Part 4: Video Transmission Techniques

Vincent Roca and Christoph Neumann
{firstname.name}@inrialpes.fr

Planète project; INRIA Rhône-Alpes
MIPS'03, Napoli, November 2003

Outline

Part 1: Basic techniques
- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes
- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Network Adaptation

- QoS management
  - e.g. delay or bandwidth
- DiffServ, IntServ
- Pros:
  - Guaranteed quality (statistically with DiffServ)
- Cons:
  - QoS is supposed to be supported by the network. This is rarely the case!

Outline

Part 1: Basic techniques
- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes
- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Application Adaptation

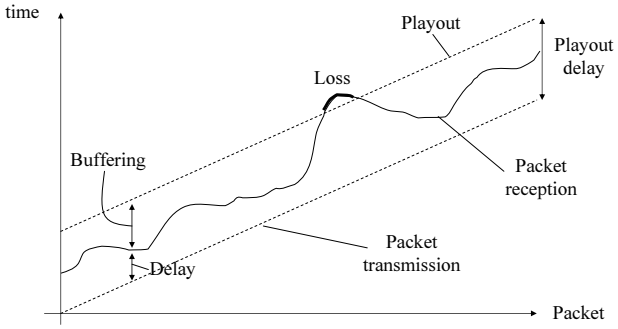
Adapt to:
- Bandwidth
  - Congestion Control and rate regulation
- Delay Jitter
  - Buffering
- Error and Losses
  - Retransmissions, ARQ
  - FEC, unequal protection

Application Adaptation (Congestion Control)

- Congestion Control, rate regulation
  - Video quality adaptation
    - **Set encoding rate when encoding on the fly**
    - **Reduce/improve video quality thanks to video scalability/FGS**
    - **Transcoding**
    - **Switch between different preencoded videos or choose different video group**
  - FEC ratio adaptation

Application Adaptation (Buffering)

- Buffering
  - At receiver side: Store some seconds of the video before display

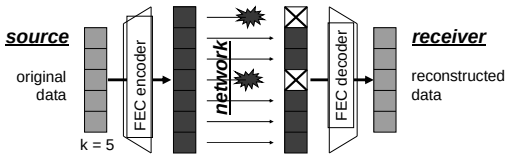


Application Adaptation (ARQ)

- Automatic Repeat Request (ARQ)
  - ask for non received frames
    - **to the source**
    - **to neighbors**
  - Send NACKs
- Variant: Pseudo-ARQ
  - Request a redundant stream in case of losses

Application Adaptation (FEC)

- FEC (Forward Error Correction)



  - Different FEC schemes and codes exist
  - Countermeasure to losses
  - But more FEC ⇒ higher Bandwidth consumption ⇒ more losses … find a balance!

Application Adaptation (FEC - UEP)

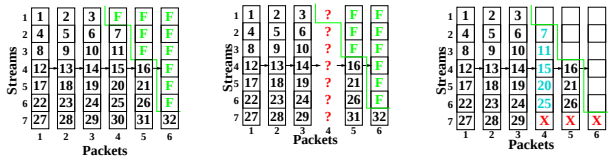
- FEC - Unequal Error Protection (UEP)
  - Some parts of the video are more important than others
    - **i.e. I- versus B-frames**
  - Better protection of important parts of the stream than the rest

Application Adaptation (FEC - UEP)

- Classification according to importance of data
  - Scalable coding:
    - **Base layer > 1st enh. Layer > 2nd enh. Layer > …**
  - Non-scalable coding (Within one GOP):
    - **I-frame > first P-frame > second P-frame > … > B-frames**
    - **I-frame > all picture headers > MB headers > MV data > VLC codewords**
    - **I-frames > picture headers > beginning of frames > end of frames**
- Unequal protection follows this classification

Application Adaptation (FEC - UEP)

- Example of UEP code:



  - Here MDS code (e.g. Reed-Solomon)
  - Most important data is: 1, 2, 3 (n/k=2)
  - Less important: 27 – 32 (no FEC, n/k=1)
- Other solutions exist (RCPC, unequal protection with LDPC, …)

