Bandwidth demand forecasting (for TR section 4.2.2)
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Ottawa IEEE 802.3 NGEPON Interim meeting
8 September 2014
Residential aggregate bandwidth demand forecast

For PON network dimensioning, add bandwidth headroom above these numbers, equivalent to the maximum service level offered

Why: subscribers will need to pass a speed test at peak hour traffic
Aggregate bandwidth demand model

Peak hour sustained and burst bandwidth demands are modeled independently.

1. Sustained bandwidth demand component:
   - Video traffic is modeling using Monte Carlo techniques. Other sustained demand (e.g. voice) is neglected
   - All of managed linear pay-TV, managed VoD and OTT Internet video (e.g. Netflix, YouTube) are included
   - No multicasting all video (managed and OTT) is unicasted in-band: worst case scenario

2. Burst bandwidth demand component
   - per subscriber averages, plus
   - maximum burst demand that a single subscriber can generate

More detail on inputs in the backup slides
Manuscript has recently been submitted to IEEE Communications Magazine
Maximum service level that can be offered

Equivalent to headroom left over after peak hour traffic is subtracted out:

Notes on WDM PON:
- WDM PON @1 Gb/s/λ loses to GPON over next 10 years.
- WDM PON must support 10 Gb/s/λ just to beat (barely) today’s 10G EPON

Based on methodology in:
Input for section 4.3: Bit Rate Trends

Question: Is this section about bandwidth offered or bandwidth demanded?

Nielsen's Law of Internet Bandwidth states that **offered** premium connection speeds to U.S. users has grown 50% YoY.

Nielsen’s Law does not say anything about:
- bandwidth **demand**
- offered speeds on **fiber** networks (off by one order of magnitude)
Nielsen’s Law ignores the bandwidth carrying managed TV service (e.g. video QAMs)
Backup
Video streams transported: “heavy scenario”

Probability distribution of number of streams per subscriber
Average ($\lambda$) = 1.8

3D content: 7.5% of HD streams
Video streams transported: “moderate scenario”

Probability distribution of number of streams per subscriber
Average (λ) =1.2

3D content: 5% of HD streams
Residential aggregate bandwidth demand forecast
“Moderate” scenario

99%-ile aggregated demand:
"moderate" scenario, 100% unicast video

No headroom included
Encoded video bit rate forecasts

- Chart forecasts nominal bit rates for good quality video
- HD and UHD bit rates are multiplied by
  - 1.275 quality factor for higher quality (heavy scenario)
  - 0.85 quality factor for higher bandwidth efficiency (moderate scenario)
- 3D content: 1.4x higher bit rate than 2D
Burst traffic demand component

Cox reported an average of 400 kb/s of downstream DOCSIS traffic per subscriber during peak hour in 2014[1]. This is consistent with private data from other operators.

- Assume that to first order it is all Internet traffic (neglect managed VoD)
- Based on Sandvine measurements[2] 36% of that traffic is bursty: 144 kb/s average peak hour bursty traffic per subscriber on a DOCSIS network.
- Traffic could be higher on fiber networks: multiply by 1.5x: 216 kb/s per subscriber
- We grow this number by 21% YoY based on inputs from the Cisco VNI[3] and Pyramid[4] and multiplying by 1.5x

Streaming video bandwidth demand, single subscriber: upper bound

Assumes no significant impact of 3D video

Based on methodology in:
Bandwidth demand: Internet traffic forecasts?

- Internet video is the driver for growth
- But subscriber traffic is still measured in 100s of kb/s!

Internet traffic forecasts miss IPTV, so underestimate access network demand