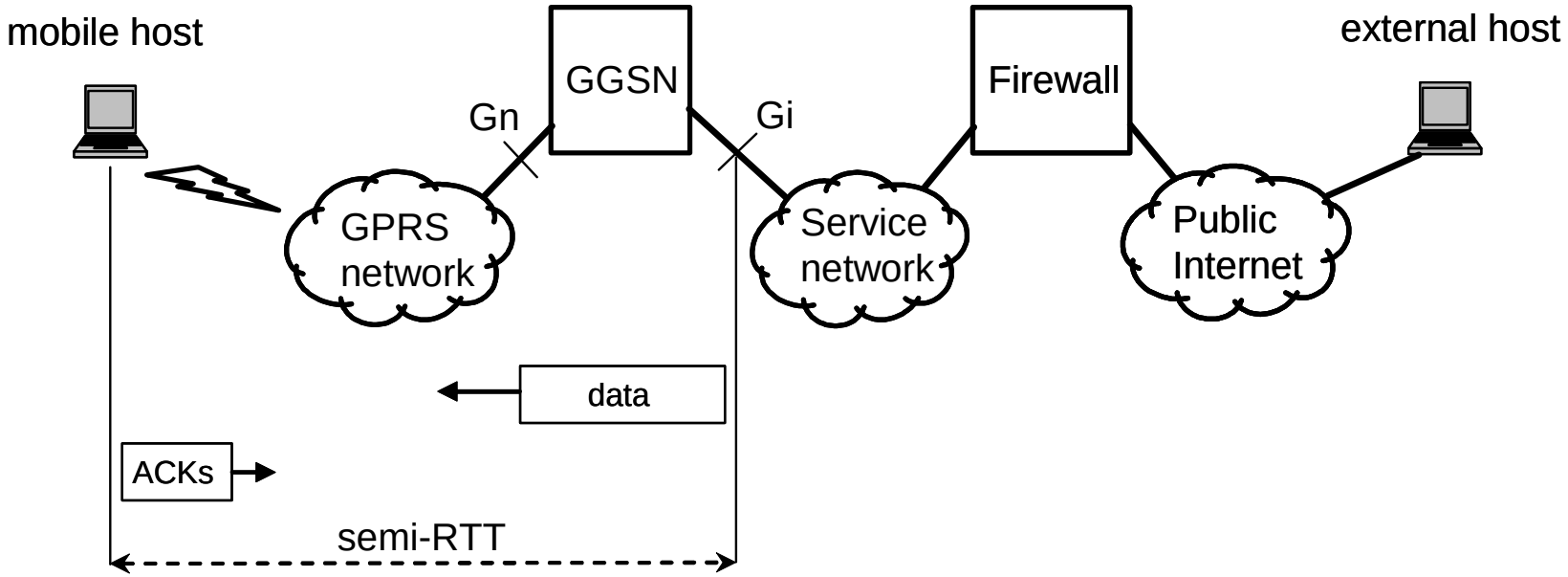
Micro- and macroscopic analysis of RTT variability in GPRS and UMTS networks

Jorma Kilpi
Systems Research
VTT Technical Research Centre of Finland
P.O.Box 12022, FIN 02044 VTT, Finland
Email: Jorma.Kilpi@vtt.fi

Pasi Lassila
Networking Laboratory
Helsinki University of Technology
P.O.Box 3000, FIN 02015 TKK, Finland
Email: Pasi.Lassila@hut.fi

Semi-RTT



- *RTT process:*

$$(t_i, RTT(t_i)) \qquad i = 1, \ldots, n$$

where $n =$ number of *valid* semi-RTT samples observed from the flow and t_i is the time stamp of the ACK packet at the Gi interface.

