QoE based Resource Management in Wireless Networks

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Overview

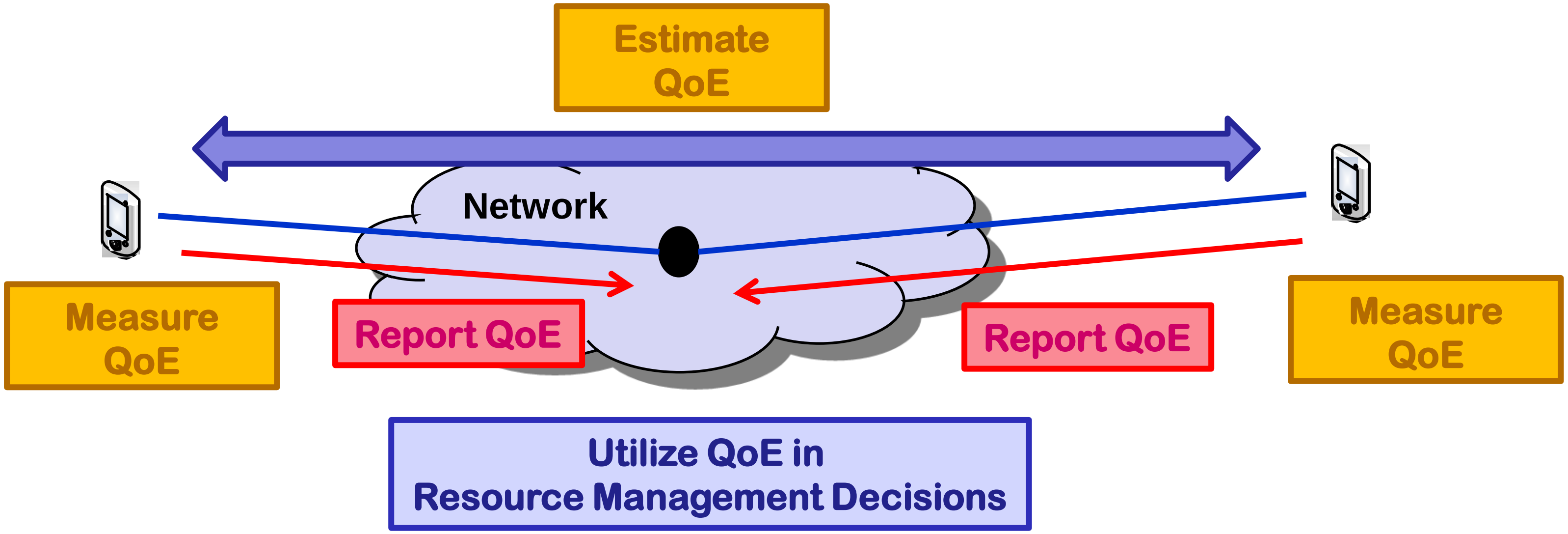
- Introduction
- Idea of QoE based resource management
- Two examples:
  - VoIP Support in Mesh Networks
  - QoE based VoIP scheduler in OFDMA networks
- Conclusion

Introduction

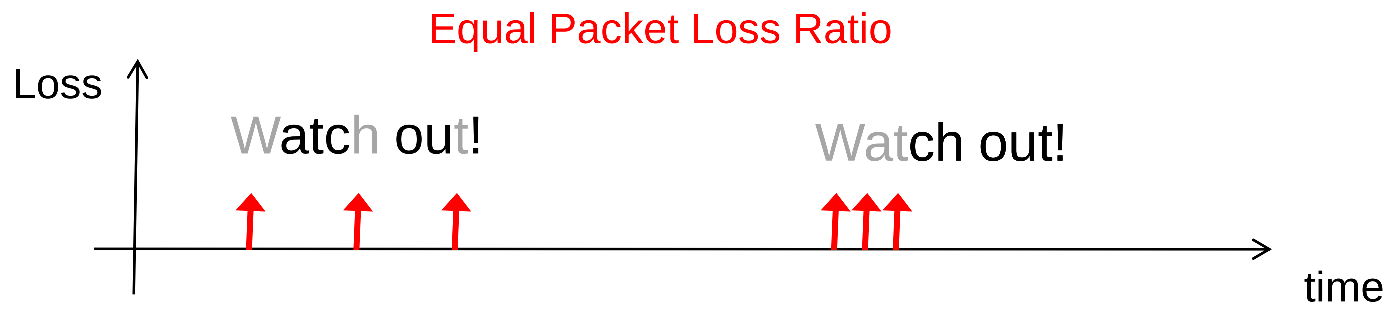
- Resource management in wireless and wired networks based on QoS parameters
  - scheduling, admission control ensure QoS
  - decoupling makes life “easy”, “I work on Layer 2”
- QoS parameters on MAC do not fully express quality on application layer
  - setting of QoS parameters difficult
- Approaches for monitoring application layer quality (Quality of Experience, QoE) available
- Idea: use of QoE for resource management in wireless networks

QoE based Resource Management

- Main functionality
  - QoE assessment
    - by the application or by the network
  - QoE based resource management decision
    - by the application or by the network
  - Signaling if assessment and resource management are not located on same machine



Intrinsic QoS vs. Subjective QoS



- Resource management typically assures long term packet loss ratio
  - Intrinsic QoS (IQ)
- Voice quality strictly speaking means speech quality
  - function of the packet loss pattern
  - bursty worse than regular/uniform
- Speech quality is highly subjective
  - Quality of Experience (QoE) or Subjective QoS (SQ)

