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Advanced Networking and Future Internet

I. Introduction

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Bern, 14.09.2020

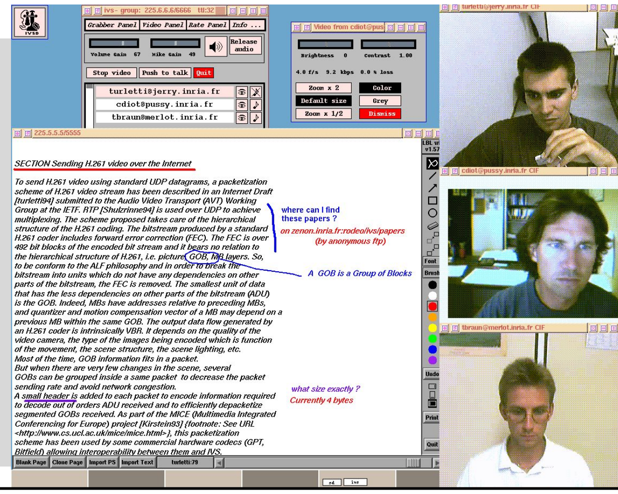
Advanced Networking and Future Internet: Introduction

Table of Contents

1. Introduction

1. Advanced Networking and Future Internet

- Internet is the basic network for all kinds of today's communication.
  - e.g., for web, TV, phone (Voice over IP)
- Internet development started in the 1970's with continuous development
  - Queuing
  - Traffic Engineering
  - Software-Defined Networking
- New challenges from new application areas
  - Content distribution, peer-to-peer networks
  - Multimedia applications, e.g.,
    - interactive TV and games
    - Virtual Reality / Augmented Reality
    - computer supported cooperative work
  - Cloud computing (data centres)
- Several international research projects on Future Internet architectures
  - Information-Centric Networking



1. Introduction
2. Multimedia

- Multi
  - in Latin: multus = numerous
- Medium
  - in Latin: medium = middle, center
  - here: a means to distribute and represent information
  - Examples: text, graphics, pictures, sound, music

5 Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 7-11

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1. Introduction

3. Media Classification

Classification of media depends on presentation space dimensions (time and space).

- Discrete (time-independent) media
  - Time-independent information items: Time is not part of semantics of discrete media.
  - Sequence of single elements without any time relationship
  - Media processing is not time-critical, but should be performed as fast as possible
  - Examples: text, graphics, pictures
- Continuous (time-dependent) media
  - Time is part of the information itself. Time is part of the semantics.
  - Changes in timing may lead to modified sequencing → altered meaning
  - Media processing is time critical.
  - Examples: sound and motion video

[6] Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 7-11

2. Quality-of-Service

1. Quality-of-Service (QoS) Parameters

Set of chosen parameters for a particular service determines what will be measured as QoS.

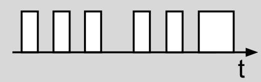
- Perceptual QoS parameters
  - Perceptive quality (media quality, window size, response time etc.)
  - Description of pricing choices
- Application QoS parameters
  - Media quality (frame rate and resolution)
  - Media relations (relations among media)
  - Adaptation rules (actions if bandwidth is scarce)
- System QoS parameters: requirements derived from application QoS
  - Quantitative criteria (concrete measures of throughput, errors etc.)
  - Qualitative criteria (functions needed to provide application QoS: synchronization, ordering, error control etc.)
- Device QoS parameters
  - Timing and throughput demands for audio / video devices
- Network QoS parameters
  - Network load
  - Network performance

7 Steinmetz, Nahrstedt: Multimedia Systems, Springer, 2004, pp. 18-20

2. Quality-of-Service

2. Network QoS Parameters

- Bandwidth
  - Number of bits that can be transferred over a network/link in a certain time period.
  - also: term used for width of frequency bands
- Throughput
  - Performance measure for systems
- Delay / Latency
  - One-way delay (difficult to measure, requires time synchronization)
  - Round trip time (RTT)
  - Delay components
    - Transmission delay = packet size / link bandwidth
    - Propagation delay = distance / propagation speed (e.g., c)
    - Processing delay for packet processing in end systems or routers
    - Queuing delay because packets might have to wait before transmission over a link
- Jitter