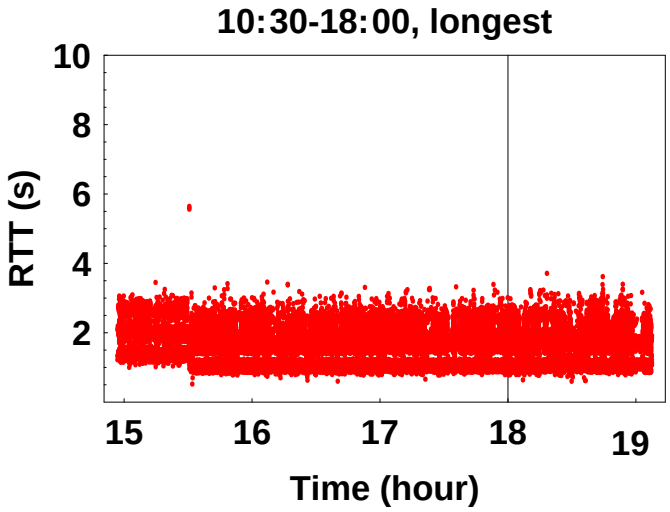
Why micro- and macroscopic analysis?

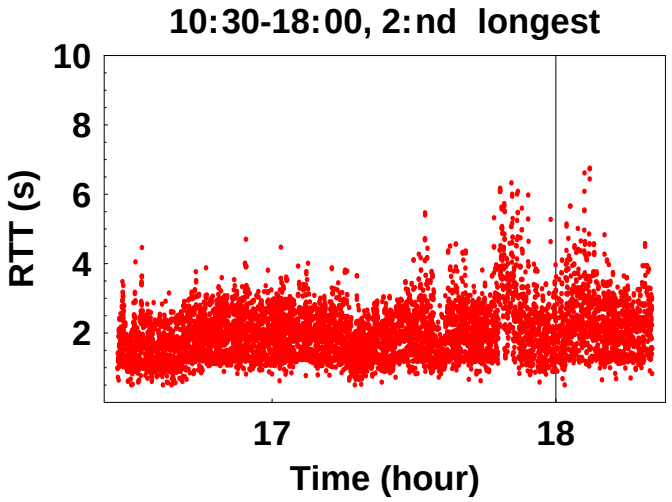
- How *individual* flows see the RTT process? (Microscopic level)
- What information does the *aggregate* RTT process tell us? (Macroscopic level)
- **Please note:** We use the word ’aggregate’ in two cases when we consider
  1. aggregate of all TCP flows from the same mobile or
  2. aggregate of all TCP flows from all of the mobiles.

