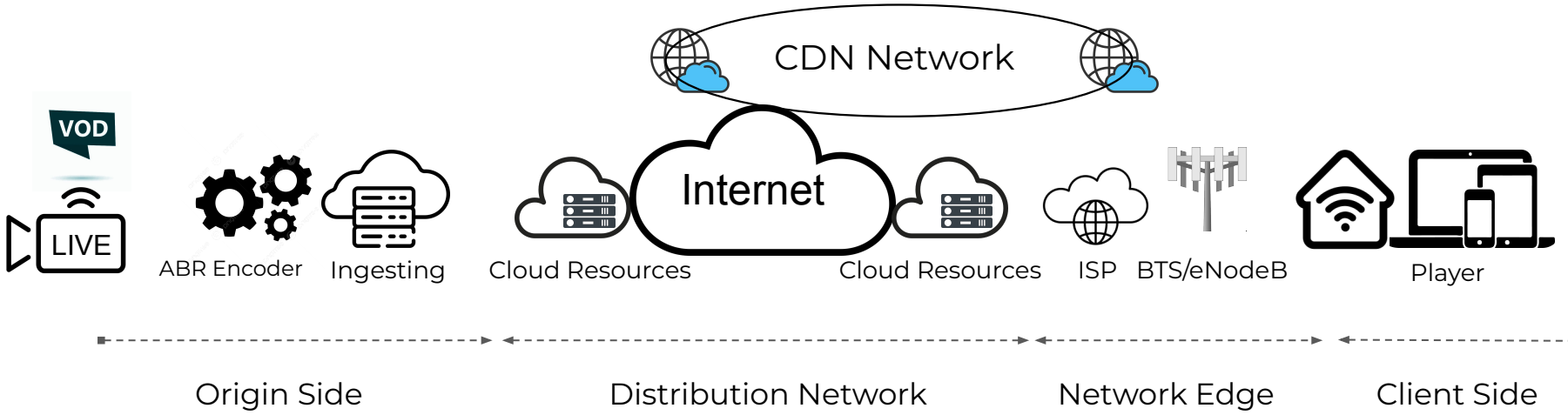


Network-Assisted Adaptive Streaming: Toward Optimal QoE through System Collaboration

Seven Years of Adaptive Streaming Research

Priv.-Doz. Dr. Farzad Tashtarian
Klagenfurt, Austria
October 07, 2026

Main Components in HTTP Video Streaming Pipeline



Network-Assisted Adaptive Streaming

Network-Assisted Adaptive Streaming

- **Objectives and Problems**
  - What are the key objectives and major challenges in video streaming?

- **Architectures and Emerging Paradigms**
  - Which architectures and emerging paradigms can help optimize video streaming performance?

- **Solution Strategies and Techniques**
  - What solution strategies and techniques can be applied to address these challenges?

Network-Assisted Adaptive Streaming

- **Objectives and Problems**
  - Key objectives in video streaming optimization
  - Related challenges and problems
  - Fundamental concept
- **Architectures and Emerging Paradigms**
- **Solution Strategies and Techniques**

Key Objectives in HTTP Video Streaming Optimization

Engagement

How much users interact with and enjoy the video—e.g., watching time, likes, or returning to the platform.



Latency

Server-to-viewer latency — shorter latency means more immediate playback and better real-time interaction.



Cost

The amount of computing, bandwidth, and storage resources required to deliver the video efficiently.



QoE

How good the streaming feels to the viewer — combining factors like video quality, buffering, and smooth playback.



Key Objectives in HTTP Video Streaming Optimization

Engagement

How much users interact with and enjoy the video—
e.g., watching time, likes, or returning to the platform.





Multi-Objective Optimization Problem

Cost

The amount of computing, bandwidth, and storage resources required to deliver the video efficiently.



