Quality of Experience Optimized Scheduling in Multi-Service Wireless Mesh Networks

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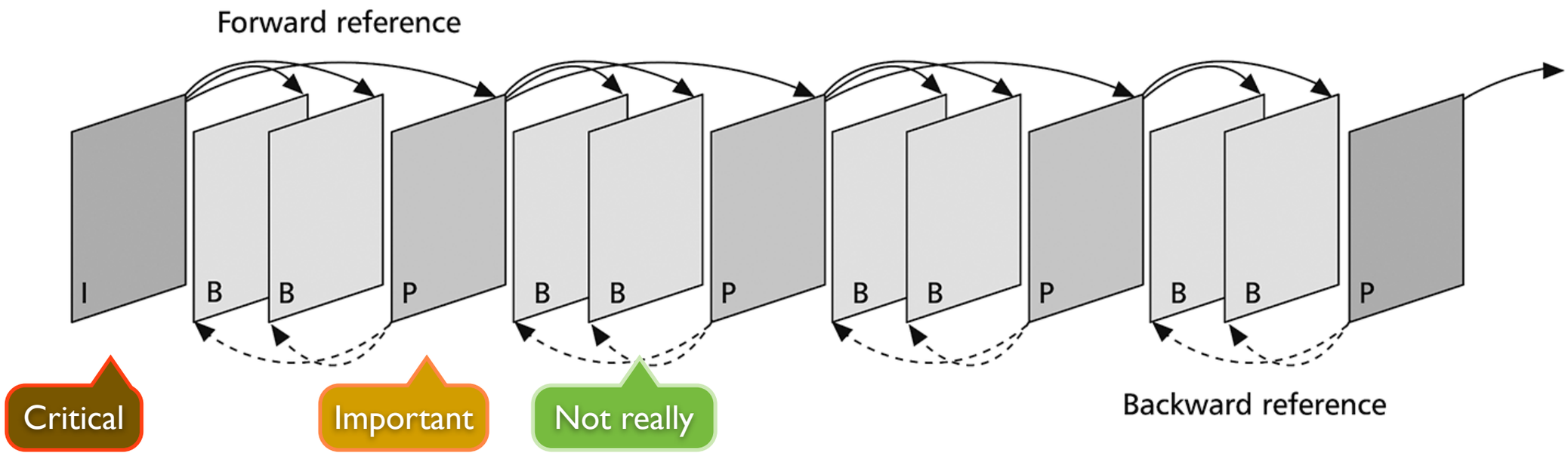
Quality of Experience

Randomly dropping packets to meet QoS goals is suboptimal for some types of traffic — e.g., video:



In a video stream, dropping a couple B-frames to meet bandwidth constrains is preferable to dropping a single I-frame.

Motivation

Next generation networks expect considerable amounts of voice, video and file transfer traffic.

Traffic in North America: ≈37% P2P, ≈16% video streaming*.

- Research trend: QoS → QoE

Network optimization with Quality of Experience metrics should deliver better satisfaction to the end-user.

* Ellacoya Networks 2007 (now Arbor Networks).

Goals

Design a multi-service packet scheduler that is QoE-aware.

- Use subjective metrics of quality (as perceived by the end-user)
- Process audio, video and file transfer services jointly

Design a scheduler that is suitable for Mesh networks.

- Run at every intermediate node
- Broadcast flow distortion to other nodes

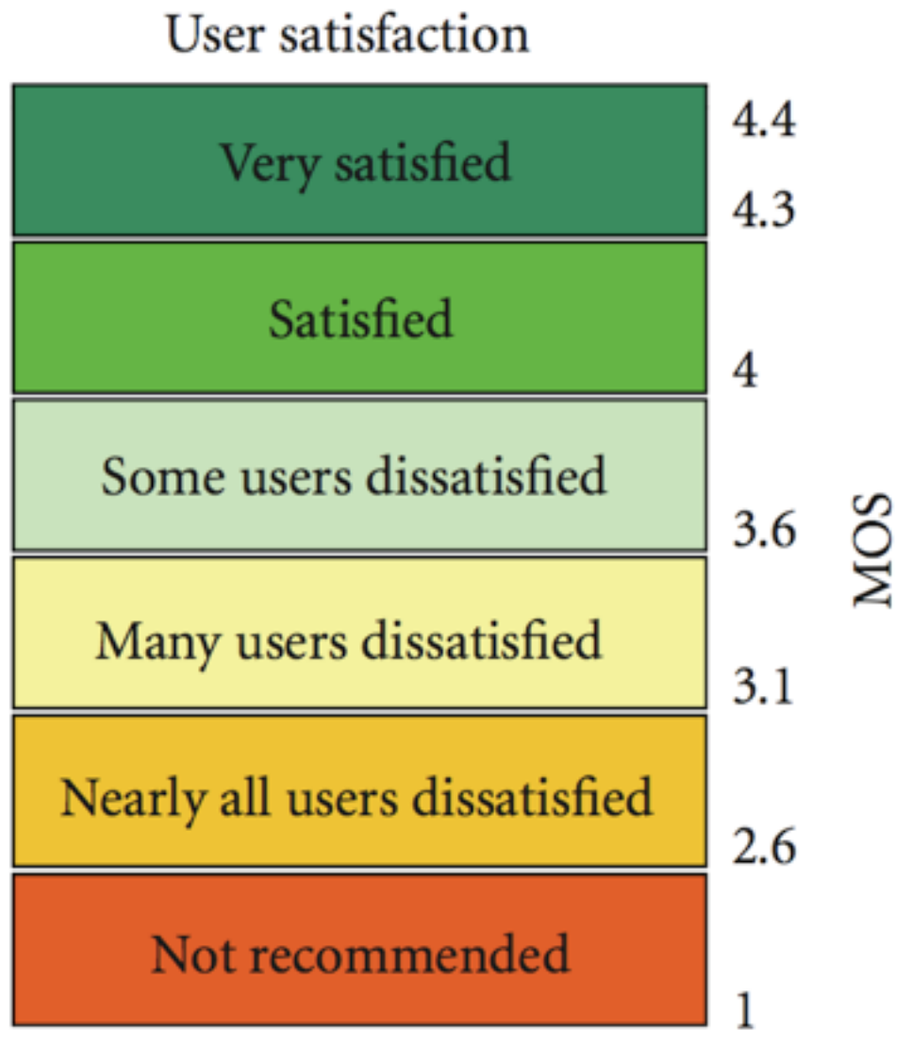
Implement and evaluate the scheduler in an NS-2 WiMAX mesh-mode simulator.

