Huawei iLab ● Superior Experience

Service Experience Technical White Paper Series

Video Experience-based Bearer Network Technical White Paper

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About This Document

Keywords

4K, experience, U-vMOS, bearer network, throughput, KQI, KPI

Introduction

This document discusses how to plan KPIs for video services carried on the fixed network targeting at varying U-vMOS scores. This document also gives analysis and typical examples for KPI and KQI correlation based on common networking of the fixed network, as well as conclusions on network bearer KPIs for 1080p/4K videos.

Abstraction

U-vMOS experience is closely related to "cloud", "pipe", and "device". "Cloud + pipe" determines the sQuality value and the prerequisites for sInteraction and sView. KPI compliance for "pipe" can then be determined based on the specified "cloud + device".

The U-vMOS algorithms for BTV and VOD vary, so are the KPIs for "cloud + device" services. Given the same U-vMOS score, the KPI requirements for "pipe" also vary.

With a specified U-vMOS score, the access mode is the determining factor with congestion not taken into consideration. When the U-vMOS score is ≥ 4, the KPI compliance is G.fast/FTTH > Super Vector > Vector > VDSL2.

The following conclusion is made from network KPI analysis on typical 1080p/4K video experience:

- The video source quality (bit rate as the typical factor) determines the minimum value of the upper limit of network RTT. The smaller the bit rate is, the smaller the upper limit of network RTT is. If the U-vMOS score is ≥ 4, the VOD source should reach at least 1080p_8M in VDSL2 access mode and the BTV source should reach at least 1080p_10M.
- A given U-vMOS score corresponds to a most effective average bit rate range that requires the lowest throughput requirements. For example, given the U-vMOS score of ≥ 4, the TCP throughput requirements are low when the 4K bit rate for VOD ranges from 15M to 30M in Vectoring access mode, and the UDP throughput requirements are low when the 4K bit rate for BTV ranges from 20M to 35M in VDSL2 access mode.
- The better the U-vMOS experience is, the higher requirements for low delay and high capacity are for the network architecture. The U-vMOS score may affect the RTT upper limit and the overall movement direction of the throughput curve. As the U-vMOS score

increases, the requirements for the RTT upper limit are lower and the requirements for the throughput are higher.

- The better the U-vMOS experience is, the higher requirements are for the video source (such as the bit rate) and the higher the most effective average bit rate range is. Taking the maximum value of TcpThrpmin as an example, when the U-vMOS score is 3.8, 1080p_10M to 4K_25M is the most effective bit rate range. When the U-vMOS score is 4.2, 4K_25M to 4K_50M is the most effective bit rate range.

Contents

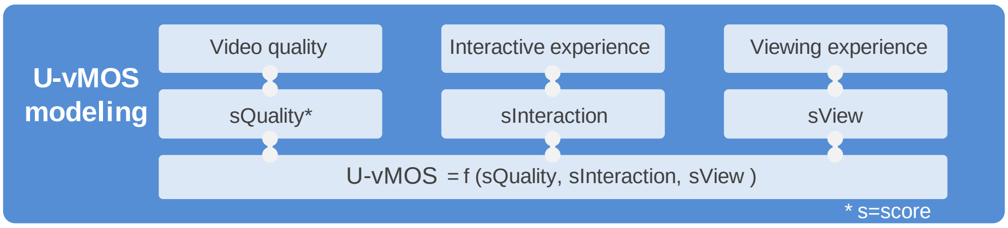
1 U-vMOS Overview

U-vMOS (User, Unified, Ubiquitous-Mean Opinion Score for Video) is the video experience measurement system developed by Huawei on video experience and network optimization. Huawei's 2012 iLab conducts human factor engineering experiments and uses eye trackers and physiographs to track people's reactions while watching videos. The data collected using the test instruments and the reports provided by test engineers help to set up a mathematical model and determine the U-vMOS scoring standard, aiming to reflect users' subjective video experience in an objective way.

The evaluation mode of the U-vMOS consists of three parts: video quality (sQuality), interactive experience (sInteraction), and viewing experience (sView). U-vMOS covers various aspects of video, such as the resolution, number of video sources, screen size, operating experience, and playback fluency. U-vMOS scores are based on a 1-5 scale, where 5 is excellent, 4 good, 3 average, 2 poor, and 1 bad. A higher score comes from a larger screen size, higher content resolution, and more fluent video viewing.

$$U - vMOS = f\left(sQuality, sInteraction, sView\right)$$

Figure 1-1 U-vMOS modeling methodology



1.1 sQuality

DisplaySize indicates the screen size, VideoComplexity the complexity of video content, Resolution the video resolution, BitRate the bit rate, CodecType the coding type, and VideoFrameRate the frame rate.

Figure 1-2 sQuality factors

sQuality = f(DisplaySize, VideoComplexity, Resolution, BitRate, CodecType, VideoFrameRate)

Codec type: H.264/H.265	Bit rate	Video complexity
Resolution	Frame rate	Display size

Table 1-1 Maximum values of sQuality at different resolutions on typical screens

Resolution	Screen size						
	4.5-inch	5.5-inch	7-inch	9.7-inch	42-inch	84-inch	100-inch
8K	5.0	5.0	5.0	5.0	5.0	4.9	4.9
5K	4.96	4.95	4.93	4.91	4.90	4.81	4.78
4K	4.90	4.88	4.86	4.82	4.78	4.66	4.62
2K	4.77	4.73	4.69	4.63	4.53	4.31	4.25
1080P	4.62	4.58	4.52	4.44	4.25	3.96	3.87
720P	4.32	4.26	4.17	4.05	3.69	3.29	3.18
480P	3.89	3.79	3.68	3.52	2.95	2.48	2.37
360P	3.49	3.38	3.25	3.06	2.36	1.91	1.80

1.2 sInteraction

The channel change time is marked as Zapping time, and the initial loading time as Loading time.