Assessment of Subjective and Objective QoS - Example: Speech Quality -

- Perception depends on context, content, auditory and memory potentials

- Auditory assessment
  - ultimate assessment, involves humans

- Perceptual evaluation of speech quality (PESQ)
  - compare speech sequences before and after transmission

- Instrumental assessment
  - Objective QoS (OQ)
  - map measured parameters to known SQ ratings
  - E-Model: measure and map information loss, delay, noise to SQ rating

E-Model and MOS

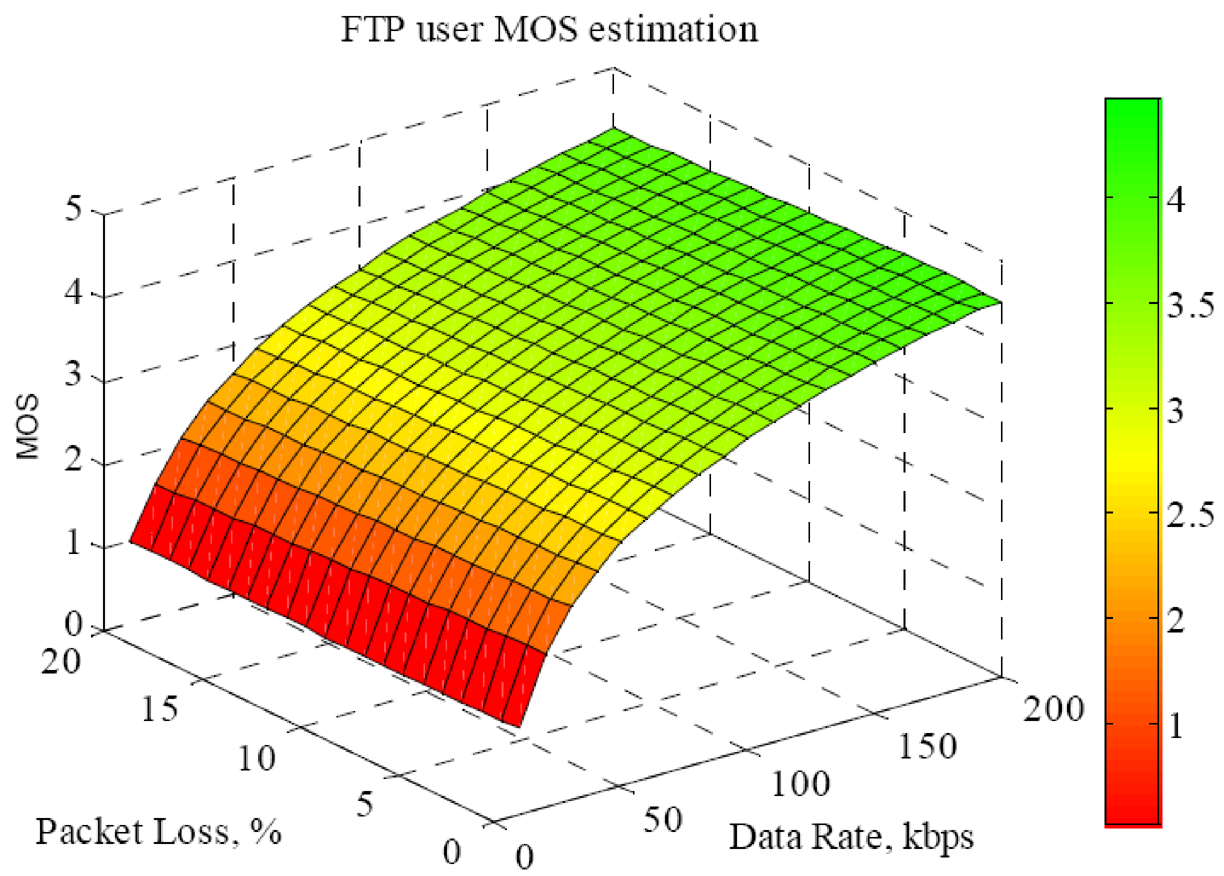
- ETSI study adopted by ITU
  - ITU G-107 The E-Model, a computation model for use in transmission planning

$$R = R_0 - I_S - I_d - I_e + A$$

- I_S: signal-to-noise impairment
- I_d: mouth-to-ear delay impairment
- I_e: equipment impairment (packet loss)
- A: advantage factor (mobility)

R-factor	Quality of voice rating	MOS
90 < R < 100	Best	4.34 – 4.5
80 < R < 90	High	4.03 – 4.34
70 < R < 80	Medium	3.60 – 4.03
60 < R < 70	Low	3.10 – 3.60
50 < R < 60	Poor	2.58 – 3.10

