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High Performance Adaptive video Streaming using NDN WLAN Multicast

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Outline

- Background
- Motivation and Challenges
- System Architecture and Goals
- Design of HPNM
  - AP-based Interest proxy
  - Layer-based multicast data rate selection
- Performance Evaluation
- Conclusions

Video Streaming Today

- Increasingly video applications

Video on Demand

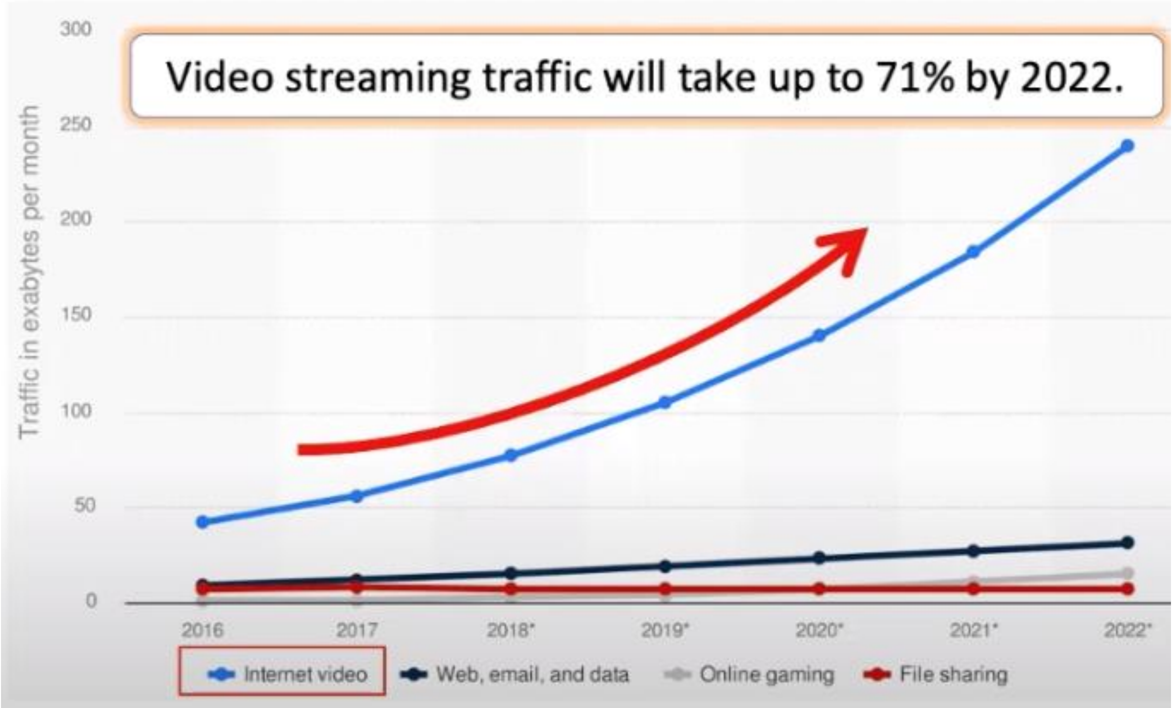
Live Video

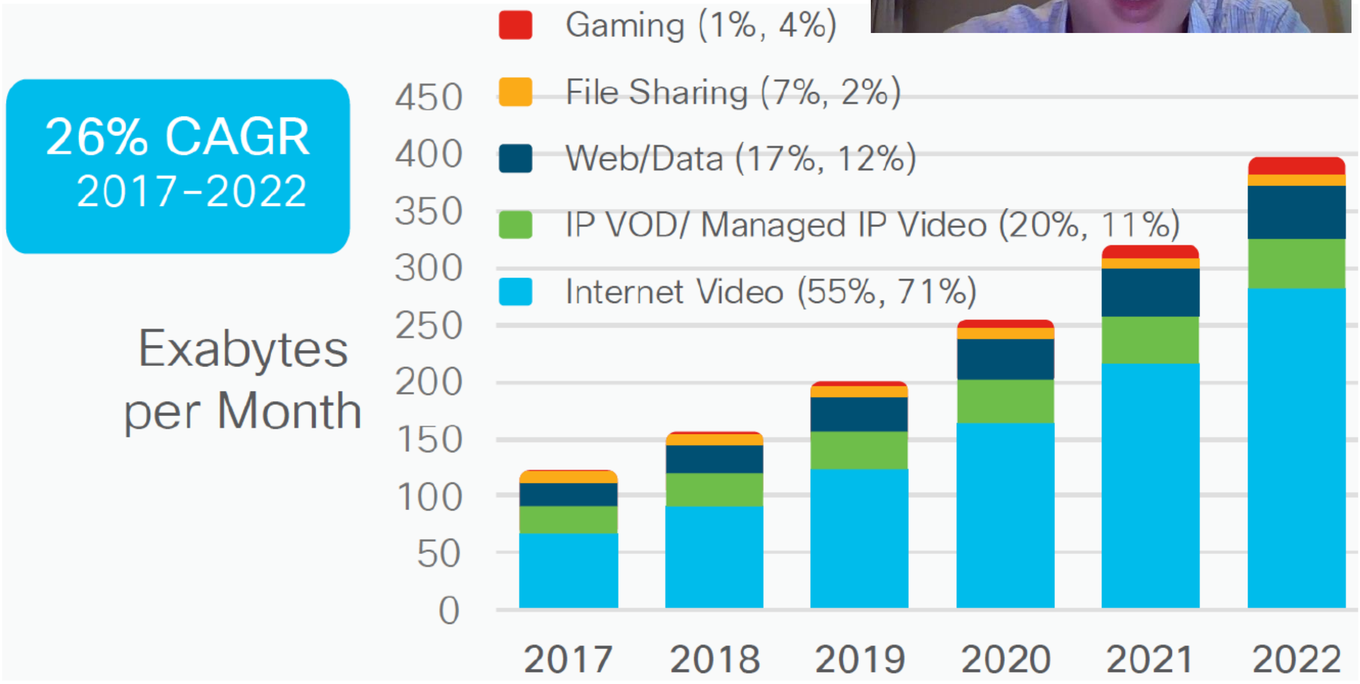
Video Conference

Short Video

Online Education

video keeps dominating the Internet traffic





Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Improve User's QoE in Video Streaming

ABR	Network measurement	Network protocol
CBA [INFOCOM' 19]	Pensieve [SIGCOMM' 17]	AMVS-NDN [INFOCOM' 13]
Comyco [MM' 19]	CS2P [SIGCOMM' 16]	NAS [ICME' 17]
QUAD [MMSys' 19]	HotDASH [ICNP' 18]	DASH-NDN [LCN' 18]
Steward [NOSSDAV' 19]	OnRL [Mobicom' 20]	NM-ABR [Infocomwp' 20]

