Bandwidth Estimation Metrics and Terminology

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Bandwidth Estimation Metrics and Terminology
Bandwidth (Hz) versus Bandwidth (bps)
Bandwidth Estimation in the Physical Layer
Major bandwidth metrics

- Bulk-Transfer Capacity (BTC)

Available bandwidth

Capacity

- Bandwidth Estimation workshop, CAIDA, December 9-10, 2003
**Definition of capacity**

- Link capacity: $C$ for link $i$ (bps) 
- Path capacity: $C_i$ for path $i$, related to transmission clock 
- Typically constant at layer-2, related to transmission clock 

Path capacity is limited by narrow link: 

\[ u_i = \min_{j=0}^{H_i} \min_{C_j} C \leq C \]
Beware of: traffic shapers, wireless links, time-varying capacity

\[ \frac{C_{\text{L2}}}{H} + I = \frac{C_{\text{L3}}}{H} \]

- Capacity at IP-layer as function of CL2 at Layer-2:
- Capacity at IP-layer
Definition of average link utilization

Note: Variance of random process decreases with $T$

\[ xp(x) n \int_{T}^{\infty} \frac{T}{t} = \langle T \rangle_{n} \]

Average utilization $\langle T \rangle_{n}$ in timescale $T$:

\[ \{ 0, 1 \} \subseteq \langle x \rangle_{n} \]

Instantaneous link utilization $\langle x \rangle_{n}$

Definition of average link utilization
Available bandwidth is limited by tight link.

\[ \text{Avail-bw of link } i = \min H_{0}^{H} \]

End-to-end avail-bw:

\[ (\Delta n - \sum_{i=1}^{t} H_{0}^{H}) \]

Available bw of link \( i \):

\[ A_{i} = \min_{i=1}^{t} H_{0}^{H} \]

Average utilization of link \( i \) in time interval of length \( T \) (\( T \geq n \geq 0 \))

Definition of available bandwidth
Bulk-Transfer Capacity (BTC): long-term average TCP throughput

BTC depends on:
- Exact TCP implementation at sender & receiver
- Available bandwidth
- Link buffer sizes
- Cross traffic responsiveness (elasticity)
BTC can be derived mathematically

Simplest model:

Throughput = \frac{c \cdot MSS}{RTT \cdot \sqrt{lossrate}}

Note: such models cannot be used to predict BTC, because RTT and lossrate may be increased due to new TCP connection