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WORKSHOP:
TRAFFIC ENGINEERING OPTIMIZATION II

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Traffic Engineering in a Fiber Deep Gigabit World

John Ulm
Eng Fellow, Broadband Systems
ARRIS

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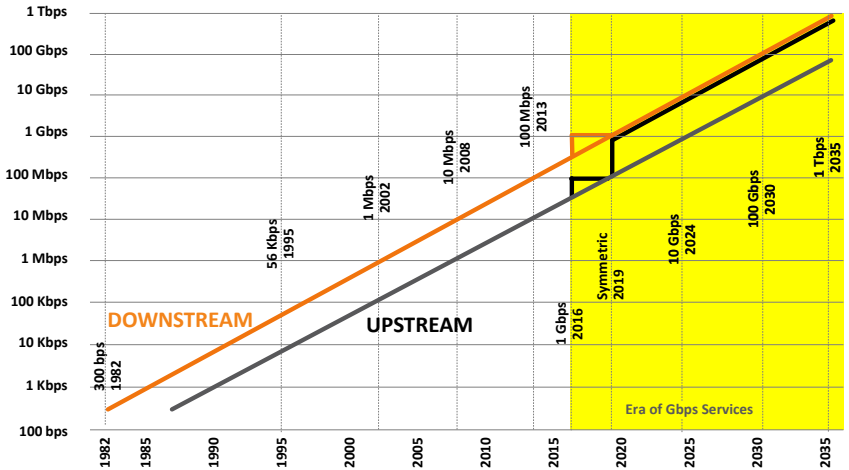
Traffic Engineering in a Fiber Deep Gigabit World

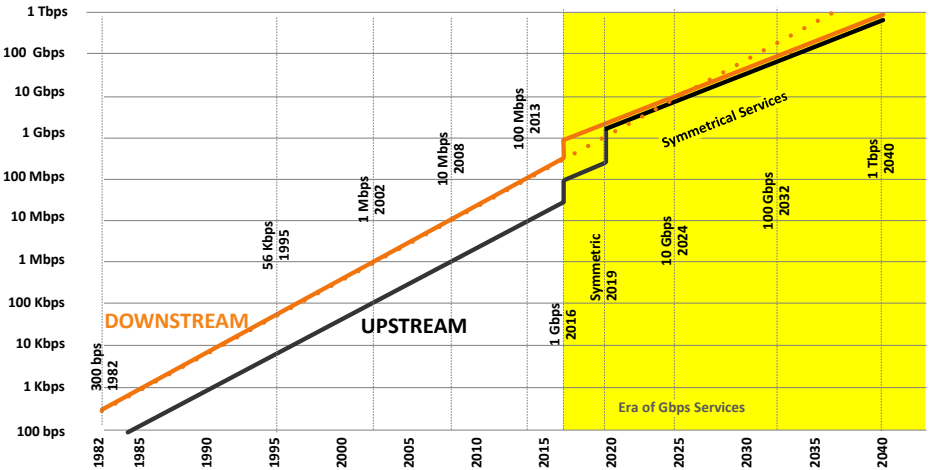
- Traffic Engineering Drivers – What has changed?
  - DOCSIS 3.1, Fiber Deep, DAA – R-PHY, DOCSIS Full Duplex (FDX), Nielsen's Law
- Broadband Bandwidth Trends, Traffic Eng review
- Subscriber Bandwidth Behavior
  - Month-to-month, Day-to-day, Time-of-day
  - Service Group Considerations – SG Size, SG to SG variations
  - Service Tier impacts
- Updating the Traffic Engineering Formula – A New Basic Formula
- Big Data Analytics

