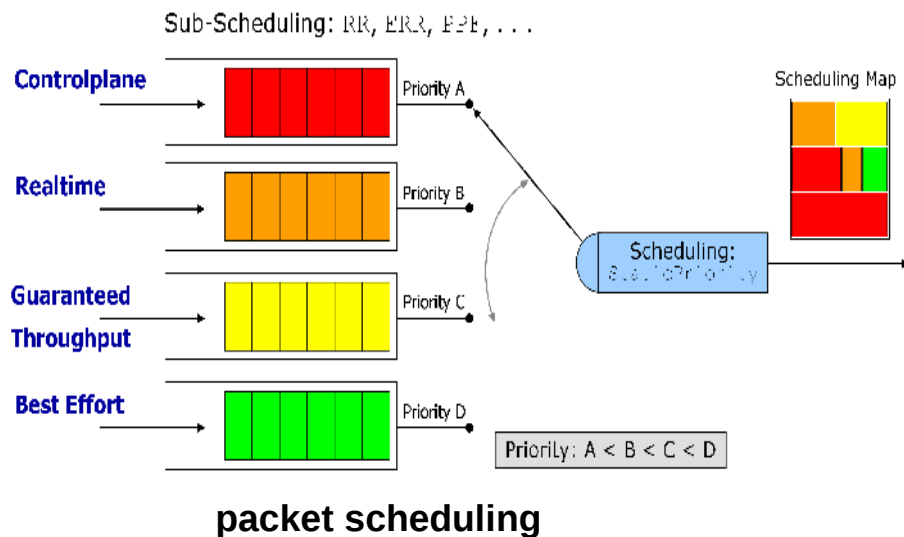
Outline

- Packet vs. resource scheduling:
- Packet scheduling: QoS, Priorities etc.
- Resource scheduling
 - Fading channel (frequency & time varying)
 - Channel State Information (CSI,CQI)
 - OFDMA scheduling under fading conditions
 - Dynamic Subcarrier Assignment (DSA)
 - Adaptive Modulation&Coding (AMC)
 - Adaptive Power Control (APC)
 - **Closed Loop Control Resource Scheduling**
- The schedulers in OpenWNS

Motivation

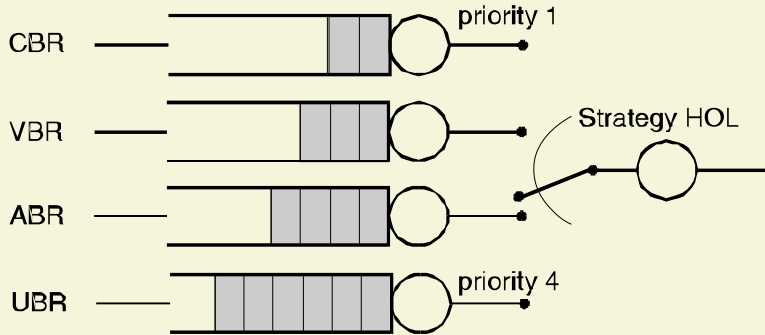
- **Packet scheduling vs. resource scheduling:**

- Packet scheduling chooses packets/bits from queue, handles QoS
- Resource scheduling allocates OFDMA subchannel, modulation and coding (PhyMode), transmit power

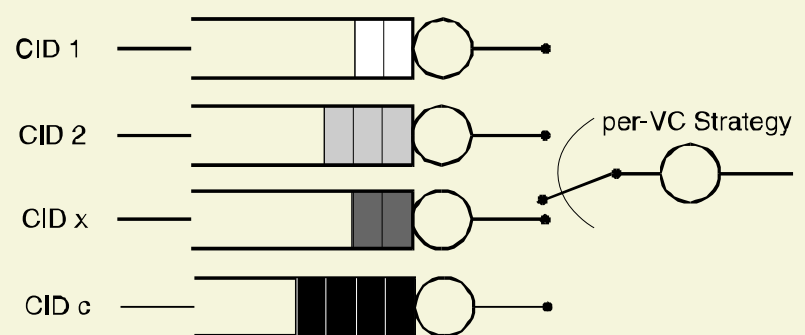


Packet Scheduling - Scheduler Classes

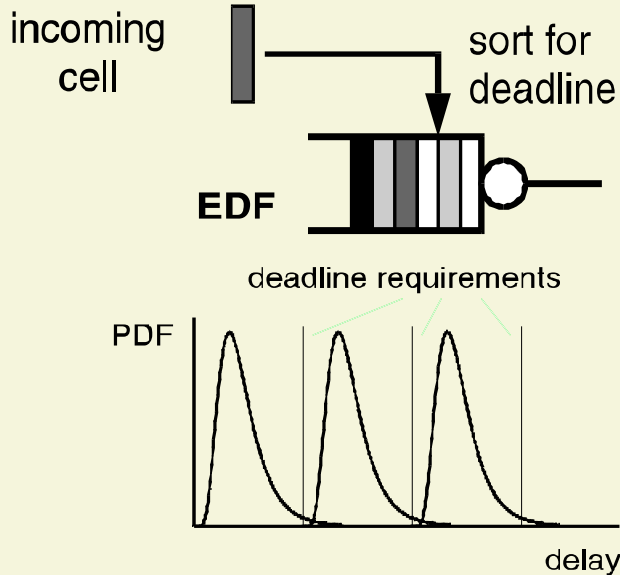
head-of-line (static priority) scheduling



