Adaptive Bitrate Streaming:

Analysis, Problems and Potentials

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INTRODUCTION

In the recent times, online video streaming has overtaken the offline video. Many video streaming services (Netflix, YouTube, etc.) are providing brilliant experience to their users. In order to do that, there are several methodologies adapted by these big industry players. Mainly the optimizations revolve around using Adaptive Bitrate Streaming in the HTTP based video streaming services. Our main focus area will be to analyse the actual data transfer rates and the latency of these streaming applications, along with the effects of network traffic congestion on these applications.

REQUIREMENTS OF ABR ALGORITHM

- **High Bitrate** : Should play the video at the highest sustainable quality (i.e., bitrate).
- **Low Rebuffering** : Should avoid rebuffering events (i.e. freezes) that occur due to the client buffer being empty.
- **Low Oscillations** : Should avoid excessive bitrate oscillations where the video quality is frequently modified during the playback.
- **Responsiveness to Network Events** : Should react quickly to network events. For instance, if the network throughput suddenly drops, the ABR algorithm should decrease the video bitrate to adjust to the new network state.
- **Responsiveness to User Events** : Should react quickly to user events.

QoE (Quality of Experience)

Given the variations of parameters on which the video streaming QoE(Quality of Experience) depends, such as network environments, device capabilities, and content properties in a commercial setting, perfecting ABR is a herculean task. For Optimal QoE, the calculations for finding the optimal bitrate selections can be done only having full knowledge of the entire network throughput trace. This implies that the optimal QoE is dependent on ABR.

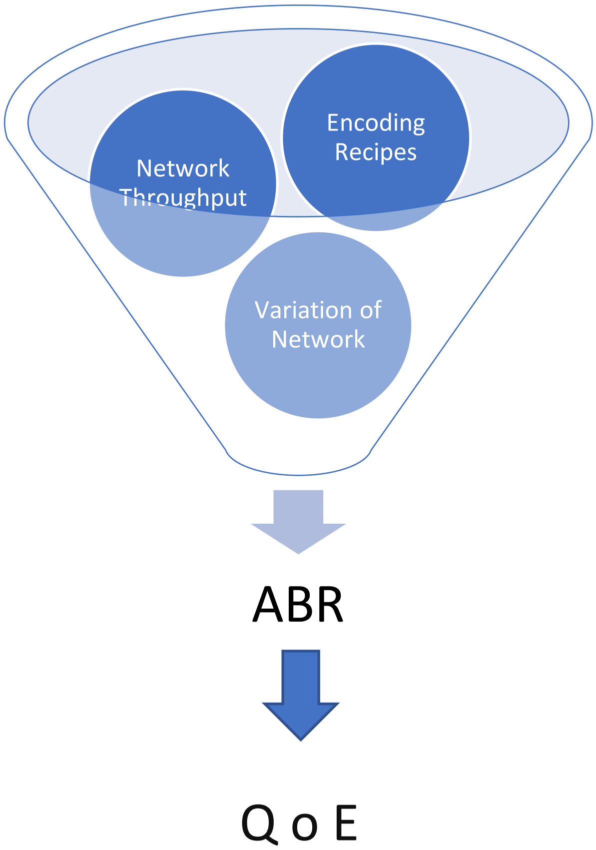

Fig. 1 - Factors affecting QoE

Packet Analysis

Our initial analysis started from capturing low layer TCP packets exchanging b/w client and server. Our main objective was to co-related high layer ABR calculation with exchange of packets. To achieve this, we captured packet data as mentioned in the below chart. Next we try to find rate of packet exchange (**R_p**) periodically. What we have found is this rate of packet exchange is directly proportional to video bitrate (**V_b**).