Nielsen's Law and Cloonan's Curves

Nielsen's Law – 50% CAGR

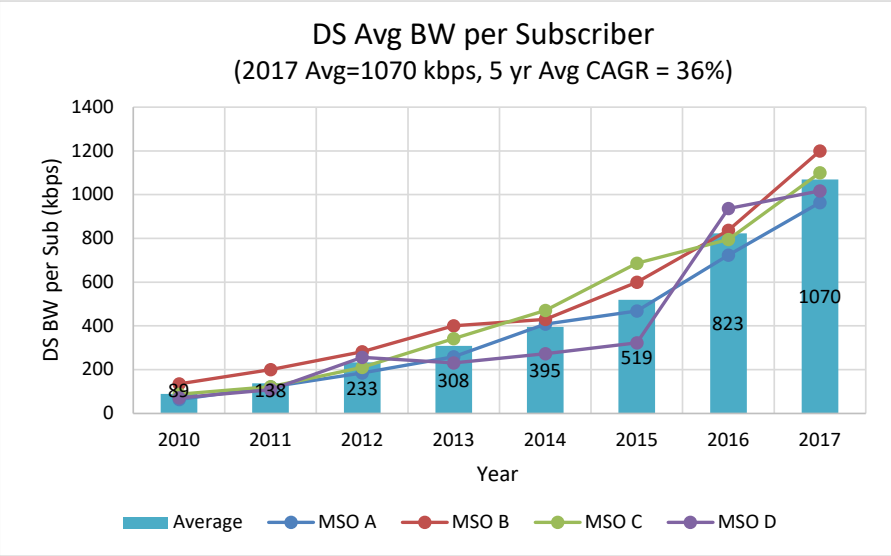


Modified Nielsen's – 33% CAGR 2018

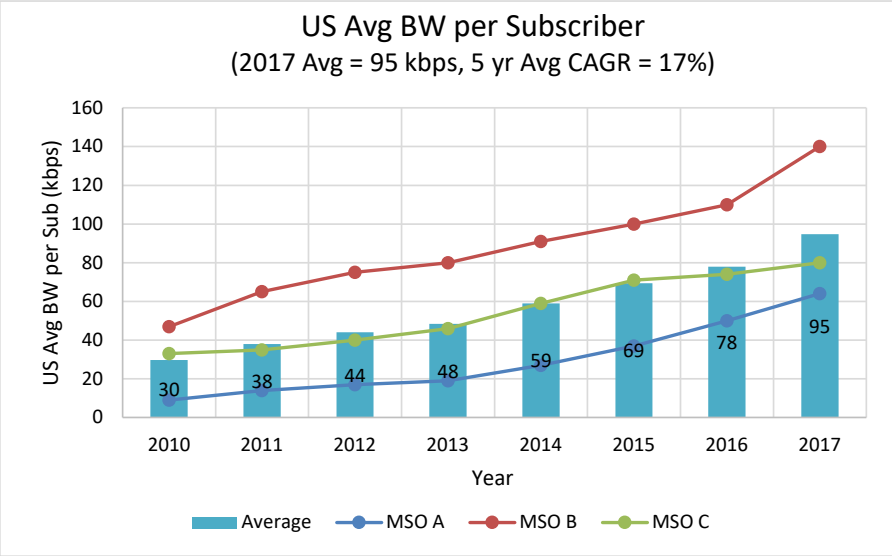


Broadband Subscriber Traffic Consumption – Tavg

Downstream Tavg @ Peak Busy Hour



Upstream Tavg @ Peak Busy Hour



The “Simple” Traffic Engineering Formula

THE “2014” TRAFFIC ENGINEERING FORMULA (BASED ON Tmax_max):

$$C >= (Nsub*Tavg) + (K*Tmax\_max) \quad (1)$$

where:

- C is the required bandwidth capacity for the service group
- Nsub is the total number of subscribers within the service group
- Tavg is the average bandwidth consumed by a subscriber during the busy-hour
- K is the QoE constant (larger values of K yield higher QoE levels)…
- where 0 <= K <= infinity, but typically **1.0 <= K <=1.2**
- Tmax_max is the highest Service Tier Tmax offered by the MSO

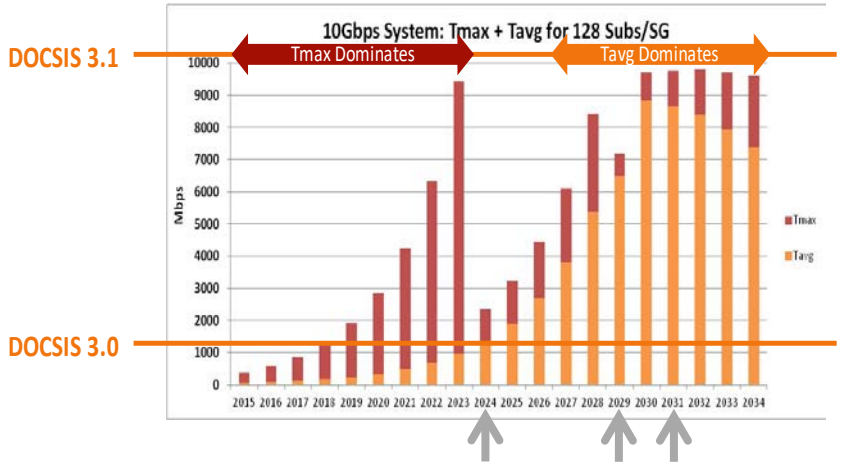
Network Capacity Planning and Selective Subscriber Migration

