An Upgrade In Place

— an effective, inexpensive, in-place network upgrade plan to improve WiFi and home and business networks worldwide - "I should do a more security focused version for rip and reflash"

Executive Summary

What Internet users most need, is not more bandwidth, but ***better bandwidth***[1]. Wider adoption of "Smart Queue Management" (SQM, RFC8290) systems on home routers and ISP infrastructure will lead to much better video conferencing, gaming, and remote work experiences for all, especially those with limited bandwidth and connectivity. They also need VASTLY better security, and IPv6 that can be provided by modern and fully open source firmware.

An "Upgrade in Place" program encouraging Internet users and their ISPs to install better routers will lead to a vastly better Internet experience for everyone and allow for more equitable adaptation to the new ability for many to work from home.

Improving the world's Internet infrastructure is very important for everyone — whether it be running more fiber, better maintaining the copper plant, helping wireless internet service providers (WISPs), or more. However, in many cases, far sooner, existing and planned Internet access services can be improved by upgrading the firmware on the existing hardware. These upgrades instantly and cheaply lead to a much better Internet experience.

During the pandemic, work habits changed permanently. However, the Internet experience for those working from home is often poor, especially when the network is shared between multiple users[2]. Video conferencing in particular can be rendered unusable when sharing a connection with multiple users.

At the root of these issues is a phenomenon known as bufferbloat, which is the undesirable latency that comes from network equipment buffering too much data. This added latency occurs, when all the capacity of a given connection is consumed, causing the buffers to overfill, and leading to delays in packet processing.

This bufferbloat problem is usually not a **lack** of bandwidth, but poor **management** of available bandwidth. And in fact, this is a **solved problem** technically — with free and open source code available, and documented in IETF RFC8290, RFC8033, and RFC7567. This code can be easily installed onto millions of existing routers with simple firmware upgrades. It is already shipped as part of newer routers such as those from EvenRoute, Eero, Mikrotik, Firewalla, Starlink and dozens of others. What is lacking, is not the technologies to manage bandwidth better, but the incentives to deploy them, and also the end-user and ISP knowledge of recognising and fixing a bufferbloat problem effectively.

Ongoing ISP services are relentlessly focused on selling more bandwidth, and not towards providing good performance in the low and middle tiers[3] of their Internet access service. New

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[1] https://gettys.wordpress.com/2018/02/11/the-blind-men-and-the-elephant/
[2] https://gettys.wordpress.com/2020/04/22/bufferbloat-in-action-due-to-covid-19/
[3]
https://www.cringely.com/2021/02/04/2021-prediction-4-WiFi-6-is-a-bust-for-now-as-bufferbloat-returns-thanks-to-isp-greed/

hardware development is also biased in this way. Yet... DSL lines in particular are expensive to upgrade, and newer higher-speed services, like cable and fiber, are difficult and time-consuming to deploy into remote areas.

Since the discovery and naming of the “Bufferbloat Problem,” the Internet community has developed the means to maximize the performance of low-rate interactive applications, such as video conferencing.

What’s been missing are any incentives to push these needed upgrades to the edge of the Internet. For example, one potential incentive would be to prominently report on latency under load in the FCC’s Measuring Broadband America program[4].

The widely-deployed solution fq_codel (standardized in the IETF as RFC8290[5]) was first developed in 2012, and is the default queuing mechanism in Linux, iOS, and macOS. It already works on tens of thousands of different routing devices on both their ISP link, and on WiFi. It’s also used in many home router quality of service (QoS) systems under various trade names, with additional support for software rate-shaping and other QoS optimizations.

The reference implementation, the open source “sqm-scripts”[6] system, is designed to deliver the best performance possible from even the lowest-bandwidth systems still deployed today. The more recently developed “sch_cake”[7] represents the best-of-breed implementation of an SQM system for DSL, Starlink, and cable modems, and delivers further optimizations. Most home routers are Linux-based, and any router using a Linux version developed in the last eight years has the capability to deploy an SQM system.