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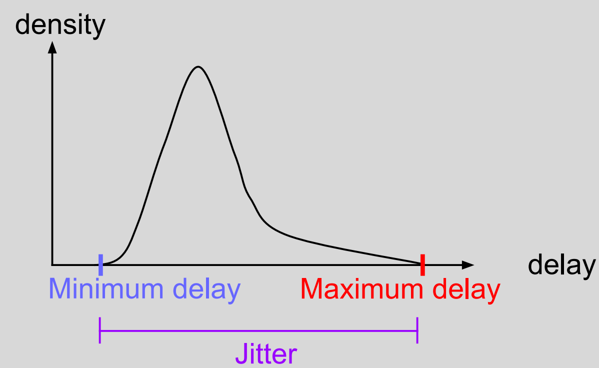
Peterson, S. 44 ff.
Kurose, S. 36

2. Quality-of-Service

3. Jitter

- Delay jitter = delay variation (difference between minimum and maximum delay)
- Jitter compensation by buffering at receiver (play-out buffer)



9 Peterson, Davie: Computer Networks, Morgan Kaufman, 2007, pp. 49
El-Gendy et al.: Evolution of the Internet QoS and Support for Soft Real-Time Applications, Proceedings of the IEEE, Vol. 91, No. 7, July 2003, pp. 1087
Braun et al.: End-to-End Quality-of-Service over Heterogeneous Networks, Springer, 2008, pp. 3

2. Quality-of-Service

4. Quality-of-Service Demanding Applications

- Interactive vs. non-interactive
  - IP telephony requires < 300 ms delay and low delay variation (< 75 ms jitter).
  - Non-interactive applications such as data backup have often large bandwidth requirements.
- Elastic vs. inelastic
  - Elastic applications (e.g., on top of TCP) can work under a variety of network conditions.
  - Many inelastic (real-time) applications need QoS guarantees.
    Soft real-time applications can tolerate some temporary QoS degradation.
- Tolerant vs. intolerant
  - Tolerant applications have QoS requirements but with ranges or levels.
- Adaptive vs. non-adaptive
  - Adaptive applications try to maintain a reasonable quality level even under poor network conditions, e.g., by changing encoding or buffering.
- Real-time audio / video vs. streaming
  - Hard delay requirements vs. adapting play-out using buffering
- Multimedia vs. large-scale data and computation
  - Cloud computing or stock data applications may also generate QoS requirements in terms of bandwidth and/or delay.

10 El-Gendy et al.: Evolution of the Internet QoS and Support for Soft Real-Time Applications, Proceedings of the IEEE, Vol. 91, No. 7, July 2003, pp. 1087

2. Quality-of-Service

5. Application Requirements

Application	Loss	Throughput	Time-Sensitivity
File transfer	0	Elastic	-
Email	0	Elastic	-
Web documents	0	Elastic (few kbps)	-
Internet telephony / Video conferencing	tolerant	Audio: few kbps – 1 Mbps Video: 10 kbps – 5 Mbps	few 100 ms
Audio/Video streaming	tolerant	cf. Internet telephony / video conferencing	few s
Virtual Reality	tolerant	many Gbps	10-20 ms
Interactive games	tolerant	few kbps – several Mbps	few 100 ms
Instant messaging	0	Elastic	partly

Kurose , S. 93

3. Quality-of-Experience

1. Quality Measures

QoE describes user-/application-oriented quality of multimedia services.

- *Subjective*: User rates perceived audio/video quality, but it is not possible to measure at run-time.
  - Absolute rating: Mean Opinion Score (MOS)
  - Comparison-based rating: Users listen/watch to reference and actual A/V sequences.
- *Objective*: A/V QoE depends on QoS measures such as A/V coding distortion, delay, jitter, packet loss
  - Estimation of QoE based on measured QoS parameters and/or A/V signals
  - Learning of correlation between QoS measures and QoE, e.g., using neural networks
  - Examples
    - Audio: comparison of reference and degraded audio waves
    - Video: Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM) Index

Jelassi et al.: Quality of Experience of VoIP Service: A Survey of Assessment Approaches and Open Issues, IEEE Communications Survey & Tutorials, Vol. 14, No. 2, 2nd Quarter 2012, pp. 491