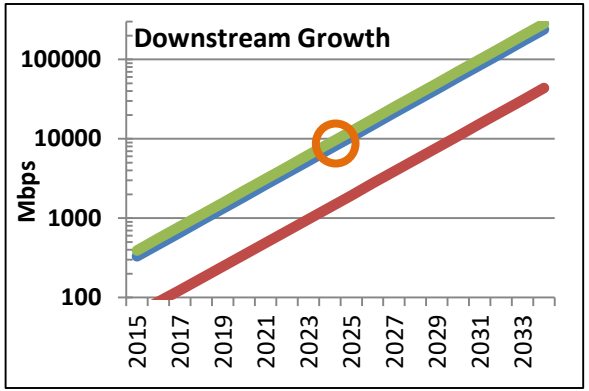
Nielsen's Law – 50% CAGR

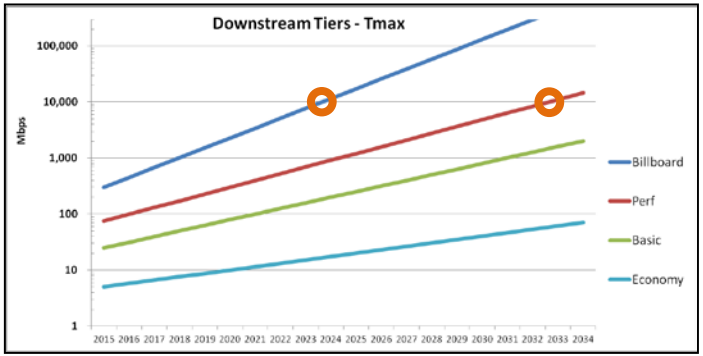
- But only for Top Tier! Others growing slower

Selective Subscriber Migration

- Move Top Tiers to FTTx extends HFC Life







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The “Simple” Traffic Engineering Formula

Limitations going Forward

$$C >= (Nsub*Tavg) + (K*Tmax\_max) \quad (1)$$

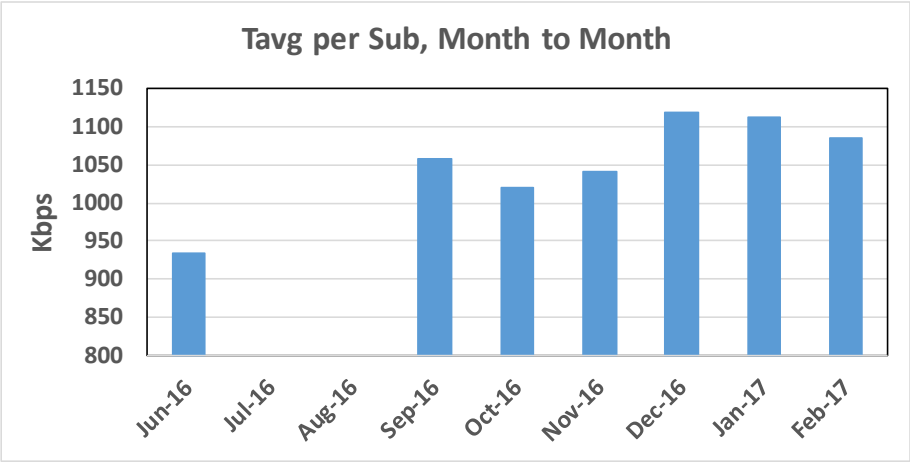
- Optimized for Service Groups (SG) of several hundred subscribers
- Distributed Access Architectures (DAA) such as Remote PHY requires traffic eng extremes:
  - Very small Fiber Deep SG (10’s) to very large CCAP Cores (10,000’s)
- Optimized values of K very complicated at these extremes
- SG to SG variations more extreme with small SG

Data Collection Methodology

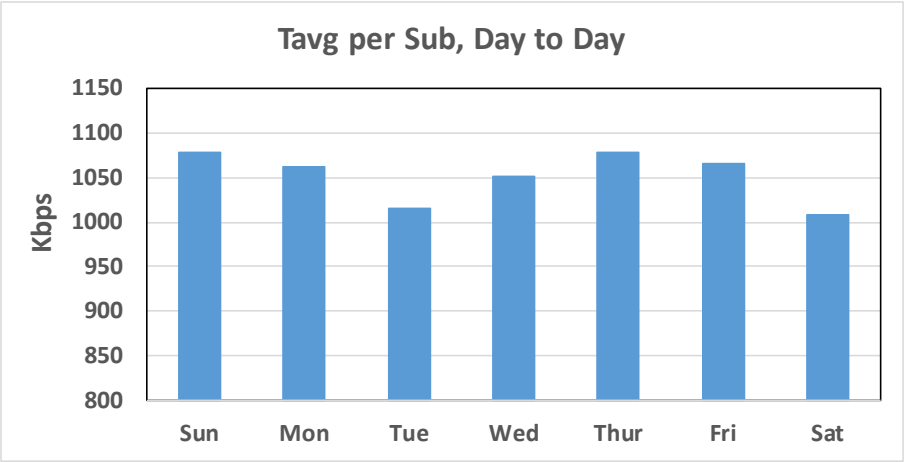
- Massive amount of data collected over one year period from single CMTS site
    - Affluent North American suburb; over **1 billion samples**
- Data collected during peak busy period: multiple samples taken during 6pm to midnight
- **Every Packet analyzed** for bandwidth analysis
- Some Topics of interest:
    - Month to month
    - Day of week
    - Time of day
    - Differing Service group sizes
    - SG to SG variation
    - Subscriber service tiers