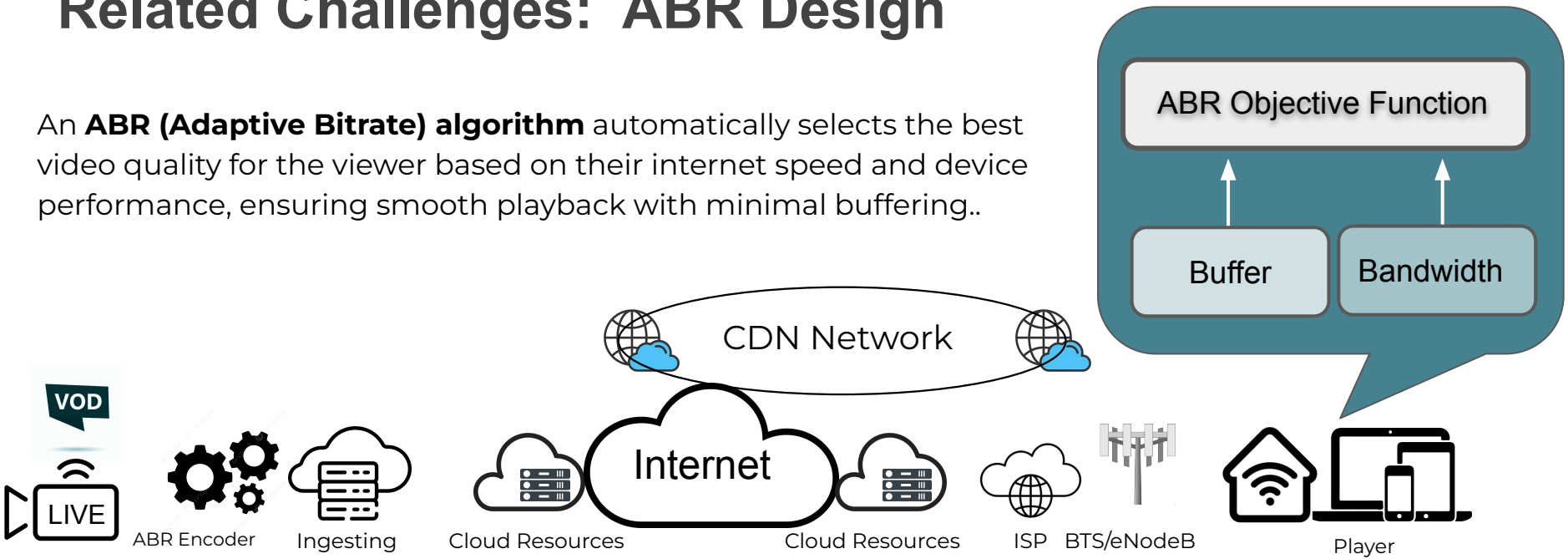
QoE

How good the streaming feels to the viewer — combining factors like video quality, buffering, and smooth playback.



Related Challenges: ABR Design

An **ABR (Adaptive Bitrate) algorithm** automatically selects the best video quality for the viewer based on their internet speed and device performance, ensuring smooth playback with minimal buffering..



QoE, Latency Engagement, Cost (energy)

Related Challenges: ABR Design

COCONUT [MMsys'24]

CaBR [WueWOWas'25]

Quality- and Energy-Aware Adaptive Neural-Enhanced Streaming (submitted) D. Lorenzi, F. Tashtarian, et. al

Receptive [TOMM'26]

MEDUSA [TOMM'24]

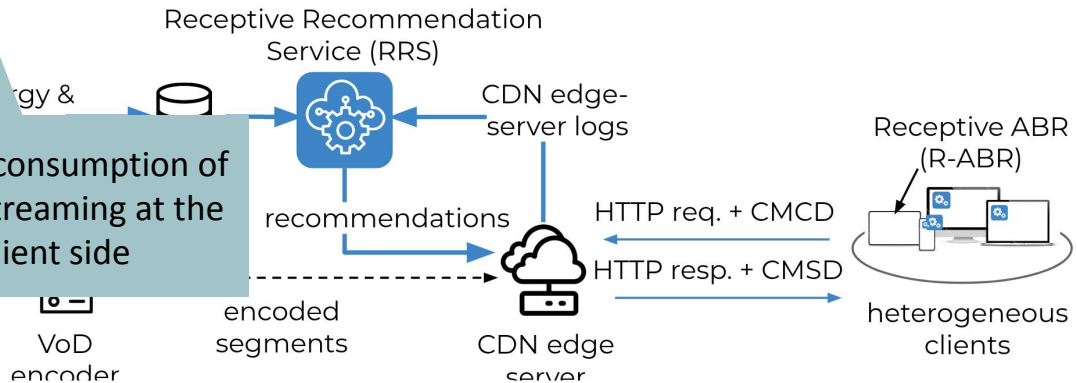
E-WISH [MHV 24]

H2BR [MTAP'24]

DoFP+ [ACCESS22]

We consider a central controller that analyzes metadata received from ABRs and provides recommendations to improve both QoE and energy efficiency.