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3. Quality-of-Experience

2. Mean Opinion Score

- Example: voice applications
- Listeners are asked to rate „absolute“ quality of speech (absolute category rating).
  - Insertion of reference (not known to users) for calibration
  - Quality scale:
    - Bad (very annoying distortions)
    - Poor (annoying distortions)
    - Fair (slightly annoying distortions)
    - Good (perceptible distortions, but not annoying)
    - Excellent (imperceptible distortions)
- Comparative approaches
  - Degradation category rating: comparison with good quality speech
  - Comparison category rating: comparison with random quality speech

Hersent, Petit, Gurle: Beyond VOIP Protocols, Wiley, 2005, pp. 77-80

Ververidis, C.N.; Riihijarvi, J.; Mahonen, P., "Evaluation of quality of experience for video streaming over dynamic spectrum access systems," *World of Wireless Mobile and Multimedia Networks (WoWMoM), 2010 IEEE International Symposium on a* , vol., no., pp.1,8, 14-17 June 2010, doi: 10.1109/WOWMOM.2010.5534892

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3. Quality-of-Experience

3. Peak Signal to Noise Ratio

- PSNR measures mean error between original and distorted frame.
- $MSE = \frac{1}{M \cdot N} \sum_{m=1}^{M} \sum_{n=1}^{N} |o(m,n) - d(m,n)|^2$
- $PSNR = 10 \log \frac{255^2}{MSE}$
- Example mapping for MPEG4 video

PSNR	MOS
> 37	5
31-37	4
25-31	3
20-25	2
< 20	1

Piamrat et al.: Quality of Experience Measurements for Video Streaming over Wireless Networks, 6th Conference on Information Technology: New Generation, 2009, doi: 10.1109/ITNG.2009.121

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3. Quality-of-Experience

4. Structural Similarity Index

- SSIM index considers that human eye extracts luminance, contrast, and structural information from images.
- $x = \{x_i \mid i=1,\ldots,N\}$: original signal
- $y = \{y_i \mid i=1,\ldots,N\}$: distorted signal
- $\overline{x}$: mean of x
- $\overline{y}$: mean of y
- σ_x: variance of x
- σ_y: variance of y
- σ_{xy}: covariance of x and y, $\sigma_{xy} = \frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x}) \cdot (y_i - \overline{y})$
- $C_{1,2}$: constants

$$SSIM = \frac{(2\overline{x}\overline{y} + C_1) \cdot (2\sigma_{xy} + C_2)}{(\overline{x}^2 + \overline{y}^2 + C_1) \cdot (\sigma_x^{\,2} + \sigma_y^{\,2} + C_2)}$$

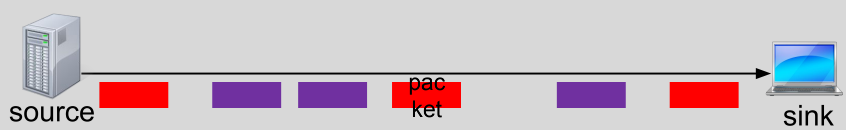
Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, "Image quality assessment: From error visibility to structural similarity," IEEE Transactions on Image Processing, vol. 13, no. 4, pp. 600-612, Apr. 2004.

Chaminda, Hewage et al.: Quality Evaluation of Color Plus Depth Map-Based Stereoscopic Video, IEEE Journal of Selected Topics in Signal Processing, Vol. 3, No. 2, April 2009, pp. 304

4. Multimedia Data Streams

1. Data Transmission

- Transmission of packets from source to sink.
- Data stream = (temporal) sequence of packets
- Packets can carry information from continuous and discrete media.
- Data transmission
  - asynchronous
  - synchronous
  - isochronous



[16] Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 13

4. Multimedia Data Streams

1.1 Asynchronous Transmission

- Transmission may start at any instant.
- Two independent clocks at sender and receiver.
- Packets shall reach receiver as soon as possible.
- Examples:
  - Best-Effort-Internet
  - Ethernet
- Appropriate for transmission of discrete media information