Example: MOS for FTP



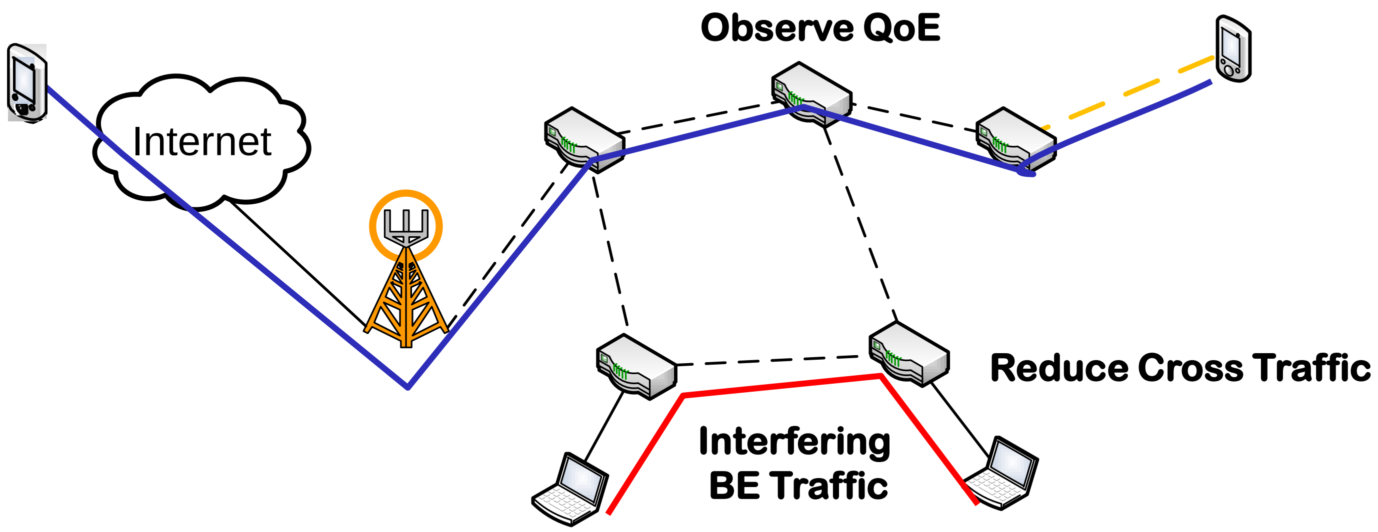
S. Khan, S. Duhovnikov, E.Steinbach, M. Sgroi, W. Kellerer, “Application-driven Cross-layer Optimization for Mobile Multimedia Communication using a Common Application Layer Quality Metric”, IWCMC 2006

EXAMPLE 1:
DYNAMIC BANDWIDTH CONTROL IN WIRELESS MESH NETWORKS: A QUALITY OF EXPERIENCE BASED APPROACH

Rastin Pries, David Hock, Nico Bayer, Dirk Staehle,
Veselin Racocevic, Bangnang Xu, Phuoc Tran-Gia

ITC Specialist Seminar, Karlskrona, Sweden, 2007

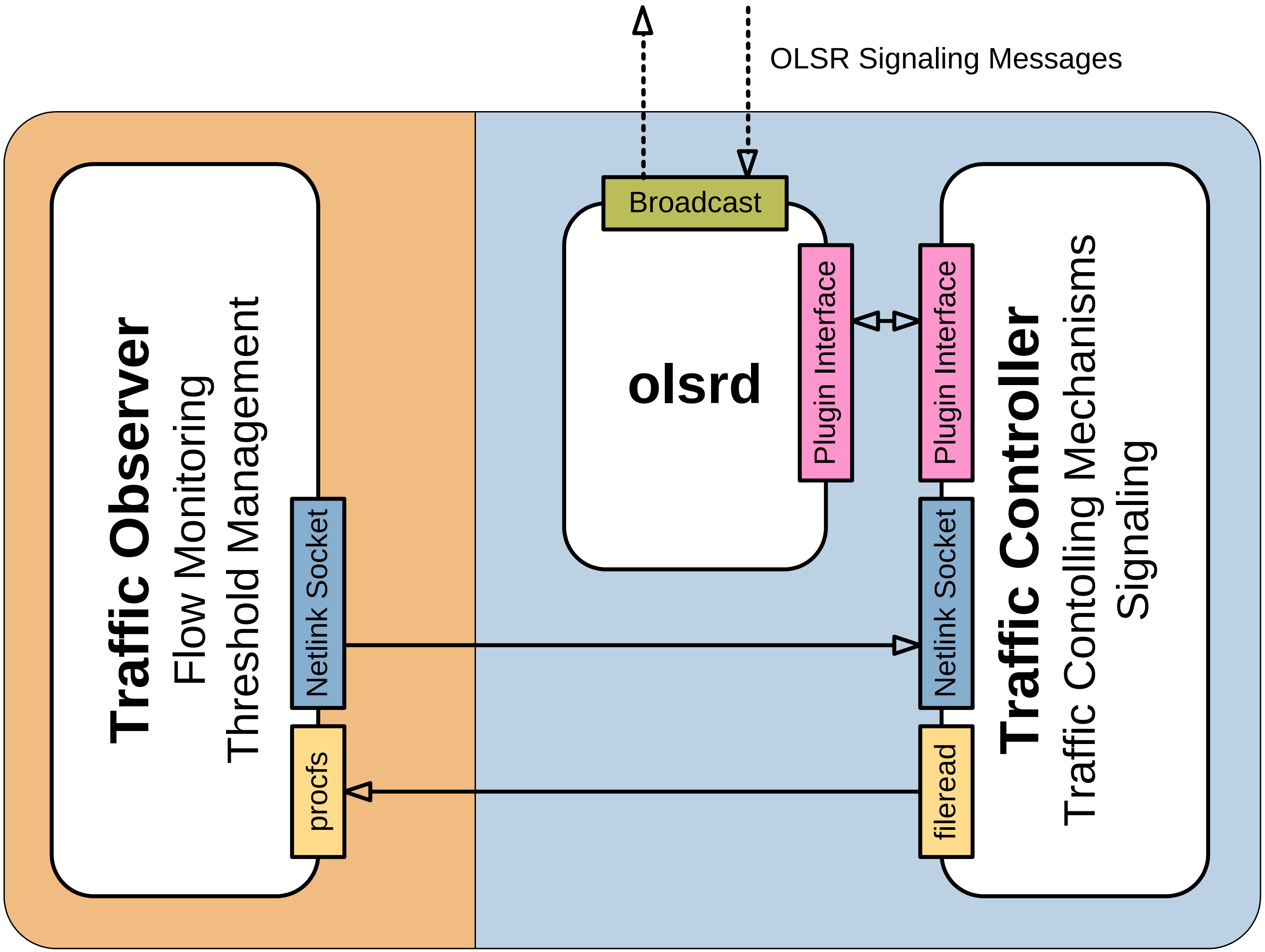
Example 1: VoIP Support in Mesh Networks