$$R_p \propto V_b$$

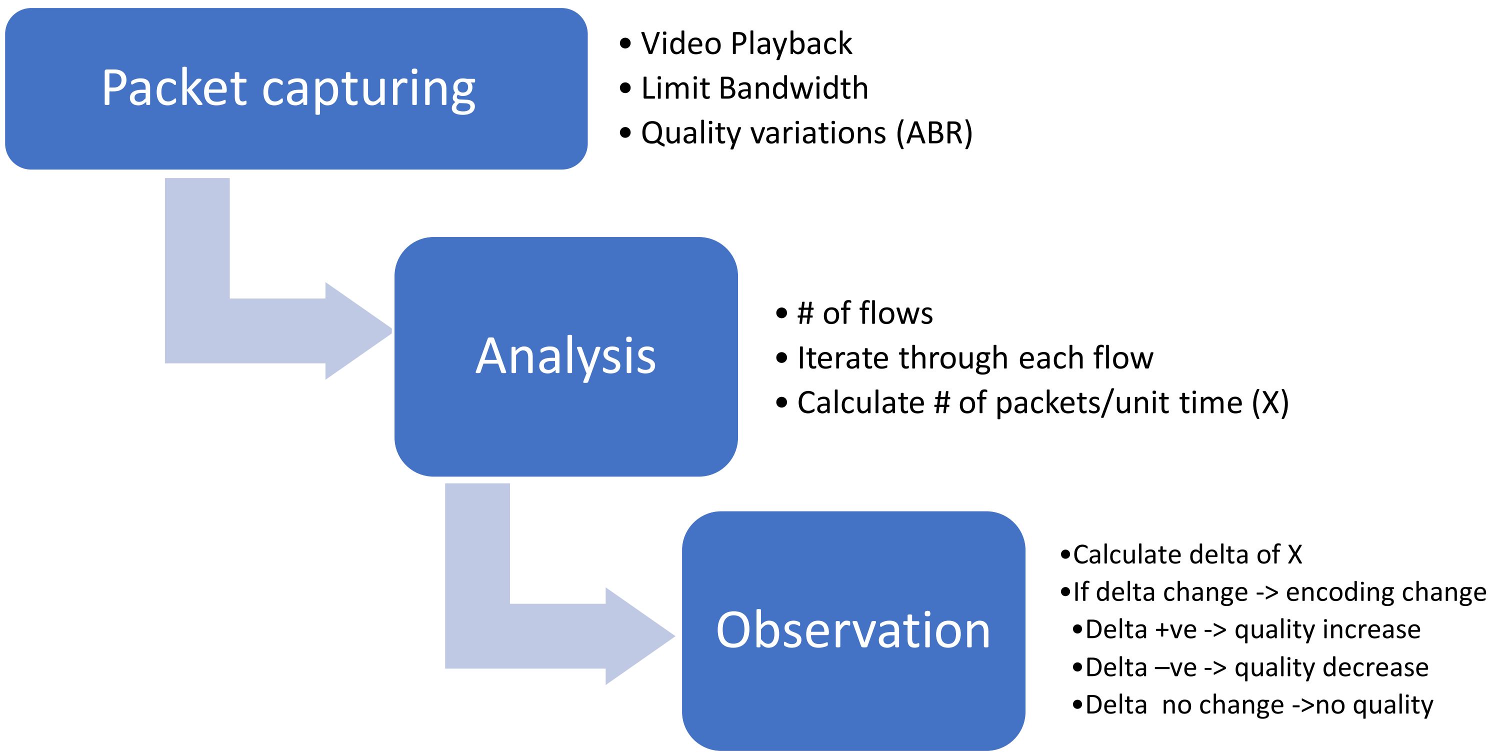

Fig. 2 – Correlation between Bitrate and Packet

SETUP

Bandwidth Limiter : Chrome Webpage Inspect utility network functionality to limit network speed/bandwidth wherever required on various Devices(Laptops) of varying configurations.

[# of high config devices: 37, # of medium config devices: 11, # of low config devices: 2]

High config - Latest i5/i7 + 8Gb/16Gb RAM + 1080p Screen

Medium config - Old i5 + 4GB/8GB + 720p Screens

Low config - any i3 + 2GB/4GB + 720p Screens

OBSERVATION

Highly varied data, only took points with coherence and left outliers to make a better understanding

1. **Device Type :**

   Devices with **Medium Configurations (e.g. 720p screen and i5 processors)** tend to start the video with 480p encoding. On the other hand, **High config devices (e.g. 1080p screens and newer i5/i7 gen processors)** started playback from HD encodings

(720/1080p). In former case, the ABR algorithm adjusts the quality in a span of few seconds.

