2.7 Cable data [*Editor's note: Tom Cloonan, ARRIS*]

This section discusses the bandwidth trends for the cable industry and also aims to predict that trend in the future. The various devices involved in the cable infrastructure [9] are shown in Figure 17.

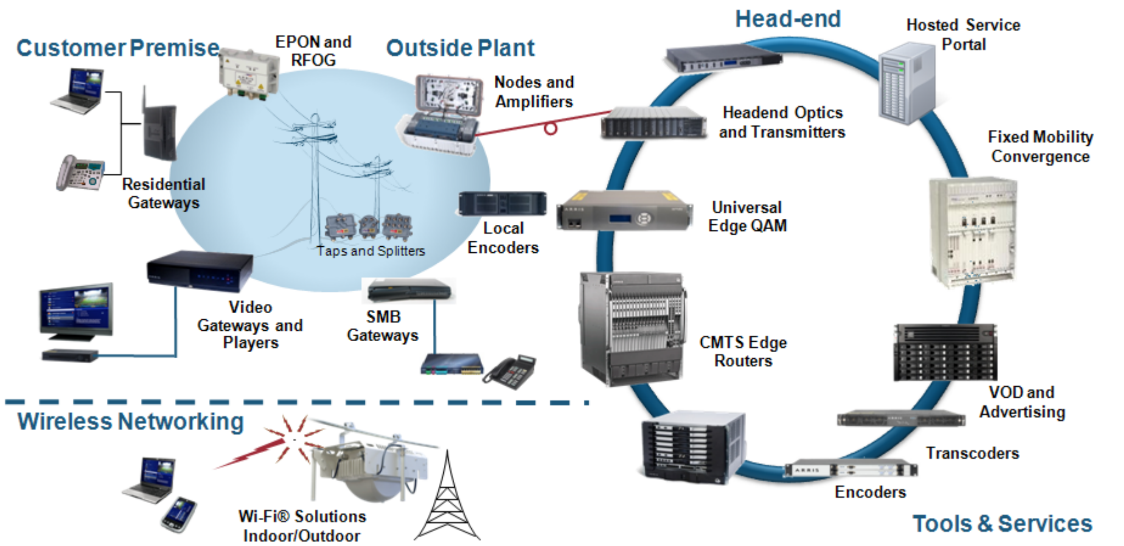

Figure 17—The cable infrastructure

The bandwidth related terms that are used in this section are defined according to Figure 18.

