EECE5698
Networked XR Systems

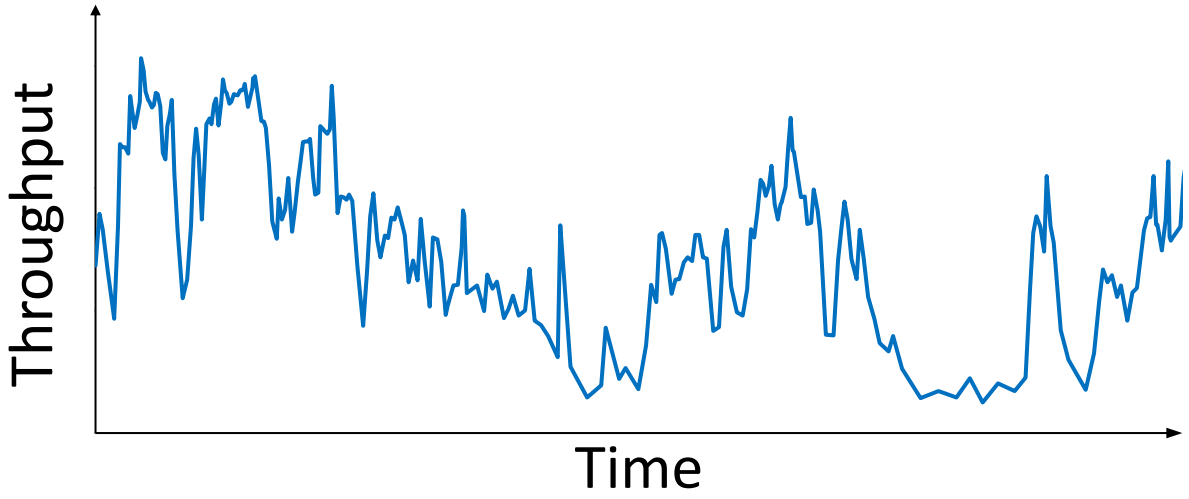
Lecture Outline for Today

- Progressive Streaming of XR Content
- Network Problem
- Compression Support
- Streaming Protocols
- Homework3 Discussion

Networking Problem

Fundamental Problems

- ❑ Limited Bandwidth
- ❑ Variability in Bandwidth



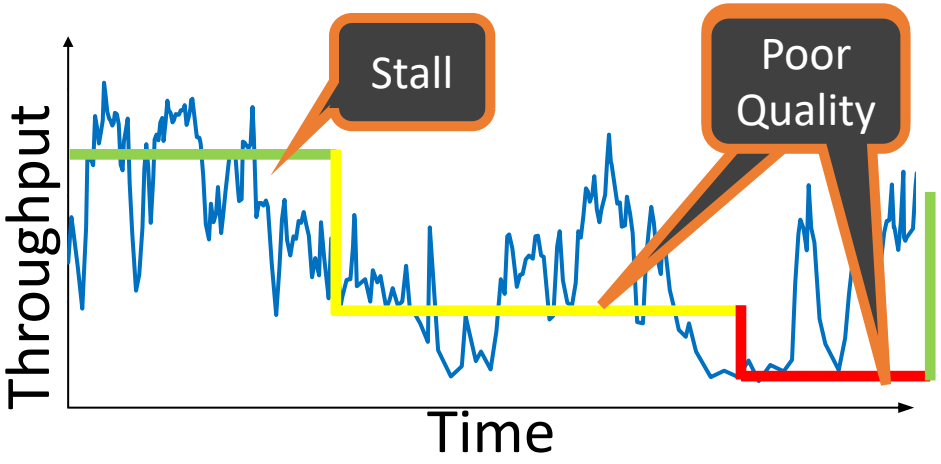
Adaptive Video Streaming

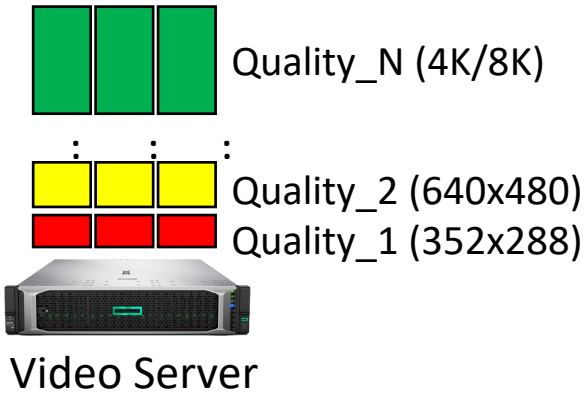
Solution

Throughput trace from Pensieve [SIGCOMM'17]

