



Work From Home White Paper

Solutions to Networking Issues While Working from Home

Abstract

This paper will outline what causes network problems at home and how they can be resolved – in particular using Maya for a quick and simple solution.

August 12, 2020

Solutions to Network Issues While Working from Home

Introduction

The Covid-19 health crisis has driven many professionals to work from home in order to avoid the disease. The home network is frequently lacking in comparison to business networks, particularly with real time interaction applications such as videoconferencing and voice.

The home network is being strained as never before - with both parents working from home using videoconferencing and cloud-based applications. Simultaneously their children are using conferencing for distance learning, then breaking to watch YouTube videos.

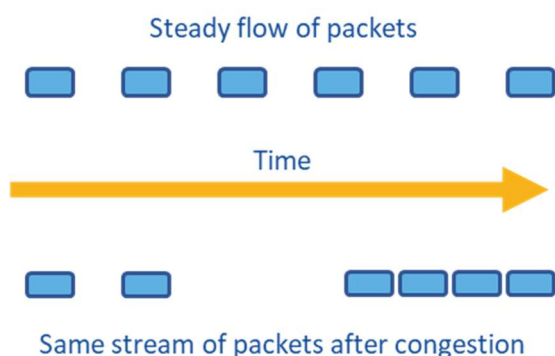


As a result, the home professional suffers from frozen video, garbled voice, slow, and erratic applications. This paper will outline what causes network problems at home and how they can be resolved – in particular using Maya for a quick and simple solution.

What Causes Problems?

When WFH (Working From Home) there are several sources of problems that affect the user experience and reduce quality while working at a computer¹.

Delay is what causes problems. As you are interacting with a computer, you type or click, and expect a response. Studies have shown that users need to get feedback within 100ms-150ms after typing or clicking, or they begin to complain of delays or “slow X,” where X is the network, computer, or the slow application.



Voice (as in phone calls and videoconferencing) is the application most sensitive to delays. Voice packets are evenly spaced every 50ms, and a delay of 100ms (2 packets) degrades voice quality. Symptoms of delayed (or dropped) voice packets are lower volume, indistinct fricatives – “f”, “p”, “v”, and “b” sounds, garbled words, metallic tones, robot voice (see [VoIP Troubleshooter](#)), hissing sounds, and silence.

Videoconferencing is somewhat less sensitive than voice. Minimum frame rate for videoconferencing is 15 frames/second – 67ms apart. Videoconferencing systems can detect bandwidth issues, and resort to various techniques to adjust to reduced bandwidth, first dropping from 60 to 30 frames/second and then to 15 frames/second, and then reducing bandwidth further by only partly

¹ Computer term includes traditional desktop computers, mobile phones, and tablets.

updating the screen – just the face, or in a pinch, just the eyes. The key is that users must see changes 15 times a second or they will feel the session is low quality. Video frames are also evenly spaced like voice packets. Delaying a video packet by 1 or 2 frame times makes for “choppy” video (see Mega Meeting [Common Videoconferencing Problems](#)). More delays result in frozen video and the Zoom warning “network is unstable”.

A second videoconferencing issue is lack of synchronization between the voice and video stream. Any delays in the network will affect the voice and video stream differently, resulting in lips that are moving either ahead of or behind the audio stream.

There are several potential sources for the delays that cause applications to not work smoothly described in the sections below.

Home Delay

The first source of delay comes from the Internet Provider modem equipment in your home. Computers are much faster than even the fastest Gigabit network. Applications generate megabytes of traffic in a few milliseconds, and then must wait for them to be dribbled out onto the network. The ever growing list of home devices, such as security systems, music systems, home automation systems and family use of the Internet for streaming video, music, and online gaming add to the packets and megabytes waiting to be transmitted.

Buffering is used for application traffic waiting to be transmitted. Whenever sensitive applications² are put in line waiting in buffers, they are delayed, and quality suffers. Buffering begins in the home modem, but also can be found on the router at each hop on the Internet. This buffering is known as “Bufferbloat”, and more is written about it in [Wikipedia](#).