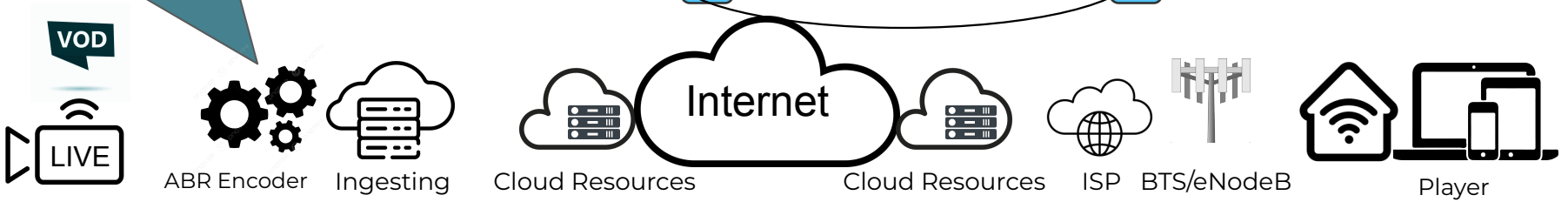
Energy consumption of video streaming at the client side



Related Challenges: Bitrate Ladder Construction

A **bitrate ladder** is a set of different video versions (bitrates and resolutions) created during encoding so that the streaming system can seamlessly switch between them.

Bitrate	Resolution
5 Mbps	1920x1080
2.8 Mbps	1280x720
1.1 Mbps	960x540



Computation Cost

Transmission Cost

Storage Cost

QoE, Latency Engagement

Related Challenges: Bitrate Ladder Construction

LALISA [NOMS 24]

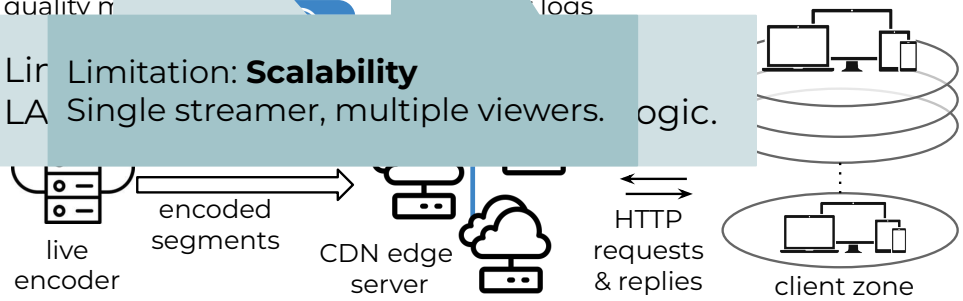
ARTEMIS [NSDI'24]

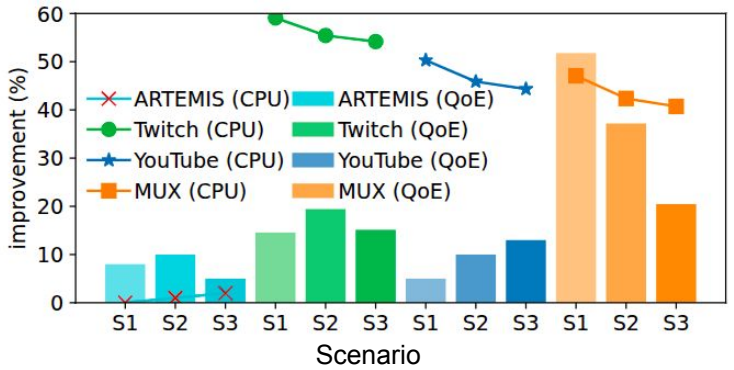
Adaptive Bitrate Ladder Opt. for Multi-Live Streaming
F Tashtarian, M Dolati, D Lorenzi, M Mozhganfar, S Gorinsky, et al