Adaptive Streaming: Recap

Video Client

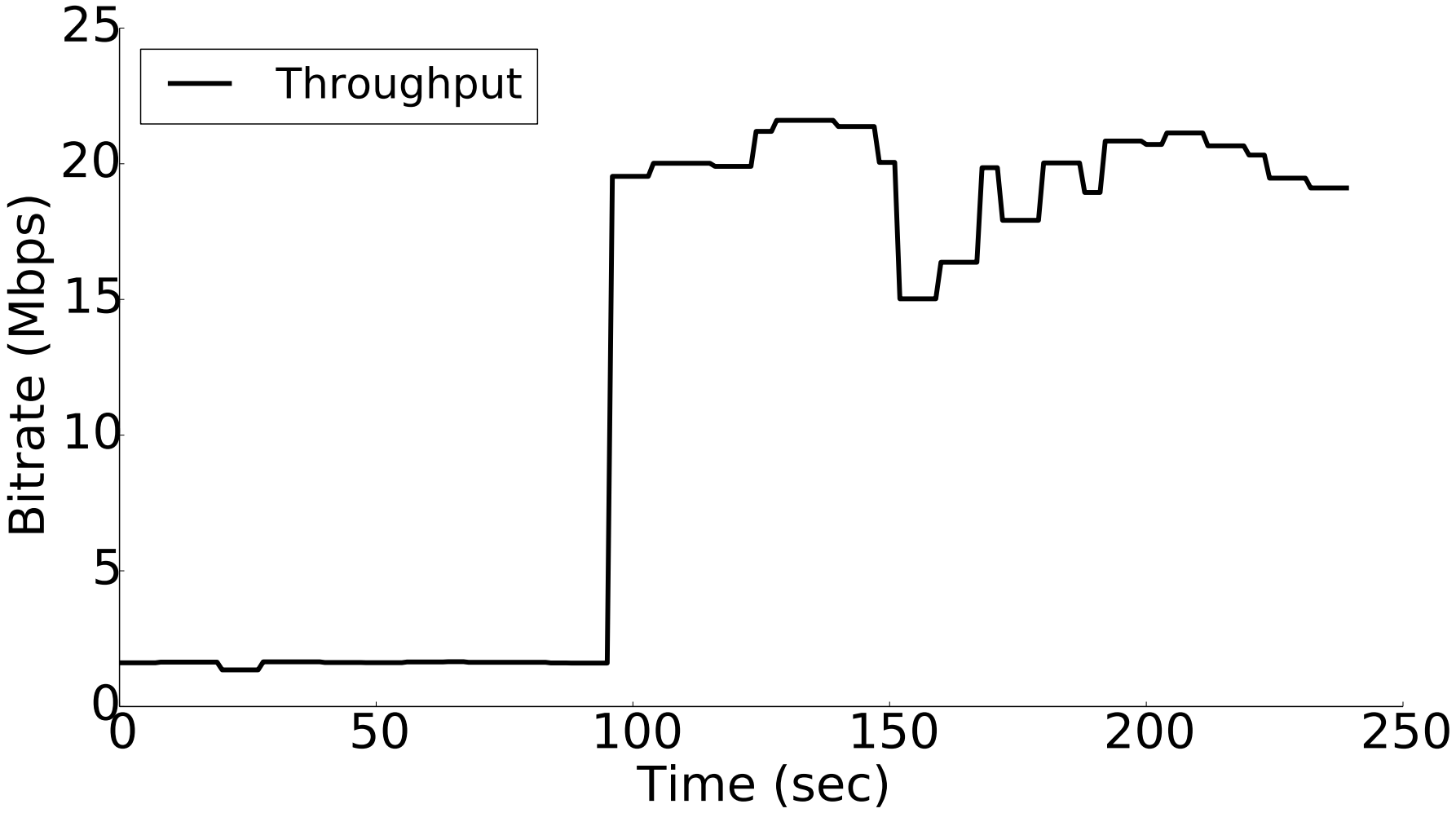




Video Server

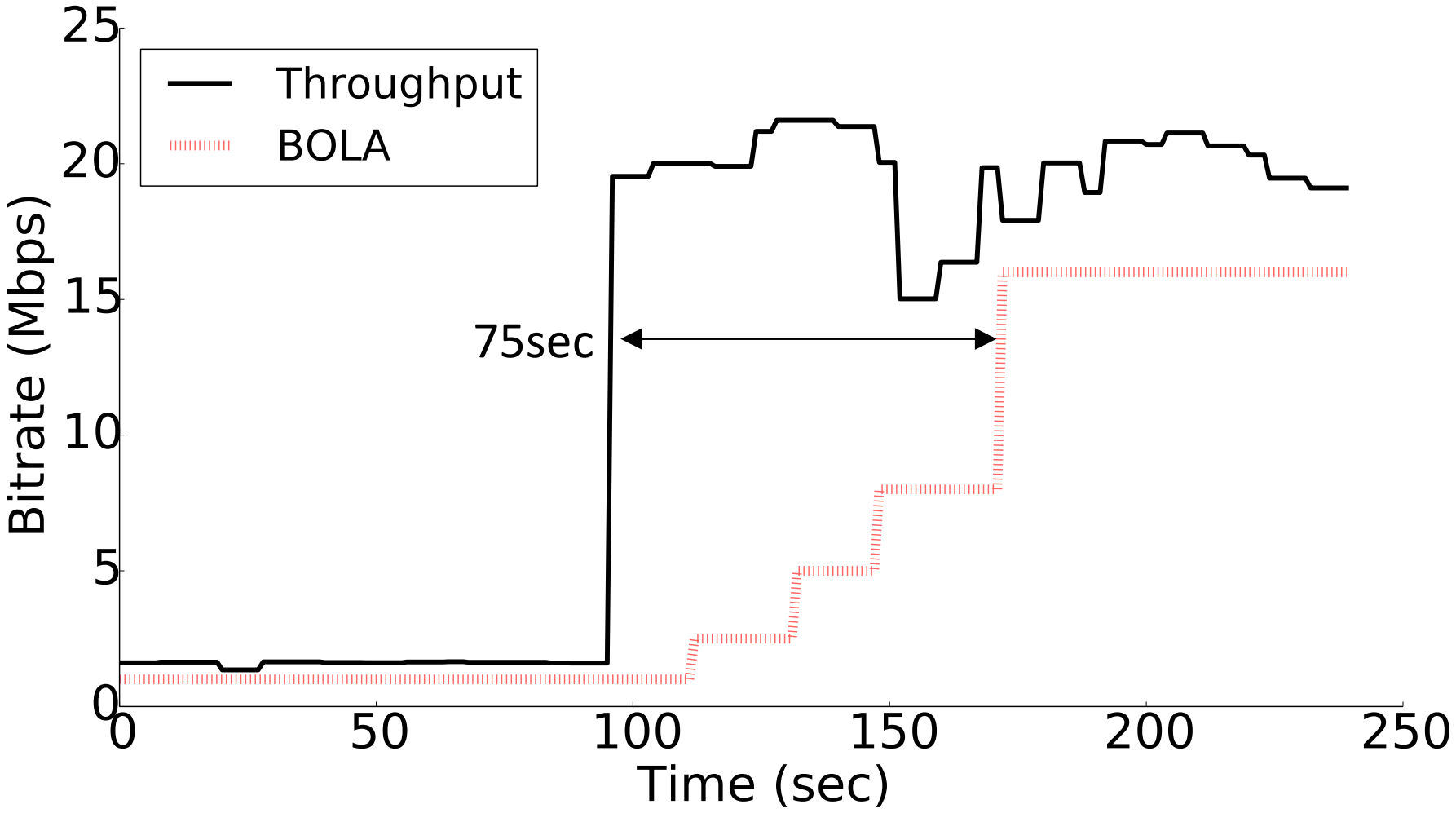
Adaptive Bitrate (ABR) Algorithms

Adaptive Streaming Problems

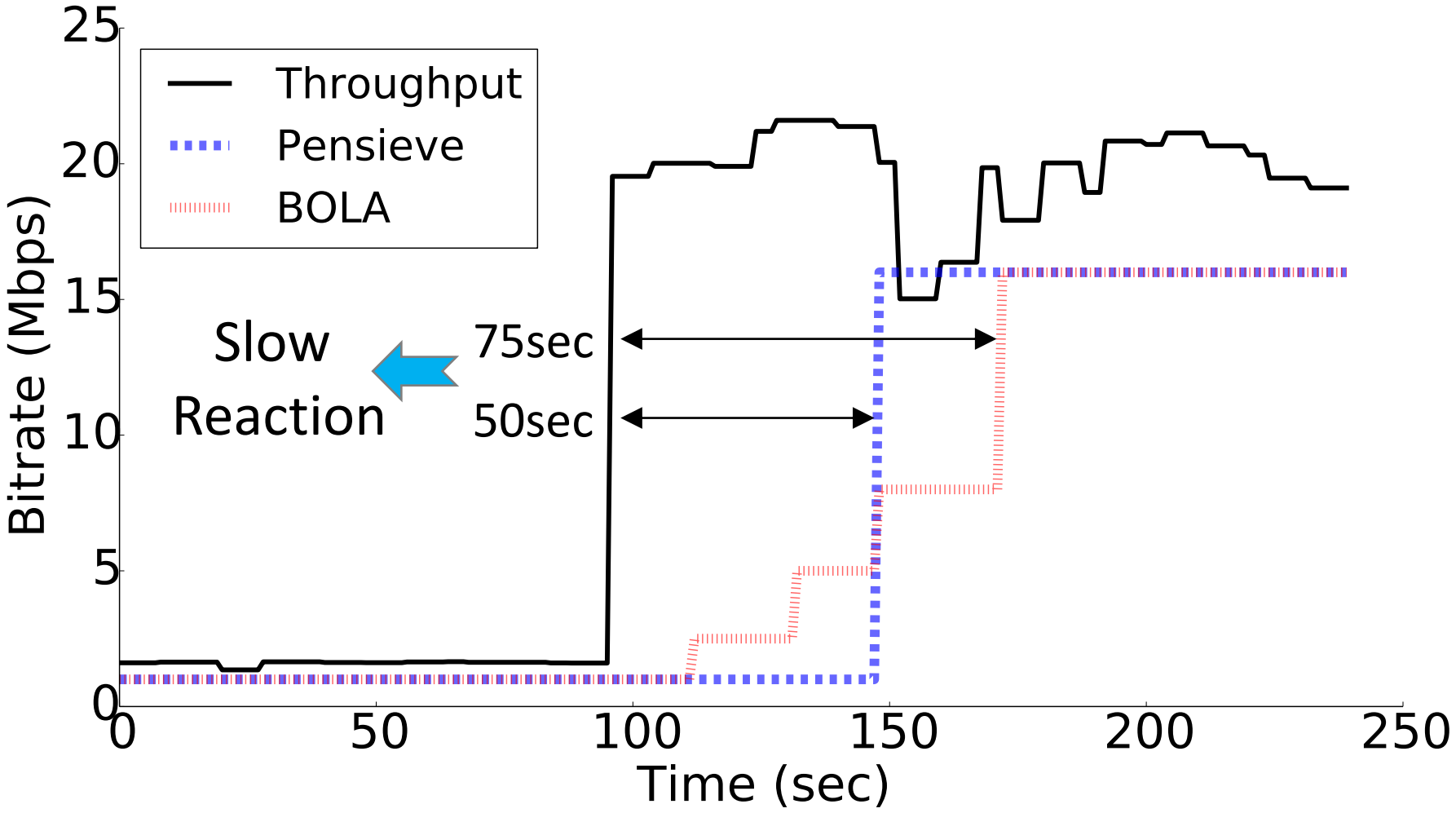


Throughput trace is from ACM/IEEE TON'2020

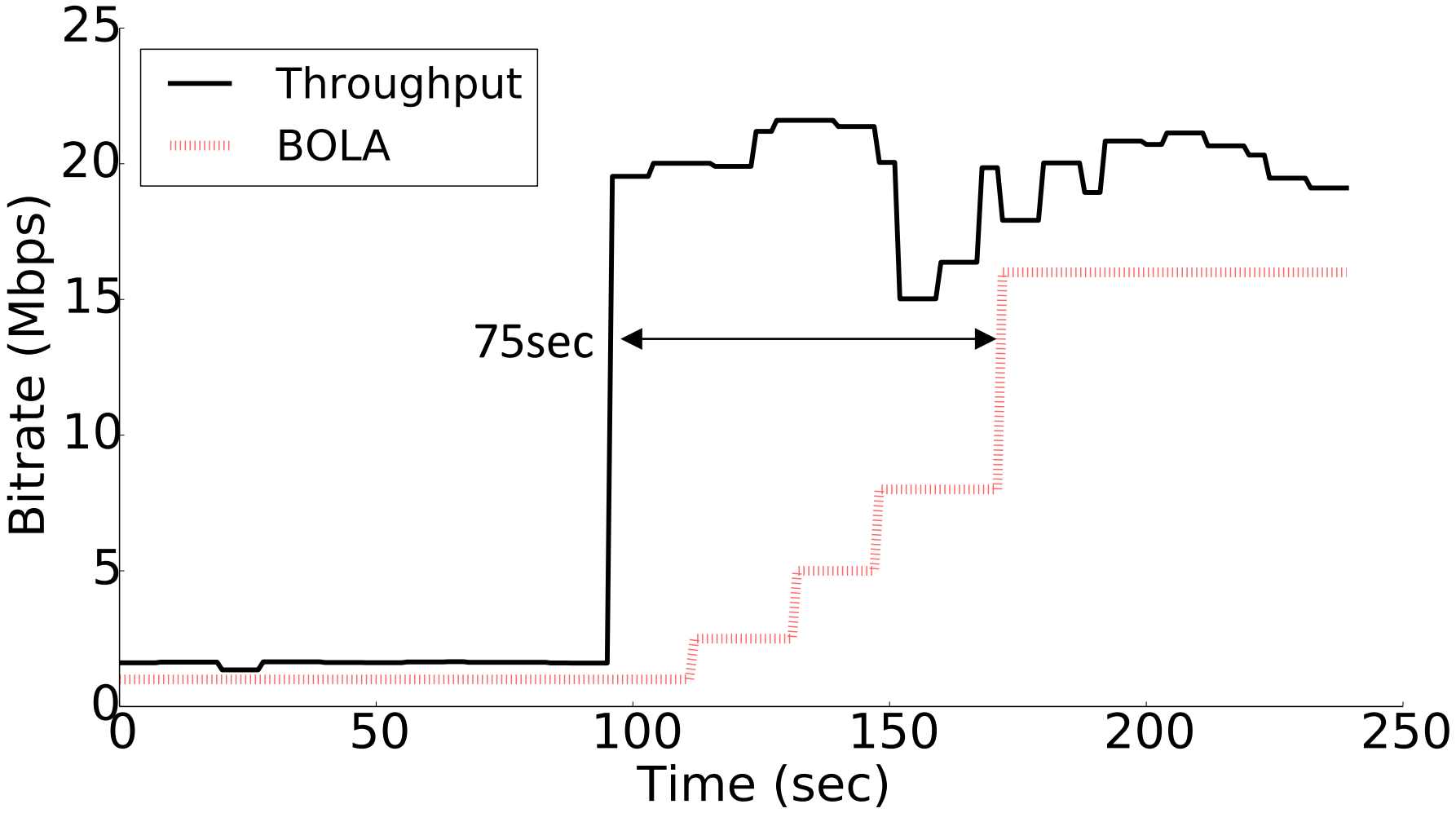
Adaptive Streaming Problems



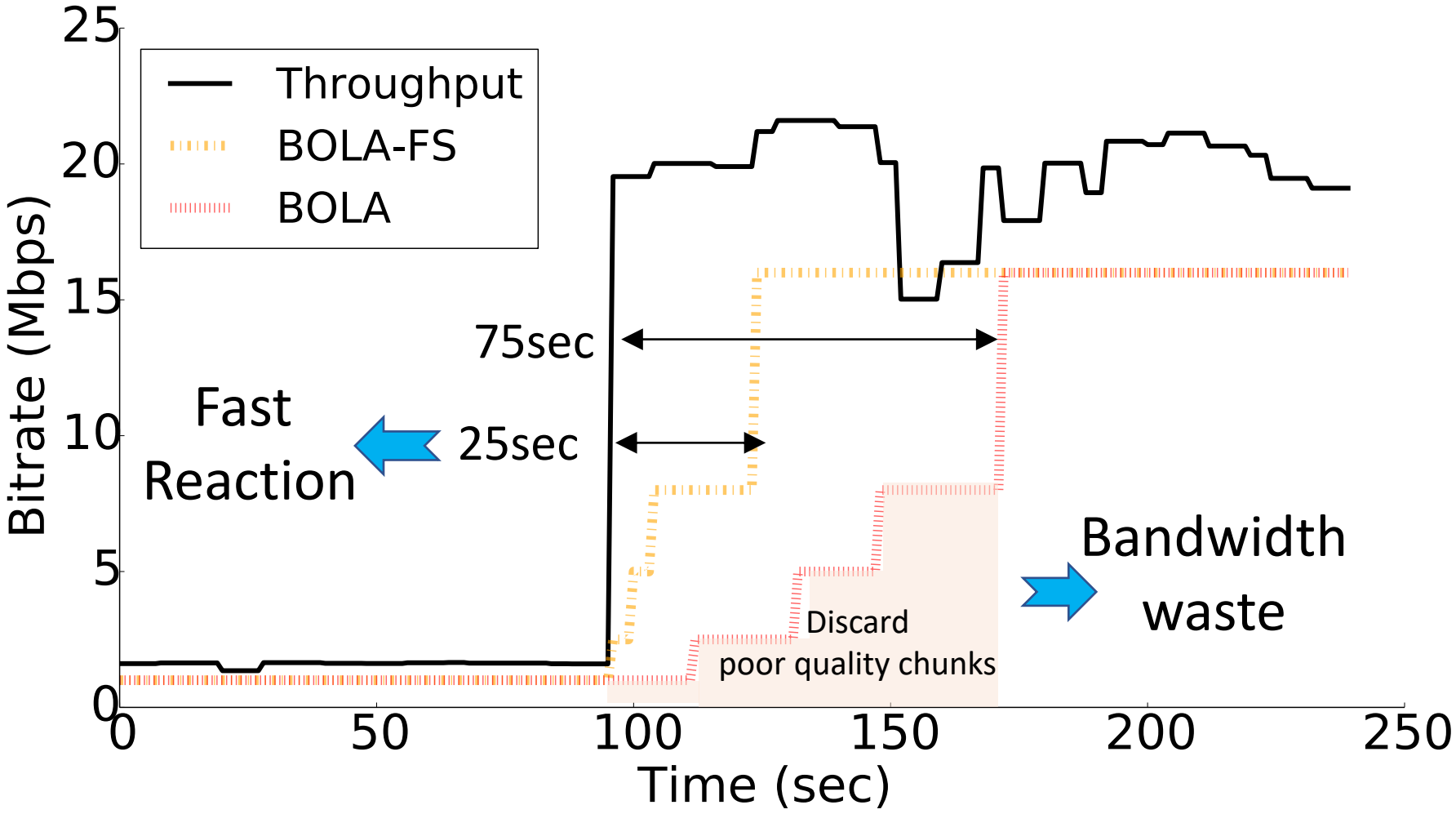
