

HOW NETWORK ROUTERS AFFECT IP VIDEO QUALITY

The User Experience Starts at the Transport Level

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Executive Summary

Service providers are making the transition to IP infrastructures to deliver video. This move offers significant economic and operational advantages, but it also comes with challenges. One of the main challenges is to ensure that the quality of the video is sufficiently high to attract and retain subscribers. Put another way, the service provider must be able to deliver a superior quality of experience (QoE) to drive adoption of IP video.

When designing a network infrastructure to deliver IP video, service providers must consider three main factors: line-rate forwarding, quality of service (QoS) and high availability. These capabilities in turn dictate the bandwidth availability, packet loss and jitter of each video stream, the primary factors that determine video quality. The choice of network components must be driven by these considerations. In particular, high-performance routing nodes are the key ingredients in building an IP video platform.

Introduction

From most of its 70-year history, video has been delivered using analog technology. Analog video is simple and reliable, and drove the widespread adoption of television as a mass medium. But as the medium grew, its inherent limitations—bandwidth inefficiency, transport quality and video processing equipment expense—drove the migration to digital video.

Digital video was first introduced commercially in 1986. The predominant delivery technology today, digital video has a number of benefits. The quality of digital video is generally higher than analog, and as importantly, is consistent over a wide range of delivery conditions. Coupled with MPEG compression technology, digital video is highly efficient. And because the audio and video are in digital form, they can be transmitted in a variety of formats.

The Next Evolution: Packet Transport

Seeking more efficiencies and economies of scale, service providers are rapidly moving to packet-based delivery for video. Figure 1 shows a typical IP video network architecture.

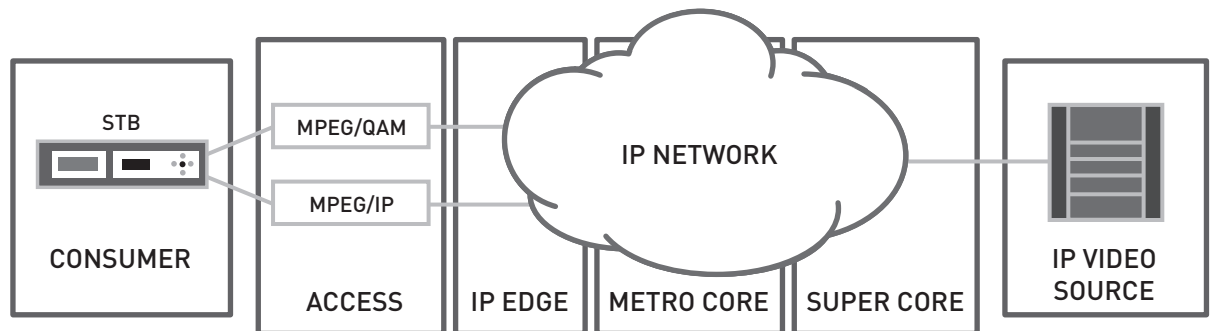


Figure 1: IP video network architecture

There are a number of factors driving service providers to IP video. For starters, there's money to be made in the short term. Service providers can potentially increase operating margins by converging multiple services onto a single IP network. Doing so avoids equipment duplication, reduces training and maintenance expenses, and simplifies overall network administration.

Looking down the road, service providers see opportunities to differentiate themselves by offering innovative value-added services (for example, Internet surfing on a TV set or combined voice and video applications), many of which depend on a unified network infrastructure. As providers track the evolution of a relatively untamed and unpredictable marketplace, their best bet is to be agile and innovative. Delivering all their services over a single converged IP network is part of that strategy.

Delivering IP Video

The promise of transporting video over an IP network is high, but as with any technology innovation, there are challenges. To fully understand those challenges requires understanding the differences between IP video and traditional broadcasting.

In fact, there is no concept of broadcasting per se in an IP network, in the sense that a video stream is sent to every user on the network. Instead, IP video uses two fundamentally different transport models: multicasting and unicasting. Virtually all commercial deployments of IP video use a mix of these two models.

Multicasting

Multicasting is similar to broadcasting in that multiple viewers can look at the same video stream at the same time. However, unlike broadcasting, multicasting is selective: A multicast stream is only sent to those viewers who have “signed up” for it. Multicasting makes efficient use of the transport network bandwidth, since a single stream traversing the core network can be viewed by a large number of end users.

