Application-driven Cross-layer Optimization in Wireless Networks

Srisakul Thakolsri*, Wolfgang Kellerer*

Shoaib Khan†, Eckehard Steinbach†

*Future Networking Lab
Ubiquitous Services Platform group
DoCoMo Euro-Labs

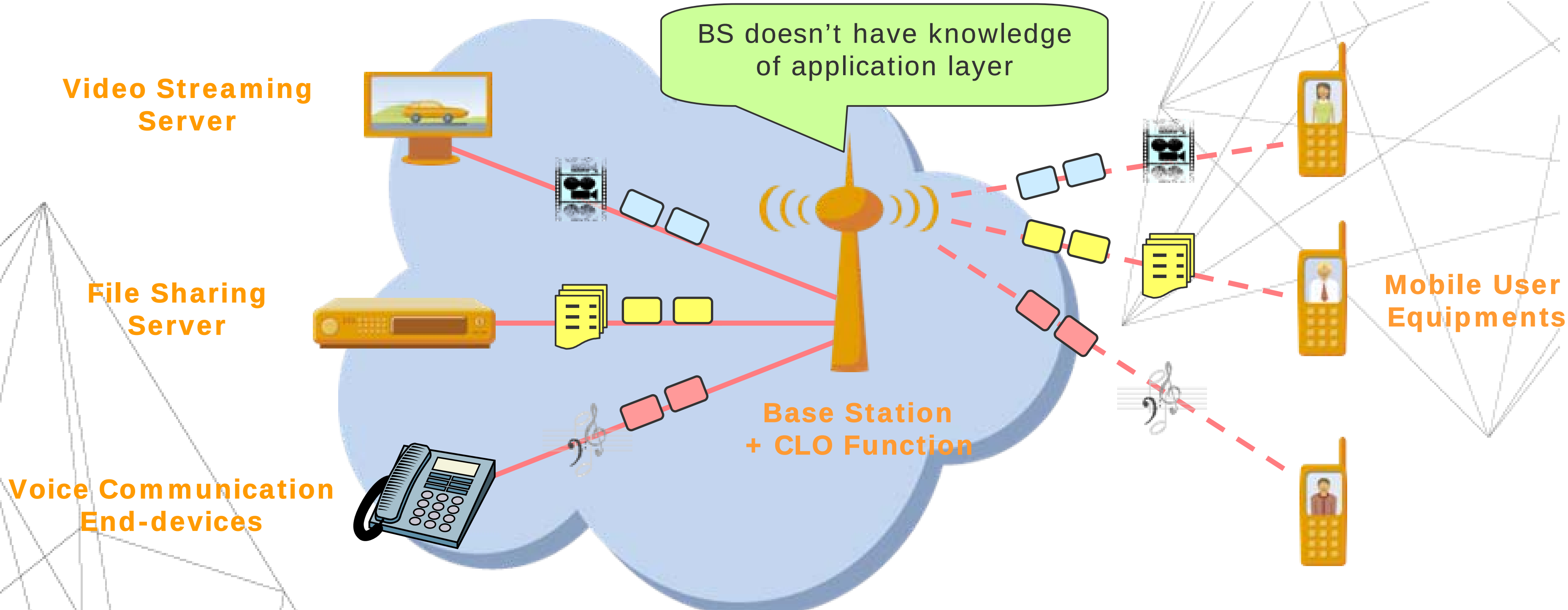
†Media Technology Group
Institute of Communication Networks
TU München

2nd Seminar on Service Quality Evaluation in Wireless Networks
University of Stuttgart
June 12th, 2007

