16.5 Media-on-Demand (MOD)

- **Interactive TV (ITV) and Set-top Box (STB)**

  ITV supports activities such as:

  1. TV (basic, subscription, pay-per-view)
  2. Video-on-demand (VOD)
  3. Information services (news, weather, magazines, sports events, etc.)
  4. Interactive entertainment (Internet games, etc.)
  5. E-commerce (on-line shopping, stock trading)
  6. Access to digital libraries and educational materials
Fig. 16.10: General Architecture of STB (Set-top Box).
Set-top Box (STB)

- Set-top Box (STB) generally has the following components:

  1. *Network Interface and Communication Unit*: including tuner and demodulator, security devices, and a communication channel.

  2. *Processing Unit*: including CPU, memory, and special-purpose operating system for the STB.

  3. *Audio/Video Unit*: including audio and video (MPEG-2 and 4) decoders, DSP (Digital Signal Processor), buffers, and D/A converters.


  5. *Peripheral Control Unit*: controllers for disks, audio and video I/O devices (e.g., digital video cameras), CD/DVD reader and writer, etc.
Broadcast Schemes for Video-on-Demand

- **Staggered Broadcasting**
  
  - For simplicity, assume all movies are of length $L$ (seconds).
  
  - The available high bandwidth $B$ of the server (measured as the multiple of the playback rate $b$) is usually divided up into $K$ logical channels ($K \geq 1$).
  
  - Assuming the server broadcasts up to $M$ movies ($M \geq 1$), they can be periodically broadcast on all these channels with the start-time of each movie staggered — *Staggered broadcasting*.
  
  - If the division of the bandwidth is equal amongst all $K$ logical channels, then the access time (longest waiting time) for any movie is actually independent of the value of $K$, i.e.,

  $$\delta = \frac{M \cdot L}{B}$$
Fig. 16.11: Staggered Broadcasting with $M = 8$ movies and $K = 6$ channels.
Pyramid Broadcasting

• In Pyramid Broadcasting:
  
  – Movies are divided up into segments of increasing sizes, i.e., $L_{i+1} = \alpha \cdot L_i$, where $L_i$ is the size (length) of Segment $S_i$ and $\alpha > 1$
  
  – Segment $S_i$ will be periodically broadcast on Channel $i$. In other words, instead of staggering the movies on $K$ channels, the segments are now staggered.
  
  – Each channel is given the same bandwidth, and the larger segments are broadcast less frequently.

Since the available bandwidth is assumed to be significantly larger than the movie playback rate $b$ (i.e. $B \gg 1$), it is argued that the client can be playing a smaller Segment $S_i$ and simultaneously receiving a larger Segment $S_{i+1}$. 
Pyramid Broadcasting (cont’d)

- To guarantee a continuous playback, the necessary condition is:

\[
playback\_time(S_i) \geq access\_time(S_{i+1})
\] (1)

The \(playback\_time(S_i) = L_i\). Given the bandwidth allocated to each channel is \(B/K\), \(access\_time(S_{i+1}) = \frac{L_{i+1} \cdot M}{B/K} = \frac{\alpha \cdot L_i \cdot M}{B/K}\), which yields

\[
L_i \geq \frac{\alpha \cdot L_i \cdot M}{B/K}
\] (2)

Consequently,

\[
\alpha \leq \frac{B}{M \cdot K}
\] (3)
Pyramid Broadcasting (cont’d)

- The access time for Pyramid broadcasting is determined by the size of $S_1$. By default, we set $\alpha = \frac{B}{M \cdot K}$ to yield the shortest access time.

- The access time drops exponentially with the increase in the total bandwidth $B$, because $\alpha$ can be increased linearly.
Skyscraper Broadcasting

- A main drawback of the above Pyramid Broadcasting scheme is the need for a large storage space on the client side because the last two segments are typically 75-80% of the movie size.

- Instead of using a geometric series, *Skyscraper broadcasting* uses \{1, 2, 2, 5, 5, 12, 12, 25, 25, 52, 52, ...\} as the series of segment sizes to alleviate the demand on a large buffer.
As shown in Fig 16.12, two clients who made a request at time intervals (1, 2) and (16, 17), respectively, have their respective transmission schedules. At any given moment, no more than two segments need to be received.
Harmonic Broadcasting

- Adopts a different strategy in which the size of all segments remains constant whereas the bandwidth of channel $i$ is $B_i = b/i$, where $b$ is the movie’s playback rate.

- The total bandwidth allocated for delivering the movie is thus

$$B = \sum_{i=1}^{K} \frac{b}{i} = H_K \cdot b,$$

where $K$ is the total number of segments, and $H_K = \sum_{i=1}^{K} \frac{1}{i}$ is the Harmonic number of $K$. 
Fig. 16.14: Harmonic Broadcasting.
As Fig. 16.14 shows: after requesting the movie, the client will be allowed to download and play the first occurrence of segment $S_1$ from Channel 1. Meanwhile, it will download all other segments from their respective channels.

The advantage of Harmonic broadcasting is that the Harmonic number grows slowly with $K$.

For example, when $K = 30$, $H_K \approx 4$. Hence, the demand on the total bandwidth (in this case $4 \cdot b$) is modest.

It also yields small segments — only 4 minutes ($120/30$) each in length. Hence, the access time for Harmonic broadcasting is generally shorter than pyramid broadcasting.
Pagoda Broadcasting

• Harmonic broadcasting uses a large number of low-bandwidth streams, while Pyramid broadcasting schemes use a small number of high-bandwidth streams.

• Harmonic broadcasting generally requires less bandwidths than Pyramid broadcasting. However, it is hard to manage a large number of independent data streams using Harmonic broadcasting.

• Paris, Carter, and Long presented Pagoda Broadcasting, a frequency broadcasting scheme, that tries to combine the advantages of Harmonic and Pyramid schemes.
Fig. 16.15: First three channel-segment maps of Pagoda Broadcasting.

- Partitions each video into $n$ fixed-size segments of duration $T = L/n$, where $T$ is defined as a time slot. Then, it broadcasts these segments at the consumption bandwidth $b$ but with different periods.
**Stream Merging**

- More adaptive to dynamic user interactions. It achieves this by dynamically combining multicast sessions.

- Makes the assumption that the client’s receiving bandwidth is higher than the video playback rate.

- The server will deliver a video stream as soon as it receives the request from a client.

- Meanwhile, the client is also given access to a second stream of the same video, which was initiated earlier by another client.
Fig. 16.16: Stream merging.
• As shown in Fig. 16.16, the “first stream” B starts at time $t = 2$. The solid line indicates the playback rate, and the dashed line indicates the receiving bandwidth which is twice of the playback rate. The client is allowed to prefetch from an earlier (“second”) stream A which was launched at $t = 0$. At $t = 4$, the stream B joins A.

• A variation of Stream merging is *Piggybacking*, in which the playback rate of the streams are slightly and dynamically adjusted so as to enable merging (piggybacking) of the streams.