Coping with Home Delay

Most users recognize the problems caused by delay and attempt to apply “home remedies” to alleviate them. For example, conducting important business work by banning video streaming or Internet gaming or waiting until the household is asleep or otherwise occupied. Some have considered putting in a second network that is reserved for “professional use”.

Service Provider Delay

Home Internet Service is called broadband by the industry and the providers are known as ISPs – Internet Service Providers. Broadband is a shared service, shared by your neighbors and everyone at your ISPs nearby POP – Point of Presence – where traffic is coalesced and placed on the backbone. The industry term for ISP sharing is oversubscription (see Emperor WiFi [Oversubscription Ratios](#)), which may vary from 8:1 or up to 40:1, meaning if they have 100 users with 1Gbps service, the actual capacity of the service is not 100 x 1Gbps, or 100Gbps, but 1/8 or even only 1/40th the capacity. The result is that when other users increase their usage, traffic backs up and delays occur.

² Sensitive applications are ones that are interacting with the user in real time – voice, videoconferencing, hosted voice, and cloud-based desktop applications like Microsoft 365 and Salesforce.

During the early days of the Covid-19 lockdown, ISP oversubscription became painfully obvious. Those with high speed connections found their bandwidth dropping as much as 98%. Needless to say, scarcely any applications were working.

ISPs do not reveal how they handle traffic surges. They fall back on their service level – quoting speed “up to XXX Mbps” and “speeds may vary.” One observed technique is to let individual customers have a brief surge before shutting down to a much lower bandwidth. It’s difficult to fathom how this helps except that the surges allowed are just enough to run a speed test – with a good, but misleading result! When pressed, ISPs’ customer service will suggest a solution of switching to higher cost business service, which presumably will allow for higher traffic surges.

Network congestion delays caused by traffic spikes are a common ISP occurrence, and more so with the huge increase in WFH users. These delays are largely outside the user’s control.

ISP Upload Slowdown

ISP broadband service is constructed to maximize download speeds at the cost of upload speed. Upload speed is typically between only 2% and up to 10% of download speed. During high congestion times, upload speeds maybe so reduced as not be high enough to support videoconferencing.

Internet Backbone Delay



ISPs utilize the Internet backbone to haul traffic from their POPs to other parts of the country and the world. The backbone is a collection of vendors, with lengths of fiber, connecting cities together across the country. (Click [here](#) for an inspiring video.) These backbone vendors share very little information on their bandwidth capacity, and their reliability.

The backbone health is made somewhat visible by users reporting slowdowns and outages to the [DownDetector](#) website. The web site lists both cloud applications as well as ISPs. There is no direct information on the backbone, but backbone issues show up as regional ISP and cloud application issues.

Although regional ISP slowdowns are nearly a daily occurrence, the backbone from point A to point B is rarely down as there are multiple routes available. Since 2008 there have been two major Internet [outages](#), in 2016 for one day and for three hours in 2019.

The figure below shows the major ISPs tracked by DownDetector.com:



Summary of Network Delays

Of the three sources of delay – home equipment, ISP, and backbone, 99% of delays are in the ISPs network, the “last mile” – the connection from your home to the ISPs POP. Solving issues in the last mile results in a reliable and well-performing network.

Hosted Application Delay

The final source of delay is in the cloud data center hosting applications. Overloaded and crashed servers, data center network issues, or denial of service attacks can slow or take hosted services down. DownDetector tracks hundreds of hosted applications and cloud services in addition to ISPs. Popular business applications such as Microsoft 365, Salesforce, and RingCentral along with cloud services like Dropbox, Slack, and LinkedIn are also reported.

A snapshot of today’s DownDetector [outages](#), as I write this, shows a couple dozen services suffering delays, with the majority being consumer applications, not business ones. There are several ISP issues which are regional, not nationwide.

Summary of Network Problems

You might be saying to yourself, “This sounds horrible! Certainly, there must be ways to make the Internet reliable.” The answer is, “Yes, and they are far too expensive and complex for home users.” Businesses achieve reliable networks first by purchasing expensive private networks (known as MPLS for Multi-Protocol Label Switching) that have fixed speeds regardless of what others are doing.