- **Analysis of real-time applications in Wireless Mesh Networks**
- Very good performance in undisturbed networks
- In highly loaded networks quality decrease due to
  - internal queuing problems
  - cross-traffic influences

→ Proposition of a mechanism to detect problems and to react on them to conserve the Quality of Experience level

Implementation - Structure



Traffic Observer

- Alerting of QoE decrease if certain thresholds are exceeded.

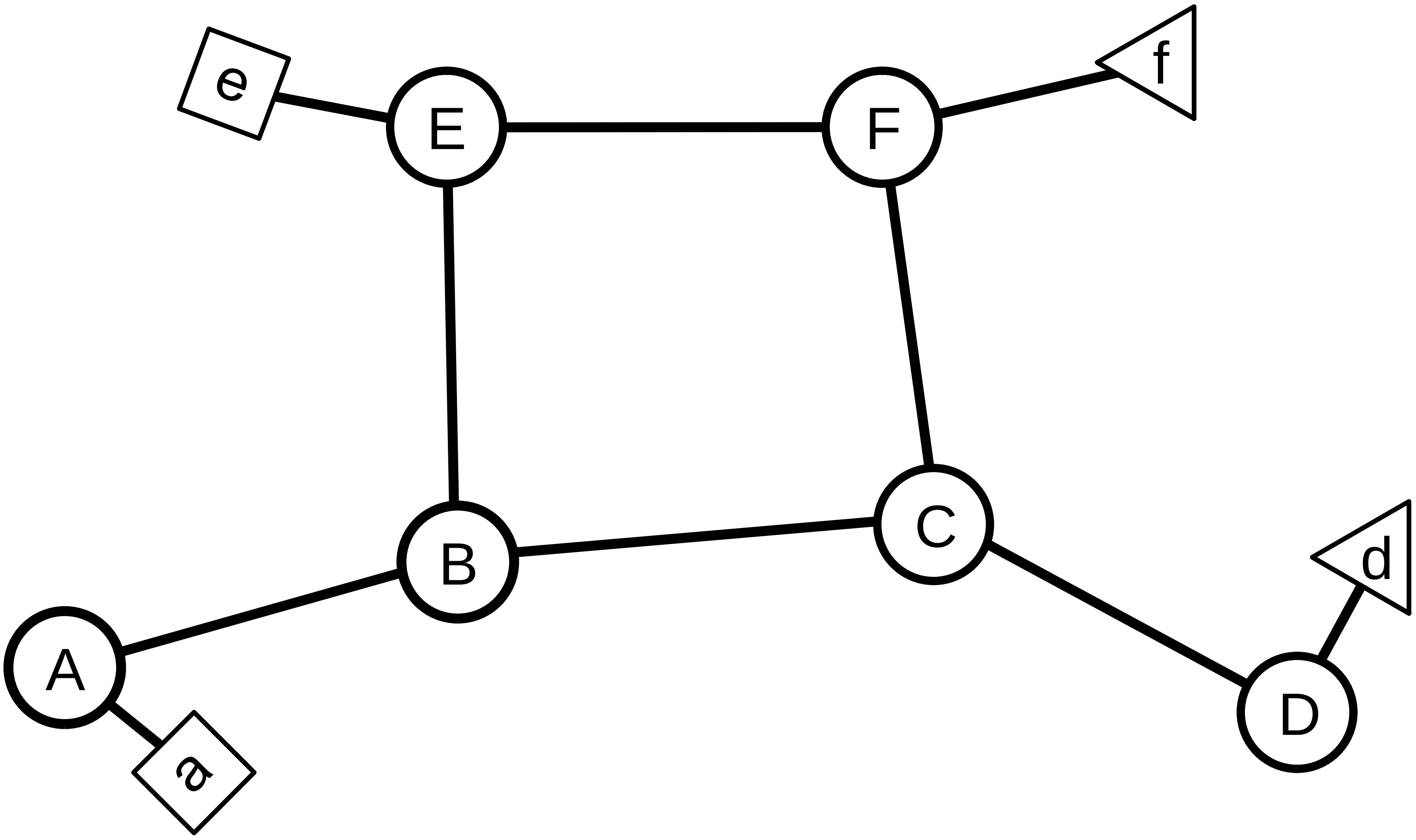
- Available: Quality of Service (QoS) parameters
  - Packet loss, Jitter
- Desired: Quality of Experience (QoE) parameter
  - Mean Opinion Score (MOS)