Optimizing for video conferencing traffic in particular is automatic. Video conferencing tends to be quite low bitrate: usually, a useful video conference can be achieved with less than 1 Mbps in both directions, which is easily supported by even lifeline services… as long as router queues are well-managed, so that other Internet traffic in the home doesn’t interfere.

[4] This test is already being run by the SamKnows platform used by the FCC but the results do not receive any prominence in the FCC MBA reports.
[5] https://tools.ietf.org/html/rfc8290
[6] https://github.com/tohojo/sqm-scripts
[7] https://arxiv.org/pdf/1804.07617.pdf

Application	Examples	Upload Bitrate	Download Bitrate
Voice	VOIP	32kbps (unless HD)	32kbps (unless HD)
Video conferencing	Webex, Zoom, etc	400kbps-4Mbit	1Mbit --20Mbit
Interactive gaming	UDP C&C traffic	64kbps	64kbps
Audio streaming	MP3 and FLAC files	16kbps	256kbps
Video streaming	MPEG-2	128kbps-1Mbit	1.5Mbit - 35Mbit
Web access	Html, images	~1/20th the download	Infinite ~2-3 sec/pg
File transfers	Dropbox, scp, etc.	infinite	infinite

ISPs in general lack an incentive to encourage users to upgrade their routers to provide a better user experience. A regulatory body is required to step in and at least measure latency under load. See Appendix A for examples from the popular speed test site DSLReports, showing the extent of the "bufferbloat" problem.

We recognize that the process of reflashing a router is a task beyond the reach of many Internet users, and while many tutorials exist, the concept of a "router reclamation center", where older devices could be reflashed professionally and made better than new might be an option moving forward, as well as leveraging the resources of an e-waste or computer reclamation center. Credits for donating a suitable router from an accepted list would also be a green solution and lead to less e-waste.

Widely-deployed and readily available third-party firmware, such as OpenWrt, DD-WRT, Tomato, is already available to address these needs.

Moving forward, the NTIA or FCC could:

- Recommend ISPs deploy CPE that guarantees a bufferbloat grade if A or better on wired tests at customer premises in the short term.
- Make it a requirement, that any new ISP CPE (whether a router with SQM, or an ONT delivering low bloat) MUST meet or exceed the above suggestion as of 2024.Require, that ISPs publish the link and framing rates, and make available interactive tools for monitoring "sag."
- Provide up-to-the-second statistics on the actual link and framing to user applications.
- Mandate the publication of bufferbloat-related figures by some agreed-upon universal metrics.
- Encourage the ISP industry to: provide latency metrics on speed tests, to generate bufferbloat grades by default, and encourage consumer device manufacturers to list latency-under-load performance in their specifications.

- Invest in the education of individuals and the industry on the importance of the quality of connectivity over simply the capacity of the link.
- Provide a government-sponsored test service and education portal. License or contract the implementation from one of the existing providers to get up and running quickly.
- Track statistics on dslreports.com on bufferbloat problems for each ISP.

FCC or NTIA rules could grow to include:

- Certification of an effective SQM system
- Establish a standardized mechanism for CPE devices to query the ISPs' current-line provisioning settings in effect (at DSLAM / CMTS), and provide other line criteria necessary to correctly set baseline QoS parameters in an automated fashion.
- Compel Internet service providers and/or device manufacturers to deploy the remote updating of routers. If a customer has obtained a router from an ISP, then pushing updates would be the responsibility of the ISP. Some ISPs in Europe already do that, though on a voluntary basis.

As for an “Upgrade in Place”....

We estimate, that as many as 30% of households might have an old router lying in a junk drawer (or an existing one in-place), that with the installation of modern open source software would dramatically improve the quality of the Internet experience, and vastly improve security for users operating at or below the existing “broadband” tier of 25/3 Mbps. Good results at 100/25 Mbps are also feasible with routers designed in the late 2000s.