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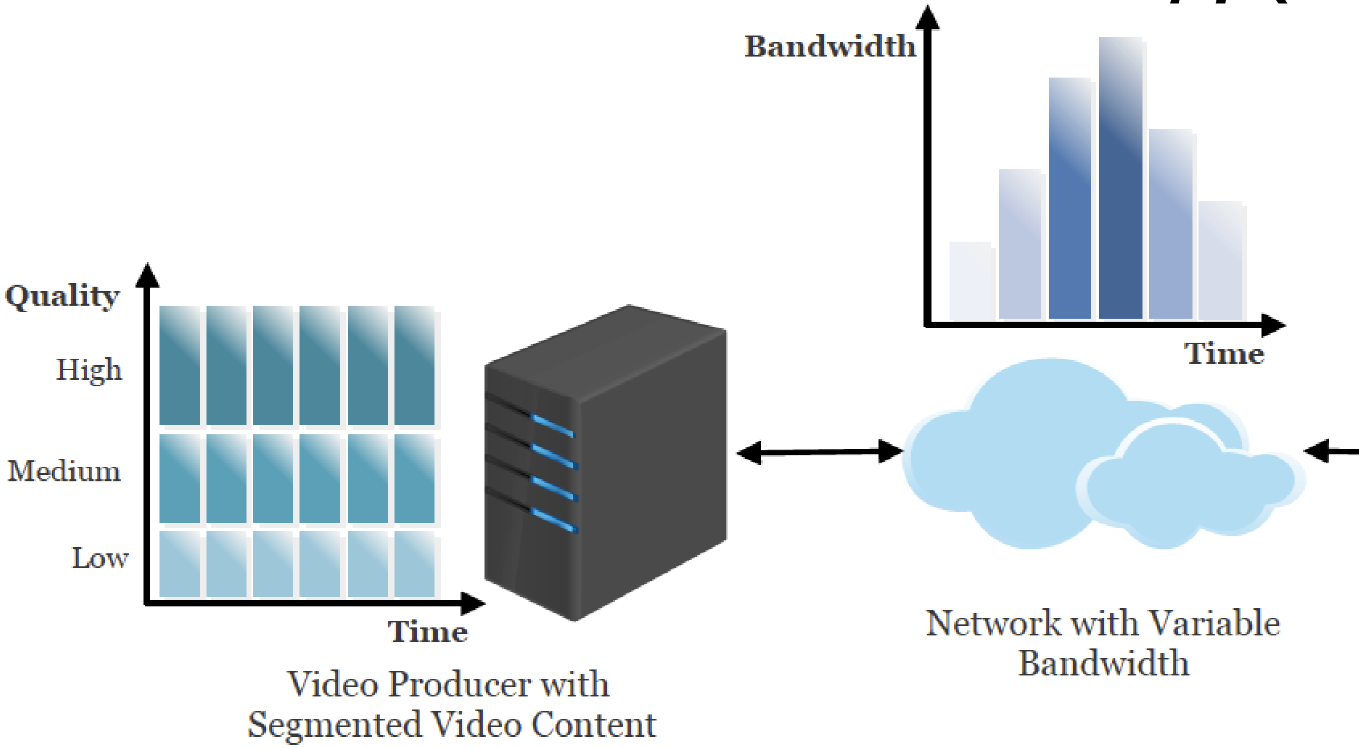
Scalable video coding (SVC)



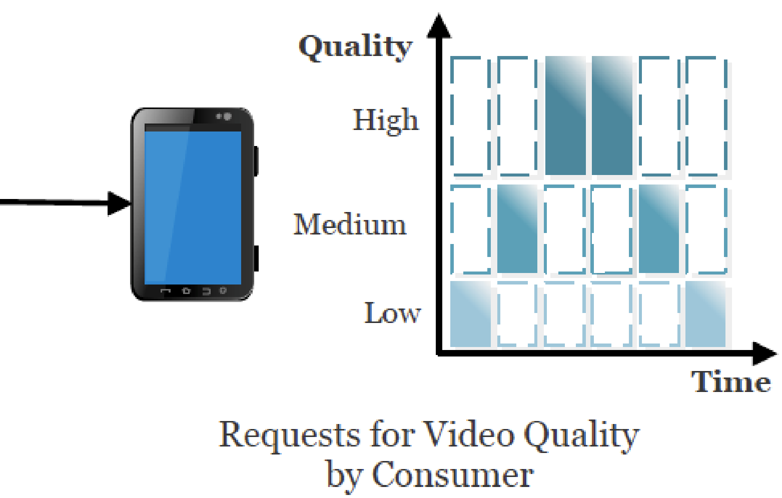
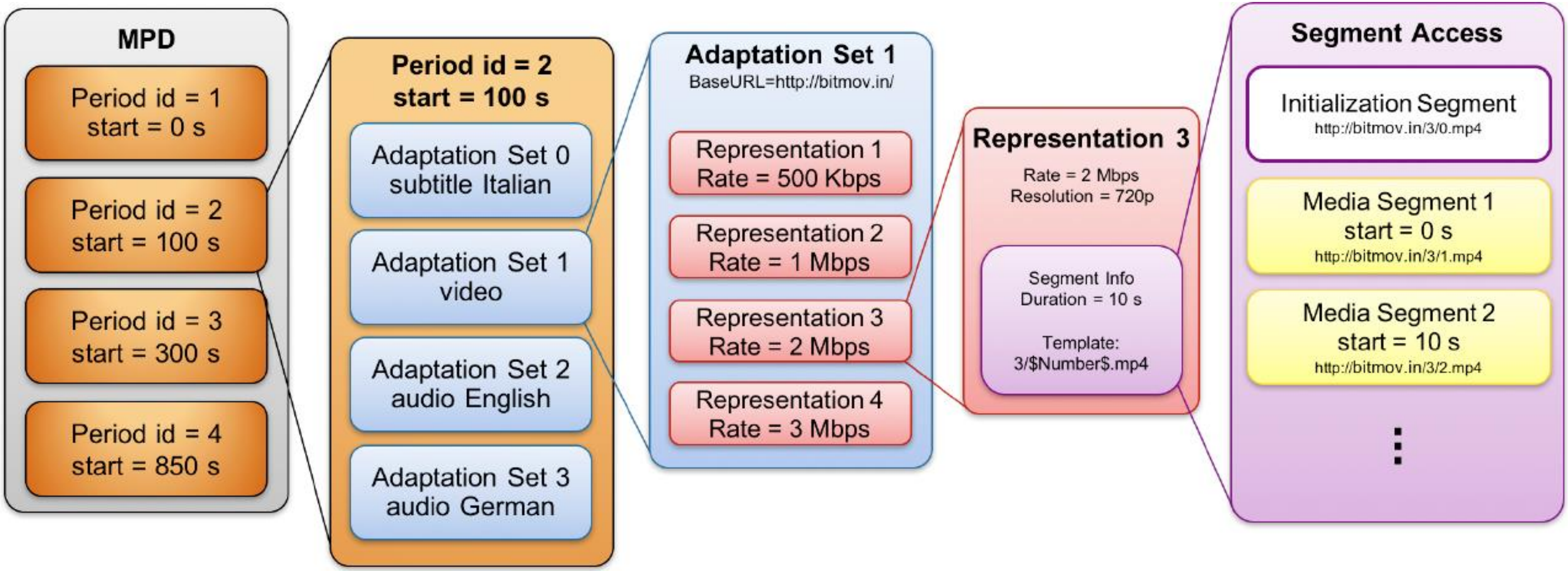


Figure 1: Live video streaming principle

- Due to different channel condition of different user in WLAN, traditional DASH-AVC(Advanced Video Coding) cannot leverage multicast. We think SVC(Scalable Video Coding) is a fit for NDN architecture because user with different bitrate request the the same low layer video packet.

