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Legacy Video Support in Residential Premises

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Table of Contents

Executive Summary	4
1 Terminology	5
1.1 References	5
1.2 Abbreviations	6
2 Introduction	7
2.1 Business Drivers	7
2.2 4K video and HDTV video	7
2.3 VR Video	9
3 End User Network for video support	9
3.1 Residential Internet Devices	9
3.1.1 Residential Gateway	9
3.1.2 Router	10
3.2 Features of Video Service Device	11
Appendix I. Network Performance Targets to Support Video	12
I.1 Network RTT of video on IPTV	12
I.2 Network RTT of video on OTT	13
Appendix II. Network Performance Targets to Support VR	14
II.1 Network bandwidth and RTT of VR	14
II.2 Network bandwidth and RTT of VR	14
Appendix III. Interconnection Technologies	15
III.3 Wireline interconnection	15
III.3.1 A wired end user network connects devices to each other and to the Internet using cables ..	15
III.3.2 Wireless interconnection	15

List of Tables

Table 1 The format of different grades of 4K and HD videos of IPTV	8
Table 2 The format of different grades of 4K videos of OTT	8
Table 3 The format of different grades of VR Video	9
Table 4 The network RTT of videos on IPTV	12
Table 5 The network RTT of videos on OTT	13
Table 6 The network bandwidth and RTT of VR	14
Table 7 The network PER of VR	14

Executive Summary

Video (IPTV&OTT) service is one of the most important services that operators provide to residential customers. The interconnected in-premises network significantly impacts the Quality of Service (QoS) and Quality of Experience (QoE) of video streaming, especially for 4k video, 8k and VR. It is valuable to have a marketing document to analyze the service requirements for bandwidth, latency, packet loss rate, etc., and to give insight into the interconnection technologies for video services support within premises, including both wireline technologies (FTTR, G.hn, Ethernet, etc.) and wireless technologies (Wi-Fi, etc.).

1 Terminology

1.1 References

The following references are of relevance to this Marketing Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Marketing Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at the www.broadband-forum.org.

Document	Title	Source	Year
[1] BT.2020	<i>Parameter values for ultra-high definition television systems for production and international programme exchange</i>	ITU-R	2016
[2] Wi-Fi QoS Management	<i>Wi-Fi QoS Management™ Specification Version 2.0</i>	WFA	2021
[3] ISG NGP	<i>Next Generation Protocols - Market Drivers and Key Scenarios</i>	ETSI	2012
[4] White paper	<i>Could VR Scenario white paper</i>	CAICT	2018
[5] White paper	<i>VR video operator opportunities in a booming market</i>	Huawei	2018
[6] F5G Use Cases	<i>ETSI GR F5G 002 V1.1.1 (2021-02), Fifth Generation Fixed Network (F5G); F5G Use Cases Release #1</i>	ETSI	2021
[7] G.9960	<i>Unified high-speed wireline-based home networking transceivers - System architecture and physical layer specification</i>	ITU-T	2018
[8]	<i>HomeGrid Forum Webinar: In-Stat's Perspective on Integrated, Segregated & Next-Generation Wired In-Home Networks</i>		
[9] Wi-Fi EasyMesh	https://www.wi-fi.org/discover-wi-fi/wi-fi-easymesh		
[10] TR-126	<i>Triple-play Services Quality of Experience (QoE) Requirements</i>	BBF	2006
[11] TR-398i2	<i>Wi-Fi Residential & SOHO Performance Testing</i>	BBF	2021
[12] Wi-Fi QoS Management™	<i>Wi-Fi QoS Management™ Specification Version 2.0</i>	WFA	2021
[13] Wi-Fi CERTIFIED WMM™	https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-wmm-programs	WFA	

1.2 Abbreviations

This Marketing Report uses the following abbreviations:

Term	Definition
4k	Video displays 3,849×2,160 pixels
8k	Video displays 7,680×4,320 pixels
AP	Access Point
BTV	Broadcast TV
DSCP	Differentiated Services Code Point
FE	Fast Ethernet (100 Mbps)
FHD	Full HD up to 1920x1080 pixels
FTTR	Fiber to the Room
GE	Gigabit Ethernet
GPU	Graphics Processing Unit
HD	High Definition
HLS	HTTP Live Streaming
IPTV	Internet Protocol Television
KPI	Key Performance Indicator
OTT	Over the Top
PC	Personal Computer
PER	Packet Error Rate
PPD	Pixel per Degree
QoE	Quality of Experience
QoS	Quality of Service
RG	Residential Gateway
RTT	Round Time Trip
TV	Television
UDP	User Datagram Protocol
UHD	Ultra HD
VR	Virtual Reality
WAN	Wide Area Network
WMM	Wi-Fi Multimedia
XR	Extended Reality, includes VR, Augmented Reality (AR), and Mixed Reality (MR)

2 Introduction

Video (IPTV&OTT) service is as one of the most important services that operators provide to residential customers. The interconnected in-premises network significantly impact the Quality of Service (QoS) and Quality of Experience (QoE) of video streaming, especially for HD, 4k, and VR.

2.1 Business Drivers

The bandwidth requirements of 4K video are challenging the performance of (1) physical layer transport and (2) existing home networking technologies, requiring network operators to consider enhancing their mass market WAN access technologies and the deployment of home network upgrades or new technologies, and increasing performance monitoring. Moreover, current centralized models of content delivery place increasing loads on metro network bandwidth so with the advance of 4K TV, carriers/operators are considering enhancing and placing content delivery functions and/or service optimization functions closer to the user. These network upgrades and network enhancements are new business drivers for network operators and OTT providers.

2.2 4K video and HDTV video

4K Video (UHD) is a high resolution video format with a minimum resolution of 3840×2160 pixels in a 16 × 9 aspect ratio. According to the definitions in ITU-R Recommendation BT.2020 specified in 2012[1], various aspects of 4 K Video (UHD) TV are enhanced compared to the current Full HD sets.

- Higher Resolution - 4 times the pixels compared to Full HD: 4K has 3840×2160 resolution versus the 1920×1080 of Full HD.
- Bigger Color Space - 64x the color range with 10-bit coding per color (1.07 billion colors) versus Full HD 8-bit coding (16.77 million colors).
- Higher Frame Rate - 4K allows for frame rates up to 120fps (frames per second) versus 60 fps in Full HD.
- Wider Luminance Range - initially the brightest and darkest 4K pixels will be comparable to the Full HD, although the luminance will probably be widened.

Table 1 describes the format of various grades of 4K and HD video by IPTV and is based on [1][3].

Table 1 The format of different grades of 4K and HD videos of IPTV

	Format	Compression	Average Bitrate	Reference (Mbps)	Typical GoP Time Interval (S)
IPTV live BTV (UDP)	HD 720P (1280*720/30P/8bit)	H.264	3~6 Mbps	5	1~1.5
	FHD 1080P (1920*1080/30P/8bit)		6~10 Mbps	8	1~1.5
	Quasi 4K (3840*2160/30P/8bit)	H.265 (HEVC)	15~20 Mbps	20	2
	Carrier-grade 4K (3840*2160/60P/10bit)		25~35 Mbps	30	2
	Ultra 4k (3840*2160/120P/12bit)		40~55 Mbps	48	2

Table 2 describes the format of various grades of 4K video by OTT and is based on [1][2][3].

Table 2 The format of different grades of 4K videos of OTT

	Format	Compression	Average Bitrate	Reference (Mbps)	Typical GoP Time Interval (S)
OTT (HTTP, streaming media, HLS, Unicast)	HD 720P (1280*720/30P/8bit)	H.264	2~5 Mbps	4	Variable
	FHD 1080P (1920*1080/30P/8bit)		6~10 Mbps	8	Variable
	Quasi 4K (3840*2160/30P/8bit)	H.265 (HEVC)	15~20 Mbps	16	3
	Carrier-grade 4K (3840*2160/60P/10bit)		25~35 Mbps	25	3
	Ultra 4k (3840*2160/120P/12bit)		40~55 Mbps	38	3

Some specific network performance targets for supporting video formats are shown in Appendix I.