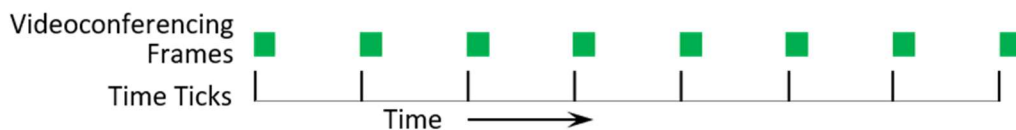
Second, they engineer their networks by setting policies for sensitive and high priority applications. Third, they have secondary and tertiary networks to call on when the primary network fails. And fourth, they have IT staff that is constantly watching for network issues, which they fix by reconfiguring their networks and calling their ISP to solve issues in real time.

Existing Network Problem Solutions

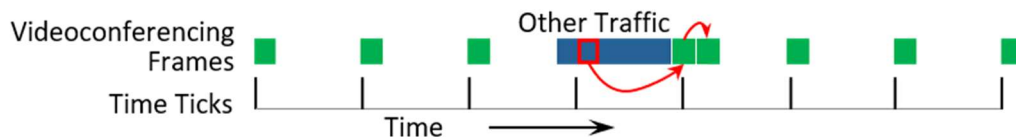
After describing all the ways networking at home can go wrong, here are solutions to the problems described above.

What About Just Buying More Bandwidth?

It's tempting to solve network problems by purchasing more bandwidth. It's a simple decision, and the ISP encourages the purchase, typically with a lower charge for a few months. In order to analyze how increased bandwidth affects network quality issues, we need to know what causes quality issues for real time and interactive traffic. Videoconferencing creates a steady flow of packets, evenly spaced in time as shown below:



The Time Ticks lines represents the time interval for frames. Typically for videoconferencing the frames are 30 per second. Now, when there's other network traffic mixed in with the videoconferencing frames, the traffic can interfere, and cause the frames to be delayed:



The blue Other Traffic begins transmitting on the network and when it's time for another green videoconferencing frame to be transmitted, the network is busy, and the frame is queued. The frame waits until the Other Traffic is transmitted and then it's sent onto the network. But the frame misses its time tick and is discarded, along with the next packet as well. The collision causes the videoconference to pause, and then attempt to resynchronize. The resynchronization packets are additional traffic, and if there's too much Other Traffic the videoconference freezes until resynchronization succeeds.

Some simple calculations may explain what's happening. YouTube HD videos consume about 4Mbps while playing and a typical videoconference consumes about 1Mbps. If the home user has a 50Mbps Internet connection³, the chance that the two streams cause queueing is:

³ U.S. average download speed in 2020 is in the 25Mbps – 100Mbps range; 50Mbps used here. See [Ookla Speedtest result](#).

$$\text{YouTubeFrameProbability} \times \text{VideoConfFrameProbability} = \text{Queued/Time}^4$$

It is not intuitive to translate Frames Queued per minute into user experience, but we know that professional home users are bedeviled with poor videoconferencing when someone in the house is playing a YouTube video. The table below shows the known quality problem in the first row – YouTube Video Effect Today:

Situation During Video-conference	ISP Download Speed/ Mbps	Status	Streaming Rate (Mbps)	Frames Queued /Minute	Videoconferencing User Experience
YouTube Video Effect Today	50	Known Problem	4	3	Poor Video-conferencing
More Bandwidth Works	500	YouTube Video After Bandwidth Increase	4	0.03	Good Video-conferencing
More Bandwidth Fails	500	8K Video After Bandwidth Increase	200	2	Poor Video-conferencing!

The column heading Frames Queued/Minute shows that the number of queued and delayed frames when the YouTube video frames and videoconferencing frames overlap is 3 frames a minute.

The second row – More Bandwidth Works – shows what happens by purchasing more bandwidth, increasing from 50Mbps to 500Mbps. The number of YouTube video and videoconferencing queueing's drop to nearly 0 (0.03) and unlikely to show any degradation.