Motivation and Challenges

- Low WLAN channel utilization due to massive Interest packet



- Q1: Sending more Interest packets when requesting high-quality video
- Q2: Severe channel competition due to massive uplink Interest packet

Motivation and Challenges

- Low WLAN channel utilization due to massive Interest packet

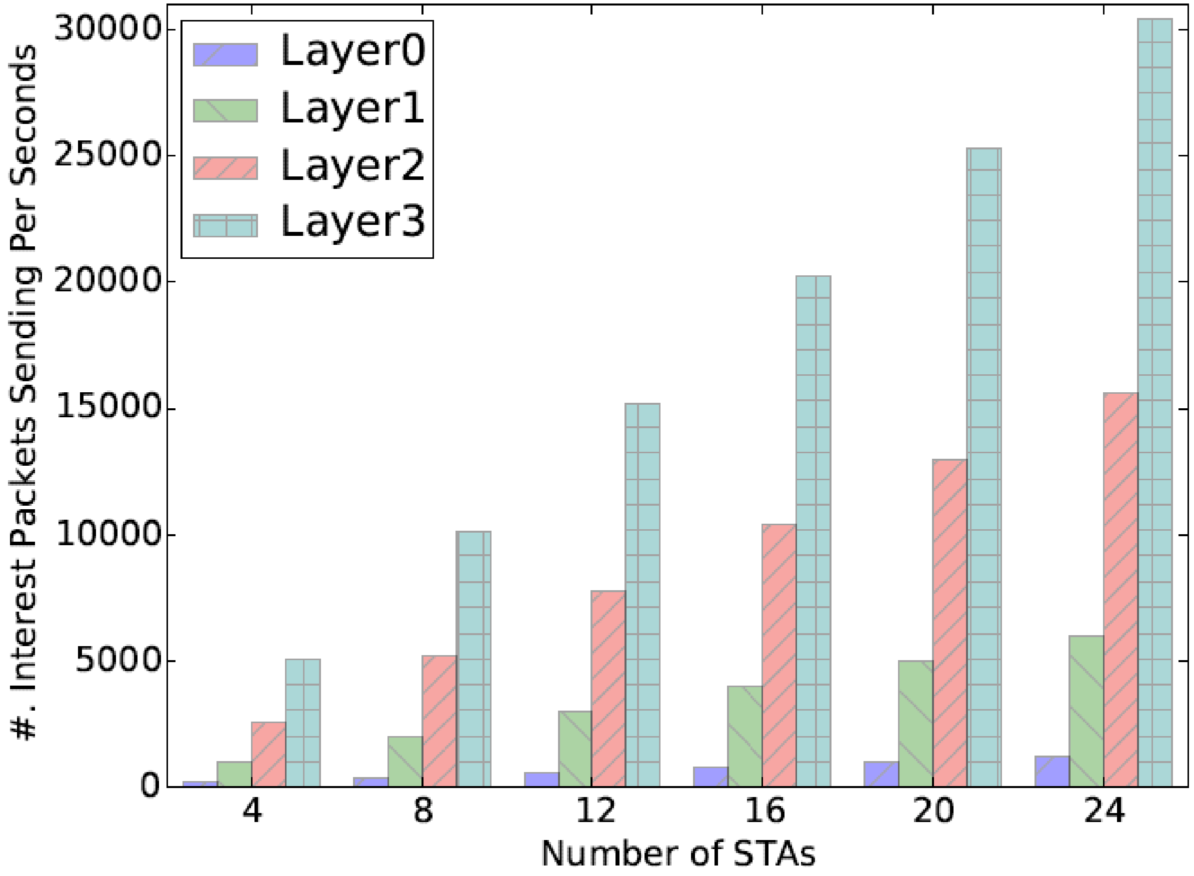


Figure 2: Interest packet sending count in different video layers with SVC.

Motivation and Challenges

- Low efficiency of multicast transmission with basic data rate

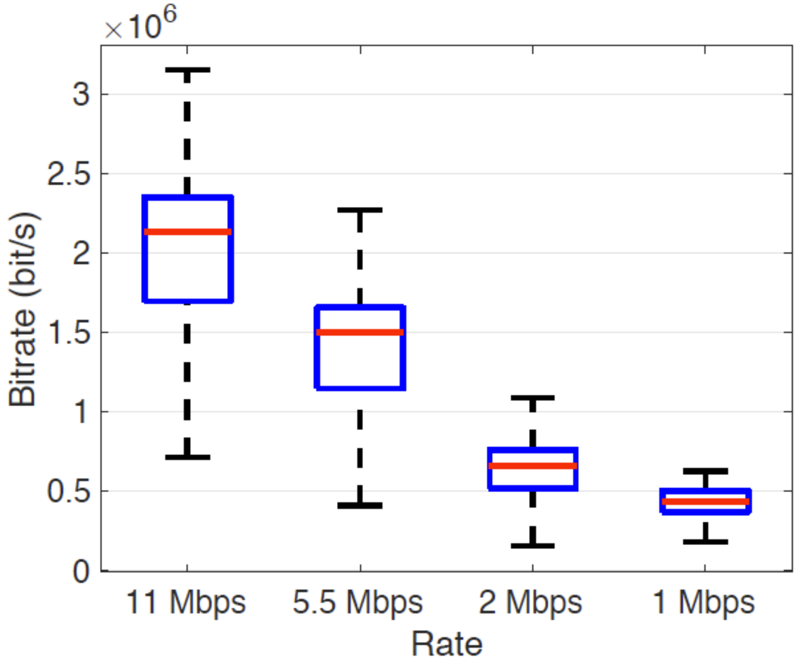


Fig. 1. Video bitrate in different data rates under IEEE 802.11b standards.

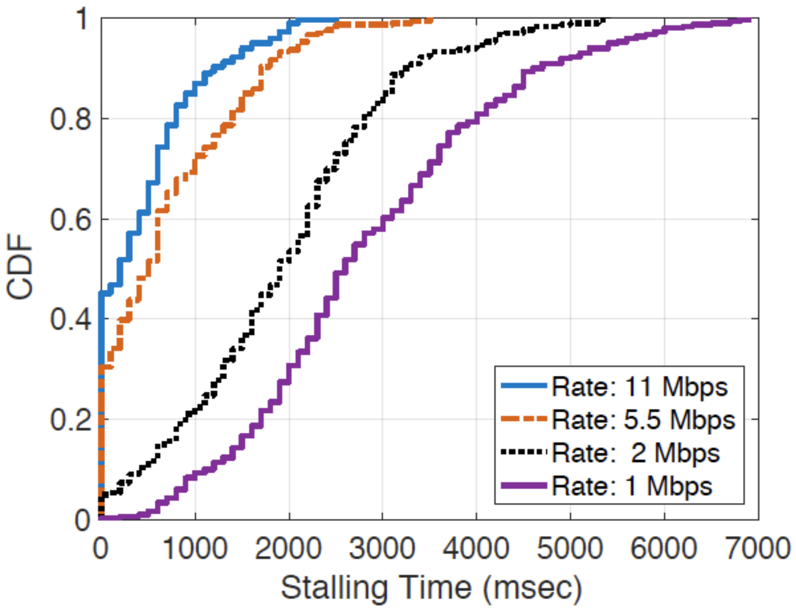


Fig. 2. Stalling time in different data rates under IEEE 802.11b standards.

  - Increase the multicast transmission time and reduce the user’s QoE
  - The basic rate multicast transmission cannot support the high-quality video streaming transmission

Motivation and Challenges

- Q1: How to leverage multicast to improve user’s QoE?
- Q2: How to leverage adaptive multicast data rate selection to improve bitrate?