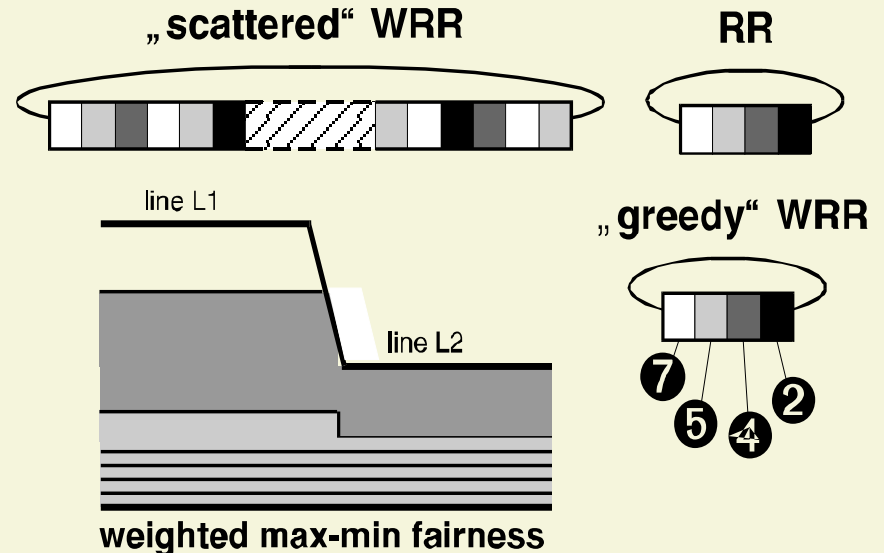
per-VC queueing



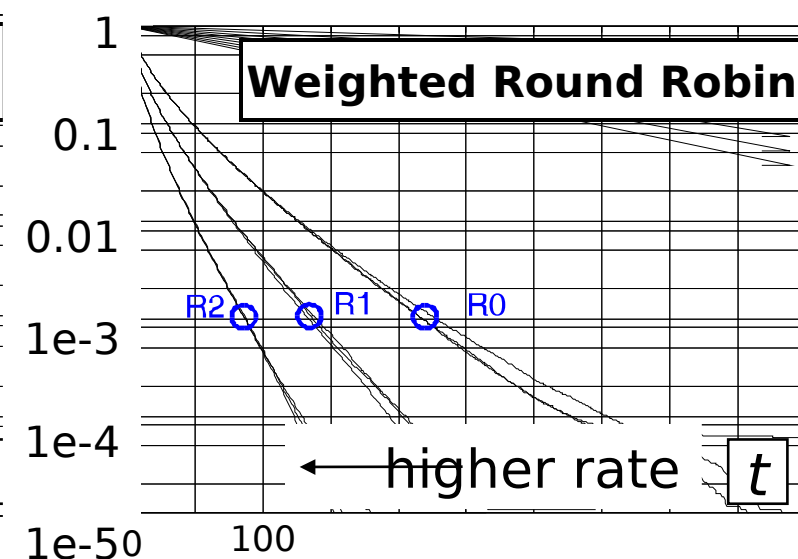
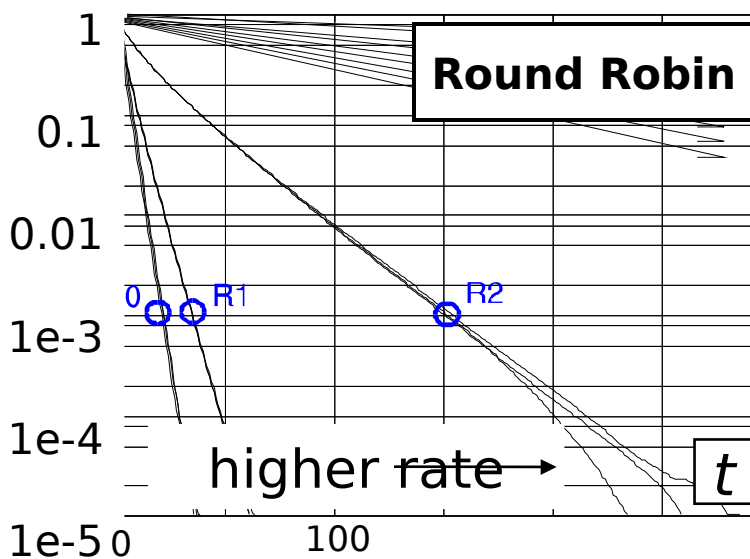
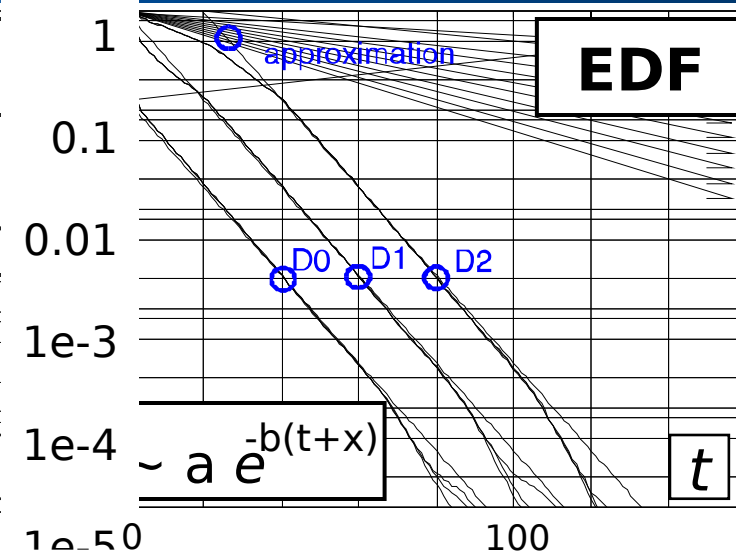
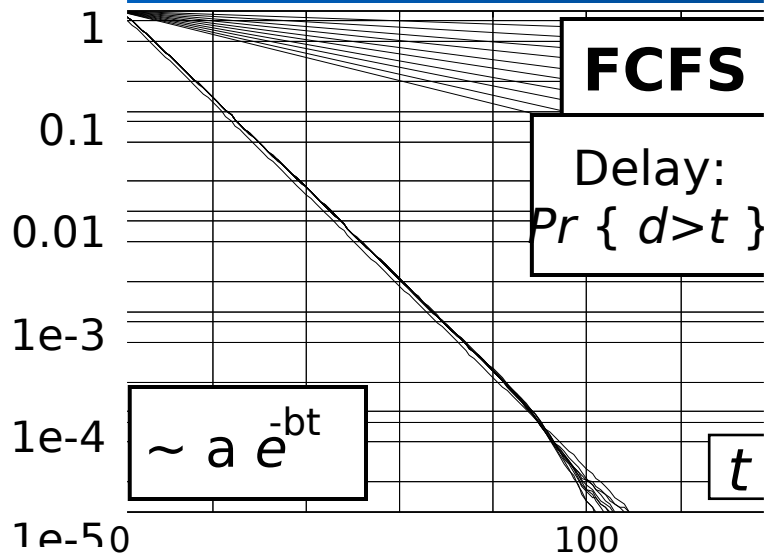
deadline scheduling



rate proportional scheduling



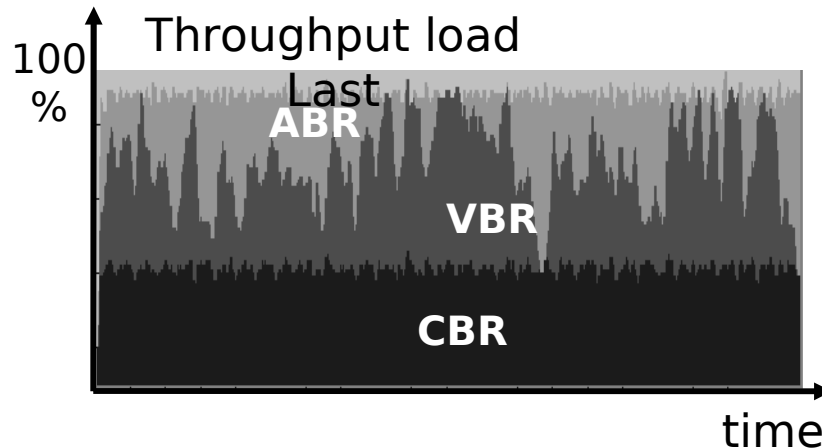
Scheduler Performance



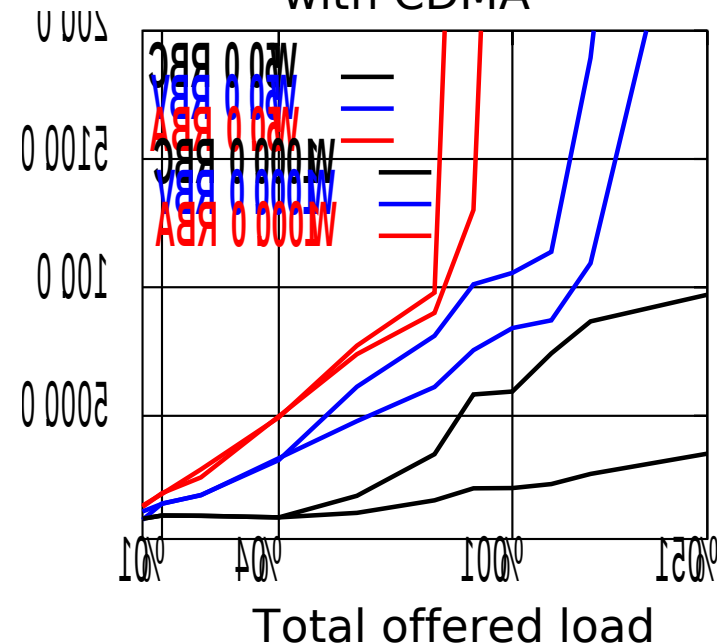
QoS with prioritisation

- **Separation of QoS classes**
- **High channel utilisation due to unlimited best effort traffic and flow control**

typical load
on a controlled channel:



