Adaptive Point-to-Multipoint Transmission for Multimedia Broadcast / Multicast Services in LTE

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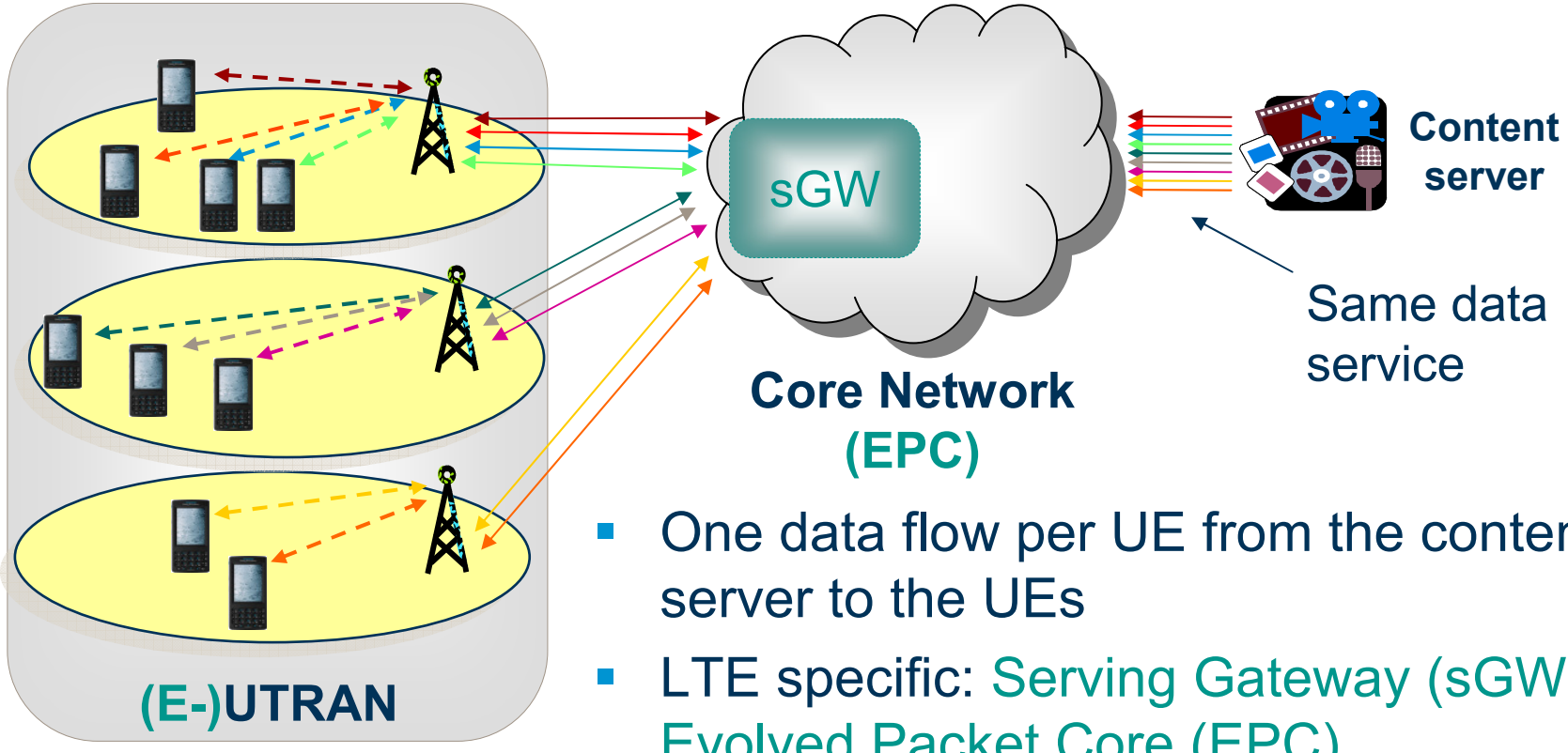
Overview

- Multimedia Broadcast / Multicast Service (MBMS)
- Application scenario
- MBMS transmission modes in LTE
- New approach: adaptive PTM
- Optimizations for downlink & uplink
- Link adaptation analysis
- Conclusion

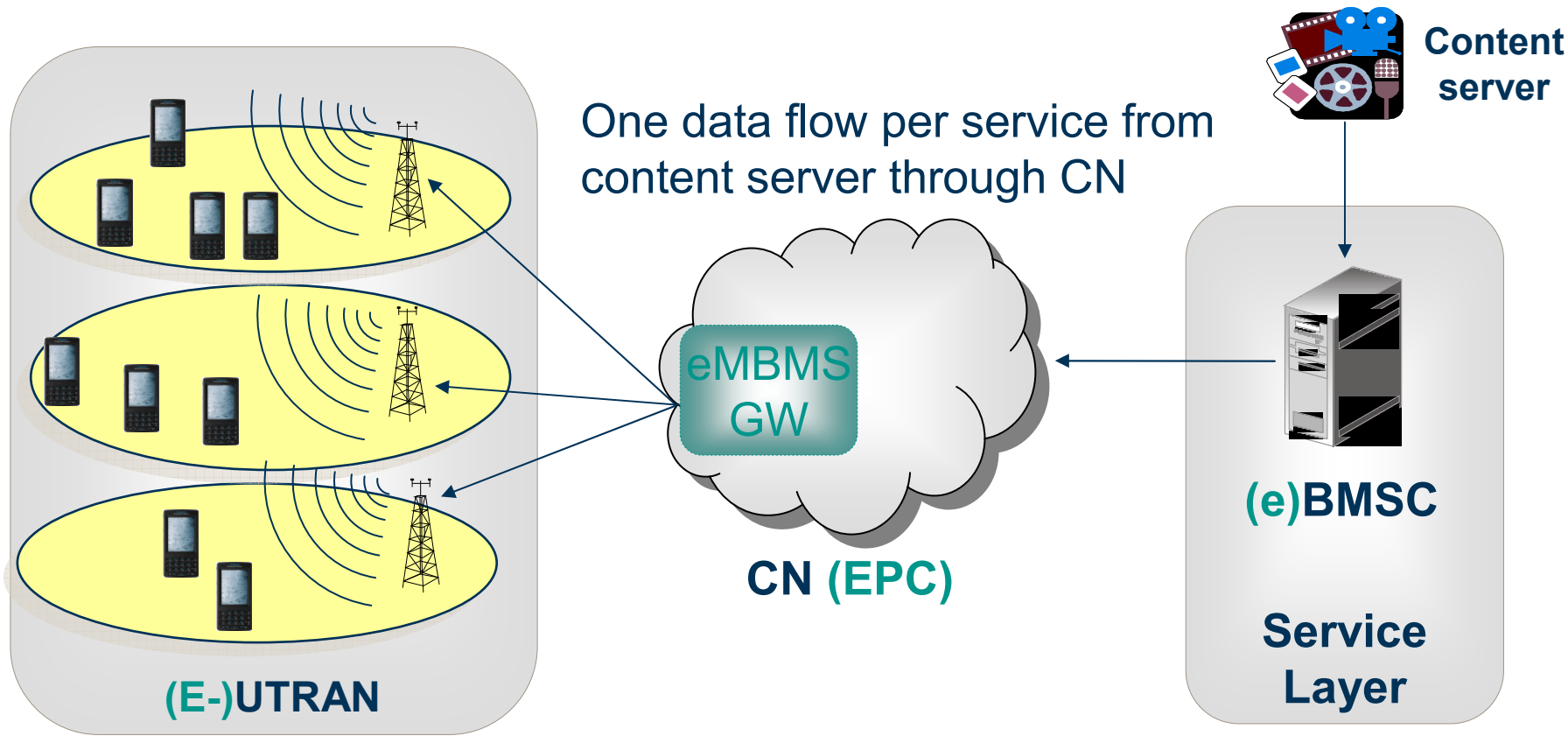
Motivation for Multimedia Broadcast / Multicast Service