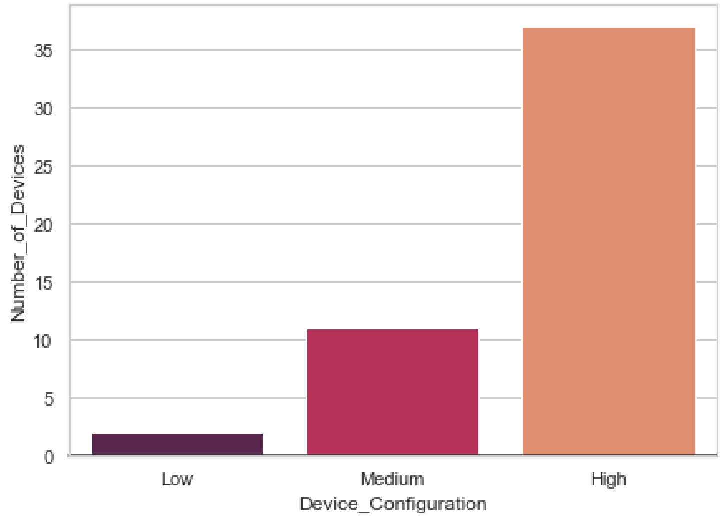

Fig3 Distribution of Devices

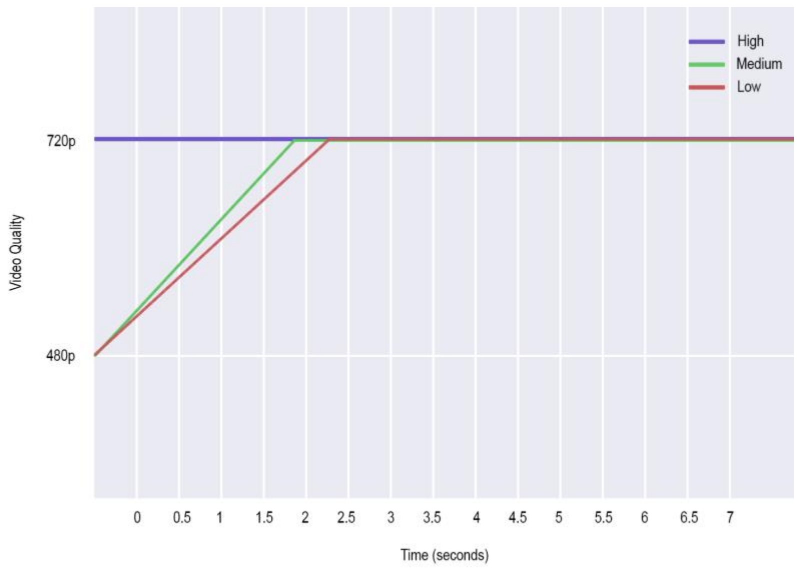

Fig4 ABR vs Device Type

2. Starting Bandwidth - 100 Mbps

Limiting the bandwidth of the network to test the spontaneity of the ABR algorithm. Videos played on various streaming services such as YouTube, Netflix, Amazon Prime, HBO, Hulu, HotStar etc. Considered average times across streaming services.

