Compound TCP+ for Fairness Improvement among Compound TCP Connections in a Wireless LAN

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Background

- Transmission Control Protocol (TCP)
  - transport layer protocol
  - used as a standard over the Internet
  - TCP NewReno can’t use up network bandwidth in high-speed and long-distance networks
    - Because of its congestion control method, loss-based:
      - uses packet loss as an index of congestion

- Compound TCP
  - One of new transport layer protocol
  - Can use up network bandwidth in high-speed and long-distance networks
  - Has two congestion control method:
    - loss-based: the same method of TCP NewReno
    - delay-based: uses network delay as an index of congestion
TCP problem
in wireless LAN (1/2)

- **Unfairness occurs among TCP connections**
  - because of **CSMA/CA** (Carrier Sense Multiple Access/Collision Avoidance)
    - CSMA/CA grants a fair transmission right to all the Wireless Terminals (WT) and Access Point (AP)
    - AP has more opportunities to receive packets from WTs than sending packets to WTs
      - Packets are accumulated in the buffer of AP
      - Packets are dropped when the buffer is full
    - Consider the case: packets are transmitted via an AP from many WTs
      - ACK packets are accumulated in the buffer of AP and dropped when the buffer overflows
TCP problem in wireless LAN (2/2)

- TCP connections that achieves low throughput
  - Has small window size
  - Hard to receive duplicate ACKs for fast retransmission by dropping ACK packets
  - Occurrences of retransmission Timeout increase
  - Retransmission Timeout happens
    - When time out happens, window size $\rightarrow 1$
    - Almost all TCP connections that experienced Timeout cannot recover the window size

Unfairness of throughput among TCP connections
Objectives

- Evaluate the performance of Compound TCP in a wireless LAN by simulation
- Show the Compound TCP throughput becomes unfair similar to TCP
- Propose Compound TCP+
  - carries out a finer congestion control
- Show Compound TCP+ shares the bandwidth fairly
Simulation environment

16 [nodes]

100 [Mbit/s], 60 [ms]

Wireless LAN specification: IEEE 802.11g

Simulator: ns-2
Simulation time: 500 [s]
Simulation results: average throughput

<table>
<thead>
<tr>
<th>Throughput [Mbit/s]</th>
<th>Terminal ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>12 13 14 15 16</td>
</tr>
<tr>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>1.60</td>
<td></td>
</tr>
</tbody>
</table>

Problem of unfair throughput exists in the case of Compound TCP.

Extremely low throughput.
Compound TCP+

Loss window

- Loss-based congestion control
  - When appropriate ACK & $dwnd = 0$
  - Network is slightly congested
    If loss window is increased, congestion will worsen
  - Decrease $cwnd$ according to $dwnd$

\[
cwnd(t + 1) = \begin{cases} 
  \frac{4cwnd(t)}{5} & \text{(appropriate ack & \ } dwnd = 0) \\
  \frac{cwnd(t)}{2} & \text{(duplicate ACKs)} \\
  1 & \text{(timeout)}
\end{cases}
\]

$cwnd$: loss window size
$dwnd$: delay window size

Less Congested
Simulation results: Fairness Index

Both of them have high fairness

Compound TCP+ achieves high fairness

Fairness of Compound TCP degrades
Conclusion and future work

- **Conclusion**
  - Show the throughput among Compound TCP connections become *unfair* in a wireless LAN
  - Propose Compound TCP+
    - carries out finer congestion control
  - Show Compound TCP+
    - achieves *high fairness* in a wireless LAN

- **Future work**
  - Investigate the appropriate parameters of Compound TCP+
Thank you for your attendance!
Compound TCP+

outline

- Not to use up the buffer of the access points
- Carries out the finer congestion control
  - use delay window, $dwnd$
    - is based on the estimated value of # of packet queued all over the network
    - small $dwnd$ means there are many packets in the network
Simulation results throughputs

![Average Throughput vs Node](image)

- **Compound TCP**: Red line and markers
- **Compound TCP+**: Green dashed line and markers
Simulation environment in a high-speed network

10 [Gbit/s], 30 [ms]

10 [Gbit/s], 5 [ms]
Simulation results throughputs

![Graph showing throughput over time for Compound TCP and Compound TCP+](image-url)
Simulation results

loss and delay window

- cwnd: size of loss window
- dwnd: size of delay window

Only Loss-based congestion control work

Congestion Control of Compound TCP carries out the same trend as that of TCP NewReno

- no increase/decrease

Diagram:

- cwnd: red line
- dwnd: green dashed line

Window Size [packets]

Simulation Time [sec]