However, that efficiency comes at the cost of network complexity. Individual nodes in the network must be smart enough to decide which of the downstream nodes need to receive a given multicast stream. (Forwarding the stream to all downstream nodes would essentially create a broadcasting model and negate the inherent efficiency of IP transport).

Multicasting is the workhorse of IP video transport. Most viewers, most of the time, are viewing content that others are also viewing —scheduled sitcoms and drama shows, live sporting events, and news programming. For these kinds of content, multicasting offers a highly efficient and practical way to transport video.

Managing Multicasting in the Video Network

Multicasting requires network nodes to determine routing video streams so that they reach the end users who have ordered them. But how is this information communicated?

The Internet Group Management Protocol (IGMP) is one mechanism used to manage multicasting at the edge of video networks. When the user selects a channel, the user’s network interface device (usually a set-top box) sends an IGMP join request, querying to be connected to that channel’s video stream. The join request works its way up the network so that upstream nodes can determine the right routes to deliver the requested stream to the viewer. For a more detailed description of the use of IGMP in video multicasting, see the Juniper Networks® white paper, “Introduction to IGMP for IPTV Networks.”

For managing multicasting in the core, some providers use a multicast protocol such as Protocol Independent Multicast (PIM). PIM sets up multicast distribution trees to ensure that video packets reach all the users who have joined a particular multicast group. An emerging alternative to PIM is point-to-multipoint MPLS, a standard that is gaining wide acceptance with service providers.

Point-to-multipoint MPLS has a number of advantages over PIM. It provides traffic engineering features such as link protection, graceful restart and fast rerouting, and includes a resource reservation mechanism. For more information on point-to-multipoint MPLS, see the Juniper Networks white paper, “Best Practices for Video Transit on an MPLS Backbone.”

Unicasting

Unicasting is the diametrical opposite of broadcasting: A unicast video stream is sent to exactly one viewer.

Unicasting is the vehicle for offering a highly personalized user experience with services such as video on demand (VOD) and personal video recorder (PVR).

Unicasting allows service providers to offer an essentially infinite catalog of content to viewers, an important competitive advantage. In addition, customized video delivery to individual viewers opens up a wide range of targeted advertising models.

But these benefits come at a price: As more viewers take advantage of services such as VOD and PVR, more of the network bandwidth must be dedicated to unicasting. To prevent network congestion, it may be necessary to limit the number of active viewing sessions, which can negatively impact customer satisfaction.

Despite these challenges, many service providers believe that unicasting will ultimately dominate the video delivery network, and are planning for it.

Video Quality Basics

Service providers have long recognized that consumers will pay premiums for high-quality video, as witnessed by the high adoption rates for pay television services such as cable and satellite, even in areas with good-quality free broadcast TV. (A wider range of channels is another significant impetus for moving to cable television as well.) Quality is the primary driver for the adoption of high-definition television (HDTV).

Network Problems Degrade Video Quality

Problems that occur anywhere between the video source and the receiver can lead to video impairments. Some can be brief or deterministic, while others are random and long-lived. As depicted in the following figure, every network component is a potential source of video impairment.

A link or node failure is one typical event that can lead to an outage that has the potential to degrade video quality. Video has a time window of about 50 milliseconds: If the network can recover in that time period, the user will likely not be affected. Obviously, humans cannot respond so quickly, so the network must be able to repair itself. Recovery techniques exist that allow networks to respond within an acceptable time window.

