Don’t Forget the Access Network

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Peer-to-peer file-sharing applications -- BitTorrent and its kin -- are not a primary focus of concern when people talk about all that ails the Internet these days. But going back 15 years reveals a stark example of a mismatch between design expectations and deployment reality when looking at the impact of peer-to-peer file-sharing on cable broadband networks. This history may be relevant to keep in mind for those considering re-visiting true peer-to-peer architectures as a way to mitigate consolidation or centralization.

Popular peer-to-peer applications are characterized by their ability to efficiently transfer large files unattended: users can configure their peer-to-peer clients to download specific files in advance and then leave those clients running in the background without the need for user interaction. This means that even if the fraction of a network’s broadband subscribers using peer-to-peer applications is small, the proportion of peer-to-peer traffic can be large. Furthermore, peer-to-peer networks only function if peers both upload and download. As a result, peer-to-peer traffic tends to be roughly symmetric, with comparable amounts of traffic being sent in the downstream and upstream directions.

Cable broadband has historically been offered asymmetrically, with far more bandwidth provided downstream than upstream. It also relies on significant shared infrastructure in the access network. Dozens of subscribers in the same neighborhood may share the same local fiber optic node, and hundreds of subscribers may share the same IP port further up in the network. Popular peer-to-peer file-sharing applications place a particular strain on this kind of architecture because they are designed to maximize the amount of data being exchanged at any one time, in part by opening many simultaneous connections to other peers. As peer-to-peer file-sharing grew in popularity in the mid-2000s, the result was that with even a small number of avid peer-to-peer users sharing a particular network link, freshly upgraded links could reach 80-90% utilization in a matter of months.

The upstream contention problem was acute for some cable operators. Performance of other applications across their networks was suffering as a result, with upstream contention taking a disproportionate toll on real-time applications such as VoIP. One study found that just 15 active BitTorrent users on a cable link shared among 400 total users could cause VoIP call quality to fall below a usable performance threshold [Martin and Westall]. When peer-to-peer file-sharing started growing significantly, some operators saw the growth of upstream traffic as unsustainable from a capacity planning perspective.

What ensued, in North America at least, was a techno-regulatory drama. Operators deployed deep-packet-inspection-based solutions to limit the number of upstream file-sharing connections on particular links, concerned users reacted with outrage, regulators intervened to different degrees. In parallel, the gap between design expectations and deployed reality began to close with the development and adoption of transport-based changes designed to ease the effects of file-sharing on other applications. The standardization and deployment of background transports such as LEDBAT [RFC 6817] and Active Queue Management algorithms such as CoDel [RFC 8289] and Flow Queue CoDel [RFC 8290] helped to reduced the effects of contention between application flows of different kinds. LEDBAT, implemented by BitTorrent in 2008, allows the file-sharing client to cede bandwidth to more latency-sensitive applications. CoDel and FQ-CoDel allow excess delay caused by bufferbloat to be controlled, better protecting latency-sensitive traffic. Notably, peer-to-peer file-sharing protocols and applications themselves did not experience significant design changes, nor did cable broadband infrastructure become more symmetrically provisioned. Residential cable broadband remains as asymmetrically provisioned as ever (see Figure 1).

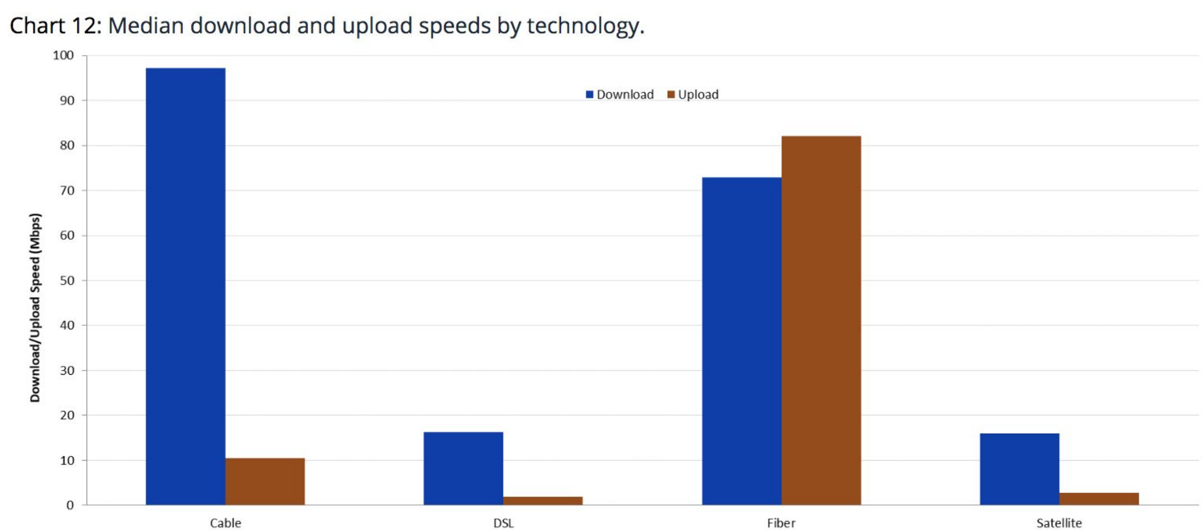

Figure 1. Median download and upload speeds on fixed access network technologies in the United States in 2018 [FCC].

This history is relevant today for those who are concerned about the privacy implications of consolidation and centralization on the Internet, particularly insofar as those trends are being driven by the market dynamics of content delivery. To offer services such as messaging, video sharing, photo sharing, and other social media in truly private ways may imply more than growing from a handful of major CDNs, DNS resolvers, or web services to a dozen of each. It potentially implies disintermediating these services and returning to ideas about direct peer-to-peer exchange of information. If (re-)decentralization is to be considered comprehensively, it would naturally include the possibility of decentralizing actual infrastructure -- possibly all the way down to the access point, home network, or user device -- and not just diversifying or increasing the number of parties providing services that themselves remain centralized.

If peer-to-peer architectures are to be further explored for the services arguably most in need of decentralization, the history of peer-to-peer file-sharing on cable broadband networks illustrates which constraints may be more flexible and which may be more rigid. Designing with the expectation that long-standing characteristics of physical access networks are unlikely to change seems wise, as does assuming that developers will want to maintain existing application protocol mechanics that they feel are already successful. Looking to supporting components of these architectures -- transport, security, perhaps identity provision -- to find avenues for easing their deployment seems like a more fruitful path.

In addition, it is important to recognize that some concentration in parts of the Internet is almost certainly inevitable, which means that the concerns about consolidation and centralization might be most correctly viewed as a choice among least-bad options. Most consumer access markets are likely to always contain only a few large players in any given geographic area, which means that diversity alone cannot solve all concerns. Whenever the interests of the access networks are at odds with whatever peer-to-peer approach is to be used, the access network’s controlling position will permit it to interfere in that operation. This means either that such considerations need to be part of the peer-to-peer design, or else that regulation to prevent such interference will be necessary.

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