➔ Estimation of QoE parameter MOS by QoE/QoS Matching:

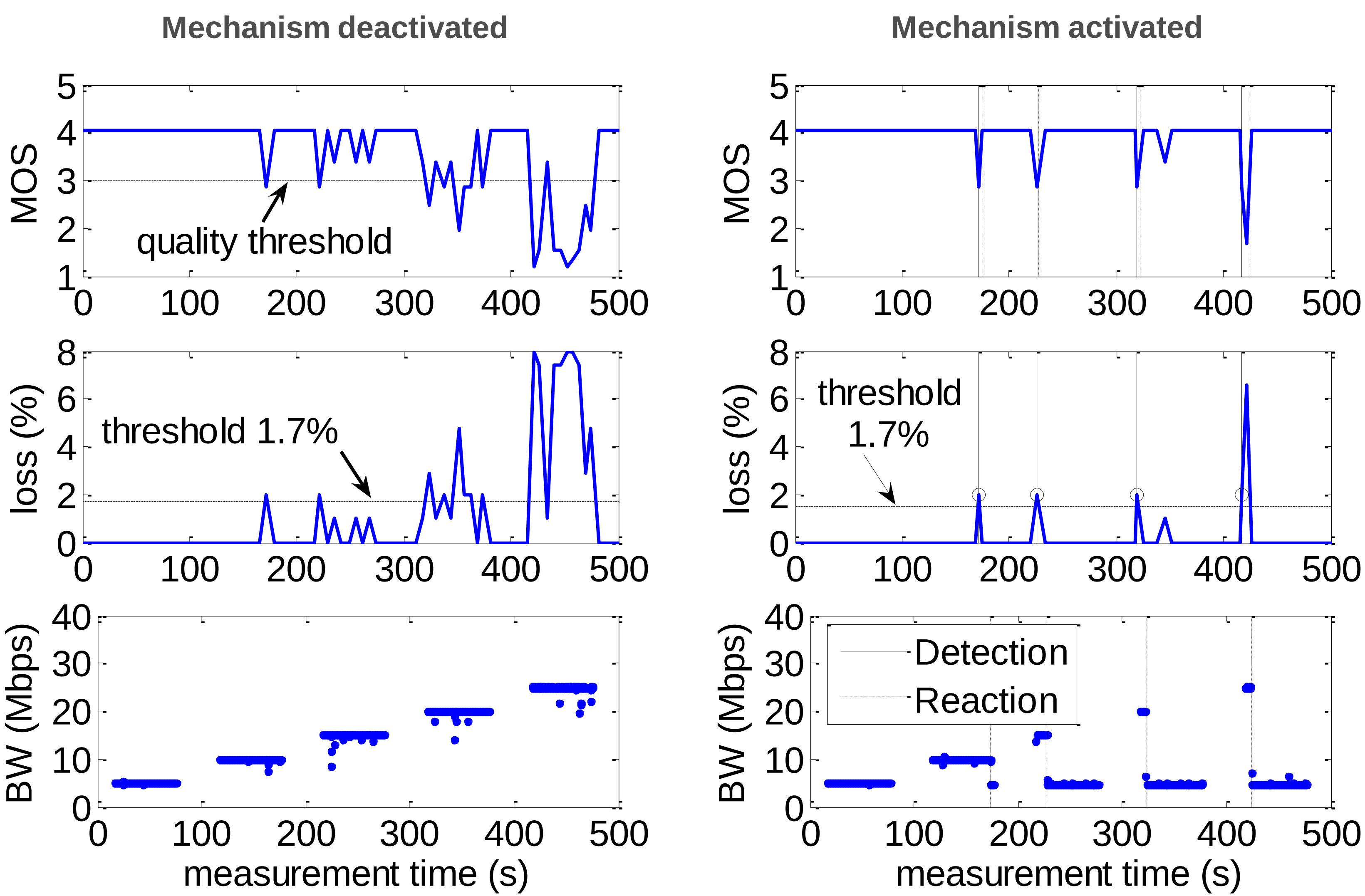
$$\mathrm{MOS}(\mathrm{loss}) = \alpha_1 \cdot e^{-\beta_1 \cdot \mathrm{loss}} + \gamma_1 \qquad \mathrm{MOS}(\mathrm{std}_{\mathrm{IPD}}) = \alpha_2 \cdot e^{-\beta_2 \cdot std_{IPD}} + \gamma_2$$

Quality Level	MOS	Packet loss	Threshold loss	$\mathrm{std}_{\mathrm{IPD}}$	Threshold $\mathrm{std}_{\mathrm{IPD}}$
Good	**3.8 – 5**	**below 0.3 %**		**below 1.7 ms**	
Average	**3 – 3.8**	**0.3 – 1.7 %**	**0.1 %**	**1.7 – 7.2 ms**	**1.5 ms**
Bad	**1 - 3**	**above 1.7 %**	**1.5 %**	**above 7.2 ms**	**7.0 ms**

