VoIP Kapazität im Relay erweiterten IEEE 802.16m System

26. ComNets Workshop Mobil- und Telekommunikation

Dipl.-Ing. Karsten Klagges

ComNets Research Group, RWTH Aachen University

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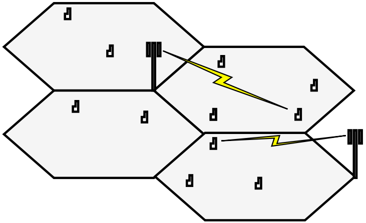
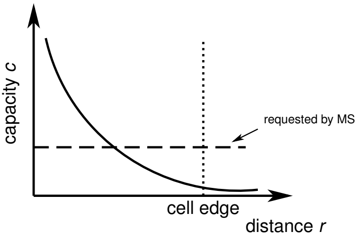
Outline





- System capacity is limited by signal-to-interference-plus-noise-ratio (SINR)
- Cell-edge user achieve low signal strength and interference from neighbor cells
- Serving low performing MS with RS at the cell edge increases SINR
- RS almost double cell spectral efficiency (CSE) and achieve rate fair scheduling at the same time[1]

Problem statement

- Does the relay-enhanced system allow to serve delay-critical services like VoIP?
- How can I investigate a relay-enhanced mobile network with VoIP traffic load?
- Does the location of RSs affect the system capacity?

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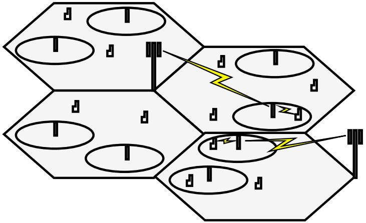

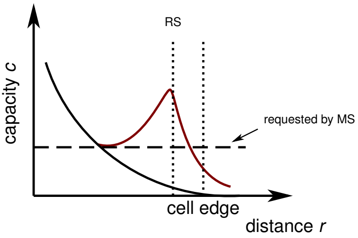

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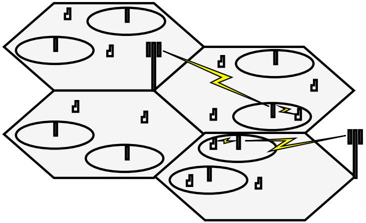

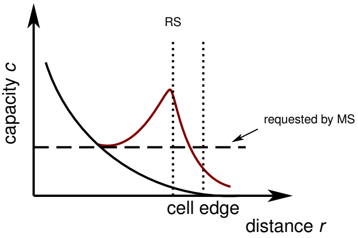

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IEEE 802.16m TDD Radio Frame

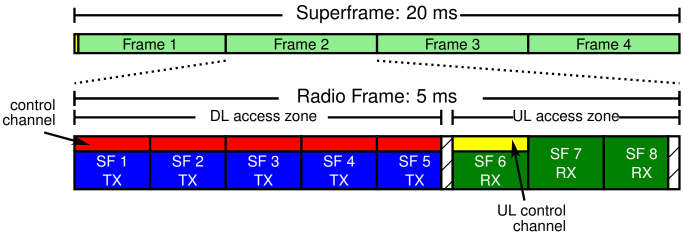


Figure : OFDMA TDD Radio Frame

- 20 ms periodic radio-superframe divided into four 5 ms radio frames
- Division of radio-frame in downlink (DL) and uplink (UL) access zone, separated by guard periods
- Subdivision into eight subframes (SFs)
- Control channel in DL SF indicates radio resource allocation for DL and UL
- UL control channel can be used to send bandwidth requests to the BS