ALPHAS [INFOCOM'25]

- Key Objective: QoE Enhancement
- Scalable | Multi-Steamer | Multi-Subscriber
- NP-Complete Problem → Submodular optimization technique

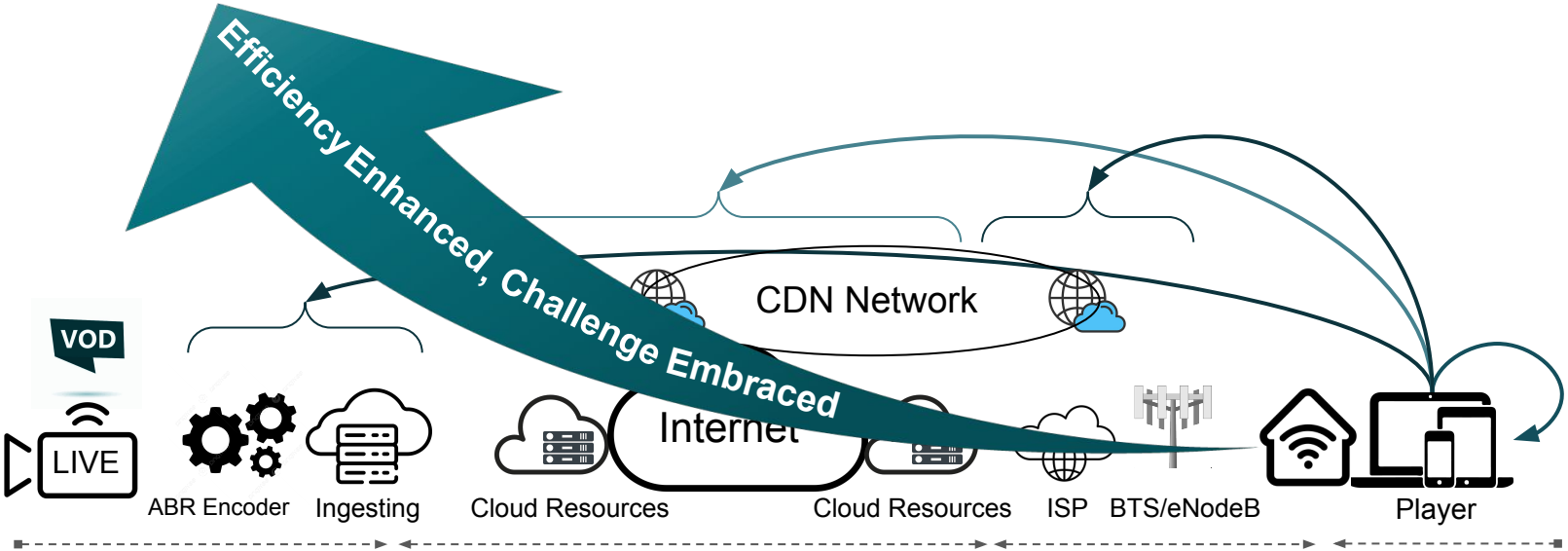
Limitation: **Scalability**
Single streamer, multiple viewers.





ARTEMIS: adaptive bitrate ladder optimization for live video streaming
F. Tashtarian, A. Bentaleb, H. Amirpour, S. Gorinsky, J. Jiang, H. Hellwagner, et al.
21st USENIX Symposium on Networked Systems Design and Implementation (NSDI), 2024

