Outline (New)

*** = Nicht für Nebenfach !**

1. Introduction and Motivation

Part I: Web Technologies for Interactive MM

2. Interactive Web Applications
3. Web Paradigms and Interactivity *
4. Web Programming with Java *
5. Communities, the Web, and Multimedia

Part II: Content-Oriented Base Technologies

6. Digital Rights: Definition and Management
7. Cryptographic Techniques
8. Multimedia Content Description

Fusion zweier Kapitel

9. Electronic Books and Magazines
10. Multimedia Content Management and Distribution
11. Web Radio, Web TV and IPTV

Part IV: Conversational Multimedia Services

12. Multimedia Conferencing
13. Signaling Protocols for Multimedia Communication *

14. Visions and Outlook

10 Multimedia Content Management and Distribution

Literature:

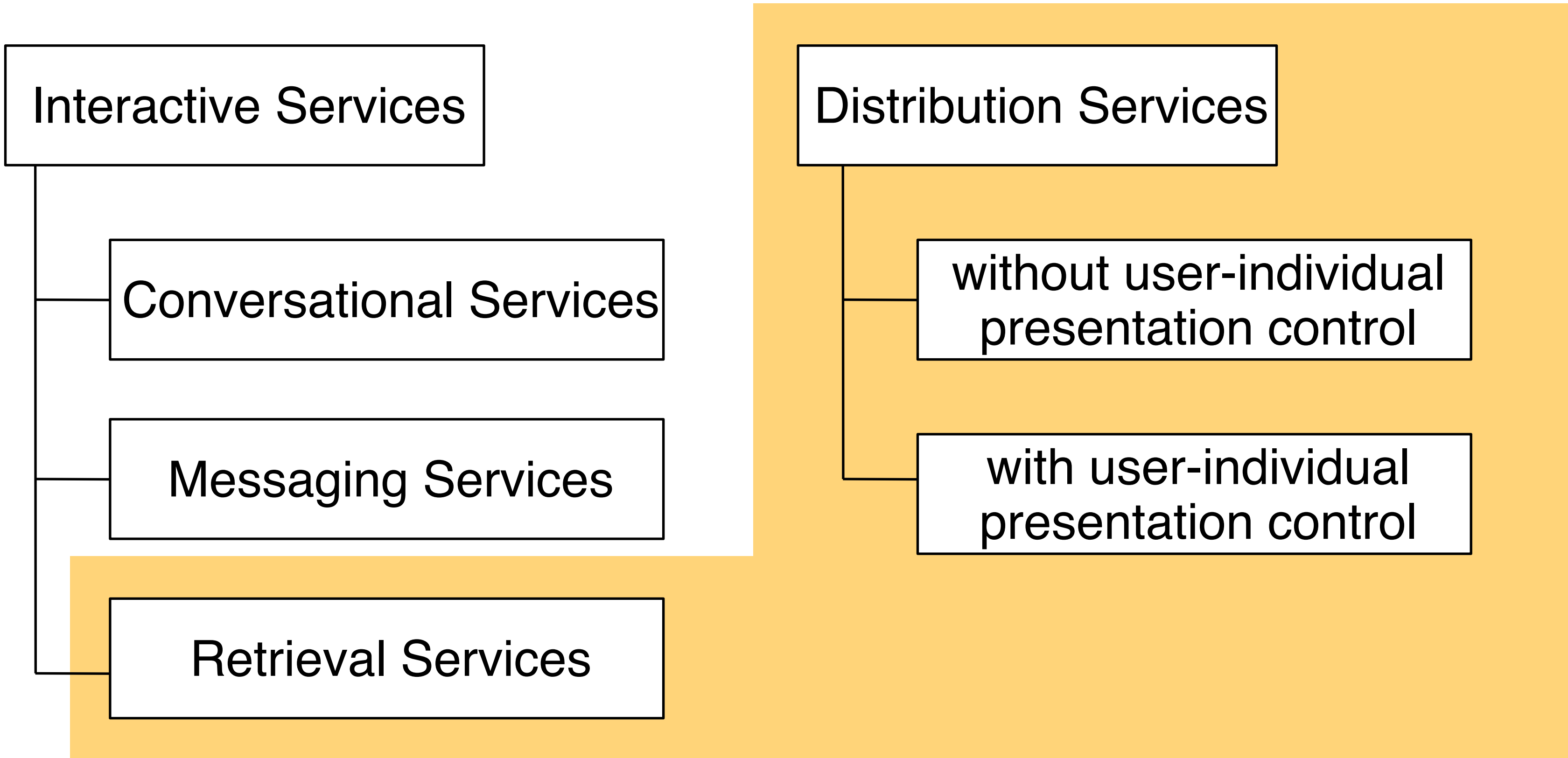
Gregory C. Demetriades: Streaming Media, Wiley 2003

Tobias Künkel: Streaming Media – Technologien, Standards, Anwendungen, Addison-Wesley 2001

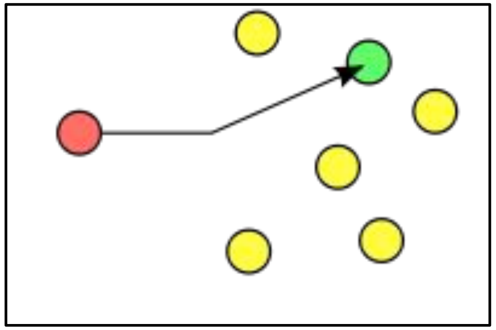
Troncy/Huet/Schenk, Multimedia Semantics - Metadata, Analysis and Interaction, Wiley 2011

A Classification of Multimedia Services

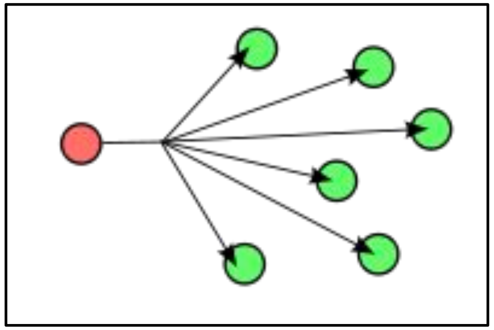
- According to ITU-T recommendation I.211 “B-ISDN Service Aspects”



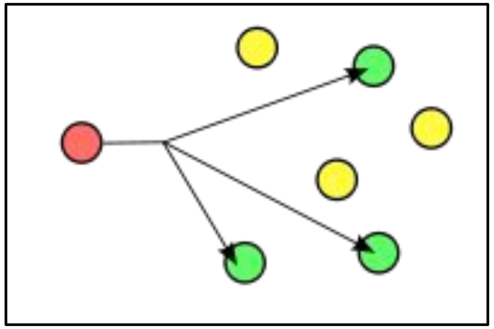
Unicast, Broadcast, Multicast, Anycast



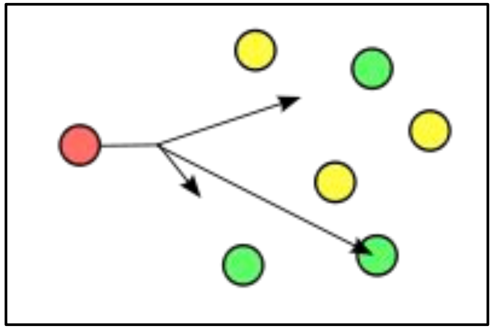
Unicast:
One specific receiver



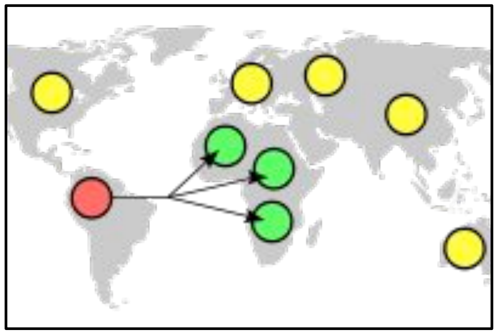
Broadcast:
Many receivers, all on the network



Multicast:
Many receivers, all of a specific group



Anycast:
One receiver, "nearest" of a specific group



Geocast:
Many receivers, all of a geographic region

Pictures: Wikipedia

Presentation Control in Distribution Services

- **Without** user-individual presentation control:
  - Continuous “live” stream of information from sender to receiver(s)
  - Replacement of other distribution media (e.g. radio) by digital networks
    - » Real-time service (e.g. fixed start time for transmission)
- **With** user-individual presentation control:
  - Pause, resume, skip backward, skip forward
  - **Server** control:
    - » Individual stream (or group of closely related streams)
    - » Full interactivity (including “seek” and “fast-forward”)
  - **Client-local** control:
    - » Outdated solution for interactivity: “Near Video-on-Demand” (NVOD)
= Staggered broadcast of multiple transmissions of the same content
    - » Time-shifted recording enables limited interactivity (pause/resume)
    - » Download in advance enables “fast-forward”

Bandwidth Economy

- Fully heterogeneous individual requests:
  - Required bandwidth = stream bandwidth x number requests
- Homogeneity of request helps saving bandwidth:
  - Same content for many clients, but different playback times:
    - » Broadcast with caching
  - Same content at same time for many clients
    - » Multicast (splitting streams)
- Pre-planning saves bandwidth
  - (Individual) transmission of pre-booked content in non-real time ("download and play")

High-Level View of A/V Media Production

- Premeditate
- Create Media Asset
- Annotate
- Package
- Query
- Construct Message
- Organize
- Publish
- Distribute

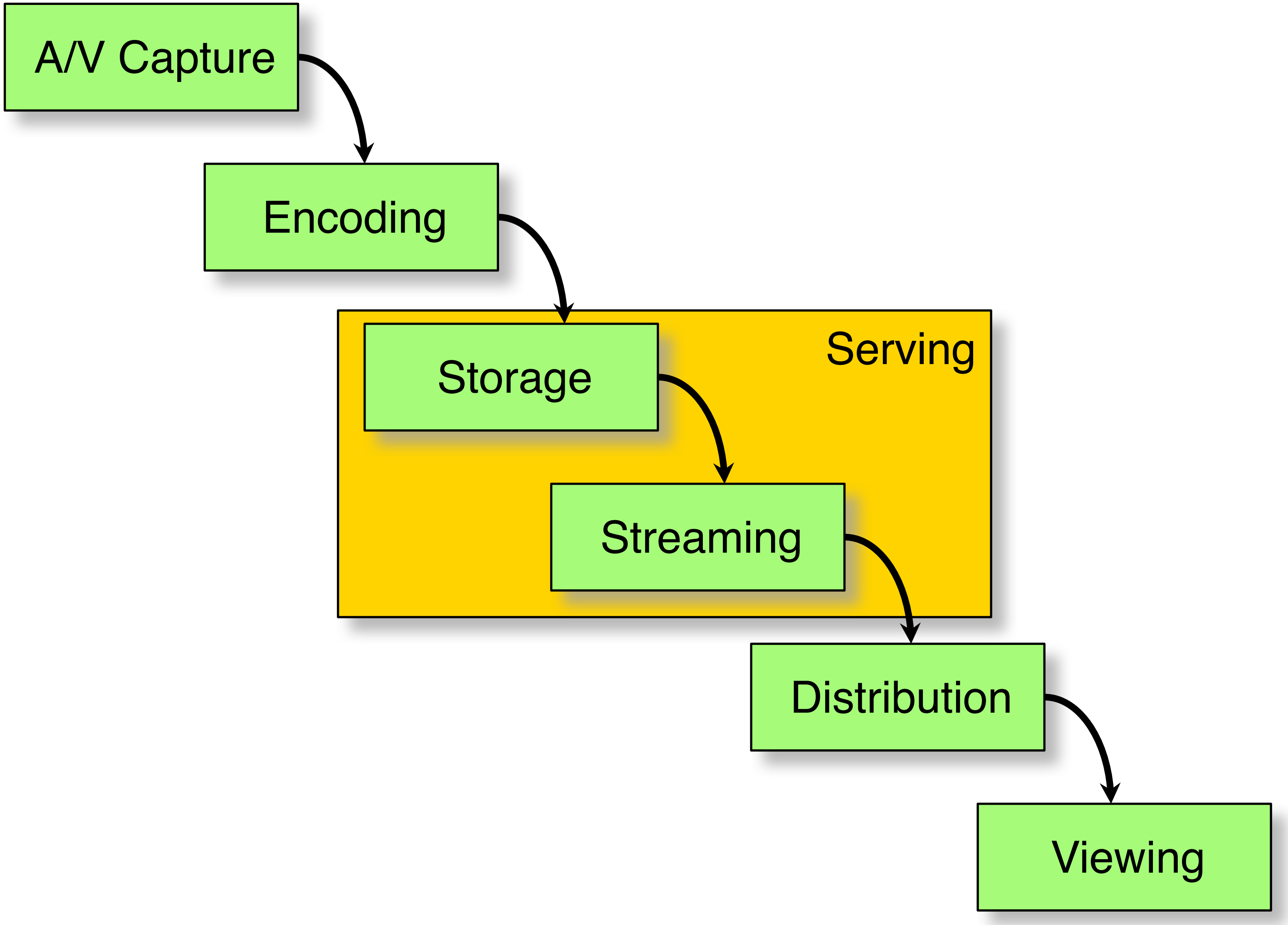
Production process of books is significantly different –
but not for (online) magazines