IEEE 802.16m TDD Multi-hop Radio Frame

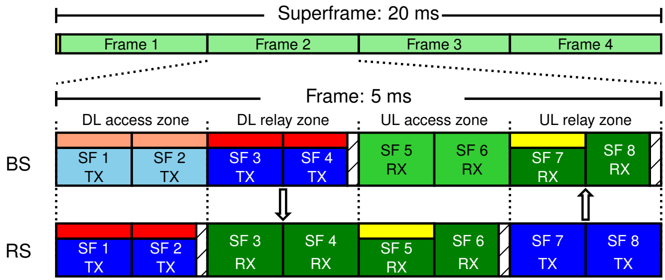


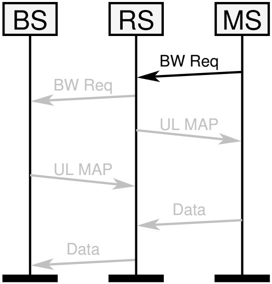
Figure : Relay Enhanced Radio Frame

- Division of frame in access and relay zone for DL and UL
  - access-zone Communication between RS $\leftrightarrow$ MS
  - relay-zone Communication between BS $\leftrightarrow$ RS and BS $\leftrightarrow$ MS
- relay station (RS) communicates with base station (BS) in relay zone
- RS performs radio resource management in relay cell
- BS allocates radio resources for single-hop mobile station (MS) and backhaul link

UL Data Flow with RSs and ertPS

Enhanced real-time polling service (ertPS)

- offers resource allocation on periodical intervals and polls MS for changes of data rate requirements
- optimized to serve delay-critical services by requesting bandwidth before packet arrives



- MS and RS have established transport connections
- MS sends BW Req to RS with requested data rate
- RS sends BW Req to BS with requested data rate
- RS indicates allocated radio resources for MS in UL MAP
- BS indicates radio resource allocation to RS
- MS sends user data according to allocation to RS
- RS sends user data to BS

Allows to deliver user data from MS to BS via RS within two radio frames. Useful for delay-critical services.

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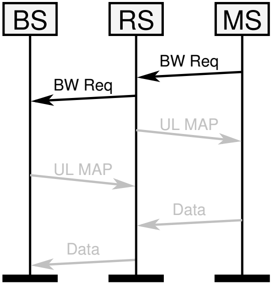

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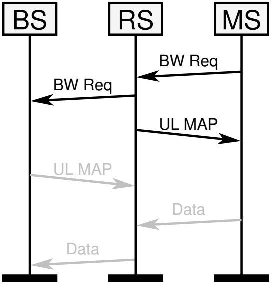

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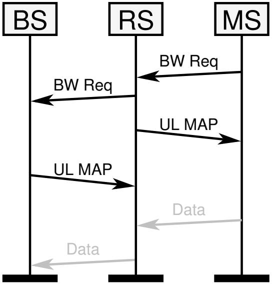

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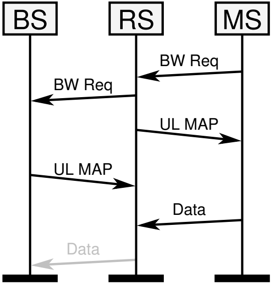

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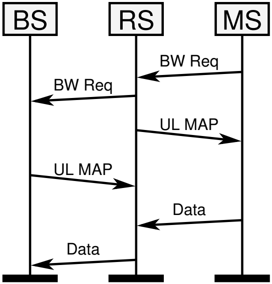

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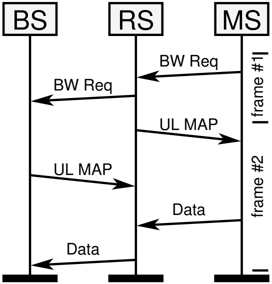

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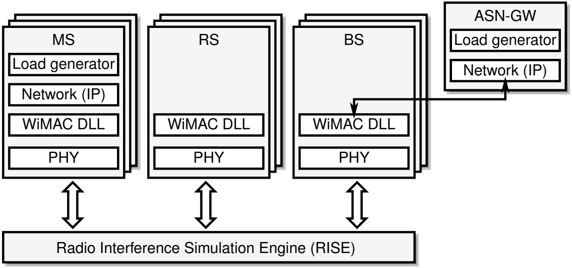
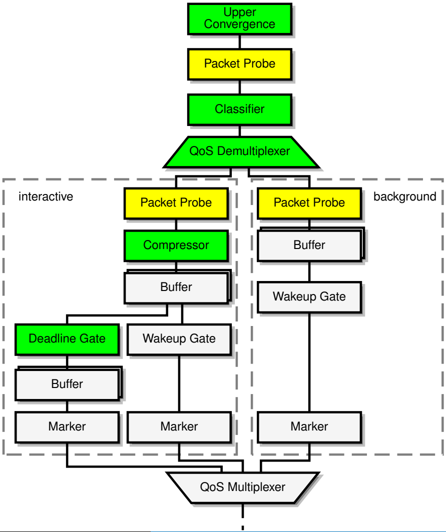
openWNS Simulator Model