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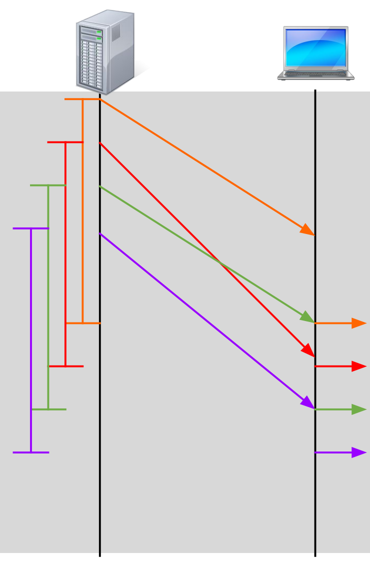
Steinmetz, Nahrstedt: Multimedia-Technologie, Springer, 2000, pp. 15

Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 13

4. Multimedia Data Streams

1.2 Synchronous Transmission



- Defines a maximum end-to-end delay for each packet of a stream
- Packet can reach receiver early.
- Jitter compensation by buffering requires large buffers, e.g.,
  - Data rate: 20 Mbps
  - Jitter: 1 s
  - Buffering of 2.5 MB data

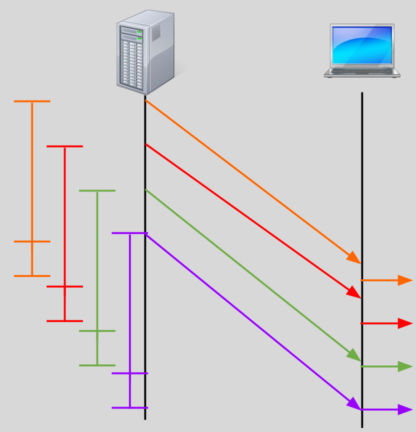
Steinmetz, Nahrstedt: Multimedia-Technologie, Springer, 2000, pp. 15

Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 14

4. Multimedia Data Streams

1.3 Isochronous Transmission

- Limitation of jitter (and reduction of buffer) by maximum and minimum end-to-end delay
- Requires scheduling support along the whole transmission path



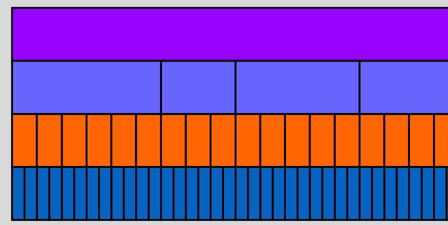
19 Steinmetz, Nahrstedt: Multimedia-Technologie, Springer, 2000, pp. 15

Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 14

4. Multimedia Data Streams

2. Continuous Media Data Streams

- Continuous media consist of a temporal sequence of information.
- Information Units
  - Protocol Data Unit (PDU)
    - or: packet
    - depends on properties of communication system
  - Logical Data Unit (LDU) (or Application Data Unit, ADU)
    - Application dependent
    - Hierarchy possible, e.g.: movie, scene, single image, pixel
- Classification
  - Strongly and weak periodic data streams
  - Variation of data volume of consecutive information units

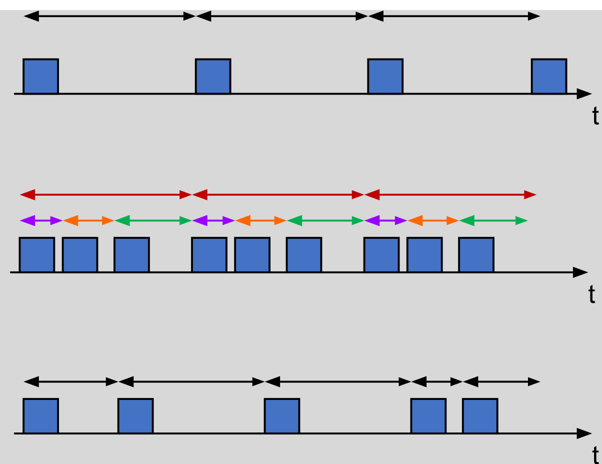


20 Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 15, 19-20

4. Multimedia Data Streams

2.1 Strongly and Weak Periodic Data Streams

- Strongly periodic
  - Example: PCM audio
- Weakly periodic
- Aperiodic
  - Example: interactive application