Hardman, Obrenović, Nack: Canonical Processes of Semantically Annotated Media Production, Chapter 3 in Troncy et al. 2011

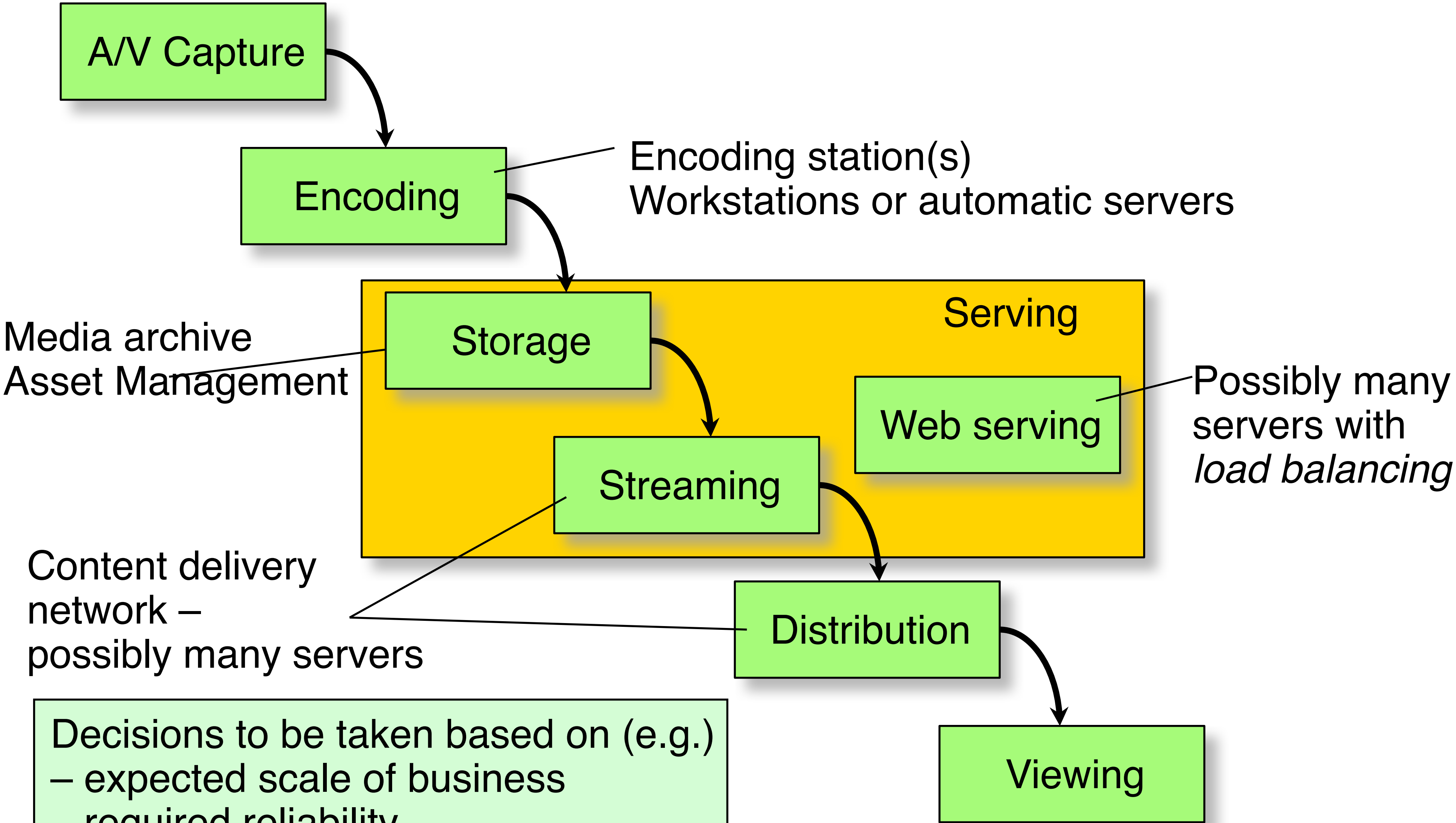
Digital Asset Management

- Very similar acronyms:
  - Digital Asset Management DAM
  - Media Asset Management MAM
    - Rich Media Asset Management RMAM
  - Digital Media Management DMM
- Basic idea:
  - To make the right media material *(media assets)* available for each specific use, in the right version and the right format
- Integration technology:
  - Workflow integration
  - Integration with various media processing tools
  - Integration with content management and syndication solutions
- Broad range of product offerings
  - From large IT companies (IBM, EMC) to niche vendors

Streaming Delivery Chain for Audiovisual Media

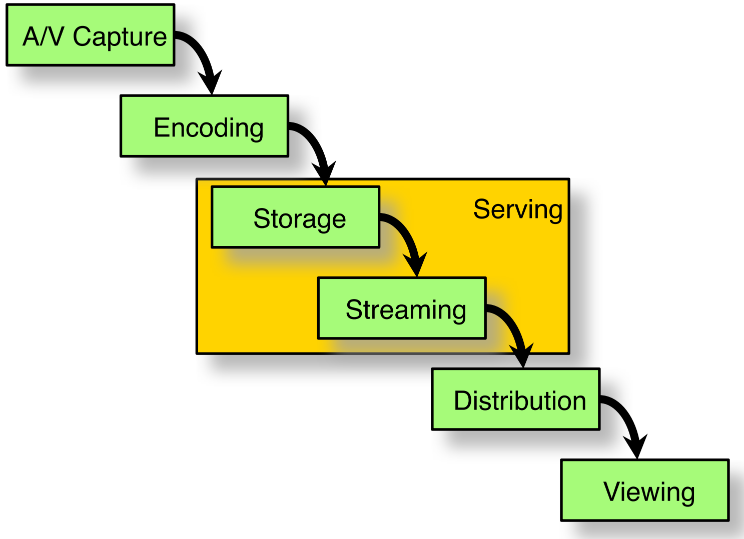


Hardware in the Streaming Delivery Chain



Decisions to be taken based on (e.g.)
– expected scale of business
– required reliability

Encoding



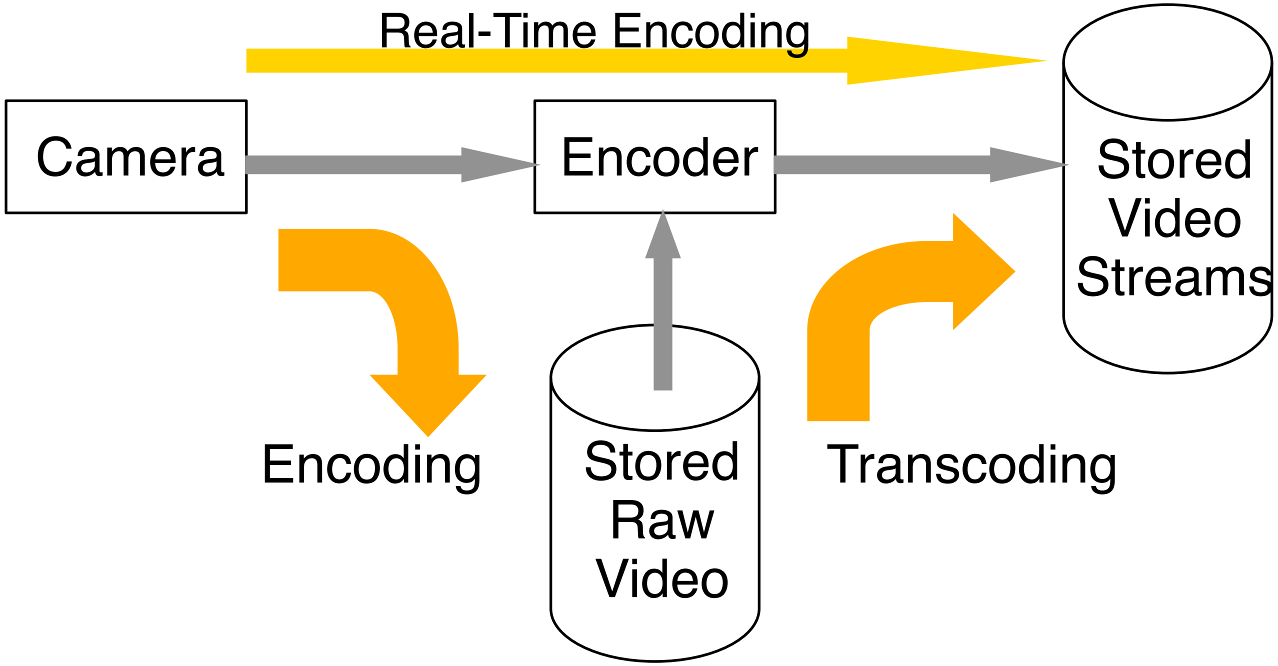
- Format conversions
  - E.g. analog/digital conversion
  - E.g. downscaling of picture size
- Compression
  - Adequate for player capabilities and typical transmission bandwidth
- Indexing
  - Analyzing internal structure
- Metadata creation
  - Possibly including digital rights specification

Example: Multiple Bit Rate Encodings

	Video source	Broadcast (DVB)	DSL/ cable	Modem
Target data rate	(270 Mbit/s)	4 Mbit/s	500 kbit/s	35 kbit/s
Required data reduction		40:1	330:1	4700:1
Frame size	720 x 480 (CCIR 601)	720 x 480	192 x 144	160 x 120
Frame rate	30	30	15	5
Colour sampling	4:2:2	4:2:0	YUV12	YUV12
Uncompressed data rate (Mbit/s)	166	124	5	1.15
Fraction of original data rate		1:1.33	1:33	1:144
Required compression		30:1	10:1	30:1

From: D. Austerberry

Encoding and Transcoding



- Audio and video needs to be converted for streaming delivery
  - Compression, proprietary formats
- *Transcoding*: Conversion of media files from one format to another
- *Repurposing:* Using existing content for new purposes
  - e.g. using TV ads as streaming content

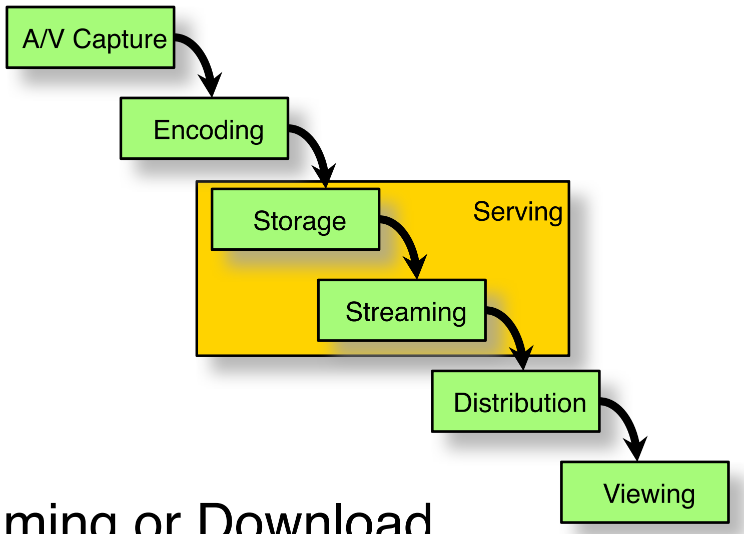
Combining Media Elements to Compound Media

- Combining video streams, audio streams, text captions, graphics, links to Web locations
  - In space on the screen (e.g. video with banner advertisement)
  - Temporally (e.g. “pre-roll advertisement” with video streams)
- Enhancing interactivity and flexibility
  - E.g. free navigation
  - E.g. language options
- Technological basis:
  - Spatio-temporally structured compound multimedia documents
  - with high degree of interactivity
  - Example technologies:
    - » SMIL (RealPlayer)
    - » MPEG-4
    - » HTML5 and JavaScript
    - » Proprietary players e.g. using Flash, Silverlight

Automated Transcoding

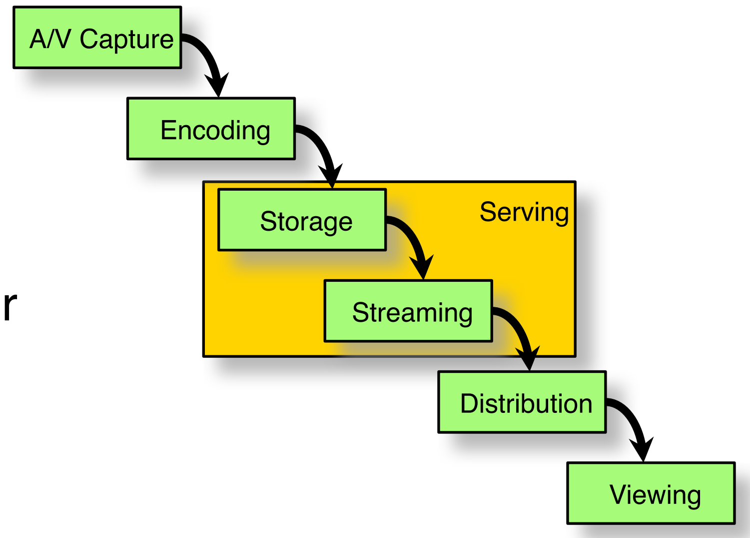
- Example 1: Multiple Formats
  - TV Broadcaster
  - Repurposing into streaming media for Web-based Video-on-Demand
  - Live capturing, encoding (e.g. MPEG)
  - After program end: transcoding to different bit rates, delivery to streaming server
- Example 2: Flipping on Demand
  - Media archive for a cable channel to be made available through Web
  - Media kept in single, high-quality format
  - On demand (request), files are transcoded, watermarked, streamed
- Example 3: Collaboration Distribution
  - Large company working on marketing materials
  - One rough cut of a new commercial to be distributed to 100 clients with varying quality expectations and platforms
  - *Content distribution service* transcodes according to client requirements
- Example product: Telestream FlipFactory (www.telestream.net)