Outline

Part 1: Basic techniques

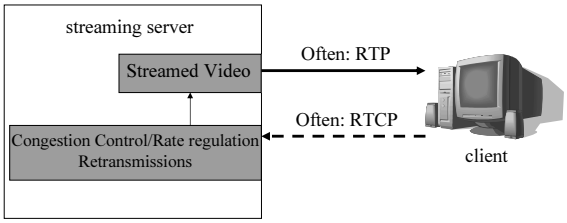
- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes

- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Unicast

- Feedback to server
  - Retransmission request
  - Reports (loss rate, video quality, …)

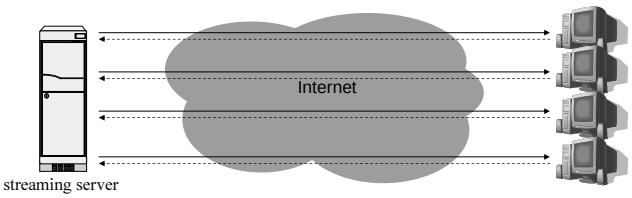


Unicast

- Adaptation of the video according to feedback
  - Preencoded video:
    - **Adapt FEC ratios**
    - **Add/drop quality if scalable compression**
    - **Switch between different preencoded videos**
    - **Transcode**
  - On the fly encoding:
    - **Adapt video encoding rate**
    - **Adapt FEC ratio**

Unicast

- One session per client



- Cons:
  - Requires lots of processing and big access link on server side
  - Not scalable!

Outline

Part 1: Basic techniques

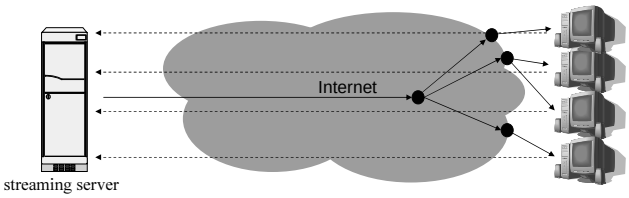
- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes

- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Multicast - Sender based approaches

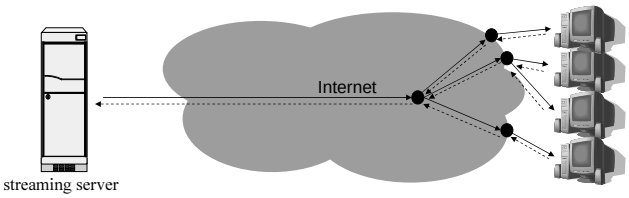
- Feedback and adaptation of the video (similar to unicast approach)



- Unicast feedback
  - Aggregation at source (possible feedback implosion!!)

Multicast - Sender based approaches

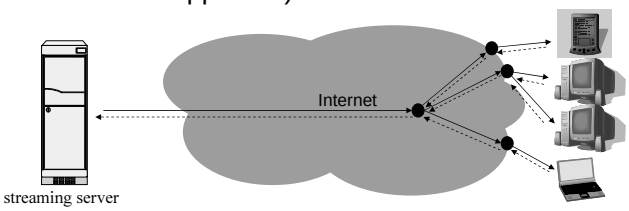
- Feedback and adaptation of the video (similar to unicast approach)



- Aggregated feedback
  - Aggregation at routers/intermediate nodes
    - **has to be supported by routers/intermediate nodes !**

Multicast - Sender based approaches

- Feedback and adaptation of the video (similar to unicast approach)



- Aggregated feedback
  - How to aggregate: Consider fastest/slowest or avg. client? Or are there other ways to aggregate?

Multicast - Sender based approaches

- Scalable feedback control for multicast video distribution in the Internet
  - Bolot, Turletti, Wakeman, SIGCOMM'94
  - Feedback control mechanism
    - **similar to probabilistic feedback technique**
      - Sender: Probabilistic polling mechanism with increasing search scope (TTL)
      - Receiver: Randomly delayed reply scheme
    - **Here:**
      - Receivers/sender generate random keys every cycle
      - Sender: sends out a random key
      - Receiver: responds if last *n* bits in key matches (if *n*=0 all receivers can respond)
      - If no responses (within a timeout) decrease *n*
      - If enough responses restart a new cycle

Multicast - Sender based approaches

- Scalable feedback control for multicast video distribution in the internet… (cont')
  - RTCP feedback contains:
    - **Network state: UNLOADED, LOADED or CONGESTED**
    - **RTT**
  - Action of Sender due to feedback:
    - **adapts to the worst network state (for example by in/decreasing video bandwidth)**
    - **Adapt timeout to maximum RTT**