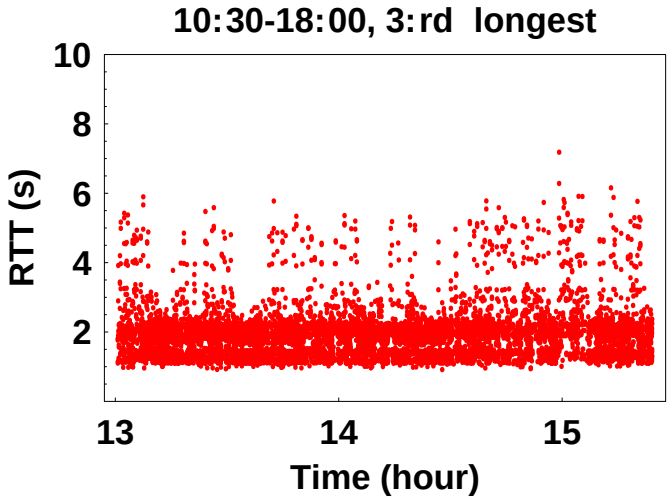
Reconstruction of TCP flows

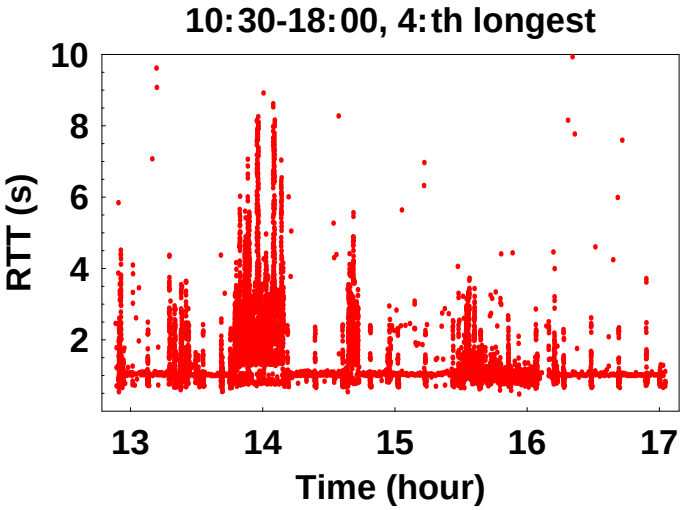
- Mobile TCP connections: GSM/GPRS and UMTS access.
- Mobile host <-> Internet host.
- All down- and upstream traffic of a TCP connection goes through the same GGSN.
- We used a program called Tstat (`http://tstat.tlc.polito.it/`) which reconstructs TCP connections from TCP/IP packet level data.
- Moreover, Tstat was modified slightly in order to obtain RTT processes $(t_i, RTT(t_i))$, $i = 1, \ldots, n$ of a large number of flows.
- *Biased* view of mobile traffic in the sense that we only present analysis of non-anomalious successful TCP connections.