Mean Opinion Score

MOS is a subjective quality metric, originally designed for audio streams.

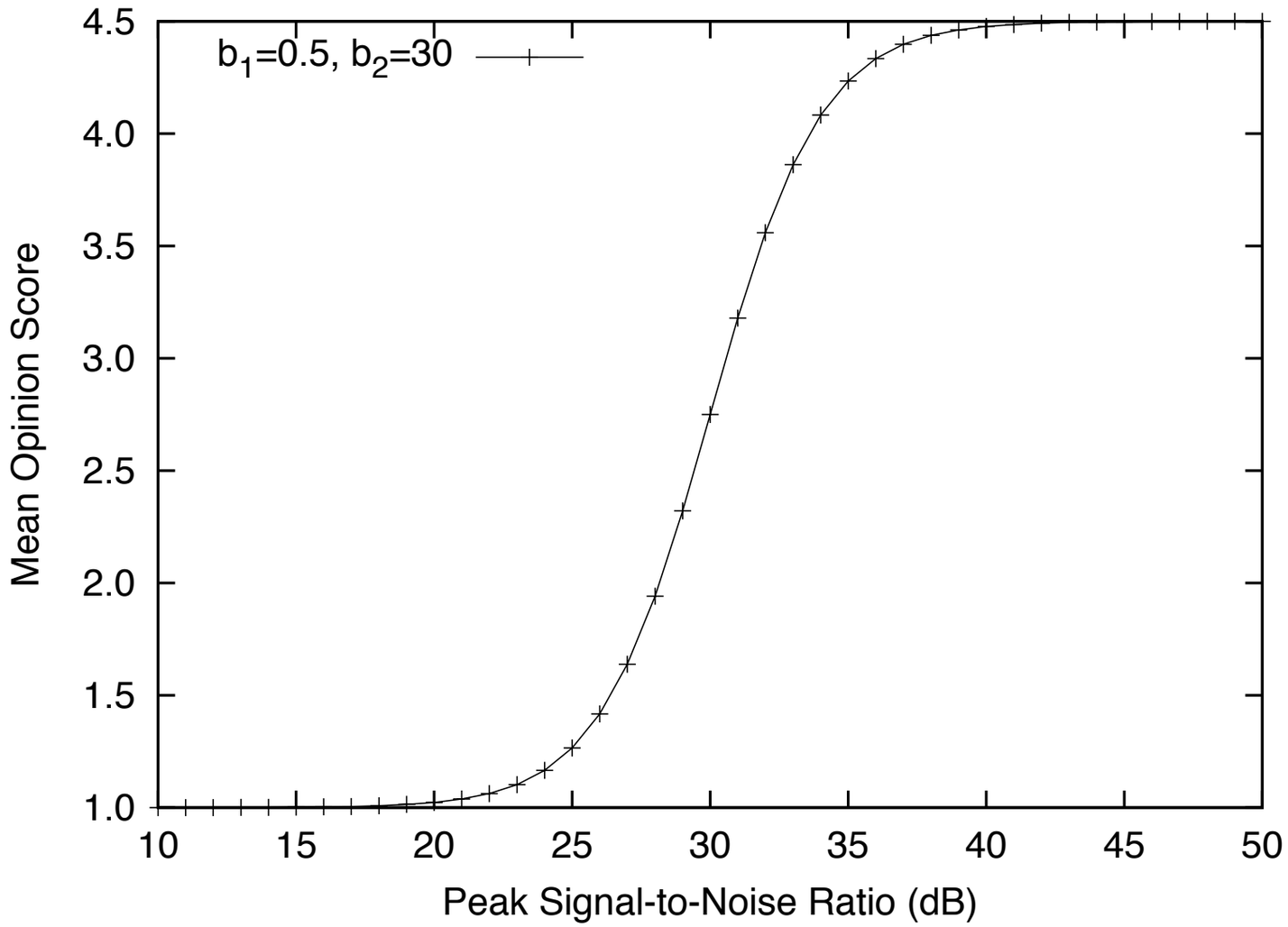
Scores range from 1 (worst) to 4.5 (best).