Multicast - Sender based approaches

This class of solutions has the following properties:

- Pros:
  - Less server load than unicast approach
  - Can address more clients than unicast solutions
- Cons:
  - is limited in terms of number of users
    - **feedback**
    - **intermediate nodes may be needed for aggregation**
  - No heterogeneity support
    - **source considers an aggregation of all clients capacities**

Outline

Part 1: Basic techniques

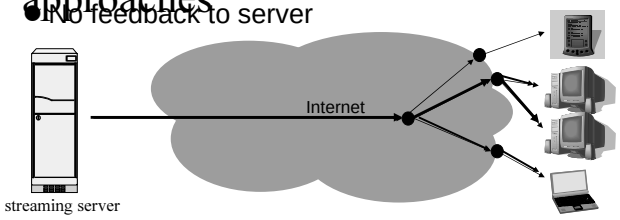
- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes

- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Multicast – Receiver based approaches

- No feedback to server



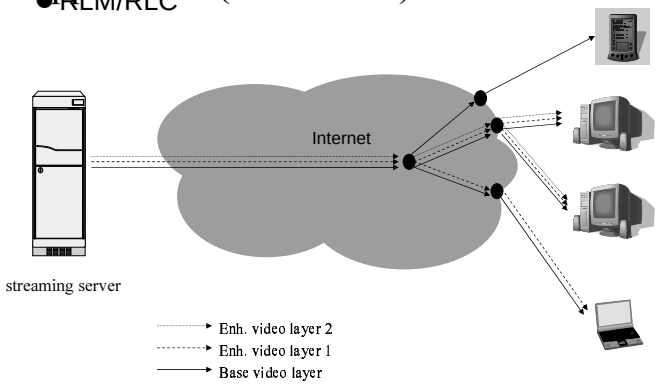
- Adaptation only on receiver side
  - e.g. add/drop video quality (through video layers)
  - e.g. add/drop FEC
  - e.g. retransmission request to neighbor receivers
  - e.g. «retransmission» through FEC or delayed data streams

Multicast – Receiver based approaches (RLM/RLC)

- Receiver-driven Layered Multicast (RLM)/Receiver-driven layered congestion control (RLC)
  - RLM: McCanne, Jacobson, SIGCOMM'96
  - RLC: Vicisano, Crowcroft, Rizzo, INFOCOM'97
  - Sender transmit stream in multiple layers
    - **Each video layer is sent to a separate multicast group**
  - See part 3

Multicast – Receiver based approaches (RLM/RLC)

- RLM/RLC



Multicast – Receiver based approaches (RLM/RLC)

- Pros of RLM/RLC for video streaming:
  - Unlimited scalability
  - Addresses clients heterogeneity
  - Bandwidth adaptive
    - **But only in a limited manner…**

Multicast – Receiver based approaches (RLM/RLC)

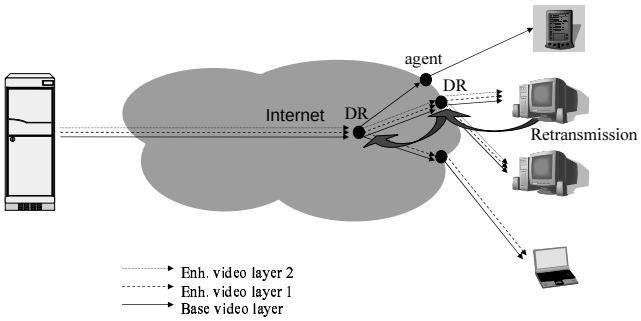
- Cons of RLM/RLC for video streaming:
  - RLM and RLC suffers both of periodic losses and periodic congestion
  - Frequent changes of video quality
  - Video quality is strongly linked to network load
  - Quality adaptation and bandwidth adaptation dependent of the number of video layers
  - Layered video difficult to achieve!
    - **Often only one enhancement layer is available**
- Conclusion: Academic approach with many practical limitations

Multicast – Receiver based approaches (LVMR)