Outline

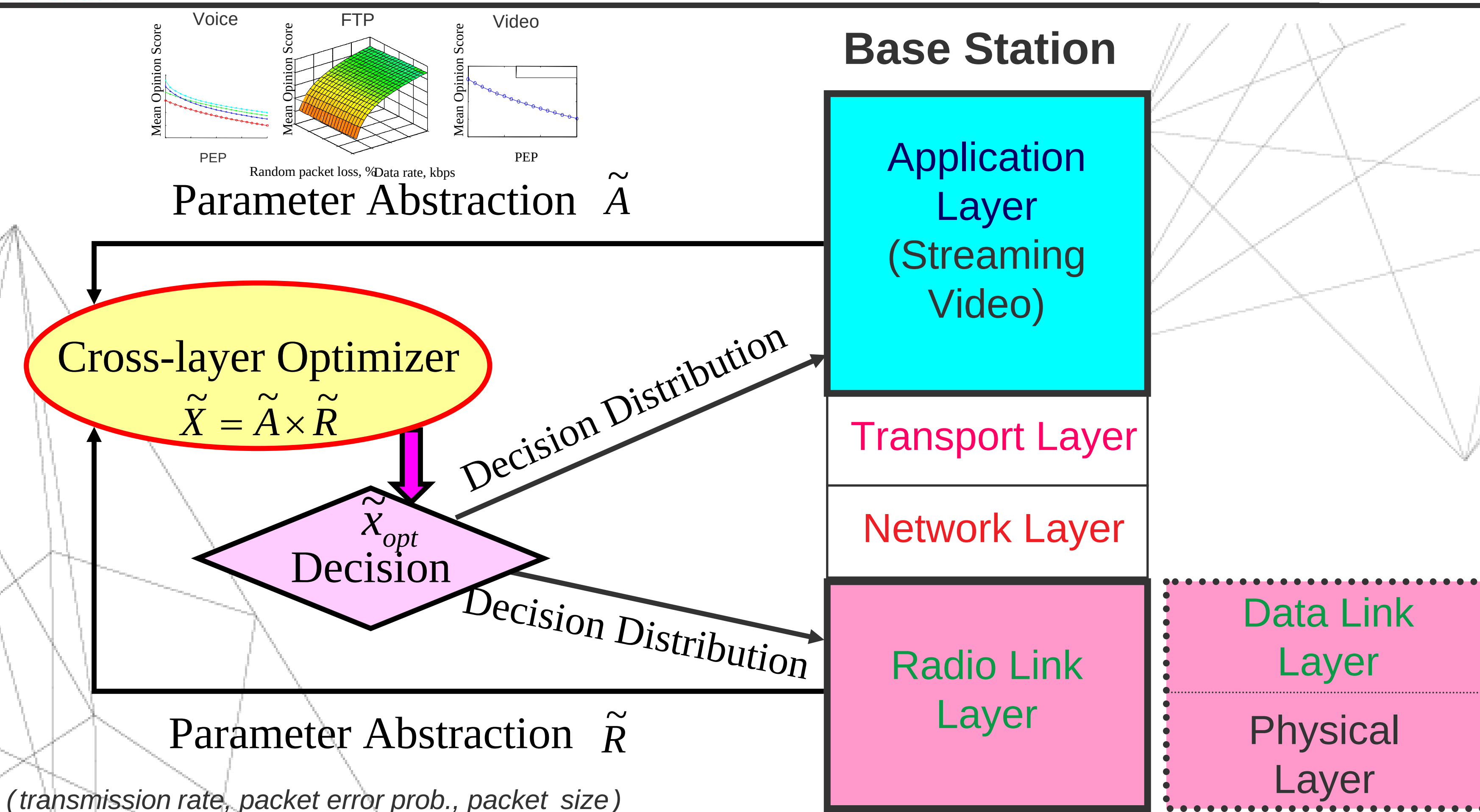
- Motivations
- Cross-Layer Optimization (CLO) Architecture
- Multi-application CLO
  - Voice
  - Streaming
  - File transfer
- Simulation results

Motivations



- Multiple users sharing wireless medium, e.g. in a cell, usually run different applications simultaneously
- Impact of losses on user-perceived quality is application-dependent
- Optimizing the system for different users and applications requires:
  1. defining a common metric that quantifies the user satisfaction
  2. mapping network and application parameters onto this metric.