Figure 1-3 sInteraction factors

BTV	VOD
sInteraction = f（sZapping）	*sInteraction = f（sLoading）*
sZapping = f （zapping time）	*sLoading = f （loding Time, DisplaySize）*

Table 1-2 Typical sZapping values

sZapping	
Score	Delay (ms)
Excellent (5)	<=100
Good (4)	500
Average (3)	1000
Poor (2)	2000
Bad (1)	>4000

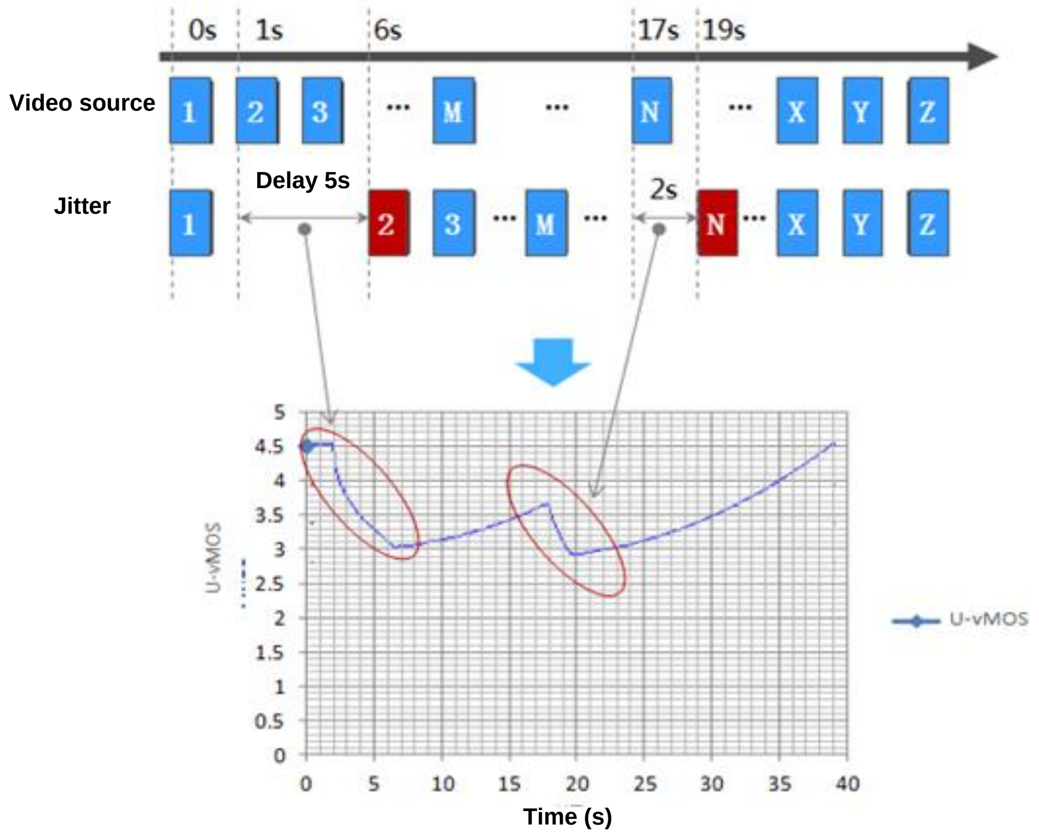
Table 1-3 Typical sLoading values

sLoading		
Score	sLoading Time@TV	sLoading Time@phone
Excellent (5)	<=100	<=100
Good (4)	1000	1000
Average (3)	2000	3000
Poor (2)	5000	5000
Bad (1)	8000	10000

1.3 sView

Buffers that occur because data packets do not reach the destination in time lead to video freezes, which have great impacts on video experience. Video quality deterioration is closely related to the stall duration and stall interval. For longer video playback, video quality deterioration is closely related to the stall frequency and stall duration. When video playback is restored from a stall, video experience experiences a slow recovery. If the video can normally play afterward, the real-time video quality experience is restored to normal. However, if another stall occurs, the video quality experience will be affected by both the stall duration and stall interval. Figure 1-4 shows real-time changes of U-vMOS scores during a video stall.

Figure 1-4 Real-time changes of U-vMOS scores during a video stall



The average duration for multiple video stalls is marked as Duration, the average interval between two video stalls as Interval, and the frequency of video stalls as Frequency.

Figure 1-5 sView factors

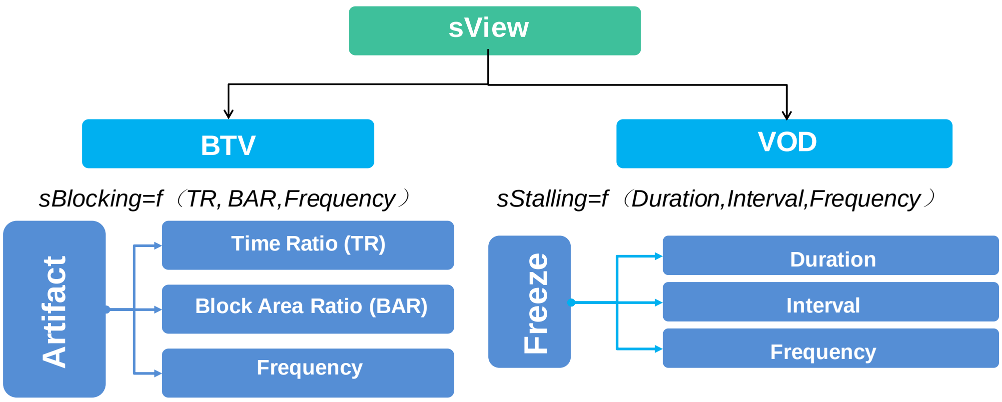


Table 1-4 Typical sStalling values on the smartphone/PAD (one-minute collection)

Typical sStalling values on the smartphone/PAD				
	Frequency	Average freeze interval (s)	Average freeze duration (s)	Freeze duration proportion
5	0	0	0	0%
4	1	0	2.7	5%
3	2	>10	3	10%
2	>2	<5	>5	15%
1	>3	<2	>10	30%

Table 1-5 Typical sStalling values on the TV (45-minute collection)

Typical sStalling values on the TV				
score	Frequency	Average freeze interval (s)	Average freeze duration (s)	Freeze duration proportion
5	0	0	0	0%
4	1	0	2.7	0. 1%
3	3	>30s	9	1%
2	6	>30s	22.5	5%
1	>10	>30s	>27	10%