Out-Band Scenario



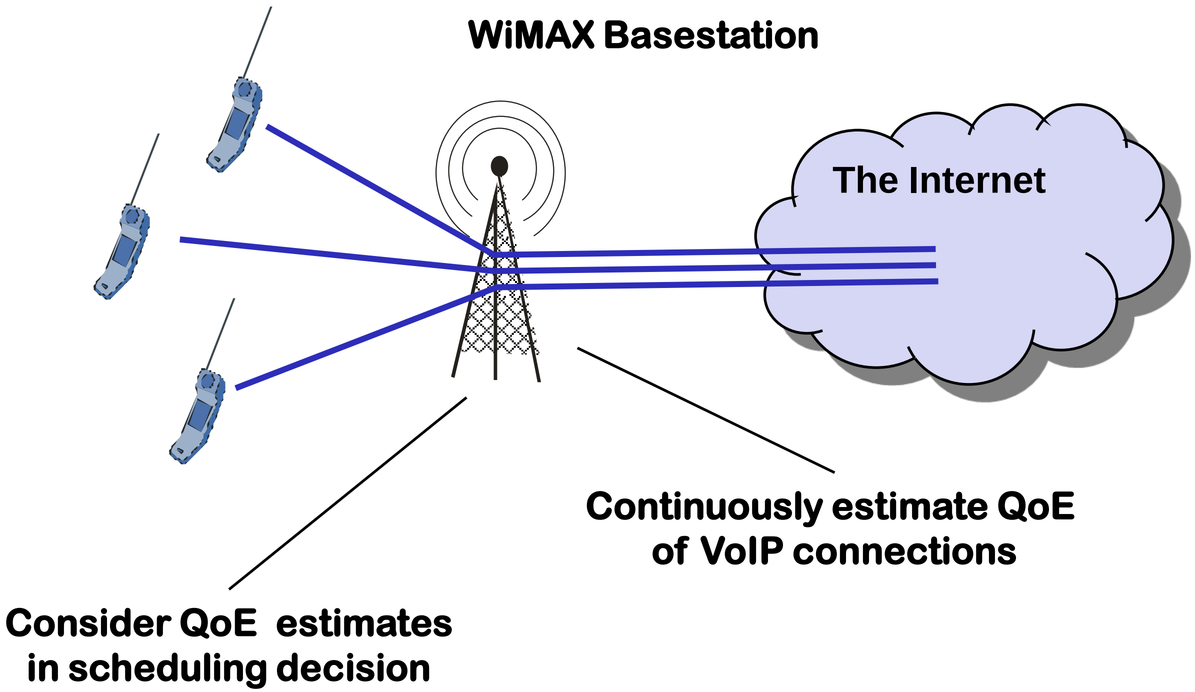
Performance Measurements – Out-Band Scenario



EXAMPLE 2:
QOE BASED VOIP SCHEDULER AT THE EXAMPLE OF IEEE802.16

Hankang Wang, Dirk Staehle, Thomas Bohnert

QoE based VoIP Scheduler

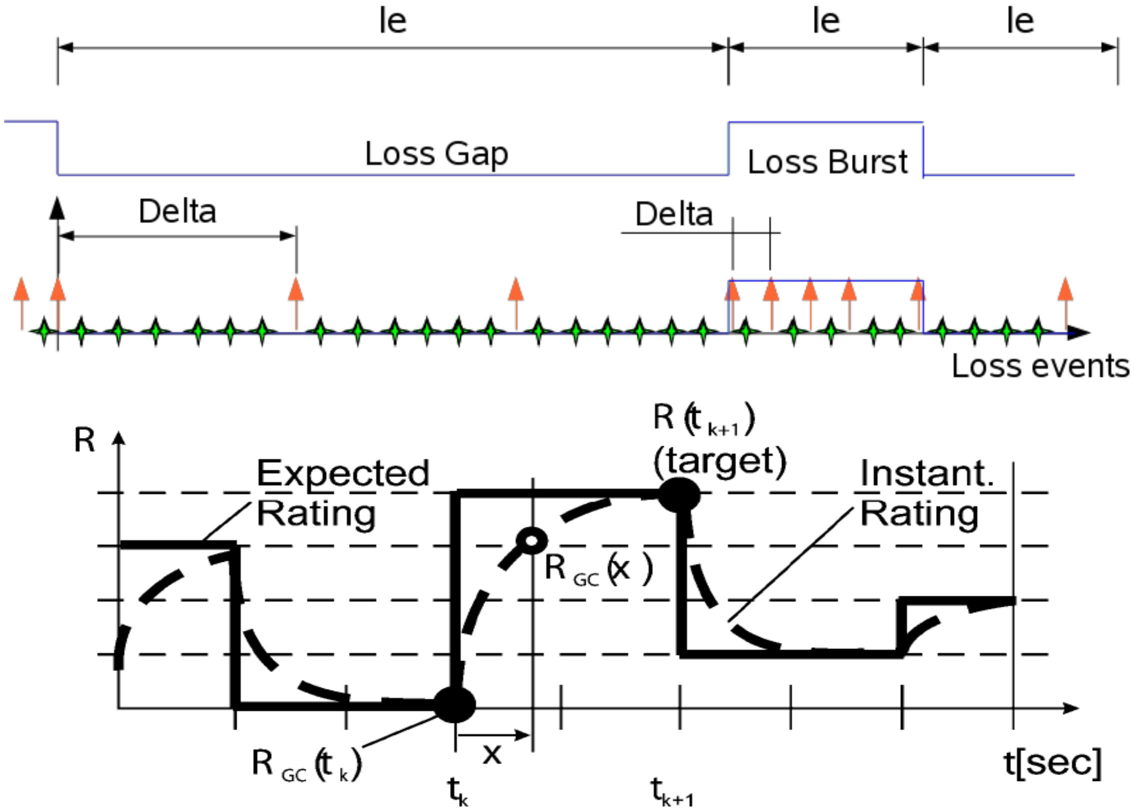


- Objective:
  - investigate potential of QoE aware short-term scheduling decisions
  - example: downlink of IEEE802.16e with BandAMC (frequency-selective scheduler)

