1. Multimedia Networking

Assume three MPEG streams are being transmitted over a Wireless Local Area Network (WLAN), whose bandwidth is 6.5 Mbps. Also assume that the traffic behavior of each MPEG stream is as show in Figure 1.

![Traffic behavior of a MPEG stream](image)

**Figure 1.** Traffic behavior of a MPEG stream

For the first 0.95 second the stream is at 1.2 Mbps while for the next 0.05 second the stream is at 5.0 Mbps. After a period of 1 second, the same sequence of traffic repeats. Assume that the bursty period of each stream will not coincide. What is the total loss rate (Mbps) when the three streams are simultaneously transmitted?

**Sol**

Because the same sequence of traffic repeats after a period of 1 second, we can consider only the first second. In such a period, the total bandwidth that are required for three MPEG streams can be depicted in the following graph.

![Total bandwidth required](image)
The network cannot accommodate enough bandwidth when any of three MPEG streams becomes bursty. This will result in data loss. In one second there are three bursty periods; each requires bandwidth at 7.4 Mbps and lasts for 0.05 second. Hence, the loss rate is:

\[3 \times (0.05) \times (7.4 - 6.5) = 0.135\text{ Mbps}\]

2. Video Caching

Assume the network architecture of video caching from the main server to the end users is as shown in Figure 2. As can be seen, the main server, the metropolitan area server and the local server have storage cost $0.1, $0.2 and $0.5 per hour per one video respectively. The transmission cost between the main server and the metropolitan area server is $1.2 per one video while that between the metropolitan area server and the local server is $0.4. Assume the first user, the second user and the third user would like to watch the video at 7am, 5pm and 7pm respectively. Find the optimal caching sequence. Assume that the video content is available at the main server at 7am.

![Network structure of video caching](image)

**Figure 2.** Network structure of video caching

**Sol**

In order to find the optimal caching sequence, we need to consider each user one-by one starting from user 1.

For the user 1, there is only one case to consider. We only need to transfer a video from a main server to the user. This incurs a cost of $1.2 + $0.4 = $1.6.
For the user 2, there are three possible cases.
Case 1: caching at the main server. A video is cached at the main server for 10 hours and transmitted from the main server to the user. This results in a cost of $10\times0.1 + 1.2 + 0.4 = 2.6$.
Case 2: caching at the metro area server. A video is cached at the metro area server for 10 hours and transmitted from that server to the user. This will incur a cost of $10\times0.2 + 0.4 = 2.4$.
Case 3: caching at the local server. A video is cached at the local server for 10 hours and transferred directly to the user. This will incur a cost of $10\times0.5 = 5$.

First, we choose to cache the video for user 2 at the main server. We have three cases to consider:

Case 1.1: caching at the main server. A video is cached at the main server for 2 hours (from 5pm-7pm) and transmitted from the main server to the user. This will incur a cost of $2\times0.1 + 1.2 + 0.4 = 1.8$. The total cost for making a video available for three users is thus $1.6 + 2.6 + 1.8 = 6$.

Case 1.2: caching at the metro area server. A video is cached at the metro area server for 2 hours and transmitted from that server to the user. This will incur a cost of $2\times0.2 + 0.4 = 0.8$. The total cost for making a video available for three users is thus $1.6 + 2.6 + 0.8 = 5$.

Case 1.3: caching at the local server. A video is cached at the local server for 2 hours and transferred directly to the user. This will incur a cost of $2\times0.5 = 2$. The total cost for making a video available for three users is thus $1.6 + 2.6 + 2 = 6.4$.

To this point, the optimal solution we got is $5 where we cache a video at the main server for user 2 and at the metro area server for user 3.

Second, we try to cache the video for user 2 at the metro area server and check whether we can find a better sequence of caching (lower cost). We have three cases to consider:

Case 2.1: caching at the main server. Since at 5pm the video is not present at the main server, we need to first transfer it from the metro area server to the main server, cache the video for 2 hour and transfer the content back to the user. This will incur a cost of $1.2 + 2\times0.1 + 1.2 + 0.4 = 3$. The total cost for making a video available for three users is thus $1.6 + 2.4 + 3 = 7$.

Case 2.2: caching at the metro area server. A video is cached at the metro area server for 2 hours and transferred from that server to the user. This will incur a cost of $2\times0.2 + 0.4 = 0.8$. The total cost for making a video available for three users is thus $1.6 + 2.4 + 0.8 = 4.8$. 
Case 2.2: caching at the local server. A video is cached at the local for 2 hours and transferred to the user directly. This will incur a cost of $2 \times 0.5 = $1. The total cost for making a video available for three users is thus $1.6 + 2.4 + 1 = $5.

We can find a better sequence of video caching where we do caching at the metro area for both user 2 and user 3. This results in a cost of only $4.8.

Note that we need not to consider the case in which we do caching at the local server for user 2. This is because only making the content available for the first two users it results a cost of $5 which is worse than the optimal sequence we have.

3. Asynchrony in media playback

Denote \( \theta \) a nominal playback period (sec), \( \rho \) a maximum fractional drift in playback, \( \Delta_{\text{max}} \) a maximum network delay, \( \Delta_{\text{min}} \) a minimum network delay, \( \mu_m \) a media unit being played back at the fastest media player and \( \mu \) a media unit being played back the slowest player. Derive the equation to compute the maximum asynchrony between two media players receiving multimedia streams from the video server.

\[
\mu_m - \mu \leq \frac{(\Delta_{\text{max}} - \Delta_{\text{min}}) + 2 \cdot \theta \cdot \rho \cdot \mu}{\theta(1 - \rho)}
\]

See lecture note for more detail (http://www-cse.ucsd.edu/classes/sp03/cse126/lecture/note16.pdf) or a complete proof at (http://www.cse.ucsd.edu/groups/multimedia/papers/rr93.pdf).