We adopt this metric for subjective scoring of audio, video and file transfer services, through mapping functions.



Video Model

Quality estimated by the number of dropped frames and their type (I,P,B), and mapped from PSNR (a common video metric) to MOS*.

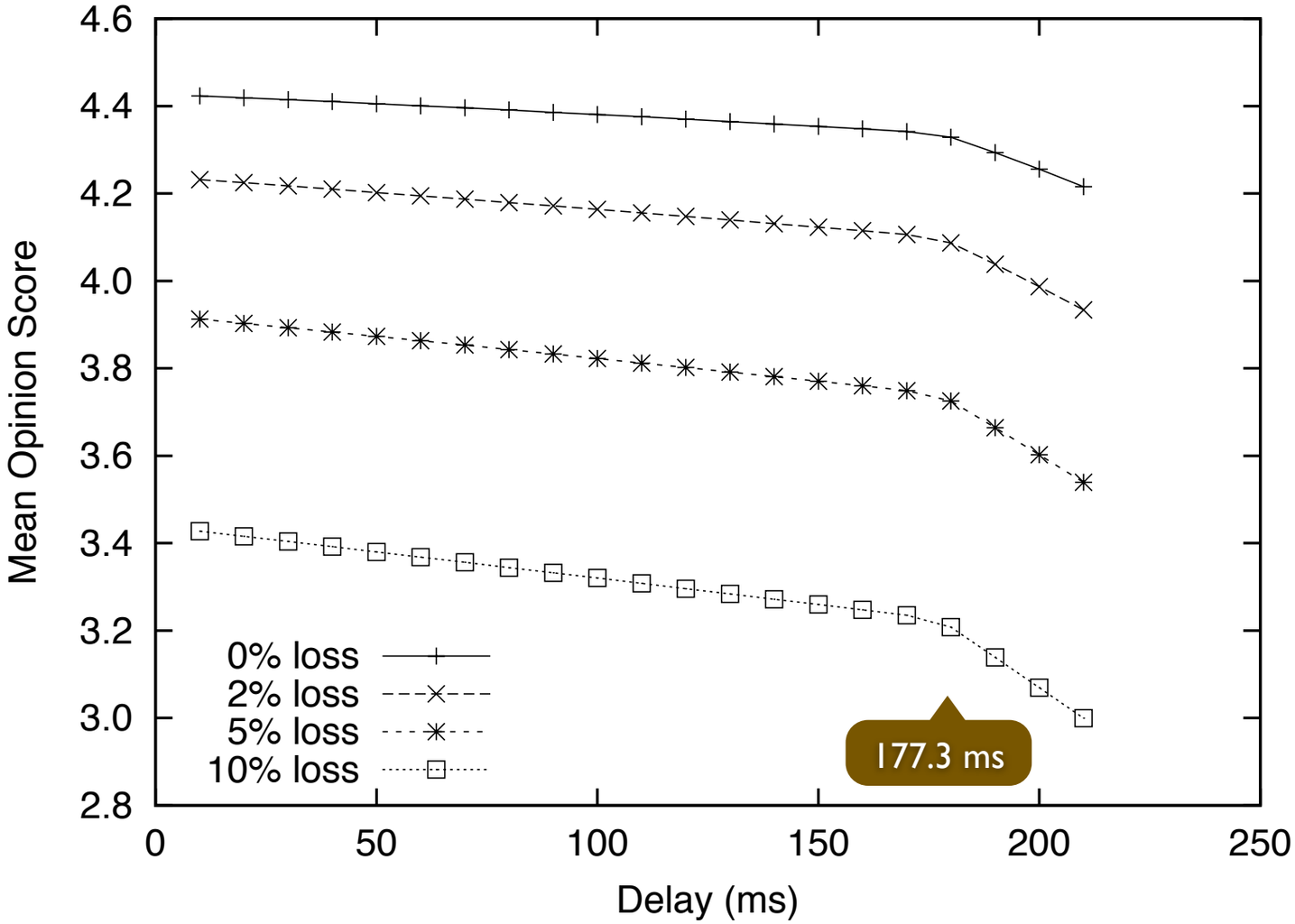


Non-linear mapping de-emphasizes the impact of losses when quality is already very high or very low (changes are less perceivable at these points).

* *Real-Time Monitoring of Video Quality in IP Networks*, R. Guerin, 2008

Audio Model

ITU-T E-model determines voice chat quality from delay and packet loss metrics*.

