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
- YouTube
- Netflix
- iQIYI
- Douyu
- Twitch

Live Video
- Bigo Live

Video Conference
- Tencent Meeting
- Zoom
- TikTok
- WeChat
- Snapchat
- Instagram

Short Video
- Bilibili
- Douyu
- Instagram

Online Education
- Coursera
- edX
- China University MOOC
- CC Talk
video keeps dominating the Internet traffic

Source: Cisco VNI Global IP Traffic Forecast, 2017-2022
# Improve User’s QoE in Video Streaming

## ABR
- CBA [INFOCOM’ 19]
- Comyco [MM’ 19]
- QUAD [MMSys’ 19]
- Steward [NOSSDAV’ 19]

## Network Measurement
- Pensieve [SIGCOMM’ 17]
- CS2P [SIGCOMM’ 16]
- HotDASH [ICNP’ 18]
- OnRL [Mobicom’ 20]

## Network Protocol
- AMVS-NDN [INFOCOM’ 13]
- NAS [ICME’ 17]
- DASH-NDN [LCN’ 18]
- NM-ABR [Infocomwp’ 20]
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Scalable video coding (SVC)

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

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.
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
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

![Diagram of Interest registration process](image)
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**

```
1: extract MaxSeg, MaxChun, and BaseUrl from registration_packet
2: // MaxChun : The number of chunks in a video segment.
3: // BaseUrl : Part of Interest prefix for SVC video.
4: For each video segment (MaxSeg);
5: for j = 1; i <= MaxChun; i ++ do
6:    interest_naming_i = BaseURL/i
7:    interest = createInterest(interest_naming_i)
8:    proxySendInterest(interest)
9: 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

![Diagram showing multicast paths and interfaces]

- 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
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

1: Initialize data = receiveData;
2: Initialize naming = data.Name;
3: Initialize size = PITMatch(naming);
4: if size == 0 then
5:   Drop the data.
6: else if size == 1 then
7:   UnicastSend(data)
8: else
9:   layer = getLayer(data)
10: if layer == L0 then
11:   BasicMulticast(data)
12: else if L1 ≤ layer < L3 then
13:   MinimalMulticast(data)
14: else
15:   GreedyMulticast(data)
16: end if
17: end if

Case 1: 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

1: Initialize $data = receiveData$ ;
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6: else if $size == 1$ then
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8: else
9:     $layer = getLayer(data)$
10: if $layer == L0$ then
11:     BasicMulticast($data$)
12: else if $L1 \leq layer < L3$ then
13:     MinimalMulticast($data$)
14: else
15:     GreedyMulticast($data$)
16: end if
17: end if

Case 2: 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:

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

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

1. Initialize data = receiveData;
2. Initialize naming = data.Name;
3. Initialize size = PITMatch(naming);
4. if size == 0 then
   5. Drop the data.
   6. else if size == 1 then
      7. UnicastSend(data)
   8. else
      9. layer = getLayer(data)
      10. if layer == L0 then
          11. BasicMulticast(data)
      12. else if L1 ≤ layer < L3 then
          13. MinimalMulticast(data)
      14. else
          15. GreedyMulticast(data)
      16. end if
   17. end if

Case 3: 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:

$$\max_{r_i} \sum_{k=1}^{N} C_k(r_i) \ast SR_i,$$

subject to $C_k \in R$, $C_K(r_i) \in Nr$, $N = |R|$. (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)
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.
Figure 9: Video bitrate in different schemes under IEEE 802.11n.

Figure 10: Average video bitrate in different number 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.
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?