average packet delay [s]
with CDMA



Advanced Wireless Scheduling

- **Why is the scheduler so complicated?**

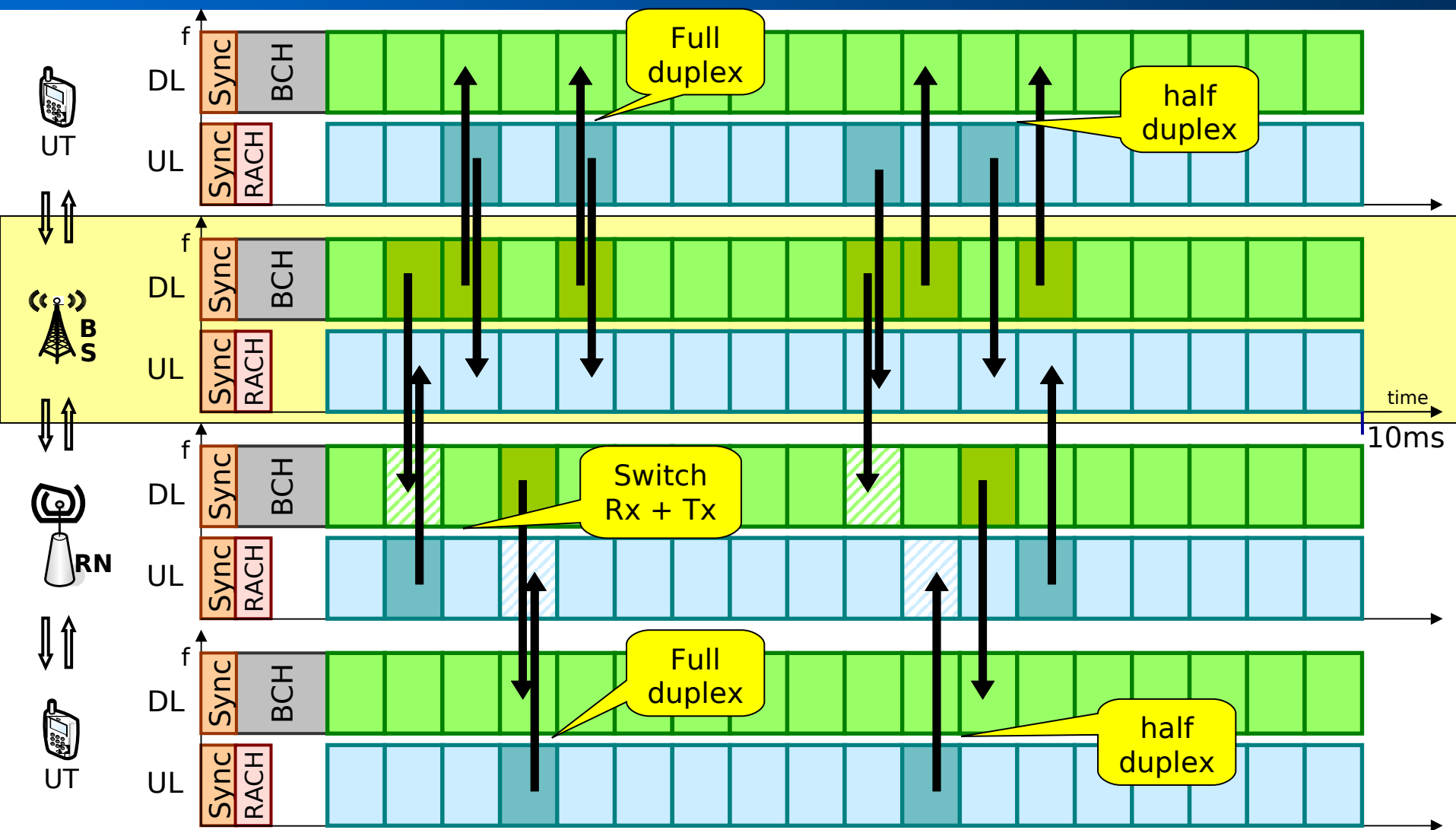
- **Components of the scheduler:**

- CQI : Channel Quality Indication
- DSA : Dynamic Subcarrier Assignment
- AMC : Adaptive Modulation & Coding
- APC : Adaptive Power Control
- Multi-Antenna: MIMO/Beamforming
- Resource Partitioning
- QoS : Priorities and Substrategies
- Buffer/Queue management