Table 1-6 Typical sBlocking values

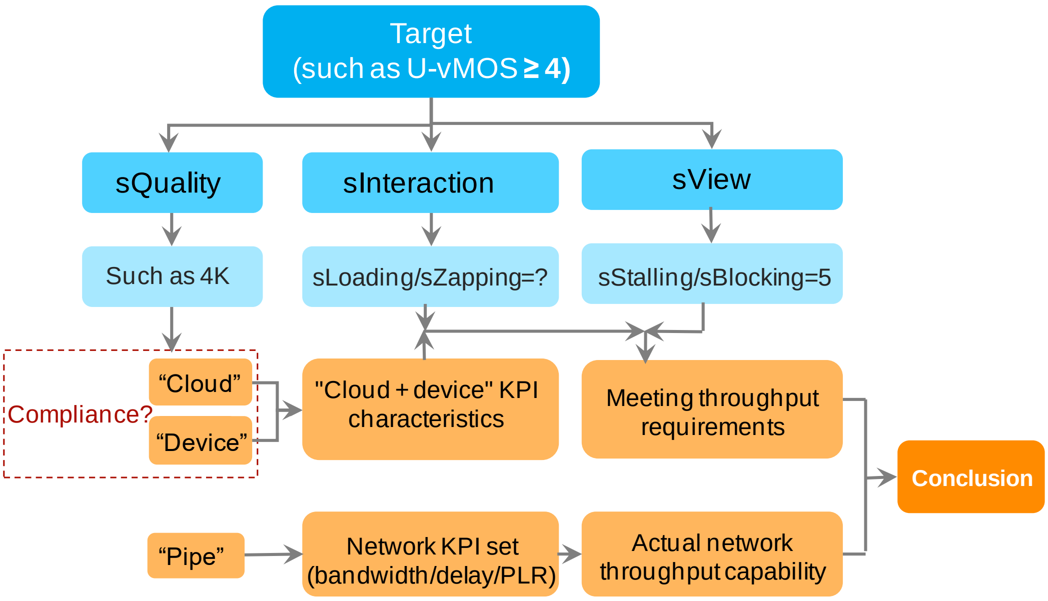
Typical sBlocking values			
sBlocking Score	Erratic display time proportion	Erratic display area proportion	Erratic display times
5	0%	0%	0
4	4%	35%	1
3	10%	45%	2
2	15%	35%	6
1	50%	95%	12

2 U-vMOS-based KPI Analysis for the Fixed Bearer Network

2.1 Methodology for U-vMOS-based KPI Evaluation

Basic principle: Video experience is a combined result of "cloud", "pipe", and "device". With a given U-vMOS score, "cloud + device" determines the sQuality. With a given characteristic KPI parameter set for "cloud + device", sInteraction and sView determine the TCP/UDP throughput requirements. Combined with the actual capabilities of "pipe", whether the bearer network is ready can then be determined.

Figure 2-1 Basic process of U-vMOS-based fixed network KPI planning



This principle applies to both preliminary E2E planning and the E2E evaluation on the existing video services. The recommended procedure is as follows:

Step 1 Determine the U-vMOS score (≥ 4.0 as the typical score) and break it down into requirements for the three factors (sQuality, sInteraction, and sView).

Step 2 Evaluate sQuality compliance based on the characteristics of "cloud + device".

Step 3 Based on the existing KPI characteristics and the requirements for sInteraction and sView, TCP/UDP throughput requirements can be determined. Based on the live network or target network architecture, the KPI parameter set for typical networks can be determined, delivering the actual throughput capability for "pipe". A comparison of the two can be used to conduct KPI compliance evaluation.

Step 4 Make a conclusion. In actual network planning, in case of BTV and VOD sharing the CDN server and network, network KPI parameter sets can be combined for BTV and VOD. Otherwise, plan the network as required.

----End

2.2 Determining the U-vMOS Target Score

The U-vMOS score of 5 is demanding for the current video industry. Currently, the typical U-vMOS target score is ≥ 4.0. The three factors of U-vMOS are closely relevant. Typically, the viewing experience has the highest requirements, that is, sView = 5. In this case, sInteraction can be ≥ 4, and sQuality then maps to 2K or 4K. Alternatively, the interactive experience can have the highest requirements, that is, sInteraction = 5. In this case, sView can be 5, and sQuality then maps to 1080p/2K/4K.

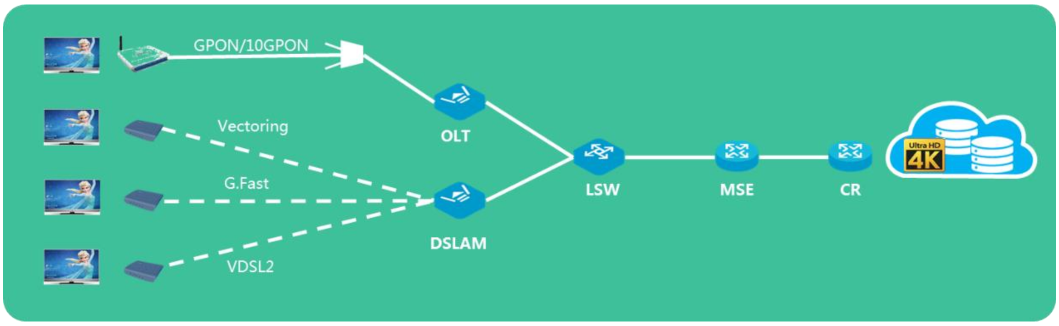
2.3 Evaluating "Cloud + Device" Compliance

Taking 4K video as an example, to ensure that the U-vMOS score is ≥ 4, "cloud" requires an average bit rate of ≥ 20 Mbps for VOD (based on the current H.265 coding capability, VBR) and an average bit rate of ≥ 30 Mbps for BTV (based on the current H.265 coding capability, CBR). "Device" requires hardware support for fluent 4K video playback, such as support for H.265.

2.4 Evaluating KPI Compliance of "Pipe"

The evaluation emphasis on "pipe" is E2E, that is, terminal <-> bearer network <-> CDN. The typical fixed bearer network consists of the access, metro, and backbone. With CDN deployment taken into consideration, metro/backbone is likely to exist.

Figure 2-2 Typical fixed bearer network for video service



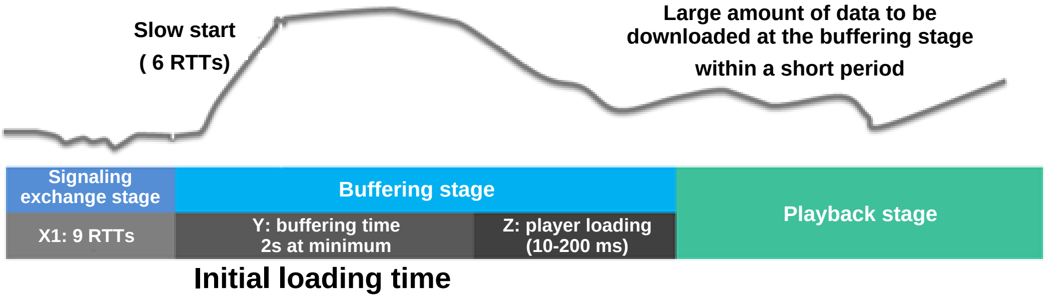
The range of TCP/UDP throughput requirements can be determined based on a given "cloud + device". The KPIs for "pipe" can be used to obtain the viable range of TCP/UDP throughput, and the latter must comply with the former. Whether the network with a specific U-vMOS score is ready can be determined based on a secondary comparison of the throughput exported by sView. The analysis varies from VOD to BTV.

2.4.1 VOD

Theoretical Analysis

1. Evaluate whether network KPIs are compliant with a given sInteraction (sLoading).

Figure 2-3 Composition of the HLS initial buffering time



The initial buffering comes in three stages: signaling exchange (X1), minimum time for decoding buffered media packets (Y), and video load on a player (Z). Ensure that X1+Y+Z ≤ T (target sLoading value).