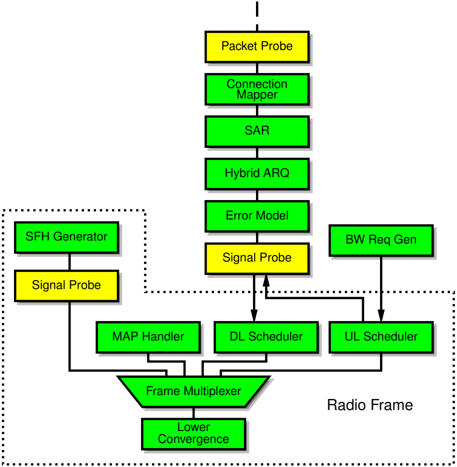
- Model is based on nodes that contain entities of each protocol layer (components)
- Components offer protocol services for higher layer protocols
- WiMAC data link layer (DLL) entities implement IEEE 802.16m protocol and are station specific
- Components are modeled with modular functional units (FUs) that implement atomic protocol functions

WiMAC BS Component (upper part)



- Custom FUs (green) are dedicated FUs of the WiMAC protocol
- Standard FUs (white) provide regular queues and improved flow control
- Probe FUs (yellow) provide measurements of packet delay and throughput
- Upper part of protocol layer offers SAP to next layer and classification of data packets
- Data packets are sorted into different queues by the type of service
- Action in upper part of protocol layer is triggered by send data requests at upper convergence

WiMAC BS Component (lower part)



- Most of the FUs are customized to model the IEEE 802.16m radio frame
- Signal probes measure channel quality (SINR, carrier strength, interference power)
- Action in lower part of protocol layer is triggered by DL/UL radio resource scheduler by wakeup calls

Simulation Scenario

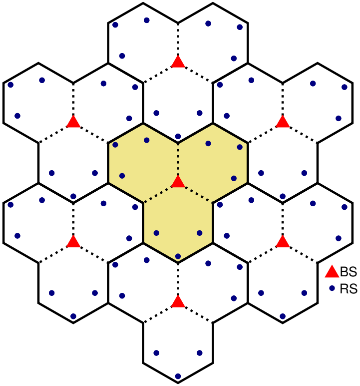


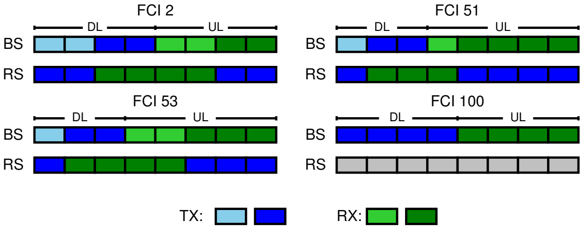
Figure : Simulation scenario

- Each BS site covers 3 cells by directional 120° antennas
- 500 m inter-site distance
- 3 RSs per cell, location optimized for DL capacity
- Urban macro ITU-R pathloss model [2]
- Pure line-of-sight (LOS) pathloss model for BS ↔ RS backhaul link
- 20s simulation time
- Carrier center frequency 2 GHz, 2.5 MHz bandwidth
- BS TX power: 40 dBm, RS/MS TX power: 21 dBm

[2] IMT-Advanced Evaluation Guidelines, M.2135, ITU-R

Radio Frame Setup

Simulation campaign to investigate frame setup on system performance.