The third row– More Bandwidth Fails – shows what will be happening in the future as bandwidth usage increases. As an example of this increase, YouTube videos will progress from High Definition, to 4K Ultra High Definition (today's top performer), to Full Ultra High Definition 8K videos, and the user will find videoconferencing failing again at 2 frames/minute. Increasing bandwidth is only a **BAND-AID®** briefly fixing the home worker's videoconferencing problem.

A side note on another temporary fix of this problem: YouTube felt home users' pain during the Covid-19 pandemic and reduced YouTube videos from High Definition 1080p resolution to 480p

⁴ Computations: **YouTube** BW% = 4Mbps/50Mbps = 8%; Vconf% = 1Mbps/50Mbps = 2%; Queueing% = 8% x 2% = 0.16%; Frames/Min. = 30Frames/sec. x 60sec./min. = 1800; Frames queued/min. = 0.16% x 1800 = 2.88 ~ 3.
More BW, YouTube BW% = 4Mbps/500Mbps = 0.8%; Vconf% = 1Mbps/500Mbps = 0.2%; Queueing% = 0.8% x 0.2% = 0.0016%; Frames queued/min. = 0.0016% x 1800 = 0.03 ~ 0.
8K Video BW% 200Mbps/500Mbps = 40%; Queueing% = 40% x 0.2% = 0.08%; Frames queued/min = 0.08% x 1800 = 1.44 ~ 2

for the duration in order to help out the stay at home working families where family YouTube watching has clogged the Internet.

SD-WAN

SD-WAN – Software Defined Wide Area Networking – is an emerging solution to a variety of networking issues including videoconferencing performance. SD-WAN today is strictly an enterprise solution with its accompanying cost, complexity, and IT staff requirements. Although not appropriate for the WFH user, here are some key technologies used by SD-WAN vendors⁵:

Traffic Shaping

Traffic shaping means identifying and classifying traffic according to business priorities. The traffic is prioritized and queued. IP voice and videoconferencing are generally the highest priorities. Traffic shaping is the main SD-WAN technique for providing application quality.

Path Control

Path Control means the monitoring of two or more WAN connections and balancing the traffic according to their (generally fixed) capacity. This is used for failover and moving traffic that's failing quality measures.

Forward Error Correction

Forward Error Correction is used when the ISP circuit experiences dropped and delayed packets. To work around the problem, multiple circuits are used, and the traffic is replicated on each additional circuit. The SD-WAN Cloud module combines the multiple streams, hoping that at least one copy of each packet has arrived, and drops duplicates. Multiple circuits is a costly solution and must be selectively applied only to critical traffic, typically voice and videoconferencing.

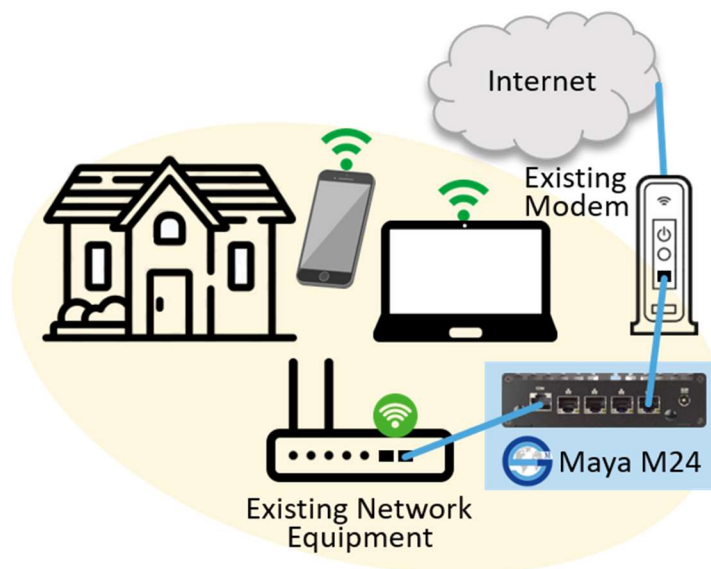
The Maya Solution

The Maya Internet Quality Service (IQS) Solution consists of a service, a small hardware device, and software that solves the quality problems described in this paper. Maya is attuned to the WFH environment where multiple people are contending for the network with multiple videos, Wi-Fi phone calls, and multiple videoconferencing apps – such as Zoom – simultaneously. Other than a quick and simple install, Maya performs its streamlining quality of service silently without human intervention.