With a worldwide initiative in repurposing these older routers, a can-do spirit, and a little education, a good portion of the internet could not only be upgraded to vastly better queue management, but also enable IPv6 more widely, and vastly improve security and reliability.

As we’ve already noted, many off-the-shelf routers can implement better bandwidth management, but the users need to be educated, and the ISPs need to start supplying equipment that can be automatically configured properly.

To gain immediate resolution for affected users, possibly funding a program to subsidize individual purchases of qualifying products, coupled with an educational campaign would work.

In the long term, we’d recommend federal support to independent networking firmware efforts such as these, as these are user-focused efforts developing software that can be used for any purpose, not just better, more secure, IPv6-capable firmware.

Sincerely,

Dave Taht Co-founder, Bufferbloat Project	

Additional Signatories

LINKS for footnotes

https://blog.apnic.net/2020/01/22/bufferbloat-may-be-solved-but-its-not-over-yet/

https://lwn.net/Articles/758353/ https://evenroute.com/quick-vs-fast

https://www.cringely.com/2021/02/04/2021-prediction-4-WiFi-6-is-a-bust-for-now-as-bufferbloat-returns-thanks-to-isp-greed/

The previous FCC filing, The original bufferbloat article, vint cerf, the mailing list

https://bufferbloat-and-beyond.net/

GLOSSARY OF TERMS

CMTS

FAIR QUEUING

ACTIVE QUEUE MANAGEMENT

CGNAT

QOS

QOE

BANDWIDTH

CAPACITY

SPEED

SQM

SECURITY

IPV6

IPV4

IPV4 Address exhaustion

CGN

WiFi

RANGE

https://archive.org/details/video1_20191129

APPENDIX A — EXISTING BUFFERBLOAT-RELATED DATA

The largest source of bufferbloat-related data is the popular dslreports.com “speedtest,” which does a detailed analysis, and has logs going back eight years. This dataset is flawed, as the site is used extensively by SQM users to fine-tune their implementation, thus it understates the true amount of bufferbloat in most under-configured home devices.

There has been much improvement over the past eight years regardless, but the typical user can still experience unneeded delays and latency of well over a quarter of a second, and DSL users suffer especially, given the lack of link layer compensation in most commercial SQM implementations.