With determined "cloud + pipe", the minimum TCP throughput is marked as $TcpThrp_{min}$. Then:

$$\mathbf{TcpThrp_{min}} = \frac{\boldsymbol{Rate_{video} * Buffer_{time} - Ds}}{\mathbf{T - (X + S) * RTT - \boldsymbol{T}_{load}}}$$

It can be inferred from the preceding formula that the denominator must be larger than 0. Then:

$$\mathbf{RTT} < \frac{\mathbf{T - \boldsymbol{T}_{load}}}{\mathbf{X + S}}$$

Here, $Rate_{video}$ indicates the average bit rate, $Buffer_{time}$ the minimum time for buffering media packets, Ds the data amount for TCP slow start, T the target initial buffering delay, X*RTT the RTT for signaling exchange, S*RTT the delay for TCP slow start, and T_{load} the delay for player loading.

With determined KPI characteristics of "pipe", the TCP throughput is marked as $TcpThrp_{pipe}$. Then:

$$\mathbf{TcpThrp_{\boldsymbol{pipe}}} \leq \mathbf{min(Max(BW), \frac{WSS}{RTT}, \frac{MSS}{RTT} \times \frac{1}{\sqrt{p}})}$$

Here, P indicates the packet loss rate, BW the physical bandwidth, MSS the minimum transmission unit, and RTT the delay from the terminal to the server.

"Pipe" indicates that the maximum TCP throughput provided by the network cannot be smaller than the minimum TCP throughput determined by "cloud + device". Considering that WSS/RTT is generally not a limiting factor, it can be ignored here. The data amount for TCP slow start can also be ignored because it is small. The inferred calculation formula is as follows:

$$\mathbf{min}(\mathbf{Max}(\mathbf{BW}), \frac{\mathbf{MSS}}{\mathbf{RTT}} \times \frac{\mathbf{1}}{\sqrt{\mathbf{p}}}) \geq \frac{\boldsymbol{Rate_{video}} * \boldsymbol{Buffer_{time}}}{\mathbf{T} - (\mathbf{X} + \mathbf{S}) * \mathbf{RTT} - \boldsymbol{T}_{\mathbf{load}}}$$

2. Use sView to evaluate whether network KPIs are compliant.

   sView is typically on a 1-5 score scale. Based on Huawei iLab test results, single TCP throughput should be ≥ 1.5 times of the average bit rate.

$$\mathbf{min}(\mathbf{Max}(\mathbf{BW}), \frac{\mathbf{MSS}}{\mathbf{RTT}} \times \frac{\mathbf{1}}{\sqrt{\mathbf{p}}}) \geq \mathbf{1.5} * \boldsymbol{Rate_{video}}$$

3. Get the final formula.

   Formula 1: whether network KPIs meet experience KPIs for the VOD source

$$\mathbf{min}(\mathbf{Max}(\mathbf{BW}), \frac{\mathbf{MSS}}{\mathbf{RTT}} \times \frac{\mathbf{1}}{\sqrt{\mathbf{p}}}) \geq \boldsymbol{max}(\frac{\boldsymbol{Rate_{video}} * \boldsymbol{Buffer_{time}}}{\mathbf{T} - (\mathbf{X} + \mathbf{S}) * \mathbf{RTT} - \boldsymbol{T}_{\mathbf{load}}}, \mathbf{1.5} * \boldsymbol{Rate_{video}})$$

   Here:

$$\mathbf{RTT} < \frac{\mathbf{T} - \boldsymbol{T_{load}}}{\mathbf{X} + \mathbf{S}}$$

   The right part of the formula is determined by "cloud + device" except for RTT. In the left-part KPIs of the formula, BW indicates the physical bandwidth, RTT the delay, and P the packet loss rate. If the preceding formula is met, the target sInteraction/sView values can be met. With the sQuality value already met the requirement, the U-vMOS target score can be met.

Instance Analysis

Table 2-1 lists the typical KPI characteristic values for the fixed bearer network.

Table 2-1 Typical network KPIs for the fixed bearer network

Access Mode	RTT	PLR	Bandwidth Per User
VDSL2	10-20 ms	10^{-4-5}	50M@ < 1000m
Vectoring	10-20 ms	10^{-4-5}	50-120M@ < 800m
Super Vector	10-20 ms	10^{-4-5}	100-300M@300-500m
G.fast	2-6 ms	10^{-4-5}	200M-1.2G@100-500m

Access Mode	RTT	PLR	Bandwidth Per User
FTTH	2-3 ms	< 4 x 10^{-7}	20M-1G (common planning)

Metro/Backbone	RTT	PLR	Bandwidth
SDH	50-120 us/hop	0/hop (no congestion)	No congestion
WDM	25 us/hop	0/hop (no congestion)	No congestion
Router	30-50 us/hop (no congestion)	0/hop (no congestion)	No congestion
Switch	< 5 us/hop	0/hop (no congestion)	No congestion
Fiber	5us/km	< 4 x 10^{-7}	No congestion

The metro/backbone architecture is similar for all types of fixed bearer networks. The difference lies in the access network. In any typical access mode, RTT/PLR/BW is always changing within a specific range. Regardless of changes, the $TcpThrp_{pipe}$ range can be obtained, which includes the minimum and maximum values in the left part of formula 1. In the right part of formula 1, all the items except for RTT are known conditions, whose minimum and maximum values can also be obtained. The final conclusion can be made by a comparison of the ranges in the left and right parts of formula 1. An example is as follows:

Target: U-vMOS ≥ 4; sQuality for 4K (20M); sInteraction = 4, with T as 1000 ms; sView = 5, indicating no freeze

"Cloud + device" conditions: The value of $Rate_{video}$ is 20 Mbps. Taking the mainstream video streaming technology HLS as an example, the minimum time for decoding buffered media packets ($Buffer_{time}$) is 2s, the signaling exchange time is X x RTT (9 RTTs), the TCP slow start time is S x RTT (6 RTTs), the time for player loading (T_{load}) is 200 ms, and the MSS is 1460 bytes.