Adaptive Streaming Problems



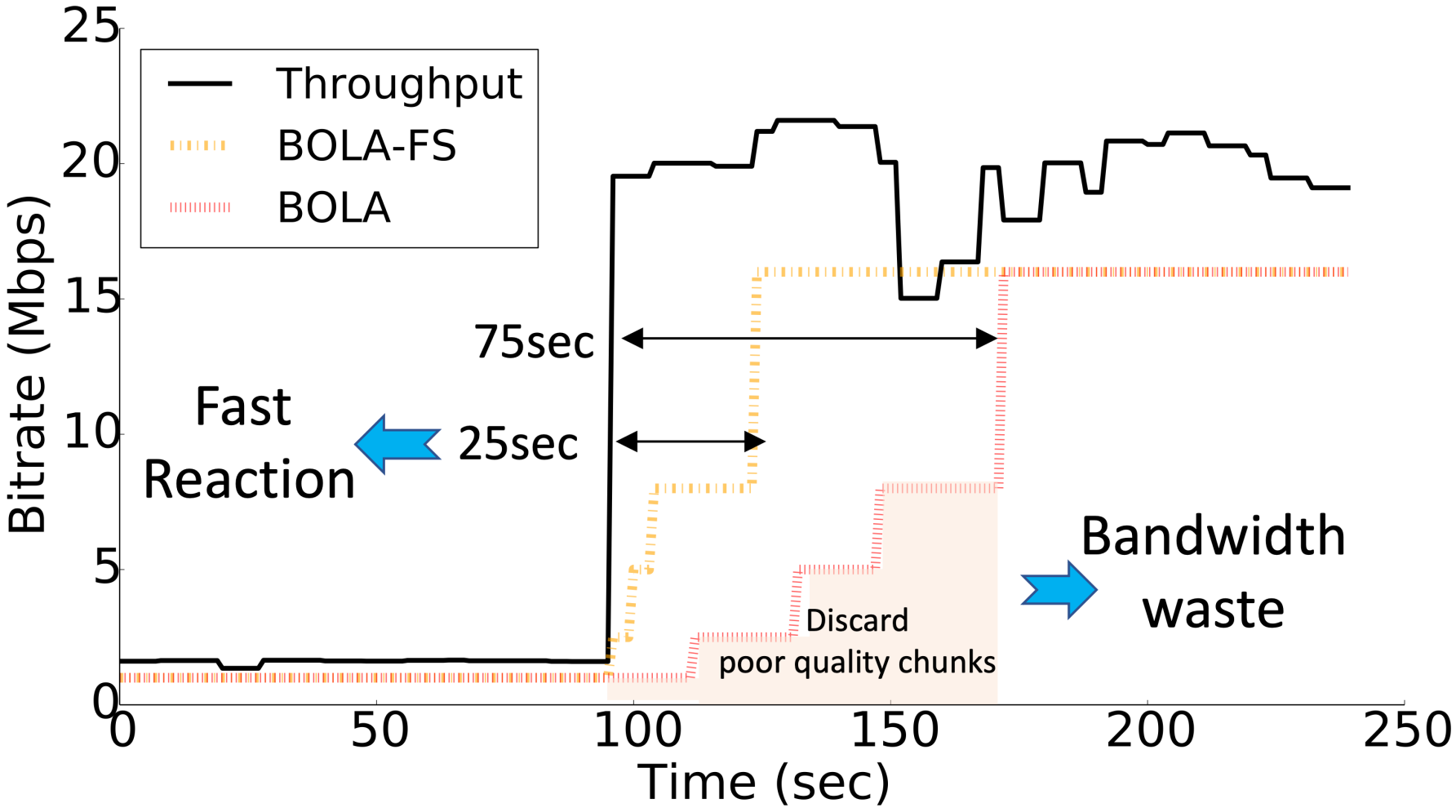
Adaptive Streaming Problems



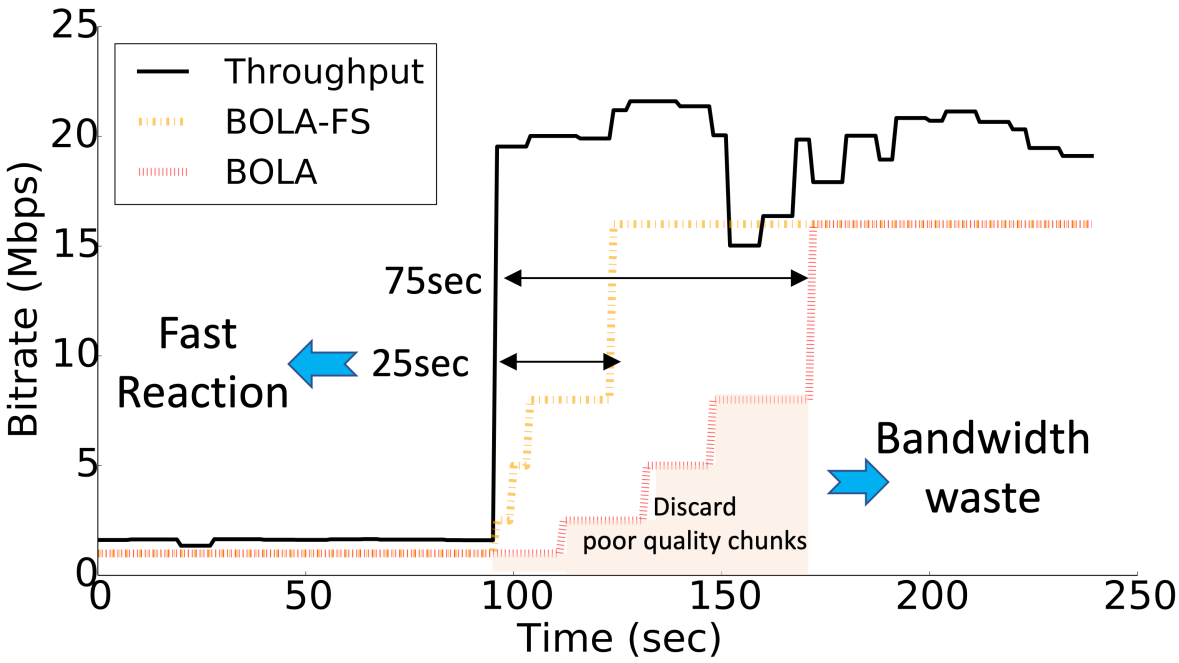
Adaptive Streaming Problems



Adaptive Streaming Problems



Adaptive Streaming Problems



- ❑ Bandwidth Efficient
- ❑ Slow Reaction -> Poor QoE
  - ❑ BOLA, Pensieve

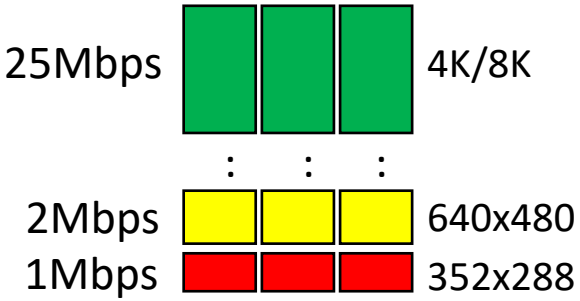
- ❑ Bandwidth Inefficient
- ❑ Fast Reaction -> Better QoE
  - ❑ BOLA-FS

