Toward Optimal Performance with Network Assisted TCP at Mobile Edge

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Problem Statement

• TCP performs poorly in cellular networks mainly because of two fundamental issues:

1. Generalization issue: Most of the TCP designs are intended to be general solutions
   • TCP becomes Jack of all trades, master of none!

2. Having a distributed nature:
   • Distributed measurements downgrade the overall performance of TCP
TCP: Jack of all trades, master of none!

Cellular networks differ significantly from their general wired counterparts, which impacts the performance of a TCP designed as a general solution:

1. Multiple order of magnitude faster capacity fluctuations (at millisecond timescale)
   • TCP either underutilizes the links or causes bufferbloat

2. Higher non-congestive packet loss rates
   • TCP has no means to differentiate congestive pkt loss from non-congestive ones

3. Deep per-user buffers at BTS
   • Potentially can cause large self-inflicted packet delays

4. Schedulers/Resource-manager at BTS
   • Extra uplink/downlink scheduling delays
Distributed Measurement Paradox

- It is impossible to create a **distributed algorithm** that converges to the point where (any form of) $Power = \frac{Throughput}{Delay}$ is maximized (Jaffe. 1981).

- Intuition:
  - A Measurement Paradox!

  Problem becomes even worse when link bandwidth is **not** a flat and **stable** one!
Overview of the solution

1. A domain-specific design:
   • Consider the unique properties of the network to design a better congestion control
     • Servers are located very close to the RAN
     • Single authority manages the network and servers, ...

2. Employ Centralized measurements:
   • Cellular networks already have a notion of centralized measurements
   • Abandon the distributed measurement approach and use a centralized one.
   • Let the network do the measurements!
     • The wireless scheduler (at BTS) knows per-user quality of channel, queue occupancy, etc.
       in a fine-grain timescale (1ms timeframes)
Network-Assisted TCP

1. Per-User Info.
2. Min Delay Measurement
3. Feedback

UE

NetAssist

E-GW

MEC

Edge Server
Two versions: a **clean-slate** & a **backward-compatible**

**NATCP:**
- A clean-slate design replacing the TCP at end-hosts
- Periodically, receives **feedback** information (avg. $Bw$ and $Delay$):
  - $Cwnd = \alpha \times Delay \times Bw$
  - $Pacing_{rate} = Bw$

**NACubic:**
- A backward compatible design
- Underlying TCP still calculates the $Cwnd$
- The **feedback** from NetAssist is used to cap the values of $Cwnd$
  - $Cwnd_{Max} = \alpha \times Delay \times Bw$
  - $Cwnd = Min(Cwnd_{Max}, Cwnd)$
  - $Pacing_{rate} = Bw$
Overall results (averaged over more than 15 cellular traces)

\[
P_{\text{NATCP}} \div P_{\text{Scheme}}
\]

\[
P = \frac{\text{Throughput}}{\text{Delay}}
\]
Conclusion

• The controversial points of the paper
  • Exploring new design space and philosophy for designing TCP for MobileEdge

• What kind of feedback you are looking to receive
  • Any feedback on the implementation of NATCP!

• Under what circumstances the whole idea might fall apart
  • If components dealing with the measurements are providing wrong feedback

• The open issues the paper does not address
  • How to provide security for communications among different entities?
  • The standardized/detailed protocols for communication among various component
BKP Slides
NATCP: Fairness

- In a general network number of competing flows is not known, but this is not the case in cellular networks!

- Per-User buffers at BTS:
  - Number of competing flows is known by client!

- Inter-Fairness
  - Wireless scheduler handles it

- Intra-Fairness
  - The client sends fairness info. to the server
Do we really need the delay feedback?

TG[23] is a scheme based on providing only Bw feedback in an in-band manner.
In-Band vs. Out-of-Band Signaling

• Comparison between In-Band (IB) and Out-of-Band (OoB) signaling when feedback only consists of Bw and the time it has both Bw & delay (NATCP):

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Bw (IB)</th>
<th>Bw (OoB)</th>
<th>NATCP (IB)</th>
<th>NATCP (OoB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{95}$</td>
<td>1×</td>
<td>3.47×</td>
<td>7.32×</td>
<td>9.31×</td>
</tr>
</tbody>
</table>