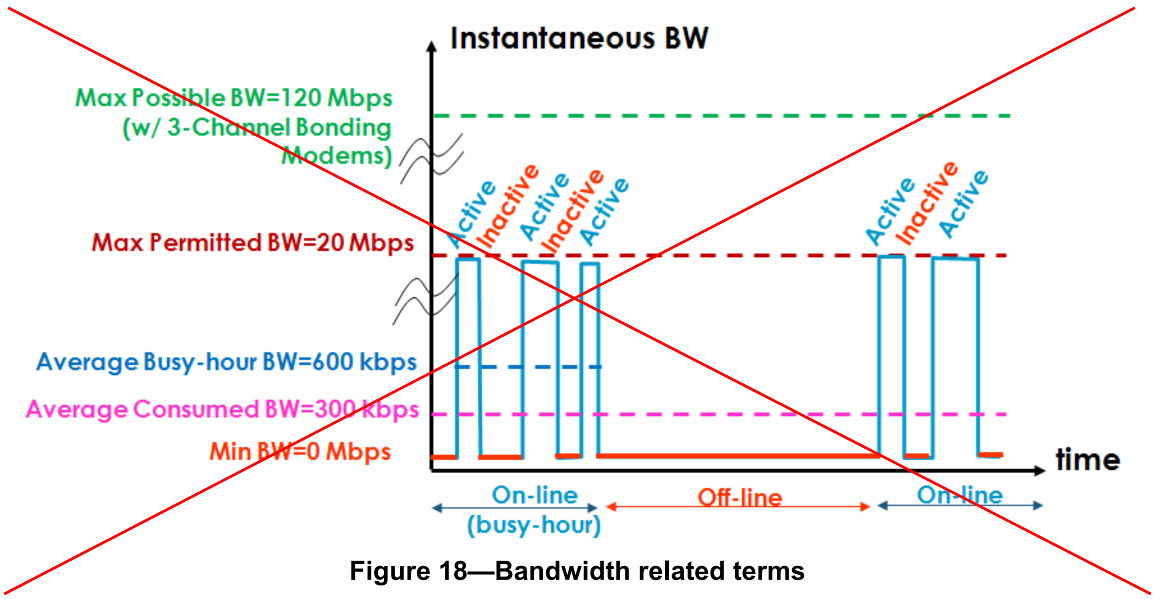

Figure 18—Bandwidth related terms

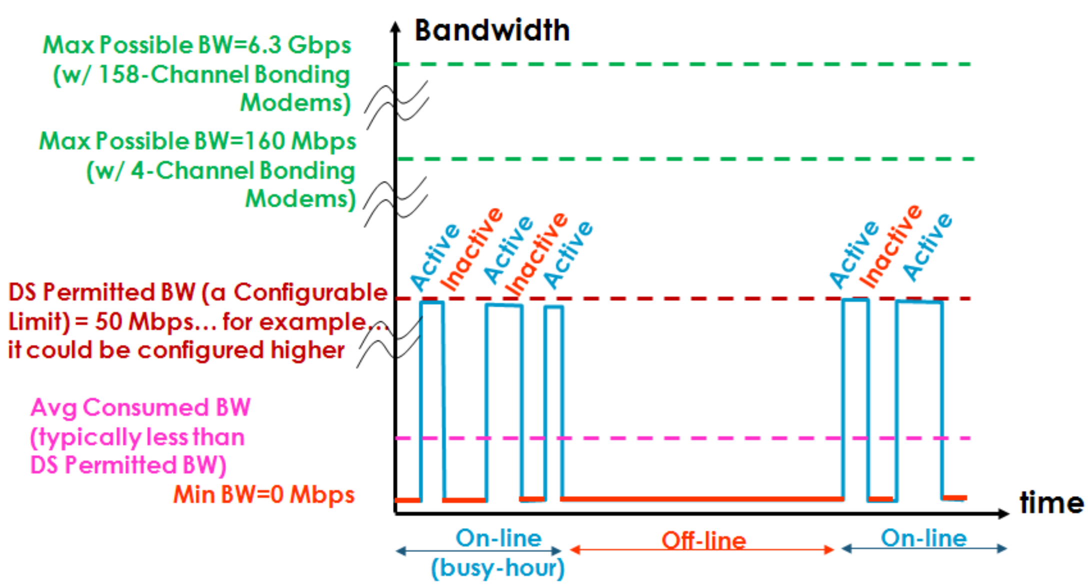

Figure 18—Bandwidth related terms

Where the average busy-hour bandwidth and the The average consumed bandwidth are is used quite extensively for traffic engineering calculations (determining how much capacity is required to satisfy a given Service Group (pool) of subscribers).

Data for the maximum permitted downstream bandwidth over time is plotted in Figure 19 [9]. This plot (which is on a logarithmic vertical scale) shows a roughly constant rate of increase in maximum permitted downstream bandwidth of about 1.5 times per year over the 29 years from 1982 to 2011.