Macro Trends – Averaged over 10 months of data

Month-to-month

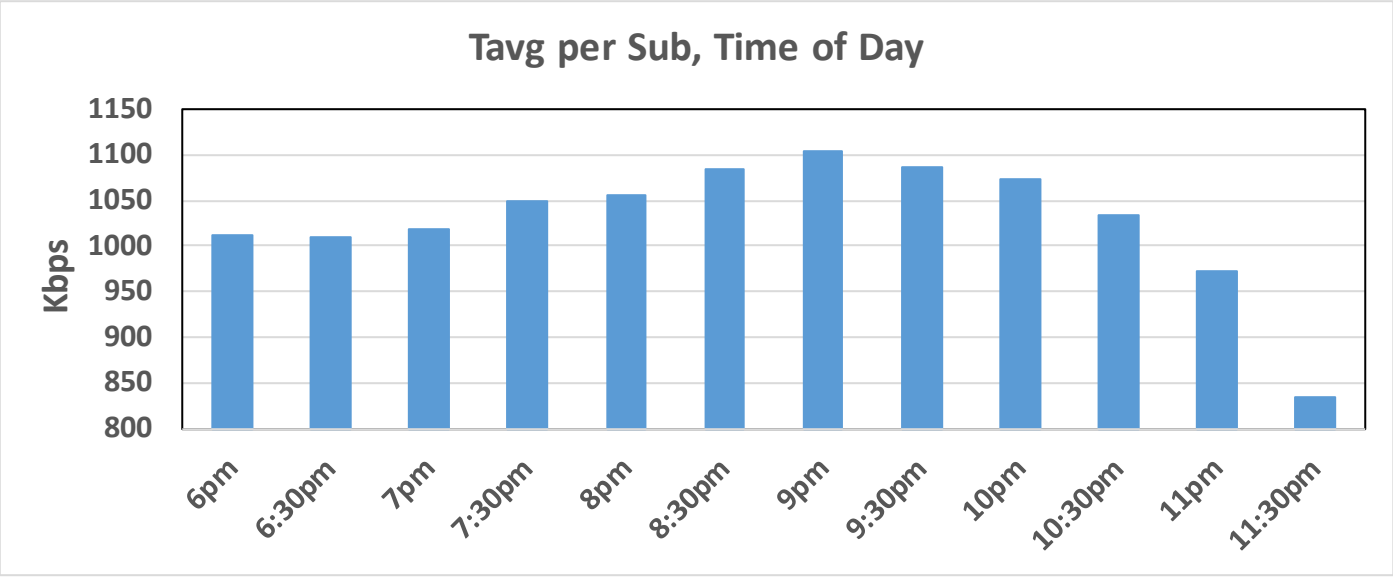


Day-to-day



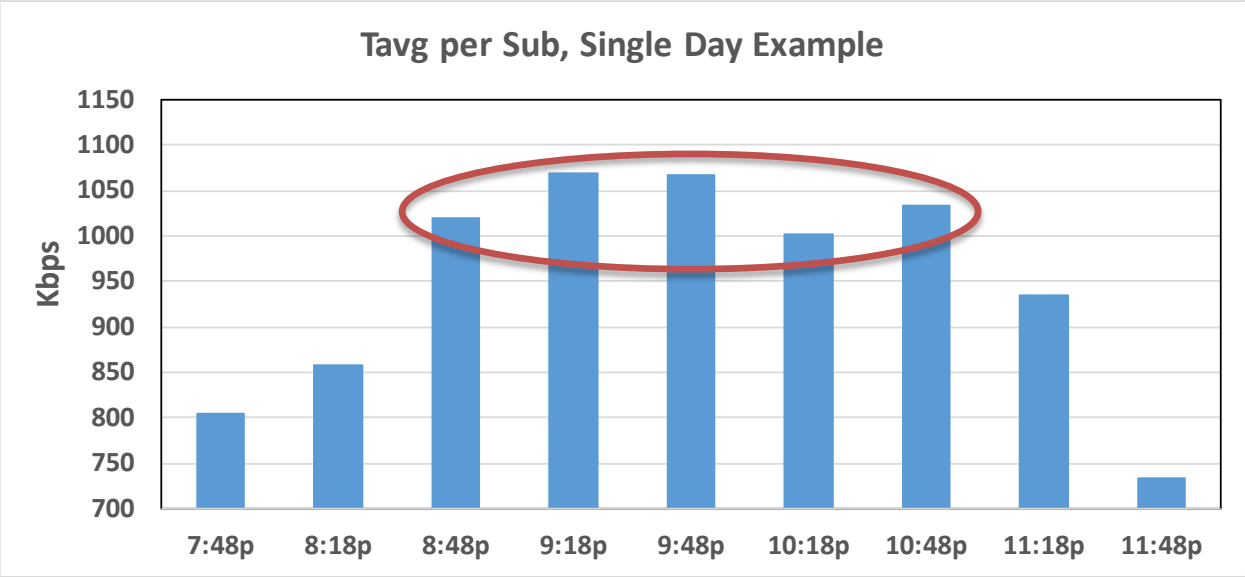
Macro Trends – Averaged over 10 months of data