- One data flow per UE from the content server to the UEs
- LTE specific: Serving Gateway (sGW), Evolved Packet Core (EPC)

- Standardization of Multimedia Broadcast / Multicast Service (MBMS) for UMTS Release 6 in 2005
  → more efficient delivery of identical multimedia contents to several consumers interested in the same service

MBMS architecture



- New transmission mode:
  - Introduction of point-to-multipoint (PTM) bearers
  - Broadcast on radio interface
- (e)BMSC controls MBMS sessions and corresponding bearers

MBMS opportunities in LTE context

- Conventional **single-cell** transmission modes for MBMS
  - Point-to-Point (PTP) transmission
    - Dedicated downlink and uplink channels for each user
    - Transport format selection and retransmissions based on individual feedback
  - Classical Point-to-Multipoint (PTM) transmission
    - No feedback
    - Common channel with fixed transport format (TF)

- New approach:
  - Adaptive PTM transmission based on user-individual feedback
    - Group-specific transport format selection
    - Retransmissions based on feedback

Application scenario

Video live streaming (Mobile TV)

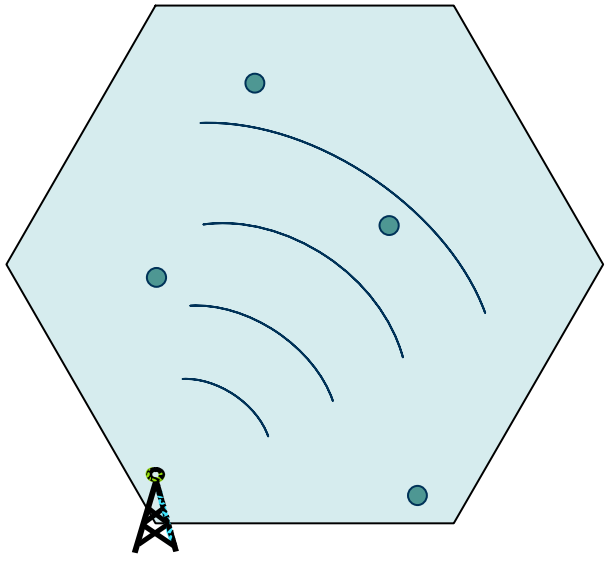
- Initial buffering only permits low delay jitter
- Max. delay of 2 seconds
  → limited application-layer coding possible
- User satisfaction rate depends on
  - Video frame error rate (FER) and
  - Buffer underrun
- In this study
  - Source data rate of 128 kbps
  - Frame rate of 12.5 fps
  - Fixed video frame size
  - Tolerated FER = 1%
  - No buffer underrun tolerated

PTP transmission in LTE

- Orthogonal Frequency Division Multiplex (OFDM) technology
  - Allows for frequency-selective scheduling
    → Requires channel quality indicator reports for each subband (multiband CQI reporting)
  - Basic configuration: periodic measurements and CQI reporting for active users

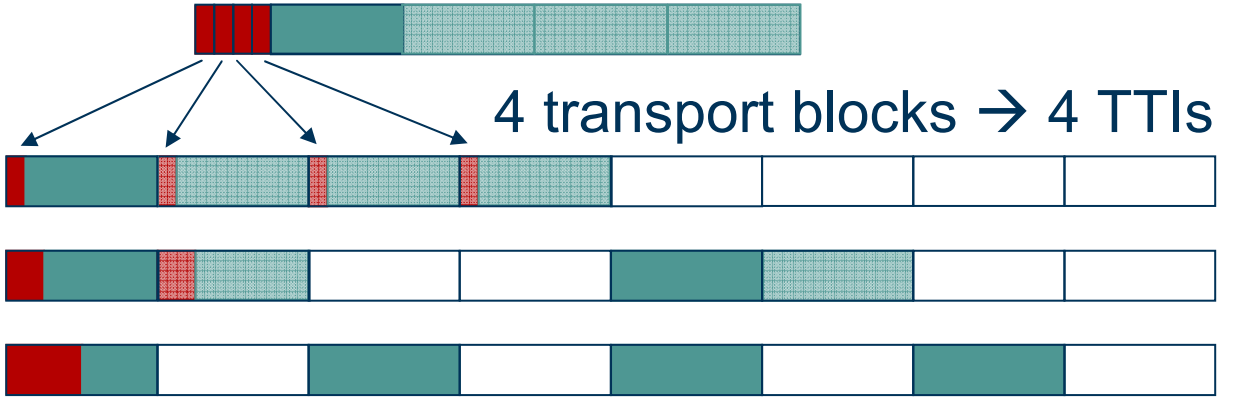
- Hybrid Automatic Repeat reQuest (HARQ)
  - Status report for decoding result of transport block (TB)
    - Success: ACK
    - Failure: NACK
  - on reception of NACK → retransmission by base station
  - Incremental redundancy scheme