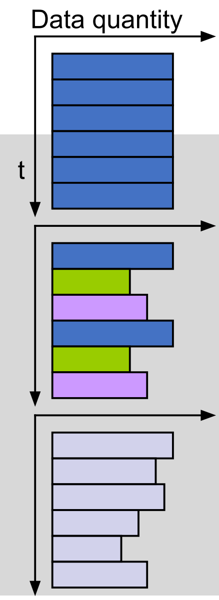


21 Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 15-16

4. Multimedia Data Streams

2.2 Variation of Data Volume of Consecutive Information Units

- Strongly regular
  - Example: PCM audio
- Weakly regular
  - Example: MPEG video
- Irregular



22 Steinmetz, Nahrstedt: Multimedia Fundamentals: Media Coding and Content Processing, Prentice Hall, 2002, pp. 16-17

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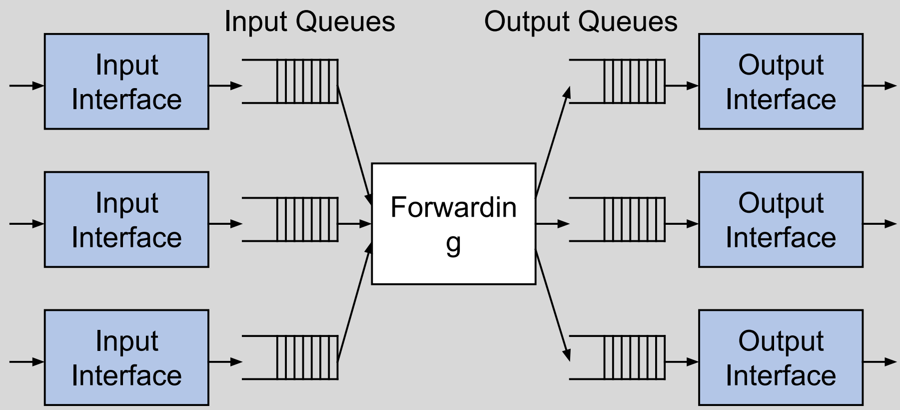
5. Lecture Overview

2. Queue Management
3. Peer-to-Peer Networks
4. Traffic Engineering
5. Software-Defined Networking
6. Data Centre Networking
7. Multicast
8. Information-Centric Networking
9. Audio/Video Compression
10. Audio/Video Transport
11. Audio/Video Conferencing and Streaming
12. Virtual Reality

5. Lecture Overview

2. Queue Management

- Packet scheduling must select one packet among queued ones.
- Dropping mechanism decides when and which packets to drop in overload conditions.



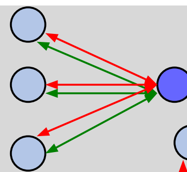
Ferguson, Huston: Quality-of-Service, Wiley, 1998, pp. 55-56
Kurose, Ross: Computer Networking, 5th edition,

24

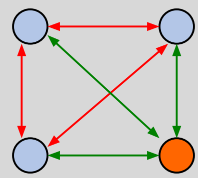
5. Lecture Overview

3. Peer-to-Peer-Networks

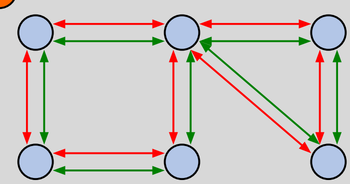
- Index and file server
  - contains file index and corresponding files



- P2P network with central index server
  - contains file index
  - Files are distributed among peers.



- Distributed P2P network
  - Index and files are distributed among peers.
  - Redundancy
  - Load balancing
  - Categories
    - Unstructured, flat overlay network with random searching
    - Structured overlay network; more efficient search based on mapping of keys to nodes



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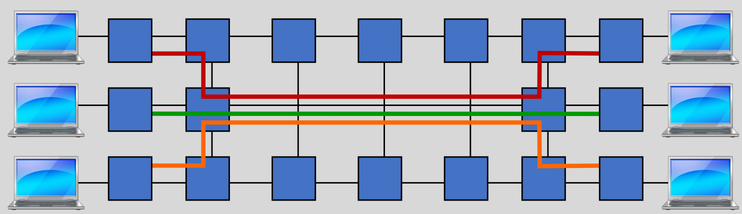
M. Parmeswaran: P2P Networking: An Information-Sharing Alternative, IEEE Computer, July 2002, pp. 31-38