- LVMR
  - Li, Paul et al, NOSSDAV'97
  - « Extension » of RLM
  - Receivers can ask neighbors (*designated receivers* DR) for lost packets
  - Adaptation to network congestion and heterogeneity using Hierarchical Rate Control
    - **Management of shared information (cf. RLM) is done by each *agent***
    - **Reduces overhead traffic**
  - *Agents* and *Designated Receivers* have to be deployed within the network

Multicast – Receiver based approaches (LVMR)

- LVMR



Multicast – Receiver based approaches (LVMR)

- Pros of LVMR:
  - Addresses clients heterogeneity
  - Bandwidth adaptation
    - **But only in a limited manner…**
  - Video quality is more stable than with RLM/RLC
  - Does not rely on any QoS mechanism or other components in the network
    - **Immediately deployable**

Multicast – Receiver based approaches (LVMR)

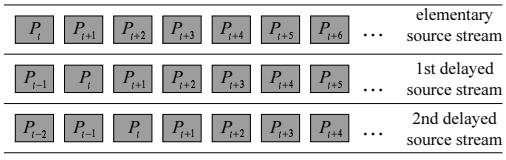
- Cons of LVMR:
  - Limited scalability
  - Neighbor are not necessarily available
  - Video quality is still linked to network load
    - **But less than in RLM**
  - Statically designated DR and agents, makes this approach difficult to deploy
  - Quality adaptation and bandwidth adaptation dependent of the number of video layers
  - Layered video difficult to achieve!
    - **Often only one enhancement layer is available**
- Conclusion: Academic approach with many practical limitations

Multicast – Receiver based approaches (P.ARQ)

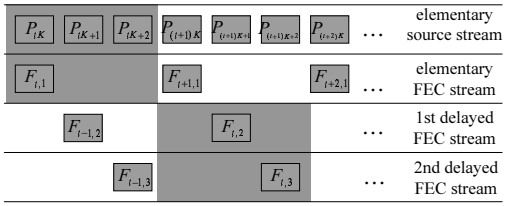
- Pseudo ARQ
  - Chou et al, Communication Theory Workshop'99
  - Sender transmits stream in multiple layers
    - **Each layer is sent to a separate multicast group**
  - Sender transmit additional delayed streams on separate multicast groups
    - **pure data (*Pseudo-ARQ*) or FEC (*Hybrid FEC/Pseudo ARQ*)**
  - Receivers listen to as many layers/groups as possible
  - Listen to delayed groups if losses occurs to reconstruct lost packets
    - **corresponds to the retransmission request**

Multicast – Receiver based approaches (P.ARQ)

- Pseudo ARQ



- Hybrid FEC/Pseudo ARQ



Multicast – Receiver based approaches (P.ARQ)

- Pros of Pseudo ARQ:
  - Unlimited scalability
  - Addresses clients heterogeneity
  - Bandwidth adaptation
    - **But only in a limited manner…**
  - Video quality is more stable than with RLM
  - Does not rely on any QoS mechanism or other components in the network
    - **Immediately deployable**

Multicast – Receiver based approaches (P-ARQ)

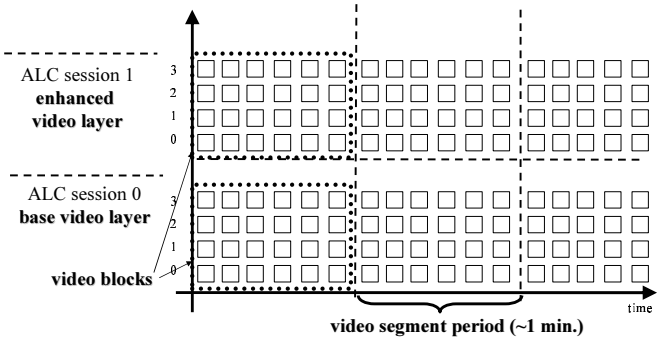
- Cons of Pseudo ARQ:
  - Video quality is strongly linked to network load
  - Quality adaptation and bandwidth adaptation dependent of the number of video layers
- Conclusion: Good potential

Multicast – Receiver based approaches (SVSoA)

- Scalable Video Streaming over ALC (SVSoA)
  - Neumann, Roca, INRIA Research Report 4769
  - Rely on ALC and associated congestion control
  - Partition video into segments of constant duration
    - **For each segment, there is a video *block* per video layer**
  - Transmit each block as a file
    - **Use a distinct ALC session**
    - **Transmit each segment in *on-demand* mode**
  - Receive the most important video block first
    - **Get only one video layer at a time**
    - **Receive higher video layers only if time is left**