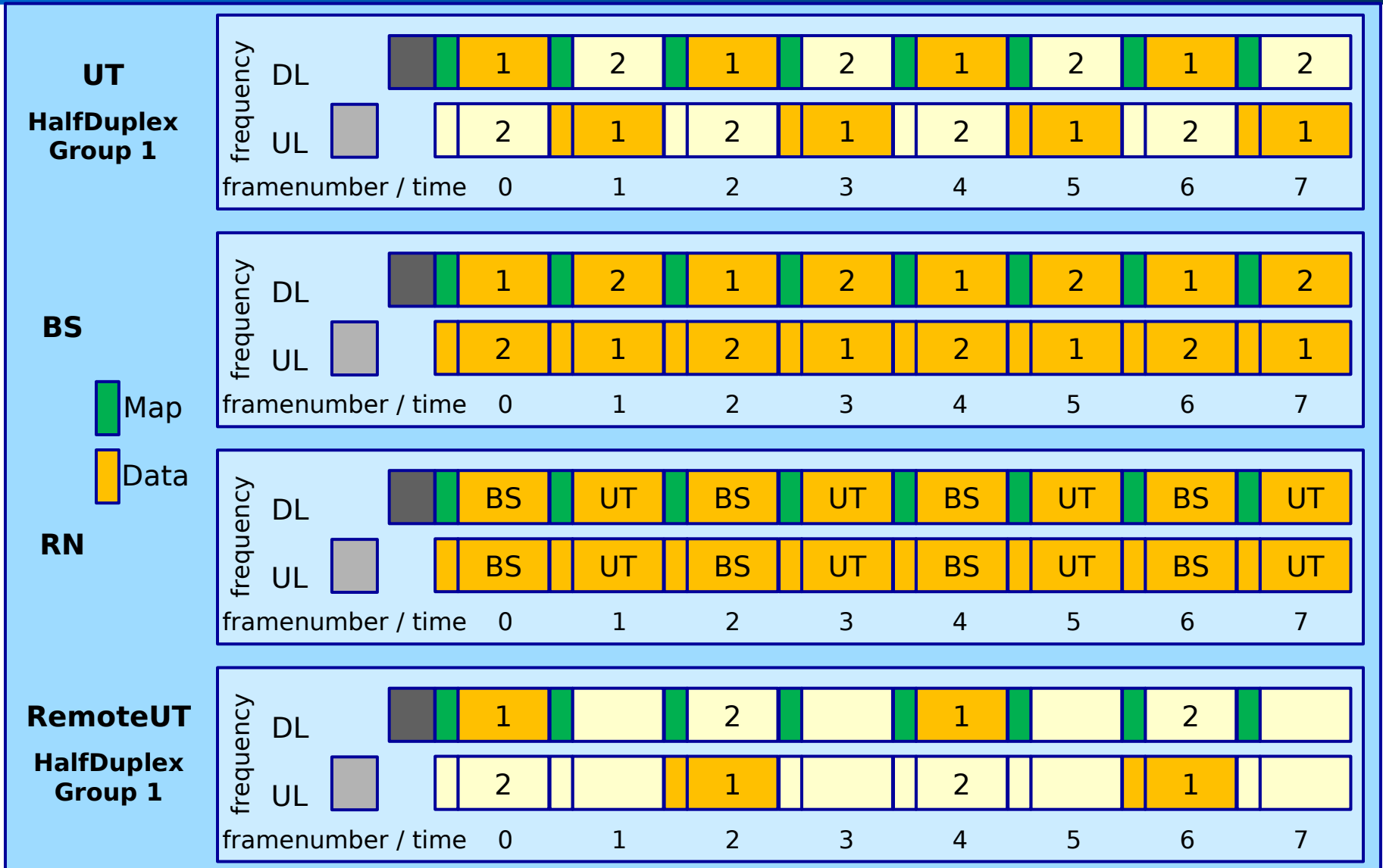
resource
scheduling

packet
scheduling

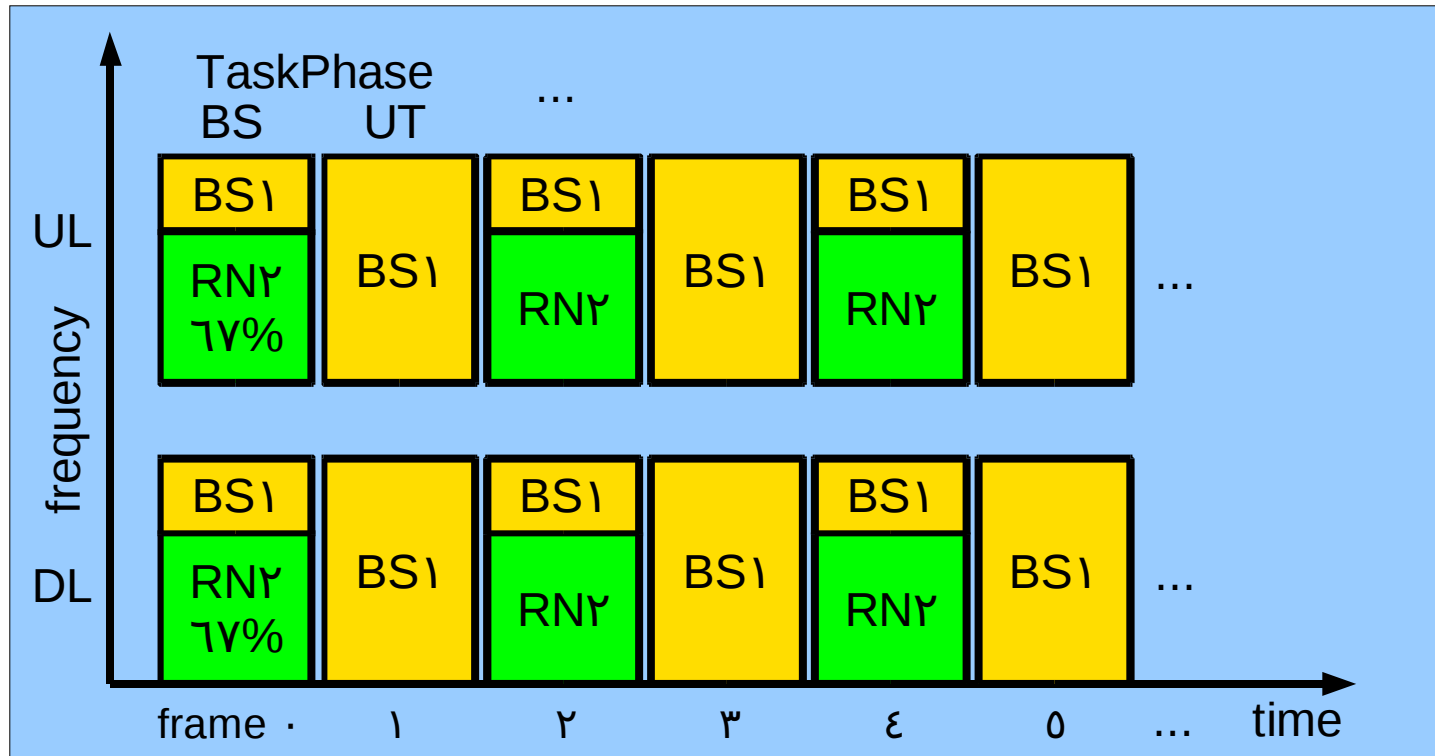
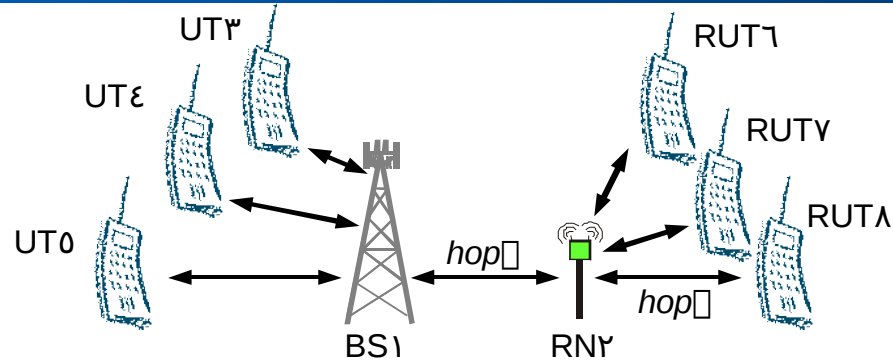
FDD Multihop Frame Scheduling for LTE Advanced



Half-Duplex FDD Frame Scheduling

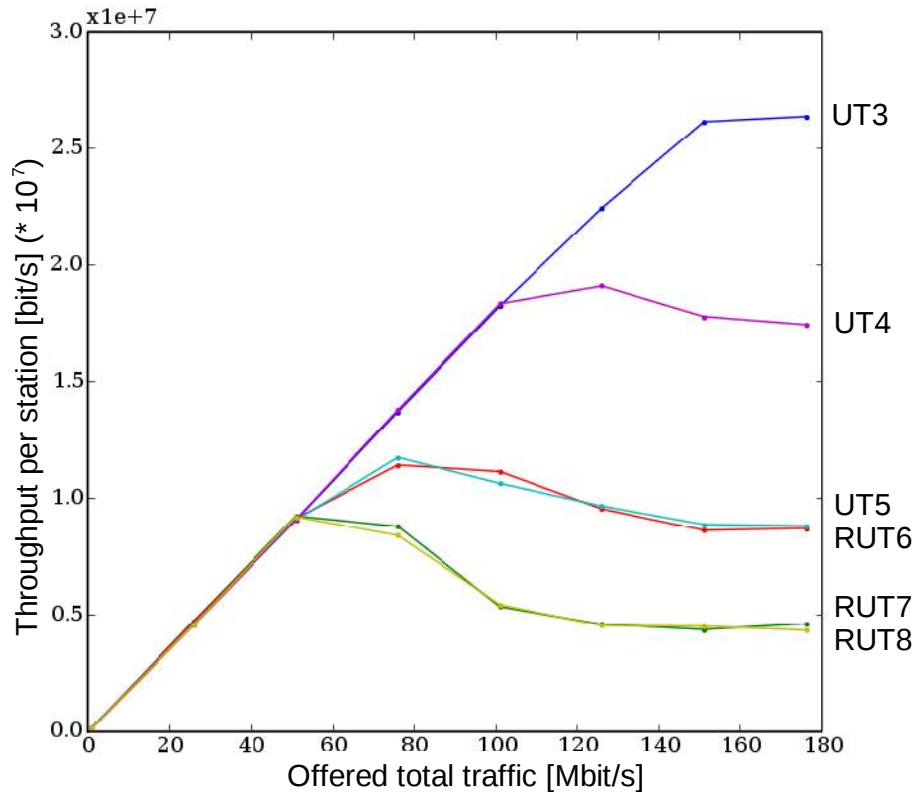


Multihop Resource Partitioning (between BS and RN)