Table 2-2 KPI compliance for typical 4K service (20M bit rate)

VideoType	$Rate_{video}$ (Mbps)	Upper delay limit (ms)	$TcpThrp_{min}$ Minimum (Mbps)	$TcpThrp_{min}$ maximum(Mbps)	E2E network		RTT (ms)	$TcpThrp_{Pipe}$ Minimum (Mbps)	$TcpThrp_{Pipe}$ maximum(Mbps)	Pipe support
4K BTV H.265	20	53.33	63.12	82.69	VDSL2	1 Switch+2 Router+200km fiber	11.085~21.085	0.00	50.00	Not supported
	20	53.33	63.12	82.69	Vectoring		11.085~21.085	50.00	120.00	May support
	20	53.33	63.12	82.69	Super Vector		11.085~21.085	55.28	300.00	May support
	20	53.33	53.07	57.66	G.Fast		3.085~7.085	164.53	1174.01	Support
	20	53.33	53.07	54.15	FTTH		3.085~4.085	20.00	1000.00	Basically support

"Pipe" conclusion 1: In VDSL2 access mode, the pipe cannot meet requirements because the maximum value of TCP throughput ($TcpThrp_{Pipe}$) is less than the minimum TCP throughput required for playback ($TcpThrp_{min}$).

"Pipe" conclusion 2: In G.fast access mode, the pipe can meet requirements because the minimum value of TCP throughput ($TcpThrp_{Pipe}$) for "pipe" is greater than the maximum value of TCP throughput ($TcpThrp_{min}$) required for playback.

"Pipe" conclusion 3: In Vectoring/Super Vector/FTTH access mode, the pipe may meet requirements because the range of TCP throughput ($TcpThrp_{Pipe}$) for "pipe"and the range of TCP throughput for playback ($TcpThrp_{min}$) have intersections. In actual deployment, the specific requirements can be determined based on factors like the access line quality and length. In FTTP deployment, some KPIs meet requirements with common planning of 20 to 1000 Mbit/s, and the bandwidth must be greater than 54.15 Mbit/s. All the requirements can be met by appropriate network planning. The delay KPI can meet the upper threshold requirement.

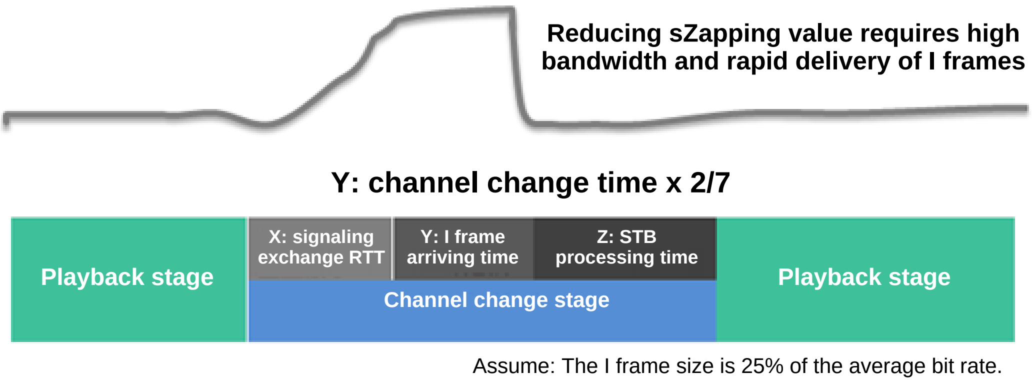
2.4.2 BTV

Theoretical Analysis

1. Evaluate whether network KPIs are compliant with a given sInteraction (sZapping).

For a mainstream UDP BTV system, the channel change comes in three stages: signaling exchange (X), download of a complete I frame (Y), and video load on a player (Z). Ensure that X+Y+Z ≤ T (target sZapping value).

Figure 2-4 Composition of the UDP initial buffering time



To speed up BTV channel change, the fast channel change (FCC) solution is generally deployed. To ensure normal operation of the FCC solution, ensure that the bandwidth per user is ≥ 1.3 times of the average bit rate.

With determined "cloud + device", the minimum UDP throughput is marked as $UdpThrp_{min}$.

$$\mathbf{UdpThrp_{min}} = \mathbf{max}\left(\frac{\boldsymbol{Rate_{video}} * \boldsymbol{GopTime} * \boldsymbol{IFRatio}}{\mathbf{T} - \mathbf{X} * \boldsymbol{RTT_{join}} - \boldsymbol{T_{Load}}}, \mathbf{1.3} * \boldsymbol{Rate_{video}}\right)$$

Here, $Rate_{video}$ indicates the average bit rate, GopTime the duration for GoP packets, T the target channel change time, $X*RTT_{join}$ the RTT for signaling exchange (joining a multicast group), and T_{load} the delay for player loading.

With determined "pipe", the maximum value of $UdpThrp_{pipe}$ is theoretically the physical bandwidth marked as BW.

$$\mathbf{UdpThrp_{pipe}} \le \boldsymbol{BW}$$

"Pipe" indicates that the maximum UDP throughput provided by the network cannot be smaller than the minimum UDP throughput determined by "cloud + device".

$$\mathbf{BW} \geq \mathbf{max}\left(\frac{\boldsymbol{Rate_{video} * GopTime * IFRatio}}{\mathbf{T - X} * \boldsymbol{RTT_{join} - T_{Load}}}, \mathbf{1.3} * \boldsymbol{Rate_{video}}\right)$$

Considering that BTV services are not sensitive to delay, the denominator in the preceding formula must be greater than 0 and the RTT is typically not less than RTT_{join}.

$$\mathbf{RTT} < \boldsymbol{RTT_{join}} < \frac{\mathbf{T} - \boldsymbol{T_{Load}}}{\mathbf{X}}$$

2. Use sView to evaluate whether network KPIs are compliant.

   The sView value of 5 is typically used, indicating that no erratic display occurs during video playback. Referring to the TR-126 standard, the network PLR of 4K BTV with no erractic display should be < 10^{-6}. Currently, the PLR is required to be decreased to 10^{-4} using technologies like RET at the application layer.

$$\boldsymbol{PLR} \leq \mathbf{10^{-6}} \left(\text{RET not considered, RET as } 10^{-4} \right)$$

3. Get the final formula.

   Formula 2: whether network KPIs meet experience KPIs for the BTV source

$$\mathbf{RTT} < \frac{\mathbf{T} - \boldsymbol{T_{load}}}{\mathbf{X}}$$

$$\mathbf{BW} \geq \mathbf{max}\left(\frac{\boldsymbol{Rate_{video} * GopTime * IFRatio}}{\mathbf{T - X} * \boldsymbol{RTT_{join} - T_{Load}}}, \mathbf{1.3} * \boldsymbol{Rate_{video}}\right)$$

$$\boldsymbol{PLR} \leq \mathbf{10^{-6}} \left(\text{RET not considered, RET as } 10^{-4} \right)$$

Instance Analysis

With reference of the counterpart in section 2.4.1 "VOD", the RTT/PLR/BW changes within a specific range for each typical access mode. Regardless of changes, the RTT/PLR range can be obtained and whether RTT/PLR meets requirements can be determined based on formula 2.