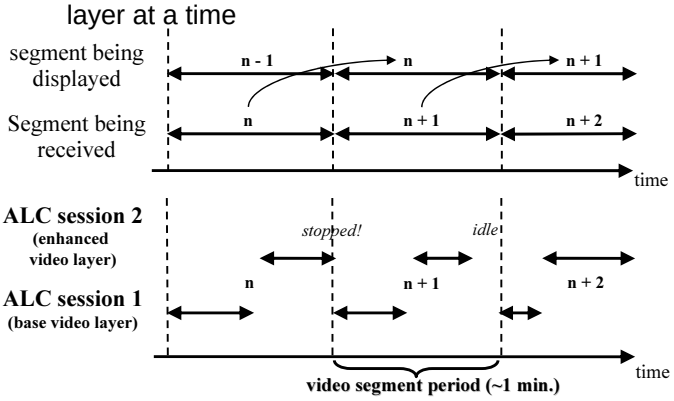
Multicast – Receiver based approaches (SVSoA)

- SVSoA – Sender: Transmit one video layer on one ALC session



Multicast – Receiver based approaches (SVSoA)

- SVSoA – Receiver: receive only one video layer at a time



Multicast – Receiver based approaches (SVSoA)

- Pros of SVSoA:
  - Unlimited scalability (thanks to ALC)
  - Addresses clients heterogeneity (thanks to ALC)
  - TCP-friendly Congestion Control (thanks to ALC)
    - **Independently of the number of video layers**
  - Smoothed video quality
    - **Even in presence of long bursts of losses**
    - **Independently of network load**
  - Does not rely on any QoS mechanism or other components in the network
    - **Immediately deployable**

Multicast – Receiver based approaches (SVSoA)

- Cons of SVSoA:
  - Pseudo real-time streaming
    - **One minute delay**
    - **Suited for non-interactive videos or TV-program distribution… but not for video-conference...**
- Conclusion: Promising approach for non-interactive streaming built on standardized protocols
- SVSoA - Future work
  - Unequal FEC protection for unscalable videos
  - Reduce startup latency

Multicast – Receiver based approaches

This class of solutions has the following properties:

- Pros:
  - Unlimited scalability
    - **no feedback**
    - **low server load**
  - Address heterogeneity of clients
    - **Every client chooses the quality adapted to its capacities**
- Cons:
  - Depends on the proposal

Outline

Part 1: Basic techniques

- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes

- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Multicast – Hybrid approaches

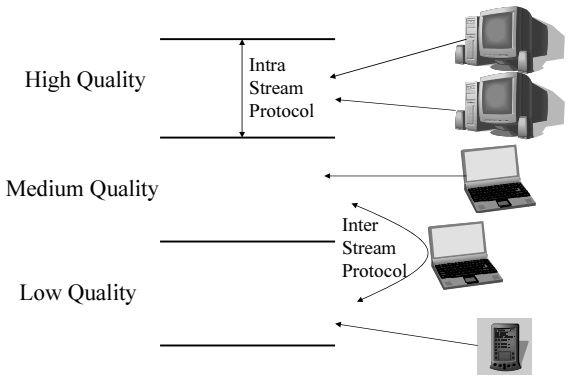
- Hybrid approaches have two features:
  - rely on feedback
  - perform both source and receiver adaptation
- Three proposals:
  - DSG
  - SAMM
  - SARC

Multicast – Hybrid approaches (DSG)

- Destination Set Grouping (DSG)
  - Cheung et al, INFOCOM'96
  - Server streams the same video on different video streams, each targeted at receivers with different capabilities
  - Intra Stream Protocol:
    - **Each stream is feedback controlled, to adjust data rate within prescribed limits**
      - Using a probabilistic feedback technique (cf. «Scalable feedback control for multicast video distribution in the internet »)
  - Inter Stream Protocol:
    - **Receivers move among the streams as their (network) capabilities change**