Serving



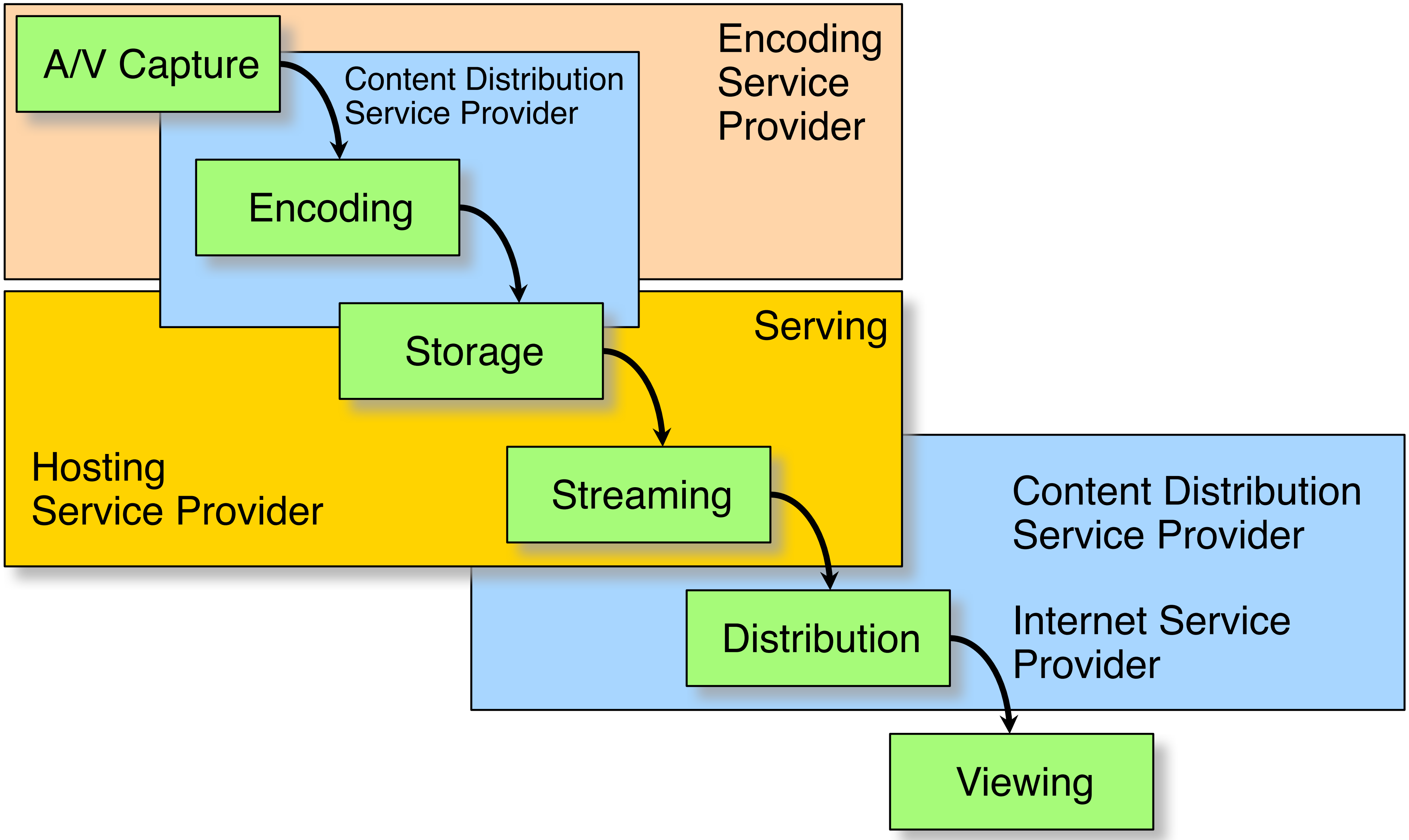
- Storage
  - Live: only buffering and archiving
  - Static files: archive management, retrieval
- Transcoding
  - Encoding adapted to client capabilities Streaming or Download
- Interactivity
  - VCR-like control (PLAY, STOP, PAUSE, FFWD, REW)
  - Random access based on various criteria
  - Hyperlinks in A/V material ("hypervideo")

Distribution



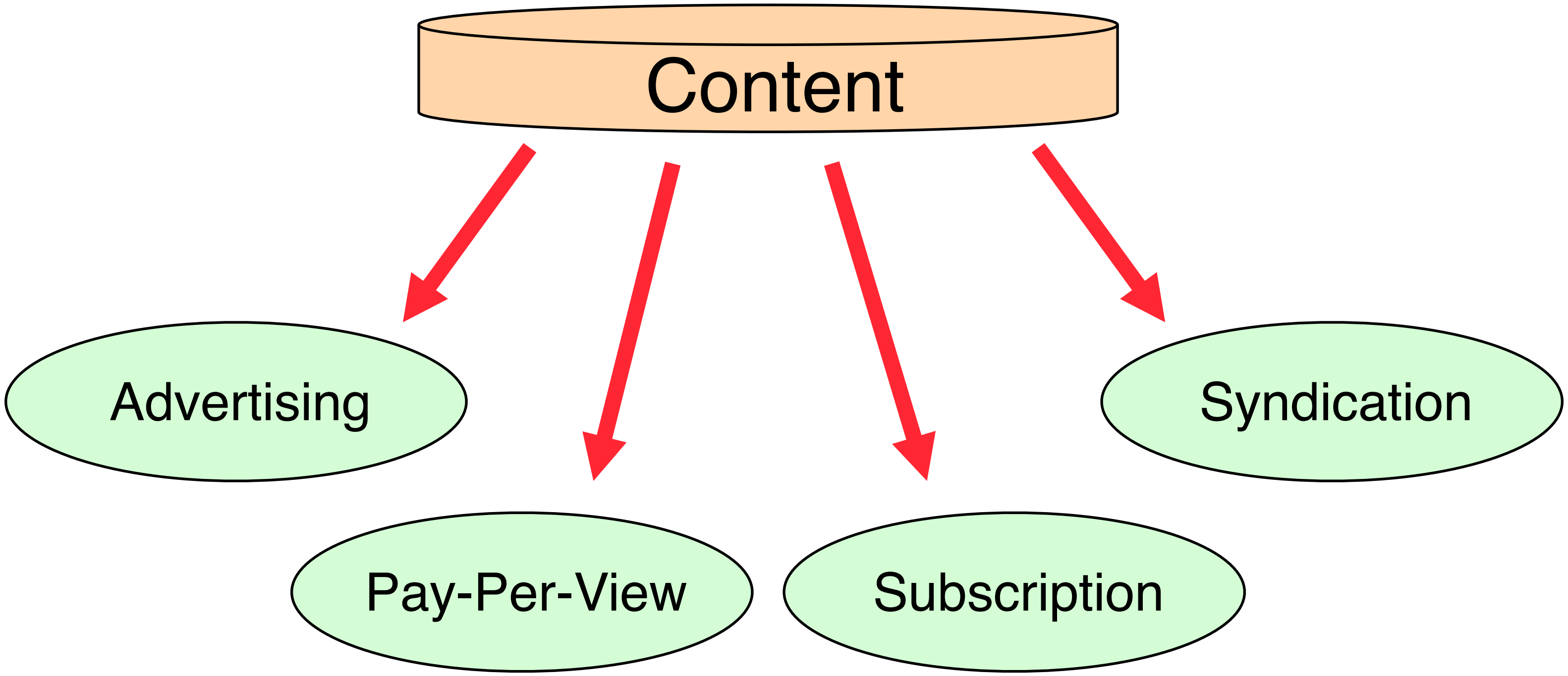
- Key topic: Quality of Service (QoS)
  - Determining realizable bandwidth, delay, jitter
- Key concepts:
  - Overprovisioning
  - Detailed reservations (“Integrated Services”, reservation protocol RSVP)
    - » Difficult to scale to large numbers of users
  - Traffic classes (“Differentiated Services”)
    - » Difficult to control access to privileges
  - Resource management layer
  - Technology-specific solutions
    - » E.g. ATM (Asynchronous Transfer Mode)

Organisations in the Streaming Delivery Chain



Content Monetization

- There are several traditional models for gaining a return on investment on content
  - Network-based media enable the integration of all models



10 Multimedia Content Management and Distribution

10.1 Media Production Chains

10.2 Streaming Technology – Push Model

10.3 Streaming Technology – Pull Model

10.4 Scalability of Multimedia Distribution

Literature:

David Austerberry: The Technology of Video & Audio Streaming, Focal Press 2002

Stephan Rupp, Gerd Siegmund, Wolfgang Lautenschlager: SIP – Multimediale Dienste im Internet. dpunkt 2002

A. Begen, T. Akgul, M. Baugher: Watching Video over the Web, Part I: Streaming Protocols, *IEEE Internet Computing*, March/April 2011

Streaming, Streaming Media

- *Streaming media* means real-time delivery of moving images, moving text and sound, from a server to client (over the Internet).
- Delivery types for audio and video content:
  – *Download and Play:* Content must be downloaded completely to the client before it can be played
  – *Progressive Download:* Playback is started while download is still in progress. Download rate independent of program bit rate.
  – *True Streaming:* Delivered media is viewed/listened in “real-time”.
    » Playback takes place with roughly the same rate as delivery of data
    » Delay between send and receive event of data packet kept small
- Subtypes of True Streaming:
  – *Static File Streaming:* Delivery of pre-recorded media files.
    Often also called *on-demand* delivery (e.g. *Video on Demand)*
  – *Live Streaming*

Based on material from www.streamingalliance.org

Session

- A *session* is an association between communicating parties, which
  - Persists over a limited time span
  - Incorporates at least two parties
  - May comprise a large number of communication connections of different characteristics
- Examples of sessions:
  - Movie streamed to consumer, consisting of audio and video parts
  - Multimedia conference among five participants, consisting of audio and video source from each of of the participants (plus possibly some global information)

- Session awareness at which levels?
  - At application level: unavoidable
  - At network level: possible
    - » Requires specific protocols

Push and Pull Models for Streaming

- Push model (e.g. Darwin Streaming Server):
  - Session-level connection established between server and client
  - Server continues sending packets *downstream* to client
  - Server listens to commands given by client (see later for protocols)
  - True real-time data distribution
  - Adaptive bandwidth control
- Pull model (e.g. YouTube):
  - Session-level connection established between server and client
  - Server is idle as long as client does not request data
  - Client continues requesting packets from server (e.g. by HTTP)
  - Playback starts after a certain client-side buffer level is reached
  - Essentially “progressive download”, enhanced in modern approaches (see later)

IP and TCP

- Internet Protocol
  - Network communication protocol (ISO layer 3)
  - Packets transferred from address to address (through routers)
  - Main problems:
    - » Variable network latency
    - » Packet order on arrival may be different than on sending
    - » Packets may be lost
- Transport Control Protocol (TCP)
  - Connection establishment (by “three-way handshake”)
    - » Connections are sequences of associated IP packets
  - Sequencing of bytes with forwarding acknowledgement number
  - Non-acknowledged bytes are re-transmitted after a defined time period
  - Flow control
- For audio/video streaming:
  - Retransmissions (and associated delays) are harmful
  - Lost packets can be tolerated to some extent