With "cloud + device" determined, the RTT range can be specified. This can be used to determine the range of the UDP throughput for BTV services, that is, the maximum and minimum values of the UDP throughput. An example is as follows:

Target: U-vMOS ≥ 4; sQuality for 4K (30M); sInteraction = 4, with T as 500 ms; sView = 5, indicating no erractic display

"Cloud + device" conditions: The value of $Rate_{video}$ is 30 Mbps, the GopTime is 2s, the proportion of I frames to GoP (IFRatio) is 25%, the signaling exchange time is $X*RTT_{join}$ (1 RTT_{join}, $RTT_{join} \approx RTT$), and the time for playback load (T_{load}) is 200 ms.

Table 2-3 KPI compliance for typical 4K service (30M bit rate)

VideoType	$Rate_{video}$ (Mbps)	Upper delay limit (ms)	$UdpThrp_{min}$ Minimum (Mbps)	$UdpThrp_{min}$ maximum(Mbps)	Upper PLR (no RET)	Upper PLR (with RET)	E2E network		RTT (ms)	BW (Mbps)	PLR	Pipe support
4K BTV	30	350.00	44.26	45.60	1.00E-06	1.00E-04	VDSL2	1 Switch+2 Router+200 km fiber	11.085–21.085	0–50	1.04E-5–1.00E-4	Not supported
	30	350.00	44.26	45.60	1.00E-06	1.00E-04	Vectoring		11.085–21.085	50–120	1.04E-5–1.00E-4	May support
	30	350.00	44.26	45.60	1.00E-06	1.00E-04	Super Vector		11.085–21.085	100–300	1.04E-5–1.00E-4	May support
	30	350.00	43.24	43.74	1.00E-06	1.00E-04	G.Fast		3.085–7.085	200–1200	1.04E-5–1.00E-4	May support
	30	350.00	43.24	43.36	1.00E-06	1.00E-04	FTTH		3.085–4.085	20–1000	8.00E-07	Basically support

"Pipe" conclusion 1: In VDSL2 access mode, the pipe cannot meet requirements because the maximum value of physical bandwidth is less than the minimum UDP throughput required for playback ($UdpThrp_{min}$).

"Pipe" conclusion 2: In Vectoring/Super Vector/G.fast access mode, the pipe may meet requirements, and the RTT can meet requirements. In Vectoring mode, the bandwidth can meet requirements in most cases, depending on the line quality. In Super Vector/G.fast access mode, the bandwidth can meet requirements. The PLR can meet requirements when RET is deployed.

"Pipe" conclusion 3: In FTTH access mode, the pipe can basically meet requirements, the RTT/PLR can meet requirements, and a common bandwidth planning of 20 to 1000M can basically meet requirements. All the requirements can be met by appropriate network planning.

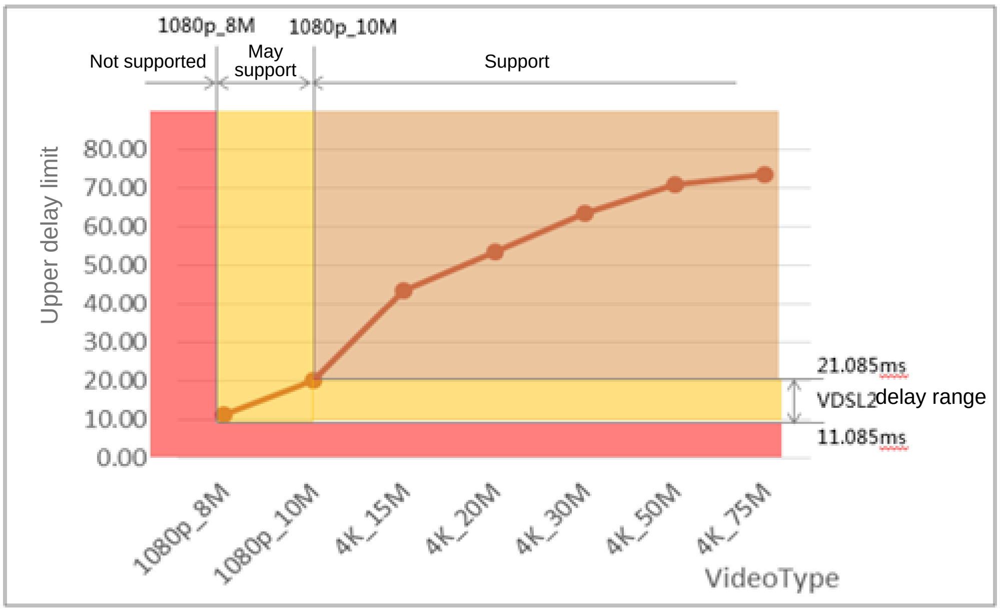
3 Summary of KPI Analysis for 1080p/4K Video on the Fixed Bearer Network

3.1 Video Source Quality Determines the Minimal Value of RTT Upper Limit

The lower the average bit rate of video source is, the smaller the sQuality value is and the larger the sInteraction value is. In this case, a smaller initial buffering delay (T) brings lower requirements for the RTT upper limit. In actual network situations, RTT cannot be unlimited small. Therefore, there should be the lowest requirements for the bit rate of video source.

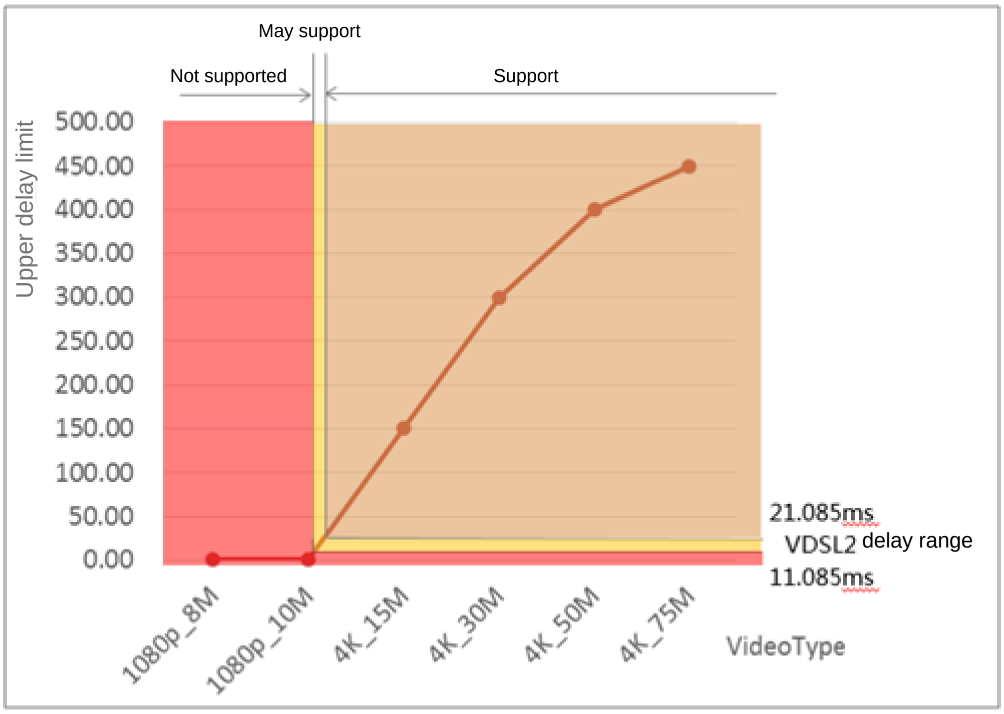
As shown in Figure 3-1, when the U-vMOS score is ≥ 4, the bit rate of VOD in VDSL2 access mode should reach 1080p_8M.

