Impact of Quality Adaptation in SVC-based P2P Video-on-Demand Systems

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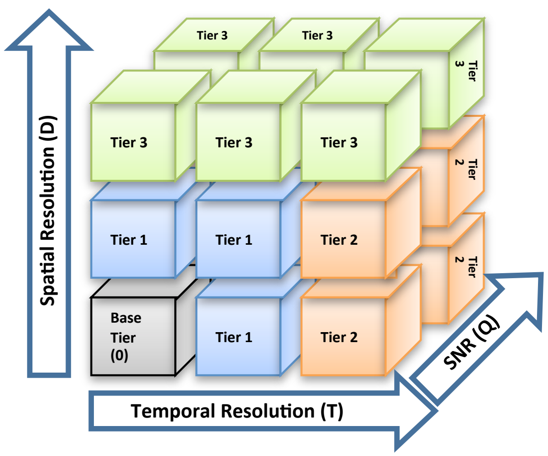

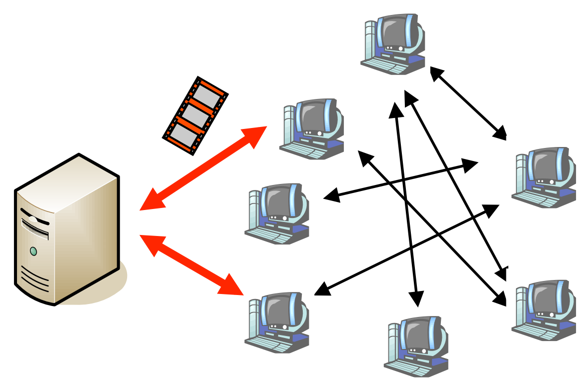

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Introduction

Video is a major part of Internet traffic [1]

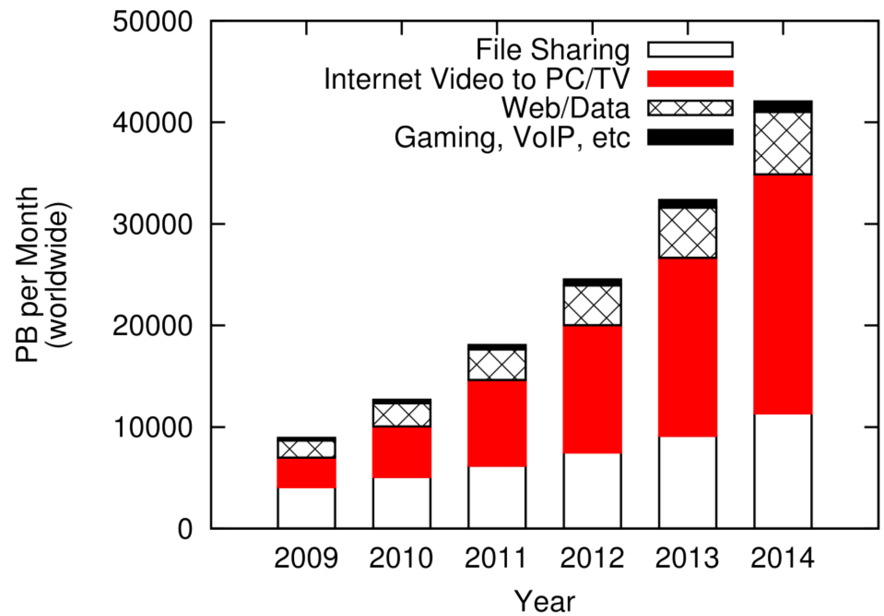
- By 2014 almost 90% of Internet traffic

Peer-assisted solution

- Reduce server load by making use of client-side resources
- System is more scalable

But how to overcome weak peer contributions and heterogeneity?

- Scalable Video Coding (SVC) can relieve and solve many issues and problems



	Bandwidth	Screen size	CPU
Home PC	10 Mbps	1920x1080	>2 GHz
Netbook	5 Mbps	1024 x 600	1.6 GHz
Smart phone	1 – 2 Mbps	800 x 480	900 MHz

[1] Cisco Visual Networking Index: Forecast and Methodology, 2009-2014

This paper

... is about

- Designing and evaluating a P2P VoD system that uses SVC to overcome resource heterogeneity and weak peer contributions

… addresses the questions

- Does SVC really help in systems with heterogeneous resources?
- How to measure the quality of an SVC-based VoD system?
- How should the SVC layer selection algorithm be configured?
- How often should these algorithms be executed?

Outline

Introduction

Scalable Video Coding

The Quality Adaptive VoD System

- Quality Adaptation Algorithms
- Peer Selection
- Connection Management
- Block Selection

Evaluation Metrics and Setup

Evaluation Results

Conclusion

Scalable Video Coding (SVC)

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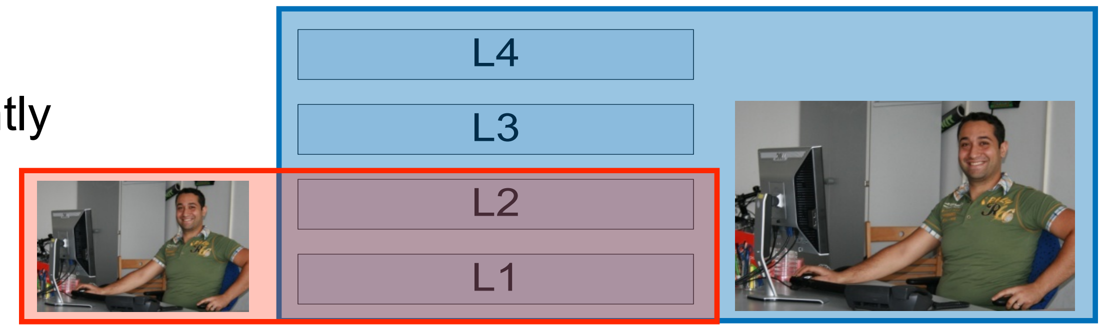
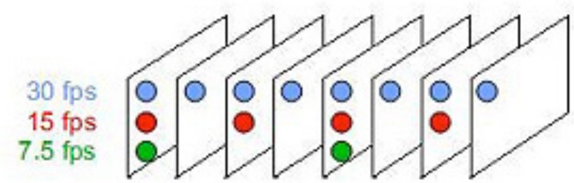
Video file encoded only once but with different quality levels