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Overview

- AP-based Interest proxy scheme
- Layer-based multicast data rate selection scheme

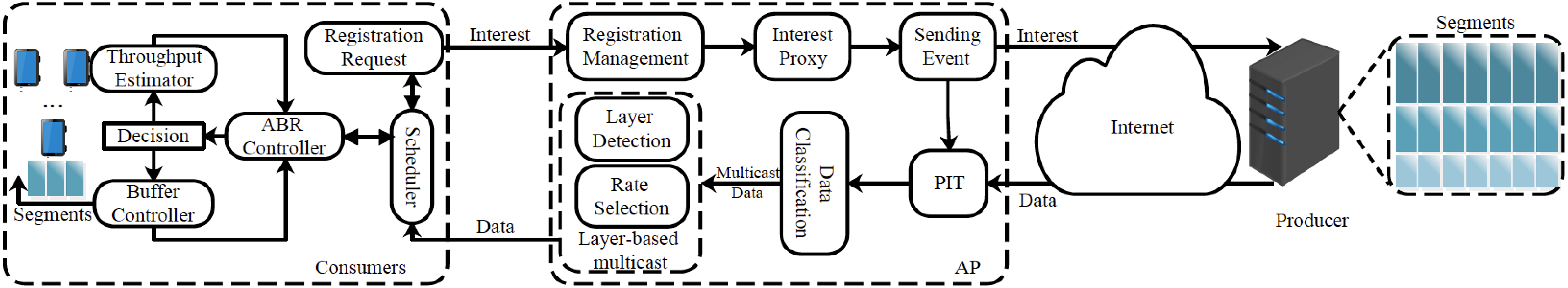

Figure 3: Overview of HPNM

Goal

To improve the overall user’s QoE

- To reduce the number of Interest sending and mitigate to the fierce competition of WLAN channel;
- To improve the video transmission efficiency by designing an adaptive multicast data rate selection scheme.

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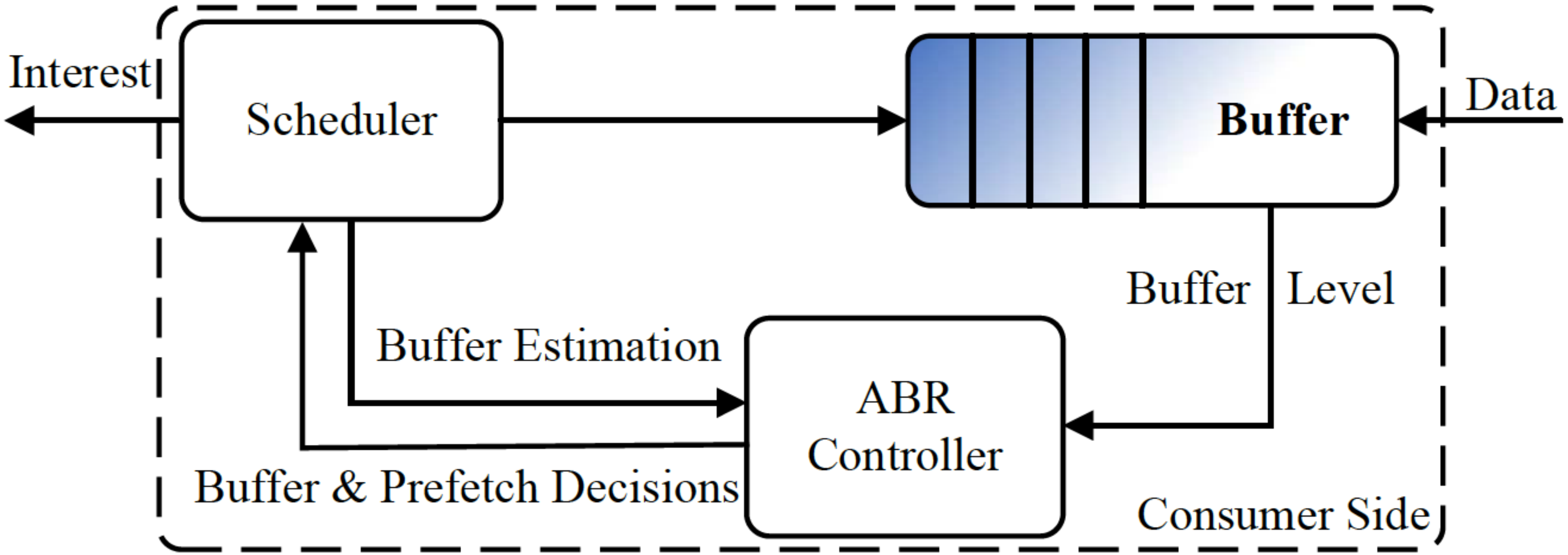
AP-based Interest proxy scheme

Interest registration in consumer side

- Naming for SVC packet.
  - BaseURL/SVC/videoname/NumLayer/segmentnumx/Ly/chunknumx
- Scheduler: adjust the Interest registration size according to ABR(Adaptive Bitrate)
  - Sending the proxy Interest to AP, and add the related Interest to PIT

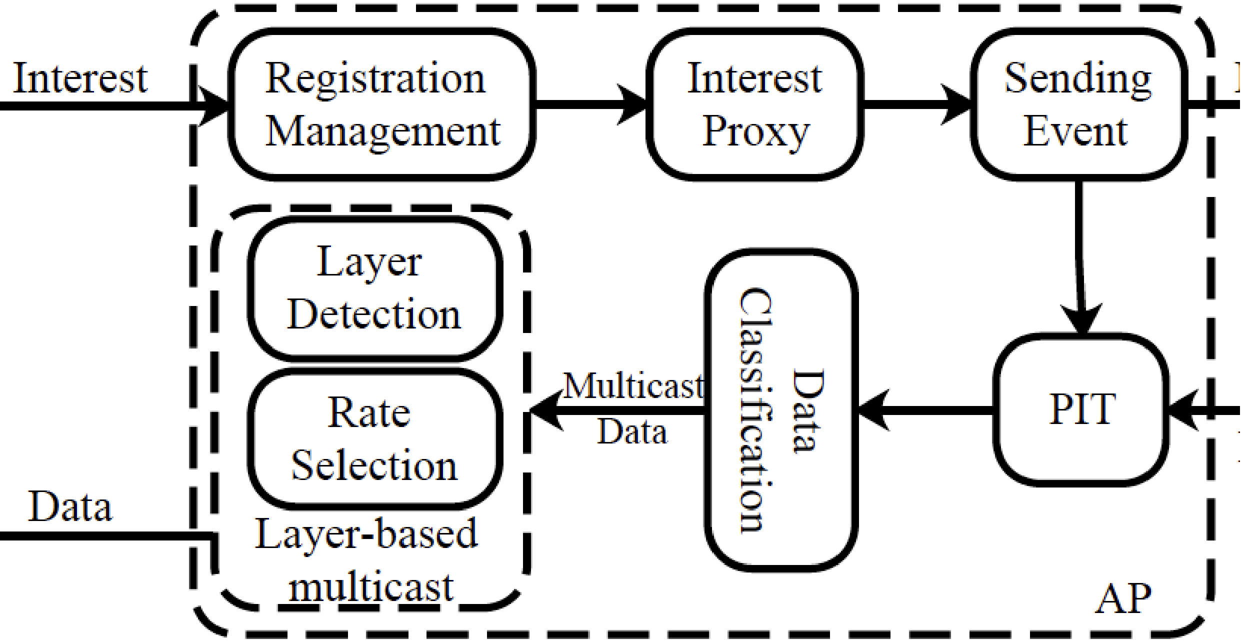


AP-based Interest proxy scheme

Interest-proxy in AP

- Add a registration table (RT): recording the BaseURL, MAC address, video layer, and MaxSeq information from an Interest packet