5. Lecture Overview

4. Traffic Engineering

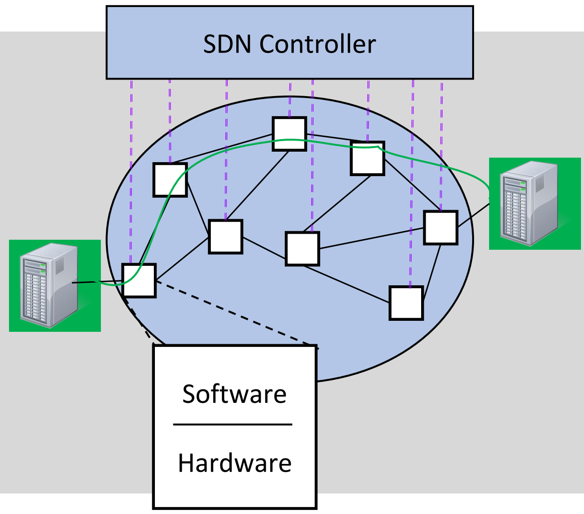
- Problem
  - Shortest path routing leads to congestion at certain links while others remain unloaded.
- Solution: Traffic engineering = process of controlling how traffic flows through a network to optimize resource utilization and network performance
  - Routing Protocol Extensions
  - Multi-Protocol Label Switching
  - Overlay Networks



5. Lecture Overview

5. Software-Defined Networking

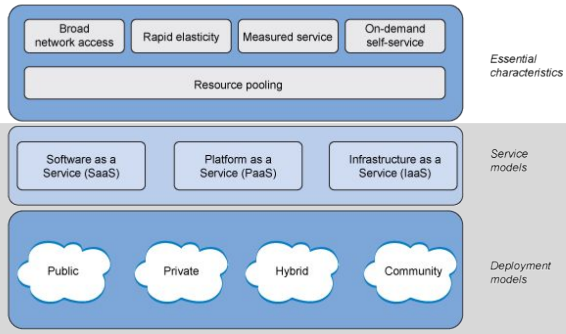
- SDN separates control and data plane
- Centralized network management by SDN controller
- Configuration protocol between SDN controller and network devices
- Software-based configuration of network devices
- Benefits for virtual and data centre networks

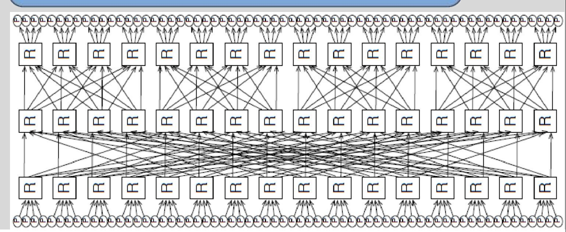


5. Lecture Overview

6. Data Centre Networking

- Architectures: Main frame → Client/Server → Clouds
- Economies of scale
- Everything as a Service
- Technologies
  - Virtualization
  - Resource allocation
  - Load balancing
  - Advanced networking mechanisms
    - Software-Defined Networking
    - Data Centre Networking: special scalable network topologies for high performance and good connectivity
- Network Function Virtualization