Maya IQS Internals

Controlling home delay requires installing a device between the ISP's modem and the home network. The device must be "inline," with all the home traffic flowing through it. A Maya install is shown below as an example.

⁵ See [The 3 pillars of SD-WAN QoS and questions to ask your providers.](#)



The Maya device provides IQS (Internet Quality Service), prioritizing voice and video packets and transmitting at a steady, even pace, as described in the [What Causes Problems](#) section above.

Other products each have their respective techniques, but Maya IQS primarily uses two techniques: Fair Queueing and Dynamic Bandwidth Control, described below.

Fair Queueing

Each application session is characterized and assigned to a queue and prioritized. Packets are sent as bandwidth becomes available, and if insufficient bandwidth, some packets will be delayed in queue. Queues are checked for too much time in queue, and if so, a session's packet will be discarded, which will signal the TCP protocol to slow down. When bandwidth becomes more available queues are shortened and packets are sent more quickly.

In the case of UDP traffic – voice and videoconferencing – the traffic is simply dropped. Videoconferencing applications detect the drop and slow the video.

In the corner case where the circuit is so slow that voice packets are dropped, this can only occur if the ISP service is not functioning correctly. The Maya service detects this condition and will notify the WFH customer.

Dynamic Bandwidth Control

The key technique unique to Maya IQS is Dynamic Bandwidth Control, which measures network delays and determines whether bandwidth can be increased or must be decreased. Dynamic Bandwidth Control is unique to Maya and is patented. The quality algorithms depend upon knowing the bandwidth, and broadband circuit capacity is continuously varying.

Other vendors' devices don't know bandwidth precisely. They hope to undershoot, and when sessions suffer delay and lost packets, they move the session to a reserve circuit. Other vendors do not really have a solution for the home worker; only Maya can provide a quality experience for the home user.

Maya IQS Solves Network Issues

Here's how each of the sources of Home Delay, Service Provider Delay, and ISP Upload Slowdown are solved by IQS:

- IQS solves the problems of [Home Delay](#) with its prioritization of voice and videoconferencing, its queueing to ensure a [steady flow of packets](#), and a combination of

prioritization and queueing to keep videoconferencing voice and video synchronized. No home remedies are needed in order to Cope with Home Delay.

- Dynamic Bandwidth Control informs IQS of the instantaneous network bandwidth, limiting buffering in home equipment, the ISP, and all network hops to the application – eliminating Bufferbloat.
- Service Provider Delay is eliminated by Dynamic Bandwidth Control as it senses just how much bandwidth the ISP is allocating to this customer's home and performing managed discards to slow the lower priority traffic to keep latency constant, avoiding delays.
- When extreme ISP Upload Slowdown is encountered (i.e. bandwidth lowered below the minimum needed for an application to run due to over-subscription) IQS solves the problem by seamlessly moving traffic to a failover service. Few home users have a failover service today as they are unaware that when they have unusable slow performance that there is a solution. The major ISPs such as Verizon and ATT offer 4G service for as low as \$15/month when used as a backup. Failover service has repeatedly proved its worth during the pandemic⁶.

Mitigating Internet Backbone Delay

Maya cannot cure Internet backbone issues directly for WFH when there's insufficient bandwidth available for most if not all users of the portion of the Internet having difficulties. To work around backbone issues, Maya uses virtual IQS devices at numerous geographically distributed cloud providers. When backbone performance issues crop up, Maya relocates customer traffic to other ISP POPs. Service may be somewhat degraded due to longer routes with lower bandwidth along with high traffic created as affected customers scramble for the remaining backbone bandwidth.

As noted above, severe backbone outages are not common, and customer affecting delays (i.e., can't really work usefully) appear to happen once or twice a year for a given geographic region and backbone carrier.