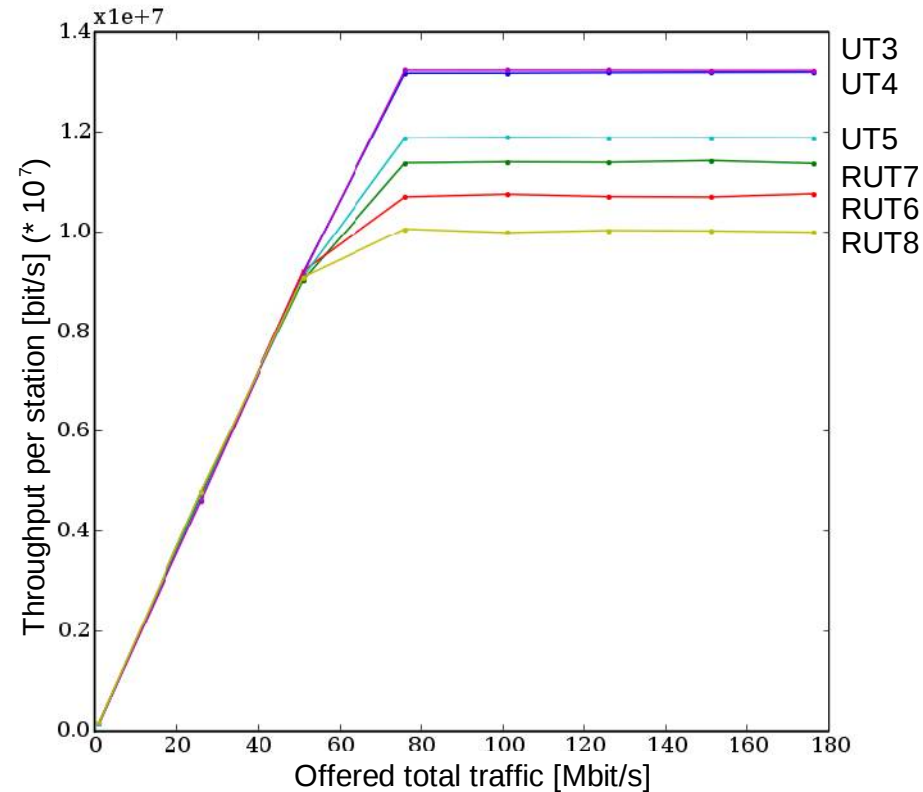


Half-duplex multihop (uplink) throughput

Using simple stateless scheduler

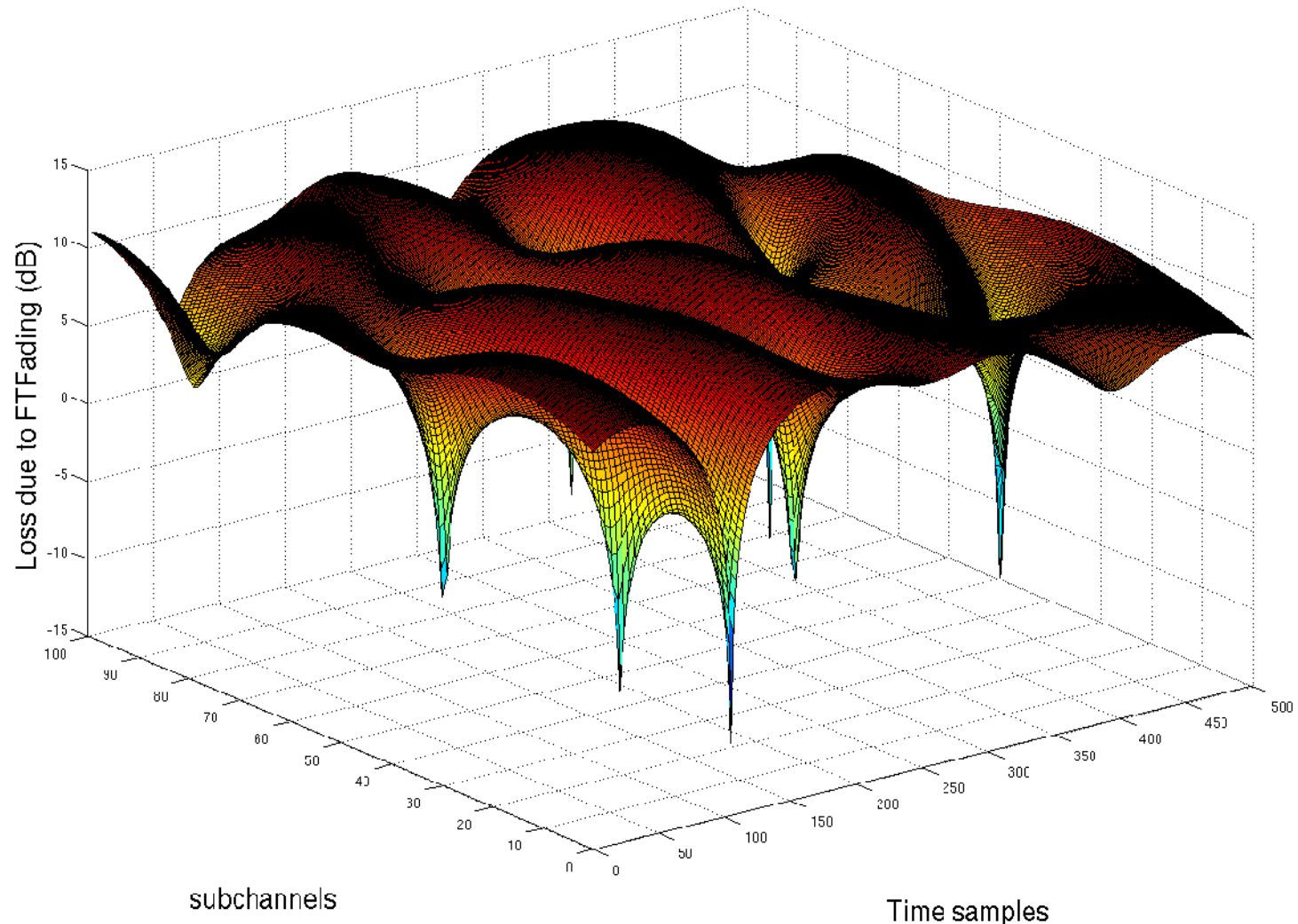


Using stateful scheduler: ProportionalFair
Using proper Resource Partitioning



Fading: Variable in Frequency and Time

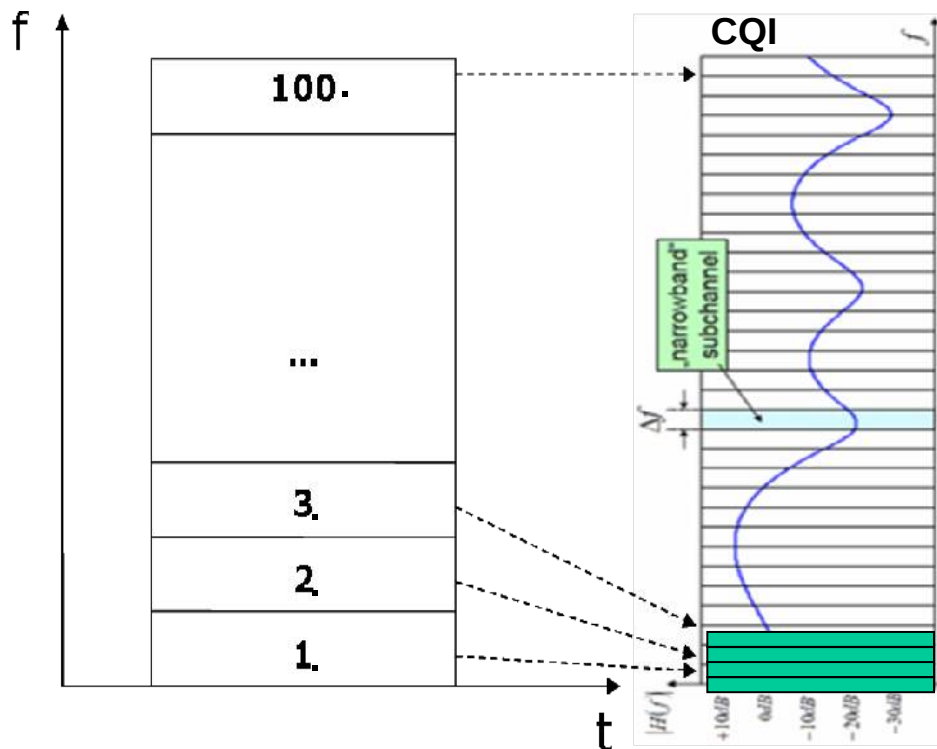
Plot of the FTTFading using the FTtdIm strategy ($\text{bwthSubCar}=180\text{KHz}$, $\text{Tapdelay} = 0.00000150\text{ms}$, $\text{DopplerShift} =$



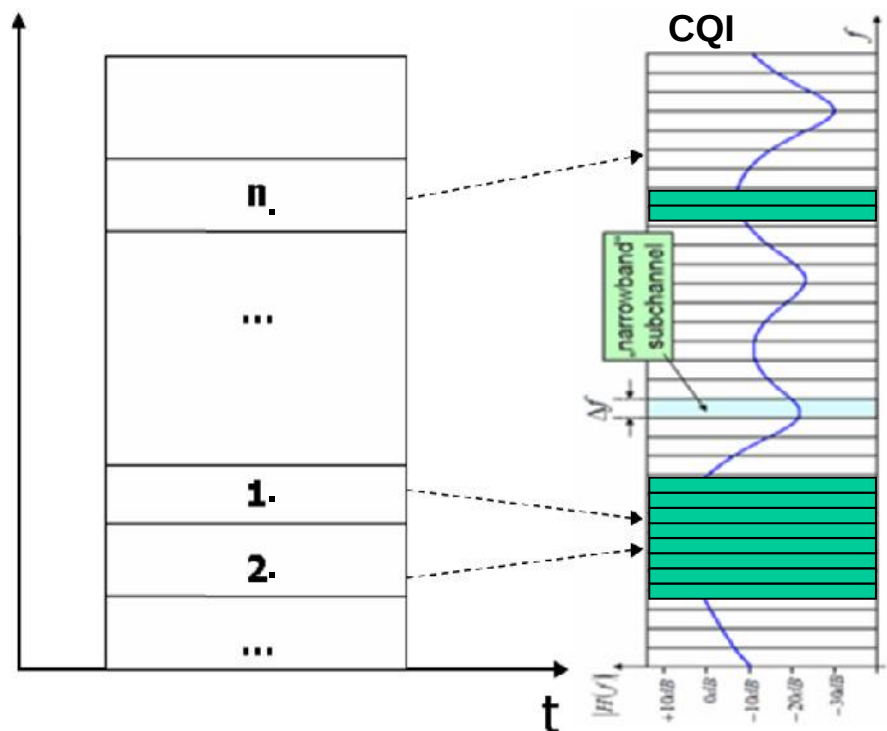
Dynamic Subcarrier Assignment

- DSA strategies:

LinearFFirst, BestChannel, BestCapacity ...