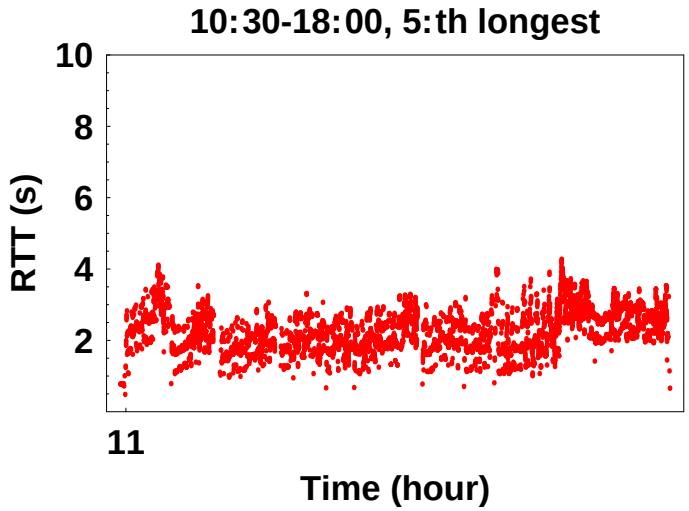
Examples of observed RTT processes

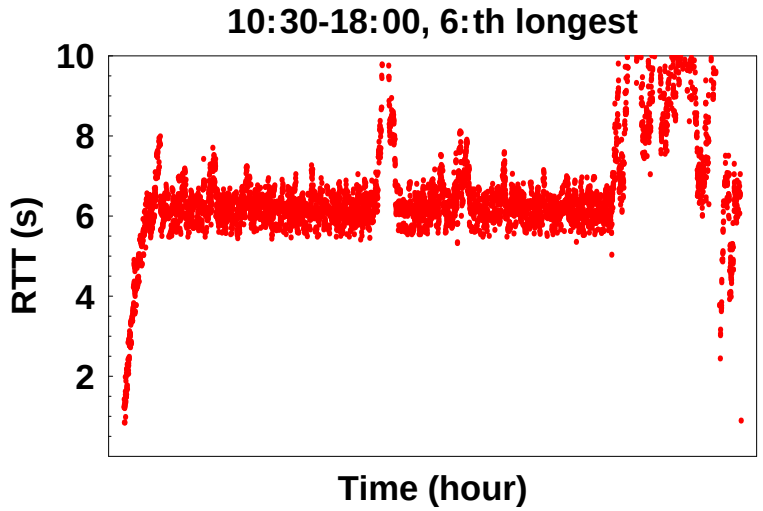


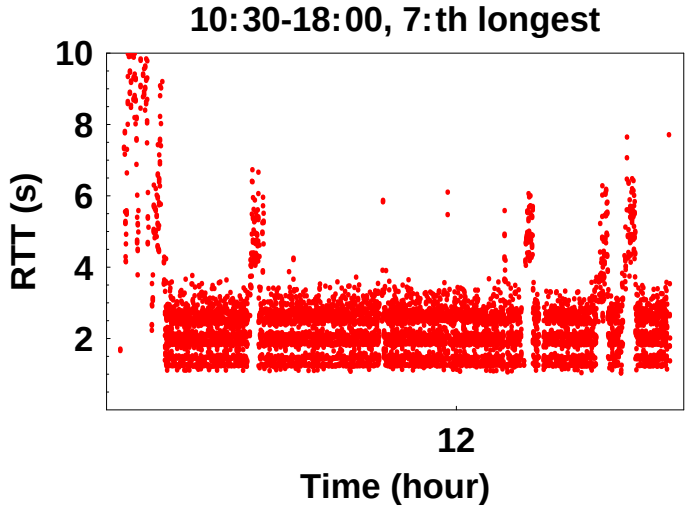


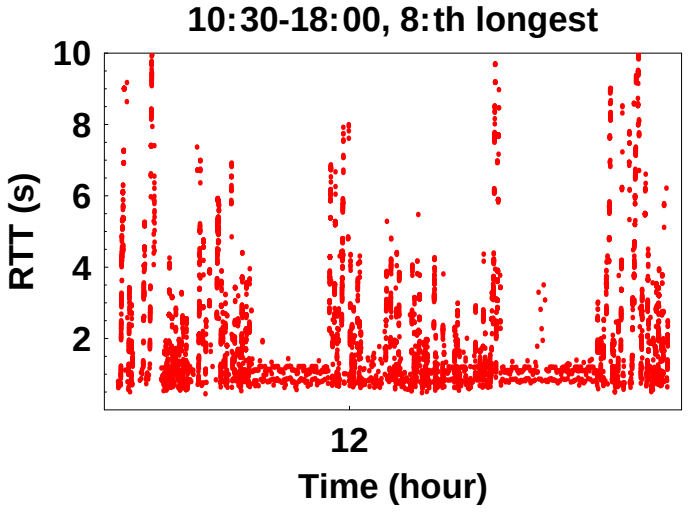