Classical PTM transmission mode

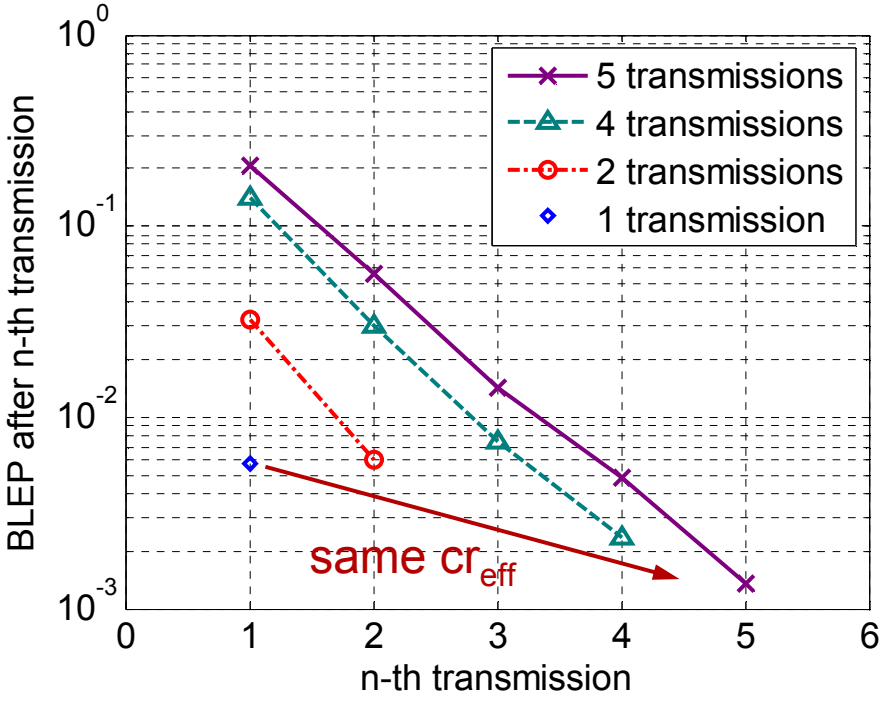


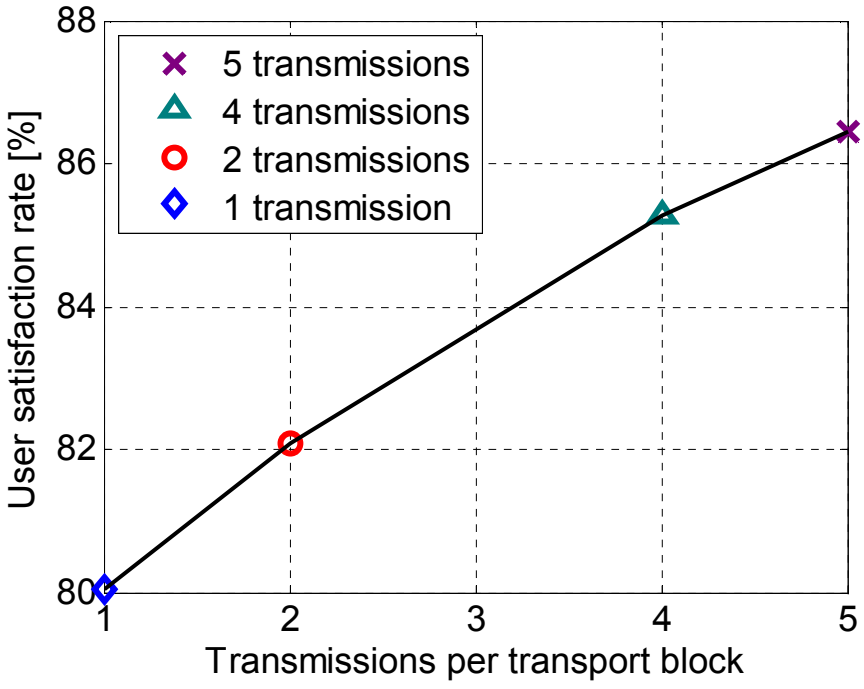
- No feedback → fixed transport format
- Required coverage
  (user satisfaction rate): 95 %
- Robust modulation scheme → QPSK
- Code rate of 1/12
- Blind retransmissions with effective code rate of 1/12 → time diversity
- Retransmissions based on incremental redundancy including repetitions

Data block Redundancy block



Classical PTM: performance evaluation





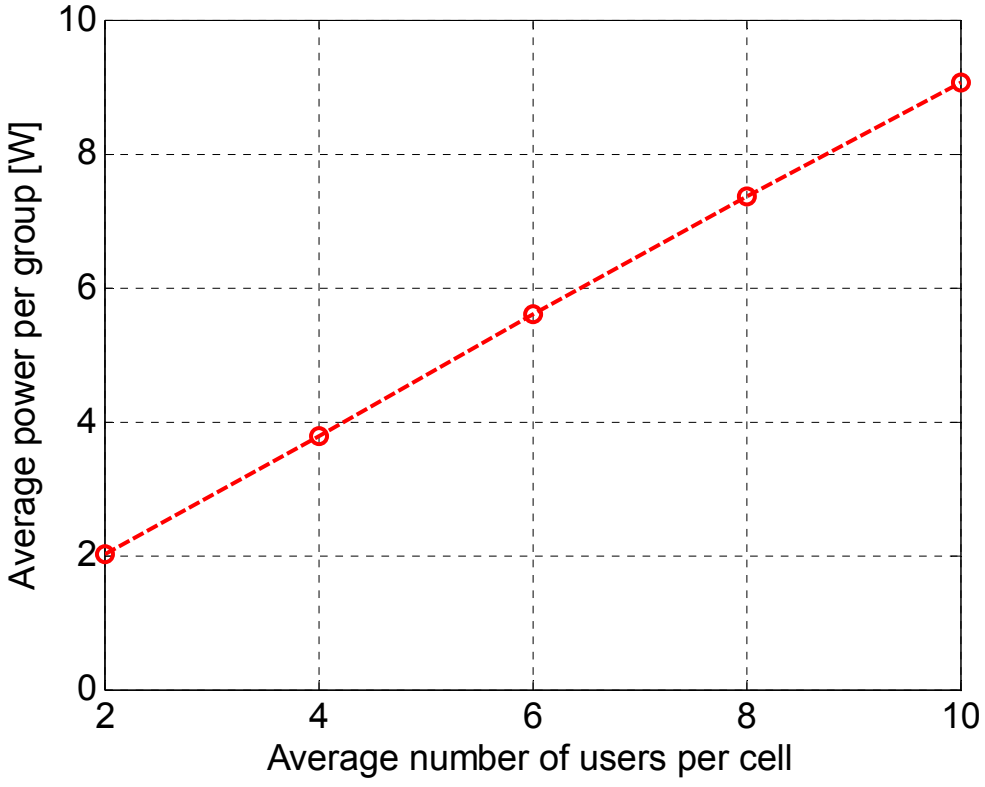
- Decreased BLER due to gain from increased time diversity
- Reduced number of transport blocks per video frame further decreases FER
- Decreased FER is reflected in user satisfaction rate