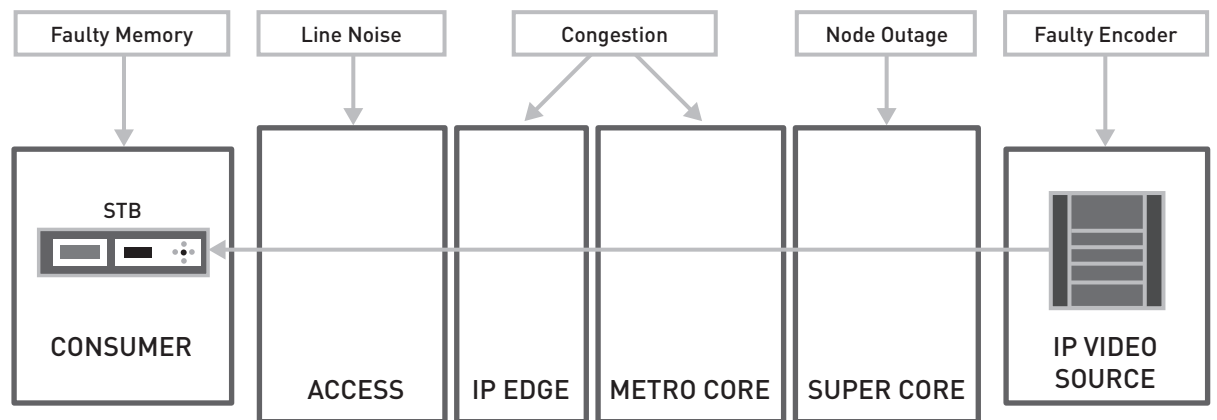


Figure 2: Typical impairments in the network infrastructure

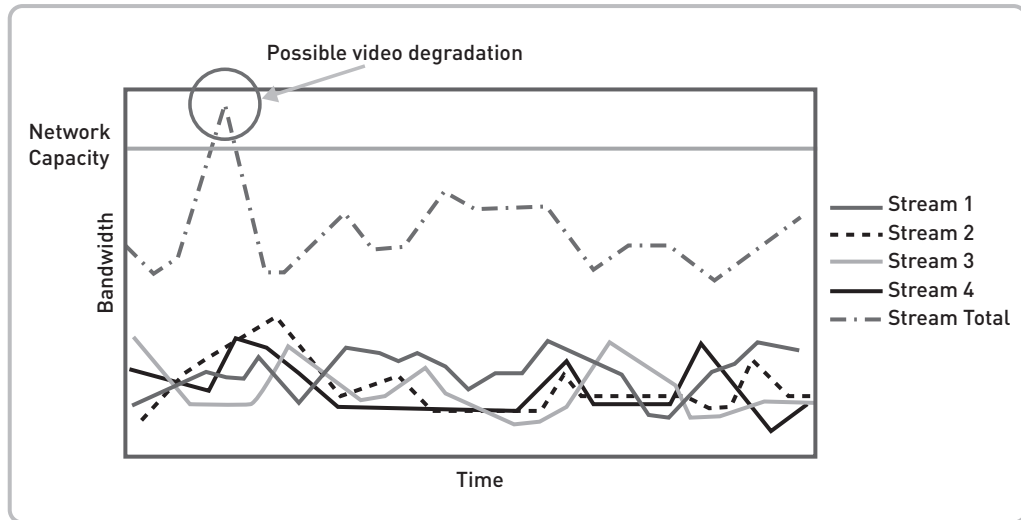
Given that consumers are so quality-conscious when it comes to video services, providers must be, too. So as service providers evaluate a transition to IP video, they must ensure that the network can deliver the required level of quality.

The quality of an IP video stream depends on three primary factors: bandwidth availability, packet loss and jitter. Of these three, the first relates to the overall design and configuration of the network. Service providers can allocate network resources so that enough theoretical bandwidth is available for the video services they offer.