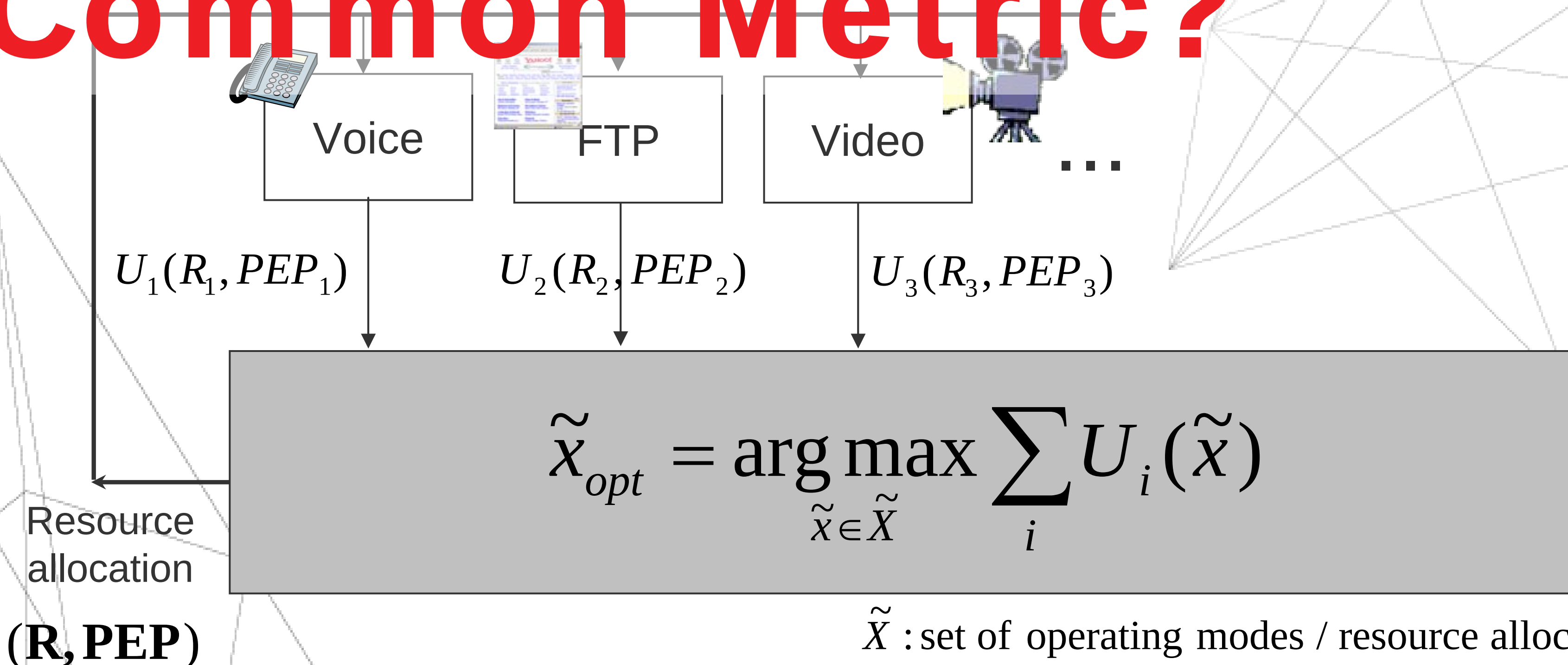
Proposed CLO Architecture



Kellerer, Choi, Steinbach, Khan
WPMC'03, ICIP'04, IEEE ComMag'06

Cross-layer Optimizer: Maximization of User Satisfaction

Common Metric?