Fundamental Concept: Degree of Freedom



Cost

Resources (Computation, Bandwidth, Storage) and Energy

QoE, Latency, Engagement

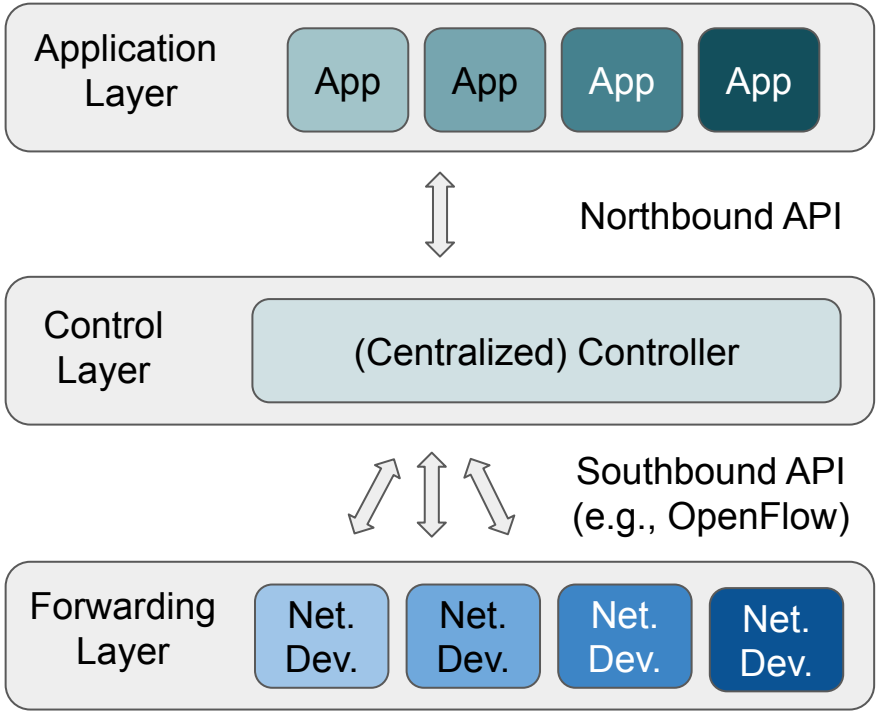
Network-Assisted Adaptive Streaming

- **Objectives and Problems**
  - Key objectives in video streaming optimization
  - Related challenges and problems
  - Fundamental concept
- **Architectures and Emerging Paradigms**
  - Network paradigms: SDN, Virtualization (e.g., NFV)
  - Execution environments: Cloud, Fog, Edge, In-Network
  - Communication standards: QUIC, CMAF, CMCD/SD
- **Solution Strategies and Techniques**

Network Paradigms: Software-Defined Networking (SDN)

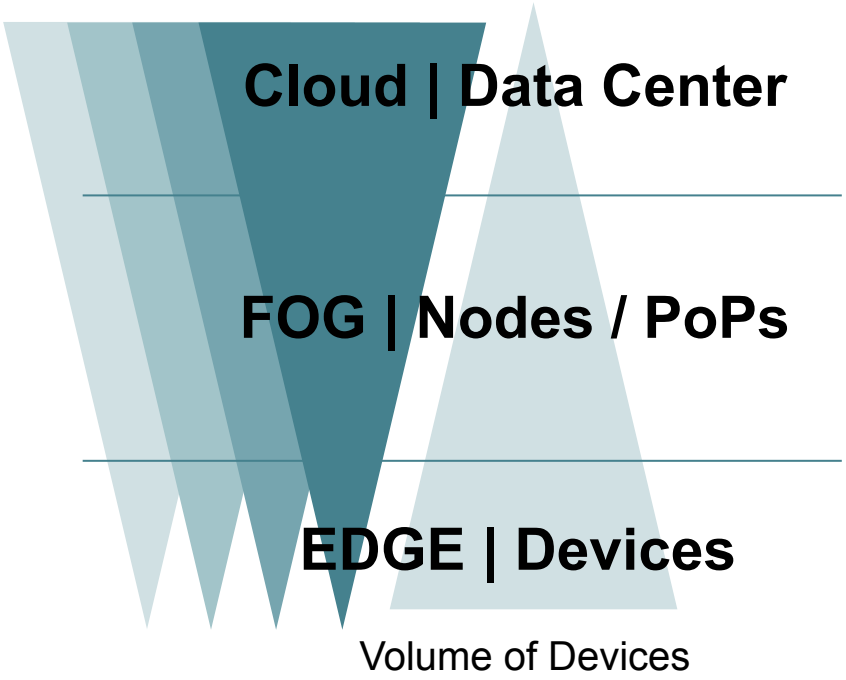
- SDN advantages
  - Holistic Network View
  - Centralized Control
  - Fast Reaction to Events (Agility)