Two-State Model

Idea from

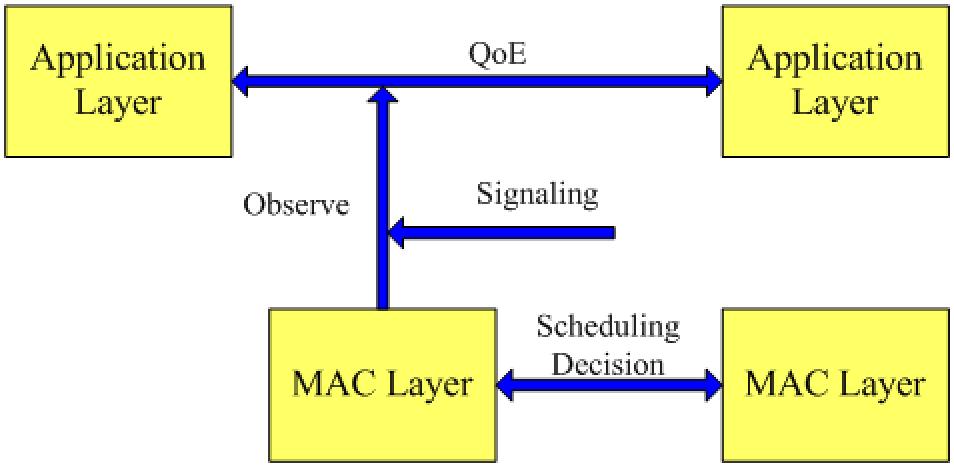
A. Raake, “Short- and Long-Term Packet Loss Behavior: Towards Speech Quality Prediction for Arbitrary Loss Distributions”, *IEEE Transactions on Audio, Speech, and Language Processing, 2006*



E-Model:
R=94 – Id- Ie

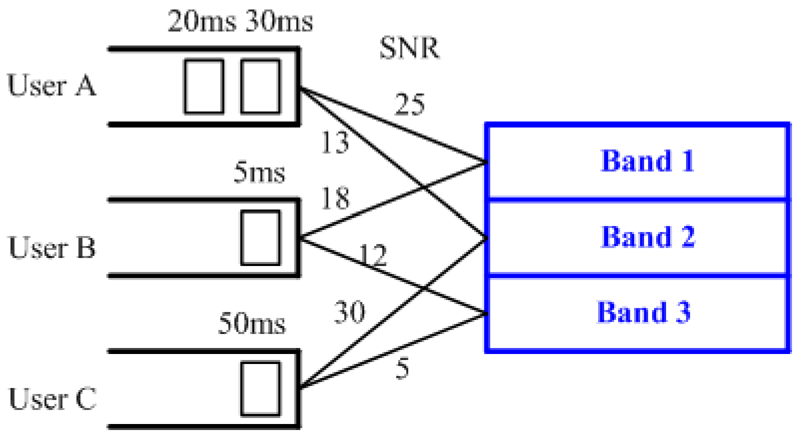
average total Ie over burst and gap phases

Idea of QoE



- Scheduling decisions based on
  - SNR per band
  - waiting delay of packet
  - R-Score
- sort packet-band pairs in scheduling order
  - use different metric