$$\tilde{x}_{opt} = \arg\max_{\tilde{x} \in \tilde{X}} \sum_i U_i(\tilde{x})$$

$\tilde{X}$: set of operating modes / resource allocations

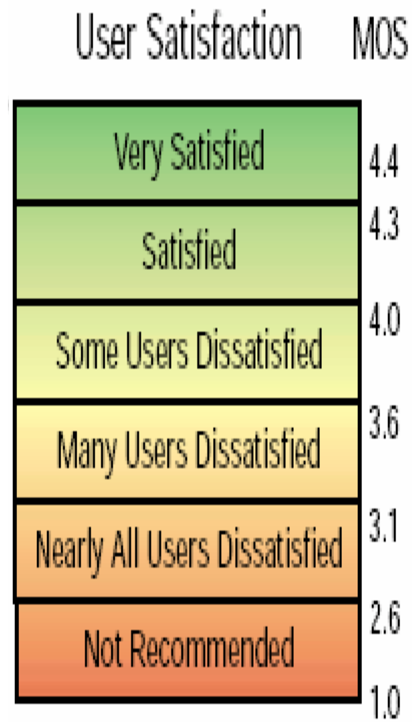
U : utility function

Khan, Duhovnikov, Steinbach, Sgroi, Kellerer, ISMW '06

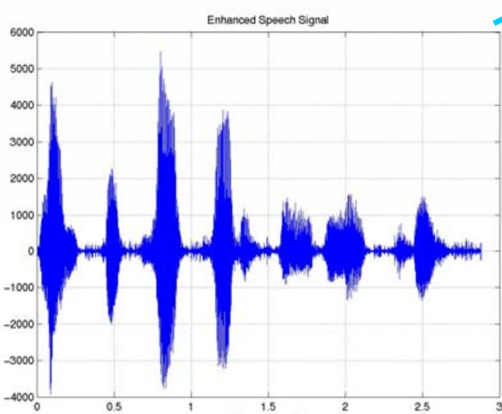
Challenge: estimating utility functions

video streaming