Time of Day



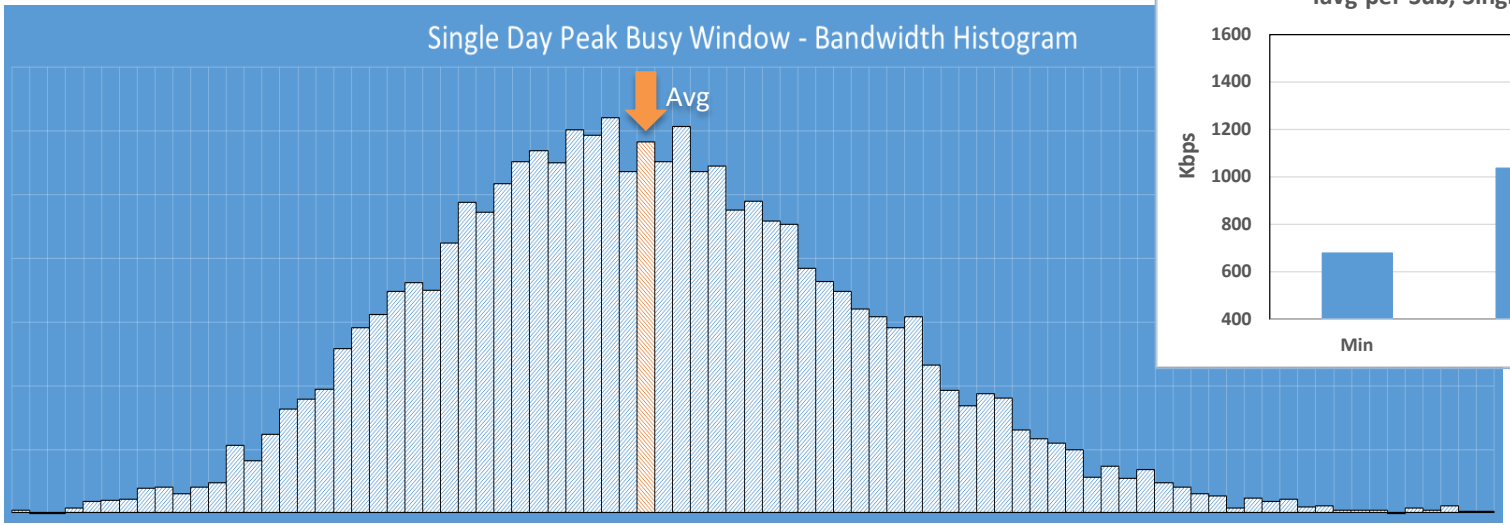
Micro Trends – Single Day View

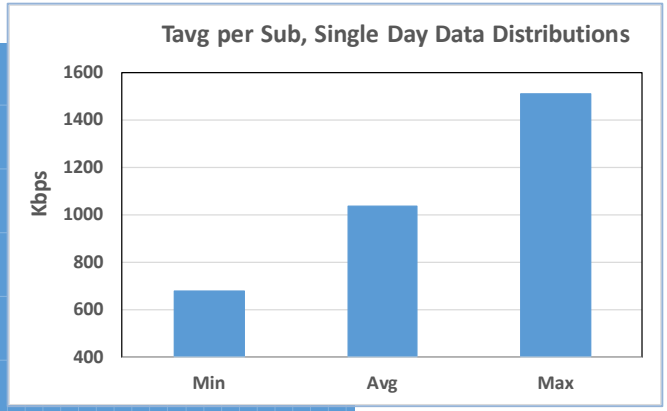
30 Minute Sample Intervals from 7:48pm



Micro Trends – Peak Busy Period View

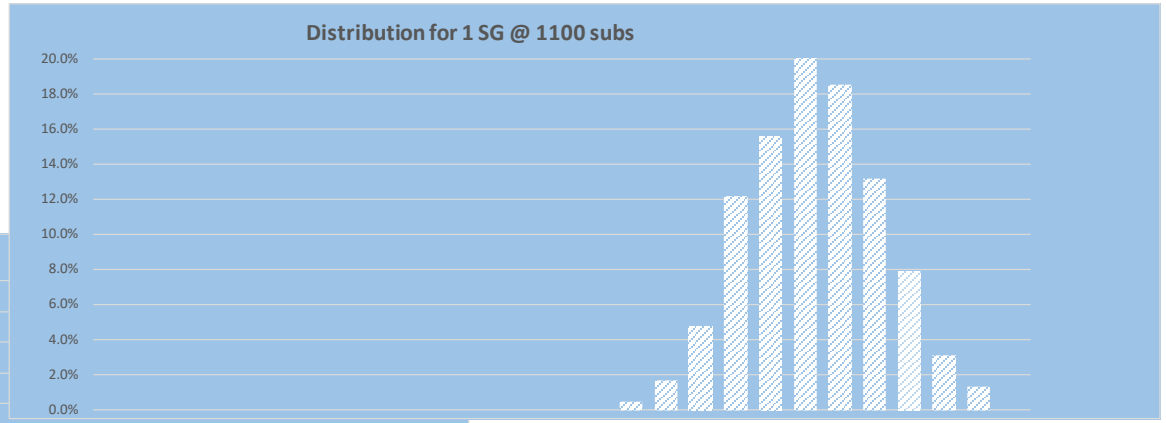
Bandwidth Histogram: for ALL traffic, 8:48pm to 11:18pm