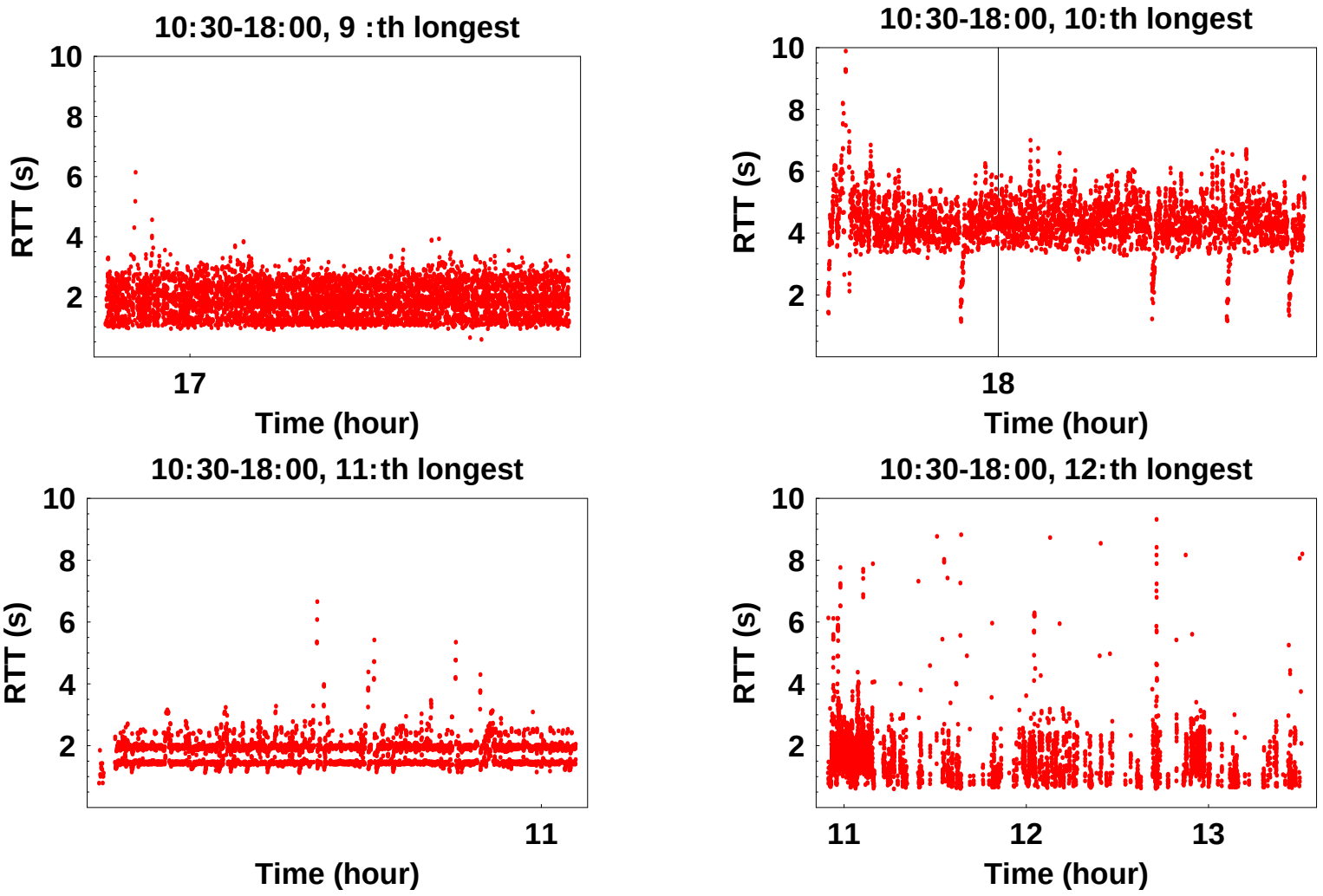



10:30-18:00, 5:th longest
RTT (s)
10
8
6
4
2
11
Time (hour)

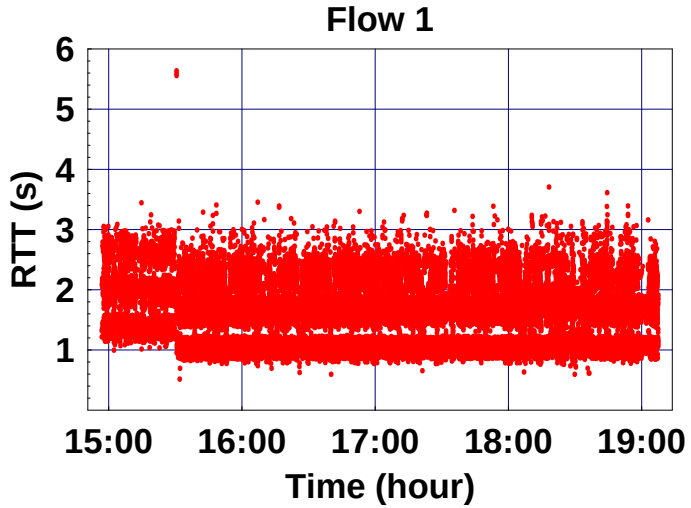

10:30-18:00, 6:th longest
RTT (s)
10
8
6
4
2
Time (hour)