FCI	access zone		relay zone		DL/UL
	DL	UL	DL	UL	ratio
2	2	2	2	2	4:4
51	1	1	2	4	3:5
53	1	2	2	3	3:5
100	4	4	0	0	4:4

- Conventional single-hop system with balanced DL/UL ratio with frame configuration identifier (FCI) 100
- Relay-enhanced system with FCI 2,51,53

Voice-over-IP VoIP Traffic Model

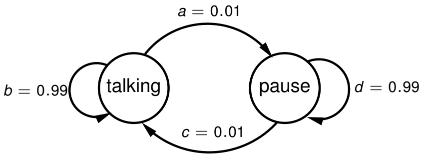
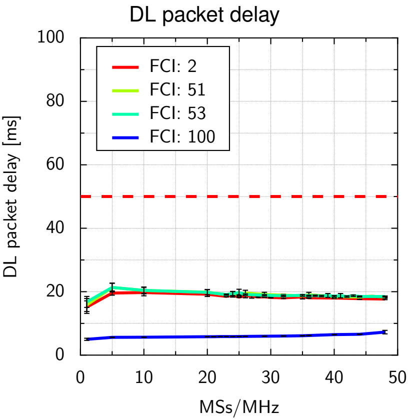


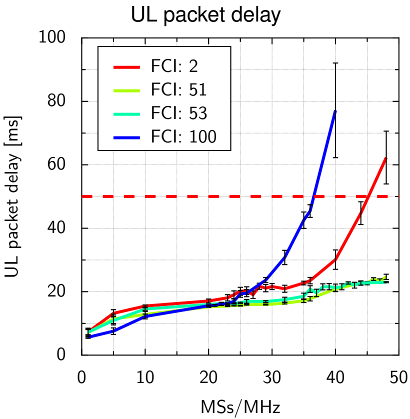
Figure : Brady model

Codec bitrate	12.2 kb/s
Encoder frame length	20 ms
Voice frame size	320 bit
Silence indicator inter arrival time	160 ms
Silence indicator frame size	120 bit
State update interval	20 ms
Voice activity factor	50 %
Mean talk spurt length	2 s

- Standard VoIP traffic model given in IMT-Advanced evaluation guidelines
- VoIP traffic realized by two-state model: talking and pause state
- Model creates data frame in talking state and silence indicator frames in pause state
- Call success condition: 98% of packets arrive within 50 ms $\rightarrow$ packet delay is crucial for VoIP service

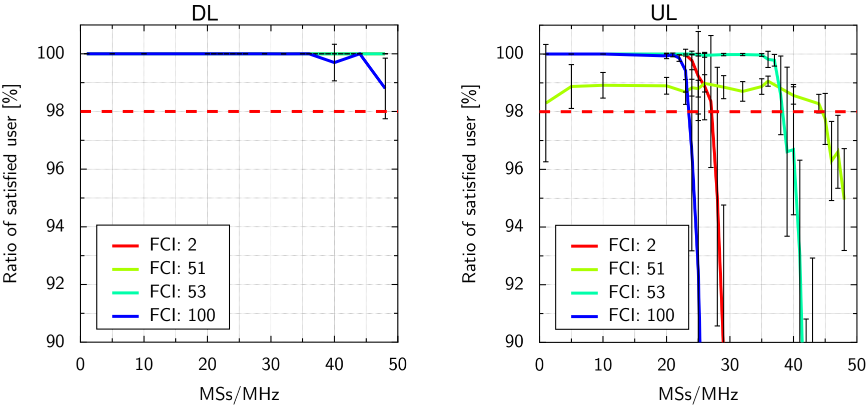
95-percentile of Packet Delay





- DL packet delay is not critical
- UL is the bottleneck of the system without RSs
- RSs reduce UL packet delay at heavy load situations

Number of Served MSs



- System always serves all calls in DL
- Single-hop scenario serves 23 MS/MHz in UL
- RSs allow to serve up to 44 MS/MHz in UL → 91% gain