- Interest-proxy packet forwarding process



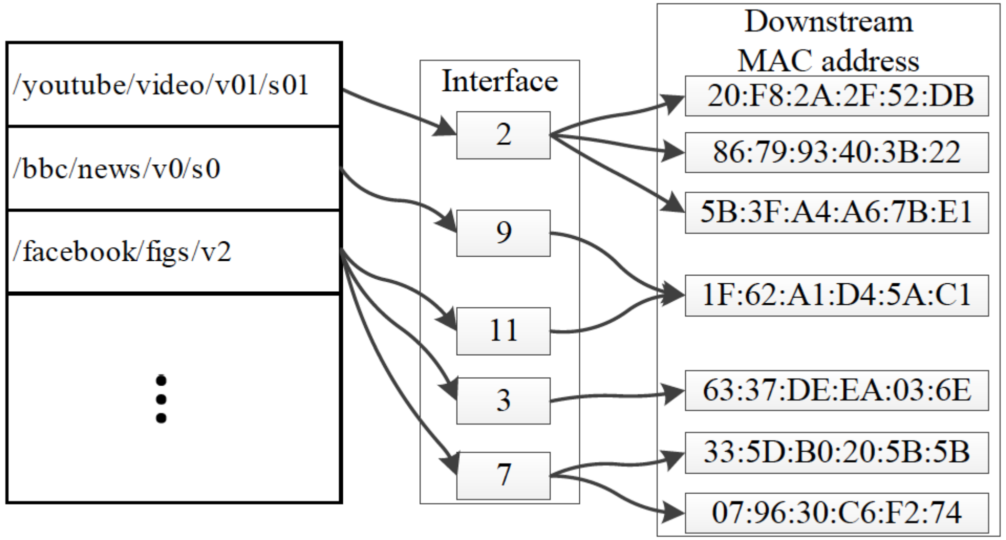
Algorithm 1 Interest Proxy

```
extract MaxSeg, MaxChun, and BaseUrl from registration_packet
// MaxChun : The number of chunks in a video segment.
// BaseUrl : Part of Interest prefix for SVC video.
For each video segment (MaxSeg);
for j = 1; i <= MaxChun; i + + do
    interest_naming_i = BaseURL/i
    interest = createInterest(interest_naming_i)
    proxySendInterest(interest)
end for
```

Layer-based multicast data rate selection

NDN WLAN Multicast

- NDN multicast is based on consumers who are requesting the same content
- NDN naturally support multicast
- Low-cost for multicast group maintenance



- Fan Wu, **Wang Yang**, Zhenyu Fan, Qingshan Guo and Xinfang Xie, "Multicast Rate Adaptation in WLAN via NDN", 27th International Conference on Computer Communications and Networks (ICCCN 2018), 2018
- Fan Wu, **Wang Yang**, Ju Ren, Feng Lyu, Peng Yang, Yaoxue Zhang, and Xuemin (Sherman) Shen, NDN-MMRA: Multi-Stage Multicast Rate Adaptation in Named Data Networking WLAN, IEEE Transaction on Multimedia, doi: 10.1109/TMM.2020.3023282

Layer-based multicast data rate selection

NDN WLAN Multicast

- NDN multicast with the Scalable Video Coding (SVC)
- NDN multicast and video layer

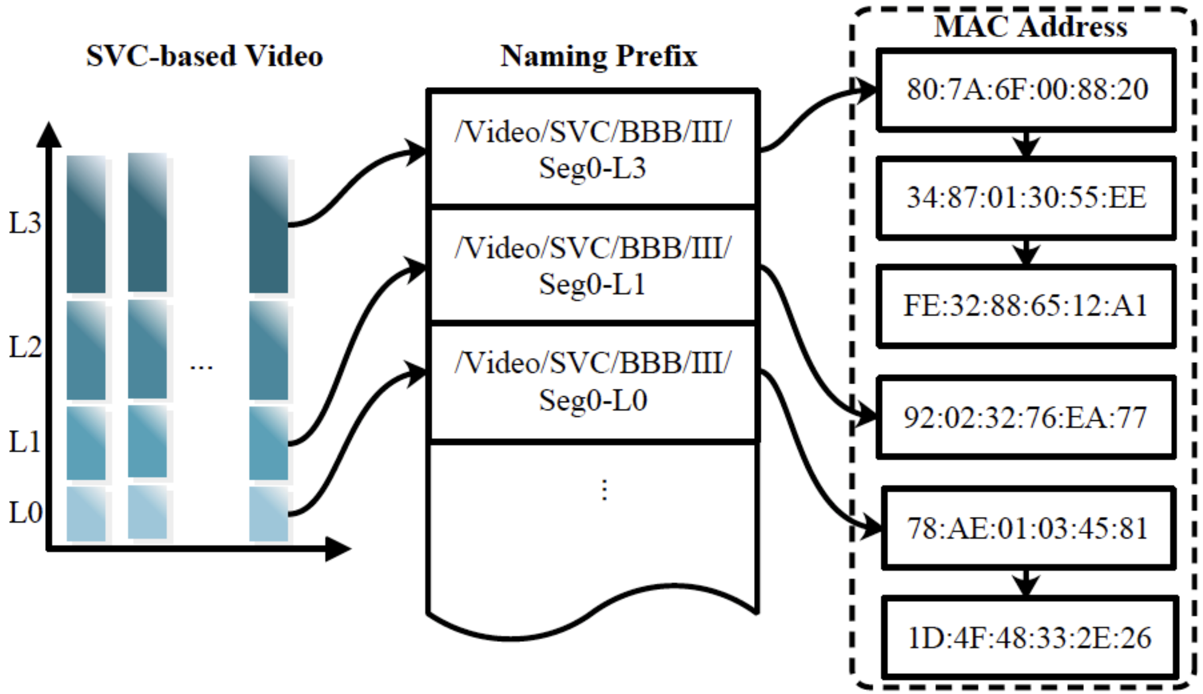
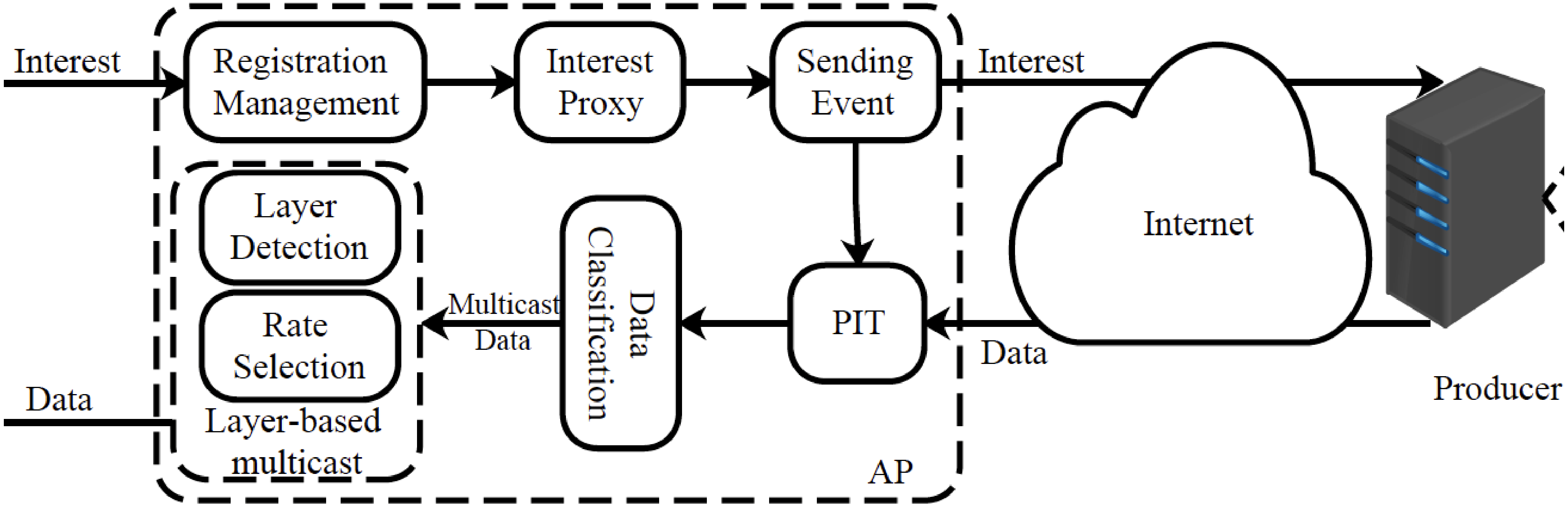


Figure 5: NDN multicast naturally supports SVC-based multimedia.