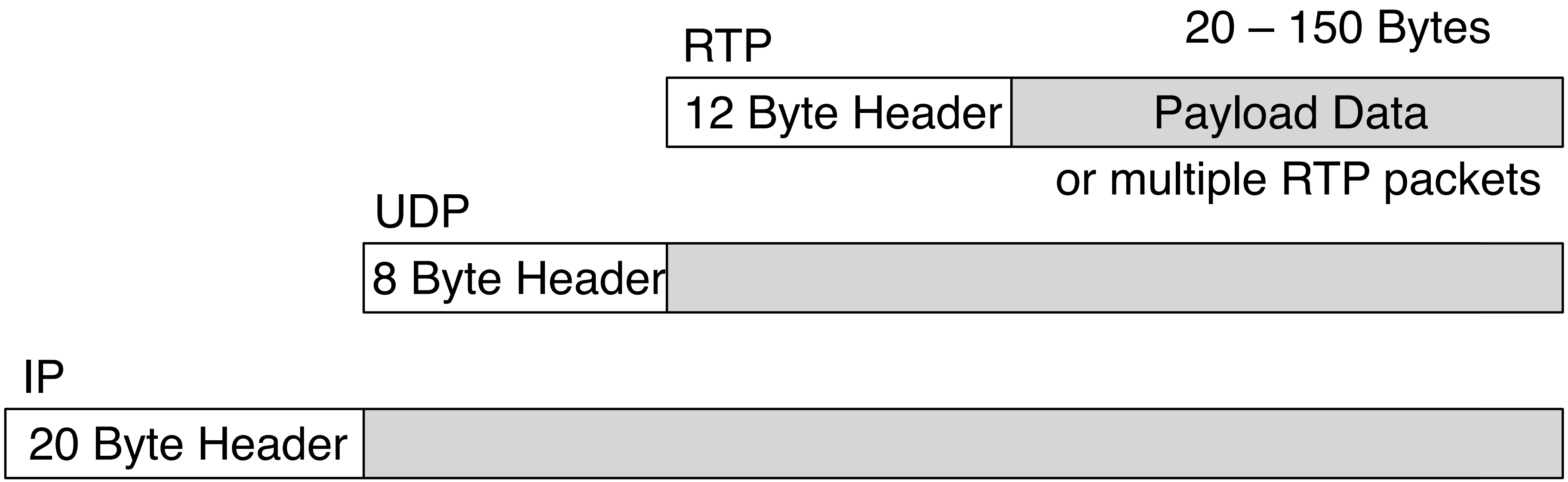
UDP

- User Datagram Protocol (UDP)
- Extremely simple transport protocol over IP
  - Connectionless (TCP: connection-oriented)
  - Unreliable (TCP: reliable)
  - No flow control (TCP: has flow control)
- Contents of a UDP datagram:
  - Ports used by application program
  - Checksum
- Basically adequate for media data transport
  - In particular for **push**-model true streaming
  - Very efficient, protocol overhead of TCP avoided
  - Flow control and handling of packet loss have to be handled by higher protocol layer

Real-Time Transport Protocol RTP

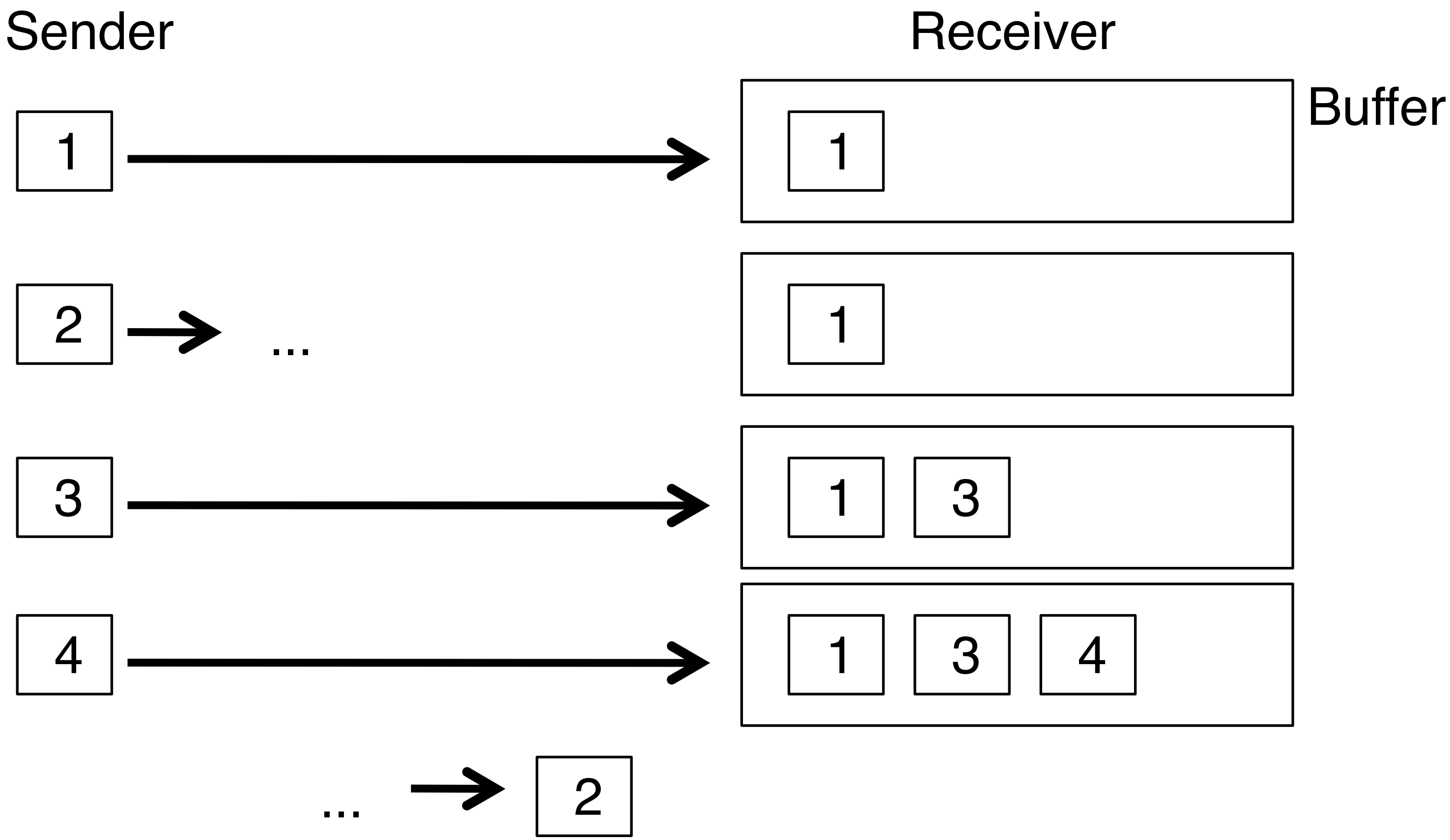
- Transport protocol specifically developed for streaming data
  - IETF (Internet Engineering Task Force) RFC (Request for Comments) 1889
- RTP usually carried over UDP and used for **push** model mainly
- Very important:
  - **RTP does not at all change the way how IP packets are transferred in the network!**
  - To achieve “Quality of Service”, additional network technologies are required (see above)
- RTP used (mainly historically) by:
  - Apple QuickTime architecture
  - RealSystems streaming architecture
- Modern Internet structure does no longer support RTP at many places
  - in particular, in Content Delivery Networks, see later

RTP Packets and Other Protocols



- IP Header:
  - Source address, destination address, length, time to live, ...
- UDP Header:
  - Port numbers (source and target processes), length, checksum
- RTP Header:
  - Codec type, sequence number, timestamp, synchronization source

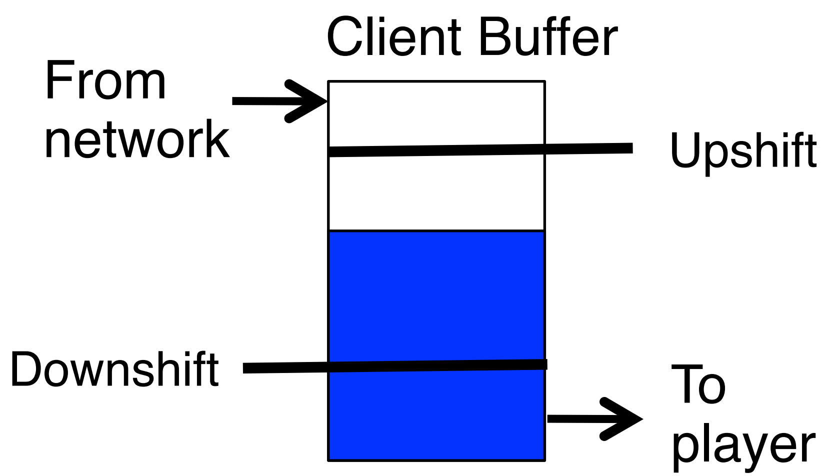
Jitter and Loss Compensation



- Options for application on receiver side:
  - Wait (*not* adequate), repeat last packet (1), interpolate (between 1 and 3)
  - Missing audio information is difficult, missing video can be compensated

Adaptive Transmission Rate Control

- Application-level mechanism
- Define "downshift" and "upshift" thresholds on buffer (possibly several)
- Downshift:
  - Buffer is close to drain ("underrun")
  - Server should select lower-bitrate encoding (less quality)
- Upshift:
  - Buffer is close to be full ("overrun")
  - Server can try to select higher-bitrate encoding (better quality) (if network can support that)
  - Alternatively server may switch to lower transmission rate
- Communication between client/server required!



Session Description Protocol (SDP)

- IETF Standard (RFC 4566) 2006
- Description mechanism for multimedia communication sessions
  - announcement, invitation, parameter negotiation
- Defines:
  - media components (an their types) belonging to a session
  - alternative formats available for media components
  - session profiles
- Applicable for various purposes
  - for conferencing examples see later chapter
    - » in streaming: announcement of available options from server to client

Real-Time Control Protocol RTCP

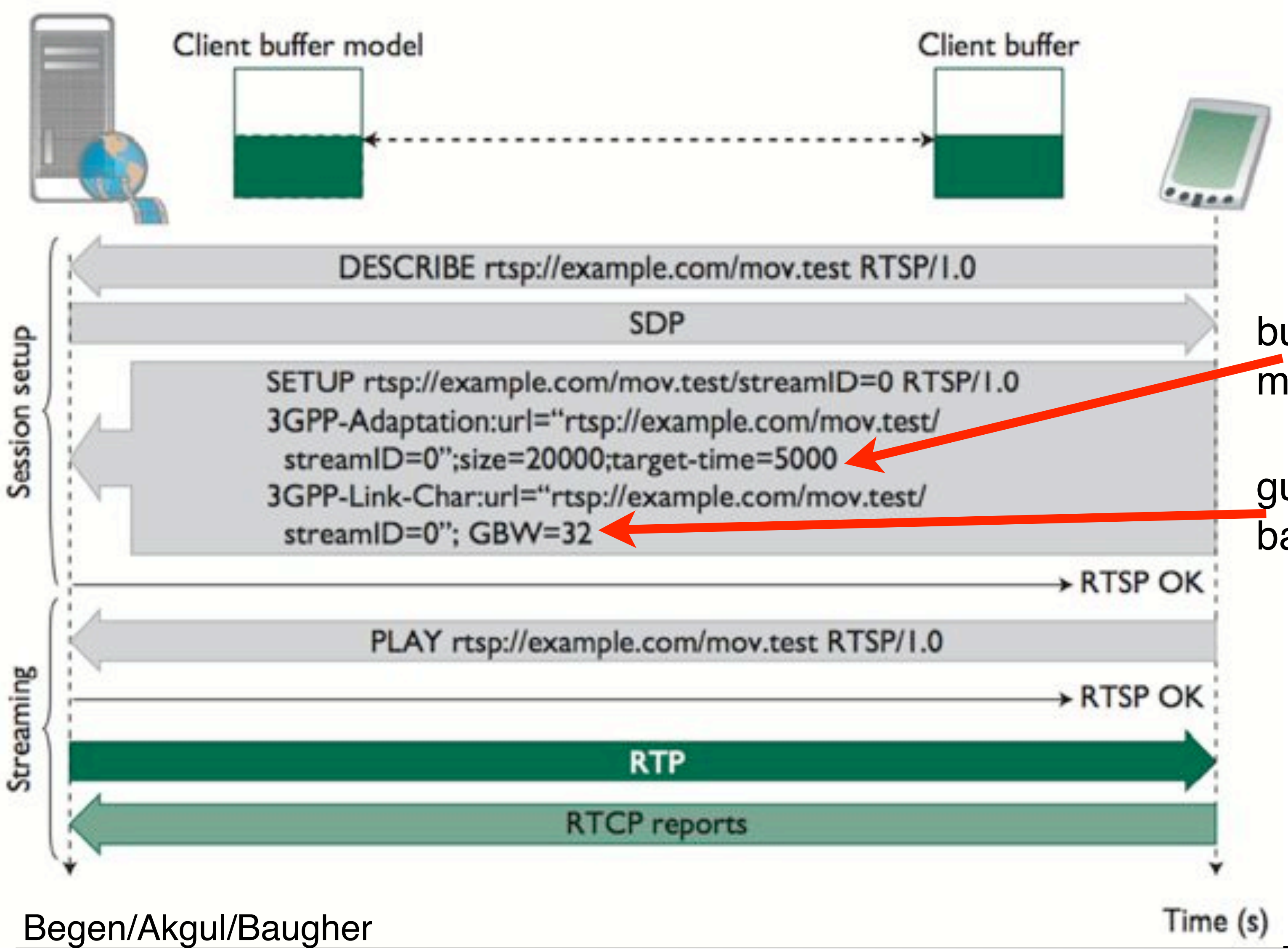
- RTCP controls the transmission (not the setup of connection)
- RTCP periodically sends monitoring information to all participants in a streaming session
- Main functions of RTCP:
  - Feedback on QoS of transmission
    - » Information for adaptive codecs, e.g. whether problem is local or global
  - Identification of sender by “canonical name”
    - » Helpful when synchronization source changes
    - » Supports lip synchronization between audio and video
  - Number of participants in a session
    - » Adaptation of sending rate of RTCP control information to number of participants, to avoid network overload
  - Transmission of additional information, e.g. names of session participants