- Can be requested independently



Enables quality adaptation

- Video quality adjustable according to static and dynamic resources



Scalability in 3 dimensions

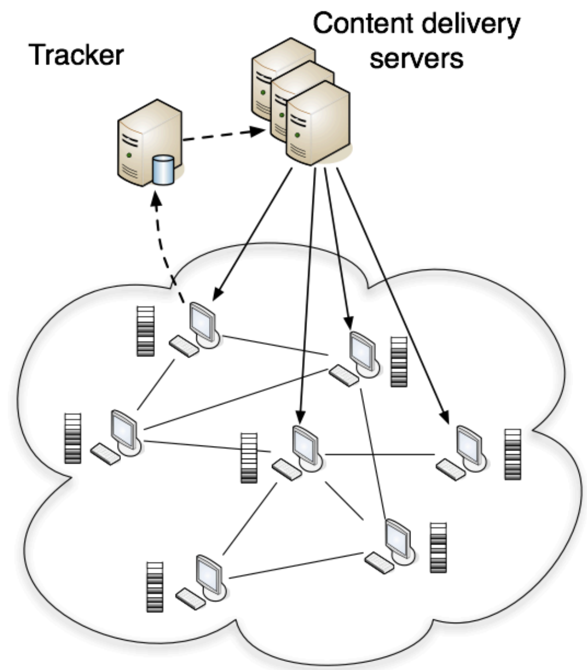
- Temporal: Frames per second
- Spatial: Resolution of the picture
- Quality: Quantization levels, sharpness

Picture sources: http://www.hhi.fraunhofer.de/index.php?id=2767&L=1

The P2P Video-on-Demand System

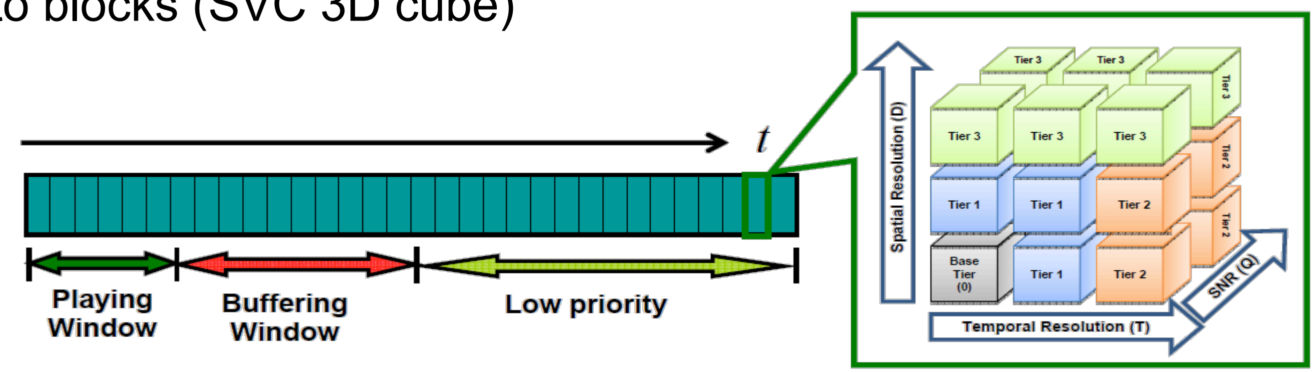
Peer-assisted architecture

- Mesh-based pull approach
- Hybrid server/P2P solution
  - Servers with modest resources are deployed
  - Inject the initial content, guarantee QoS
- Tracker with contact information of the peers



Video streaming

- Video divided into chunks (time domain)
- Chunks divided into blocks (SVC 3D cube)



Quality Adaptation Algorithms

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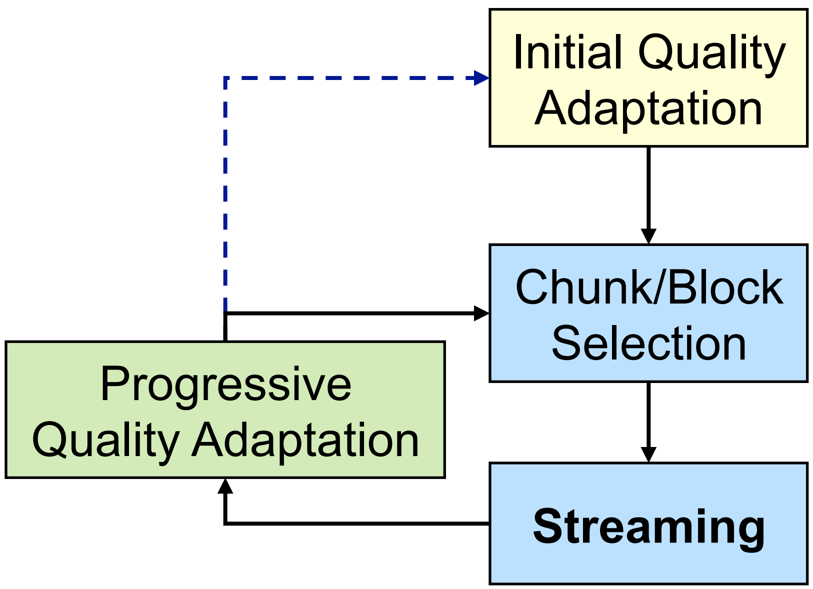
Select SVC layer according to

- Peer resources and network dynamics
- Different strategy depending on the stage of the streaming session



Initial Quality Adaptation (IQA)