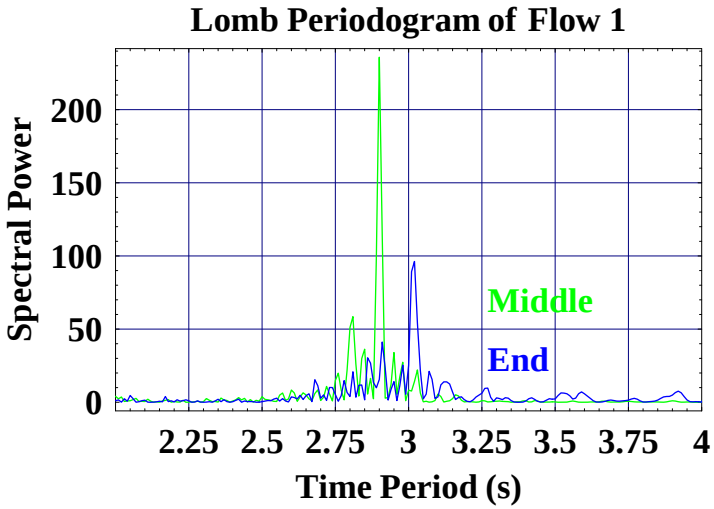

10:30-18:00, 7:th longest
RTT (s)
10
8
6
4
2
12
Time (hour)

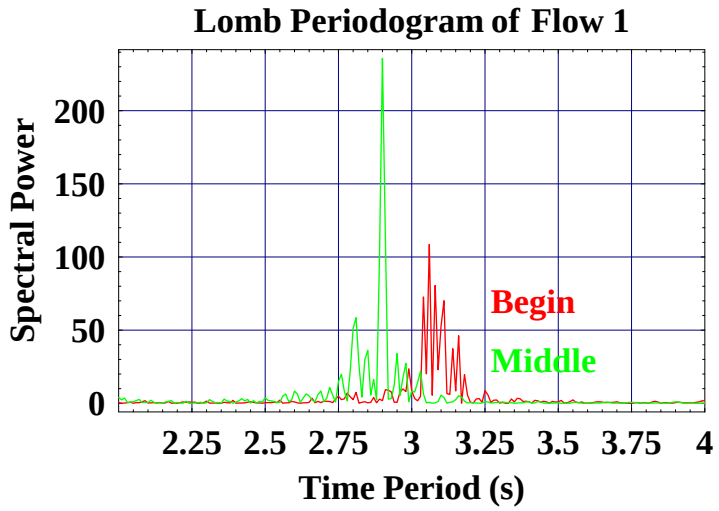

10:30-18:00, 8:th longest
RTT (s)
10
8
6
4
2
12
Time (hour)

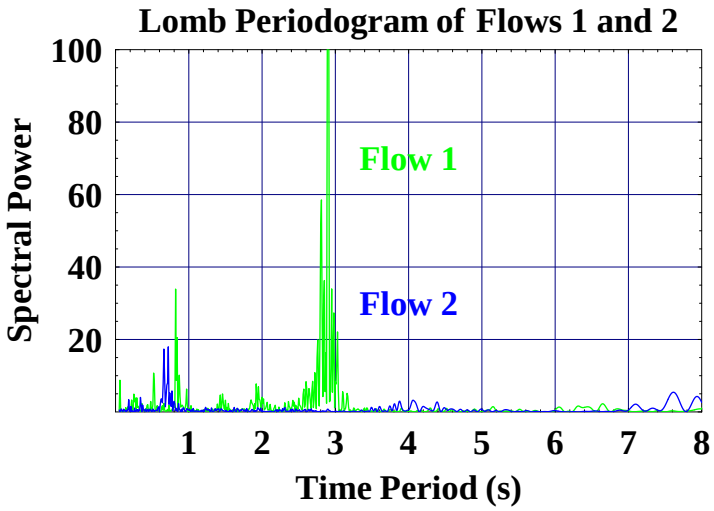

10:30-18:00, 9 :th longest
RTT (s)
10
8
6
4
2
17
Time (hour)
10:30-18:00, 10:th longest
RTT (s)
10
8
6
4
2
18
Time (hour)
10:30-18:00, 11:th longest
RTT (s)
10
8
6
4
2
11
Time (hour)
10:30-18:00, 12:th longest
RTT (s)
10
8
6
4
2
11
12
13
Time (hour)

Microscopic level: Flow 1 in TCP port 80 (HTTP) but not a web page downloading!