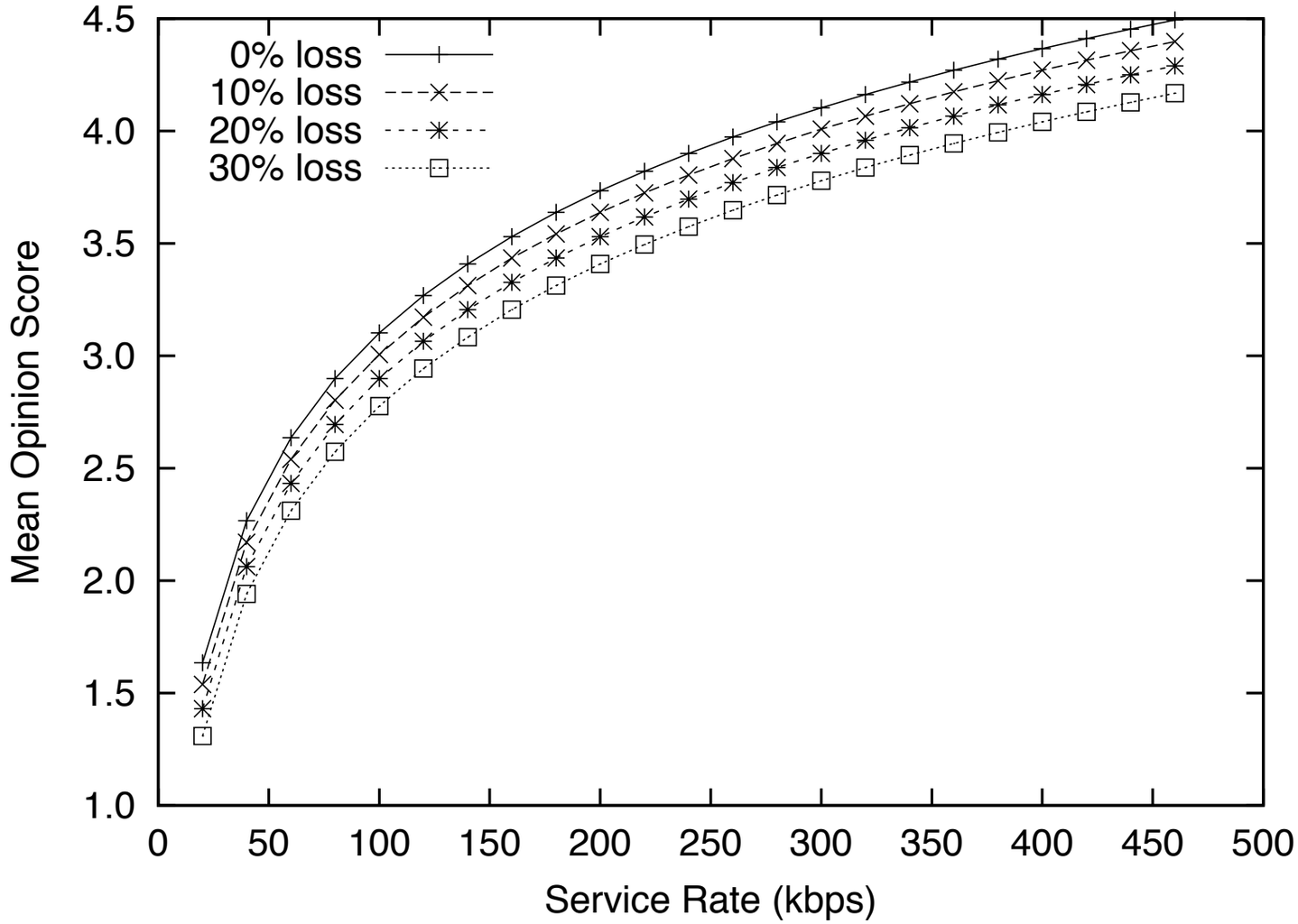


- Research indicates that voice conversation suffers when the delay exceeds 177.3ms.

* *ITU-T Recommendation G.107*

File Transfer Model

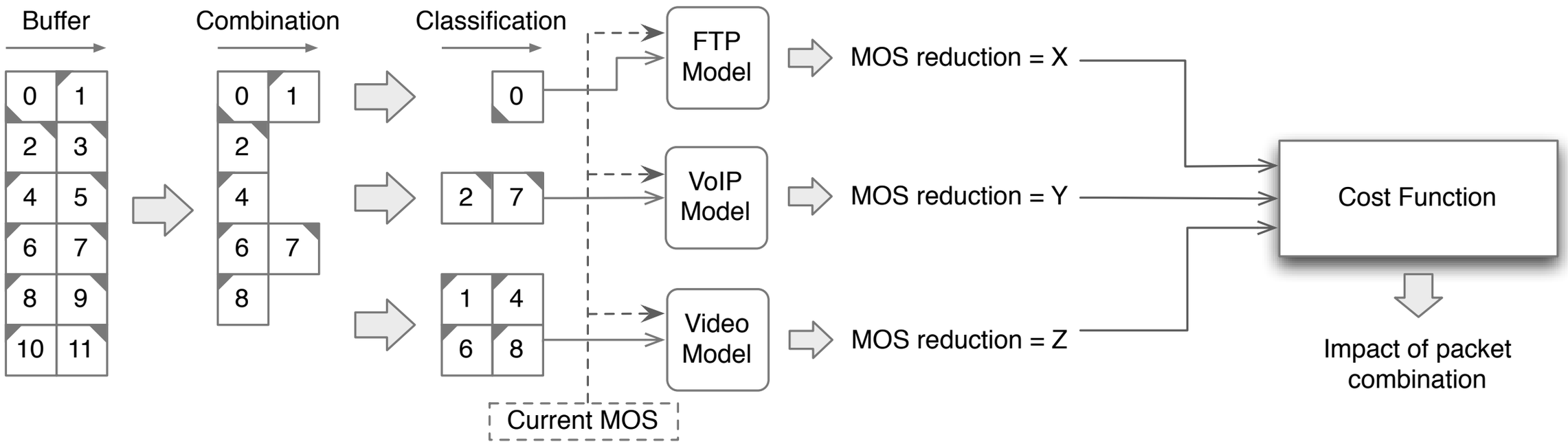
User perception measured as a factor of the provided data rate*.