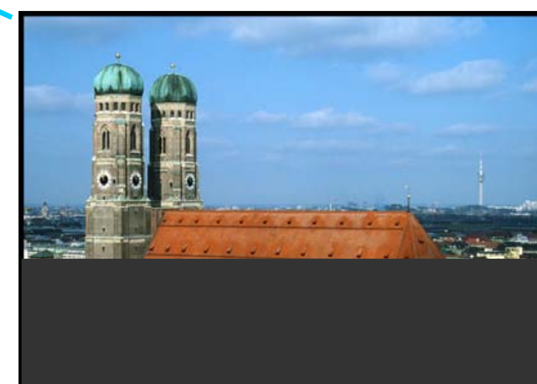
video conferencing



Mean Opinion Score

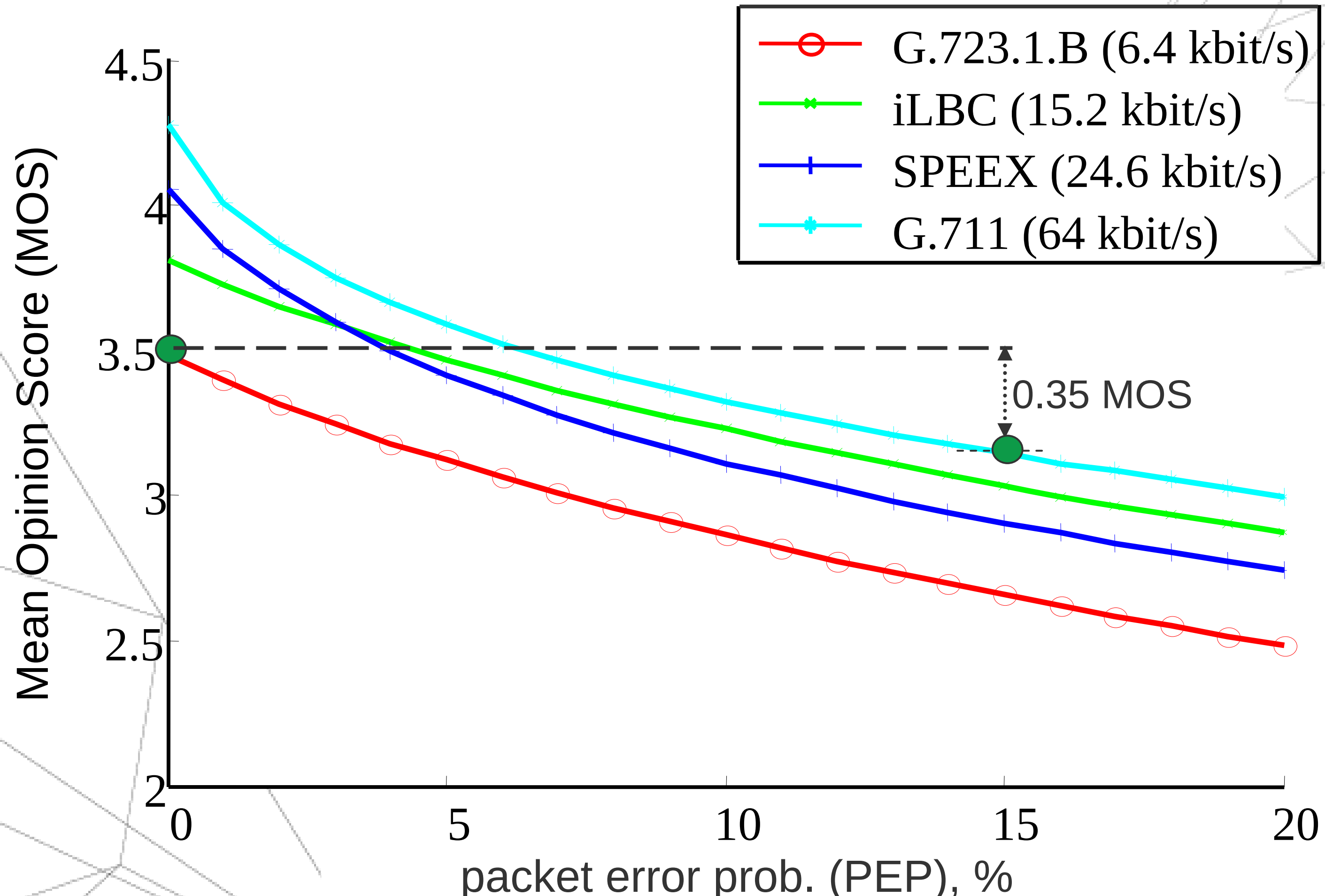


voice



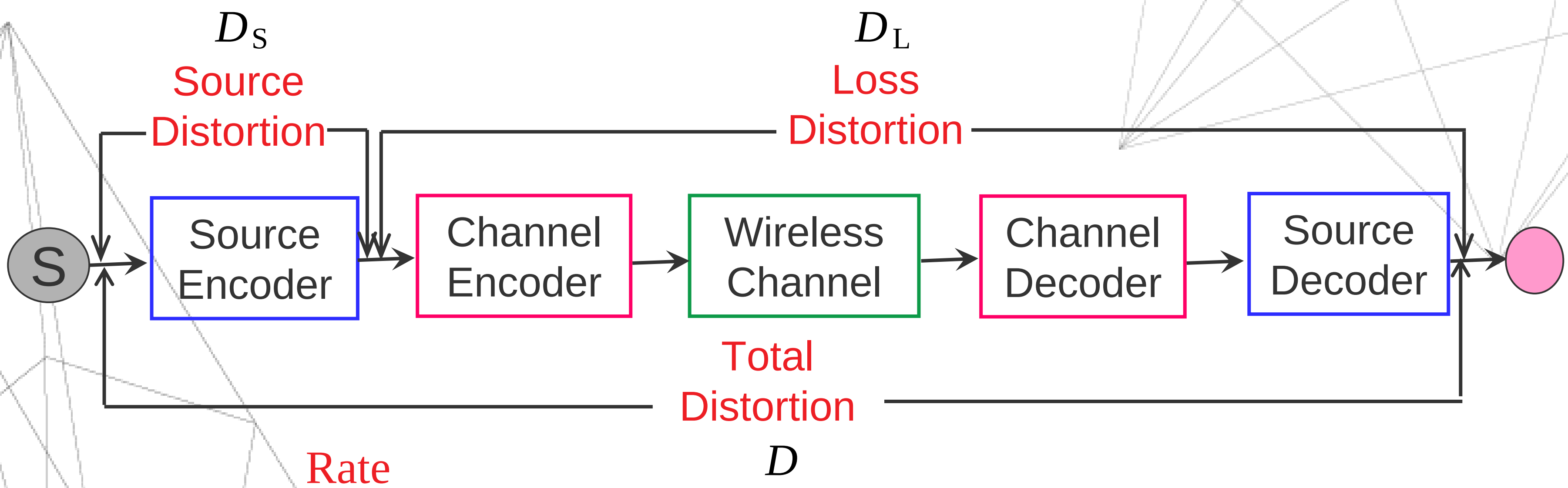
FTP(image download)

Utility Function (PESQ) of Voice Codecs



Video streaming: Estimating reconstruction quality at the receiver

- Source Distortion due to compression
- Loss Distortion due to transmission loss