Service Group Considerations – SG Size Impacts

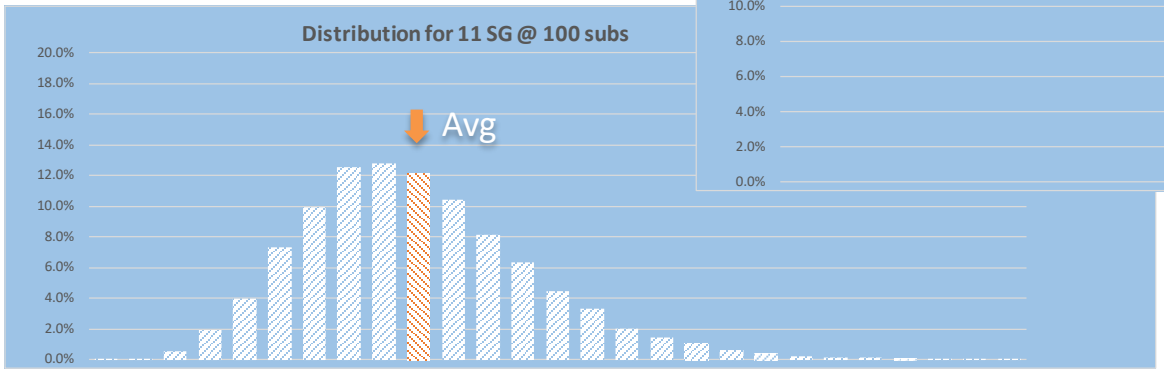
1 SG @ 1100 subs



- Max is 40% > Mean
- Max is twice Min

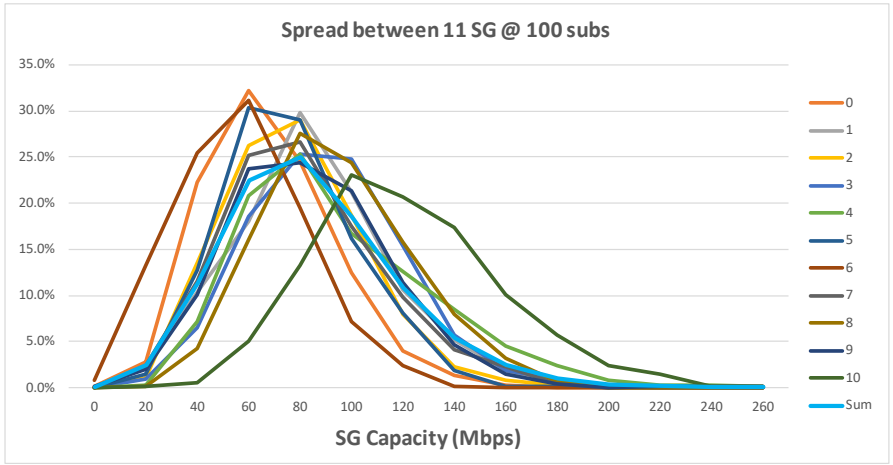
11 SG @ 100 subs

- Max is 3 X Mean
- Minimum near zero

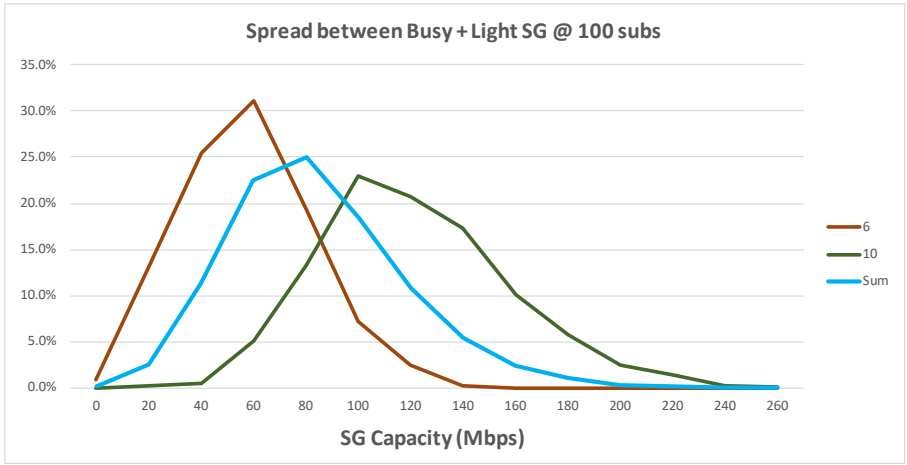


Service Group Considerations – SG to SG Variations

11 SG @ 100 subs, same Tier distributions



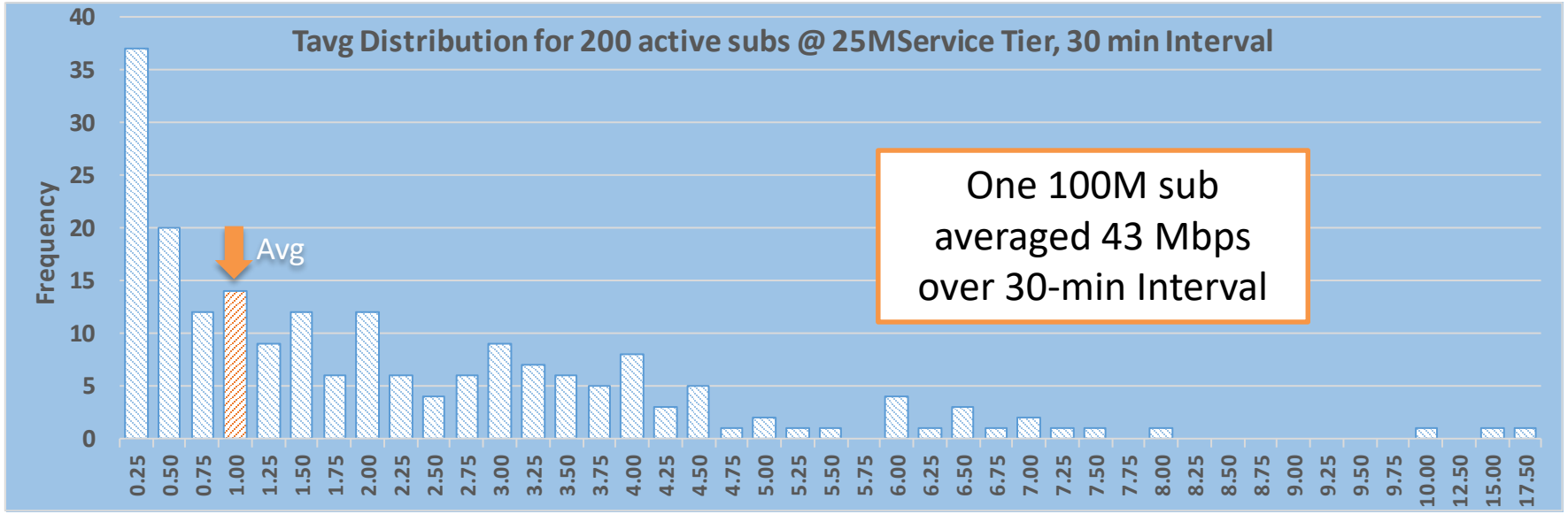
Busiest + Slowest SG



- Mean: SG_10 > 2 x SG_6

Subscriber Variations – Heavy + Active Users

Mean Tavg = ~1 Mbps; 62% of subs < 250 Kbps; 10% > 5 Mbps; 1.5% > 10 Mbps

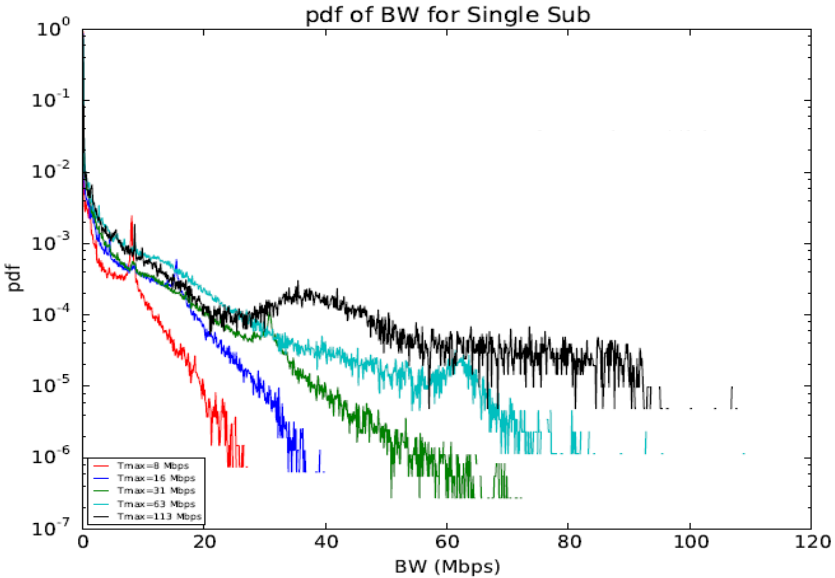


Service Group Considerations – Service Tier Impacts

Example BW Distribution by Tier

Service Tier	% of Subs	Tavg per Sub (Mbps)
6M	8%	0.49
12M	24%	0.67
25M	44%	1.01
50M	11%	1.68
100M	3%	2.66
Avg	100%	0.91

Example Transmit Burst Prob. Distr.



The New Basic Formula

$$C >= T_{burst} + T_{data} \quad (2)$$

$$C >= T_{max\_max} + T_{avg\_sg} + QoE_{margin} \quad (3)$$

Where:

- C is the required bandwidth capacity for the service group
- Tburst is the bandwidth target used to meet the SLA test
- Tdata is the overall network bandwidth at the time of Tburst
- Tmax_max is the highest Tmax offered by the MSO