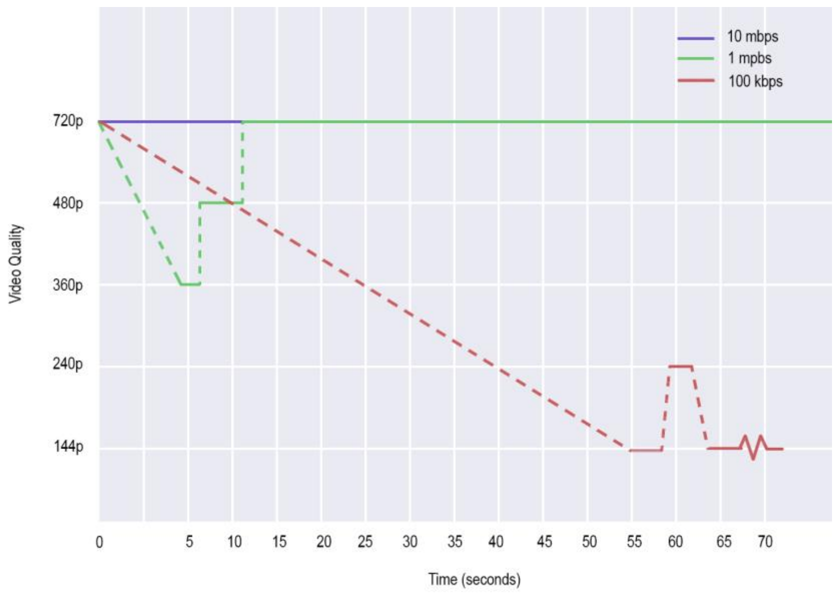

Fig 5 ABR vs Network Bandwidth Start 100Mbps

3. Starting Bandwidth - 1 Mbps

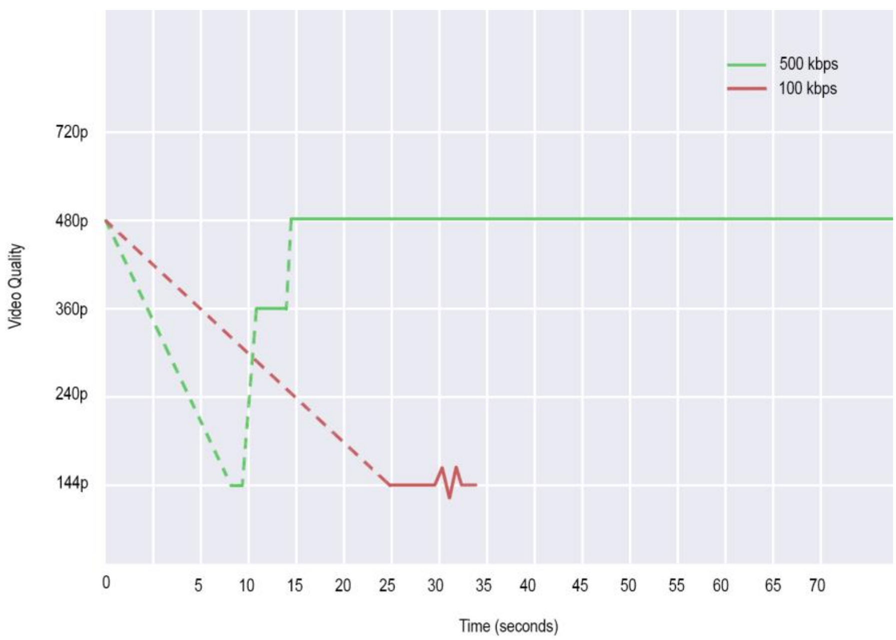

Fig 6 ABR vs Network Bandwidth Start 1 Mbps

4. **Responsiveness to User Events :**

Click at future video frames. Subsequent frames except first one use cached ABR.

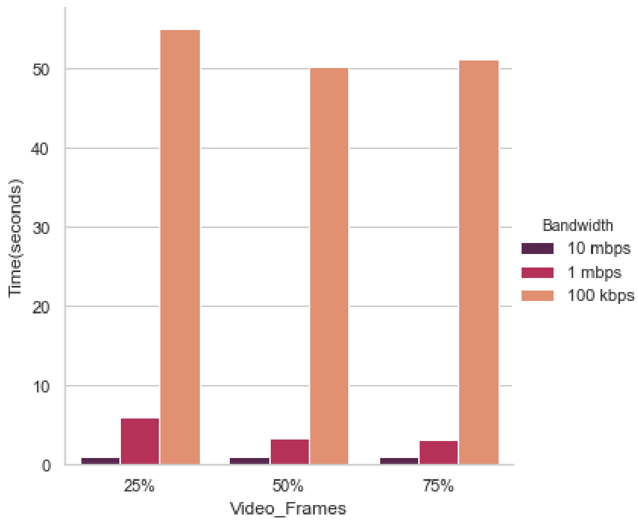

Fig 7 ABR vs User Events

ABSTRACT VIEW OF ABR:

Based on our study, observation and research, the high level view of ABR algorithm is presented in Fig 8

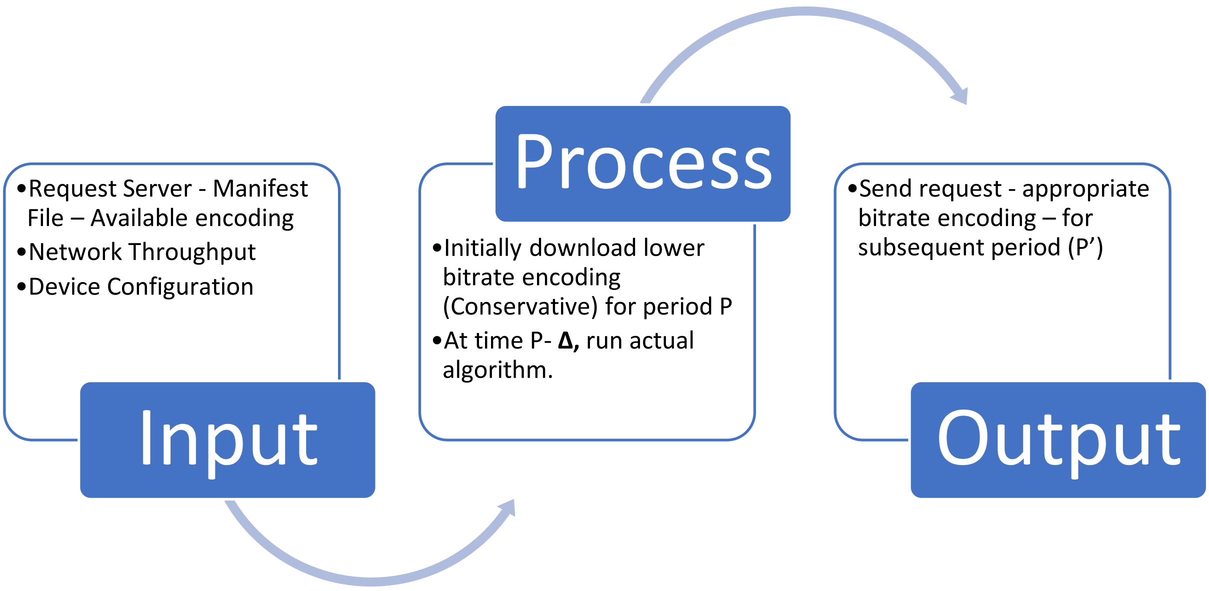

Fig 8 Abstract View of ABR

NETFLIX - HINDSIGHT - OPTIMAL ABR

To identify shortcomings effectively at a large scale, a scalable methodology is needed to evaluate ABR algorithms under various changing parameters that differ widely over quite a range. However, optimal ABR is an NP-hard problem and therefore is costly to be deployed at a commercial scale. NETFLIX has developed its own ABS algorithm named HINDISGHT to know which encoding to download at the client side. The original algorithm behind the decision is an NP-Hard problem which HINDSIGHT tries to solve using the Subset Sum problem technique or using the Greedy algorithm to make the calculations scalable.