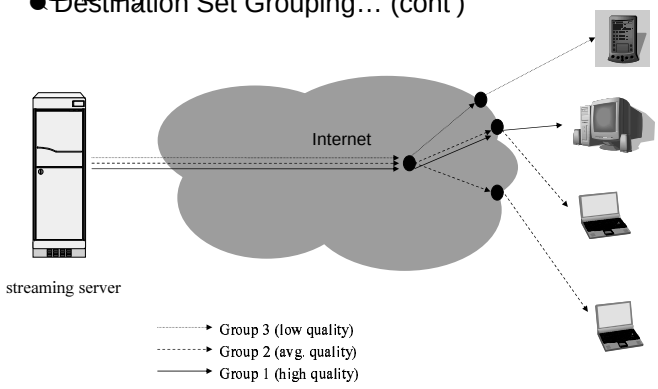
Multicast – Hybrid approaches (DSG)

- Destination Set Grouping… (cont')



Multicast – Hybrid approaches (DSG)

- Destination Set Grouping… (cont')



Multicast – Hybrid approaches (DSG)

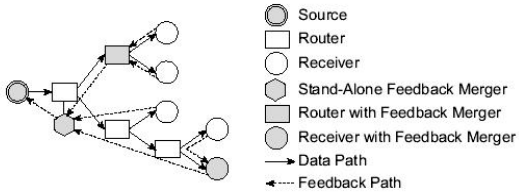
- Pros of DSG:
  - No assumption on video coding scheme
  - Addresses heterogeneity
- Cons of DSG:
  - Duplicated traffic
  - Limited number of receiver sets
    - **limits heterogeneity support**
- Conclusion: good, realistic approach

Multicast – Hybrid approaches (SAMM)

- Source adaptive multi-layered multicast (SAMM)
  - Vickers et al, ACM Transactions on Networking'99
  - Assumes scalable video coding
  - Video dynamically adapted according to the aggregate feedback :
    - **Number of layers**
    - **Rate of layers**
  - Feedback is generated by:
    - **1st solution: Network intermediate nodes that monitor network state (*network-based SAMM*)**
    - **2nd solution: Receivers (*end-to-end SAMM*)**

Multicast – Hybrid approaches (SAMM)

- SAMM… (cont')
  - Relies on *feedback mergers* within the network



Multicast – Hybrid approaches (SAMM)

- SAMM… (cont')
  - *end-to-end SAMM:* Receivers estimates supported rates by analyzing losses
  - Feedback contains
    - **list of rates requested by receivers**
    - **the number of receivers requesting it**
  - *Feedback mergers* adapt this list to the maximum number of layers supported by the encoder by merging rates that are close if necessary
  - The sender adapts the number of layers and their rates according to the list of rates in the feedback messages

Multicast – Hybrid approaches (SAMM)

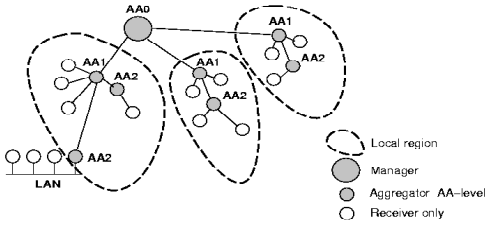
- Pros of SAMM:
  - Heterogeneity well addressed
- Cons of SAMM:
  - Intermediate nodes needed
  - Special video codec needed
    - **bandwidth adaptation of video layers**
- Conclusion: Academic approach with many practical limitations

Multicast – Hybrid approaches (SARC)

- Source-channel Adaptive Rate Control (SARC)
  - Vieron, Turletti, Salamatian, Guillemot, EURASIP Journal on Applied Signal Processing, 2004
  - Assumes FGS video coding
  - Video dynamically adapted according to the aggregate feedback :
    - **Number of layers**
    - **Rate of layers**
    - **Level of protection of layers**
  - Filtering mechanism based on a clustering algorithm to classify/aggregate receivers

Multicast – Hybrid approaches (SARC)

- SARC… (cont')
  - Relies on *managers* and *aggregators* within the network
    - **This aggregator tree hierarchy keeps the feedback traffic under 5% of the overall traffic**



Multicast – Hybrid approaches (SARC)

