Throughput Analysis of TCP Proxy Mechanism

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These applications require high quality transport services.
Conventional approaches for quality control

- **End-to-end solution (TCP, TFRC)**
  - Data transmission quality across the present Internet cannot be assured essentially because of best-effort basis.

- **Network layer solution (IntServ, DiffServ)**
  - They need to deploy additional mechanisms to all routers that all traffic-flows traverse.

- **Underlay solution (MPLS, GMPLS)**
  - They need additional mechanisms such as bandwidth broker.

- **Overlay solution (RON [11], FBR [12])**
  - They need additional overheads such as signaling messages and redundant traffic.

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TCP overlay network

Sender host

Router

TCP proxy

Receiver host

Regular TCP connection

Split TCP connection

APP
TCP
IP
MAC
TCP
IP
MAC
TCP
IP
MAC
APP
TCP
IP
MAC

Advanced Network Architecture
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TCP overlay network
Advantages of TCP overlay network

- Split TCP connection
- High applicability to the network
- Shorter TCP loop
- Fast recovery from packet loss
- High applicability to the network
- Mobile
- Satellite
Subjects on this presentation

- Introduce an analysis approach to estimate average end-to-end throughput with a TCP proxy mechanism.
- Show the analysis results give a reasonable estimation of end-to-end throughput.
- Confirm the effectiveness of TCP proxy.
TCP proxy mechanism

Sender host — TCP proxy A — TCP proxy B — Receiver host

Connection A — Connection B — Connection C

DATA

local ACK

Shorter TCP loop

Packet loss

Fast recovery

Packet retransmission

Buffering
Simple throughput estimation

- Each split TCP connection has identical hop counts in a 32 hop network.
- Packet loss ratios and RTTs of each hop are the same.
- The expected throughput $\rho$ can be calculated as follows.
  \[
  \rho = \min_i \rho(i)
  \]
  $\rho(i)$ is the throughput of each split TCP connection $i$.
  It can be estimated by using Padhye’s equation for the average TCP throughput.

The average end-to-end throughput is greatly improved because of the shorter RTT and lower packet loss ratio.
Problem in TCP proxy mechanism

The upward sender/proxy

TCP proxy

The downward receiver/proxy

No relayed data until the lost packet is retransmitted and arrives at the TCP proxy

The send buffer of downward connection becomes empty and downward connection cannot send packets to the downward receiver/proxy.
We divide an end-to-end TCP connection into $m$ split TCP connections. We calculate $\rho_k$, the throughput of split TCP connections $C_1, C_2, \ldots, C_m$ in this order ($k <= 1 <= m$). Now, we consider the throughput $\rho_k$ of connection $k$ ($C_k$).

$\rho_k$ depends on the network condition.

$\rho_k$ is limited by $\rho_{k-1}$.

or

$\rho_k$ deteriorates by the problem in a TCP proxy mechanism.

$\rho_k$ is limited by the remaining buffer size of the receive buffer.
Analysis approach considering performance degradation

The number of transmitted packets

- Connection $k$ transmits all packets stored in the send buffer.
- The first packet drop in connection $k-1$.
- The arrival of the retransmitted packet.
- The second packet drop in connection $k-1$.

Performance degradation

Depending on the packet loss ratio.

We assume that this amount equals to the value of the number of packets in the send buffer.
Evaluation model

We assume that users access the Internet via satellite or wireless networks.

- **LAN1**: $D_{LAN1} = 0.0005$ [s]
- **WAN**: $D_{WAN} = 0.0005$ to 0.5 [s]
- **LAN2**: $D_{LAN2} = 0.05$ [s]

- **LAN1**
  - Send/receive buffer size = 64 [pkts]
  - $P_{LAN1} = 0.00001$
  - $BW_{LAN1} = 10$ [Gbps]

- **WAN**
  - $P_{WAN} = 0.0000$ to 0.1
  - $BW_{WAN} = 10$ [Gbps]

- **LAN2**
  - $P_{LAN2} = 0.01$
  - $BW_{LAN2} = 1.5$ [Mbps]
Confirmation of analysis results

The analysis results give a reasonable estimation of average end-to-end throughput.
Evaluation model

Case1: One end-to-end connection is established between sender and receiver hosts.
Case2: One end-to-end connection is split at two proxies.

\[ DL_{AN1} = 0.0005 \text{[s]} \]
\[ DL_{AN2} = 0.005 \text{~0.5[s]} \]
\[ DL_{LAN2} = 0.00001 \text{~0.1} \]
\[ PW_{AN} = 0.01 \]
\[ PW_{LAN2} = 0.00001 \text{~0.1} \]
\[ BW_{LAN1} = 10 \text{[Gbps]} \]
\[ BW_{LAN2} = 10 \text{[Gbps]} \]
\[ BW_{WAN} = 10 \text{[Gbps]} \]
Effectiveness with a TCP proxy

The performance ratio is always larger than 1 and the degree of performance improvement is up to about 3 times.

The ratio of throughput in case 2 to that in case 1

Performance Ratio

The ratio of throughput in case 2 to that in case 1

Performance Ratio
Conclusions and future works

• Conclusions
  – Introduce an effective analysis approach to estimate average end-to-end throughput considering the problems that will occur in introducing a TCP proxy mechanism.
  – Find that we cannot ignore performance degradation caused by these problems.
  – Confirm the effectiveness of the TCP proxy mechanism.

• Future works
  – Need to investigate the performance of the TCP proxy mechanism when it handles Web traffic, where its file transfer delay is severely affected by the processing delays of a TCP proxy.
  – Intend to discuss issues relating to the design of TCP overlay networks in large scaled networks.