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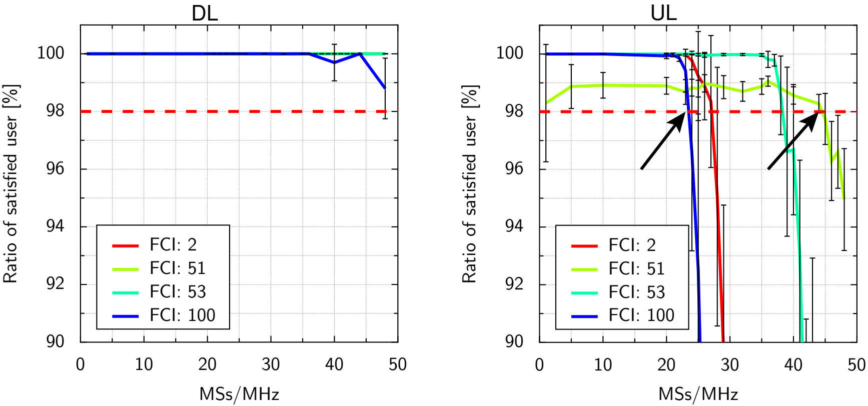

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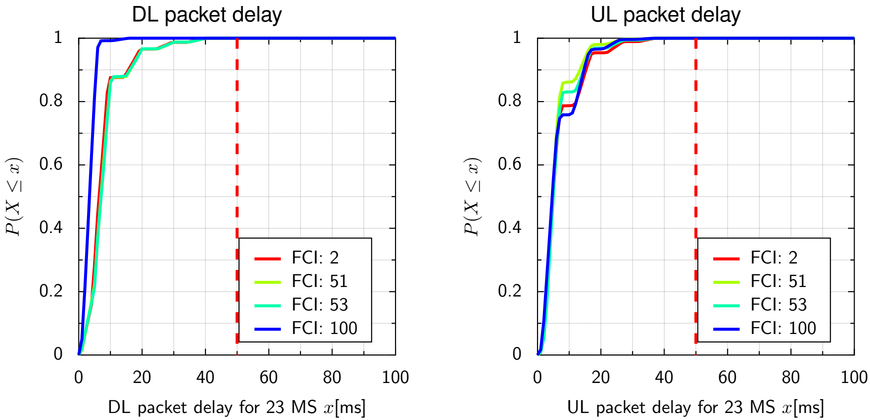
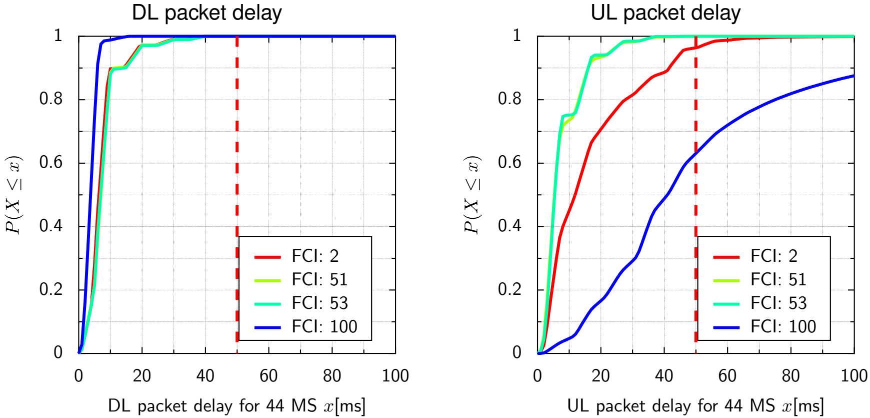
Packet Delay with 23 MS/MHz



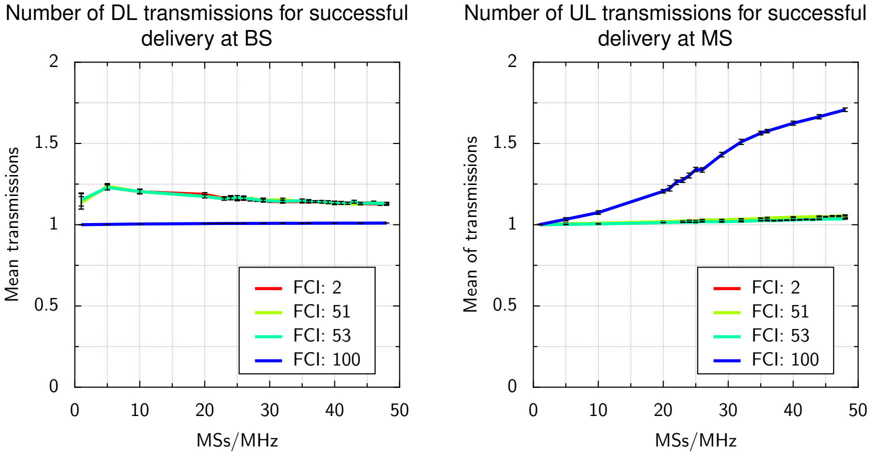
- RSs increase DL packet delay marginally due to second hop
- RSs reduce UL packet delay at first transmission