Determines stream-able SVC layers

- Based on static peer resources
- Invoked at the beginning of video playback

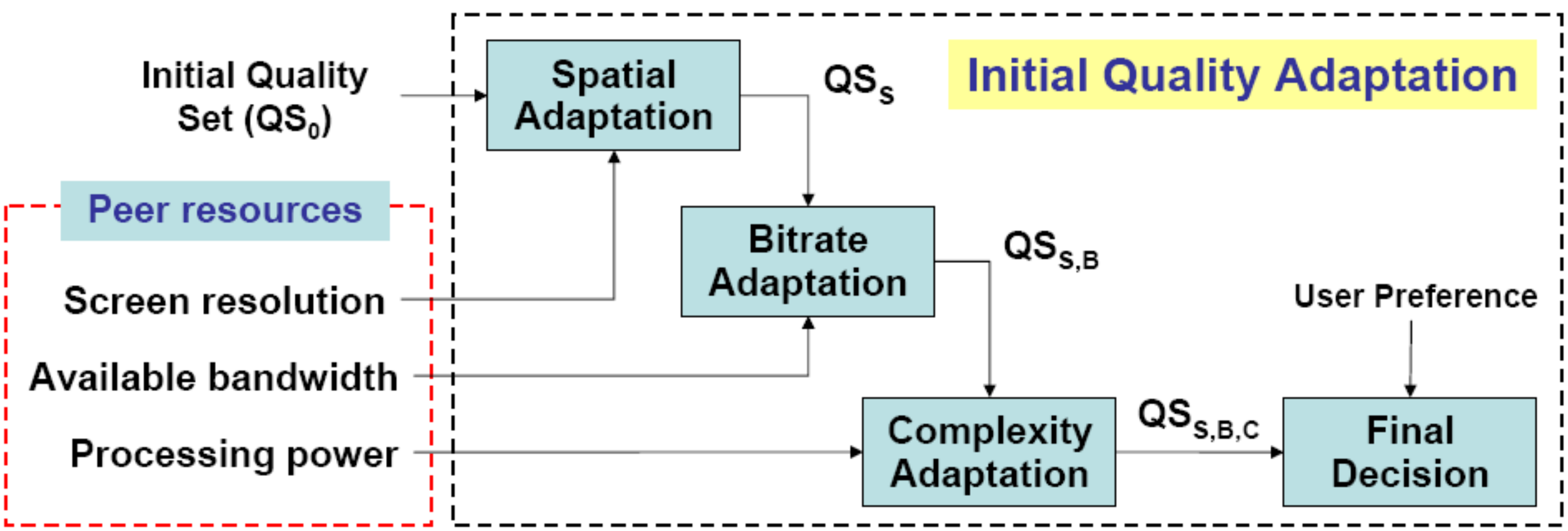
Goal

- Avoid long startup times
- Match resources at session start

Uses static peer resources

Stages

- Spatial adaptation
- Bit-rate adaptation
- Complexity adaptation



Progressive Quality Adaptation (PQA)

Adapt to real time changes of the network

- Activated periodically (every T seconds)
- Based on real time network information

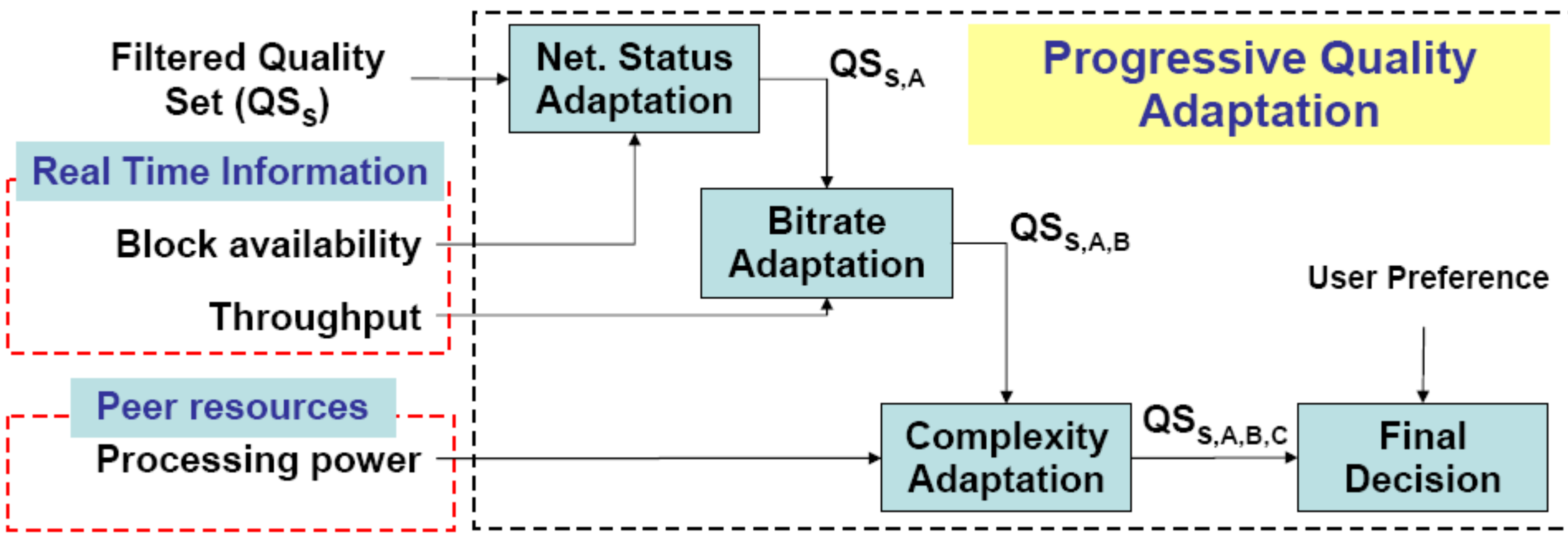
Goal

- Predict possible stalls before they happen
- Avoid stalls by temporary switching the layer

Uses real time information

Stages

- Net-status adaptation
- Bitrate adaptation
- Complexity adaptation



PQA Stages

Net-status Adaptation

- Only request layers that are available within local neighborhood
  - Determine the highest supported SVC layer
  - Avoid waiting for rare blocks by temporary switching the layer

Bit-rate Adaptation

- Adjust layer according to throughput of high priority set
- Throughput observed through the fullness of the high priority set
- Avoid buffer under run by switching down the layer when throughput is low
- Switch layer up in case throughput high enough

Complexity Adaptation

- Use models that estimate required processing speed for decoding each layer

Peer Selection and Neighbor Management

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Tracker manages: active peers and layers they currently stream

- Important in order to connect correct providers and consumers

Peers advertise currently streamed SVC layers

- After successful IQA/PQA to the tracker and neighbors
- During connection establishment phase with neighbors
- Buffer maps are extended to support SVC

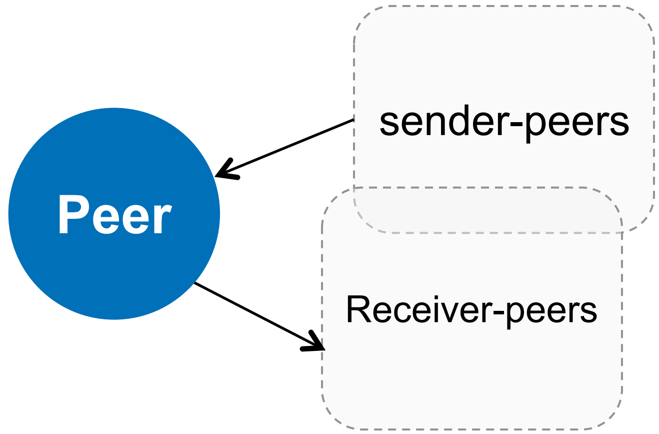
The mechanism is bi-directional

- Peers are eventually clustered according to their resources
- Seeders/caches support both weak and strong peers.