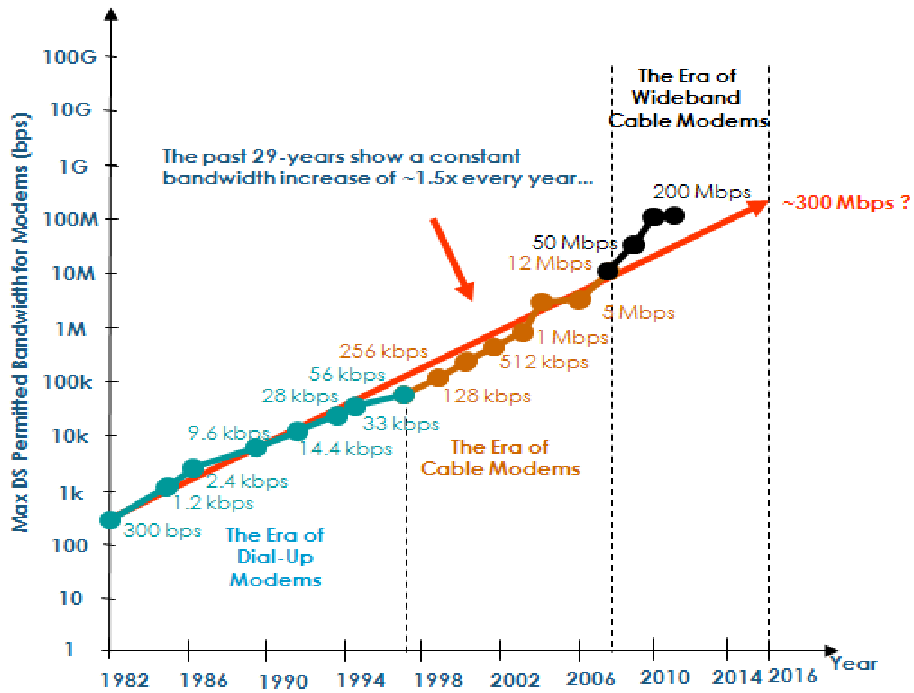

Figure 19—Maximum permitted downstream bandwidth trend

This trend (a 50% Compound Annual Growth Rate (CAGR) for a high end user's Internet connection speed) is called "Nielsen's Law of Internet bandwidth". If this trend were to be continued, it would predict a maximum permitted downstream bandwidth of about 300 Mb/s by 2016.

Data for the average downstream ~~bandwidth~~ byte consumption for a typical 40k HHP (House-Holds Passed) head-end over time is plotted in Figure 20 ~~[9]~~. This plot (which is also on a logarithmic vertical scale) predicts an average downstream ~~bandwidth~~ byte consumption in a 40k HHP head-end of about ~~3~~8~~.5 Mb/s~~ 5×10^{15} bytes by 2016 which is an increase of roughly 10 times over the average downstream ~~bandwidth~~ byte consumption seen in 2011.

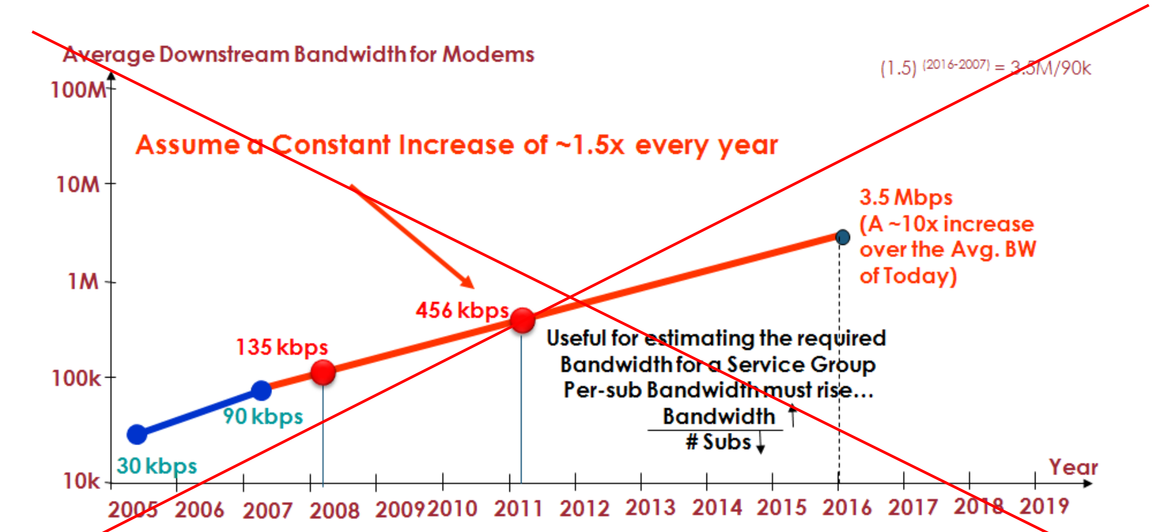

Figure 20—Average downstream bandwidth trend

~~As a sanity check, the ratio of average downstream bandwidth to maximum permitted bandwidth predicted for 2016 here (~1.2 %) roughly matches the predictions from [22].~~