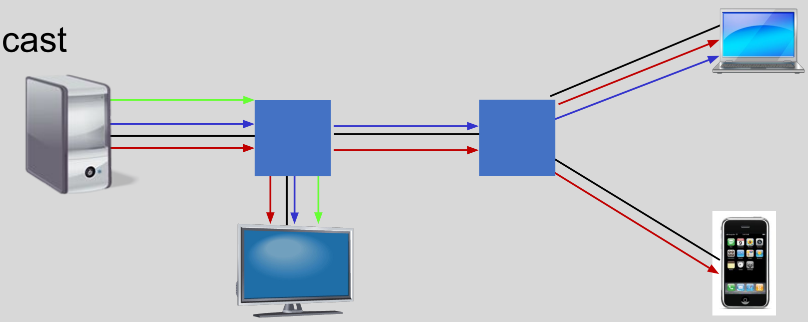


5. Lecture Overview

7. Multicast

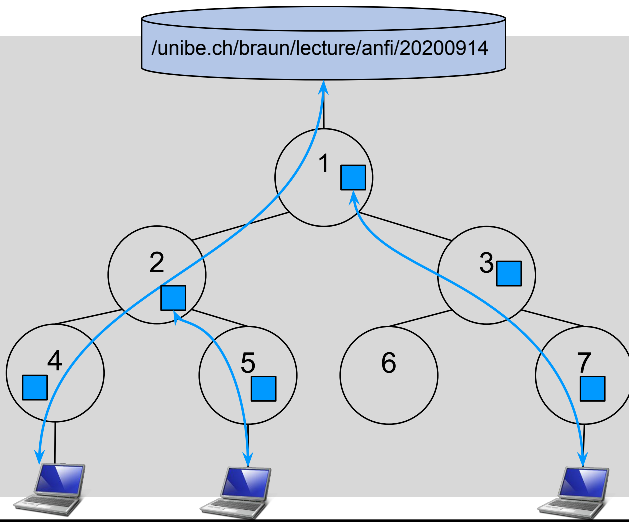
1 sender, n receivers

- IP Multicast routing
- Application Level Multicast



5. Lecture Overview

8. Information-Centric Networking



5. Lecture Overview

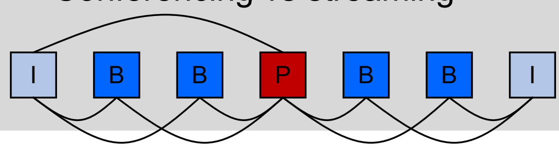
9. Audio/Video Compression

Audio Compression

- Waveform coding: approximation of original audio wave form in time domain, determines relation between subsequent audio samples
- Vocoding: transformation of audio into frequency domain and characterization of signal and frequency parameters

Video Compression

- Encoding of differences between pictures
- Compression of still images and difference values
- Conferencing vs streaming

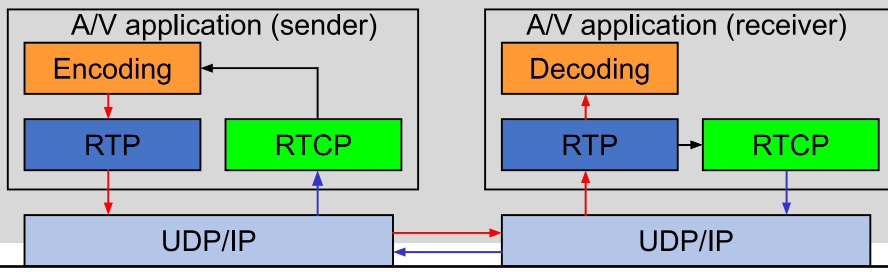


5. Lecture Overview

10. Audio/Video Transport

- Transport of (real-time) audio and video requires
  - advanced mechanisms such as media scaling to support heterogeneous devices and bandwidth adaptation to current network conditions
  - time synchronization of video and audio streams
  - message formats, e.g., time stamps and coding information

→ Real-Time Transport (Control) Protocol

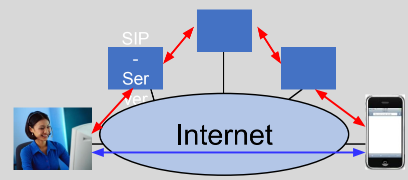


5. Lecture Overview

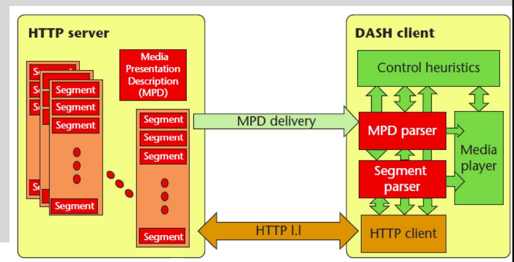
11. Audio/Video Conferencing & Streaming

- A/V conferencing and streaming require control message exchange between entities exchanging A/V data
- A/V conferencing
  - Call establishment, adaptation, and termination
- A/V streaming
  - Commands to start, adapt, stop A/V data stream

Signalling (Session Initiation Protocol)



Voice data stream



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5. Lecture Overview

12. Virtual Reality

1. Sensor measurements (body and head movements) and transmission to server
2. Analysis of measurements and flight simulation
3. Calculation of user's view
4. Transmission of user's view to VR equipment, possibly using 360° video

Thanks

for Your Attention

Prof. Dr. Torsten Braun, Institut für Informatik

Bern, 14.09.2020