Real Time Streaming Protocol RTSP

- Client-server multimedia presentation protocol, designed specifically for streamed media
  - IETF (Internet Engineering Task Force) RFC (Request for Comments) 2326 ("MMUSIC" work group), 2004
  - "The Internet VCR remote control protocol" (www.rtsp.org)
  - Independent of the use of RTP for transport
  - Syntactically similar to HTTP 1.1 (carried over TCP or UDP)
- Main operations supported by RTSP:
  - Transport & capability negotiation (SETUP)
    - » e.g. disallowing a "seek" function
  - Session control (SETUP, REDIRECT, TEARDOWN)
  - Control of media playback (PLAY, PAUSE, PING)
  - Invitation of a media server to a conference

3GPP Bitrate Adaptation

3rd Generation Partnership Project (3GPP)



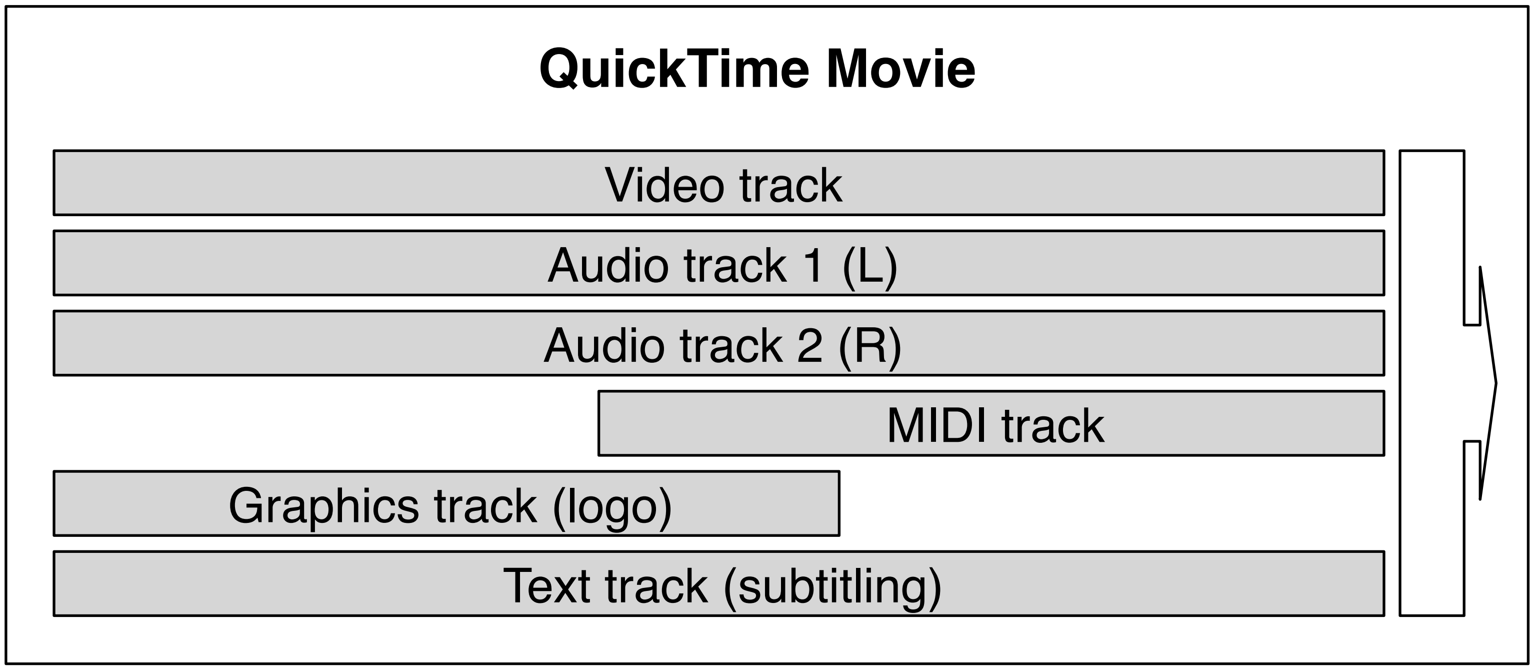
buffer size, minimum buffering

guaranteed receive bandwidth

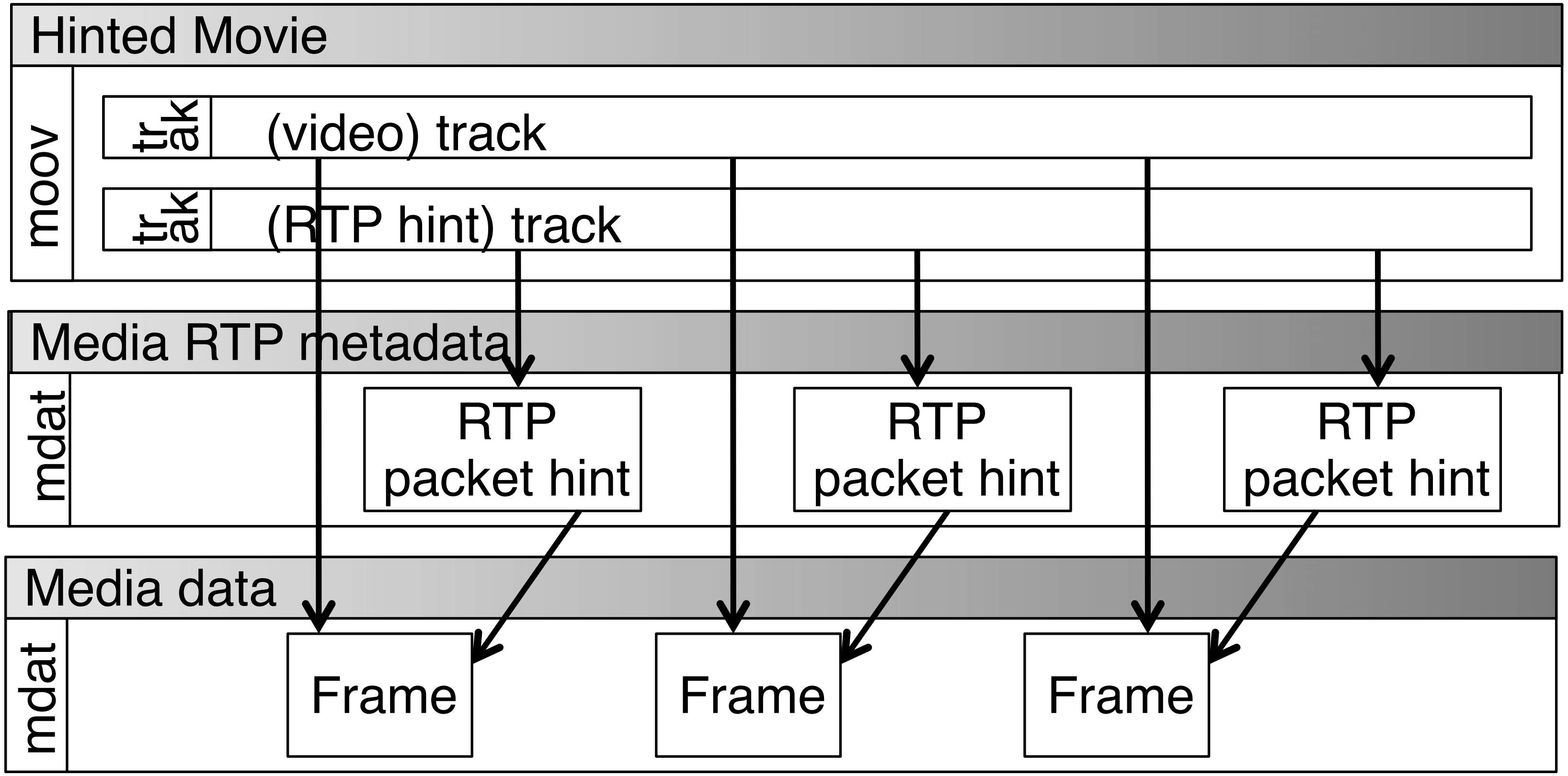
Begen/Akgul/Baugher

Example File Format: QuickTime Movie Files

- Modular and flexible architecture
  - Multimedia files organized in tracks
  - Example:



Hint Tracks in QuickTime and MPEG-4



- Hint track gives server software pointers to the RTP information to serve the relevant media chunks
- Concept from QuickTime, integrated in MPEG-4 (streaming)

10 Multimedia Content Management and Distribution

Literature:

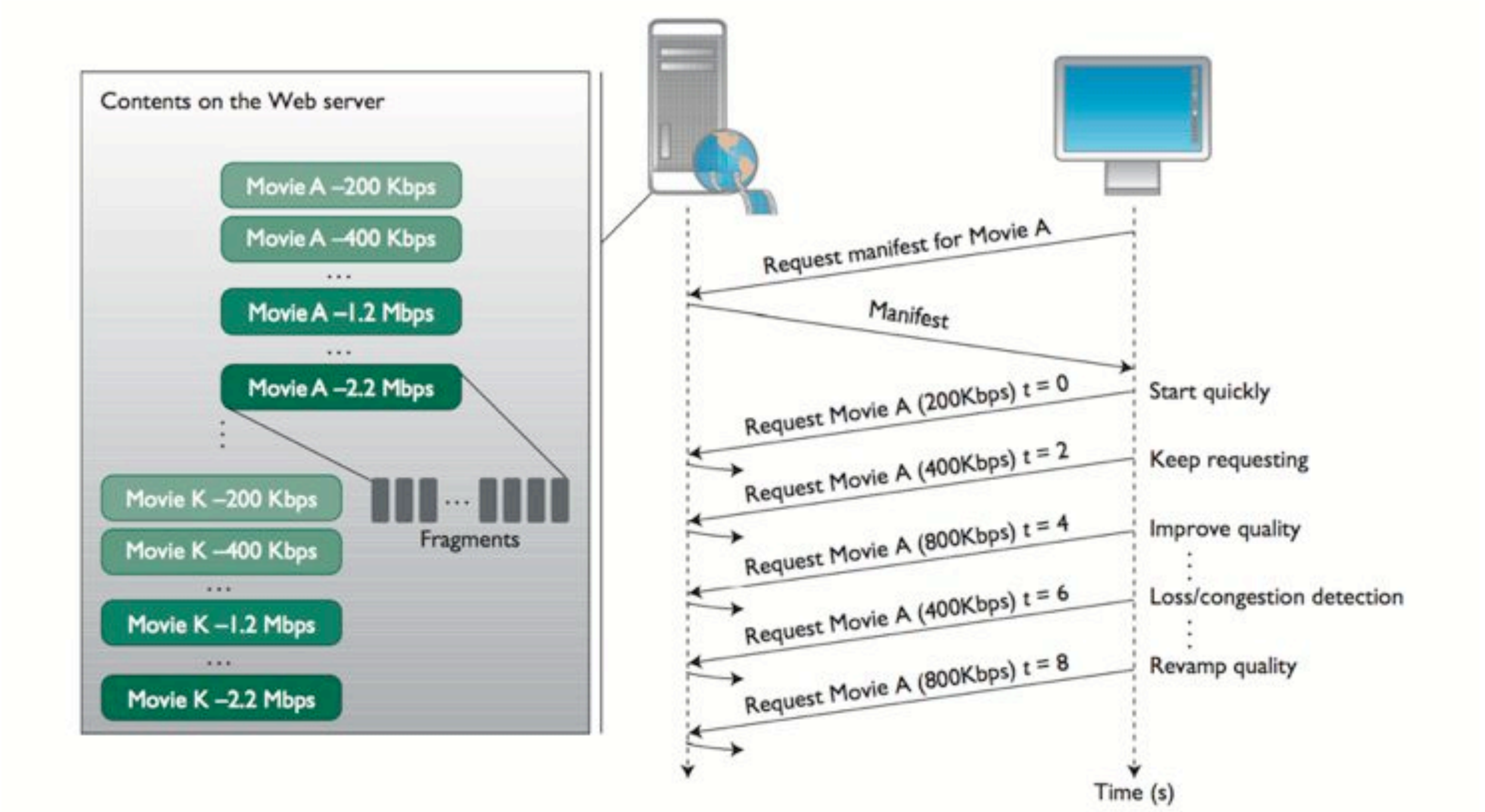
A. Begen, T. Akgul, M. Baugher: Watching Video over the Web, Part I: Streaming Protocols, *IEEE Internet Computing*, March/April 2011