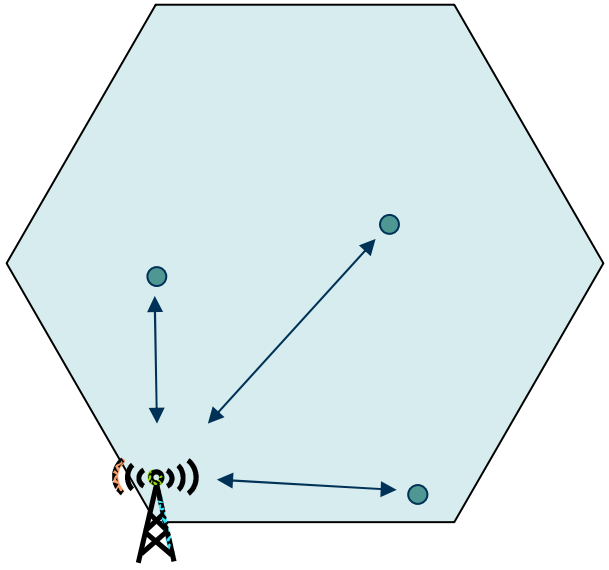
Simulation parameters

Network size	7 sites (3-sector hexagonal grid)
Cell radius	500 m
Distance attenuation	29.03 + 3.52 · 10 · log(d) distance d in [m]
Multipath fading	3GPP Typical Urban
Shadow fading	log-normal, σ = 8 dB
Spectrum allocation	5 MHz
eNodeB transmit power	20 W / 13 dBW
Maximum antenna gain	14 dBi
Receiver	Single antenna, **no receiver diversity**
UE speed	3 km/h
UE CQI reporting period	10 ms
Max. no. of HARQ transmissions	8

Resource allocation in downlink

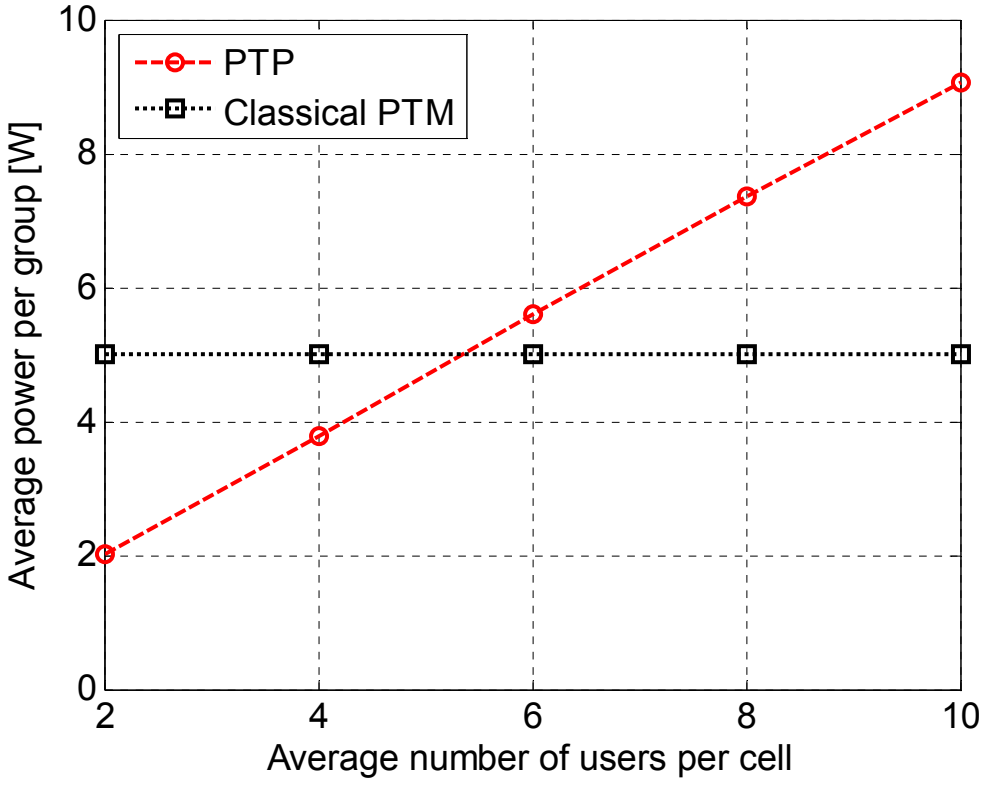
- PTP transmission
  → dedicated channels for each MBMS user

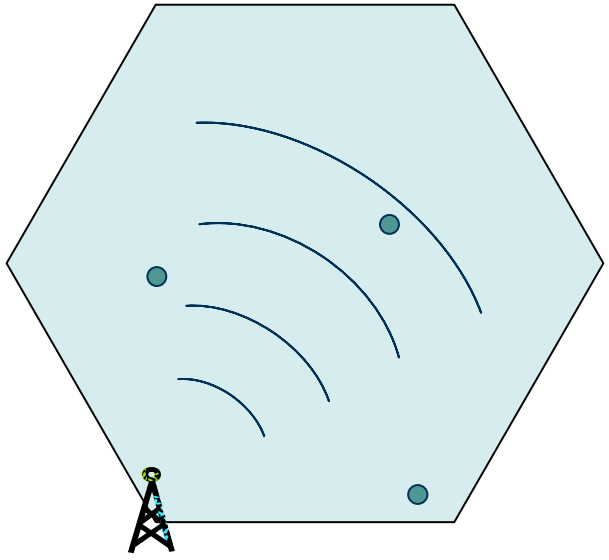




Resource allocation in downlink

- PTP transmission
  → dedicated channels for each MBMS user
- Classical PTM transmission
  → fixed robust transport format for required coverage





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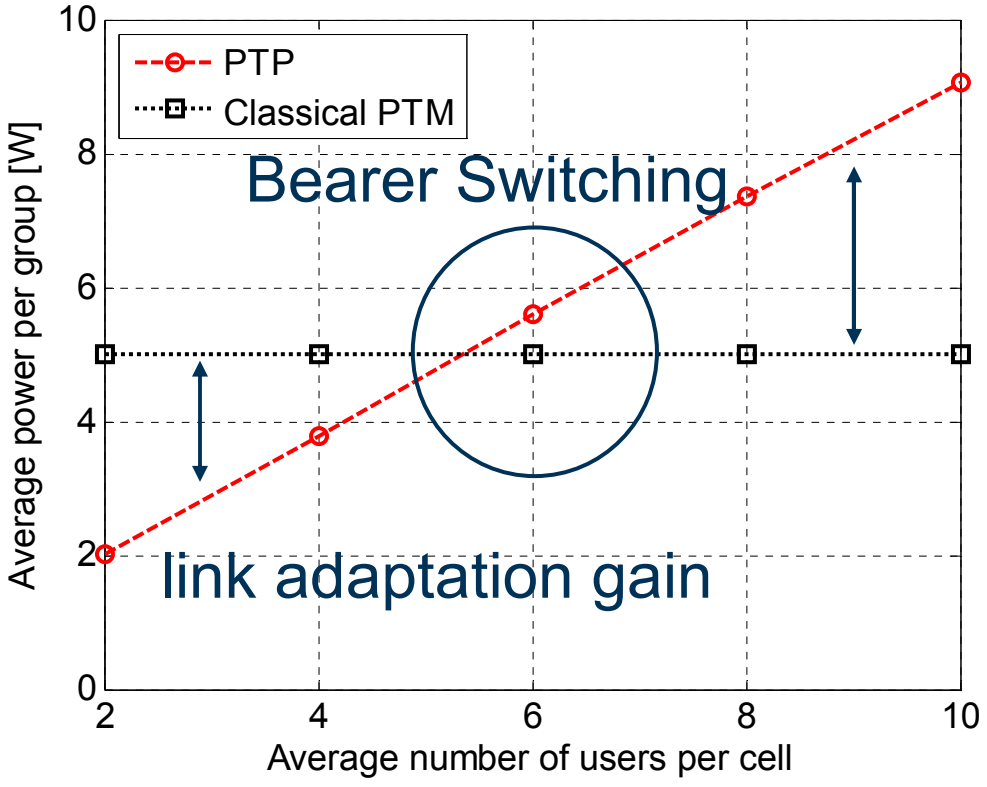


