# Traffic Types and Growth in Backbone Networks

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**Abstract:** We review the growth of the different sources of data traffic on backbones, highlight the importance and nature of IP services today, and discuss the implications on content distribution and efficient use of backbone capacity.
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## 1. Introduction

There are perceptions among many in the optical industry that the Internet is #1) growing without bound and #2) the only driver for large Optical-Layer capacity. Such perceptions are often used to amplify the need for advanced optical equipment and capabilities. The purpose of this paper is to clarify these perceptions for a large (Tier-1) US-based Internet Service Provider (ISP) (our "sample" carrier). Large terrestrial telecommunications carriers are organized into metropolitan areas (metros) and place their equipment in buildings called Central Offices (COs). Almost all COs today are inter-connected by optical fiber. The access segment of the network refers to the portion between a customer location and its first (serving) CO. The core segment inter-connects metro segments. Networks are further organized into network layers that consist of nodes (switching or cross-connect equipment) and links (logical adjacencies between the equipment), which we can visually depict as network graphs vertically stacked on top of one another. Links (capacity) of a higher layer network are provided as point-to-point demands (called traffic, connections or circuits) in lower-layer networks. In particular, Figure 1 (introduced in [1]) describes a simplified model that consists of two major types of core services: IP (or colloquially, Internet) and Private Line (PL). IP services are provided by the IP Layer, typically an IP/Multiprotocol Label Switching (MPLS) core composed of routers, and PL services are provided through three different circuit-switched layers: 1) a Wideband Digital Cross-connect System (W-DCS) Layer for low rate PL services (1.5 Mb/s), 2) a Broadband Digital Cross-Connect (B-DCS) Layer for intermediate rate PL services (45 – 622 Mb/s), which is composed of the Intelligent Optical Switch (IOS) Layer and the much smaller, legacy SONET Ring Layer, and 3) the Reconfigurable Optical Add/Drop Multiplexer (ROADM) Layer (also called Optical Layer) for high rate PL services (2.5Gb/s and up). The arrows in Figure 1 (left) depict the complex relationship among services, links, and circuits of the various layers.

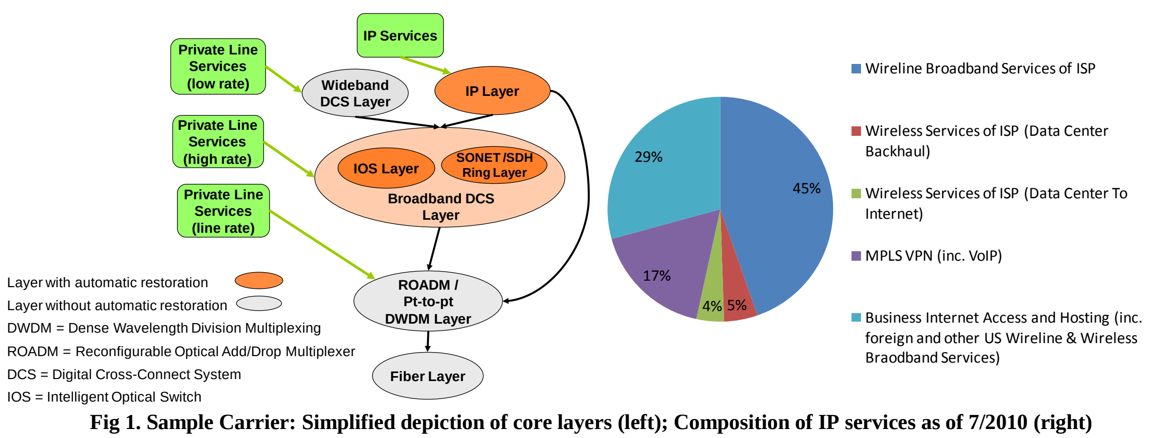


**Fig 1. Sample Carrier: Simplified depiction of core layers (left); Composition of IP services as of 7/2010 (right)**

From Figure 1 (left), we see demand for the ROADM Layer primarily arises from three upper layers (B-DCS, IP, and high rate PL). Let us denote this total demand by the variable $D_{ROADM}$. For simplicity we do not include other legacy upper network layers in $D_{ROADM}$. To estimate the relative size of those demands for our sample carrier, we define appropriate metrics. E.g., a 10 Mb/s (average rate) flow that is 1000 km long contributes 10 Gb-km toward the total IP-Layer *demand*. A 10 Gb/s IP link that is 400 km long contributes 4000 Gb-km towards total IP-Layer *capacity*. Using this methodology, we estimate (roughly) that the capacity of the B-DCS Layer, IP Layer, and High-rate private line contribute 42%, 43%, and 15%, respectively, of $D_{ROADM}$. However, this simple result can be misinterpreted because of the complex inter-relationships of the layers. For example, as Figure 1 shows, the B-DCS Layer also provides capacity for the IP Layer (e.g., lower rate links), which we estimate at over 40% of the demand of the B-DCS Layer. This better clarifies perception #2 above: both IP Services and Private lines play a major role. The remainder of the paper concerns clarification of perception #1.