Figure 3-1 Requirements for the RTT upper limit of VOD source (U-vMOS ≥ 4)



As shown in Figure 3-2, when the U-vMOS score is ≥ 4, the bit rate of BTV in VDSL2 access mode should be higher than 1080p_10M.

Figure 3-2 Requirements for the RTT upper limit of BTV source (U-vMOS ≥ 4)



3.2 A Specific U-vMOS Score Maps to a Most Effective Average Bit Rate Scope

The average bit rate of video source is not always proportional to throughput requirements. Instead, there is a most effective average bit rate range.

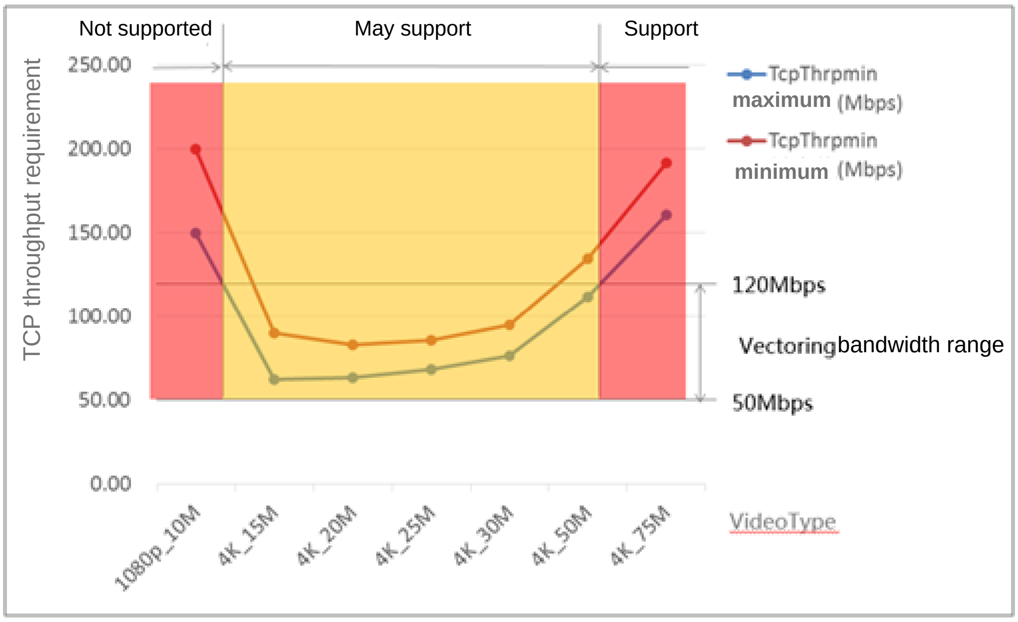
It can be inferred by formula 1 in "Theoretical Analysis" of section 2.4.1 "VOD" that TcpThrpmin is proportional to the average bit rate and inversely proportional to the initial buffering time (T). Therefore, a lower bit rate leads to a smaller TcpThrpmin.

Section 3.1 "Video Source Quality Determines the Minimal Value of RTT Upper Limit" tells us that a smaller average bit rate of video source typically leads to a smaller sQuality value and a larger sInteraction value. In this case, a smaller initial buffering delay (T) leads to a larger TcpThrpmin. These factors interact with each other. Therefore, the average bit rate of video source is not always in direct proportion to throughput requirements.

That is, when the average bit rate of VOD is small, there are higher requirements for the initial loading time, leading to higher requirements for TCP throughput; when the average bit rate of VOD is large, there are less restrictive requirements for the initial loading time, but the requirements for TCP throughput are still high. The TCP throughput requirements are relatively low only when the average bit rate is medium. Obviously, the average bit rate is the most effective only when TcpThrpmin has a smallest value.

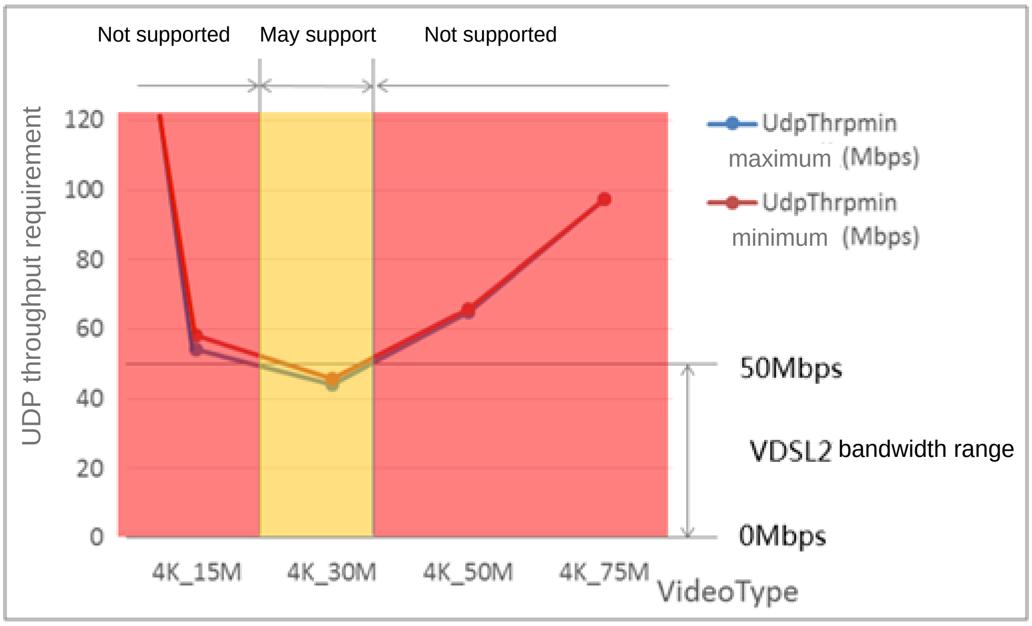
As shown in Figure 3-3, when the U-vMOS score is ≥ 4, the 4K bit rate in Vectoring access mode ranges from 15M to 30M, and the TCP through requirements are not that restrictive.

