A Case for TCP-Friendly Admission Control

Adrian S-W. Tam, Dah-Ming Chiu, John C. S. Lui, Y. C. Tay

June 21, 2006
Given a network serving both elastic (TCP) and inelastic (UDP) flows

Elastic flows perform congestion control and inelastic flows perform admission control but *not* congestion control
Given a network serving both elastic (TCP) and inelastic (UDP) flows

- Elastic flows perform congestion control and
- inelastic flows perform admission control but not congestion control

- Yes, we know the orthodox way is TCP-friendly congestion control, but we assume they are performing admission control in this study
Given a network serving both elastic (TCP) and inelastic (UDP) flows

- Elastic flows perform congestion control and inelastic flows perform admission control but *not* congestion control

- Yes, we know the *orthodox* way is TCP-friendly congestion control, but we assume they are performing admission control in this study

- How would admission control performed by inelastic flows affect the network?
  - Is it effective in avoiding congestion?
  - Would it be friendly to elastic (TCP) flows?
Admission control is to decide whether a flow can use the network or not.

Generally, admission control is a function of:

- The nature of the flows (duration, data rate, etc.)
- The nature of the network (bottleneck capacity, number of elastic flows, number of inelastic flows, etc.)
Assume the single-bottleneck network has two kinds of flows:

- **Elastic flows**: FTP flows, using TCP congestion control
- **Inelastic flows**: Video streaming, no congestion control but have a desired data rate $\alpha$

Network’s bottleneck bandwidth is normalized to 1

- Elastic flows will share the available bandwidth equally
- Inelastic flows will consume bandwidth $\alpha$ unconditionally

- Have priority to use the bandwidth
- But they have to do admission control first
We model both congestion control and admission control as fluid and with no feedback delay.

An *idealized* algorithm of admission control for inelastic flows:

1. Parameters given: $\alpha$, $\epsilon$
2. Probe and check if $n\epsilon + (m + 1)\alpha > 1$
   - Where $n$ is the number of elastic flows and $m$ the number of inelastic flows using the network
   - If the inequality is true, refuse to use the network
   - Otherwise, join the network and send data constantly at rate $\alpha$

Parameter $\alpha$ depends on the content of the stream

Parameter $\epsilon$ is knob for adjusting the aggressiveness of admission control
- Poisson arrival for both elastic and inelastic flows
  - Elastic flows’ arrival rate: $\lambda_e$
  - Inelastic flows’ arrival rate: $\lambda_i$

- All flows are finite, and in certain distribution
  - Mean file size of elastic flows: $\mu_e$
  - Mean holding time of inelastic flows: $\mu_i$

- Define: $\rho_e = \lambda_e/\mu_e$ and $\rho_i = \lambda_i/\mu_i$
The stability of network depends on elastic flows only ($\rho_e < 1$).

- Independent of inelastic flows because they have admission control
- When the network is severely congested, the elastic flows will accumulate, which prohibits new admission of inelastic flows.
- Eventually, the network has only elastic flows, thus the stability depends only on them
- Details are in Section III.B

See also Peter Key et al, “Fair internet traffic integration: Network flow models and analysis”, Annales des Telecommunications, 2004. (A different model but similar conclusion)
(in section IV.B)

- $\tau$: The remaining work in the network
- $N_e$: Poisson counter with rate $\lambda_e$
- $N_i$: Poisson counter with rate $\lambda_i$
- $1(\cdot)$: Indicator function
- $I(n, m)$: Admission control

\[
d\tau = -1(\tau > 0)dt + S_e dN_e + I(n, m)S_i dN_i
\]
(in section IV.B)

- $\tau$: The remaining work in the network
- $N_e$: Poisson counter with rate $\lambda_e$
- $N_i$: Poisson counter with rate $\lambda_i$
- $1(\cdot)$: Indicator function
- $I(n, m)$: Admission control

$$d\tau = -1(\tau > 0)\, dt + S_e dN_e + I(n, m) S_i dN_i$$

(a Poisson-counter driven stochastic differential equation — PCDSDE)
Take expectation:

\[
dE[\tau] = -E[1(\tau > 0)]dt + E[S_e]E[dN_e] + E[I(n, m)]E[S_i]E[dN_i] \\
= -\Pr[\tau > 0]dt + \frac{1}{\mu_e} \cdot \lambda_e dt + \Pr[I(n, m) = 1] \cdot \frac{\alpha}{\mu_i} \cdot \lambda_i dt \\
\]

\[
\frac{dE[\tau]}{dt} = -\Pr[\tau > 0] + \rho_e + \Pr[I(n, m) = 1] \alpha \rho_i = 0 \\
R = \Pr[I(n, m) = 1] \\
= \frac{\Pr[\tau > 0] - \rho_e}{\alpha \rho_i} \\
R = \frac{\rho' - \rho_e}{\alpha \rho_i} \\
\]

where \( \rho' \approx min(\rho, 1) \) and \( \rho = \rho_e + \alpha \rho_i \)
Admission probability $R$ is independent of aggressiveness $\epsilon$

Therefore,

- For inelastic flows,
  - Inelastic flows are either admitted or rejected
  - The performance measure depends on the probability of admission only in other words, it is independent of $\epsilon$
Admission probability $R$ is independent of aggressiveness $\epsilon$

Therefore,

- For inelastic flows,
  - Inelastic flows are either admitted or rejected
  - The performance measure depends on the probability of admission only in other words, it is independent of $\epsilon$

- For elastic flows, the performance does depend on $\epsilon$
  - If we set $\epsilon = \alpha$, we guarantee elastic flows receive bandwidth no less than that of inelastic flows
  - If $\epsilon < \alpha$, then elastic flows will be worse off
Admission probability $R$ is independent of aggressiveness $\epsilon$

Therefore,

- For inelastic flows,
  - Inelastic flows are either admitted or rejected
  - The performance measure depends on the probability of admission only in other words, it is independent of $\epsilon$

- For elastic flows, the performance does depend on $\epsilon$
  - If we set $\epsilon = \alpha$, we guarantee elastic flows receive bandwidth no less than that of inelastic flows
  - If $\epsilon < \alpha$, then elastic flows will be worse off

Therefore, it does not hurt for inelastic flows to perform “TCP-friendly admission control” (i.e. $\epsilon = \alpha$)
We verified our result by using a simulation of the *fluid* network.

Simulation result agrees asymptotically.

\[
\begin{align*}
R & \text{ vs. } \rho \\
m & \text{ vs. } \rho \\
\log(n) & \text{ vs. } \rho
\end{align*}
\]
When scaled up:

\[ R \text{ vs. } \rho \]

\[ m \text{ vs. } \rho \]

\[ n \text{ vs. } \rho \]
Conclusion and Future works

This work is based on the assumption that we can effectively probe
- We provided a skeletal algorithm in section VI

But we did not addressed:
- How to implement probing?
- How to minimize the cost of probing?

We showed that admission control is reasonable for inelastic flows
- It does not affect stability
- It can be TCP-friendly