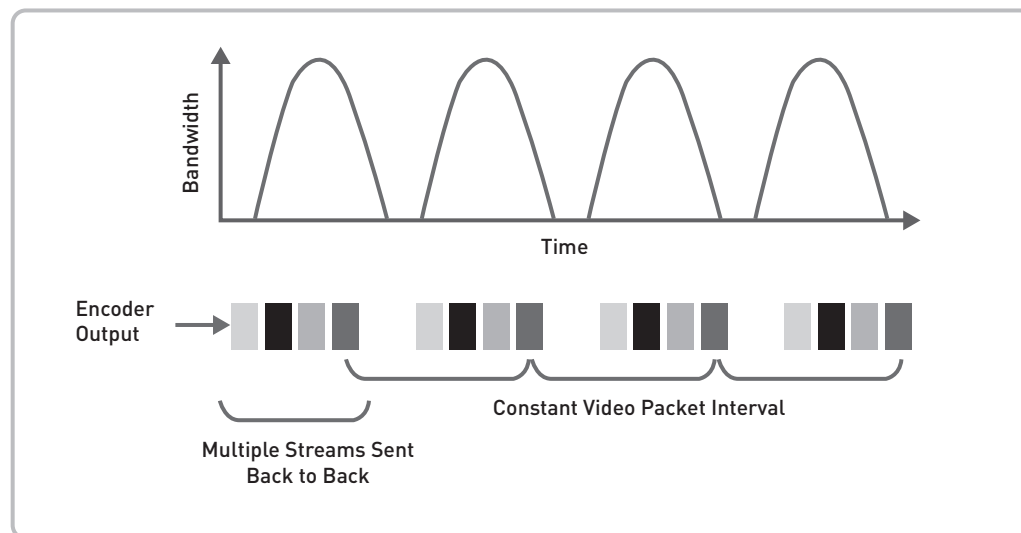
The other factors—packet loss and delay—depend on instantaneous and local conditions within the network. Packet loss can occur due to congestion in the network—if a router's buffer fills up due to downstream delays, arriving packets can be discarded. In addition, there is always some variation in the transit time from source to destination. This variation—or jitter—results from factors such as network congestion, timing drift and route changes. When jitter is higher than a threshold value, some packets will not have arrived when their video payload is needed, degrading the video quality.

Constant Bit Rate Encoding Can Still Be Bursty!

Variable bit rate (VBR) encoding maintains a constant level of video quality by increasing the bit rate as needed, for example, for fast-changing scenes. However, VBR has traditionally posed problems for service providers. When a number of VBR streams are being transmitted at the same time, inevitably there will be bursts that exceed network capacity and threaten video quality, as shown below:



Constant bit rate (CBR) encoding keeps the bit rate of the stream constant, which can in some cases reduce the video quality. However, even using CBR doesn't prevent against network oversubscription. The reason is that CBR is a per-stream concept. A number of individual CBR streams can overlap in such a way as to cause bursts on the network, as shown below.



Therefore, even video networks based on CBR encoding require careful design to avoid video degradation.

Designing for High-Quality Video

The imperative for service providers moving to IP video is to design a network that can guarantee the delivery of high-quality video. To do so requires understanding what causes video impairments.

A key design requirement for delivering high-quality video is a high-performance network that can provide line-rate forwarding, QoS and high availability. Some of the factors that can degrade video quality include:

- Network design: Too much network traffic
- Router scaling: Planned and unplanned outages, poor router node design causing packet drops or high packet latency, insufficient router buffers causing packet drops
- Multicast support: Low throughput of multicast traffic, not enough multicast groups supported

Line-Rate Forwarding

When designing an IP network for video, service providers need to look first at their choice of routers. Ideally, the routing nodes should be transparent to the video stream, a feature called line-rate forwarding. In practice, this means that the router should have microseconds of latency and no internal loss due to poor multicast scaling, head-of-link blocking or other performance-limiting attributes.

Line-rate forwarding introduces no appreciable delay as the stream transits the router. It helps service providers predict the end-to-end behavior of the network for video streams. Line-rate forwarding also allows the network to scale, since the video stream can pass through a larger number of nodes without suffering degradation.

QoS

Best-effort delivery of video packets cannot deliver the QoE needed to attract and keep subscribers. The network must be able to provide a deterministic QoS for IP video packets regardless of congestion of lower classes of service such as voice. The capability ensures that latency and jitter stay below the thresholds at which video quality begins to degrade.

High Availability

Network downtime results in video service downtime, so availability is an important focus for network designers. A range of factors determines network availability, but the reliability and resilience of the individual routers play a vital role. If the router constantly fails, the video quality will suffer. Therefore, high uptime is an essential requirement for routers used in video delivery.

Router downtime has many causes, the most obvious being a hardware or software failure. Service providers should look for routers that have demonstrated high reliability in real-world deployments.

How fast and gracefully a router recovers from a failure also impacts downtime. Features such as link-down detection, fast reroute and graceful routing engine switchover allow routers to respond rapidly and effectively to network failures and avoid negative impact to video streams.