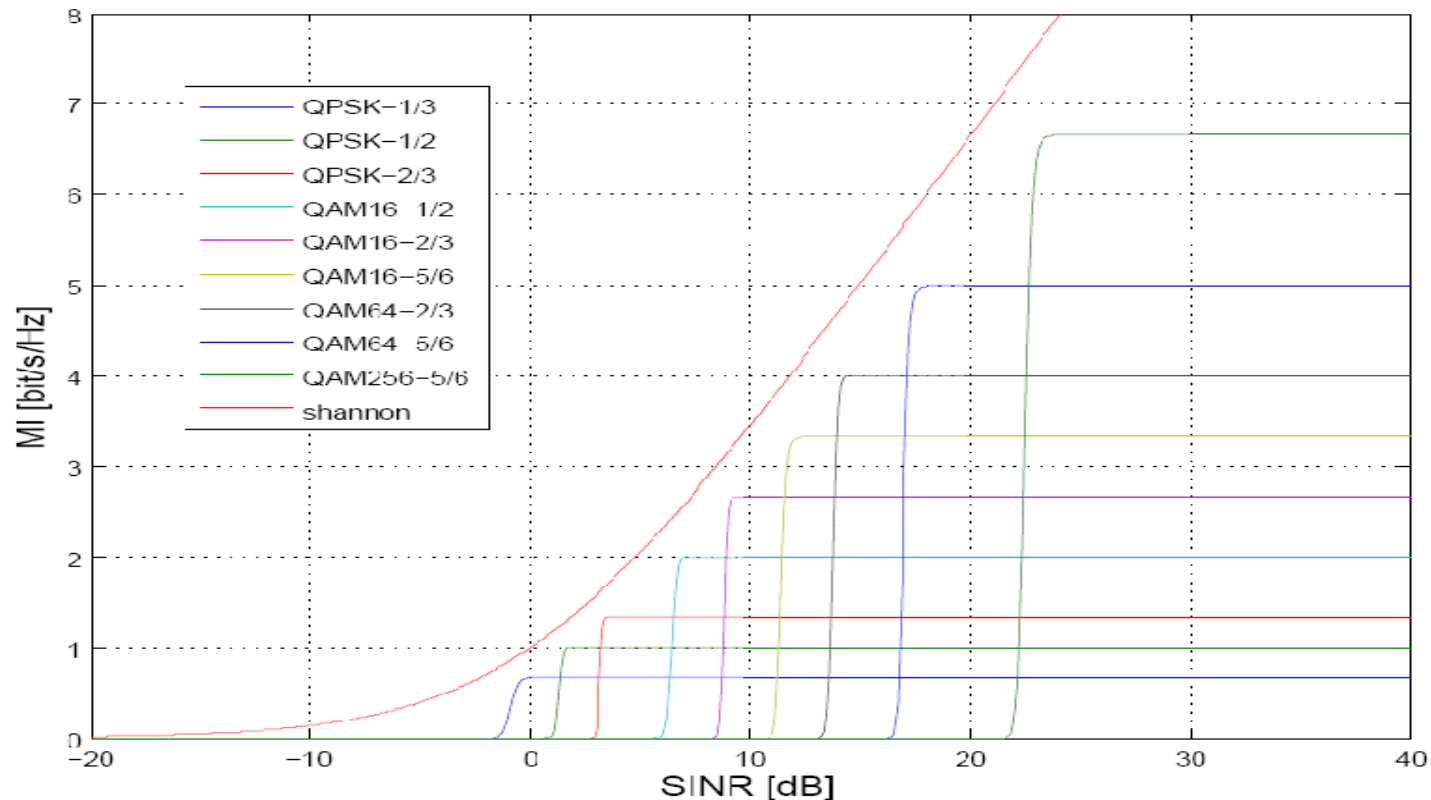
LinearFFirst



BestChannel

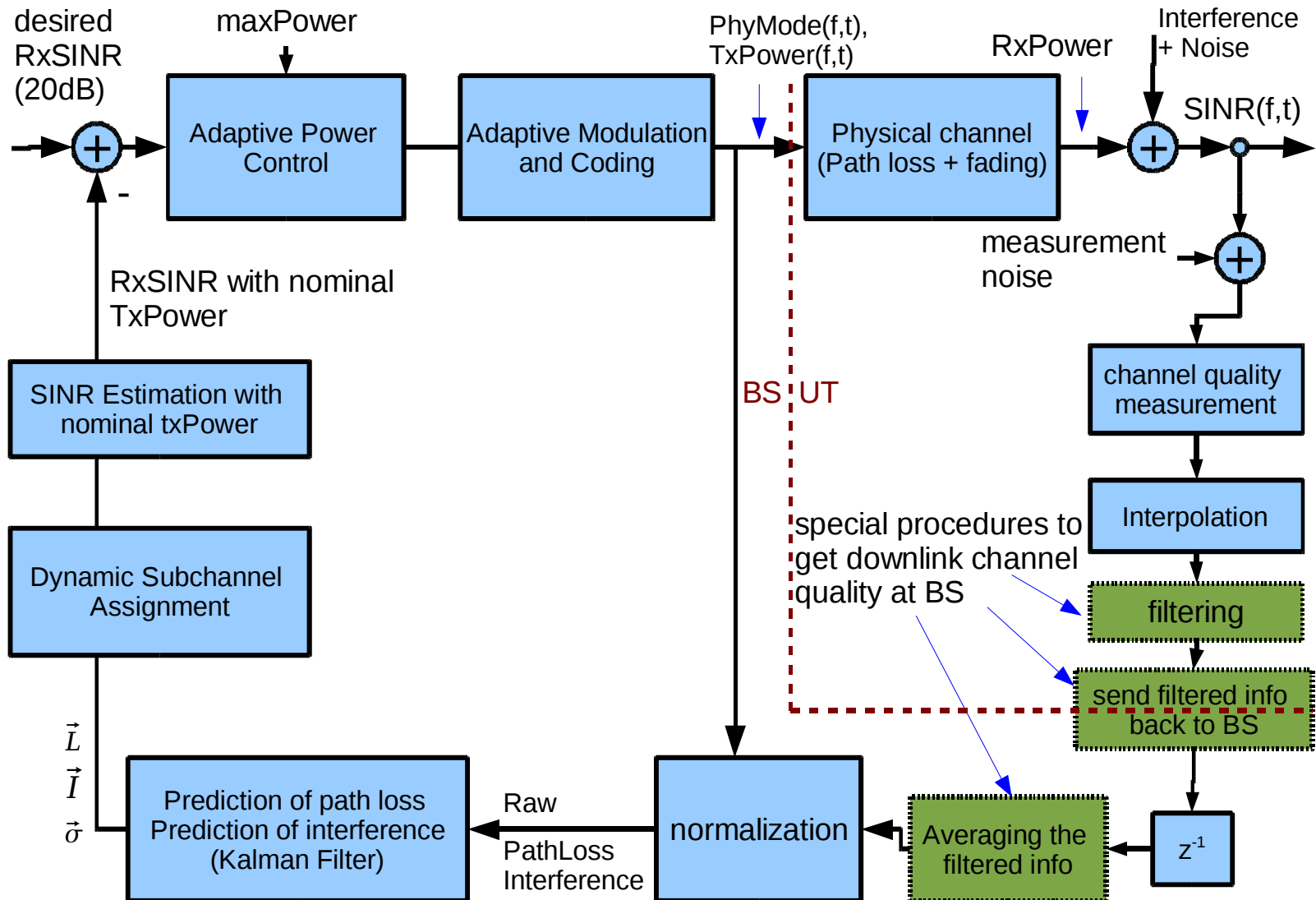
Adaptive Modulation & Coding

- AMC: PhyMode choice depends on:
 - SINR



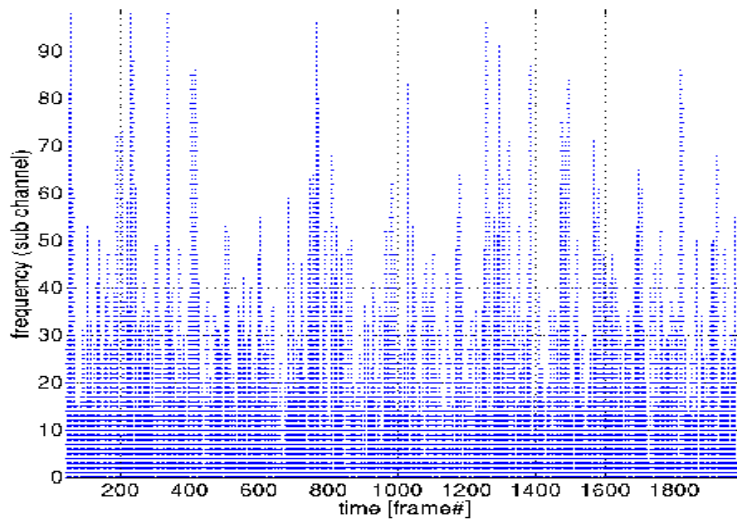
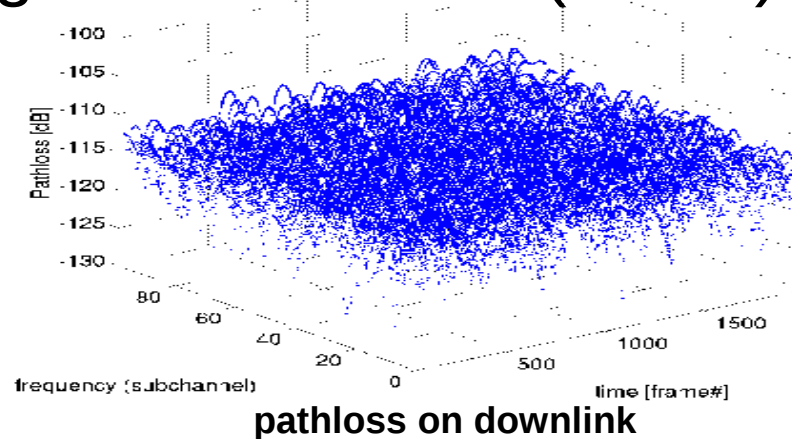
Control loop representation of scheduler

Reference: Schoenen, R. et al, "Resource Allocation and Scheduling in FDD Multihop Cellular Systems", Proceedings of the International Workshop on Multiple Access Communications (MACOM) at ICC 2009