Layer-based multicast data rate selection

SVC layer detection

- Data classification
- Unicast transmission by using Minstrel algorithm



Layer-based multicast data rate selection

Adaptive multicast data rate selection

- NDN multicast data information
- Video layer information

Algorithm 2 Layer-based Multicast Rate Selection

```
Initialize data = receiveData ;
Initialize naming = data.Name ;
Initialize size = PITMatch(naming) ;
if size == 0 then
    Drop the data.
else if size == 1 then
    UnicastSend(data)
else
    layer = getLayer(data)
    if layer == L0 then
        BasicMulticast(data)
    else if L1 ≤ layer < L3 then
        MinimalMulticast(data)
    else
        GreedyMulticast(data)
    end if
end if
```

Case1: When the video layer is $L0$, the AP selects the basic rate supported by the physical layer of the wireless network card from the IEEE 802.11n. Only when the video data of base layer is correctly decoded, the other video data of enhancement layers can further improve the video quality, otherwise, it will directly affect the smoothness of video playback.

Layer-based multicast data rate selection

Adaptive multicast data rate selection

- NDN multicast data information
- Video layer information

Algorithm 2 Layer-based Multicast Rate Selection

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    else
        GreedyMulticast(data)
    end if
end if
```

Case2: When $L1 \leq video\ layer < L3$, the AP selects the minimum data rate r_{min} (from the multicast group) to transmit the multicast data, and the rate r_{min} is represented as follows:

$$r_{min} = \min\{C_k(r_i) |\ C_k \in R, C_k(r_i) \in Nr\}, \qquad (1)$$

where R is a multicast member set, C_k is the member k in the set R, and $C_k(r_i)$ indicates the data rate of the member C_k by using the Minstrel algorithm.

Layer-based multicast data rate selection

Adaptive multicast data rate selection

- NDN multicast data information
- Video layer information

Algorithm 2 Layer-based Multicast Rate Selection

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    if layer == L0 then
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    else if L1 ≤ layer < L3 then
        MinimalMulticast(data)
    else
        GreedyMulticast(data)
    end if
end if
```

Case3: When the video layer is $L3$, the AP selects the data rate r_s to transmit the multicast data, which maximize the throughput in the group. The rate r_s is computing as follows:

$$\begin{aligned} &\max_{r_i} \sum_{k=1}^{N} C_k(r_i) * SR_i, \\ &s.t.\ C_k \in R,\ C_K(r_i) \in Nr,\ N = |R|. \end{aligned} \tag{2}$$

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Performance Evaluation

Evaluation metrics:

- Video bitrate
- Video layer ratio
- Stalling time
- Buffer level
- Startup time

Baseline methods:

- Basic Rate selection (**BR**):
- Interest-Proxy with the Basic Rate selection (**NIP-BR**)

Parameters	Value
Video layer with SVC	1 BL and 3 ELs
MaxBufferedSeconds	30 s
StartUpDelay	0.1 s
P2P link delay / bandwidth	50 ms/200 $Mbps$
AllowUpscale	True
AllowDownscale	False
ScreenWidth*ScreenHeight	$1920 * 1080$
Cache replacement strategy	LRU
Cache size (packets)	10000
IEEE 802.11 standards	802.11n
Number of STAs	$4 - 24$
Mobility mode	2-dimensional mobility
Wi-Fi Channel	$LogDistance$
Video traffic	BBB/bluesky/factory
StartRepresentationId	auto
Simulation time	3000 s

Performance Evaluation

SVC vs. AVC

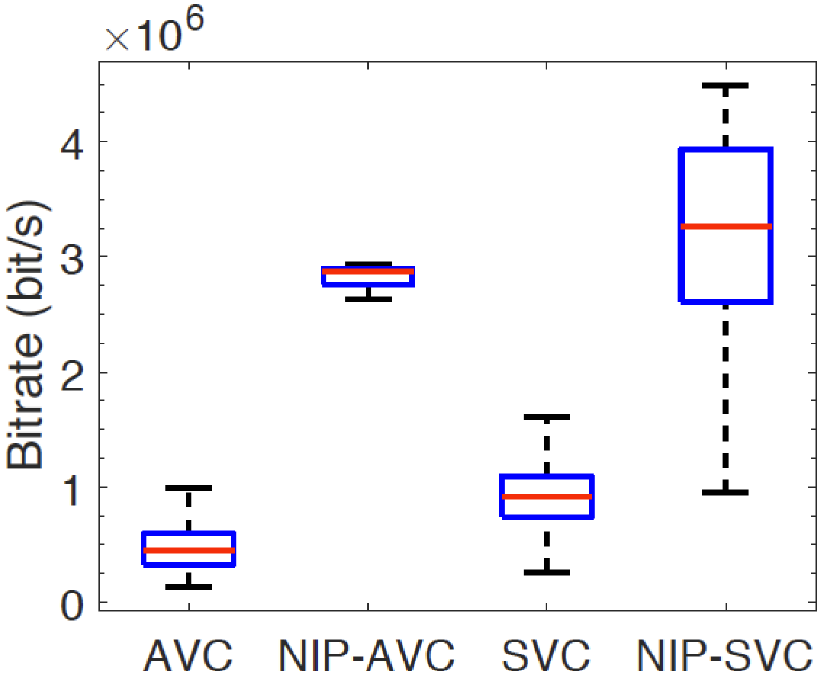


Figure 6: Video bitrate in SVC and AVC.

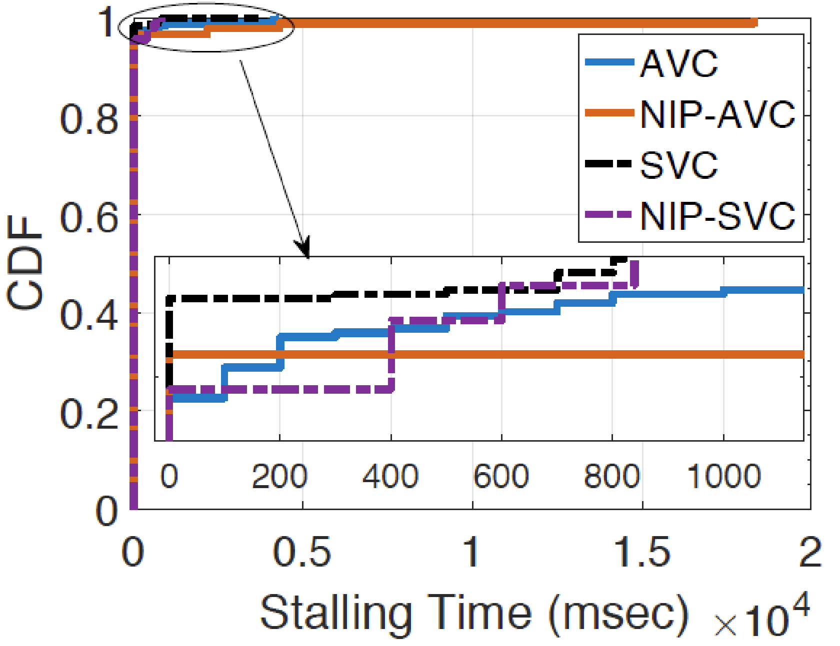


Figure 7: Stalling time in SVC and AVC.