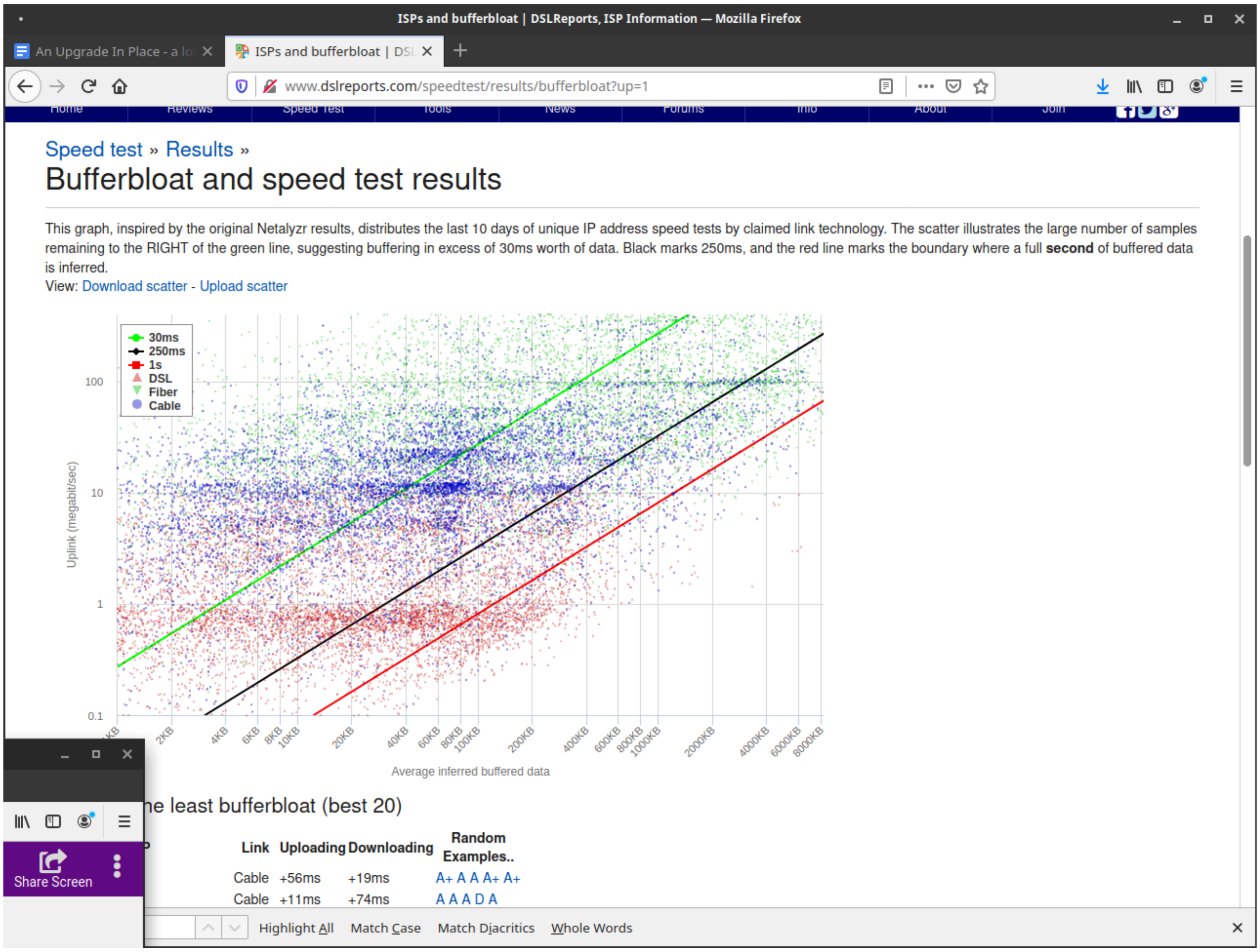
The users of an SQM system typically experience latency under load and jitter under 30 ms, which is well within a good range for a quality video conferencing experience in a shared home environment.

You’ll note that there is only one American ISP in that range.

The cable industry has standardized bufferbloat solutions in DOCSIS 3.0 and 3.1. Most or all CMTSes today have the ability to deploy the PIE AQM for downstream traffic, as

Comcast has done on all of their CMTSes (the status of other cable company deployments is unknown). For upstream traffic, AQM must be enabled in the cable modem. Customer-owned and -managed (COAM) cable modems do not generally have AQM. But some ISP-provided modems do, such as Comcast's XB6 and XB7 gateways. While Comcast has been focused on adding AQM to their cable modem gateways for some time, and while it runs automatic latency-under-load tests as part of its network performance measurement system[8], it is unclear whether other cable companies have been doing so. COAM devices would generally use a buffer control setting that varies by provisioned speed, which is not as good as AQM, but is better than nothing.

[8] See system description at https://www.netforecast.com/netforecasts-report-on-comcasts-network-performance-measurement-system-results-data/. This report focused on speed, not latency under load, but this system runs a variety of tests.



ISPs and bufferbloat | DSLReports, ISP Information — Mozilla Firefox

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www.dslreports.com/speedtest/results/bufferbloat?up=1

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Bufferbloat and speed test results

This graph, inspired by the original Netalyzr results, distributes the last 10 days of unique IP address speed tests by claimed link technology. The scatter illustrates the large number of samples remaining to the RIGHT of the green line, suggesting buffering in excess of 30ms worth of data. Black marks 250ms, and the red line marks the boundary where a full **second** of buffered data is inferred.