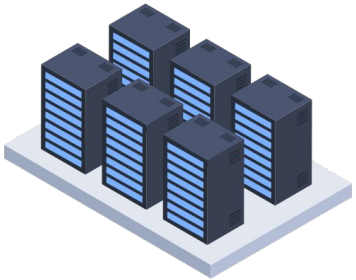
- Virtualization benefits:
  - Resource Efficiency
  - Scalability and Elasticity
  - Cost Reduction
  - Flexibility and Service Agility
  - Portability and Migration

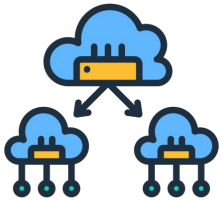


Execution Environments: Cloud, Fog, Edge, In-Network

Video Streaming Functions









Some Related Publications

Q-AVC [IWQoS'18]

S2VC [ComNet'18]

AVC-RT [Netfost'20]

SOCAR [TNSM'21]

QoCoVi [ComCom'22]

MCOM [MMM'23]

MCOM-live: A multi-codec optimization model at the edge for live streaming
D. Lorenzi, F. Tashtarian, H. Amirpour, C. Timmerer, H. Hellwagner
International Conference on Multimedia Modeling (MMM), 2023.

HxL3 [TMM'22]

HxL3: Optimized Delivery Architecture for HTTP Low-Latency Live Streaming
F. Tashtarian, A. Bentaleb, A. Erfanian, H. Hellwagner, C. Timmerer, R. Zimmermann
IEEE Transactions on Multimedia (TMM), 2022.

OTEC [ViSNext'22]

OTEC: an optimized transcoding task scheduler for cloud and fog environments
S. Afzal, F. Tashtarian, H. Hadian, A. Erfanian, C. Timmerer, R. Prodan
Proceedings of the 2nd international workshop on design, deployment, and evaluation of network-assisted video streaming (ViSNext), 2022.

Dis-UGC [LCN'21]

A Distributed Delivery Architecture for User Generated Content Live Streaming over HTTP
F. Tashtarian, A. Bentaleb, R. Farahani, M. Nguyen, C. Timmerer,
IEEE 46th Conference on Local Computer Networks (LCN), 2021.

Network-Assisted Adaptive Streaming

- Objectives and Problems
- Architectures and Emerging Paradigms
- **Solution Strategies and Techniques**
  - Mathematical Optimization
  - Heuristic Solutions
  - AI/ML-based Approaches

Mathematical Optimization

- **Multi Objective Optimization**
  - Engagement, Latency, QoE, and Cost
- **Constraints:**
  - Resources (e.g., computation, bandwidth)
  - Application requirements (e.g., delay, cost)
- **Variables:**
  - Binary: decision variables (e.g., choose bitrate variant i or not)
  - Real: continuous allocation (e.g., bandwidth share or transmission rate)
- **Optimization Types:**
  - BLP (Binary Linear Programming)
  - MILP (Mixed Integer Programing Model)
    - NP-hard → exponential time complexity in the worst case
    - Often solved with relaxations or heuristic algorithms for scalability

Adaptive Bitrate Ladder Optimization for Live Video Streaming
F. Tashtarian, A. Bentaleb, H. Amirpour, S. Gorinsky, J. Jiang, H. Hellwagner, C. Timmerer

ARTEMIS
[NSDI'24]

AI/ML-based Approaches

- **Reinforcement Learning (RL), Large Language Models (LLMs), GANs, and Diffusion Models,...**

- **Advantages:**
  - High scalability
  - Real-time decision-making
  - Contextual reasoning
  - Cross-domain adaptability
  - Numerous applications

- **Disadvantages:**
  - Training instability
  - High exploration cost
  - Interpretability issues
  - High computational overhead
  - Inference overhead



Future Research Directions

Bridging content, network, and user intelligence for next-generation multimedia systems.


ATHENA
Thank you for your attention