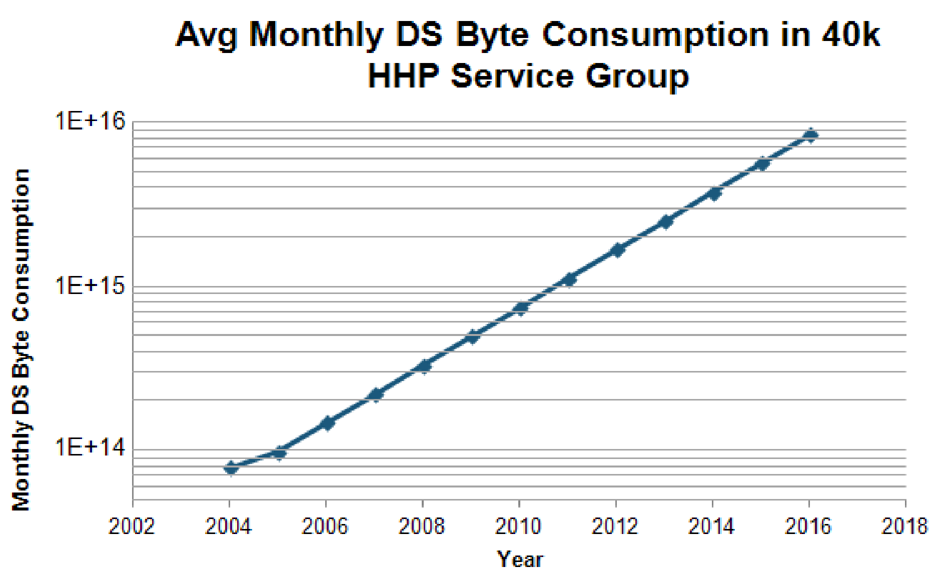

Figure 20—Average downstream byte consumption trend

Data for the maximum permitted upstream bandwidth over time is plotted in Figure 21 [9]. This plot (which is on a logarithmic vertical scale) shows a roughly constant rate of increase in maximum permitted upstream bandwidth of about 1.1 times per year. ~~However, recent activity suggests an accelerating rate of increase.~~ Upstream bandwidth is comprised of two types of traffic: protocol messages (e.g., HTTP GETs, TCP ACKs, etc.) and uploads (e.g., P2P torrents, web page inputs, FTP transfers). The protocol message bandwidth is predictable [9] and so it should increase in line with the rate of downstream bandwidth increase. The upload bandwidth is harder to predict [9] as it is highly dependent on the popularity of apps at any given time. For example when P2P ~~was big~~ represented a large percentage of the traffic in 2008, upstream bandwidth was ~41 % of downstream bandwidth. However, when over the top IP video became ~~big~~ popular in 2010, upstream bandwidth dropped to be only ~28 % of downstream bandwidth.