- Tavg_sg is the average bandwidth consumed by a service group during the busy-hour
- QoE_margin is additional margin required due to data utilization fluctuations

Mapping the older “Simple” Formula to New Basic one

$$C >= Tmax\_max + Tavg\_sg + QoE\_margin \quad (3)$$

$$C \geq Tmax\_max + (Nsub*Tavg) + (0.2*Tmax\_max)$$

$$C \geq (Nsub*Tavg) + (1.2*Tmax\_max) \quad (4)$$

Where:

- C is the required bandwidth capacity for the service group
- Tmax_max is the highest Tmax offered by the MSO
- Nsub is the total number of subscribers within the service group
- Tavg is the average bandwidth consumed by a subscriber during the busy-hour
- **QoE Margin = 20% Tmax_max!!!**

Tavg_sg – Adjusting for Service Tier Mix

$$C \geq Tmax\_max + \sum Nsub(i)*Tavg(i) + QoE\_margin \qquad (5)$$

Where:

- C is the required bandwidth capacity for the service group
- Tmax_max is the highest Tmax offered by the MSO
- Nsub(i) is the number of subscribers on the i^{th} service tier
- Tavg(i) is the average BW consumed per sub during the busy-hour on the i^{th} service tier
- QoE_margin is additional margin required due to data utilization fluctuations

QoE Margin – The Magic Delta

- Simple Formula – Still valid after all these years; know its limits
- Operational Considerations
  - Tavg_sg – easily measured on SG by SG basis
  - QoE Margin – found by statistical analysis of large data set or monitoring individual SG
- Big Data Analytics
  - Ideally suited to analyzing massive amounts of subscriber bandwidth data
  - Many complicated variables and relationships at play here
  - Goal – leverage Big Data Analytics to select optimum QoE margins in existing networks
    - Become tool to predict how networks will morph and the QoE margins of the future

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- Broadband Bandwidth Trends, Traffic Eng review
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- Subscriber Bandwidth Behavior
  - Month-to-month, Day-to-day, Time-of-day
  - Service Group Considerations – SG Size, SG to SG variations
  - Service Tier impacts
- Updating the Traffic Engineering Formula – The New Basic Formula:

$$C >= Tmax\_max + Tavg\_sg + QoE\_margin \quad (3)$$

  - "Simple" Formula still valid – QoE_margin = 20% Tmax; know its limits
  - Operational considerations
- Big Data Analytics – Tool to predict how networks morph and the QoE margins of future

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THANK YOU!

John Ulm
john.ulm@arris.com

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