Software upgrades are another area that can cause downtime. In-Service System Upgrades (ISSU)—a standard feature of Juniper Networks routers—provides a mechanism by which router software can be upgraded without causing network downtime.

Other Video Design Considerations

Some of the technical challenges are specific to the type of video being delivered, multicast or unicast. Multicasting by its nature requires packet replication at various network locations, so routers must be able to perform this function without impairing the line-rate throughput of the device. This consideration increased in importance as the network scales, since larger multicast trees require more replication.

Video on demand (VOD), a unicast application, also has the potential to overload the router if the network allows too many users to subscribe to unicast streams at the same time. Proper network engineering requires limiting the number of VOD sessions to prevent sustained interface congestion.

The High-Performance Routing Node

To better understand how routers impact video performance requires a deeper dive into the router itself. Figure 3 shows the internal architecture of a typical routing node.

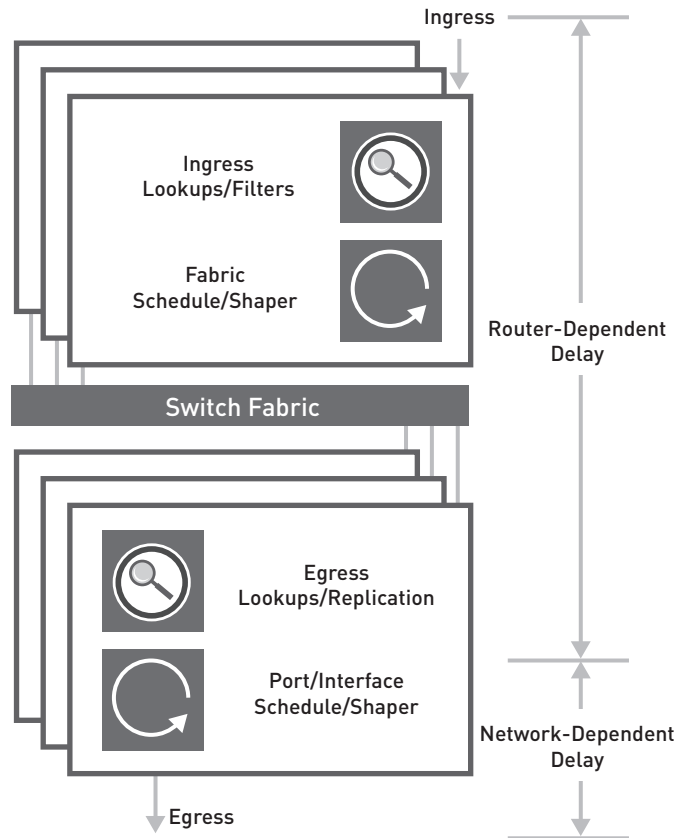


Figure 3: Internal architecture of routing node

From the ingress port to the egress queue, the transit delay is determined by the design of the router. This portion of the path should be deterministic, introducing latency on the order of microseconds. There are a number of network-dependent factors that can introduce delays and packet loss at the egress queue:

- Forwarding delays caused by downstream congestion
- Priority queuing delays caused by higher-priority traffic consuming large amounts of bandwidth (multiservice networks only)
- Egress queue overflows caused by sending too much video traffic across the network or concurrent microbursts of variable bit rate (VBR) streams that temporarily oversubscribe the egress interface

The first two factors can be managed with QoS, which can ensure that video traffic is allocated sufficient network resources to guarantee timely, loss-free delivery of video packets. Egress queue overflow can be eliminated through proper network design.

Conclusion

Although often overlooked, the network plays a critical role in the delivery of IP video services. To ensure high-quality video delivery, service providers must design their network infrastructures using high-performance network nodes and make skillful use of traffic engineering in network operations. Routers that support line-rate forwarding, QoS and high availability—for example, the Juniper Networks E Series Broadband Services Routers, M Series Multiservice Edge Routers, MX Series Ethernet Services Routers, and T Series Core Routers—provide the best path for service providers making the transition to IP video infrastructures.

About Juniper Networks

Juniper Networks, Inc. is the leader in high-performance networking. Juniper offers a high-performance network infrastructure that creates a responsive and trusted environment for accelerating the deployment of services and applications over a single network. This fuels high-performance businesses. Additional information can be found at www.juniper.net.

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