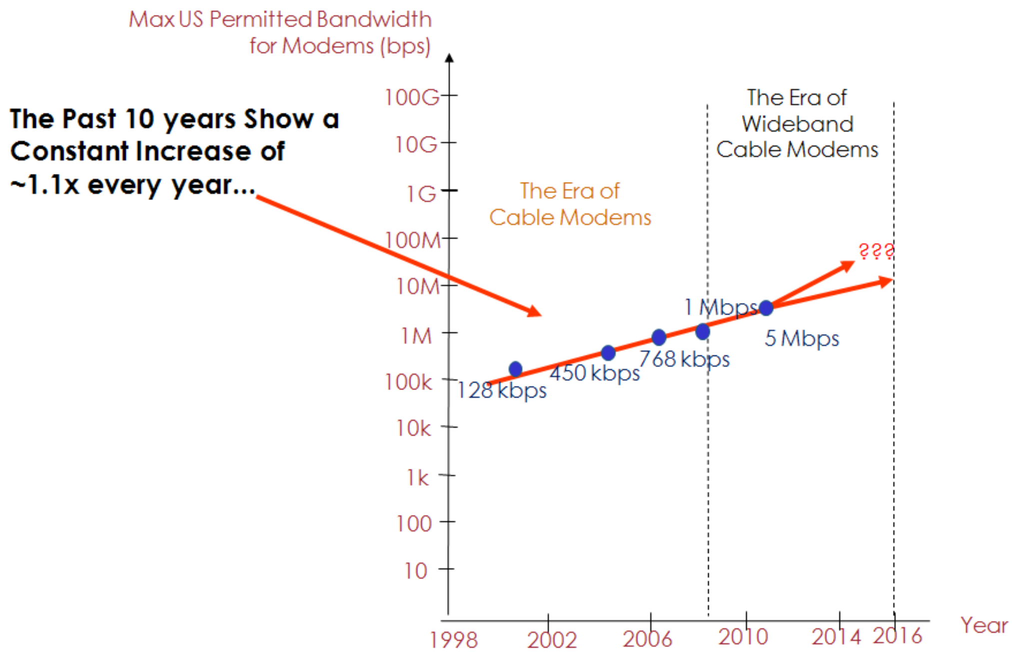

Figure 21—Maximum permitted upstream bandwidth trend

If the maximum permitted upstream bandwidth ~~is assumed~~ trend continues to ~~be one fifth of the maximum permitted downstream bandwidth [9]~~grow at a 10 % CAGR, then it would be expected rise to ~~~60~~8 Mb/s by 2016. ~~Also~~However, ~~if the average~~ indicators are that this upstream ~~bandwidth of 73 kb/s in 2010 is assumed to~~ trend could grow ~~by~~ at a ~~factor of 1.5 times per year~~ much faster rate in ~~line with average downstream bandwidth [9], then it would be expected rise to ~0.8 Mb/s by 2016~~the next four years.

~~In the period since 2009, there has been a rapid uptake of over-the-top IP video which has cause a change in slope of the downstream bandwidth per subscriber curve [9]. See Figure 23.~~

Data for the average upstream byte consumption for a typical 40k HHP (House-Holds Passed) head-end over time is plotted in Figure 22. This plot (which is also on a logarithmic vertical scale) predicts an average downstream byte consumption in a 40k HHP head-end of about 4.2×10^{14} bytes by 2016 which is an increase of roughly 2.7 times over the average downstream byte consumption seen in 2011.