2.3 VR Video

Virtual reality (VR) is a computer-generated scenario that simulates a realistic experience. The immersive environment can be similar to the real world in order to create a lifelike experience grounded in reality or science fiction.

VR use cases are varied. Customer applications include VR IMAX, live broadcast, 360° videos, gaming, music fitness, etc. while business applications contain education, eSports arena, marketing, healthcare, tourism, etc. according to the “Could VR Scenario while paper” from CAICT [5]. The network requirement of VR mainly depends on the VR format, interaction type, the location where data is processed. Video rendering in the cloud or edge requires video bandwidth through the access and premises networks, video rendering in a local PC can require video bandwidth through the premises network, and video rendering in the headset is local. In reality, cloud VR will have more strict requirement on E2E network since the processed data or command need to be transferred through the whole network. In this section, cloud VR is considered for network requirement.

VR video is a typical application by customers. Table 3 describes the format of various grades of VR video and is based on [6].

Table 3 The format of different grades of VR Video

	Format	Application time interval (min)	PPD (pixel per Degree)	Single-eye resolution	Compression	Typical bit rate (Mbps)
VR (weak interaction)	4K VR (3840*1920/30P/8bit)	<20	11	960*960	165:1	16
	8K VR (7680*3840/30P/8bit)	<20	21	1920*1920	165:1	64
	12K VR (11520*5760/60P/10bit)	20~60	32	3840*3840	215:1	419
	24K VR (23040*11520/120P/12bit)	>60 min	64	7680*7680	350:1	4395

Some specific network performance targets for supporting VR are shown in Appendix II.

3 End User Network for video support

3.1 Residential Internet Devices

3.1.1 Residential Gateway

The Residential Gateway (RG) is the key device that serves as a bridge to connect the access network of service provider and home network. The RGs behaviors significantly impact the QoS of video service. A full

set of RG requirements are defined in BBF WT-124. In order to support all video services that are described in Chapter 3 **Error! Reference source not found.**, dedicated performance and function should be supported.

3.1.1.1 Physical interface

WAN interface

Currently, the typical data rate of VDSL2 cannot reach above 150Mbps; limiting the number and types of video streams. Therefore, G.fast and GPON, which offer up to 1 Gbps data rate, and XG-PON/XGS-PON are recommended as the WAN interfaces for video service delivery.

LAN interface

- For video service via Ethernet, the recommendation is that the RG integrates at least GE interface instead of a FE interface that only supports 100Mbps data rate. Further, to support future high-speed services, a 2.5G interface is recommended.
- For the service flow via wireless, the recommendation is that the RG, at a minimum, support the 802.11ac/802.11ax Wi-Fi interface. To support evolving video services, such as VR with 60fps, 3*3 or 4*4 configuration with MU-MIMO are recommended. New standards, such as Wi-Fi 7, support higher data rates, lower latency, and enhanced reliability for AR/VR/XR applications.
- Support of data transmission through power lines, telephone wires, and coaxial cables via standards such as G.hn and MoCA, is also recommended as options to be included in the RG.

3.1.1.2 Functionality

- It is recommended that the RG supports WMM™[13] and QoS Management™[12], if using Wi-Fi to carry the video service.
- It is recommended that the RG supports DSCP, 802.1p to provide high priority for special service.
- It is recommended that the RG supports the MOD transform function defined in BBF WT-399.

3.1.2 Router

A router is a networking device that forwards data packets between computer networks, which is a stand-alone device or a part of an RG. Routers perform the traffic directing functions on the Internet. Data sent through the internet, such as a web page, email or video, is in the form of data packets. A packet is typically forwarded from one router to another router through the networks that constitute an internetwork (e.g. the Internet) until it reaches its destination node.

The most familiar type of IP routers are home and small office routers that simply forward IP packets between the home computers and the Internet.

3.1.2.1 Physical interface

WAN interface

Currently, most home wireless routers support GE ports as uplink ports. With the evolution of chip technology in the future, more high-speed interfaces will be supported, such as 2.5G RJ45 interface and PON interface.

LAN interface

Like the RG, all home wireless routers support both wired and wireless physical ports.