Connection Management

Two separated peer sets

- Sender peer set
- Receiver peer set



Sender peer set

- Rank peers
  - Trace their contribution
  - Drop bad ones

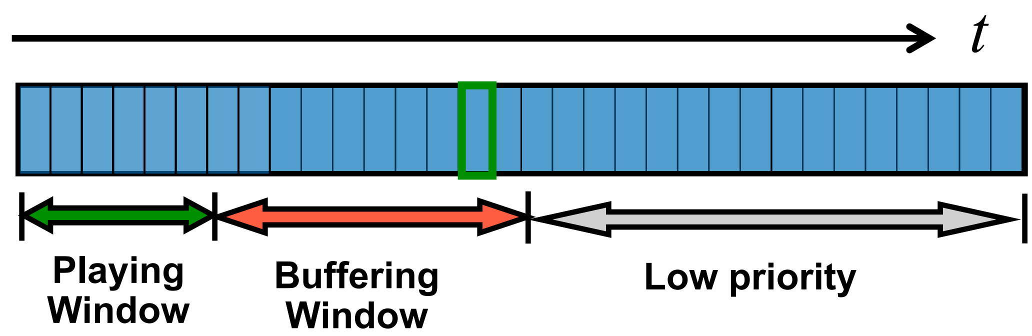
Receiver peer set

- Limit the number according to upload bandwidth
- Assign upload slots according to how urgent a request is.

Block Selection

High priority set

- Sliding buffer window, updated with playback position



Download task dispatching

- Parallel download from multiple peers
- Keep all peers as busy as possible

Priority calculation

- High priority set: use greedy approach
  - Chunks close to playback position and base layer get highest priority
- Low priority zone: use non-greedy approach
  - Download blocks "soon most wanted" by receiver set

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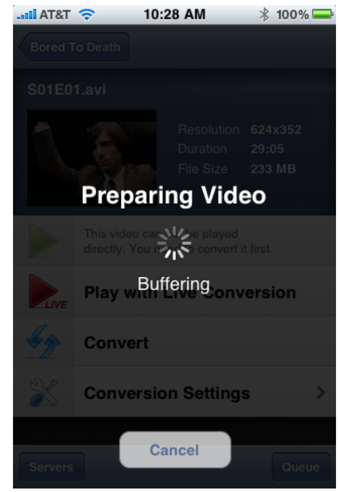
Evaluation Metrics

Session Quality

- Relative playback delay

$$Relative_{delay} = \frac{Delay_{init} + \sum_{i=1}^{n} Stall_i}{Time_{playback}}$$