Scheduling Algorithms: Example

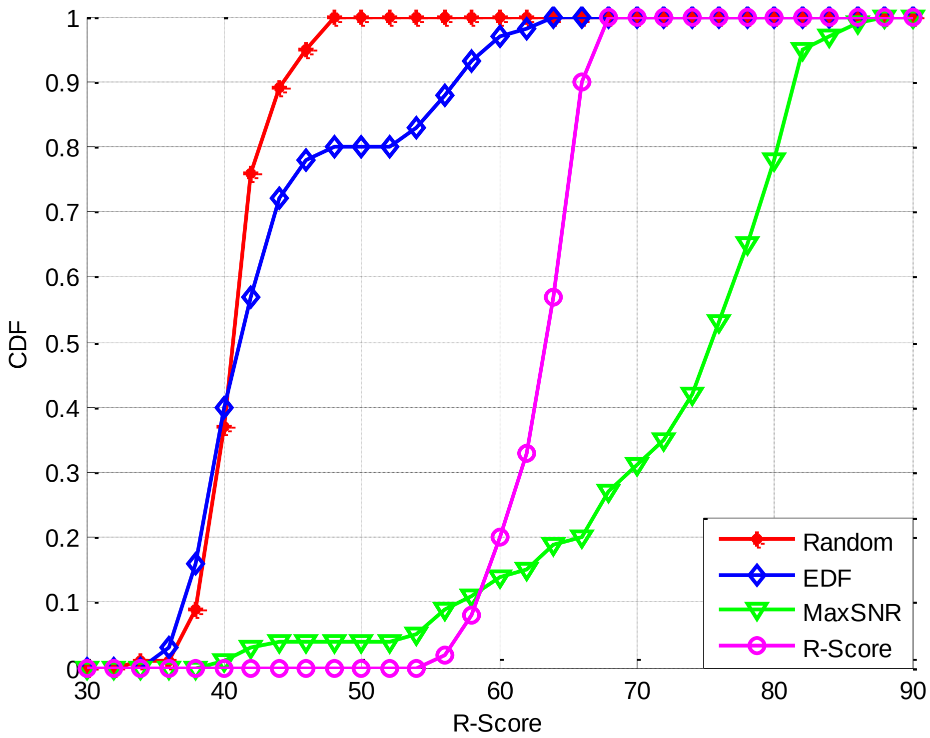


$$U = 1 \cdot SNR - 1 \cdot Rscore + 100 \cdot Delay$$

User	Packet	Band	SNR	Delay	R-Score	MaxSNR scheduler	LF Scheduler	
							Metric	Order
A	1	1	25	30ms	80	2	-52	2
A	1	2	13	30ms	80	5	-64	6
A	2	1	25-2	20ms	80	3	-54	3
A	2	2	13-2	20ms	80	7	-66	7
B	1	1	18	5ms	75	4	-56.5	4
B	1	3	12	5ms	75	6	-62.5	5
C	1	2	30	50ms	84	1	-49	1
C	1	3	5	50ms	84	8	-74	8

Performance of Basic Schedulers

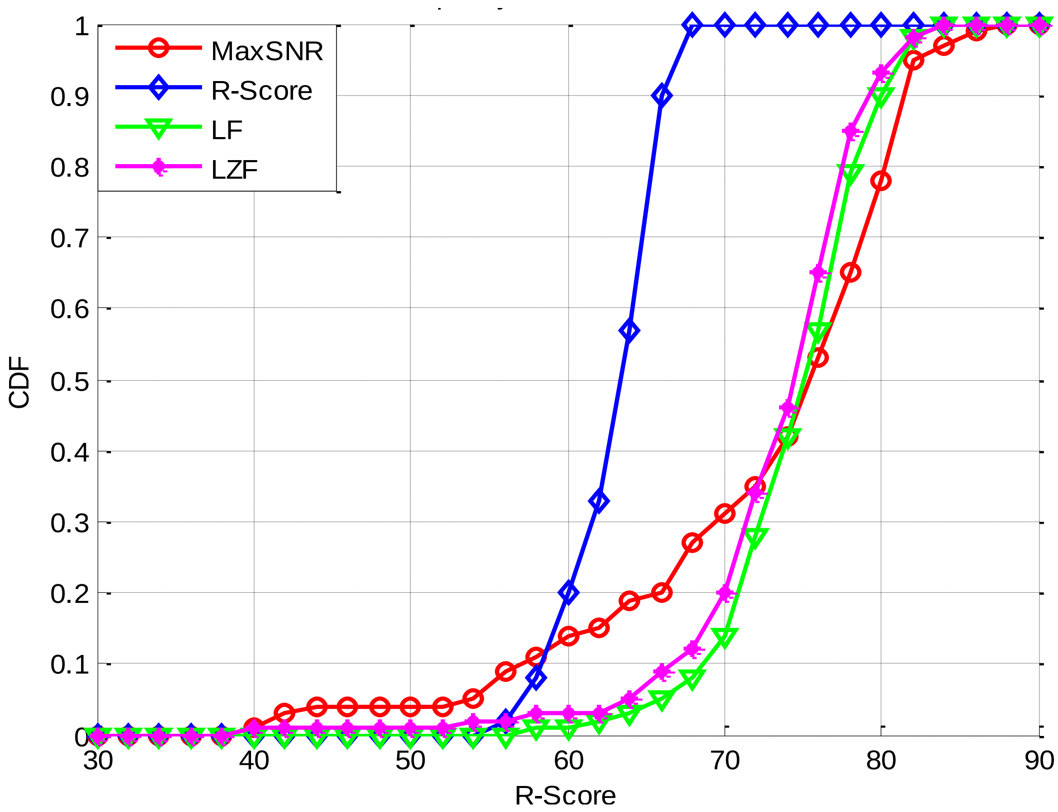
Basic Schedulers:
- Random Scheduler (metric: random value)
- R-Score Scheduler (metric: lowest R-Score first)
- EDF Scheduler (metric: longest waiting time first)
- MaxSNR Scheduler (metric: highest SNR first)



- Scenario
  - 100 mobiles,
  - G711 codec,
  - IEEE802.16e,
  - 5MHz band,
  - packet dropping threshold 100ms,
  - mobile velocity 3km/h
  - ITU PB channel

Performance of Combined Metrics

- Schedulers with combined metrics:
  - LF (linear function) scheduler: $U = \alpha \cdot SNR - \beta \cdot Rscore + \gamma \cdot Delay$
  - LZF (linear plus Z function): $U = \alpha \cdot SNR - \beta \cdot Rscore + \gamma \cdot ZF(delay)$



Conclusion and Outlook

- Summary:
  - Concept of QoE based resource management
  - Proof of Concept of QoE based dynamic bandwidth control
    - Technology independent implementation
    - QoE ensuring without changes to the MAC layer
    - Realization in a real testbed
  - Demonstration of QoE based VoIP scheduler
    - combines advantages of channel-aware and QoE-aware schedulers
- Outlook:
  - QoE based resource management in mesh networks
    - gateway selection/switching
    - congestion control
  - Make QoE aware scheduler multi-class

Thank you for your attention!

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