I. Sodagar: The MPEG-DASH Standard for Multimedia Streaming Over the Internet, *IEEE Multimedia*, Oct/Dec 2011

Trend: Adaptive HTTP Streaming

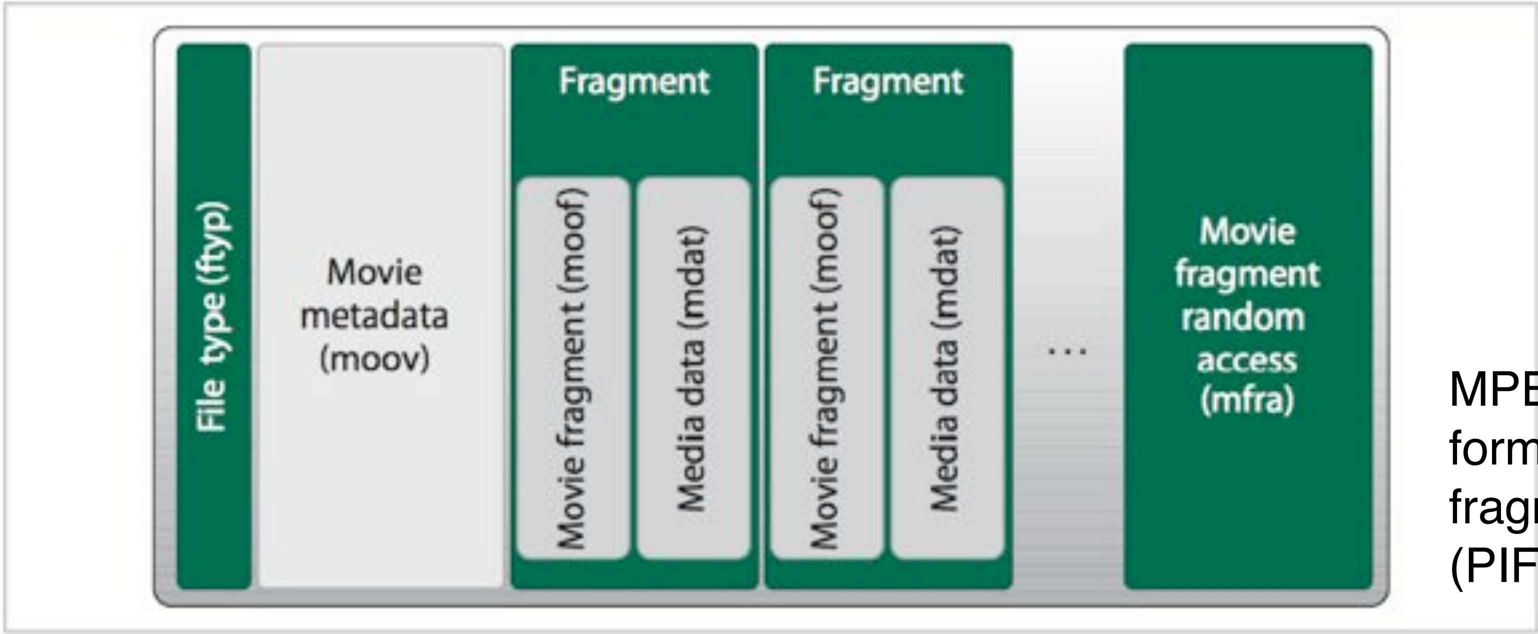
- Conventional streaming technologies (push-model) being superseded by (proprietary) adaptive HTTP-based solutions:
  - Apple HTTP Live Streaming
  - Microsoft Smooth Streaming
  - Adobe HTTP Dynamic Streaming
- Reasons for trend change
  - Firewalls, NAT devices etc. support HTTP but often not other protocols
  - HTTP caching infrastructures can be re-used for video
  - Server responsibility for bitrate adaptation is problematic for scalabity
  - Better network speed allows larger junks to be exchanged
- Basic idea: Small video file fragments
  - Fragments exist at different bit rates
  - Index file for all available fragments
  - Client requests appropriate next fragment by GET request

Bitrate Adaptation in HTTP Adaptive Streaming



Begen/Akgul/Baugher

Example: Video Fragmentation in Microsoft Smooth Streaming



MPEG4-based format for fragmented video (PIFF)

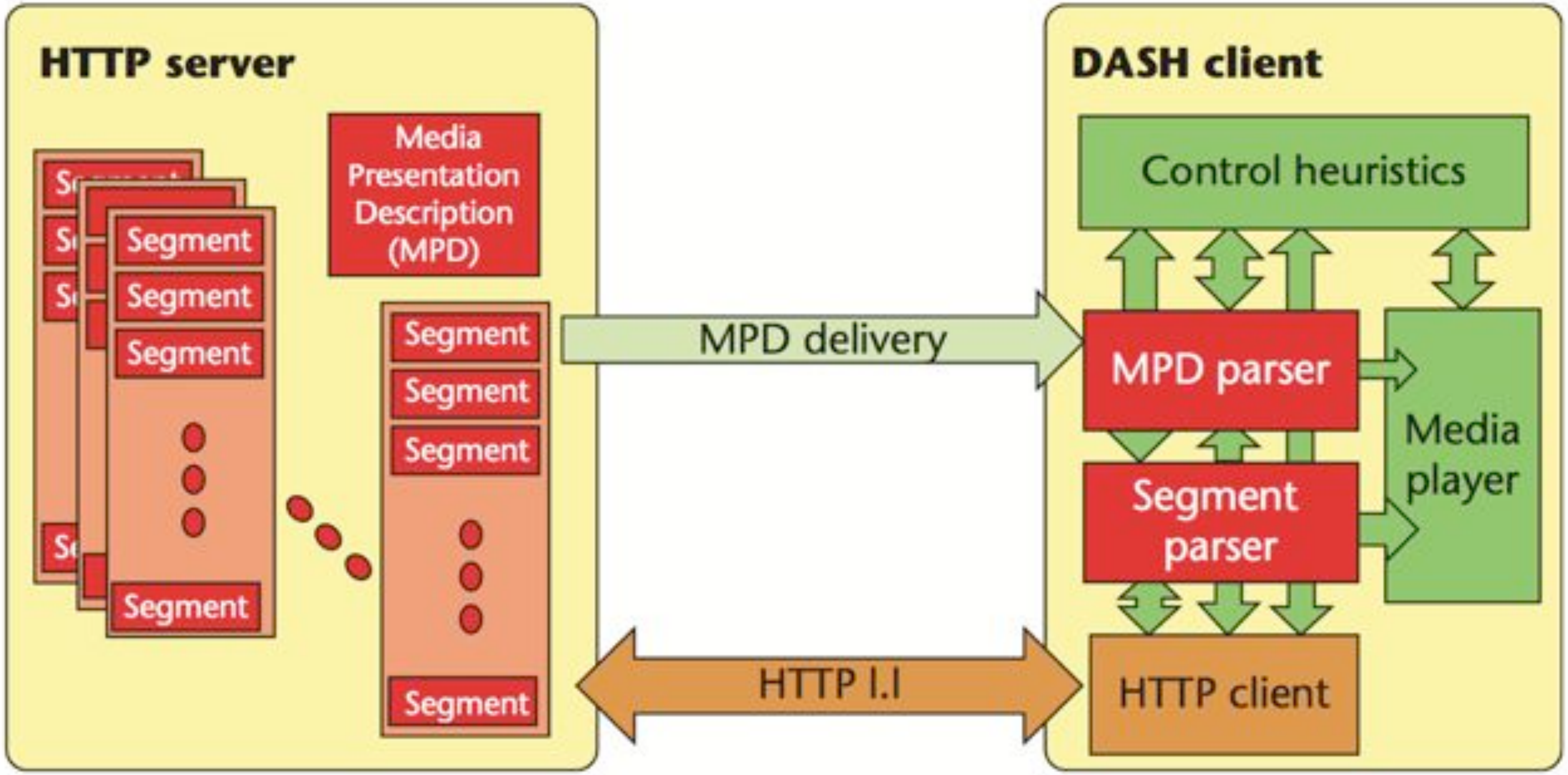
- Fragments always containcomplete Groups of Pictures (GOP)
- Client (Silverlight-based Web player) sends requests which contain:
  - requested bitrate (version of the video)
  - requested time offset for fragment

```
GET/example.host/myvideo.ism/QualityLevels(64000)/
  Fragments(video=150324) HTTP/1.1
```

Begen/Akgul/Baugher, based on alexzambelli.com/blog/2009/02/10/smooth-streaming-architecture/

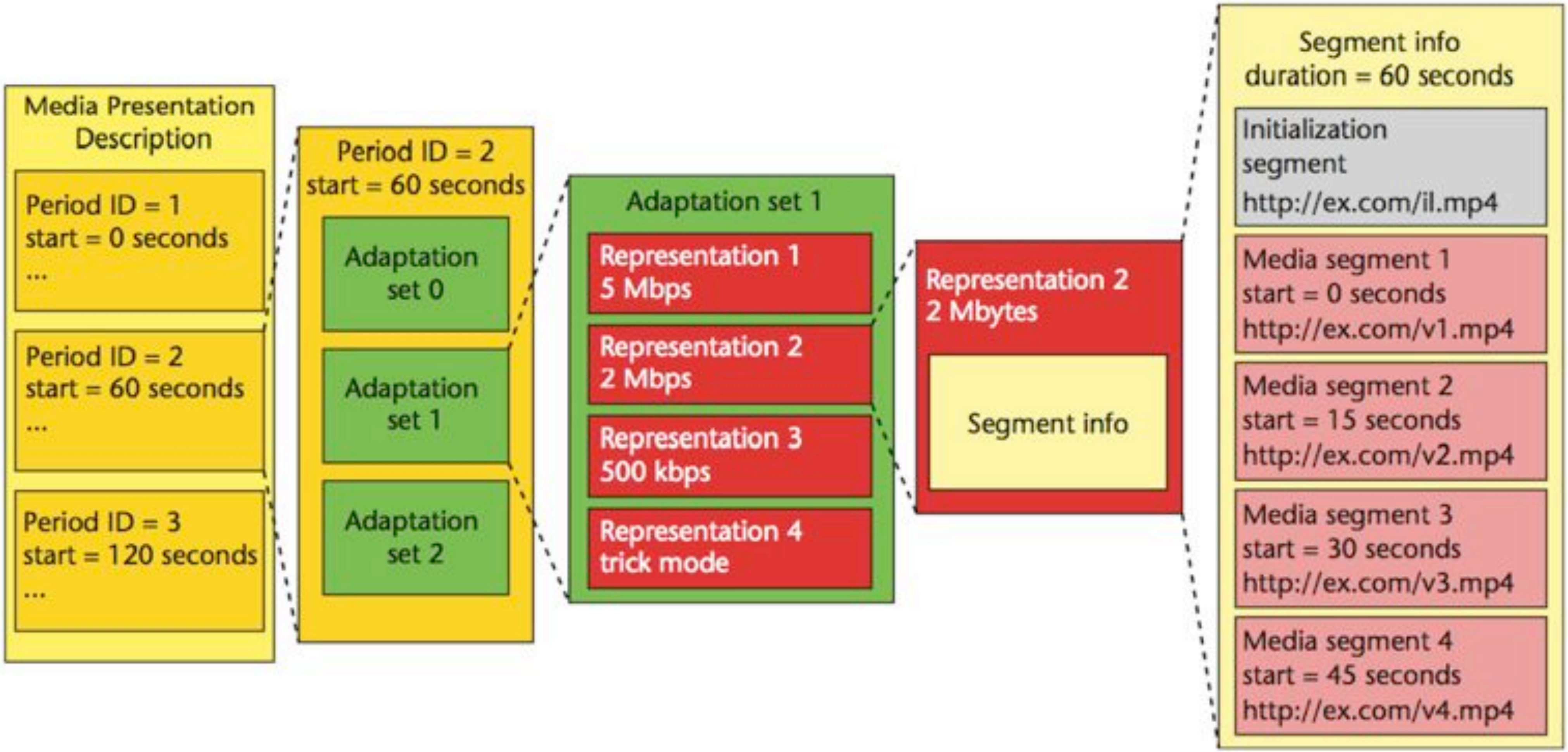
MPEG-DASH Standard

- MPEG call and selection process for HTTP streaming standard (2009–2011)
- ISO/IEC standard (ISO 23009) April 2012



Sodagar

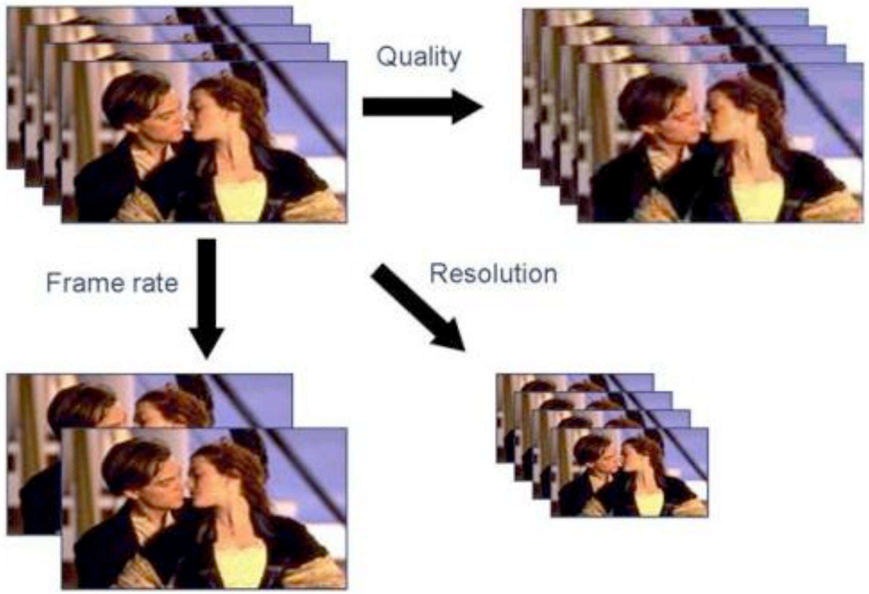
Multimedia Presentation Description in DASH