Rate

$$D_s = f(R)$$
$$D_L = f(R, PEP)$$

Packet Error Probability

$$D = D_S + D_L$$

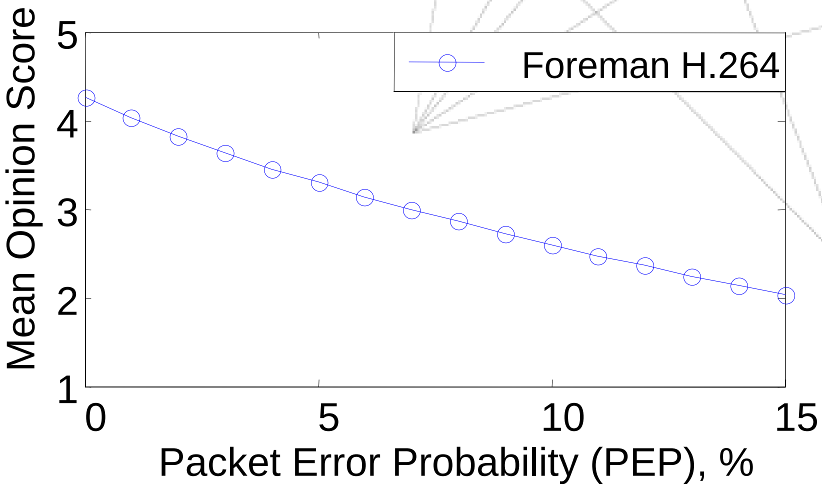
Utility function of streaming video

$$D = D_S + D_L$$

$$PSNR = 10 \cdot \log_{10}\left(\frac{255^2}{D}\right)$$

$$MOS = a \cdot PSNR + b$$

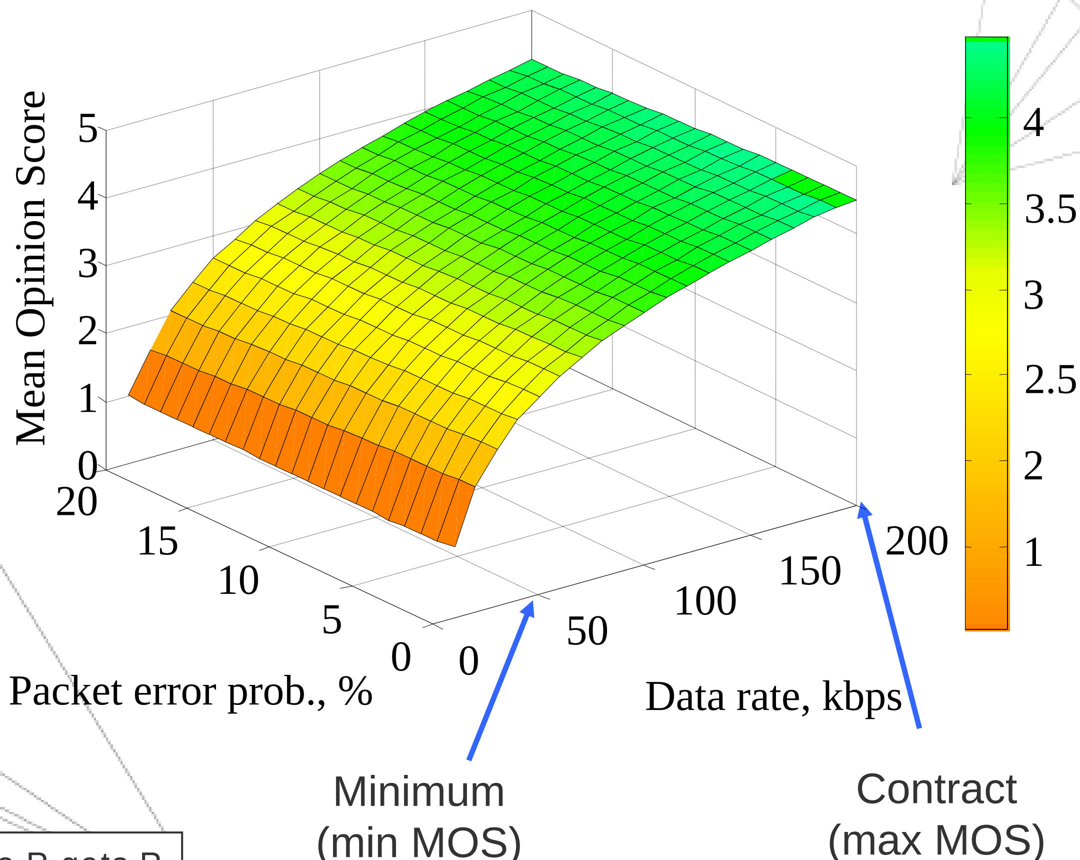
PSNR 40 dB = MOS 4.5
PSNR 25 dB = MOS 1



Utility function of FTP

$$MOS(R, PEP) = a \cdot \log_{10}\left(b \cdot R(1 - PEP)\right)$$

A. Saliba et al. 2003



4.5: user subscribed to R gets R
1: minumum R
→ a, b

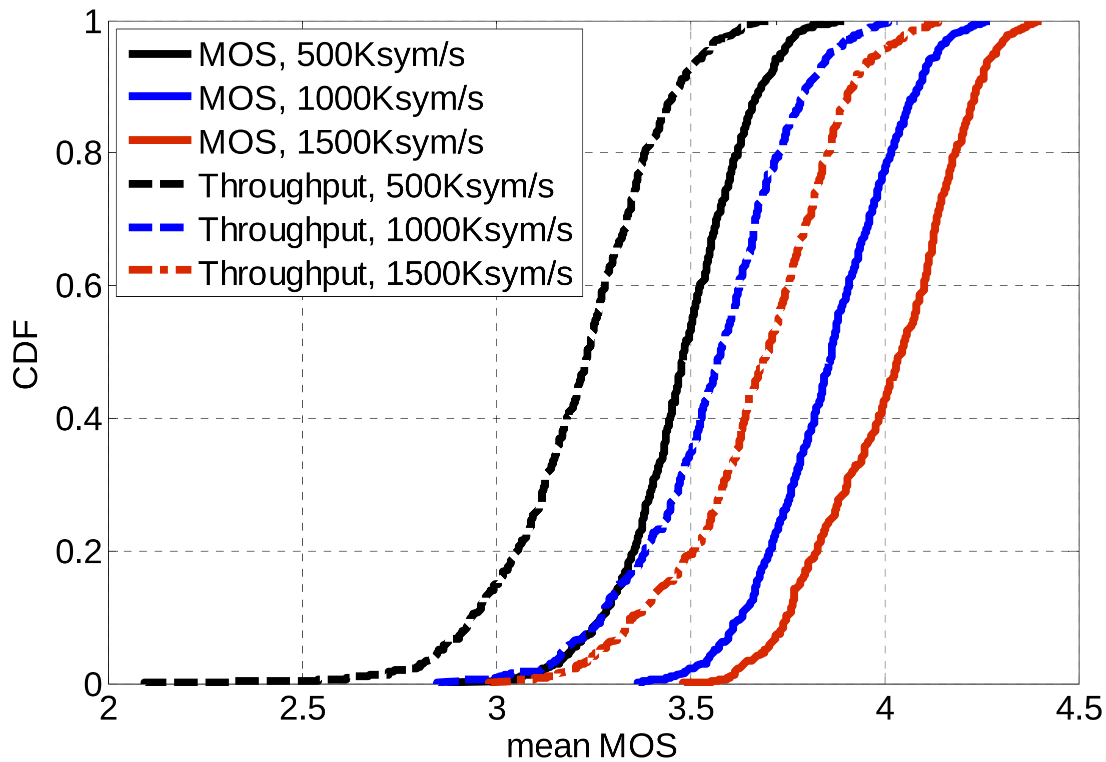
Performance of Utility-based optimization