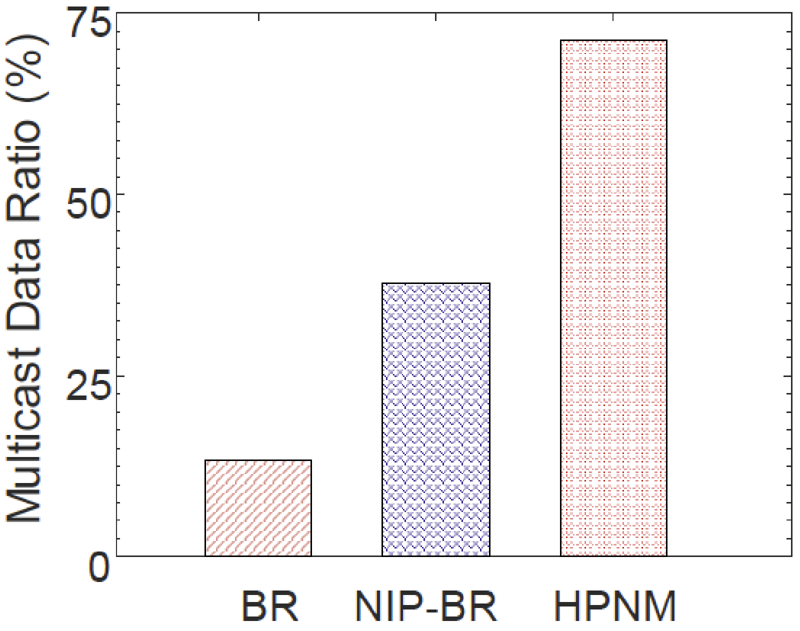


Figure 8: Multicast data ratio in different schemes.

Performance Evaluation

Video bitrate & video layer ratio

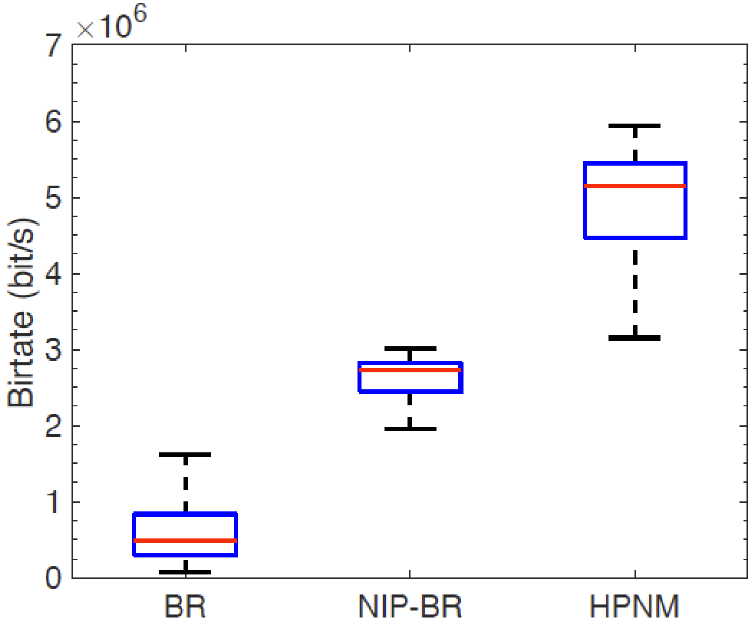


Figure 9: Video bitrate in different schemes under IEEE 802.11n.

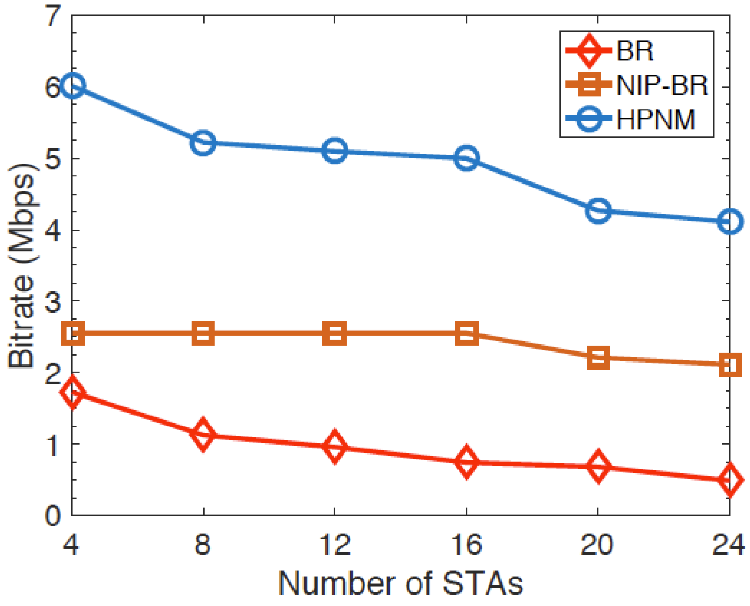


Figure 10: Average video bitrate in different numbers of STAs.

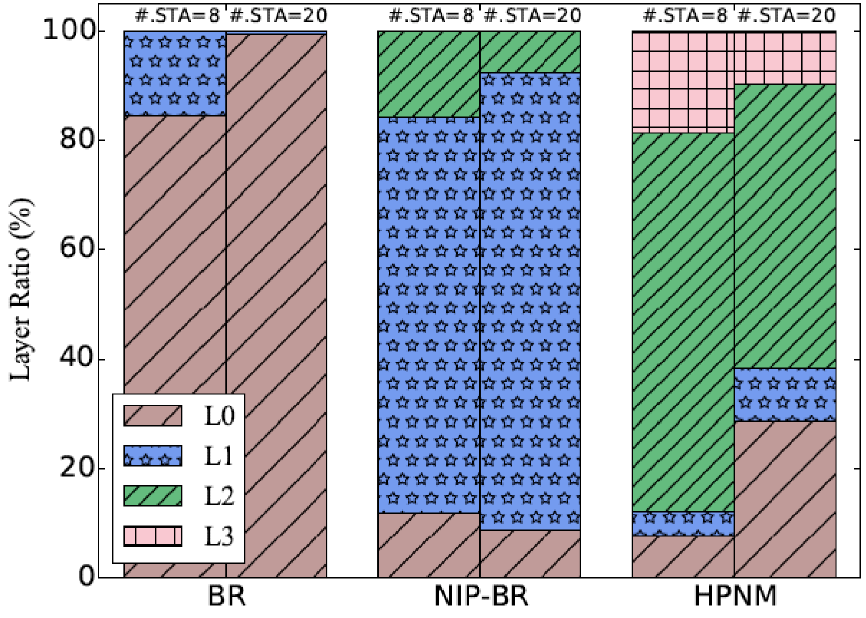


Figure 11: Video layer ratio in different schemes.

Performance Evaluation

Stalling time & Buffer level & startup time

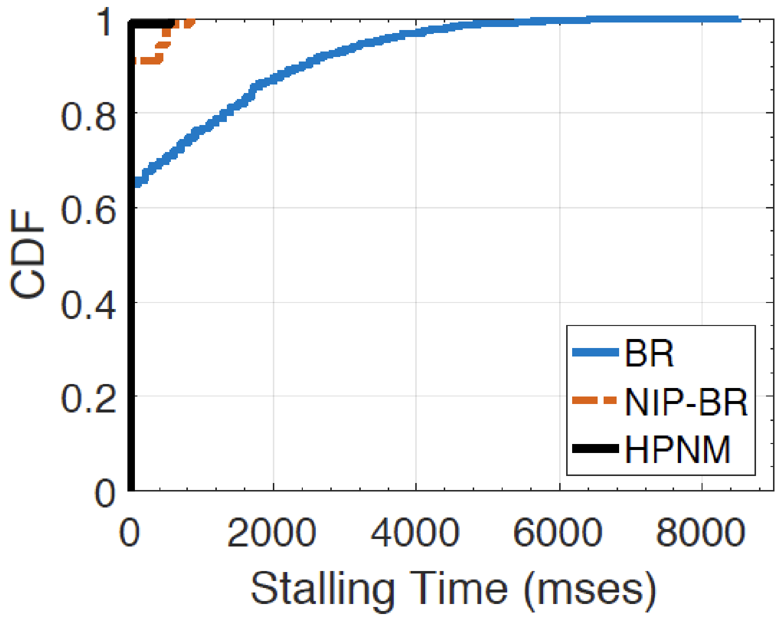


Figure 12: Stalling time in different schemes under IEEE 802.11n.