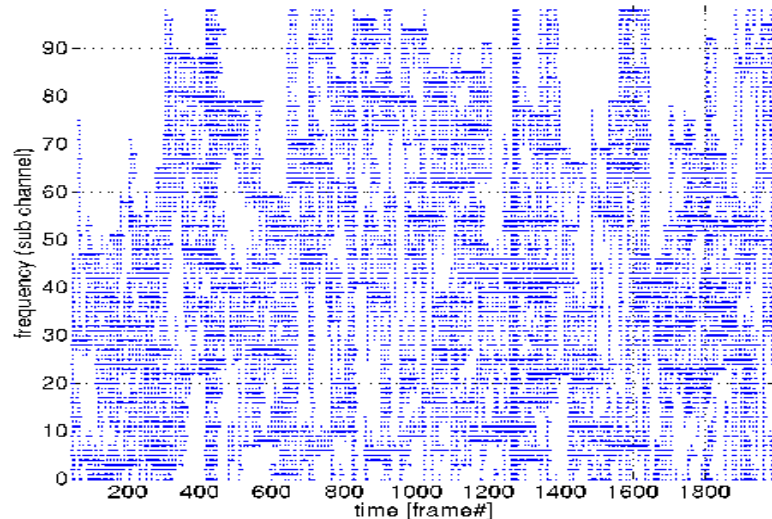


Performance of adaptive resource scheduling Dynamic Subcarrier Assignment

- DSA Strategies Evaluation: (768m)



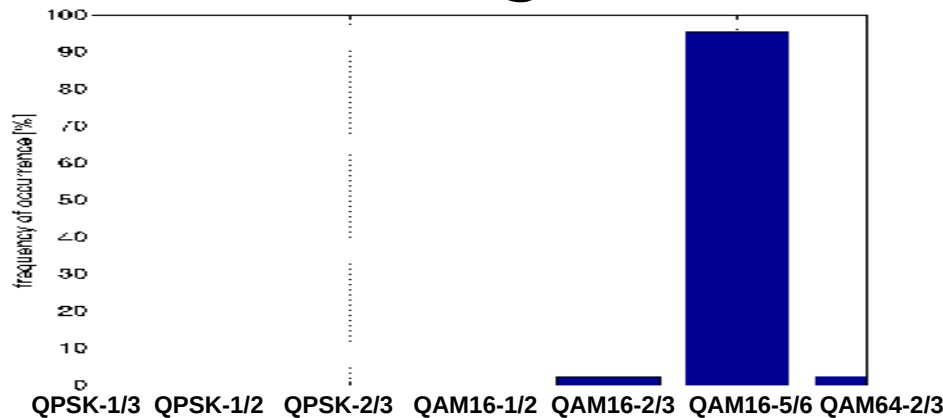
Resource usage: old method
(LinearFFirst) on downlink



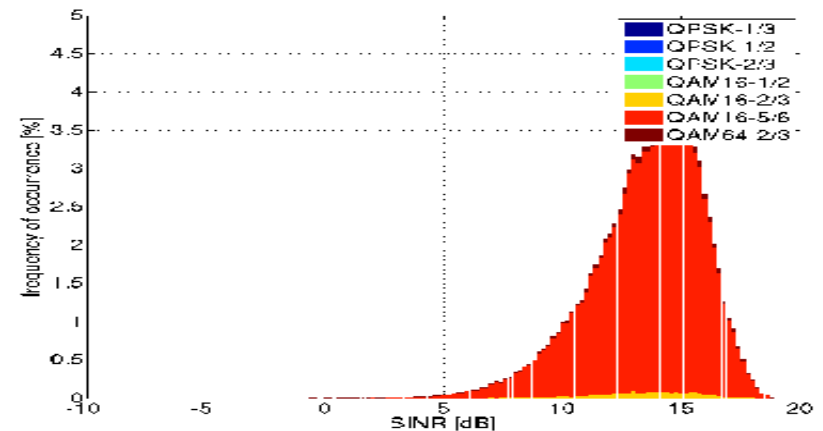
Resource usage: new method
(BestChannel) on downlink

Performance of adaptive resource scheduling Adaptive Modulation & Coding

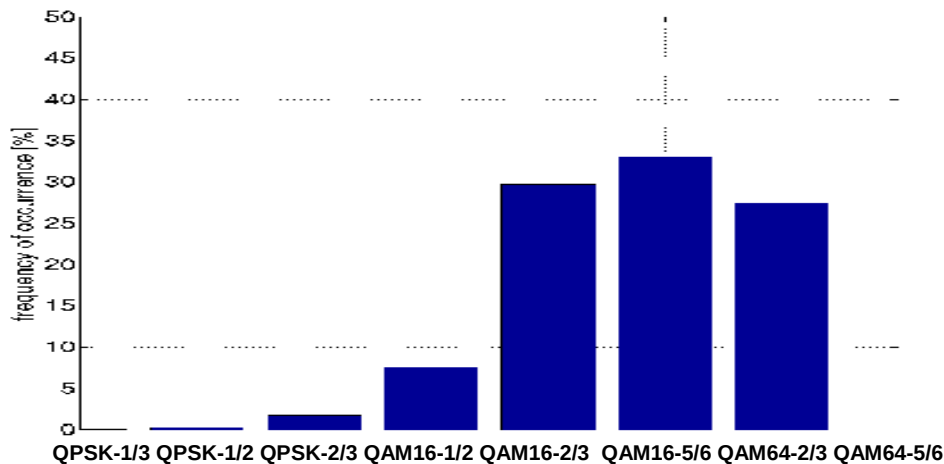
• AMC Strategies Evaluation: (1600m)