one-to-many gain

How to combine both gains better?

Known approach* for HSDPA

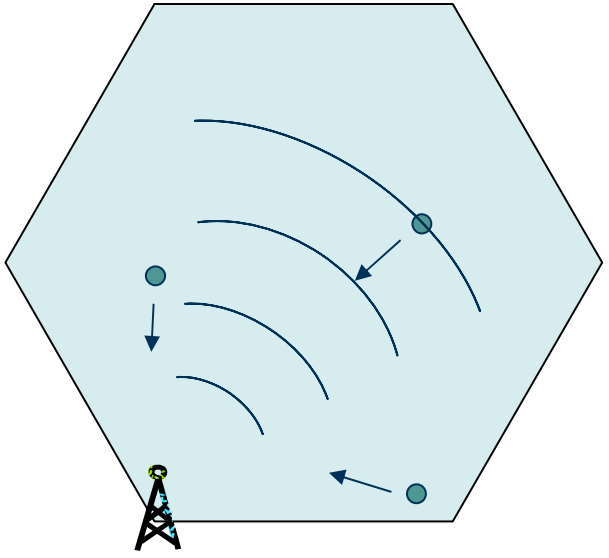
- HS-DSCH used for PTM transmission
  - received by all users in the same service group
- Fixed transport format and power
- Number of retransmissions determined by HARQ feedback
- Retransmissions based on chase combining
- Compared to fixed number of 5 transmissions per TB
  - 70 % transmission savings for 2.38 users per group
  - 40 % transmission savings for group size of 23.8 users
- User satisfaction rate: 96-97 %

* V. Vartiainen, J. Kurjenniemi, “Point-to-Multipoint Multimedia Broadcast Multicast Service (MBMS) Performance over HSDPA”, in Proc. IEEE Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Athens, Greece, September 2007, pp. 1–5.

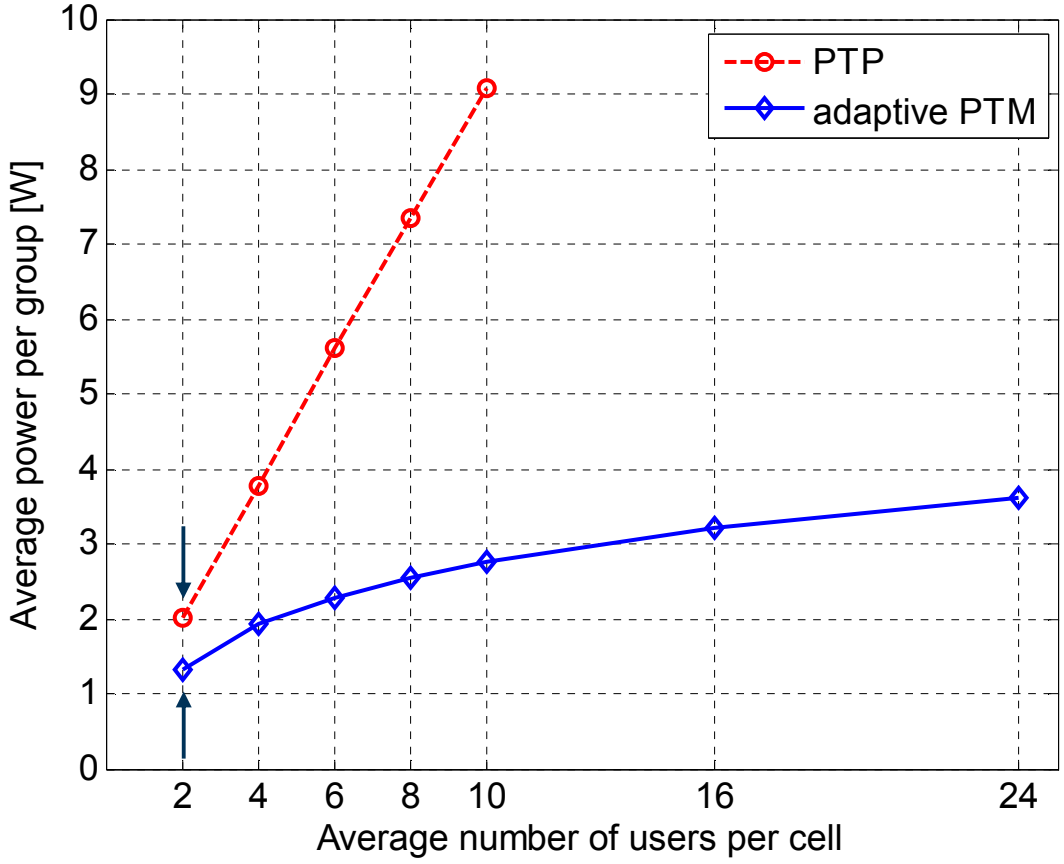
Approach for LTE: adaptive PTM

- One common downlink channel (PTM concept)
- Dedicated uplink channels for each MBMS user (PTP concept)

- Periodic channel measurements and CQI reporting from each user for each subband
- Transport format selection determined by worst user → based on lowest CQI value
- ACKs and NACKs from each single user
- Retransmissions until
  - all receivers can decode the packet or
  - maximum number of allowed transmission attempts reached