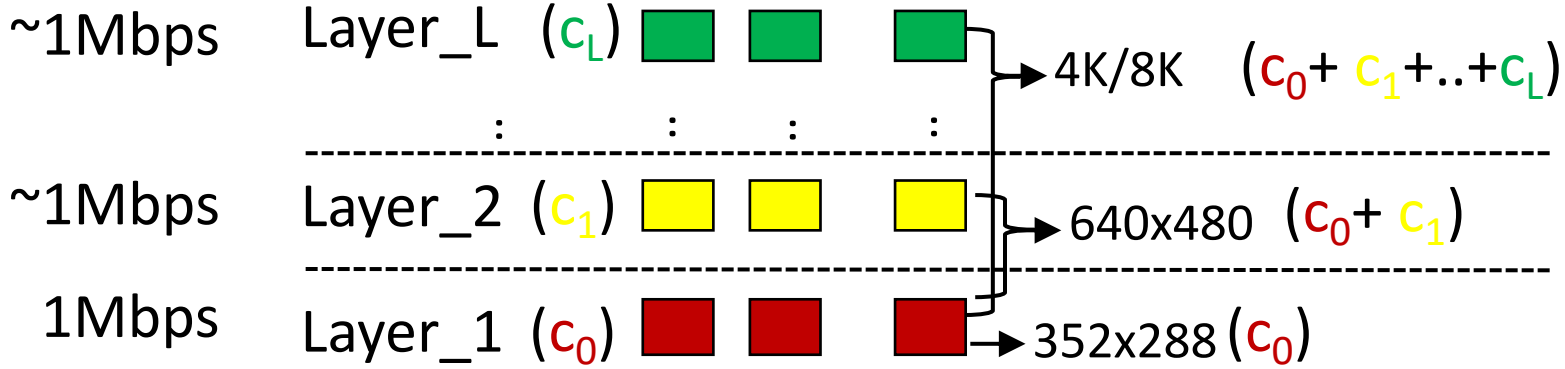
Adaptive Streaming Problems

- Key Issue: Lack of proper compression support
  - Once you make a download decision – difficult to make adjustments to it, that is needed in case of variable networking conditions
- Solution: Layered coding or compression

Layered Compression

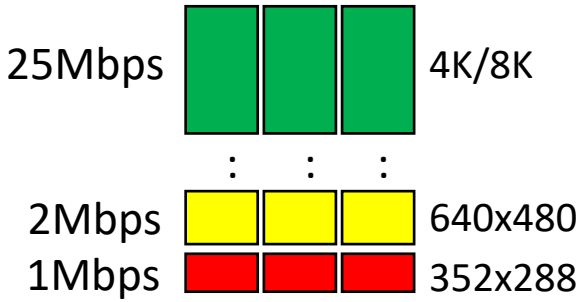
- **A well-suited technique for streaming variable network conditions**

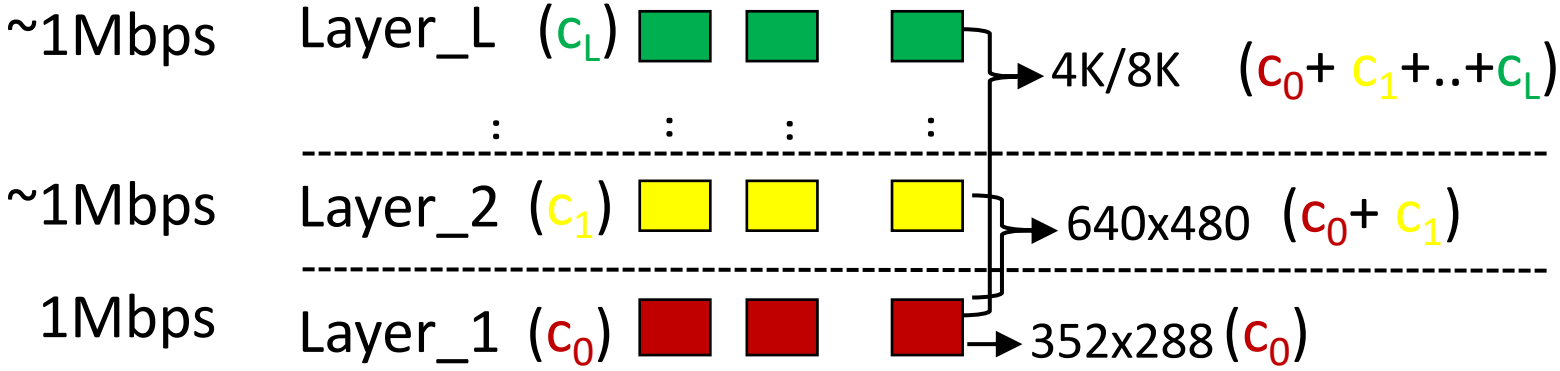




Layered Compression

- **A well-suited technique for streaming variable network conditions**





Original (MS-SSIM=1) | Code (c_0) (MS-SSIM=0.94) | Code($c_0 \oplus c_1$) (MS-SSIM=0.97) | Code($c_0 \oplus c_1 \oplus c_2$) (MS-SSIM=0.99)

Layered Compression

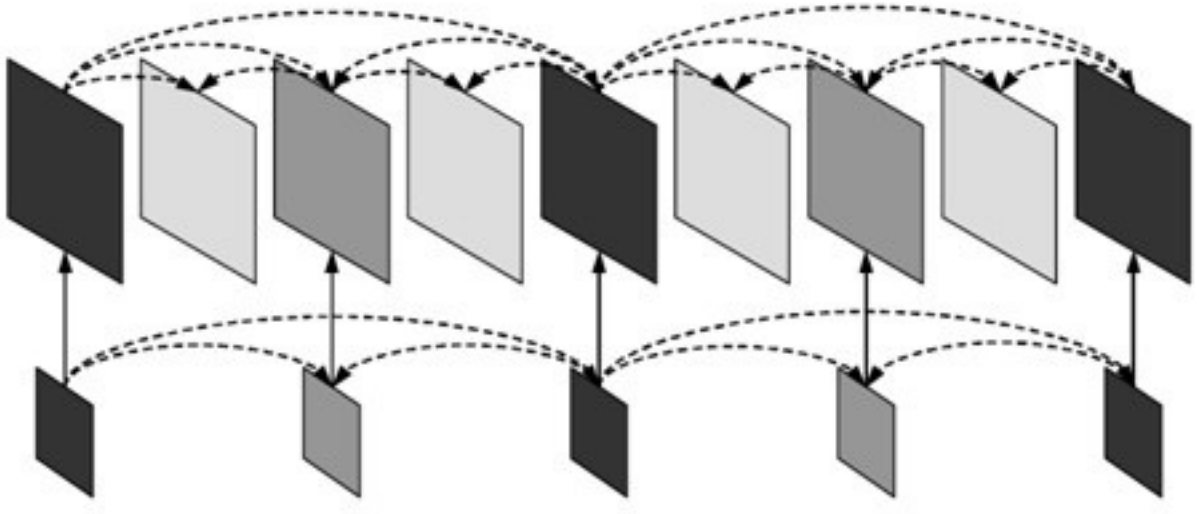
- In H.26x world also called scalable video coding (SVC)
- Three forms of SVC
  - Quality Scalability
  - Spatial Scalability
  - Temporal Scalability

Layered Compression – Quality Scalability

- Special case of spatial scalability but equal resolutions are used.
- Scalability is achieved using different quantization parameters in each layer.
  - E.g., decreasing quantization along the layers