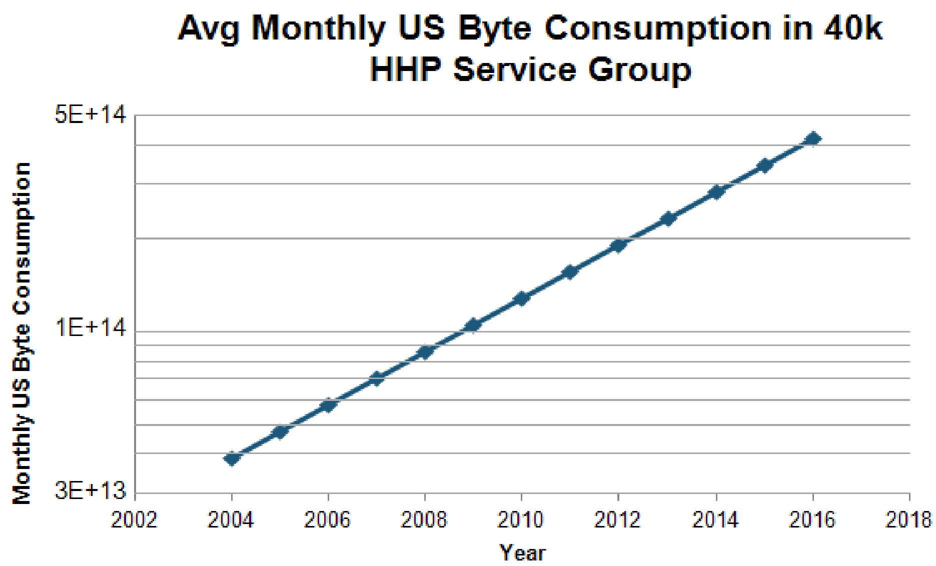

Figure 22—Average upstream byte consumption trend

~~The increase in average downstream bandwidth per subscriber during the period 1Q 2010 to 1Q 2011 [9] is shown in Figure 23~~.

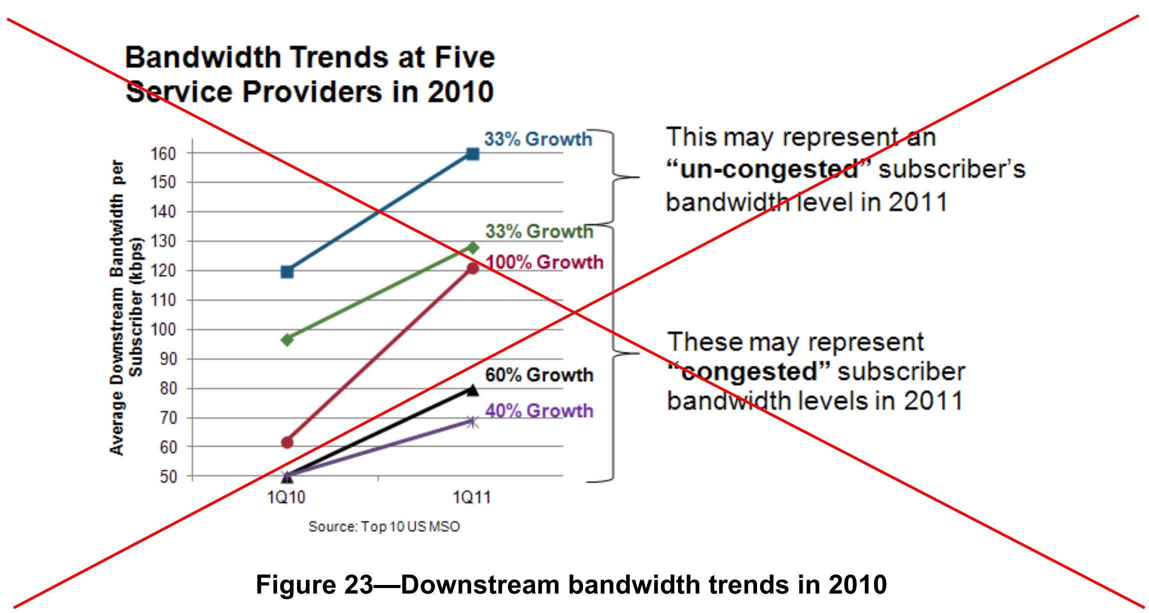

Figure 23—Downstream bandwidth trends in 2010

In the period since 2009, there has been a rapid uptake of over-the-top IP video which has helped drive the continual increase in downstream consumption that is shown in Figure 20. This transition has also changed the mix of traffic types carried over the cable networks. These changes can be clearly viewed within Figure 23.