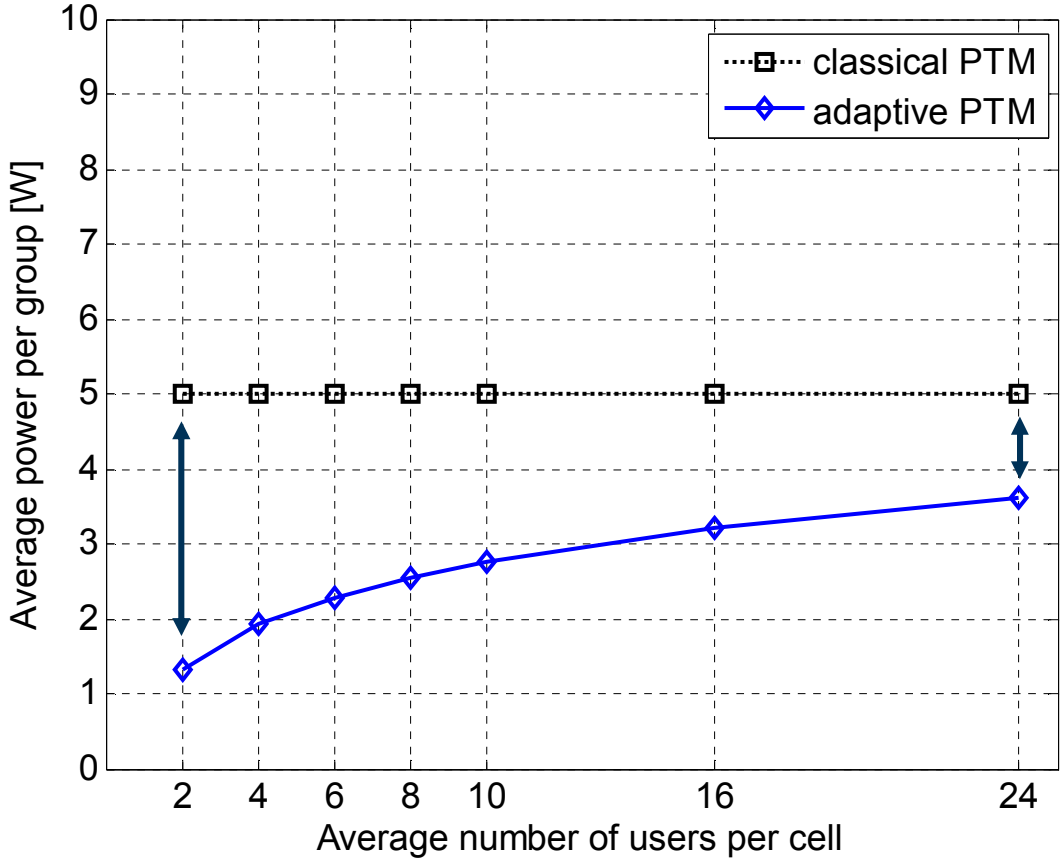


Resource savings achieved by adaptive PTM



- Compared to PTP at least 33% resource savings

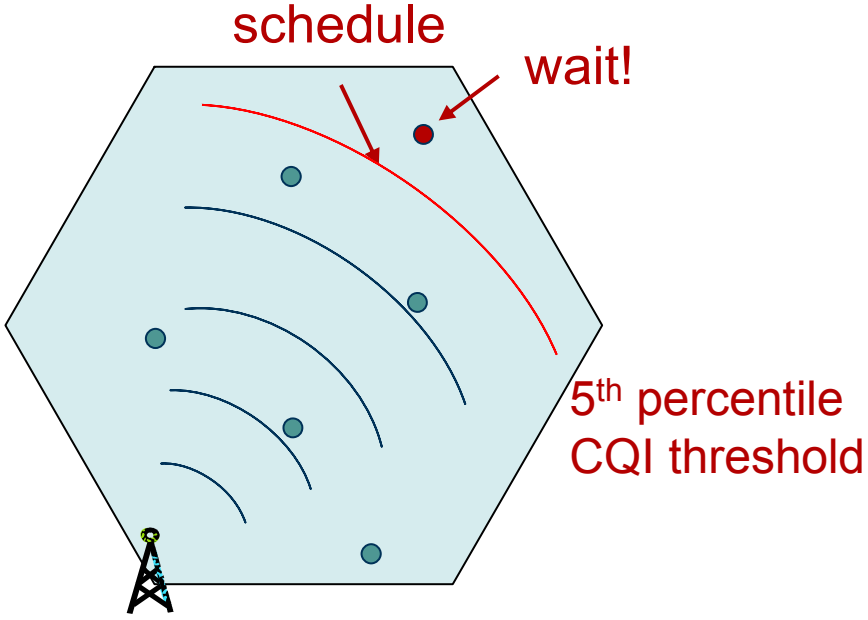
Resource savings achieved by adaptive PTM

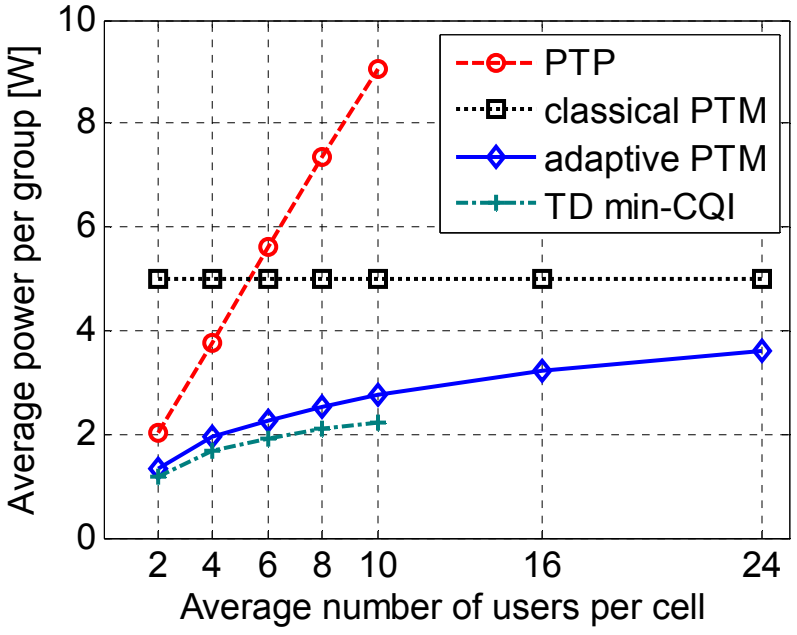


- Compared to classical PTM
  - 73 % resource savings for group size of 2 users
  - Still 30 % resource savings for more than 20 users