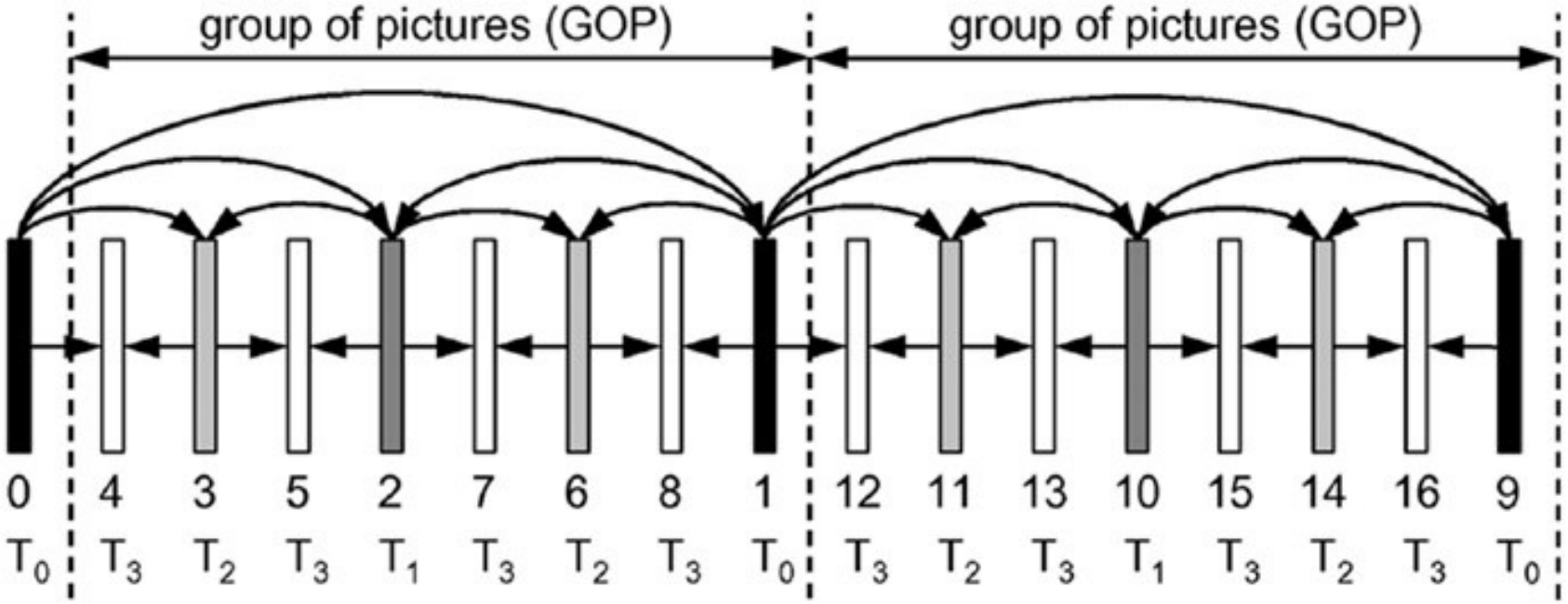
Layered Compression – Spatial Scalability

- Motion-compensated prediction and intra prediction in each spatial layer - Resolution
- Inter layer prediction



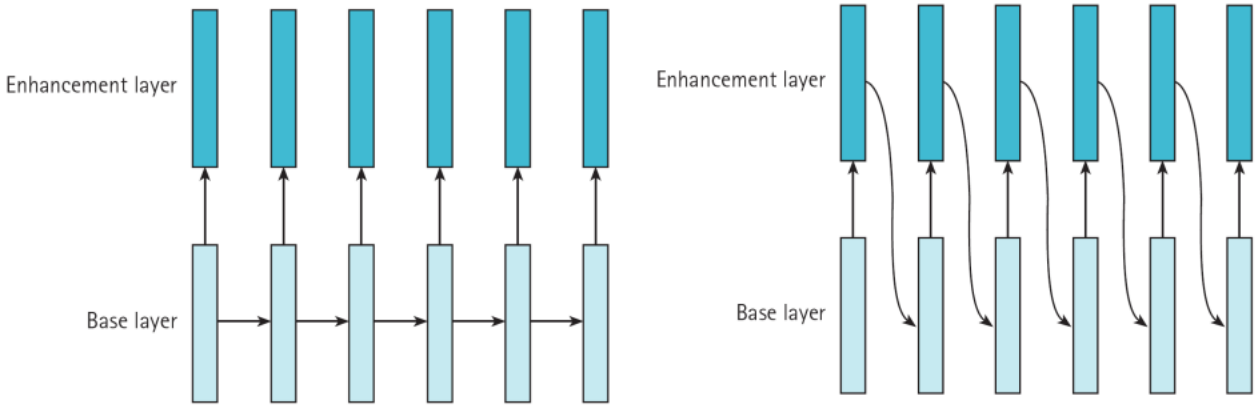
Layered Compression – Temporal Scalability

