Exercise
for Lecture "P2P Systems"

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– Example Solution –

Problem 8.1 - Video Streaming

Discuss the advantages and disadvantages of the following topologies for P2P video streaming.

A) Single tree topology with respect to high/low peer churn. How do multi tree topologies perform in comparison?

Solution: Single tree based topologies work well for the dissemination of video streams, if peer churn is low. In this case, overhead costs are low and playback performance is high, as a push-based scheduling mechnism can be used. However, with rising peer churn, an increasing amount of messages has to be exchanged for reassociating pruned branches of the tree. Pruned branches also lead to stalling in the respective subtree. Multi tree topologies are more robust to peer churn by design, as peers participate in multiple trees, thus the problem is solved by introducing redundant connections.

B) Single tree based topologies and multi tree topologies with respect to fairness.

Solution: In single tree based topologies, intermediate peers have a high load, as they are served by one peer and have to serve at least two peers. Moreover, leaf peers receive service without having to contribute to the system. Thus, there is a certain amount of unfairness in the system. In multi-tree topologies, peers can join in several trees at different positions, e.g., as an intermediate peer in tree A and as a leaf peer in tree B, so load balancing can be achieved easily.

C) Tree-based topologies and mesh-based topologies with respect to a strict upper bound for delay.

Solution: In tree based topologies, a strict upper bound for a chunk of the video can be guaranteed, as the path of the stream from the source to a peer is fixed. Thus, the upper bound for delivery is the sum of all delays on this path. Mesh based topologies do not offer a fixed path for data by design, so a strict upper bound cannot be defined. However, a stochastic upper bound can be given.

Problem 8.2 - Video Streaming

A) Name and explain two reasons why in video streaming the use of a buffer is required.

Solution:

Slide 5: Reasons: "to account for jitter and bandwidth fluctuations"

B) Explain what happens if a too small buffer is used.

Solution:

Frequent playback stalling and even crashing of the media player can happen. The latter can happen if the player e.g. tries to decode a video frame that depends on a future frame that is not yet there (can happen using state-of-the-art video codecs where P frames can depend on future I/P frames).

C) What are alternatives to overlay multicast approaches? Explain in which cases alternatives could be more efficient than overlay multicast. Note: "efficiency" is understood in terms of network traffic required for the delivery of a video stream to a given number of clients.

Solution:

- Slide 11: Alternatives are IP Unicast, IP(MAC) Broadcast and IP Multicast.
- In case of a single broadcast domain where almost all clients in the network want to retrieve the stream, IP Broadcast might be an efficient solution (depending on the ratio between clients which want to receive the stream and those which do not).
- In cases were IP multicast is available (e.g. in a big company network or a network of a single ISP), IP multicast is an efficient solution.

D) In the lecture you got to know the differences between single- and multi-tree streaming approaches. Discuss which of the two approaches would be better suited for scenarios with very heterogeneous clients (i.e. some clients have very low upload connection bandwidths).

Solution:

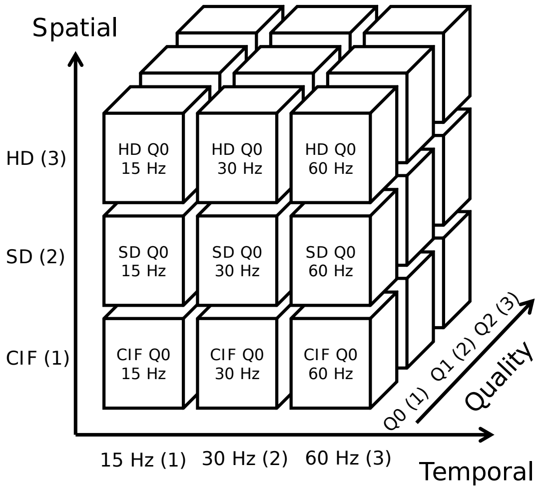
- Which is better, depends! In single tree approaches, weak clients could be places as leafs and, thus, do not have to upload anything. Using a multi-tree approach, the number of inner-node positions of weak nodes could be adapted to the available bandwidth. Therefore, the multi-tree approach allows for a more fine-granular adjustment of required upload capacities of individual clients.