Sodagar

MPEG-4 Scalable Video Coding (SVC)

- SVC: Splitting of raw video data into multiple streams
  - MPEG/ITU-Standard 2007 (H.264/AVC Extension)
  - subsets of the data, self-contained
  - subsets can be combined to achieve better quality
  - dimensions: temporal resolution (frame rate), spatial resolution, SNR (loss)
- DASH is compatible with SVC
- Strategical question for player:
  - Download additional quality information for current segment, or
  - Download future segment (in lower quality)?
- See: Andelin et al., Quality selection for Dynamic Adaptive Streaming over HTTP with Scalable Video Coding, 3rd Multimedia Systems Conference, 2012



www.imec.be

MPEG-4 Multiple View Coding (MVC)

- SVC: Multiple camera images in a multiplexed video stream
  - MPEG/ITU-Standard 2008 (H.264/AVC Extension)
- Main application area: Stereoscopic (3D) video
  - Generalizable to multiple camera positions
- DASH is compatible with MVC
  - Server announces availability in MPD
  - Client adapts requests to the current needs

10 Multimedia Content Management and Distribution

Literature:

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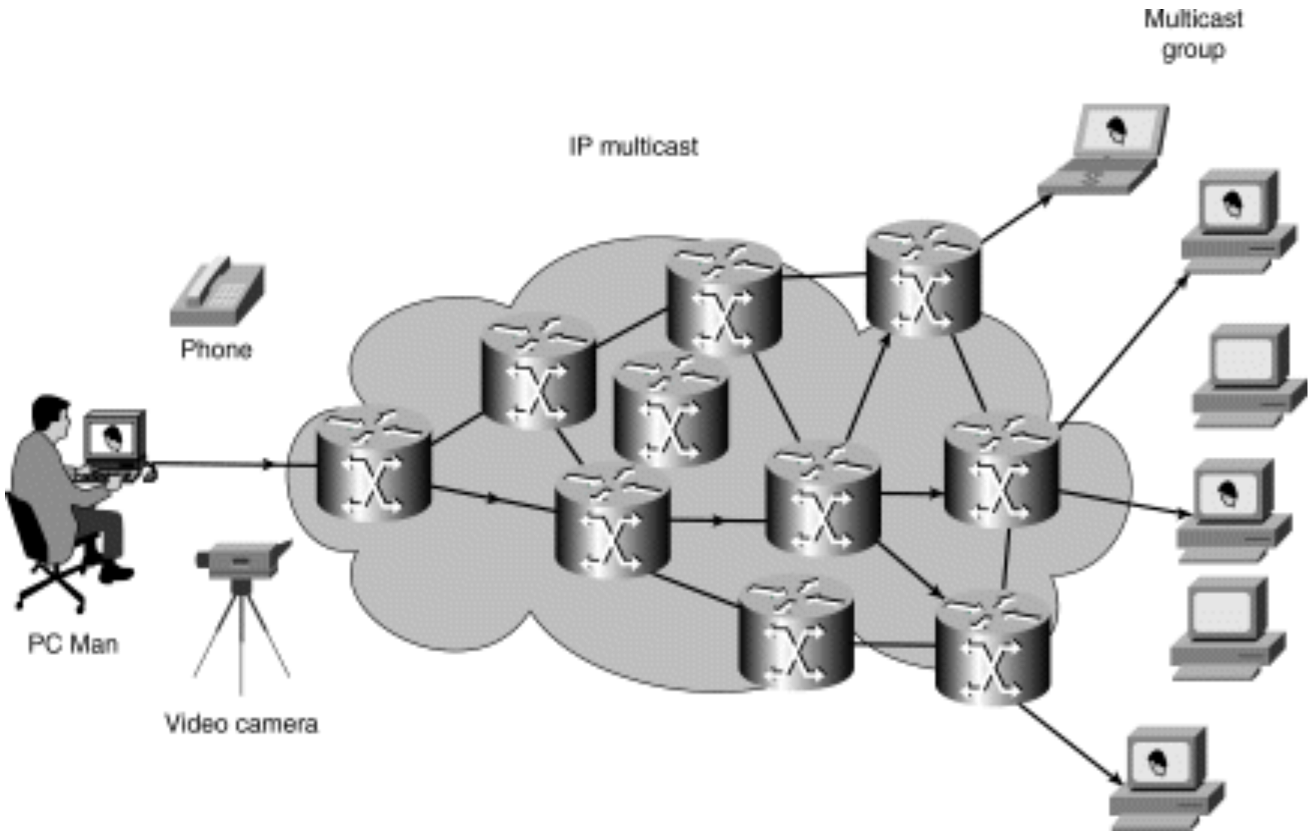
Gregory C. Demetriades: Streaming Media, Wiley 2003

Xueyan Tang et al.: Web Content Delivery, Springer 2005

Traditional Solution: IP Multicast

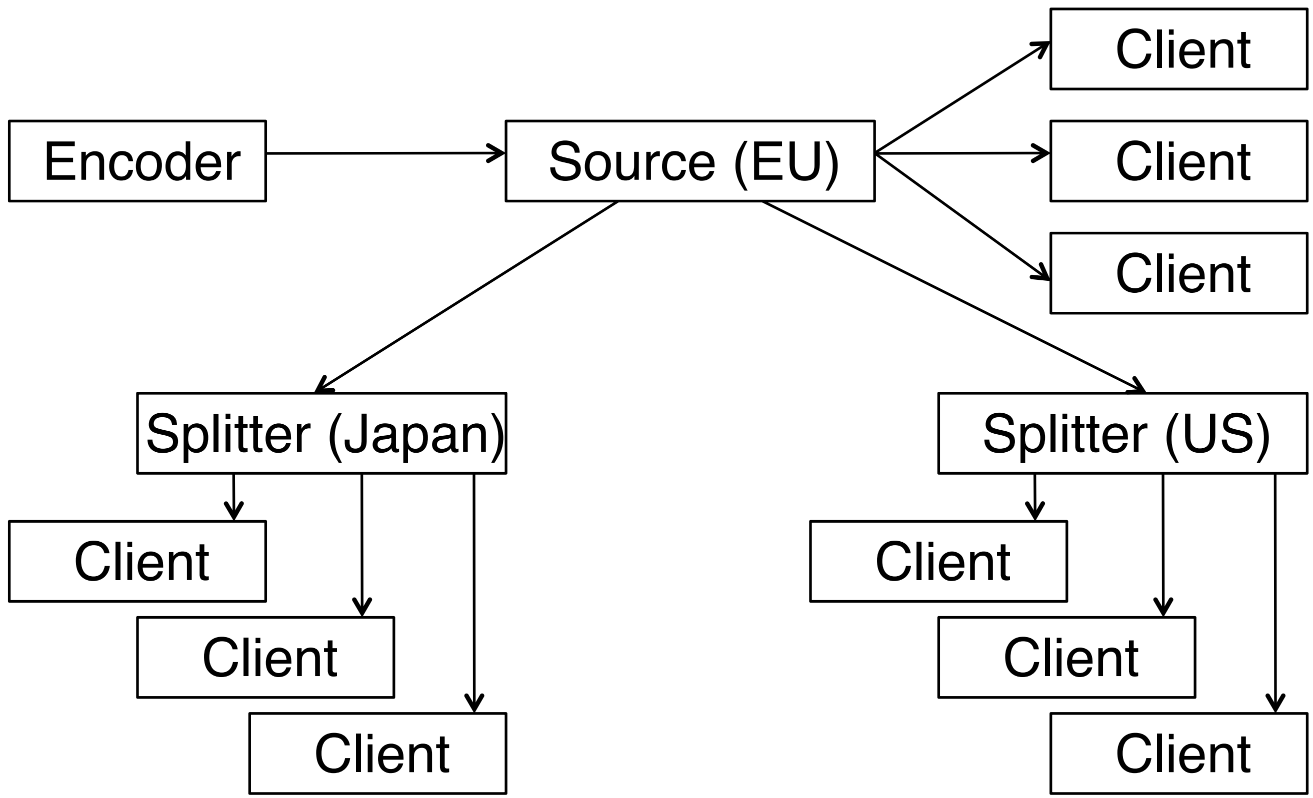
- Multicast relatively easy to integrate in routers
- IP versions 4 and 6 provide special multicast addresses



- Reliable multicast: e.g. “Mbone” overlay network, 1992
- Multicast still rarely used in today’s Internet
- Problems: Charging and access control

Splitting

- Video servers are limited in capacity
- Assuming clients at spatially distant locations
  - Intermediate, forwarding server is useful: “splitter”



Content Delivery Networks (CDN)

- Serve content closer to to the user
  - “edge serving”
- Main components of CDN:
  - Smart routing
  - Edge caching of content
  - Proxy serving
  - Splitting of live webcasts
- Examples:
  - Akamai
    - » Runs 137,000+ servers in 87 countries
  - InterNap CDN Services
    - » Media streaming
  - Amazon CloudFront

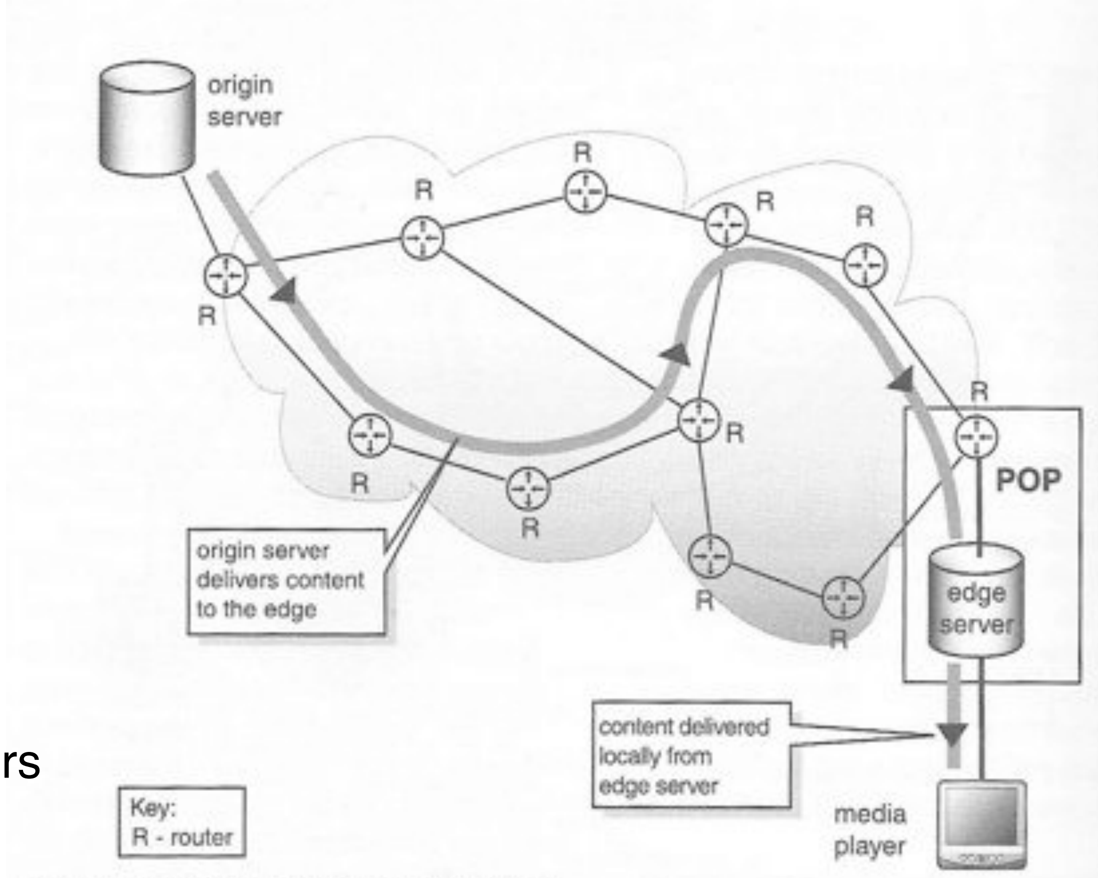
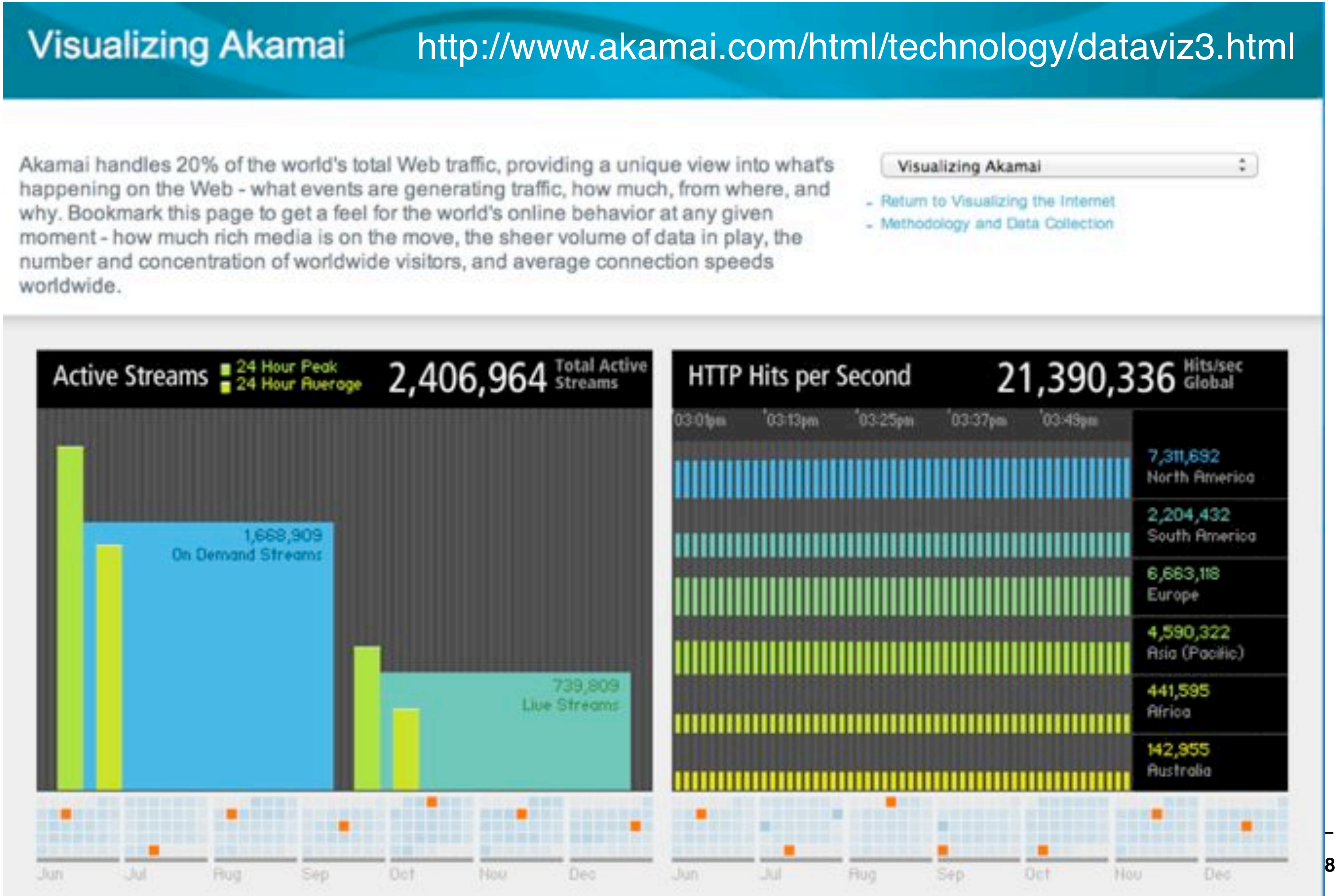