- As the name suggests, different layers have different frames temporally



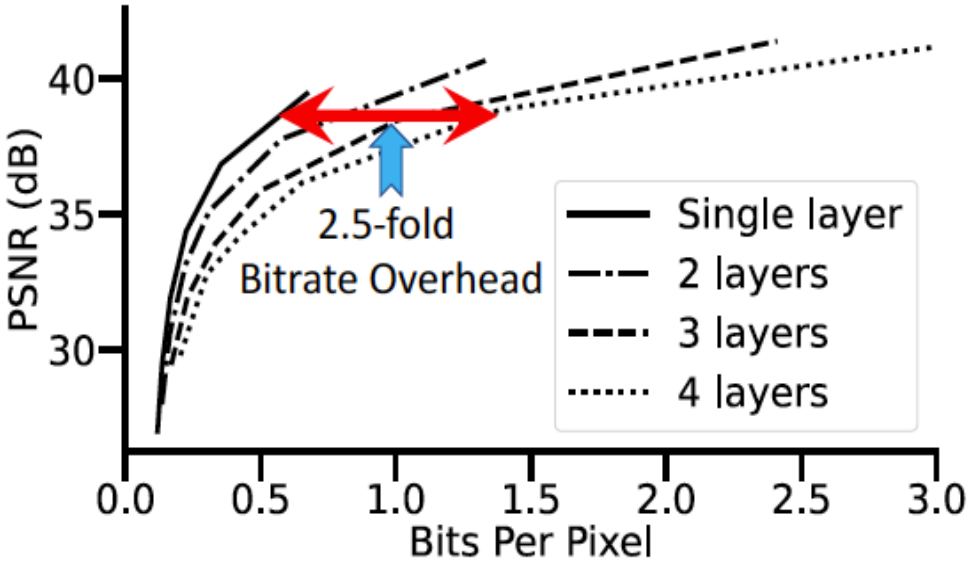
Layered Compression - SVC

- Computationally very expensive – Inter layer motion compensation



Layered Compression - SVC

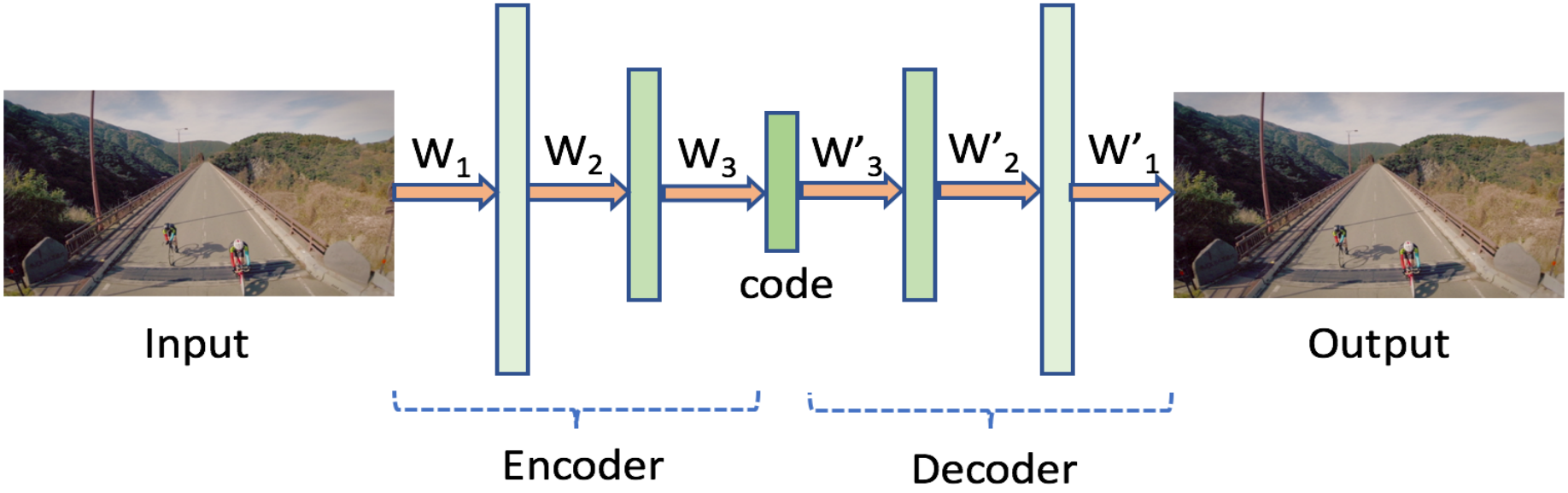
- Bandwidth overhead



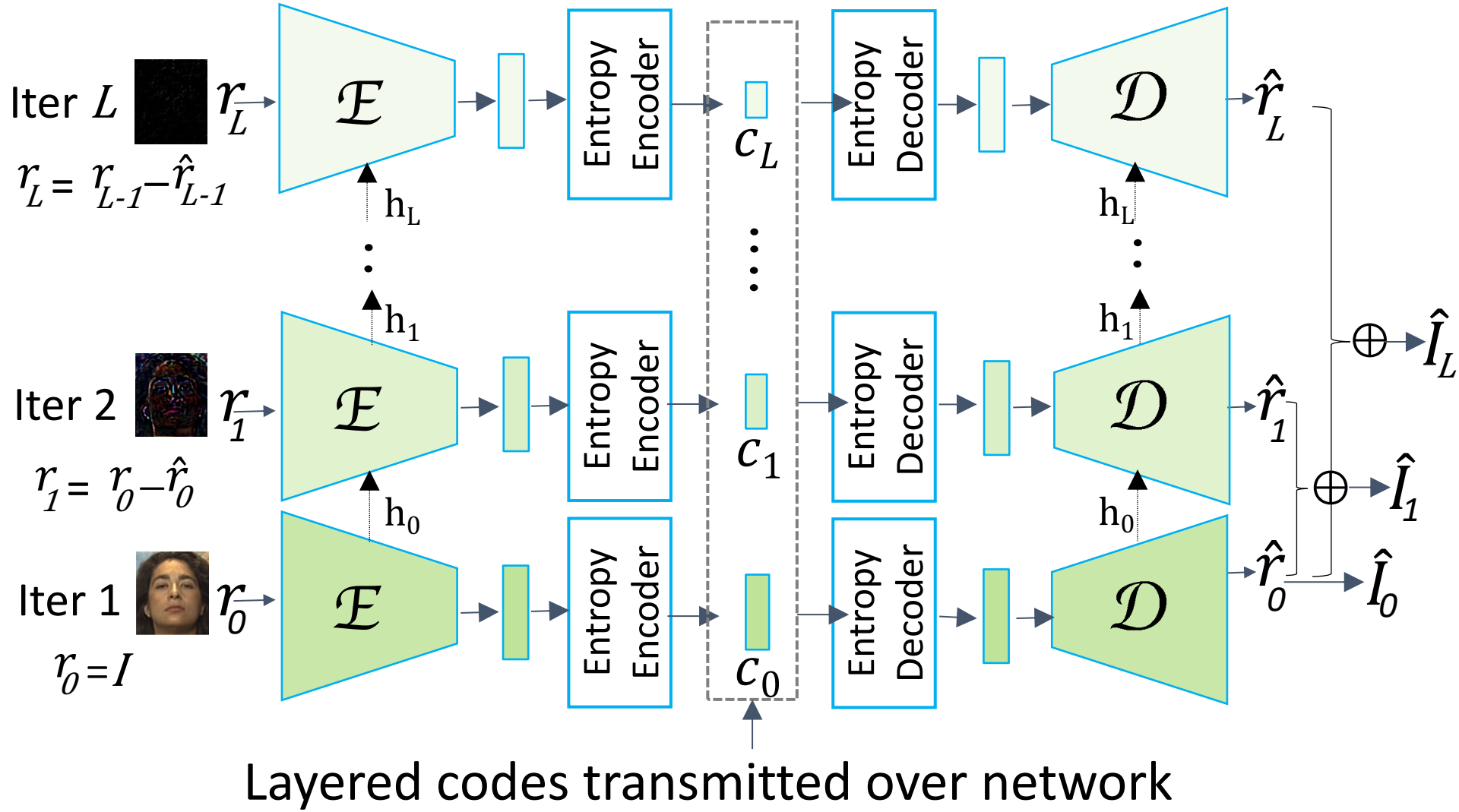
Increases proportionately as we increase the number of layers

ML based Layered Compression

- Recall Autoencoder based video compression



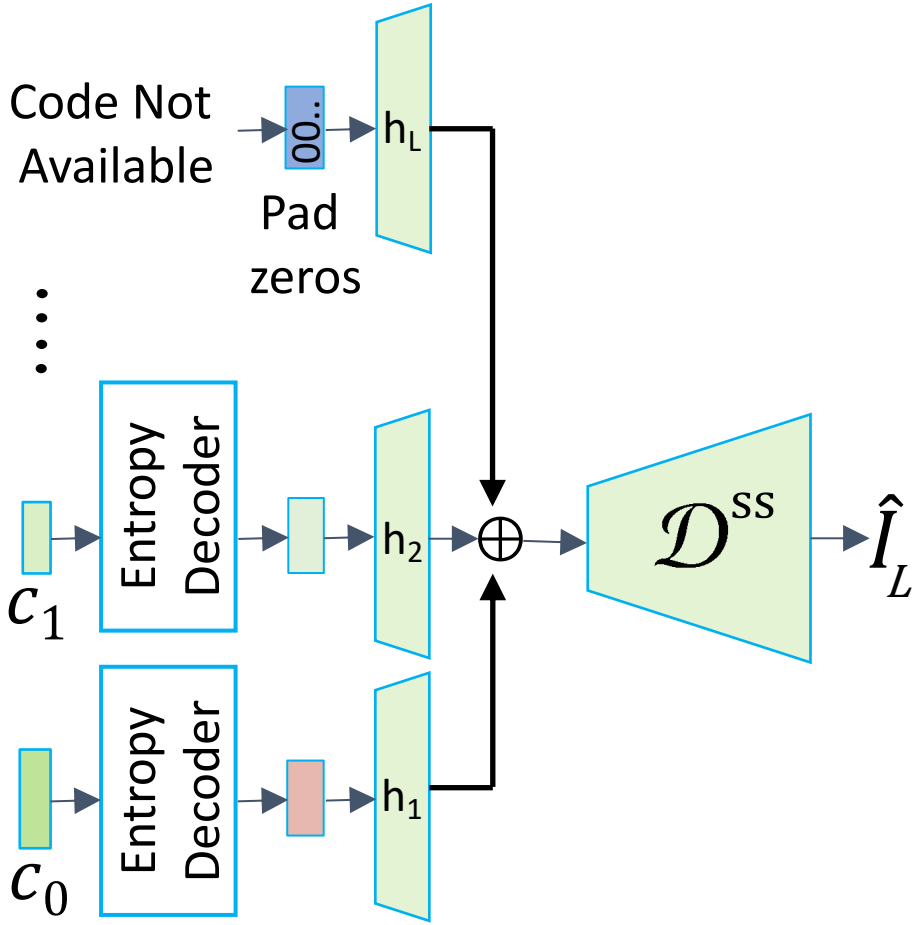
ML based Layered Compression



ML based Layered Compression

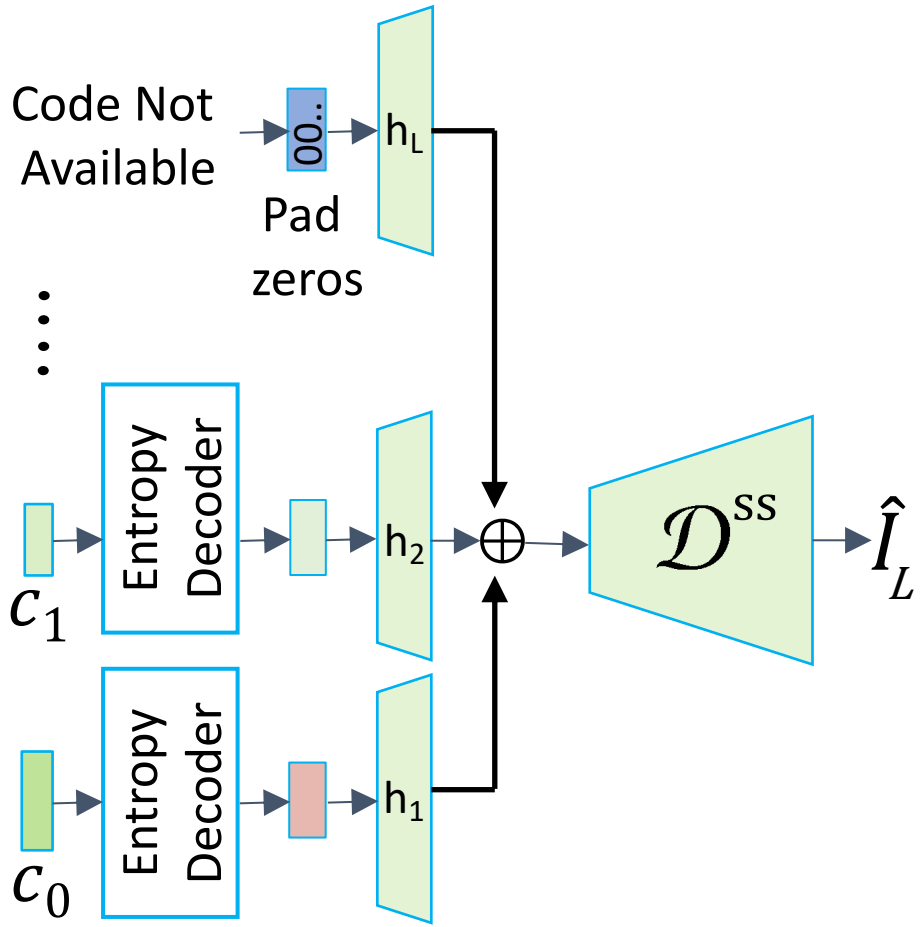
1. Iterative Decoding is Slow
   - ❑Need real-time decoding for playback

Single-shot Decoder



ML based Layered Compression

2. Compute Resource Contention
   - ❑Need to scale well with other applications



ML based Layered Compression

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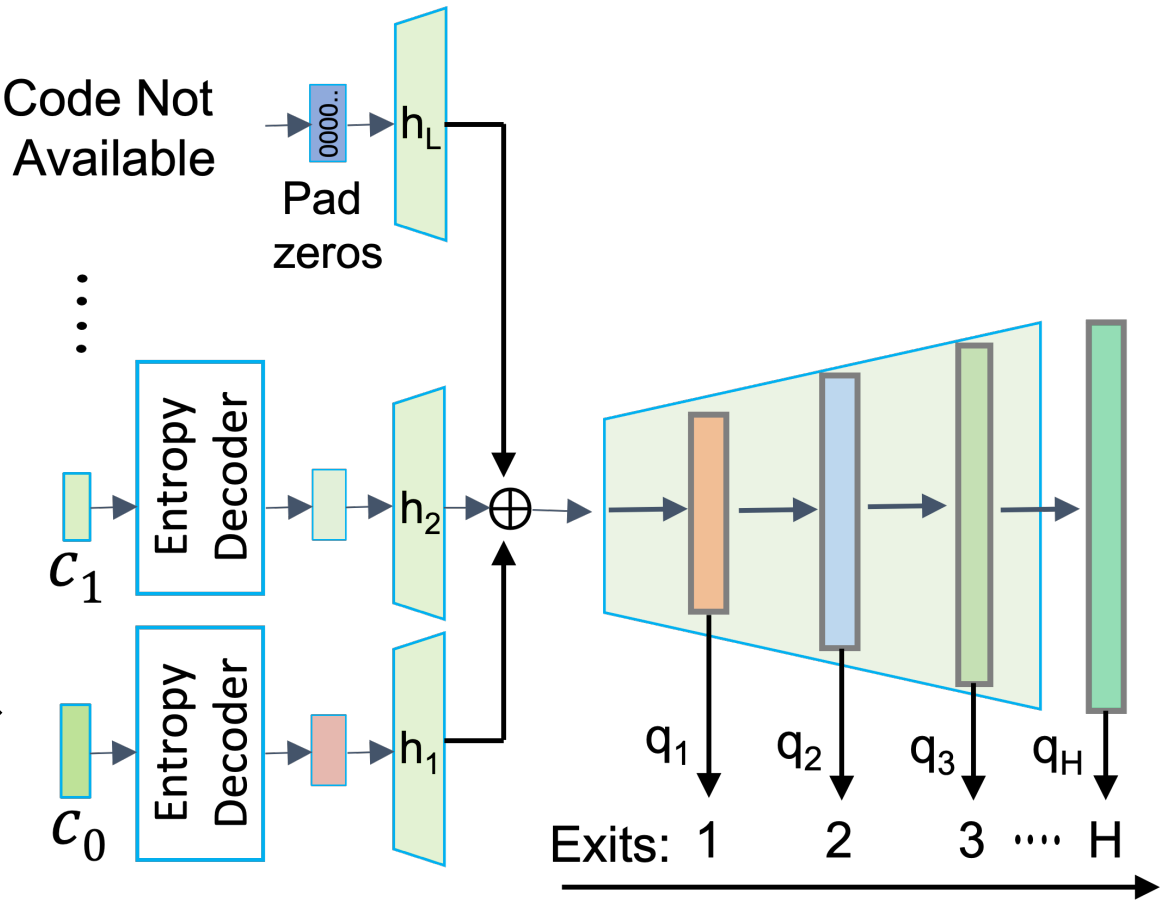
Multiple Exits