- Maximize mean MOS:

$$\arg\max_{\tilde{x}\in\tilde{X}} \frac{1}{K}\sum_{k=1}^{K} MOS_k\left(R_k(\tilde{x}), PEP_k(\tilde{x})\right)$$

- Maximize Throughput:

$$\arg\max_{\tilde{x}\in\tilde{X}} \sum_{k=1}^{K} R_k(\tilde{x})\cdot\left(1-PEP_k(\tilde{x})\right)$$



- Seven users: 3 voice users, 2 FTP users, 2 video users
- Total system rates **500, 1000, and 1500 ksymbols/sec**
- Session duration: 30 sec
- Resource allocation update: every 1 second

Greedy Allocation Algorithm

Greedy Optimization

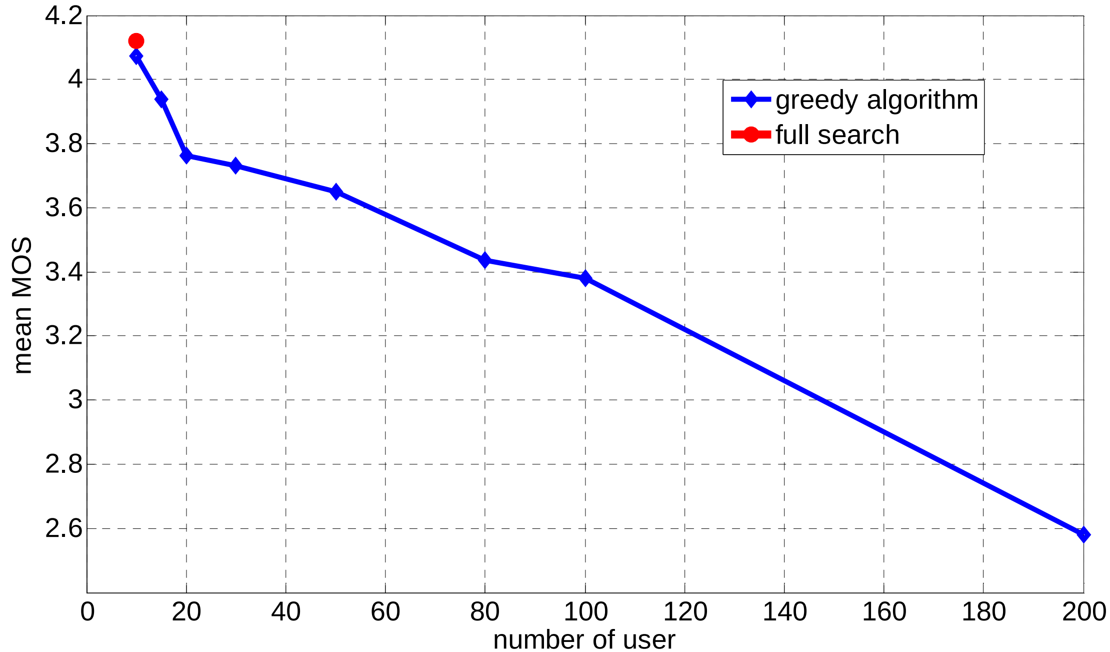
$$\max_{(i,j)\in\{1,\ldots,K\}} \frac{\Delta U_i}{\Delta U_j}, \quad i \neq j$$