- SARC… (cont')
  - **Filtering mechanism**: Aggregators receive RTCP reports from the lower hierarchy level (instead of multicast RTCP)
    - RTCP Reports (loss rate, TCP-Friendly rate) are aggregated into clusters (the nearest neighboring clustering algorithm is used)
    - Clustering of similar reception behaviors into homogeneous classes
  - Feedback information for each cluster:
    - **Loss rate**
    - **Bandwidth limit**
    - **Number of receiver within a given cluster**
  - Sender adapts FEC, number and bandwidth of layers according to feedback

Multicast – Hybrid approaches (SARC)

- Pros of SARC :
  - Heterogeneity well addressed
  - Scalability
  - Feedback generated with high frequency, even with large groups
- Cons of SARC :
  - Intermediate nodes needed
  - Uses non-standard RTCP extensions
- Conclusion: Good solution, but requires FGS coding

Outline

Part 1: Basic techniques

- Network Adaptation
- Application Adaptation

Part 2: Streaming schemes

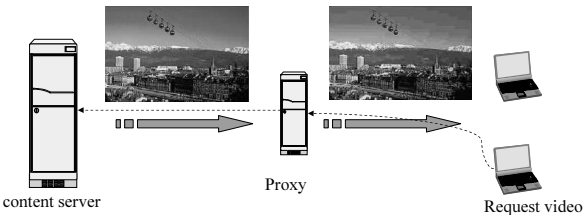
- Unicast approaches
- Multicast approaches
  - Sender based approaches
  - Receiver based approaches
  - Hybrid approaches
- Network components

Network components

- Four proposals:
  - Network Proxies
  - Transcoders
  - Content Delivery Networks (CDN)
  - MDC & CDN/P2P

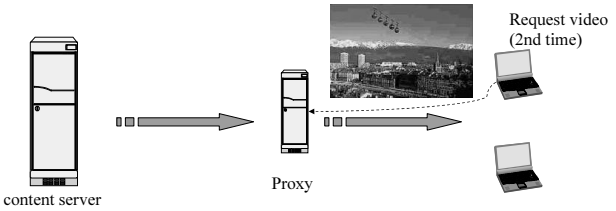
Network components

- Network Proxies
  - Distribution of the video within the network (network cache)
  - Repartition of network load
  - Repartition of server load
  - Mainly for Video-On-Demand



- 1st request of video

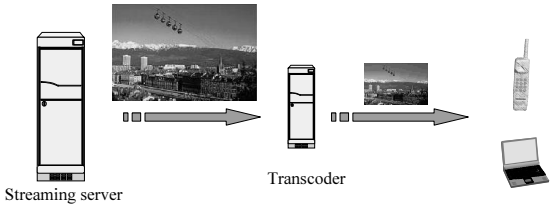
Network components



- 2nd request of video

Network components

- Transcoders
  - Adapt the video to the capabilities of the receiver
    - **Decode then re-encode**
    - **Computationally expensive**
  - Have to be present throughout the network
  - Can be coupled with proxies

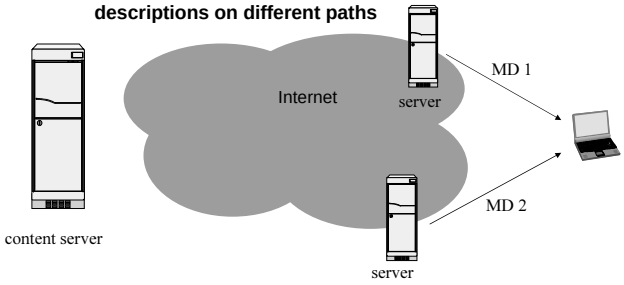


Network components

- Content Delivery Networks (CDN)
  - Provides all the required mechanisms
    - **Server placement problem**
      - Where should the servers be placed on the network?
    - **On which server should each piece of content be replicated?**
    - **Cache all the video (requires significant amount of storage), or only parts of the video?**
    - **For each request, where is the optimal server to direct the client to for delivery of the content?**
    - **Streaming sessions are long**
      - midstream hand-off from one server to another are often required

MDC & CDN/P2P

- MDC & CDN/P2P
  - MDC streams distributed across the edge servers of the CDN
  - Client requests a stream:
    - **Servers streams simultaneously complementary descriptions on different paths**



MDC & path diversity

- MDC combines well with path diversity
  - Losses on two paths are likely to be uncorrelated
  - … unless losses take place on the last router
- Another example: Peer-to-peer-streaming