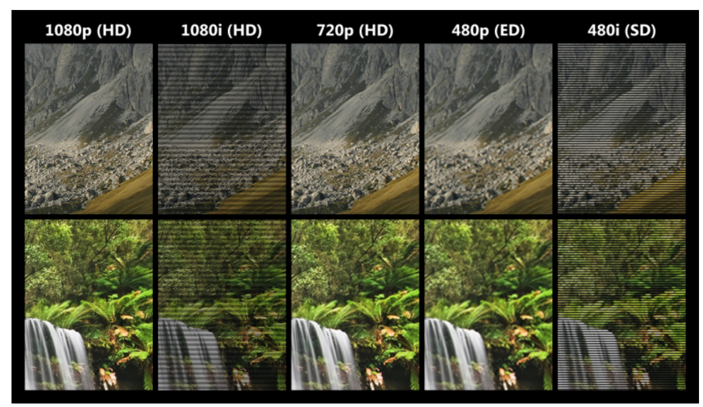


Video Quality

- Number of layer changes
- Relative received layer

$$Quality_{rel}(d, t, q) = \frac{d + t + q}{D_{init} + T_{init} + Q_{init}}$$

- Less layer changes or higher relative received layer → Better user experience



Evaluation Setup

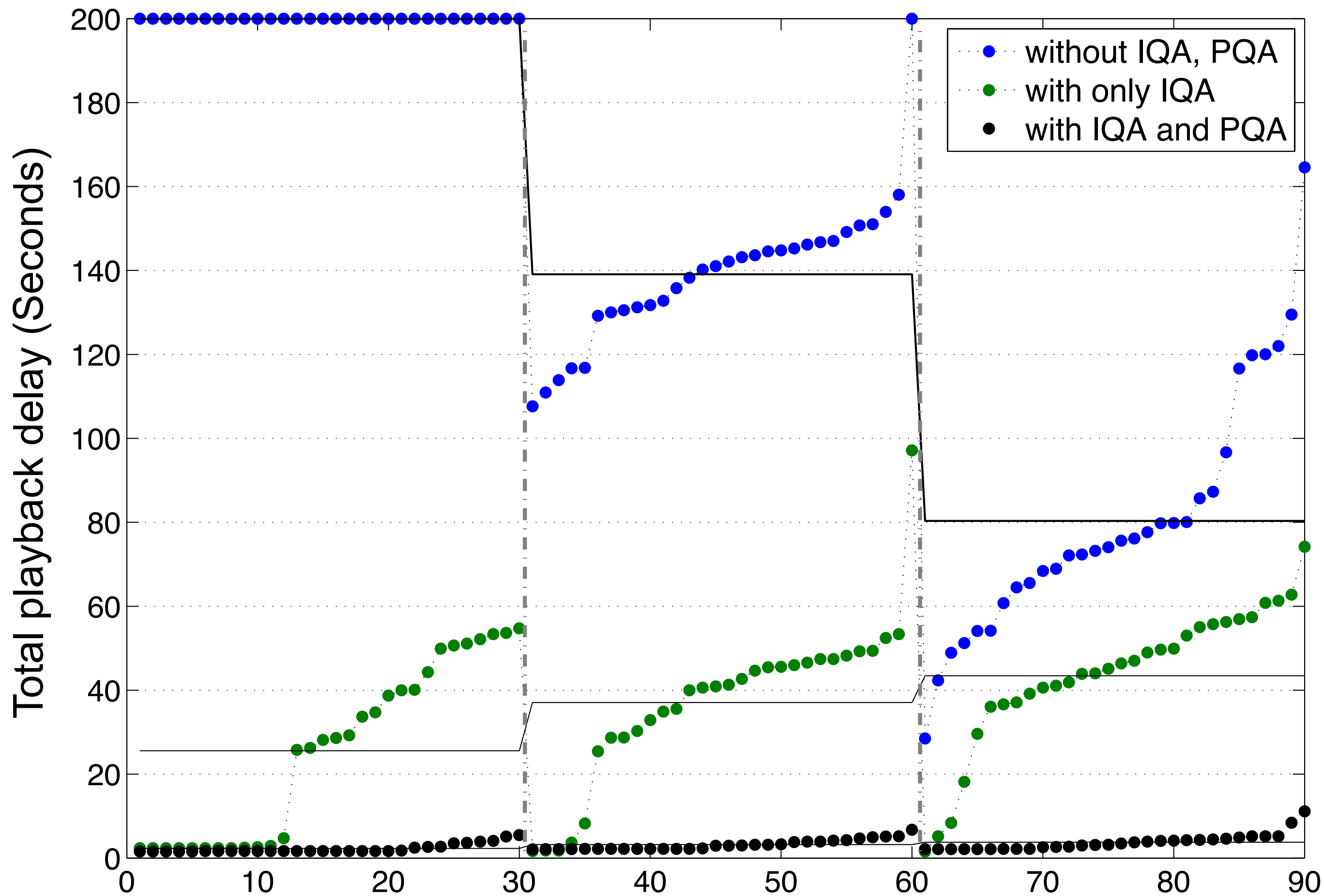
Simulation Parameters

Parameter	Value
Simulation duration	200 minutes
Number of peers	90
Peer arrival pattern	Exponential
Number of servers	4
Server upload capacity	6 Mbps
Play-out buffer size	7 seconds
Neighborhood size	10
Video length	5 minutes

Peers divided into three sets according to resources

	Set 1	Set 2	Set 3
Number	30	30	30
Screen size	176×144	352×288	704×576
Upload speed	128 Kbps	320 Kbps	800 Kbps
Download speed	256 Kbps	560 Kbps	1200 Kbps

Impact of Quality Adaptation: Session Quality



Weak Peers **Medium Peers** **Strong Peers**

Impact of PQA Frequency: Visualization

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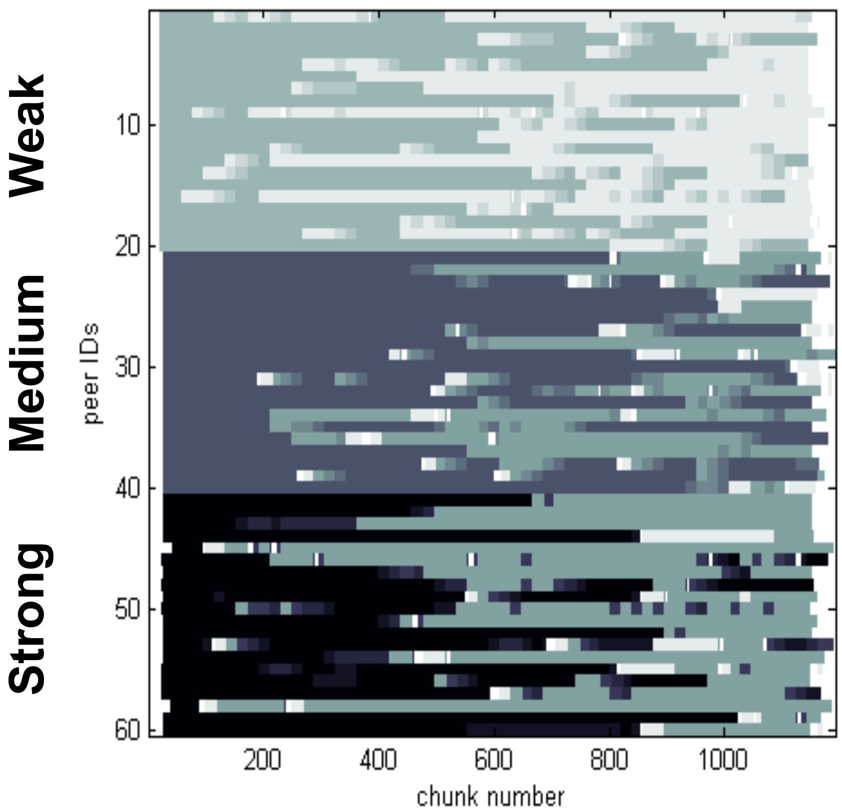
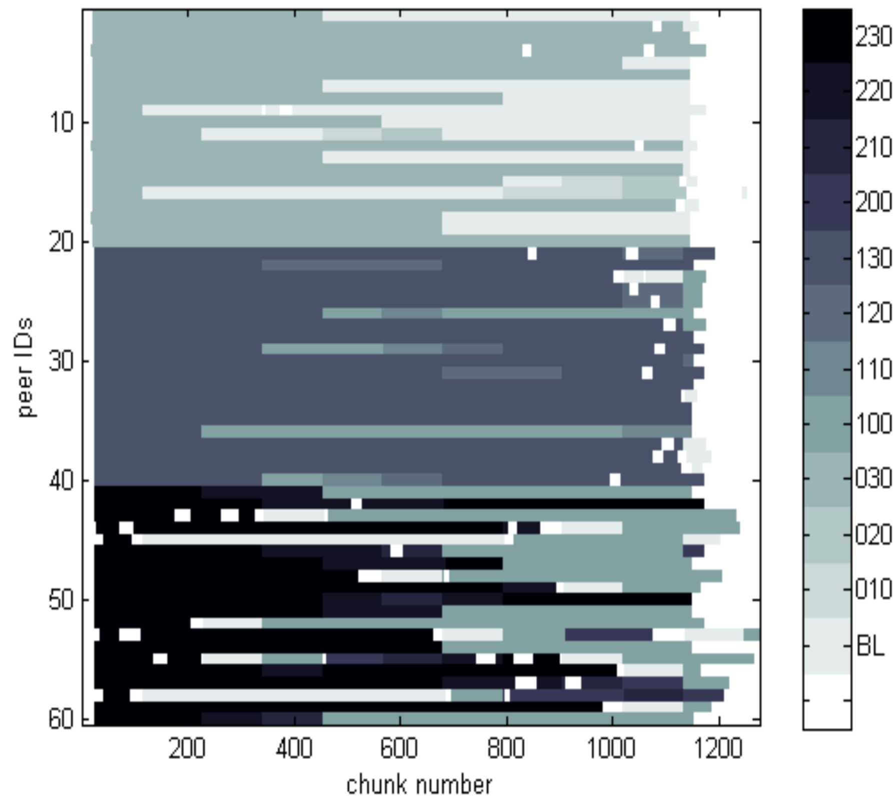
The darker, the higher is the layer. White indicates a stall