- For video service via Ethernet, the recommendation is that the Router integrates at least GE interface instead of an FE interface that only supports 100Mbps data rate. The recommendation is the Router supports a 2.5G interface for future high-speed services.
- For the service flow via wireless, Router is recommended to support 802.11ac/802.11ax Wi-Fi interface. To support the evolving video services, such as VR with 60fps. 3*3 or 4*4 configuration with MU-MIMO are recommended.
- Router could also support 802.11ad to support 10G access speed
- The Router could also support ZigBee, Z-wave or Bluetooth interface.

3.1.2.2 Functionality

- It is recommended that the Router supports Wi-Fi EasyMesh, a new standard from the Wi-Fi Alliance for Wi-Fi roaming and optimisation across multiple access points (i.e. "Wi-Fi mesh"), 802.11kvr, achieve seamless home coverage and low latency with portable devices.
- It is recommended that the Router supports WMM if using Wi-Fi to carry the video service.

3.2 Features of Video Service Device

Traditional video services are mainly carried by large-size TVs and computers. With the increasing popularity of VR services, more mobile devices appear in the home, such as VR helmets, and large screens that support 4K and 8k. PAD devices, these new terminals, no longer integrate wired ports, but carry video services through wireless technology. This places stringent requirements on wireless transmission, not only meaning the support of high data rates, but also requiring low latency and high stability. We also take into account weak mobility, so as to perfectly support new video services.

Appendix I. Network Performance Targets to Support Video

This appendix presents some targets for the desired network performance to support various types of entertainment-quality video. Note that different codecs and settings, and in particular different decoders, can support different trade-offs between bandwidth and PER than the numbers presented here.

I.1 Network RTT of video on IPTV

Table 6 describes the network RTT for 4K video on IPTV and is based on[1][3].

Table 4 The network RTT of videos on IPTV

	Format	E2E (ms)	Access (ms)	Home network (ms)
IPTV live BTV (UDP)	HD 720P (1280*720/30P/8bit)	100	20	20
	FHD 1080P (1920*1080/30P/8bit)			
	Quasi 4K (3840*2160/30P/8bit)			
	Carrier-grade 4K (3840*2160/60P/10bit)			
	Ultra 4k (3840*2160/120P/12bit)			

I.2 Network RTT of video on OTT

Table 5 describes the network RTT for 4K video on OTT and is based on [1][3].

Table 5 The network RTT of videos on OTT				
	Format	E2E (ms)	Access Network (ms)	Home network (ms)
IPTV live BTV (UDP)	HD 720P (1280*720/30P/8bit)	40	8	8
	FHD 1080P (1920*1080/30P/8bit)			
	Quasi 4K (3840*2160/30P/8bit)			
	Carrier-grade 4K (3840*2160/60P/10bit)			
	Ultra 4k (3840*2160/120P/12bit)			
	Note: RTT requirements depend on physical location of CDN.			

Appendix II. Network Performance Targets to Support VR

Some targets for network performance to support VR from ETSI F5G are presented here. Note that the Wi-Fi Alliance XR MSTG is also working on requirements for XR.

II.1 Network bandwidth and RTT of VR

Table 8 describes the network bandwidth and RTT of VR[6].

Table 6 The network bandwidth and RTT of VR

	Format	RTT (ms)		
		E2E	Access	Home Network
VR (weak interaction)	4K VR (3840*1920/30P/8bit)	40	8	8
	8K VR (7680*3840/30P/8bit)	30	6	6
	12K VR (11520*5760/60P/10bit)	20	4	4
	24K VR (23040*11520/120P/12bit)	10	2	2

II.2 Network bandwidth and RTT of VR

Table 9 describes the network PER for VR and is based on [6].