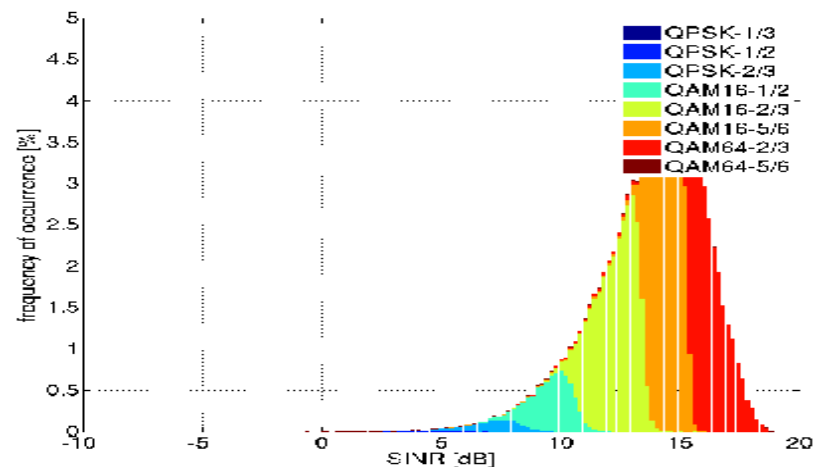
PhyMode usage: method 1
(WithoutCQI) on downlink



SINR: method 1 (WithoutCQI) on
downlink



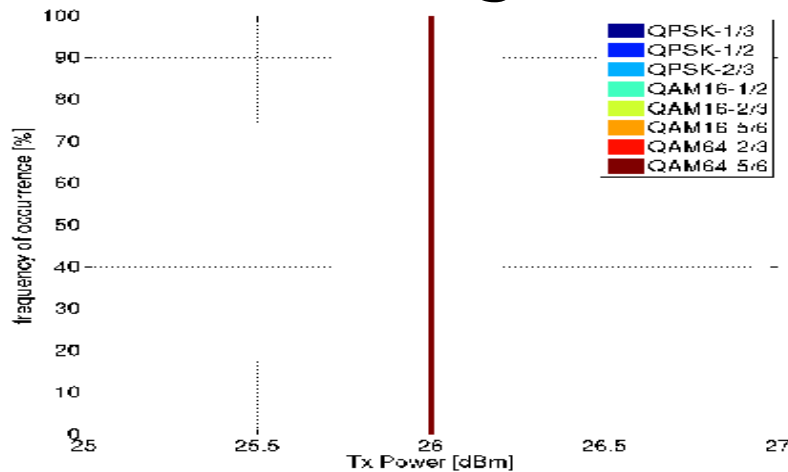
PhyMode usage: method 2
(WithCQI) on downlink



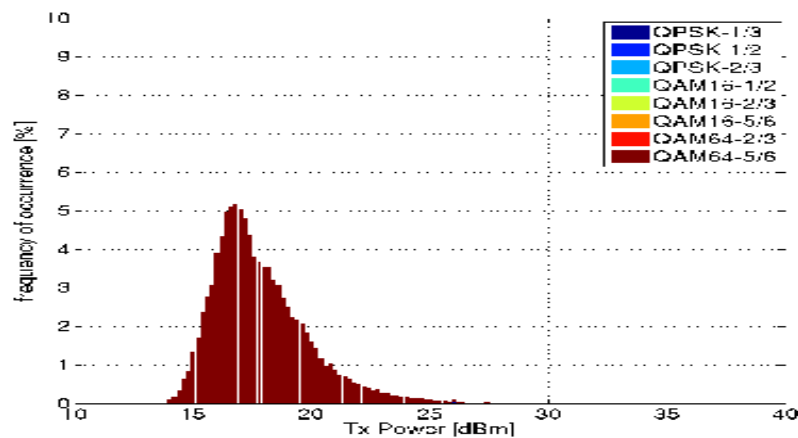
SINR: method 2 (WithCQI) on
downlink

Performance of adaptive resource scheduling Adaptive Power Control

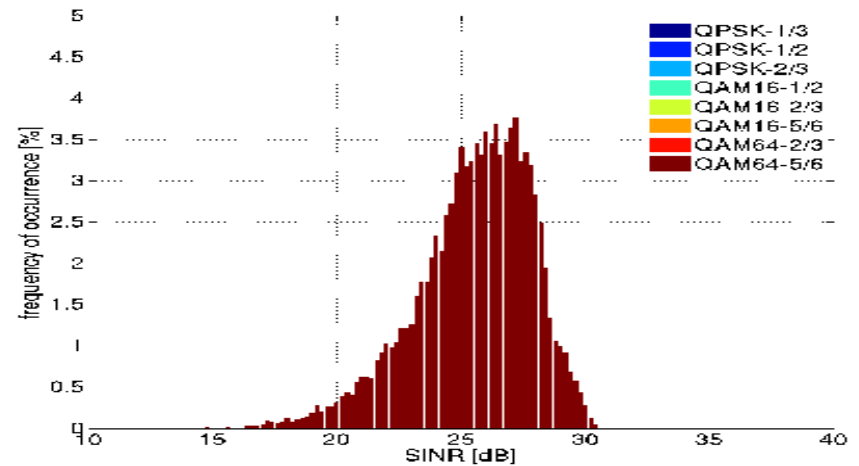
- APC Strategies Evaluation: (768m)



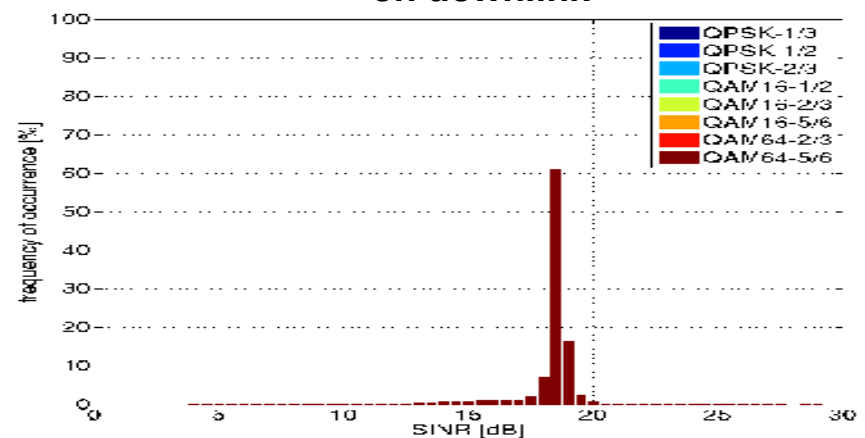
**TxPower: method 1 (UseNominalTxPower)
on downlink**



**TxPower: method 2 (FCFSMaxPhyMode)
on downlink**



**SINR: method 1 (UseNominalTxPower)
on downlink**



**SINR: method 2 (FCFSMaxPhyMode)
on downlink**

Conclusions

- Packet and resource scheduling can and must be separated
- QoS distinction by priorities is sufficient in the early phase
 - Sub-strategies are important for further QoS differentiation and fairness
- QoS aware scheduling and optimum utilization go hand in hand
- Resource Scheduling and Resource Partitioning happen on different timescales
- The wireless link is a loop (DL+UL). Delay=RTT (round trip time)
- DSA and AMC are straightforward (open loop), but
- APC requires a **closed control loop** system view
- CQI, DSA, AMC and APC optimally utilize the channel capacity
- All known algorithms are building blocks in the control block diagram

Thank you for your attention !

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Any questions?