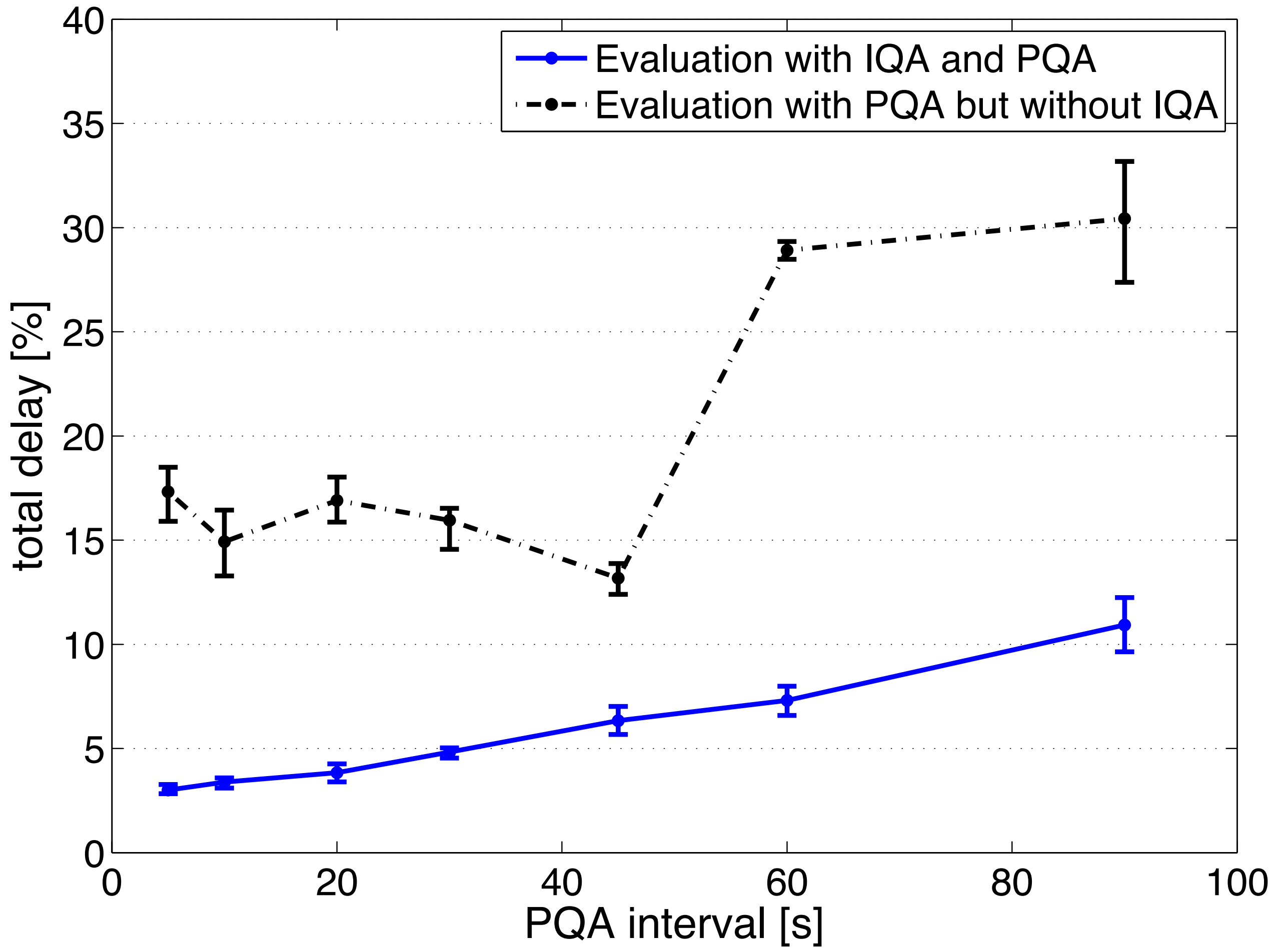


PQA every 5 seconds

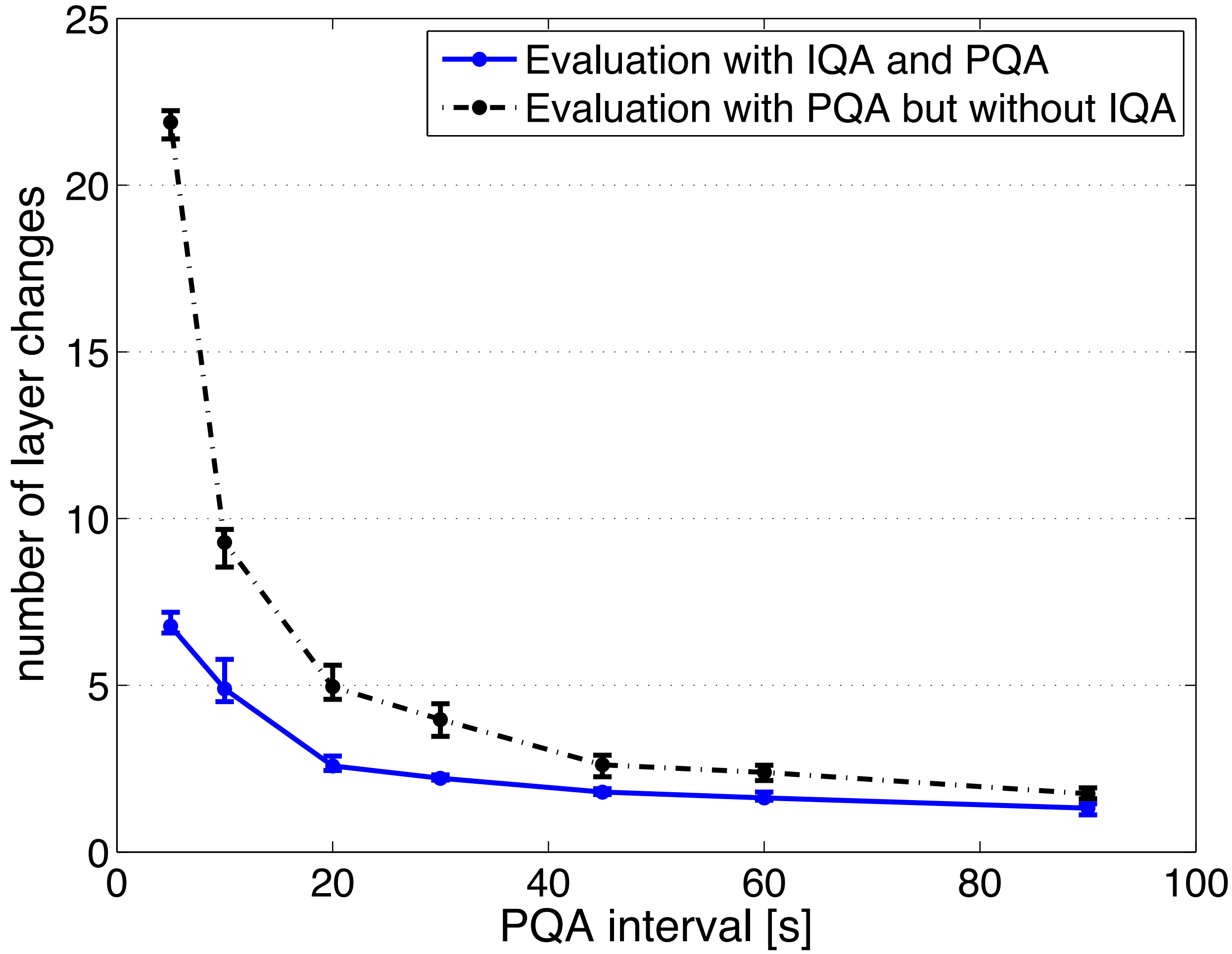


PQA every 30 seconds

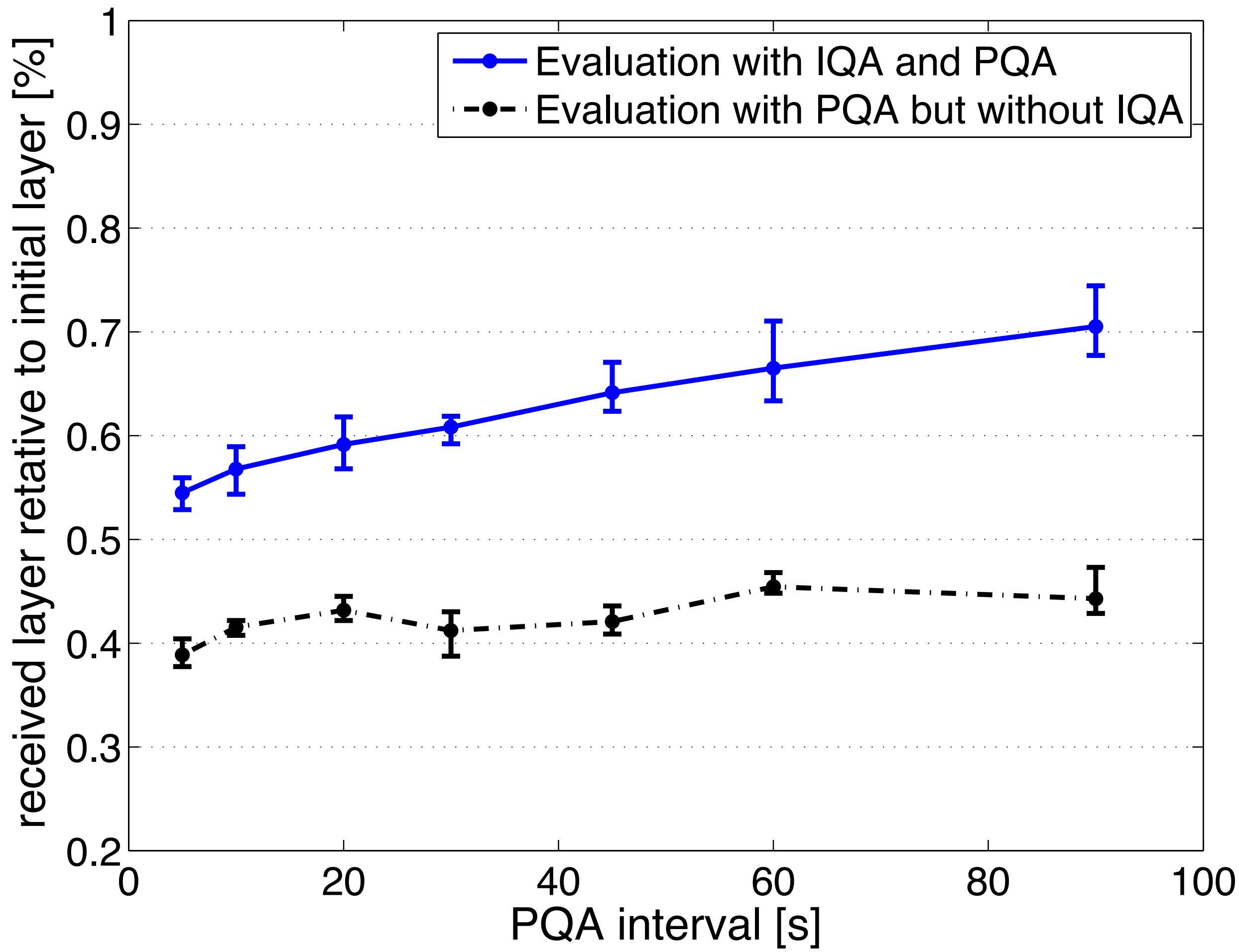
Impact of PQA Frequency on Session Quality
Relative Playback Delay



Impact of PQA Frequency on Video Quality
Number of Layer Changes



Impact of PQA Frequency on Video Quality
Relative Received Layer



Evaluation Conclusions

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IQA and PQA help in achieving

- Better session quality
- More homogeneous performance across heterogeneous peers

PQA invocation interval exhibits a performance trade-off

PQA interval ↗ Session quality ↘ Video quality ↗

Best PQA interval depends on application scenario and user expectation

Conclusions and Next Steps

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P2P Video streaming is envisioned to have more importance

- SVC is needed to
  - Support high quality streaming
  - Achieve homogenous performance at heterogeneous peers

Advanced adaptation algorithms were developed

- To enable an efficient provisioning of resources
- Performance, tradeoffs, and impact of adaptation were explored

Possible optimizations

- Adaptive PQA interval
- Prediction-based layer selection
- Map session and SVC quality metrics to Quality-of-Experience metrics

That's all folks
Thank you for your attention. Questions?