ΔU_i : utility change due to an increase of $\Delta \alpha_i$

ΔU_j : utility change due to a decrease of $\Delta \alpha_j$

$\Delta \alpha_i$:change of resource share for user i

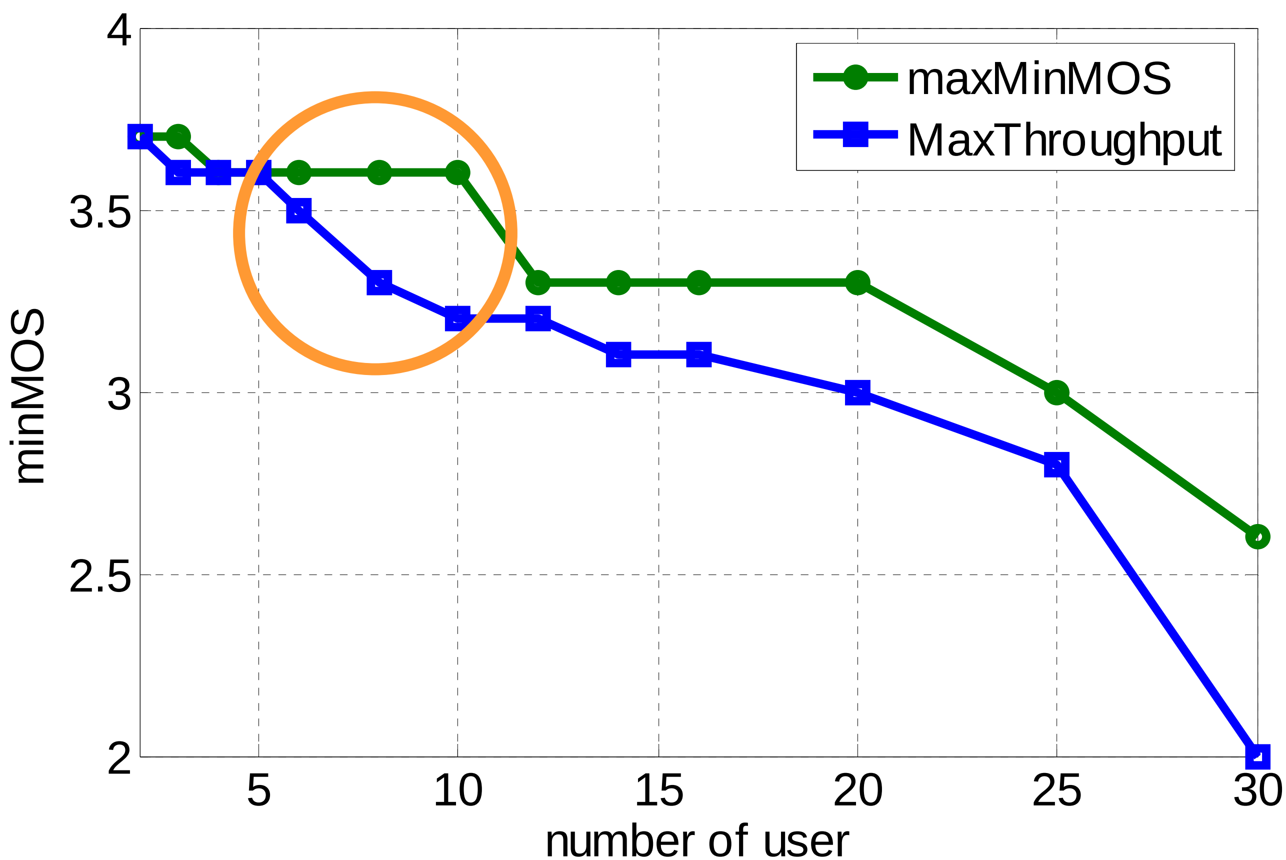
Total symbol rate = 1Msym/s



- 4 video users, 2 FTP, and (K-6) voice users
- Full search becomes computationally infeasible for K>10
- Real-time optimization for greedy algorithm

Optimizing the number of users in a cell

- Here, we maximize the minimum MOS of the users.
- A target min. MOS is set at the beginning of the simulation
- Total symbol rate is fixed: 200Ksymbol/sec
- Only voice service is considered



Summary

- Using MOS as a unifying optimization metric across different types of application
- Defined techniques for mapping network and application parameters onto MOS
- Results show advantages of MOS-based approach comparing over throughput maximization approach
  - Improve user-perceived quality
  - Optimize usage of network resource

Thanks for your attention…

Questions?