Packet Delay with 44 MS/MHz



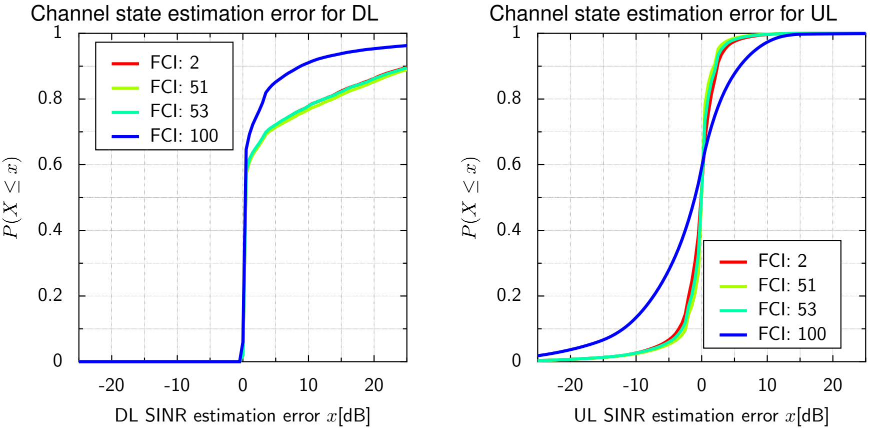
- DL packet delay is within acceptable bounds
- Single-hop scenario fails to serve VoIP packets in time in UL
- RSs are able to maintain low packet delay in heavy load situations
- Packet delay of FCI 51 and 53 differ marginally $\rightarrow$ service failure of FCI 53 caused by lost packets that are not shown here

Number of Transmissions



- RS introduce retransmissions at BS → RS link caused by Kalman-filter channel estimator
- Retransmissions cause high packet delay for UL in single-hop scenario
- RSs reduce the amount of retransmissions for UL

Channel State Estimation Error with 23 MS/MHz



- Channel state is never underestimated for DL (worst-case approach)
- RSs reduce channel state estimation error for UL significantly

Conclusion

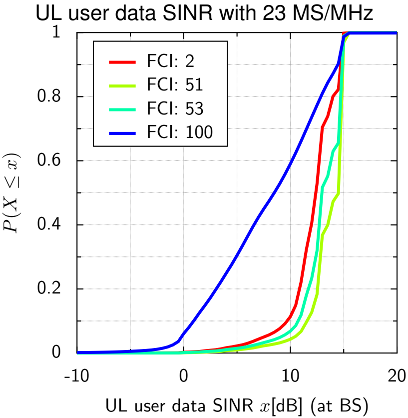
Summary

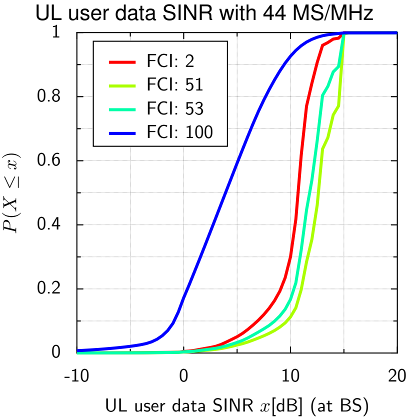
- IEEE 802.16m has been implemented in the openWNS for system level simulation of VoIP services with the help of modular FUs.
- Performance evaluation has been performed for different frame configurations (FCI).
- RSs almost double VoIP capacity by improving channel state estimation and SINR for UL.

Thank you

kks@comnets.rwth-aachen.de

UL User Data SINR distribution





- RS provide a significant gain in user data SINR for UL and DL