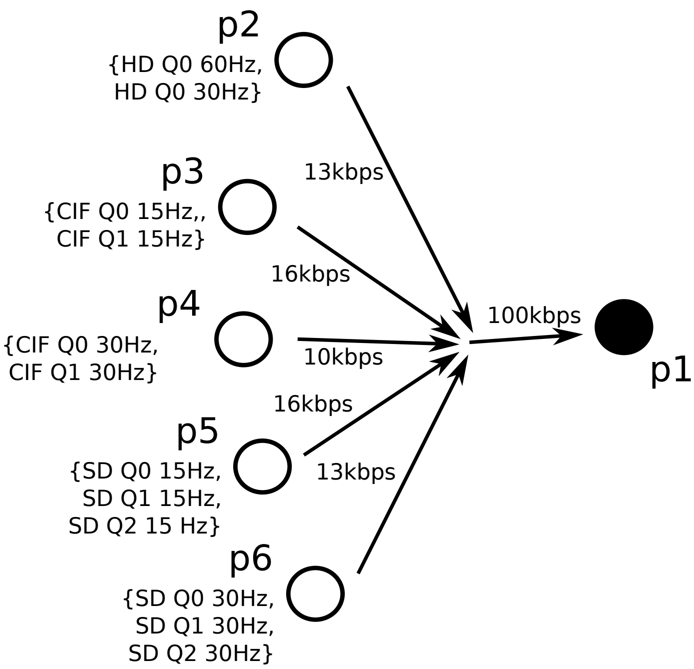
E) What would happen if in a BitTorrent Live overlay, the number of clubs is configured to be higher than the number of clients in the system?

Solution:

- Assuming that clients are evenly distributed about the clubs, the difference between the number of clubs and the number of clients describes the number of clubs that need to be served by the source. As all clients require the data from all clubs for a video playback, this results in very high resource requirements for the source. If the approach is to be used to mainly serve a small number of users, the number of clubs should be set to a low value as well. For larger scenarios, a higher number of clubs can help to better distribute load among peers.

Problem 8.3 - Scalable Video Coding (SVC)





In a video-streaming P2P network, peer $p1$ wants to watch a video. All peers are connected to a central server, which can be queried for other peers in the network providing the desired stream. The network uses SVC to deliver custom quality to its peers, and the peers decide for themselves about the quality layers of the content they want to consume. In this task you will manage the SVC layer selection for $p1$.

$p1$ wants to consume a video with a quality as high as possible. If conflicting, it prefers a high resolution (spatial) over a high coding quality, over a high frame rate (Temporal). p1 asks the server about other peers having the content, and the server returns the peers $p2$ to $p6$, holding and providing the SVC layer elements shown in the right graph above. The layer elements correspond to the ones in the SVC cube shown in the left graph.

Every layer element requires a bandwidth of $x \cdot y \cdot z$ kbps, where x, y and z are the layer IDs (shown in parentheses on the axis tics of the left graph above). So for example the layer element "HD Q0 30Hz" has a size of $3 \cdot 2 \cdot 1 = 6$ kbps.

Peer $p1$ selects on its own which layer elements to request. However, it has to respect the bandwidth limitations shown on the edges of the right graph. Answer the following questions:

What is the maximum SVC quality $p1$ can achieve?
Solution: SD Q1 30Hz

List the layer elements that have to be requested by $p1$, as well as the peers where they are requested, if $p1$ maximizes the quality obtained. Calculate the total bandwidth required for streaming these elements to $p1$.

Solution: CIF Q0 15Hz (1kbps) and CIF Q1 15Hz (2kbps) from $p3$,
CIF Q0 30Hz (2kbps) and CIF Q1 30Hz (4kbps) from $p4$
SD Q0 15Hz (2kbps) and SD Q1 15Hz (4kbps) from $p5$,
SD Q0 30Hz (4kbps) and SD Q1 30Hz (8kbps) from $p6$
$(1+2+2+4+2+4+4+8)kbps = 27kbps$

Answer the last two questions under the condition that the available bandwidth of $p1$ (formerly 100 kbps) has dropped to 25 kbps.

Solution: The previous quality requires a bandwidth of $27kbps$, thus it cannot be sent over the current client's downstream interface. The next smaller available bandwidths are SD Q0 30Hz, SD Q1 15 Hz, and CIF Q1 30 Hz. Together with all required layer elements, they each require $(1+2+2+4)kbps = 9kbps$. As $p1$ prefers a high resolution and a high coding quality over a high frame rate, **SD Q1 15Hz** is the correct solution. The requested layer elements are
CIF Q0 15Hz (1kbps) and CIF Q1 15Hz (2kbps) from $p3$,
SD Q0 15Hz (2kbps) and SD Q1 15Hz (4kbps) from $p5$.