Table 7 The network PER of VR

	Format	E2E	Access	Home network
VR (weak interaction)	4K VR (3840*1920/30P/8bit)	1.40×10^{-4}	2.80×10^{-5}	2.80×10^{-5}
	8K VR (7680*3840/30P/8bit)	1.40×10^{-5}	2.80×10^{-6}	2.80×10^{-6}
	12K VR (11520*5760/60P/10bit)	1.90×10^{-6}	3.80×10^{-7}	3.80×10^{-7}
	24K VR (23040*11520/120P/12bit)	5.50×10^{-8}	1.10×10^{-8}	1.10×10^{-8}

Appendix III. Interconnection Technologies

III.3 Wireline interconnection

III.3.1 A wired end user network connects devices to each other and to the Internet using cables

Within the F5G Use Cases [6], Fiber to the Room (FTTR) is one of use cases for the end user networking. In order to deploy PON on premise, the OLT function needs to be integrated inside the premise device, in place of the legacy LAN side Ethernet ports. For example, a typical Home Gateway has 4 Ethernet ports. Once a PON-based FTTR is deployed, some of these 4 Ethernet ports are replaced by one PON port. Potentially, the size of the device can be even smaller. A miniaturized OLT can be embedded in an intelligent home ONU or home gateway. The cascaded PONs could have common management tools and cooperative mechanisms to forward the customers' traffic (i.e. a shared media access control (MAC) function).

In order to deploy PON on-premises networking, there are several pre-conditions as follows:

- Fibre has been deployed on-premises.
- Efficient solutions to extend the PON service to the on-premises network.

III.3.1.1 G.hn

G.hn [7] is a specification for home networking with data rates up to 2 Gbit/s and operation over four types of legacy wires: telephone wiring, coaxial cables, power lines and plastic optical fiber. A single G.hn semiconductor device is able to network over any of the supported home wire types. Some benefits of a multi-wire standard are lower equipment development costs and lower deployment costs for service providers (by allowing customer self-install)[8].

G.hn was developed under the International Telecommunication Union's Telecommunication Standardization sector (the ITU-T) and promoted by the HomeGrid Forum and several other organizations.

III.3.1.2 Ethernet

Most wired network infrastructures found in homes utilize Category 5 or Category 6 twisted pair cabling with RJ45 compatible terminations. This medium provides physical connectivity between the Ethernet interfaces present on a large number of residential IP-aware devices. Depending on the grade of cable and quality of installation, speeds of up to 10 Mbit/s, 100 Mbit/s, 1 Gbit/s, or 10Gbit/s are supported.

III.3.2 Wireless interconnection

A group of devices (computers, game systems, e-readers, etc.) connected to each other and to the Internet without cables, also called Wi-Fi.

III.3.2.1 Wi-Fi

One of the most common ways of creating a home network is by using wireless radio signal technology; the 802.11 network as certified by the IEEE. Most wireless-capable residential devices now use 802.11ac (Wi-Fi 5) or 802.11ax (Wi-Fi 6) and operate in the 2.4 GHz and 5 GHz bands, and soon also the 6 GHz band. Wi-Fi is a marketing and compliance certification for IEEE 802.11 technologies. The Wi-Fi Alliance has tested compliant products, and certifies them for interoperability.

III.3.2.2 Wi-Fi EasyMesh

Wi-Fi EasyMesh that brings a standards-based approach to Wi-Fi networks that utilize multiple access points (APs), combining the benefits of easy to use, self-adapting Wi-Fi with greater flexibility in device choice that comes with interoperable certified devices. Wi-Fi EasyMesh networks employ multiple access points that work together to form a unified network that provides smart, efficient Wi-Fi throughout the home and outdoor spaces.

Wi-Fi EasyMesh is very simple to install and use. Network setup and device onboarding involves minimal user intervention. Once established, the network self-monitors to ensure optimized performance.

III.3.2.3 Wi-Fi QoS Management

The WFA has specified Wi-Fi QoS Management [12] to map flows to WMM User Priorities and Access Categories. QoS management supports the following capabilities:

The Mirrored Stream Classification Service (MSCS) enables STA-initiated negotiation of downlink QoS based on QoS mirroring.

The Stream Classification Service (SCS) enables STA-initiated negotiation of downlink QoS based on explicit stream classifiers, allowing finer-grained control than MSCS.

DSCP-to-UP mapping assigns downlink and uplink QoS based on DSCP marking of IP packets, either using a default mapping table, or using a specific mapping table configured using QoS Map capability.

The DSCP Policy capability enables unsolicited and query-based configuration of uplink DSCP marking policies by APs on STAs.

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