⁶ A failover Internet connection can become a forgotten blessing. Cable company ISPs have short, multi-minute outages during work hours a few times per year, and a multi-hour outage perhaps once a year. Home users can remain working online throughout the year, oblivious to ISP outages.

Surviving Hosted Application Delay



When a WFH user's critical application – Google Drive for example – has a service outage, there is no cure. What seasoned users tend to do is consult the DownDetector website for status information, then take a break from work until the DownDetector graph spike goes down, as shown on the left.

Maya vs. Existing Network Problem Solutions

More Bandwidth

Maya IQS avoids the need for more bandwidth with Dynamic Bandwidth Control. High priority traffic goes first, then lower priority traffic is regulated, preserving the bandwidth needed for high priority applications. In practice voice is the most important application, and its bandwidth requirements consume just a fraction of today's low cost multi-megabit bandwidth subscriptions. For most home users, there's always room for voice.

The next priority below voice is the video portion of a videoconference. The top videoconferencing services are very good at adapting to network slowdowns. They decrease the frame rate from 60 to 15 frames/sec and with further slowdowns refresh only people's eyes and lips. Humans are forgiving if the picture isn't moving well, but do not tolerate broken voice or lips out of synchronization with the voice. Maya preserves the voice and video synchronization as the videoconferencing application slows the video stream to fit in the available bandwidth.

SD-WAN

SD-WAN was designed to augment private WAN connections with a secondary connection. Private WANs cost between hundreds and thousands of dollars while the secondary connection matches up in cost with a WFH user's ISP service – cable or fiber. SD-WAN requires an additional cloud module that's paired with the home user's premise device to enable the technology. In addition to the high cost, SD-WAN has provisioning complexity beyond the expertise of a WFH user. The key SD-WAN technologies are evaluated in comparison to Maya in the sections below.

Traffic Shaping

SD-WAN traffic shaping is similar in effect to Maya's IQS. However, traffic shaping requires creating a set of policies governing the priorities of all network traffic. Maya works autonomously and requires no input by the customer or the ISP.

Maya provides an additional benefit over traffic shaping in that it maximizes the ISP's circuit goodput. Traffic shaping works with a pre-configured set of rules and an assumption for the network speed. Traffic shaping was created in the area of fixed bandwidth circuits and static configurations with a list of applications.

The WFH user's broadband service has ever-changing bandwidth along with a number of cloud applications known only to each WFH user. Maya dynamically adjusts to bandwidth and application changes while operating at peak capacity – which is maximum goodput. Traffic shaping has lower goodput due to unused reservations causing wasting bandwidth.

Path Control

Maya's Dynamic Bandwidth Control adjusts circuit load to maintain quality, eliminating the need for Path Control's second circuit.

For ISP outages and the WFH user, Maya recommends a standby 4G failover service, requiring no configuration with a very low cost from AT&T or Verizon.

For customers with multiple ISP circuits Maya can provide load balancing, but unlike Path Control, Maya does not need a pre-configured list of applications and load balancing rules.

Forward Error Correction

Forward Error Control was invented in an era when circuits were unreliable and error prone. In today's era packets are lost or delayed when a circuit is overloaded. Maya avoids lost and delayed by eliminating overloading with Dynamic Bandwidth Control.

SD-WAN can only estimate the network capacity and consequently inadvertently creates lost and delayed packets. Forward Error Correction is used to recover from SD-WANs own error. Maya has no need for Forward Error Correction as it avoids errors in the first place.

In addition to increased circuit costs, Forward Error Correction must be selectively used and then monitored for issues, neither requirement is appropriate for a WFH user.

Conclusion

To the neophyte WFH user it may appear that the Internet is a minefield of issues – and it is. The typical enterprise spends a lot on the Internet – ISP service, backup service, offline storage and an IT staff dedicated to keep it working properly. Home users are frustrated as there appears to be no answer to combat Internet issues. Maya Global Solutions offers the only service to home users that can cure network issues. Maya is simple to purchase and a snap to install. WFH users will find it a great relief and find themselves with increased productivity.