The utility of elastic traffic (such as FTP) can be predicted with a logarithmic relationship between MOS and throughput.

* *Charging and rate control for elastic traffic,* F. Kelly, 1997

Scheduler Process



Evaluate distortion impact of packet combinations, in contrast to typical single packet / single service.

- Allows for scheduling across multiple flows and services
- Better fairness as packets from all flows are considered

Optimization function

Delta-MOS uses distortion data from the other nodes

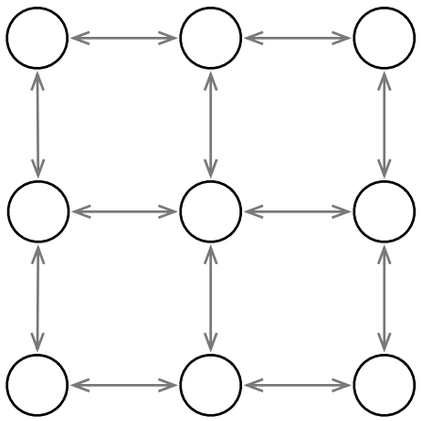
$$Q(p) = \sum_{i=1}^{n} k_i \cdot \Delta MOS_p^i - \lambda \cdot \sum_{i=1}^{n} \Delta R_p^i + \mu \cdot n \cdot \sigma(\Delta MOS)$$

- Standard deviation of the MOS decrease of all flows
- Data rate decrease to affected flows
- MOS decrease to affected flows

- But evaluating all possible combinations is expensive (2^npackets)
  - Pre-selection is required for better performance