Figure 3-3 Network bandwidth requirements for VOD source (U-vMOS ≥ 4)



A similar conclusion can be drawn from formula 2 in "Theoretical Analysis" of section 2.4.2 "BTV". As shown in Figure 3-4, the UDP throughput requirements are not that restrictive only when the 4K bit rate in VDSL2 access mode ranges from 20M to 35M.

Figure 3-4 Network bandwidth requirements for BTV source (U-vMOS ≥ 4)



3.3 Good U-vMOS Experience Comes from Low-Delay, High-Capacity Network Architecture

The U-vMOS target score may affect the overall trend of RTT and TCP throughput curves. The higher the U-vMOS target score is, the less restrictive requirements are for RTT and more restrictive requirements are for throughput.

Figure 3-5 and Figure 3-6 show RTT and TCP throughput requirements at varying U-vMOS scores for the VOD source. The analysis for the BTV source is similar and therefore not detailed here.

Figure 3-5 Requirements for RTT upper limit at varying U-vMOS scores for the VOD source

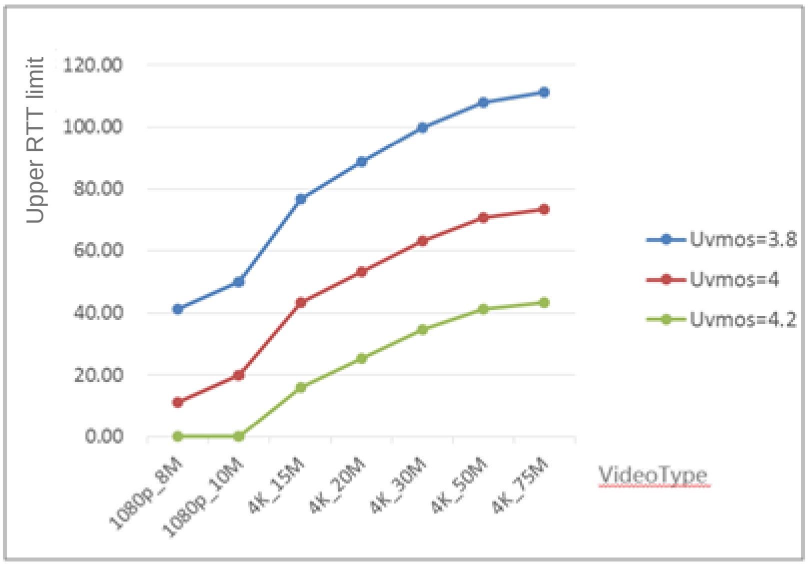
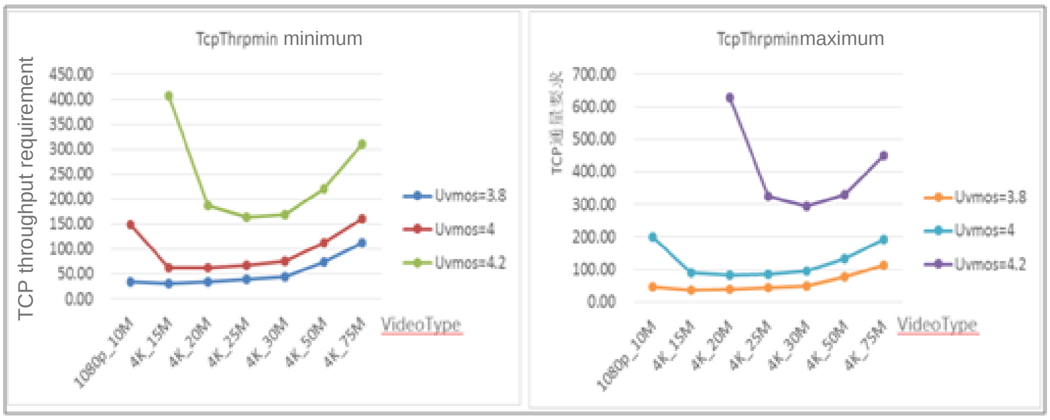


Figure 3-6 Requirements for TCP throughput at varying U-vMOS scores for the VOD source



3.4 Good U-vMOS Experience Has Higher Requirements for Video Source (Such as Bit Rate)

The U-vMOS score affects a most effective bit rate range in addition to the throughput curve.

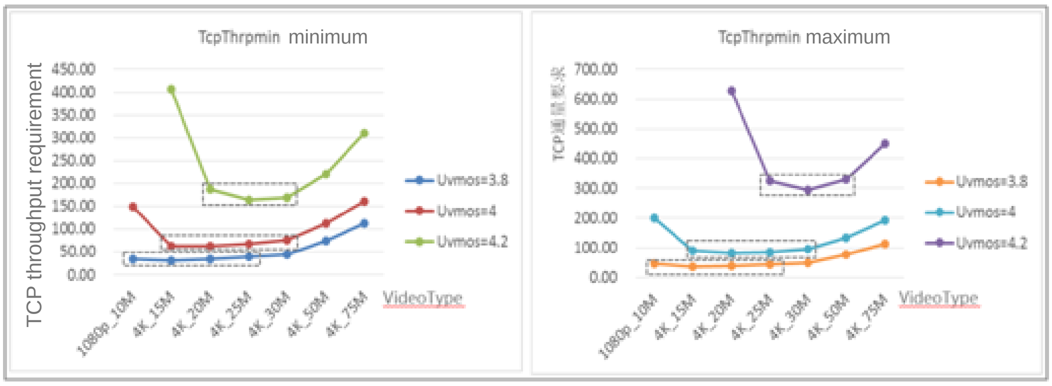
Figure 3-7 uses the maximum value of TcpThrpmin for the VOD source as an example.

1. When the U-vMOS score is 3.8, 1080p_10M to 4K_25M is the most effective bit rate range.
2. When the U-vMOS score is 4.0, 4K_15M to 4K_30M is the most effective bit rate range.
3. When the U-vMOS score is 4.2, 4K_25M to 4K_50M is the most effective bit rate range.

A similar conclusion can be inferred by the minimal value of TcpThrpmin.

The analysis for the BTV source is similar and therefore not detailed here.

Figure 3-7 Analysis of the most effective bit rate range at varying U-vMOS scores for the VOD source



A References

1. Huawei U-vMOS Video Experience Standard Technical White Paper V1.0
2. OTT Video Initial Loading Technical White Paper
3. TCP Throughput and Network Performance Technical White Paper
4. Technical White Paper for Bandwidth Requirements on OTT Fluent Playback