Resource optimization for downlink

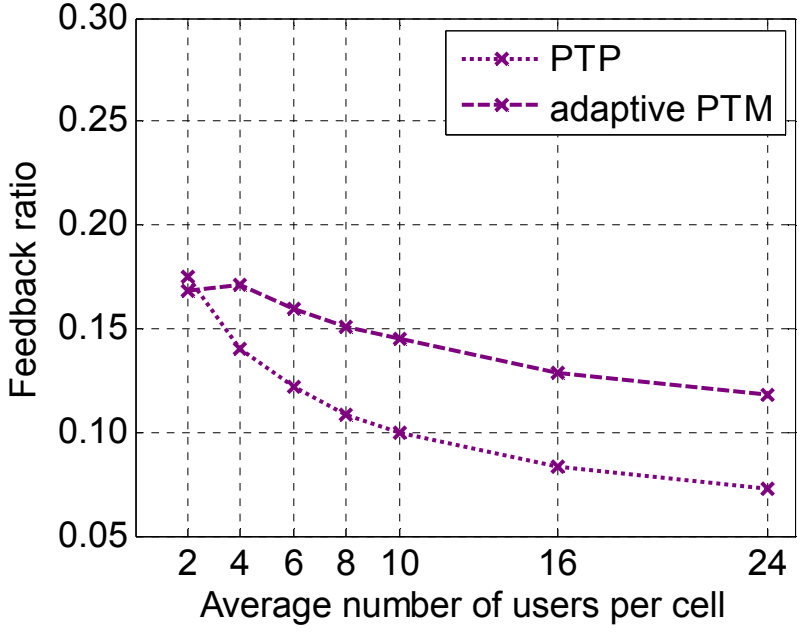
- Avoid that worst case user substantially deteriorates performance of whole group using CQI threshold
- Time-domain minimum-CQI scheduling technique **(TD min-CQI)** :
  - do not schedule while CQI too low
  - CQI threshold: 5th percentile channel quality

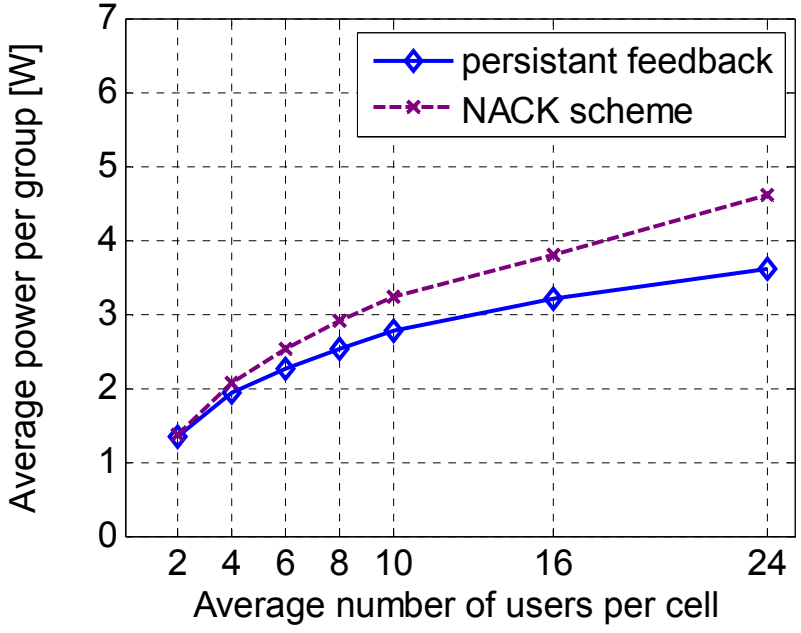




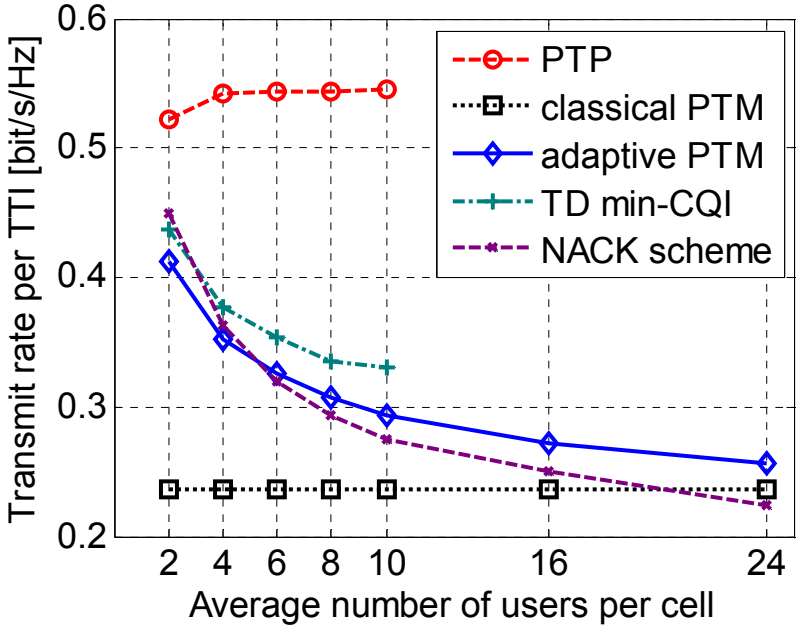
Resource optimization for uplink

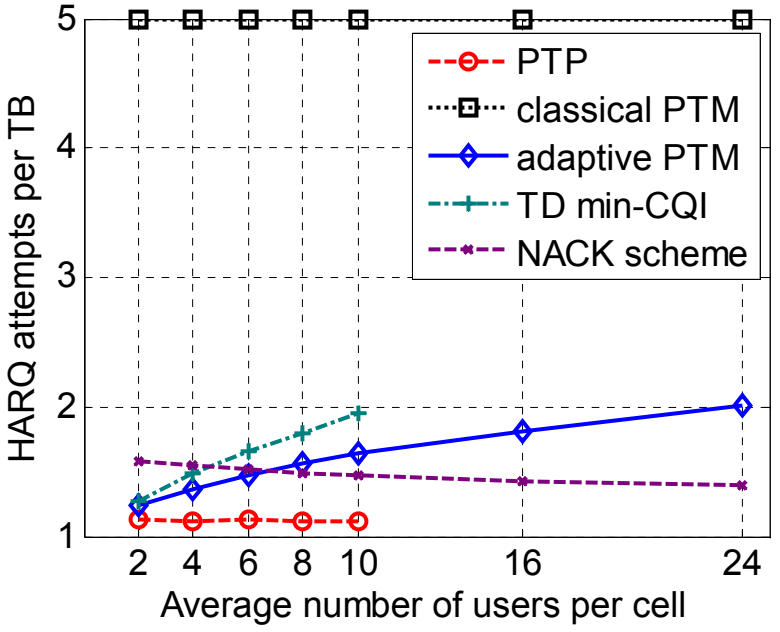
- NACK-oriented feedback scheme
  - Exclusive NACK scheme instead of combined ACK and NACK syntax
  - NACK-triggered CQI reporting: CQI report only when NACK signal transmitted → actual adaptation phase
  - Recovery phase: reduce robustness of transport format for transmission of new data