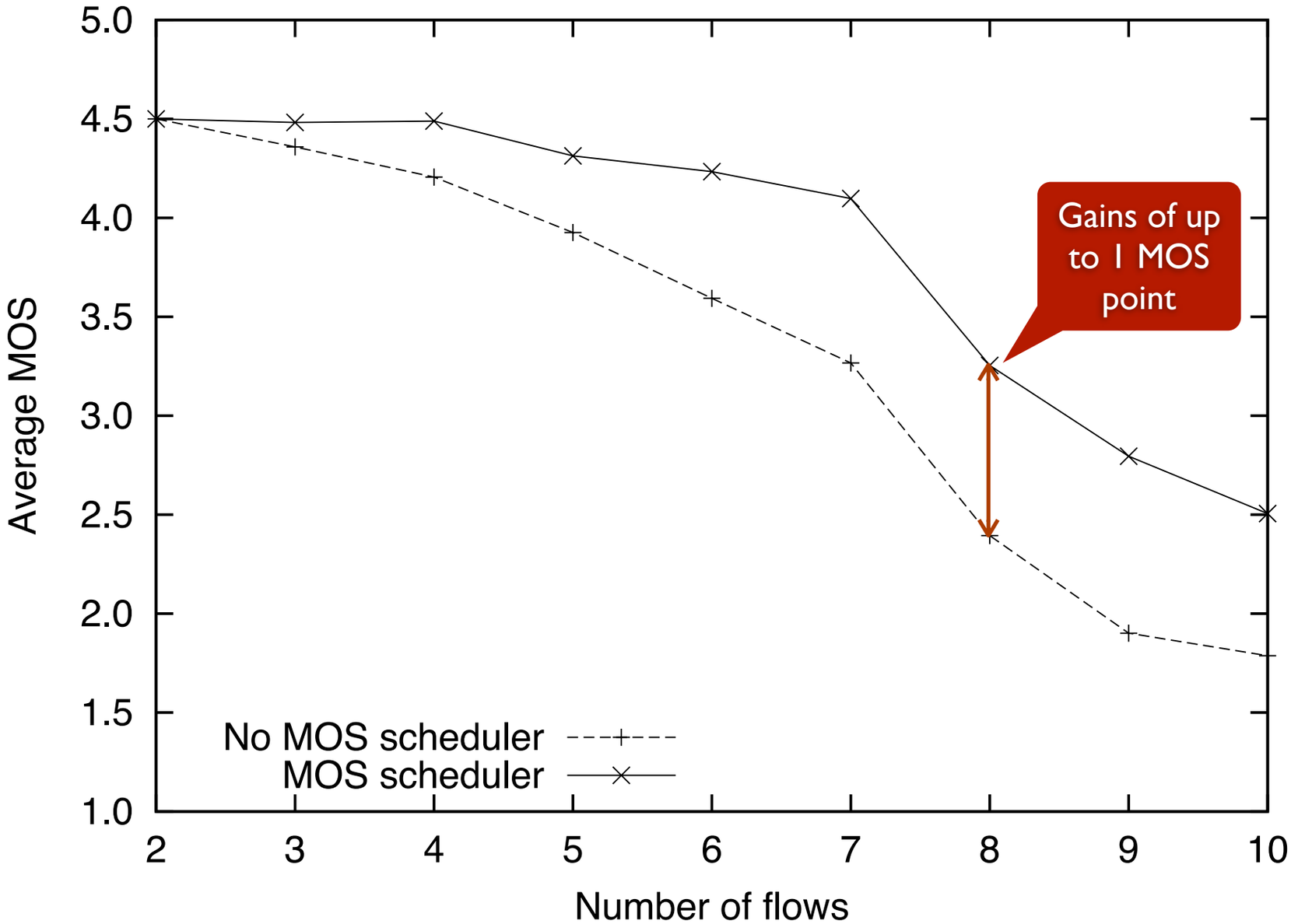
Video, mesh network

Topology:



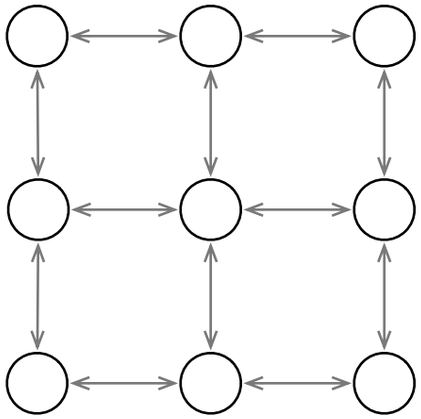
Random flow positioning

VOD services only



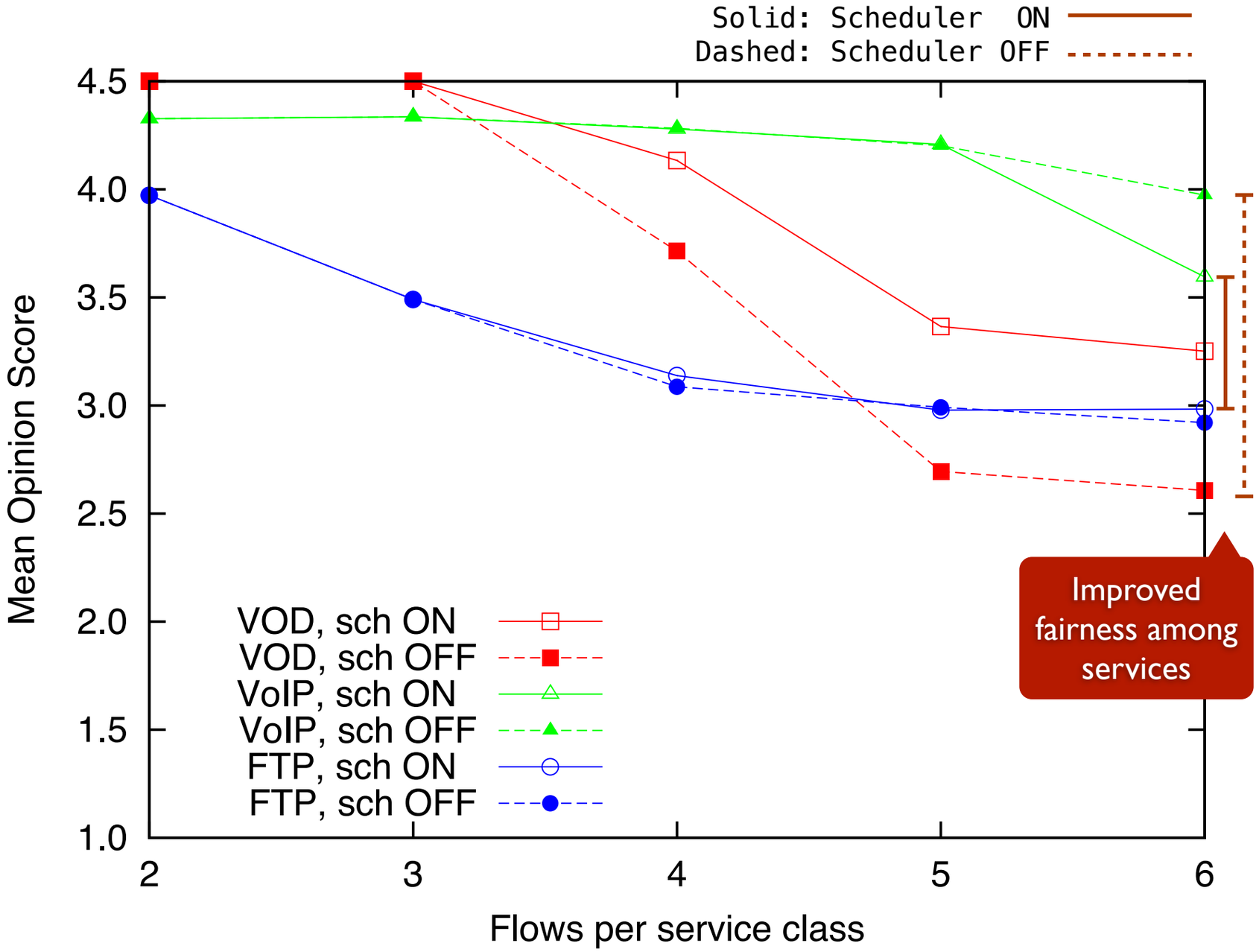
Video/Voice/Data, mesh network

Topology:

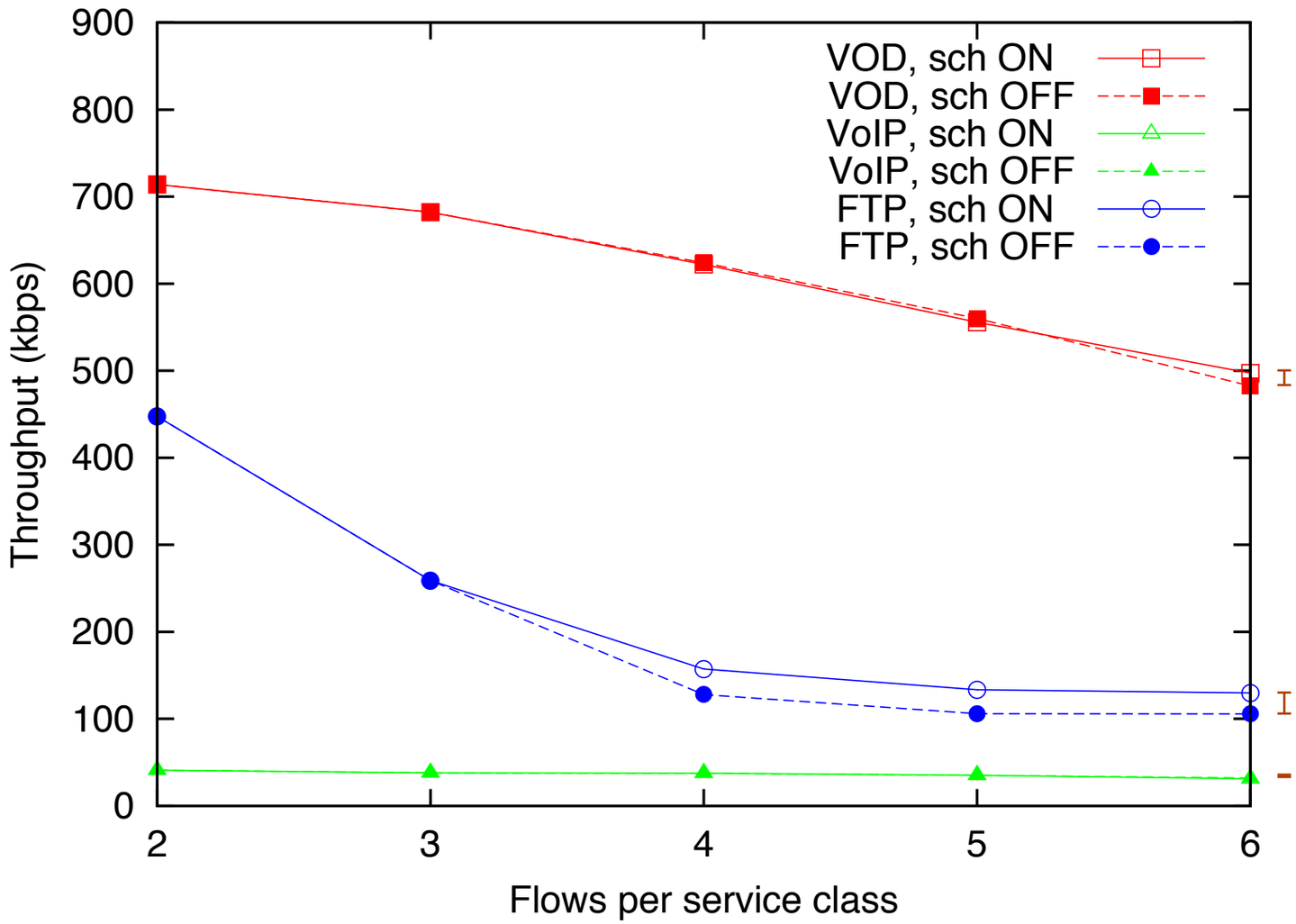


Random flow positioning

VOD, VoIP, FTP services



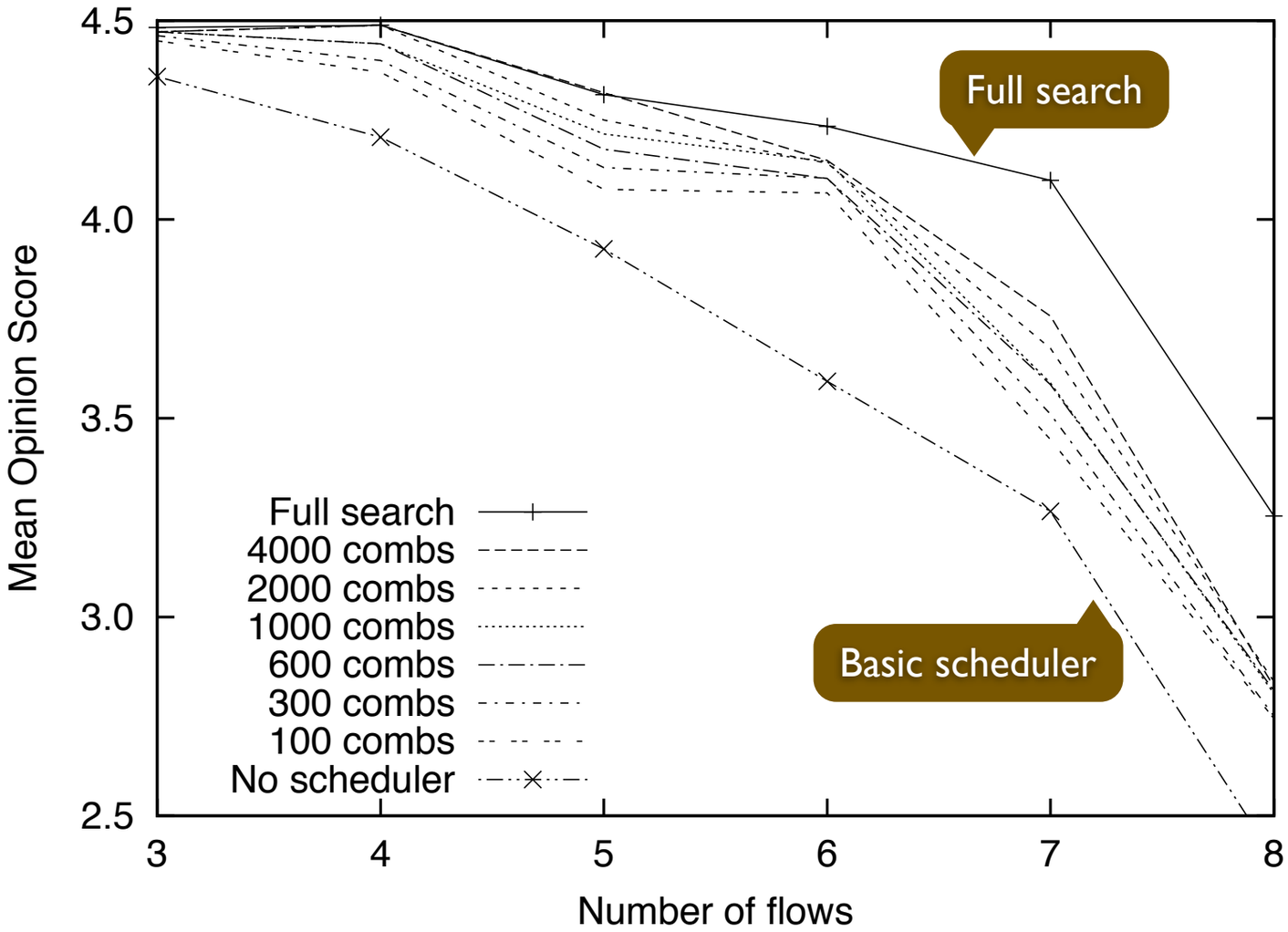
Link efficiency



- Link utilization remains the same — even increasing slightly.

Performance analysis

- Constrain # of combinations sent to $Q(p) = \sum_{i=1}^{n} k_i \cdot \Delta MOS_p^i - \lambda \cdot \sum_{i=1}^{n} \Delta R_p^i + \mu \cdot n \cdot \sigma(\Delta MOS)$



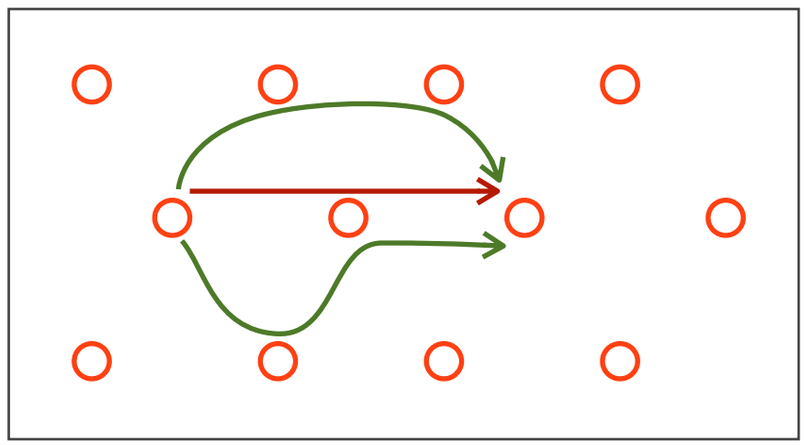
- Moderate gains can be achieved while saving on computational demand.

Conclusion

- Content-aware scheduling can significantly improve quality for the end-user.
- In a mesh network, QoE-aware scheduling must happen at the nodes where bandwidth is being constrained.
  - Intelligent scheduling along the paths is critical
- A MOS-based scheduler for audio, video and data covers a significant portion of today's traffic trends.
  - Improved quality and fairness can be had with a multi-service approach
  - Computational effort should be evaluated for feasibility of deployment

Future Work

- QoE-aware forwarding decisions aided by a modified OLSR



- Different cost functions
  - Proportional fairness
  - Exponential weighting

- Performance evaluation on wireless mesh testbeds

— Thank you —