## 2. IP Services: traffic types and growth

Figure 1 (right) shows the breakdown of IP services (demand for the IP Layer) for the sample carrier. First, we observe that its backbone is dominated by the traffic of its own "eyeballs", that is traffic from/to its own wireline broadband subscribers (45%). Second, even though the most rapidly growing component (5,000% growth 2007-2009 included, and 150% growth over the past year), IP traffic from wireless subscribers, is very small (4%). Third, IP hosting and business Internet access provided to other ISPs and content providers are another major source of traffic. Further inspection of that traffic indicates that a significant fraction is generated by other wireline broadband services. Finally, the transition of legacy private networks (such as Frame Relay, ATM, and Private Line) to MPLS VPNs on a shared core is substantial, as it now accounts for 17% of the total traffic.

Growth of aggregate wireline broadband traffic results from a combination of new subscribers and per-subscriber consumption. According to the Organization for Economic Cooperation and Development (OECD), the penetration rate of broadband services grew by 31% per year from 2000 to 2009 in the United States (decelerating from 48% to 3.5% in 2009) [2]. During the same period, Figure 2 (left) shows relatively stable growth rate of the average downstream traffic per subscriber (32% per year) for the sample carrier. This agrees with the 30-35% range for 2009 mentioned by the FCC Omnibus Broadband Initiative [3]. Combining these two numbers provides an estimate of average traffic growth of 70% per year in the US over the last decade. This is consistent with the backbone traffic growth of the sample carrier in Figure 2 (right) - two orders of magnitude over the last nine years and almost four orders of magnitude over the last 12 years. Looking forward, we expect the traffic per subscriber to continue to grow at 30% and therefore the deceleration of aggregate US traffic growth (projected to be 33% per year in the US until 2014 [4]), is due to wireline broadband market saturation.

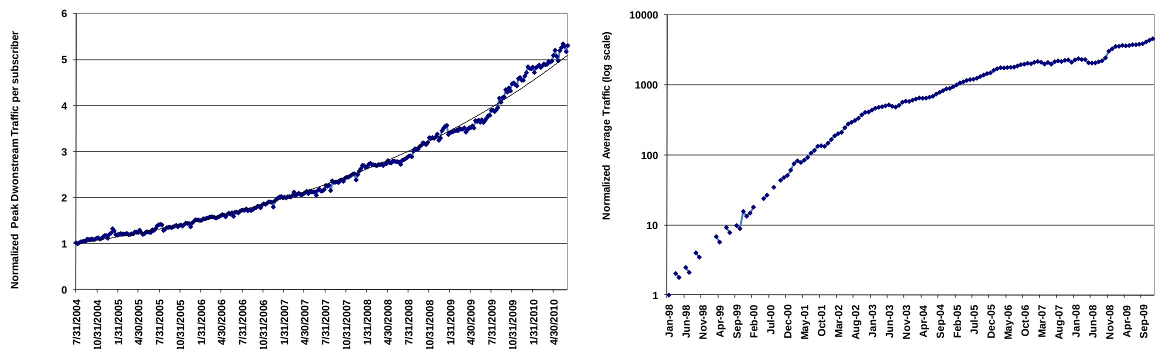


**Fig. 2. Sample Carrier: Average downstream traffic per wireline subscriber (left) & IP backbone traffic (right)**

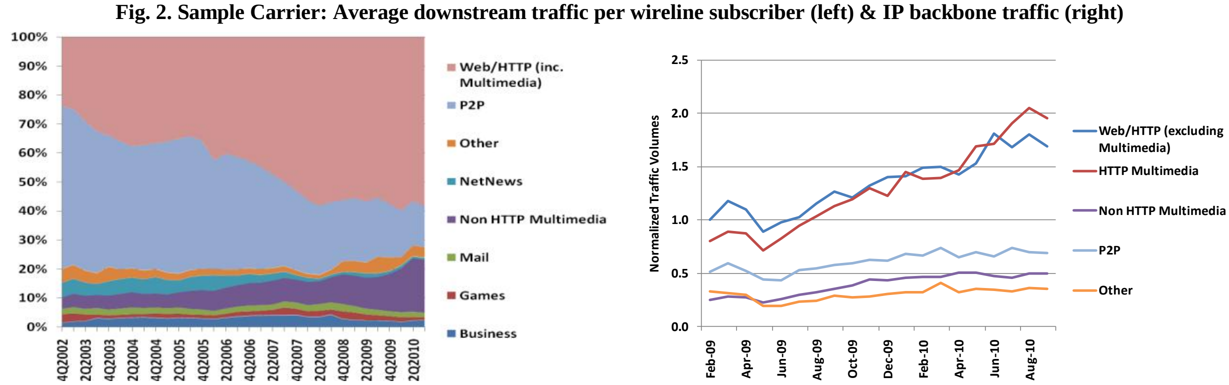


**Fig. 3. Sample Carrier: IP services application mix (left) & Downstream wireline broadband application mix (right)**

However, growth has not been consistent across applications. Indeed, Figure 3 (left) shows that over the last 8 years, HTTP traffic has grown at the expense of peer-to-peer (p2p) traffic. In particular, drilling down further into the applications running on the top of wireline HTTP (Figure 3 right), one observes that multimedia traffic is the driver. The annual growth rate of multimedia traffic per wireline subscriber during the busy hour has been 83% over the last 18 months, which is much larger than the observed long term growth rate. This may increase it if the trend persists. These results are consistent with other recent application mix studies, such as [5].