ML based Layered Compression

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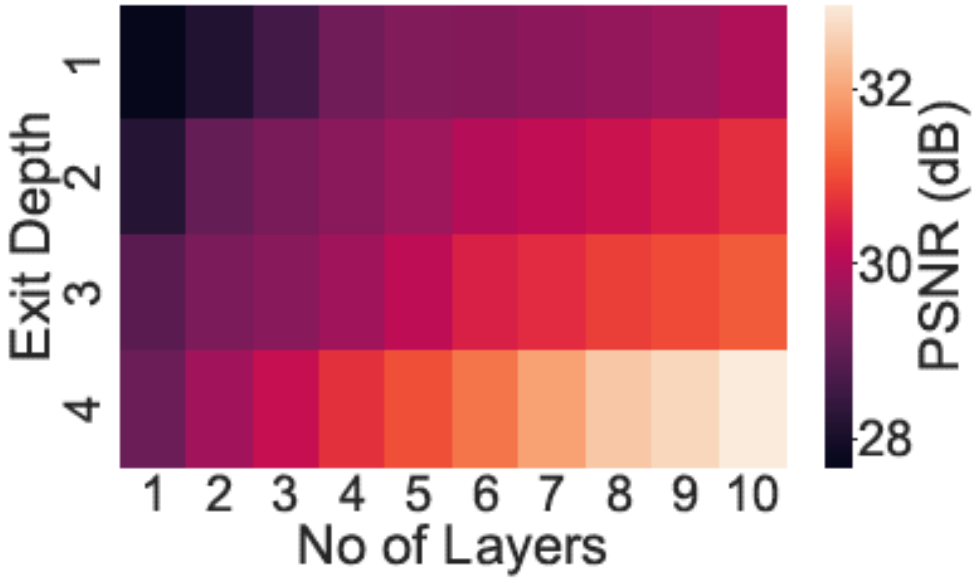

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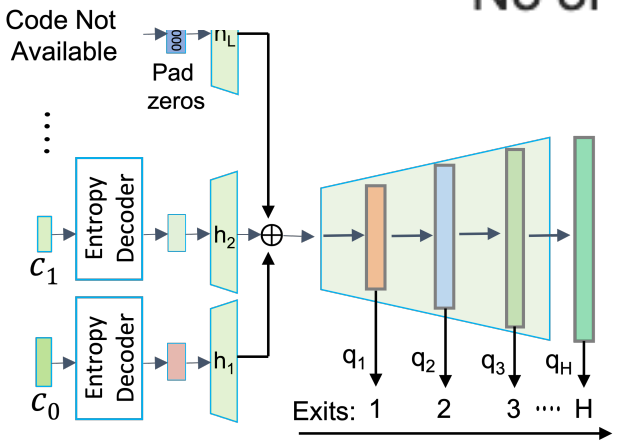
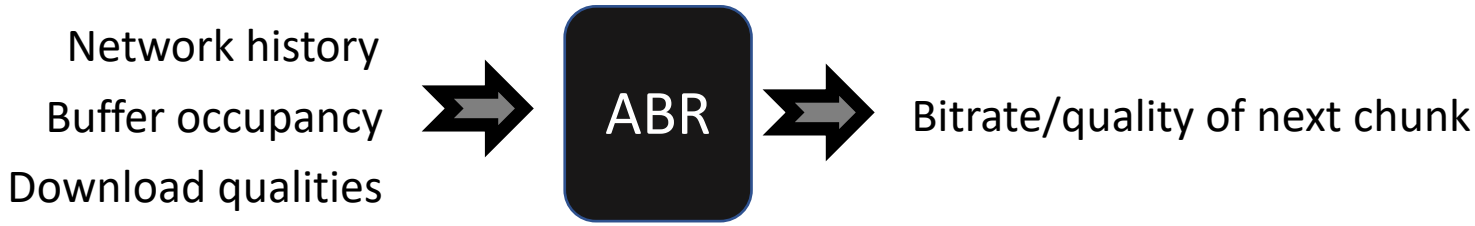
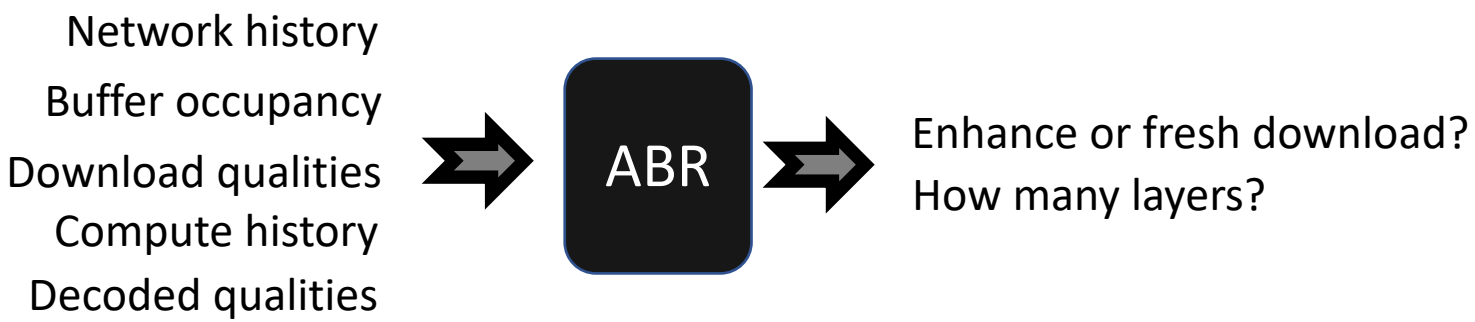