Figure 15.3 Serving from the edge with a CDN.

Figure from Austerberry 2002

See also www.cdnplanet.com/cdns/

Example: Visualizing Akamai



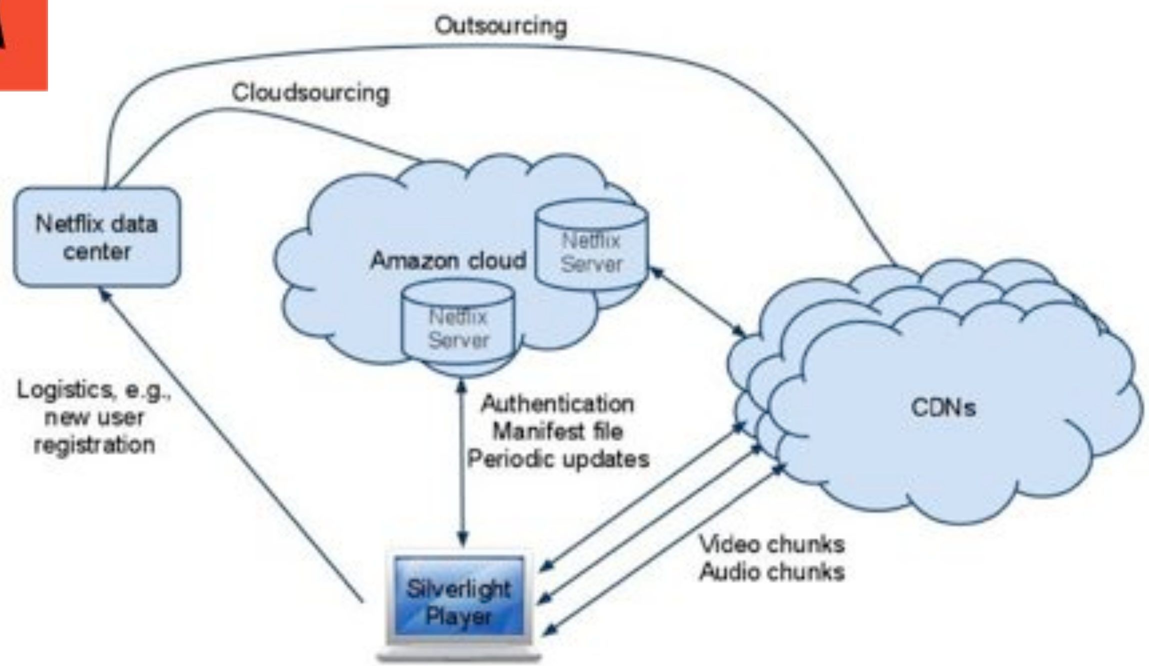
Key Problems in CDNs

- Replica placement:
  - Where to place copies of web sites or other content
  - Problem is in general NP-hard (Karlsson, Karamolis, 2004)
  - Replica placement algorithms (RPA) achieve a suboptimal solution within reasonable time frame
  - Global information is difficult or costly to get - RPA uses local information mostly
  - CDN providers typically try to observe global network performance to some extent
- Request routing:
  - Mechanism and policy of redirecting client requests to a suitable server containing the requested content
  - Redirection algorithm: Decides what node to direct a client request to
  - Redirection mechanism: Way of redirecting the request (client, network)

Streaming Media in CDN

- General idea: Local proxy caching. But: ...
  - Huge size (1 KB vs. 100 MB)
    - » To cache only portions of the original?
  - Intensive bandwidth usage
    - » Minimizing bandwidth consumption as primary consideration
  - High interactivity
    - » E.g. premature termination is frequent (Chen et al. 04: approx. 90 %)
  - However: Media content is rather static (compared to Web pages)
- Caching algorithms
  - Different for homogeneous and heterogeneous clients (in bandwidth/format)
  - Sliding interval caching: sequential access, mainly effective for similar requests in short time period
  - Prefix caching: Saves time to load remaining parts
  - Segment caching: Generalization of prefix caching to support fast forward
  - Rate-split caching: Lower layer from original server, higher layer from proxy
  - Co-operative proxy caching (e.g. Acharya/Smith: MiddleMan)

Case Study: NETFLIX



- Netflix
  - North America market leader for online movies
  - 23 mio subscribers
  - HD video, up to 3.6 Mbps
  - Single largest source of Internet traffic in US (29.7% peak downstream)
- Network architecture
  - netflix.com hosted on own data centers (only registration, payment)
  - Main servers (e.g. movies.netflix.com) hosted by Amazon cloud services
  - Three CDNs used in parallel: Akamai, LimeLight, Level-3
- Player based on Silverlight using DASH
- Dynamic CDN selection strategy influences performance, see:
  - Adhiukari et al.: Unreeling Netflix: Understanding and Improving Multi-CDN Movie Delivery, IEEE INFOCOM 2012

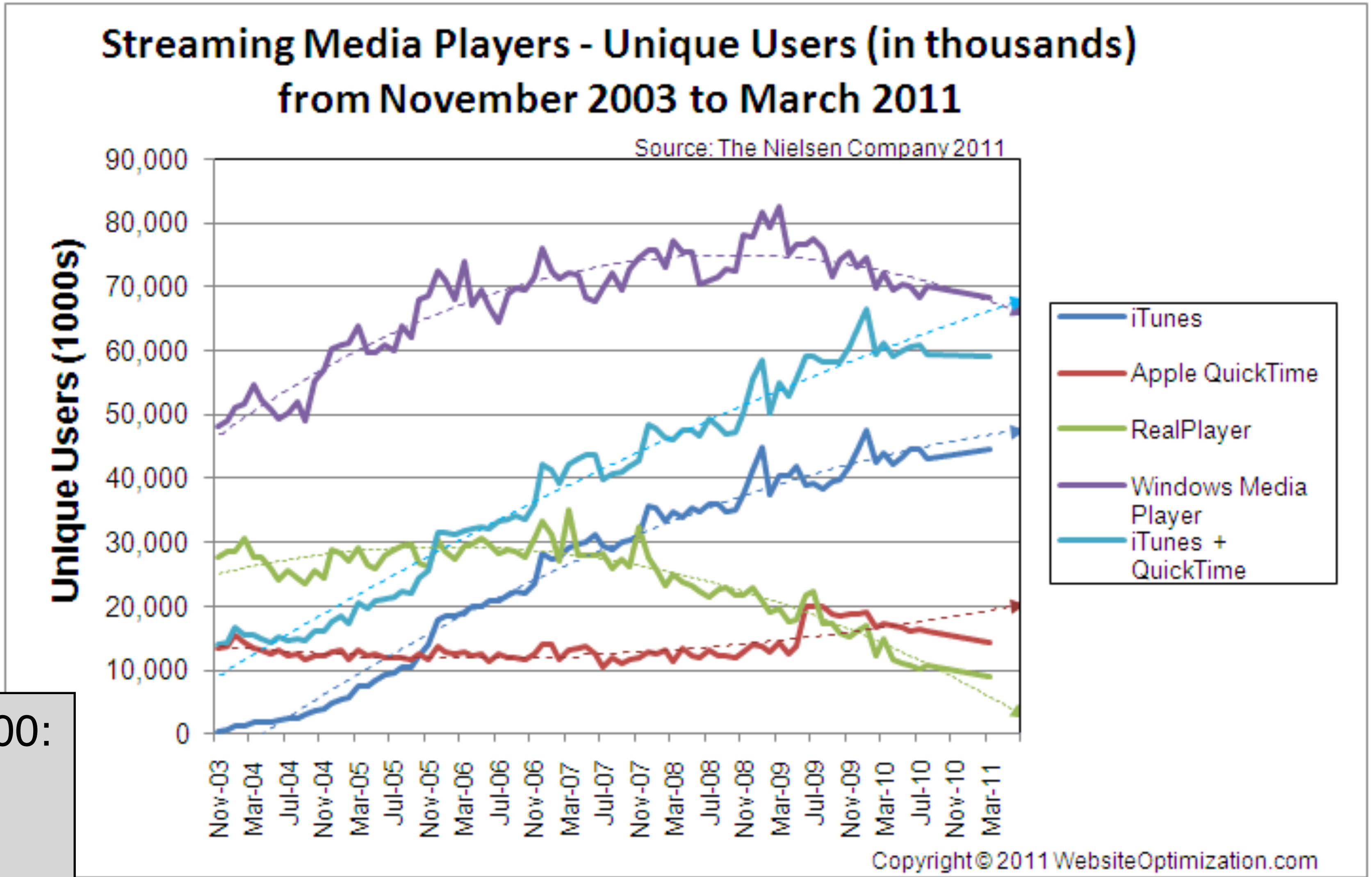
Usage of Video Streaming

Comscore.com:
- U.S. Internet users watched 52.4 billion online content and 35.2 billion video ads in December 2013;
- The total number of unique viewers was 188.2 million;
- This represents 86.9 percent of U.S. Internet users;

Forrester Research, November 2012:
"Video is the fastest-growing digital content category; we forecast that more than 90% of the online population will regularly watch online video by 2017. Online video audience penetrations will rise significantly as video on demand, pay per view, and catchup TV become mainstream. And with pay-TV penetrations in the EU-7 nations considerably lower than in the US, there's more scope for paid online video to grow."

Source: http://blog.wooshii.com/

Historical Market Shares of Streaming Players



Prediction: iTunes+QT will pass Windows Media by 2012

Back in 2000:
Real 28%
Win 22%
QT 4%
(streaming media.com)

Video Codec Wars

- Distinction Container – Content coding
  - E.g. FLV is a container format
- Video coding formats (and their codecs):
  - Usage and market share changes drastically over time
  - Examples for codecs of mainly historic codecs:
    Cinepak (for QuickTime), Indeo (Intel), RealVideo (RealNetworks)
  - Example for format with uncertain status:
    Theora, Windows Media Video
- Main alternative video formats in competition to each other:
  - Standard H.264 vs. Google VP8
  - Next generation: Standard H.265 vs. Google VP9
- Concrete market share data are difficult to find
  - H.264 appears to be market leader