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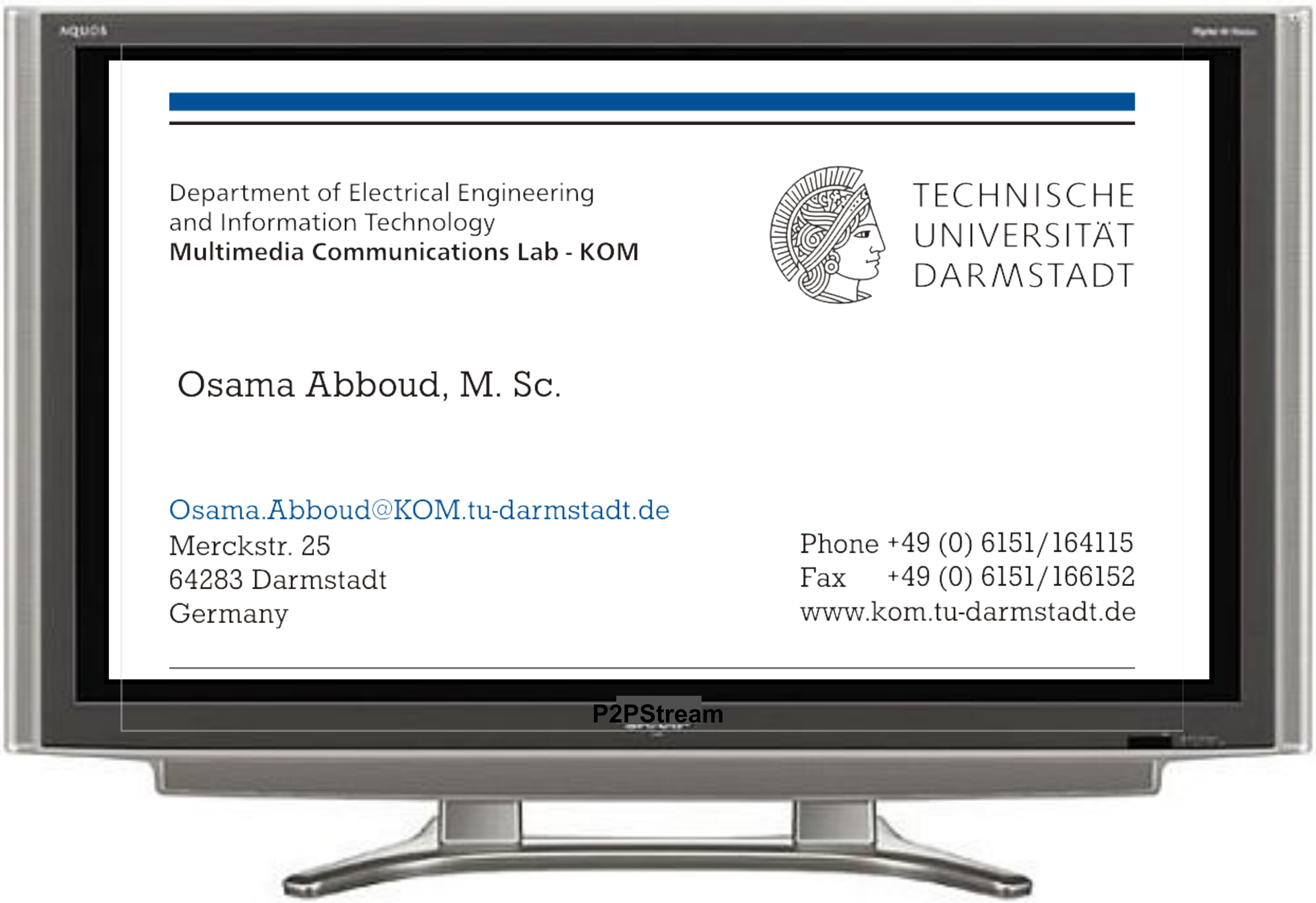

SVC: Block-based Quality Scalability

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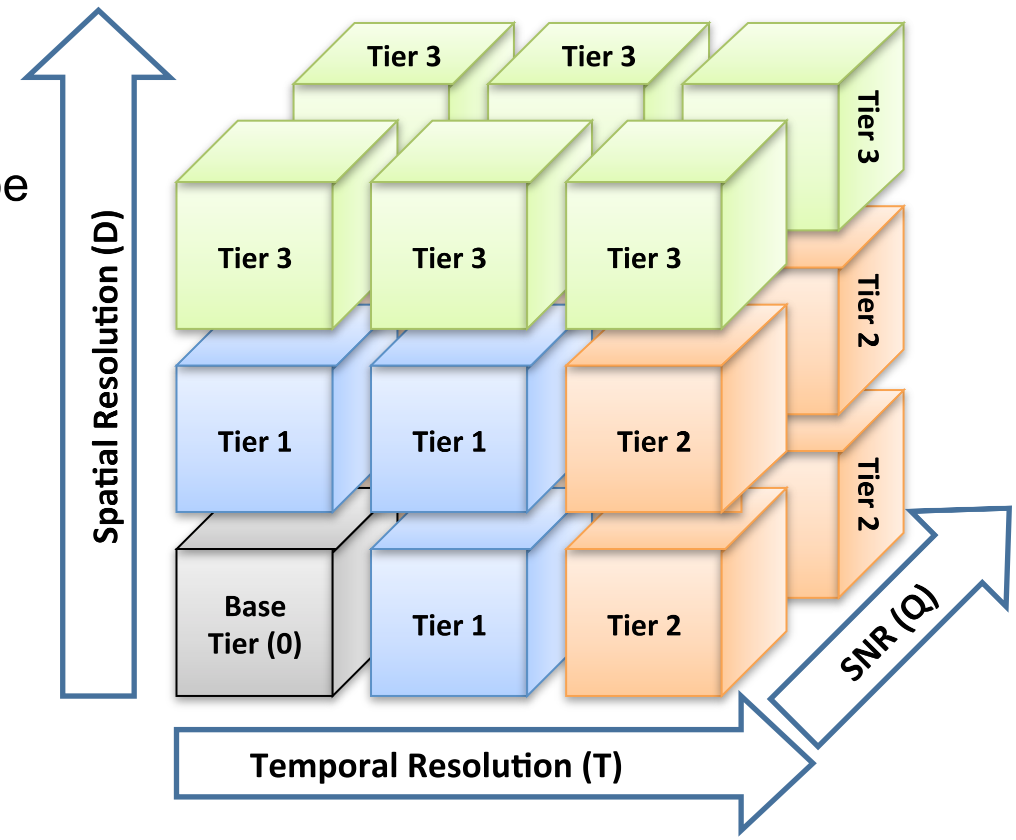
Three-dimensional scalability

SVC Cube-Model
- Each GOP is modeled by a 3D-cube
- Block-combinations form layers
- Base layer is the most important

Must consider
- Interdependencies of blocks
- Deadline of blocks
- User preference



Evaluation Scenario

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SVC Video File

- Used traces from a real nature video clip with medium activity

SVC layer (d,t,q)	Picture size	Frame rate (fps)	Partial Bit-rate (Kbps)	Total Bit-rate (Kbps)
0,0,0	176×144	3.75	60	60
0,1,0	176×144	7.5	30	90
0,2,0	176×144	15	30	120
0,3,0	176×144	30	30	150
1,0,0	352×288	3.75	180	240
1,1,0	352×288	7.5	90	330
1,2,0	352×288	15	60	390
1,3,0	352×288	30	60	450
2,0,0	704×576	3.75	270	510
2,1,0	704×576	7.5	150	660
2,2,0	704×576	15	180	840
2,3,0	704×576	30	160	1000