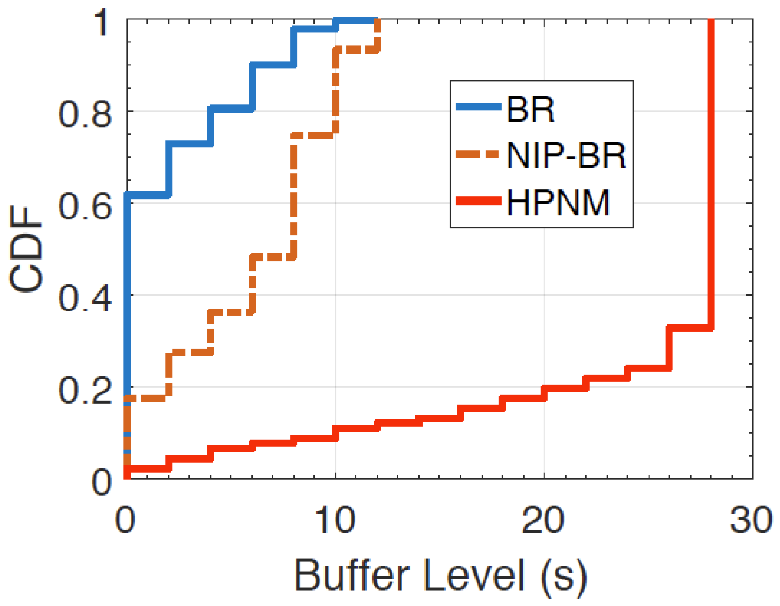


Figure 13: Buffer level in different schemes.

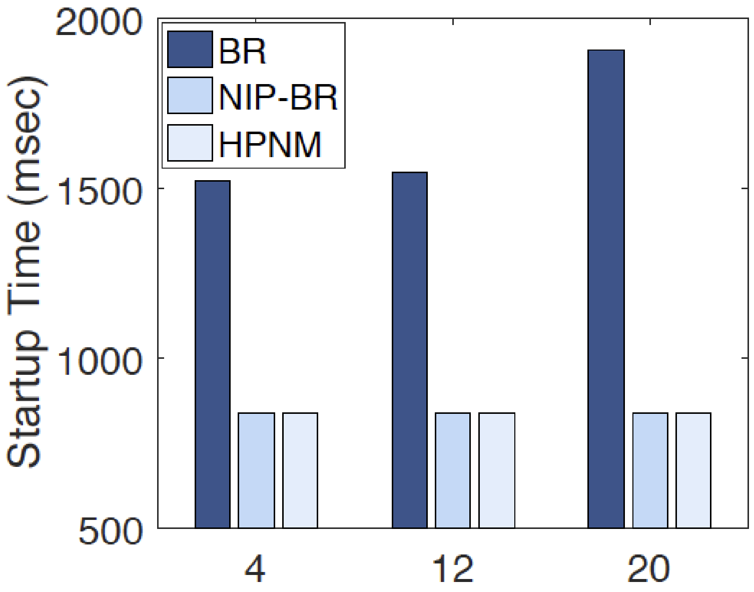


Figure 14: Startup time in different schemes under IEEE 802.11n.

Performance Evaluation

Impact of background traffic

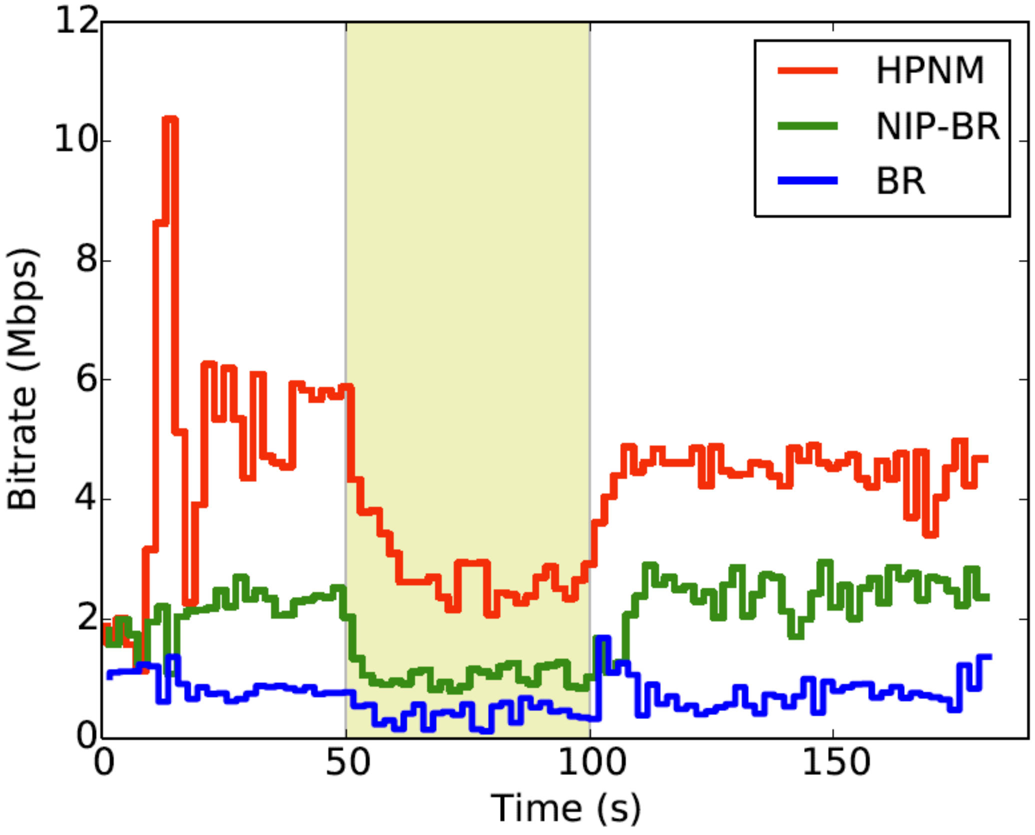
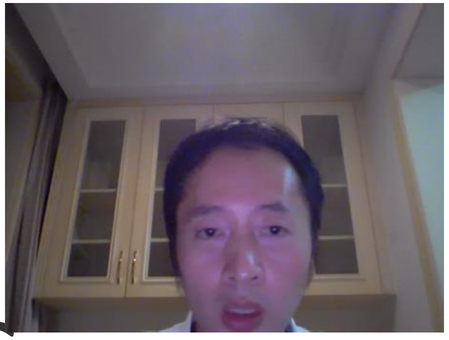


Figure 15: Video bitrate with background traffic during the 50s to 100s.

Conclusion

- To improve the overall user's QoE in video streaming, we design an HPNM to solve the challenges:
  - Interest proxy scheme can significantly reduce the number of Interest packets sending from consumers, which will reduce the WLAN uplink competition.
  - We design a layer-based multicast data rate selection scheme to fine-grained select the appropriate multicast rate for different video layers.
- HPNM can benefit many live video applications, and potentially other data-driven network protocols and applications

Future work



- ABR(adaptive bitrate algorithm) for SVC
- Multi-source multi-path with SVC

Thank You！
Q&A？