Some Comments on Available Bandwidth Measurement

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Overview of Available Bandwidth Measurement

Figure 1: Probing stream \((R = L/T)\)
Fluid Model in Available Bandwidth Measurement

• Available bandwidth measurement — one way delay difference

\[
D^k = (L + q^k)/C
\]
\[
\Delta D^k = \delta q^k / C
\]

• Fluid model

\[
q^{k+1} = \{q^k + L + u^k T - CT\}^+ \\
= \{q^k + RT - A^k T\}^+
\]
\[
\delta q^k = \{q^k + RT - A^k T\}^+ - q^k \\
= \{q^k + (R - A^k) T\}^+ - q^k \tag{1}
\]
Measuring Available Bandwidth

- Observation

\[ \delta q^k \begin{cases} 
> 0 & \text{if } R > A^k \\
\leq 0 & \text{otherwise} 
\end{cases} \]

- Testing metric

\[ S_{PCT} = \frac{\sum_{k=2}^{\Gamma} I(D^k > D^{k-1})}{\Gamma - 1} \]

If \( S_{PCT} > 0.55 \), available bandwidth is less than \( R \).
Impact of Cross Traffic Rate Distribution

• Assume \( \{A^k\} \) is a i.i.d sequence

Claim: If \( P(A^k < R) > 0.55 \), available bandwidth is less than \( R \).

• If \( A^k \) obeys the exponential distribution, then: If \( EA^k < 1.25R \), claim \( EA^k < R \).

• Depends on the distribution of \( A^k \).
Impact of Cross Traffic Arrival Pattern

Figure 2: Forward arrival pattern

Figure 3: Backward arrival pattern
Impact of Cross Traffic Arrival Pattern

- Forward arrival pattern:

\[ q^{k+1} \geq \{q^k + L - CT + u^kT\}^+ \]
\[ = \{q^k + RT - A^kT\}^+ \quad \text{(2)} \]

- Backward arrival pattern:

\[ q^{k+1} \leq \{q^k + L - CT\}^+ + u^kT \]
\[ = \{q^k + RT - CT\}^+ + u^kT \quad \text{(3)} \]

- Smooth traffic arrival:

\[ q^{k+1} = \{q^k + RT - A^kT\}^+ \quad \text{(4)} \]

- \( \delta q^k > 0 \) even if \( R < A^k \) for backward arrival pattern
Conclusions

• Characteristics of network traffic affect the accuracy of available bandwidth measurement.
  
  1. Impact of traffic rate distribution – function of interval $T$
  2. Impact of cross traffic arrival pattern
  3. Is the cross traffic stationary?

• Need to understand the network traffic better to measure it correctly

• Take applications’ point of view (streaming, file downloading)
  
  1. file downloading — $EA^k$
  2. streaming application — $EA^k$ and $Var(A^k)$