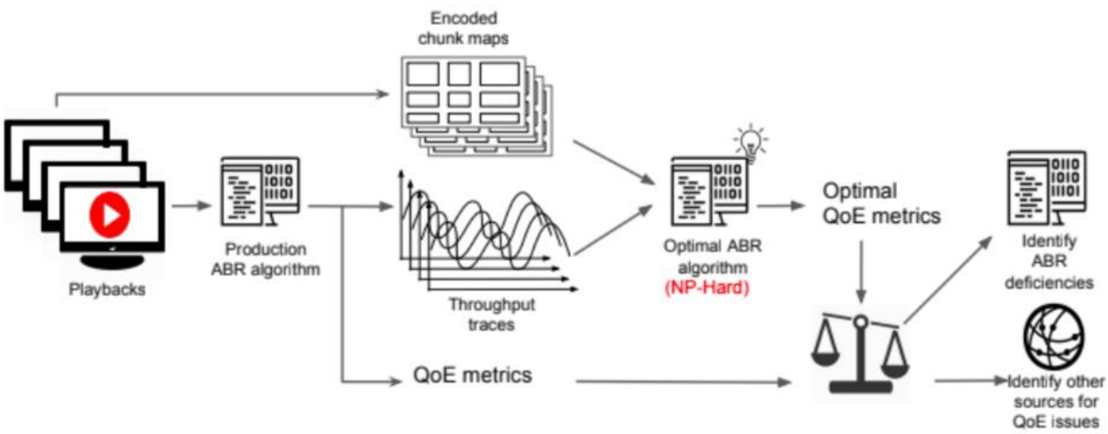

Fig 8 : Image Source : Hindsight (Netflix)

EXTRA WORK : YOUTUBE VS NETFLIX

- Netflix - starts with a lower-bitrate stream - > slowly scales up
- YouTube - majority videos only last a minute or two. - > more aggressive in sending out higher-quality video then scales down the video if necessary
- Netflix - not starting video playback for very low bandwidth
- Assumption : YouTube uses UDP/QUIC which is designed so that if a client has talked to a given server before, it can start sending data without any round trips, which makes web pages load faster.
- Netflix - not starting with low bandwidth as lower quality encodings might not be available for US users as opposed to other countries.
- Netflix - it does not load any frame for lower bandwidths - want to give maybe seamless experience to user.

		Youtube [https://www.youtube.com/watch?v=CWqpgjeJJRg]			
100 MBS		30 mins	60 mins	90 mins	120 mins
	10 MBS	no change	no change	no change	no change
	1 MBS (flunctuate b/w 480 to 360 but atlast constant at 720 p)	6 sec	3.4 sec	3.17 sec	7.45 sec
	100 KBS (flunctuate b/w 144 / 240 p)	55.5 [buffers for 15 - 20 secs at every 45 secs frame]	53.2 [same buffers for 15 - 20 secs at every 45 secs frame]	54.5 [buffers for 15 - 20 secs at every 45 secs frame]	52.3 [buffers for 15 - 20 secs at every 45 secs frame]
		Netflix [Chennai Express]			
100 MBS		30 mins	60 mins	90 mins	120 mins
	10 MBS	Buffers for 1-3 secs	Buffers for 1-3 secs	Buffers for 1-3 secs	Buffers for 1-3 secs
	1 MBS	55 secs but maintains quality	Buffers for 13 secs for degrade quality	buffers for 8.19 secs [maintain previos quality]	buffers for 10.1 secs [maintain previous quality]
	100 KBS (flunctuate b/w 144 / 240 p)	timeout [17 mins]			

Fig 8 : Netflix vs YouTube data points

OUTCOMES :

- Device dependent ABR.
- ABR caches the network variations and use retrospective information for future decisions to enhance QoE
- If higher bandwidth not seen earlier by ABR, it will not switch to HD content even though it can.

FUTURE WORK

- ABR performance on various devices (e.g. – Mobile,Tablets, etc.) – Cellular Network variation more.
- Low-Latency Live Streaming - Should perform well when streaming live videos that requires low latency, where latency is the maximum time between when the video is captured and when the user sees it. A key challenge is that since latency must be low, the client buffer is necessarily small and can hold no more than a few segments. Thus, video segments cannot be fetched by the client well in advance of when they are played out. A small buffer leaves little room for error as a single suboptimal ABR decision could result in draining the buffer, resulting in rebuffering

References:

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