Layered Streaming Protocol

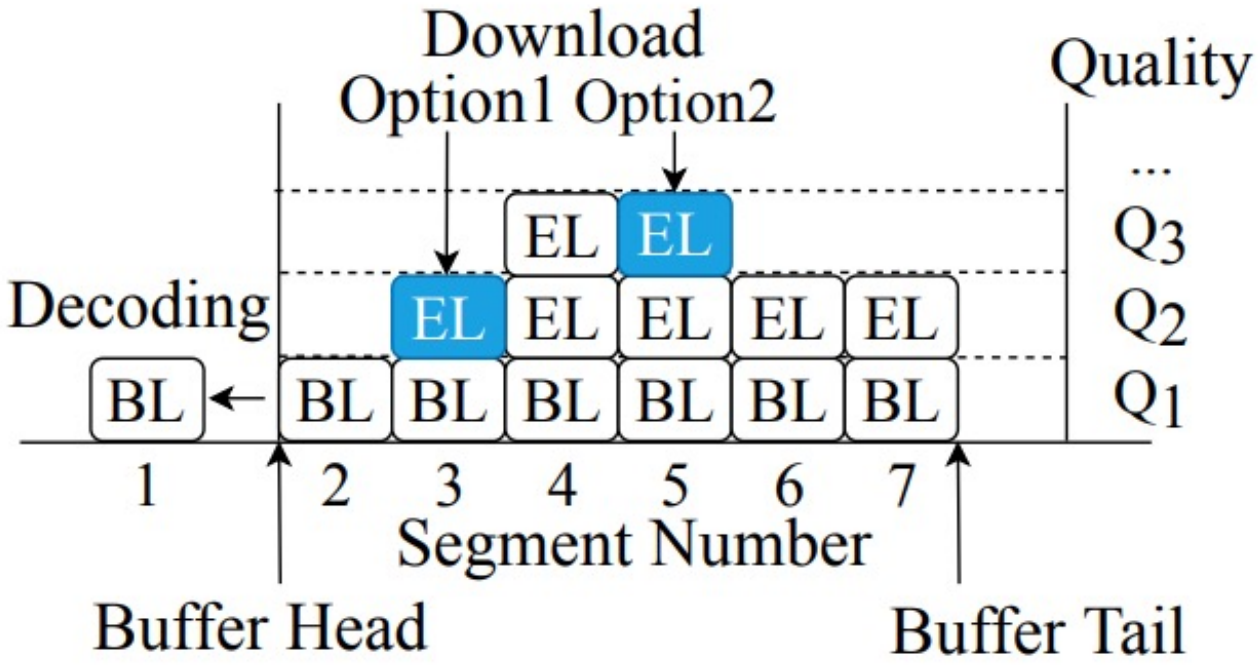
- Traditional ABR Algorithms



- Layered



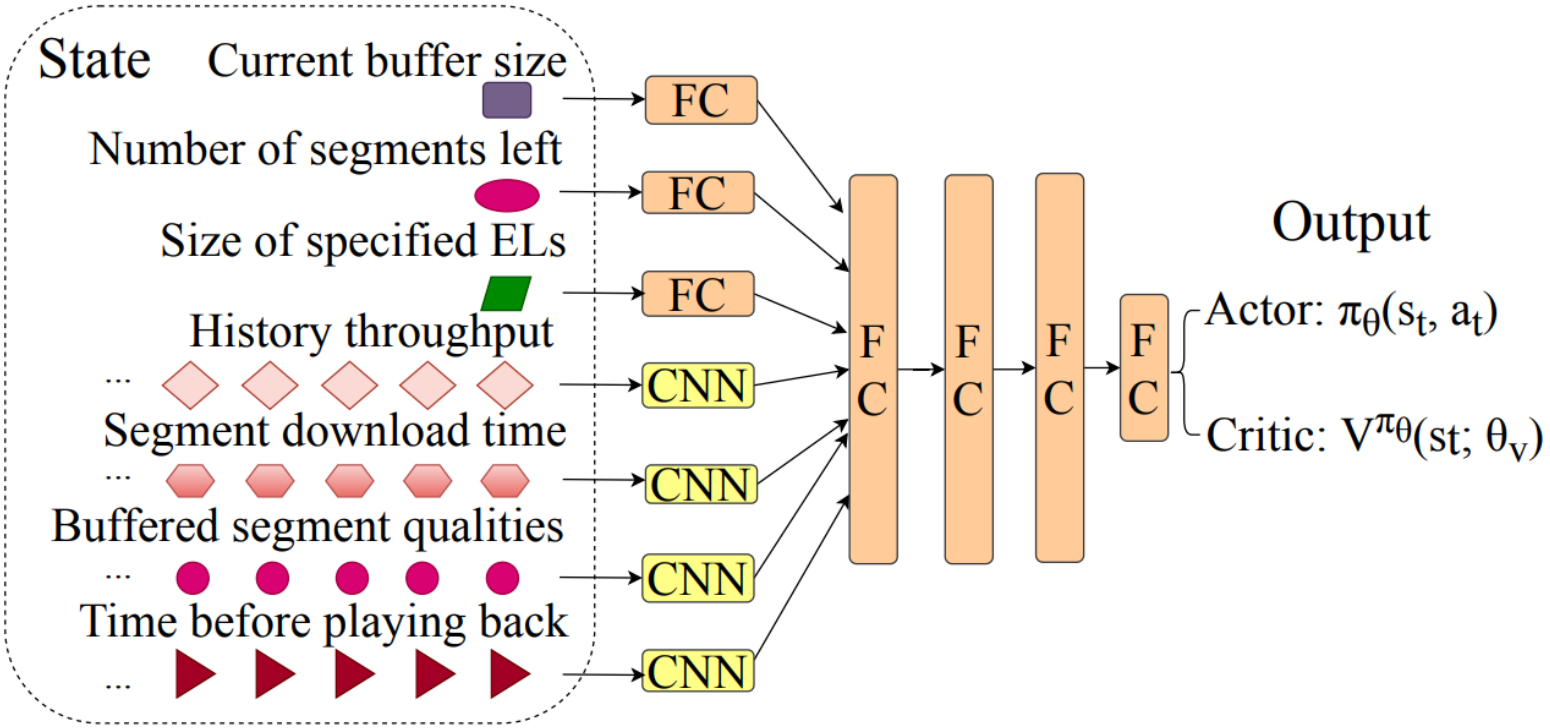
Layered Streaming Protocol



Enhance closer to buffer tail or head?

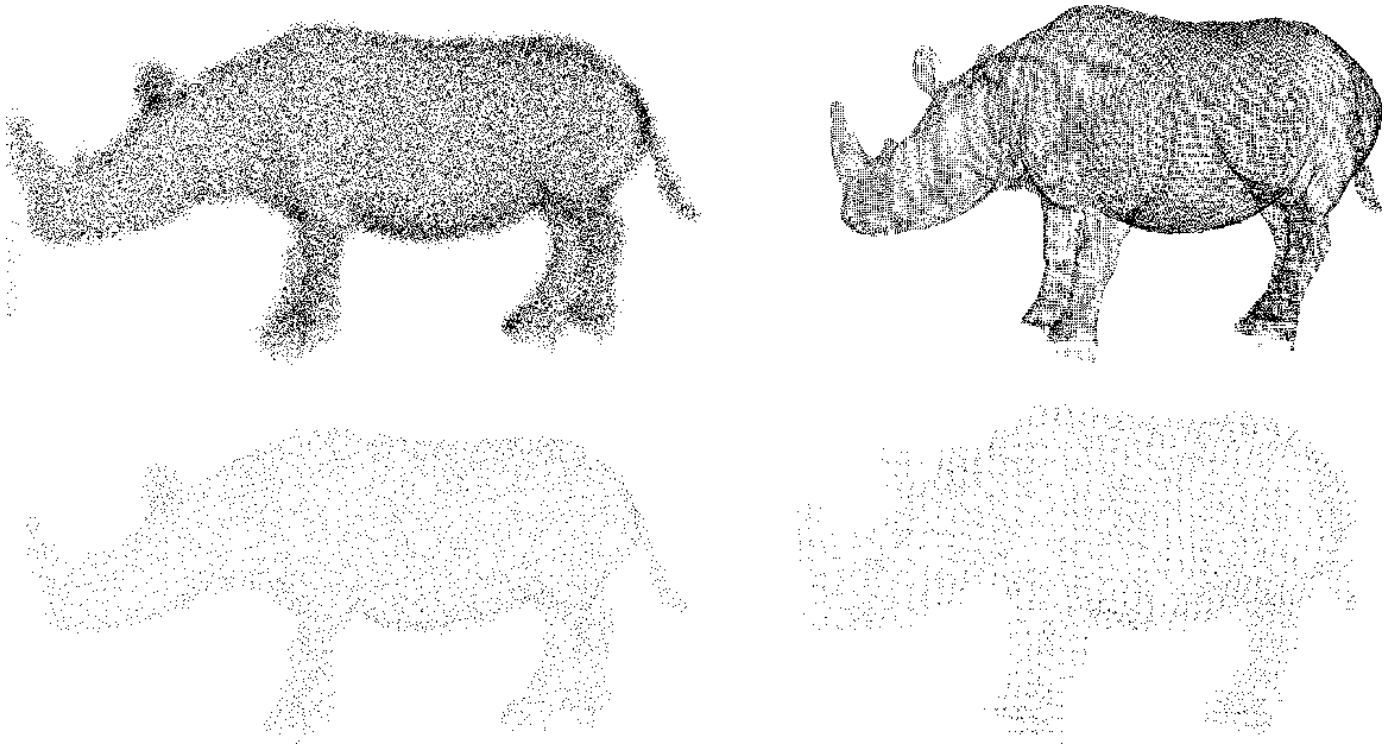
Layered Streaming Protocol

Learning based download decision



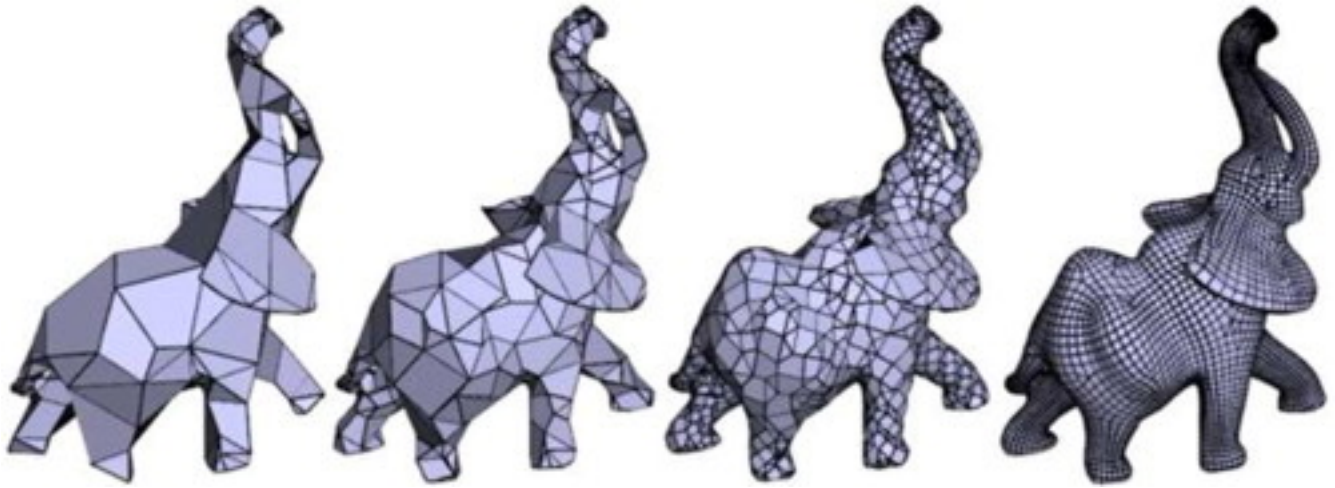
Layered Point Clouds

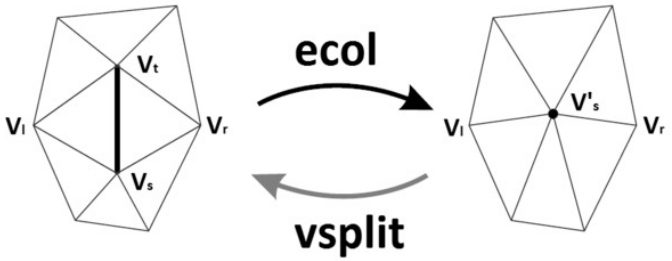
Progressively add or remove points



Layered Meshes

- Progressive meshes





Summary of the Lecture

- Variable network problem for streaming
- Problems with traditional streaming
- Layered compression
- Streaming protocols

Next up: XR Experience Session