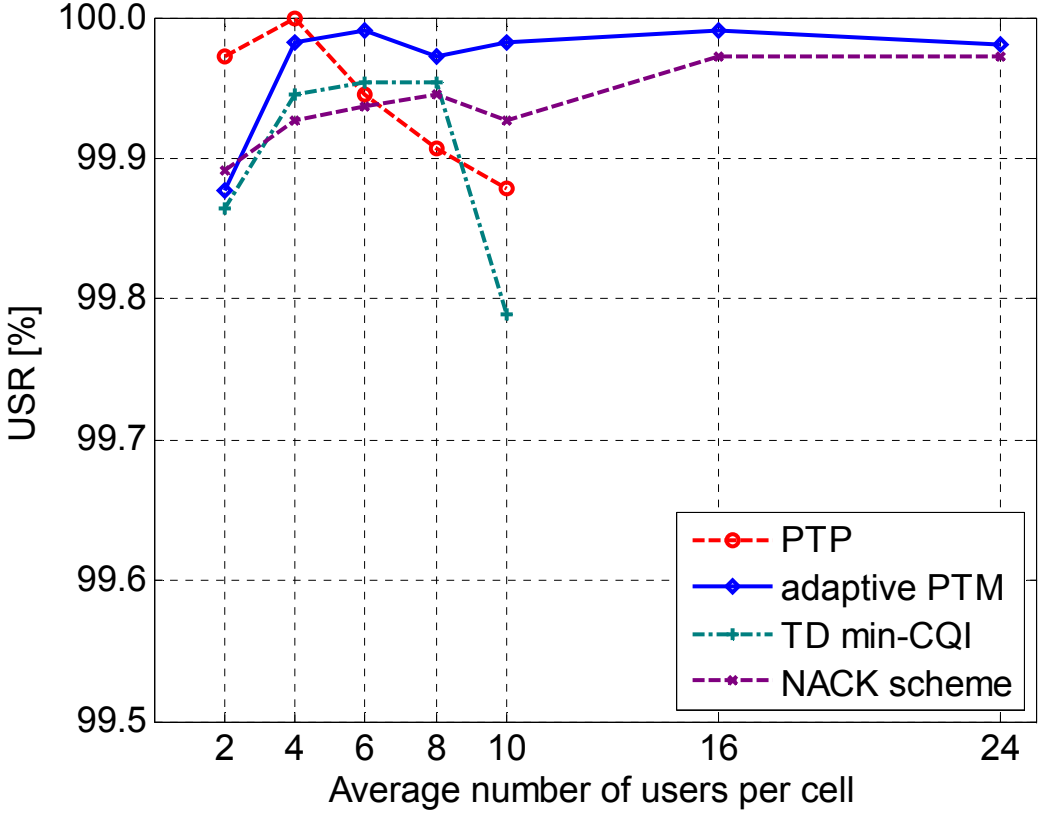
Link adaptation analysis





- Adaptive PTM: reduced transmit rate and increased HARQ transmissions for increasing group size
- The NACK-oriented feedback scheme can only slowly adapt to better channel conditions → conservative TF selection
  → Reduced HARQ attempts for increasing group size

User satisfaction rate



- All investigated PTM schemes provide USR >> 95 %
  → In the same range as PTP transmission
- Further resource savings achievable for reduced USR

Conclusion

- Significant improvement for small user groups by adaptive PTM transmission with user satisfaction rate (USR) > **99 %**
  - Compared to PTP
    - Minimum downlink power gain of 33 % (≥ 2 users per group)
    - NACK-oriented feedback scheme reduces uplink load
  - Compared to classical PTM (95 % USR)
    - Up to 73 % downlink power gain (for 2 users per group)
- NACK-oriented feedback scheme provides good compromise in both uplink and downlink resource consumption
- Assuming the typical USR of 95 % also for adaptive PTM the gains compared to classical PTM can be even higher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Drawback of segmentation

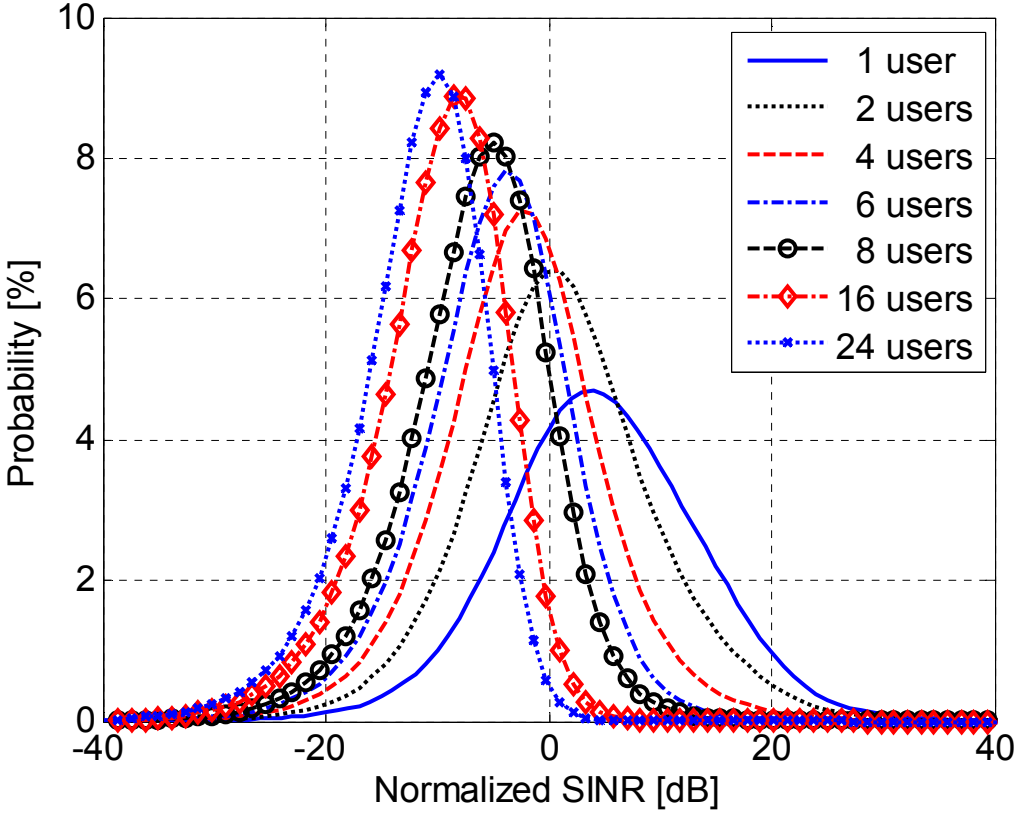
$$FER = 1 - (1 - BLER)^{N_{TB}}$$

$$\Rightarrow BLER_{\max} = 1 - \sqrt[N_{TB}]{1 - FER}$$

N_{TB} … number of transport blocks per video frame

N_{TB}	$BLER_{max}$
1	0.01
2	0.005
4	0.0025
5	0.0020

Group channel quality



- Group channel quality: channel quality experienced by user of the group with the worst reception conditions
- Normalized SINR: SINR assuming transmit power of 1 Watt