## 3. Implications of traffic types on content distribution efficiency

How efficiently IP content is distributed to eyeballs will affect the demand of the IP Layer and, hence, its required capacity and resulting demand for the Optical Layer. Figure 3 (left) implies that most of the today's demand originates from content with multiple destinations vs. point-to-point (e.g., video shows vs. VoIP calls). Multi-destination content can be replicated in multiple locations through overlay networks: on multiple clients for P2P or on multiple servers for Content Distribution Networks (CDN) which supports traffic such as HTTP. While the share of p2p protocols has decreased, the growth of multimedia client-server content has supported the growth of CDNs. On the sample carrier backbone, recently 39% of traffic was generated by CDNs; that share goes up to 55% when restricted to wireline broadband services, with most of it coming from a handful of CDNs. One metric for evaluating the efficiency of overlay networks is to compute the weighted mean of the distance traversed by traffic in the sample carrier ("on-net"). Figure 4 (left) shows that CDN overlays are 3 times more efficient than traditional non-CDN content providers (e.g., demand is reduced by 66%). In contrast, p2p overlays are not significantly more efficient than traditional non-CDN content providers. The focus has been on finding the replicated content but not on limiting the network impact or reducing the latency. Given their size, efficiency and the current trends in applications, CDNs will have a clear impact on future Optical-Layer traffic growth.

Another mechanism to efficiently distribute content over backbones is IP multicast. This approach makes it possible to generate only one IP flow on the backbone from a single source, yet replicate the same content to an unlimited number of receivers. After languishing for many years on the public Internet, multicast has recently been implemented to support the distribution of live TV over IP via IPTV protocols and the distribution of content within Enterprise networks. The result is that while IPTV typically occupies a large portion of the bandwidth of the metro distribution network, the impact on demand for the core Optical Layer is negligible. See Figure 4 (right) for the case of IPTV multicast traffic sent to 1 million hypothetical subscribers combined with their aggregate Internet usage.

A key future question is the evolution of today's mixture of video content. For example, what will be the relative mixture of 1) streaming multicast traffic on the backbone, 2) Video on Demand (VoD) served from local sources, and 3) "over-the-top" video from the Internet? Shifting from the first scenario to the third scenario would multiply the IP backbone traffic by more than an order of magnitude, given the current high efficiency of IPTV. The speed of that potential transition would also have direct consequences on the growth of IP-Layer demand.

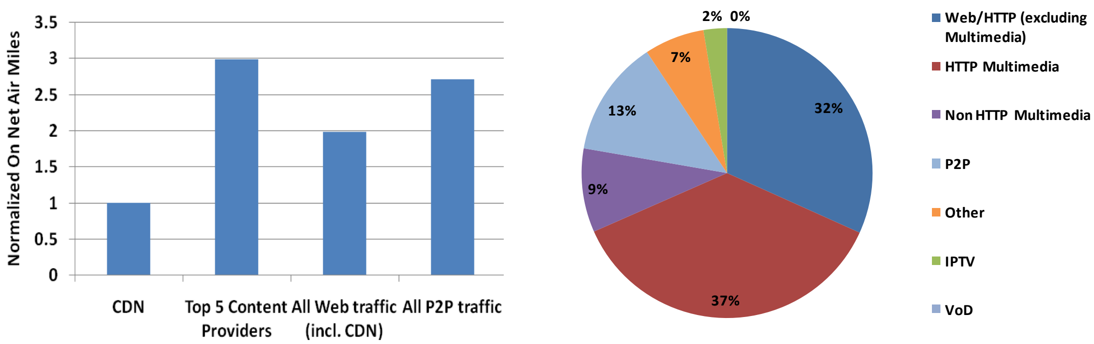


**Fig. 4. Sample Carrier: Backbone air distance by traffic types (left) & Backbone impact of IPTV multicast (right)**

## 4. Conclusion

While perceptions among many in the optical industry are that the Internet is growing without bound and still constitutes a significant driver for Optical-Layer capacity, we have shown that private line services still drive a large portion of Optical-Layer capacity in US carrier networks. Furthermore, while still growing at a healthy pace, the growth of core IP services has significantly leveled off compared to the past decade. The key questions now are how residential video content and distribution will evolve and to what relative size wireless data and video will continue to grow.

## 5. References

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