View: Download scatter - Upload scatter

...he least bufferbloat (best 20)

Link	Uploading	Downloading	Random Examples..
Cable	+56ms	+19ms	A+ A A A+ A+
Cable	+11ms	+74ms	A A A D A

Highlight All Match Case Match Diacritics Whole Words

Share Screen

ISPs with the least bufferbloat (best 20)

ISP	Link	Uploading	Downloading	Random Examples..
Exetel	Cable	+56ms	+19ms	A+ A A A+ A+
TeleNet	Cable	+11ms	+74ms	A A A D A
Sky Broadband	DSL	+51ms	+41ms	A A+ B A A
XS4ALL	Fiber	+41ms	+52ms	C A+ A+ A F
Zen Internet	DSL	+54ms	+47ms	B A A A A
Free France	Fiber	+71ms	+32ms	A C A+ A+ C
Noos NumeriCable	Cable	+32ms	+75ms	B F A A B
Buckeye Broadband	Cable	+68ms	+41ms	C A+ A A A
ER Telecom	DSL	+92ms	+18ms	A A+ A A+ A+
Vivo Brasil	Fiber	+61ms	+52ms	A+ A A+ A+ D
Armstrong	Cable	+38ms	+77ms	A A A+ A+ A
Virgin Media	Cable	+36ms	+89ms	A B A A C
Hawaiian Telcom	Unsure	+89ms	+48ms	A+ A A+ A+ F
Com Hem Bredband	Cable	+74ms	+64ms	B C A A A
Bezeqint	DSL	+101ms	+38ms	A+ B A A+ A+
SaskTel Saskatchewan	DSL	+86ms	+53ms	B A A A D
Northland Cable Television	Cable	+45ms	+98ms	A A B A A+

Saudi Telecom JSC	Fiber	+78ms	+66ms	A A A A A
Metrocast Communications	Cable	+50ms	+96ms	F B B B A
Bright House Networks	Cable	+40ms	+106ms	C A A+ A A

ISPs with most bufferbloat

ISP	Link	Uploading	Downloading	Random Examples..
Xplornet	Wireless	+705ms	+594ms	C F F F F
Telstra Bigpond	4G	+551ms	+375ms	F F A F C
Tochka	4G	+379ms	+357ms	D C D A C
Verizon DSL	Fiber	+394ms	+327ms	A A B B A
Eastlink Cable	Cable	+281ms	+397ms	C A A D D
CenturyLink	DSL	+500ms	+160ms	A D F F F
Smart Broadband	4G	+170ms	+482ms	A A B C D
Fairpoint Communications	DSL	+488ms	+153ms	F C A F D
Cingular Wireless	4G	+295ms	+334ms	F C A C B
T-Mobile	4G	+283ms	+336ms	C C B C F
SONIC	Fiber	+438ms	+134ms	F C C C B
SiOL	DSL	+480ms	+65ms	F F B F B
Verizon Wireless	4G	+328ms	+205ms	D D F A C
CanTV	DSL	+341ms	+175ms	F B C D C
Wind Telecomunicazioni SpA	DSL	+262ms	+236ms	A B F B C
Telecom Argentina	Unsure	+321ms	+178ms	F A+ D F A
Execulink Telecom	Cable	+94ms	+402ms	D F F A A
Qwest.net	DSL	+390ms	+94ms	A B C C C
Bell Aliant Regional Communications	Fiber	+185ms	+298ms	D D A+ A+ F

OptusNet	Fiber	+220ms	+262ms	D C F C F

APPENDIX B

This filing is focused on improving the Internet quality for users operating at or below 100 Mbits/s to/from their ISP. Above those speeds, the bufferbloat problem shifts to WiFi.

Also, highly asymmetric cable exhibits bad bufferbloat. My gigabit DOCSIS 3.1 (on download only) has >500ms of bloat on the 35 Mbps uplink (which is running in 3.0 mode).

APPENDIX C

New and planned network rollouts can also benefit from the adoption of IETF standards for FQ and AQM. Line-rate fiber would especially benefit from mandating ONTs with these algorithms in them.

APPENDIX D

This appendix lists various products that “do the right things” as of Feb, 2021.

Known Good SQM implementations

Flawed Implementations

Eero Pro

Non-existent

DOCSIS support