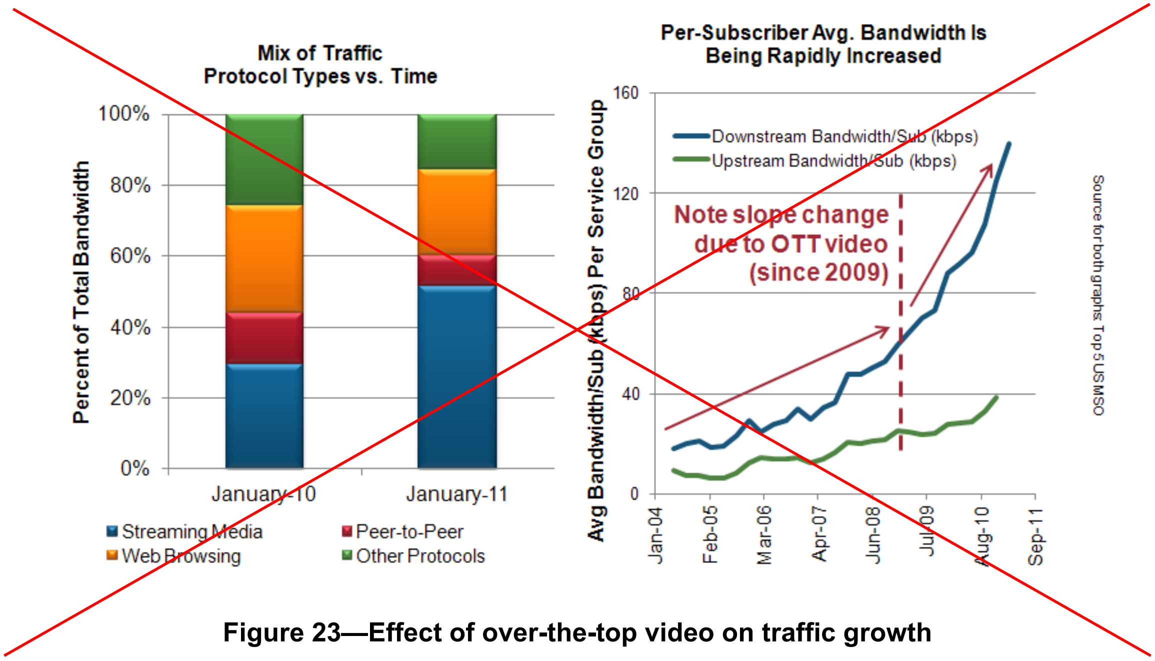

Figure 23—Effect of over-the-top video on traffic growth

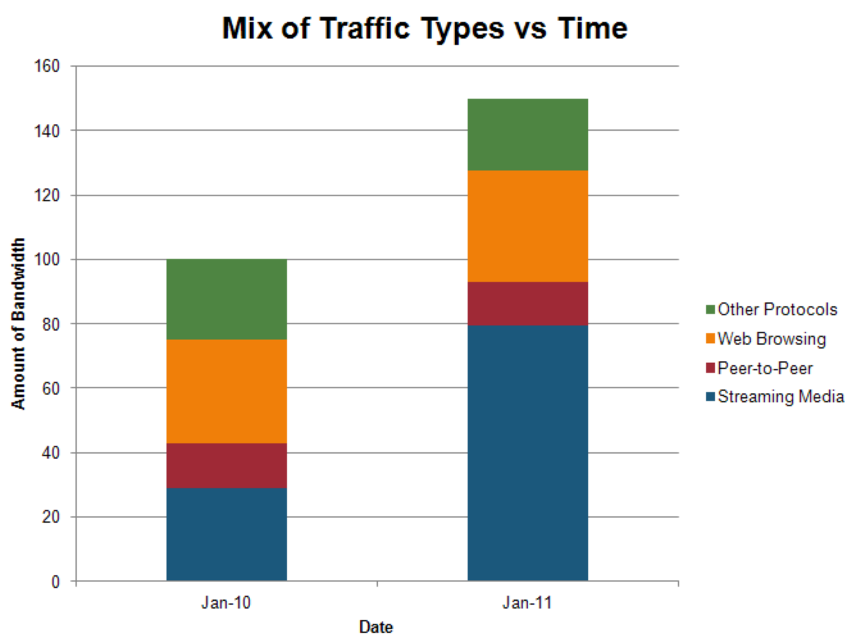

Figure 23—Mix of traffic types vs. time

In order for the bandwidth trends predicted above to materialize, the available equipment must be able to support the predicted bandwidths at acceptable cost levels. The following explores this topic from the point of view of DOCSIS Cable Modem Termination System (CMTS) equipment, which serve 20 to 50 "Service Groups". For a typical single high speed data "Service Group" with ~~~500~~ 1000 homes passed, MSOs [9] predict:

- 2008: 1 DOCSIS Downstream (~40 Mb/s)
- 2011: 4 DOCSIS Downstreams (~160 Mb/s)

- 2015: ~20 DOCSIS Downstreams (~800 Mb/s)

To support this need the Converged Cable Access Platform (CCAP) has been designed with a 20 to 80 times increase in capacity, a 14 to 60 times power per bit reduction and a 20 to 80 times space per bit reduction [9]. The new technologies becoming available to support this are described in Table 11.

Table 11—~~Global IP traffic growth 2010 to 2015~~Enabling technologies for CCAP

Building blocks	2007 capabilities	2011 capabilities	Increase factor
L2/L3 switch chips	60 Gb/s	640 Gb/s	10
~~High speed digital~~Digital-to-analog converters	1 ~~downstream~~ channel ~~per DAC~~/ chip	100+ ~~downstream~~ channels ~~per DAC~~/ chip	100
Burst receivers	2 ~~upstream~~ channels ~~per receiver~~/ chip	12 ~~upstream~~ channels ~~per receiver~~/ chip	6
Processor chips	2 cores ~~per~~ / chip	32 cores ~~per~~ / chip	16

2.8 Optical Transport Network [*Editor's note: Xi Huang, Huawei*]

For the purpose of this section the network is divided into the following categories [13] (See Figure 24):

- Access Node: xDSL, FTTx, 3G, WiFi …
- Aggregation Node: Aggregate the data from access node to the edge of metro networks
- Core Node: Transport data in backbone networks

Where the "Optical Transport Network (OTN) consists of the Aggregation Nodes and the Core Nodes.

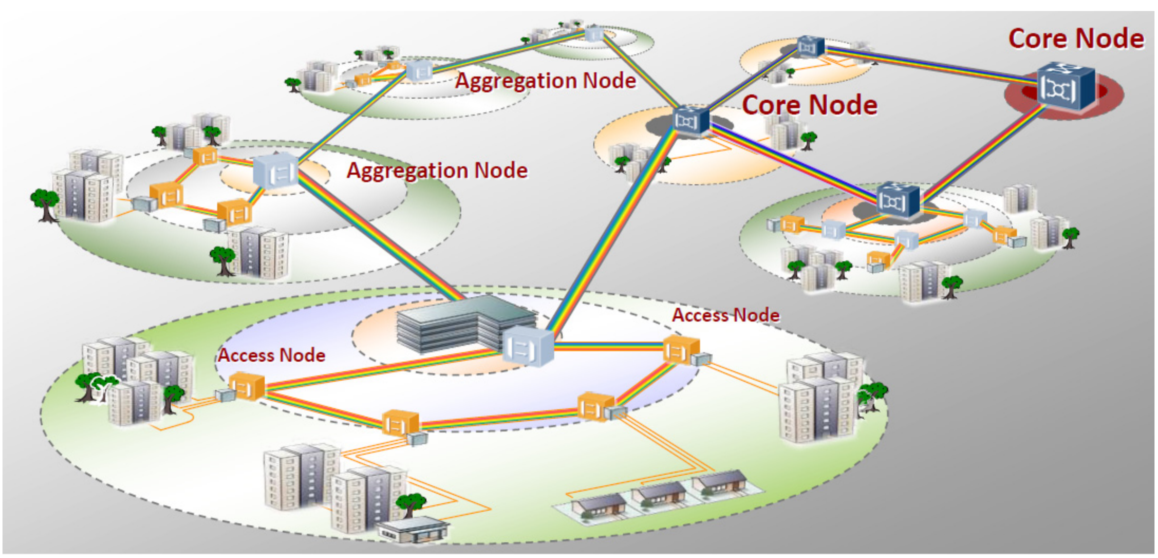

Figure 24—Network classification