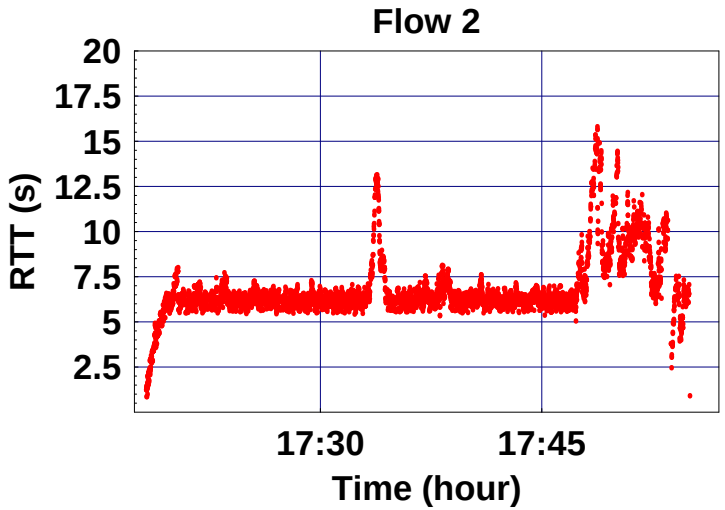


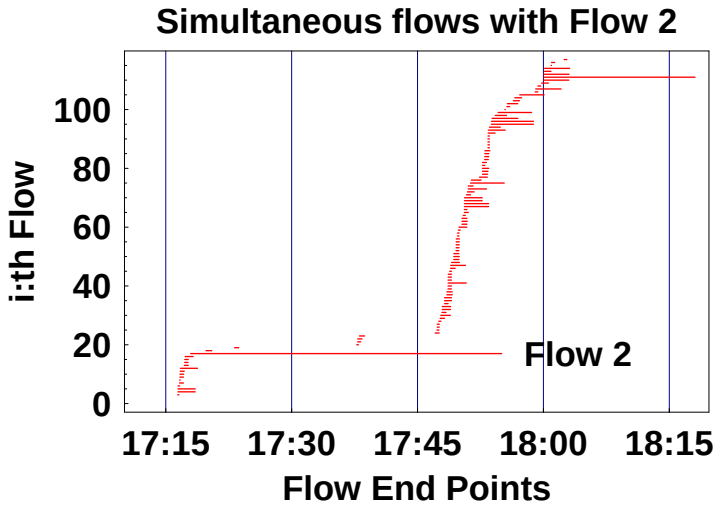


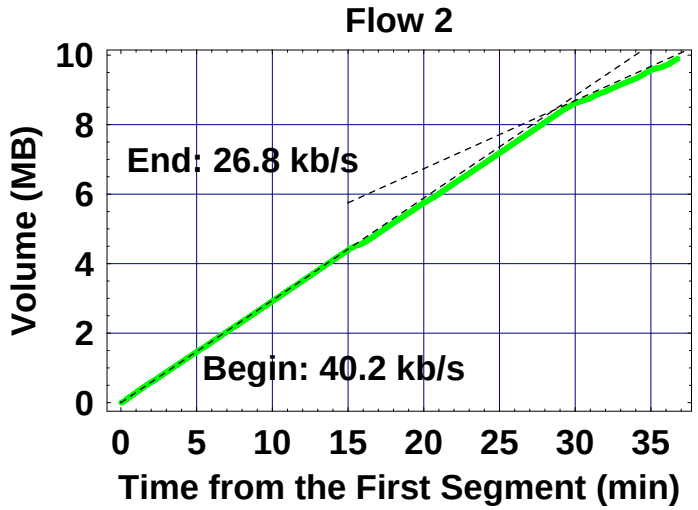




Microscopic level: Flow 2, also in TCP port 80 but lasts about half an hour!

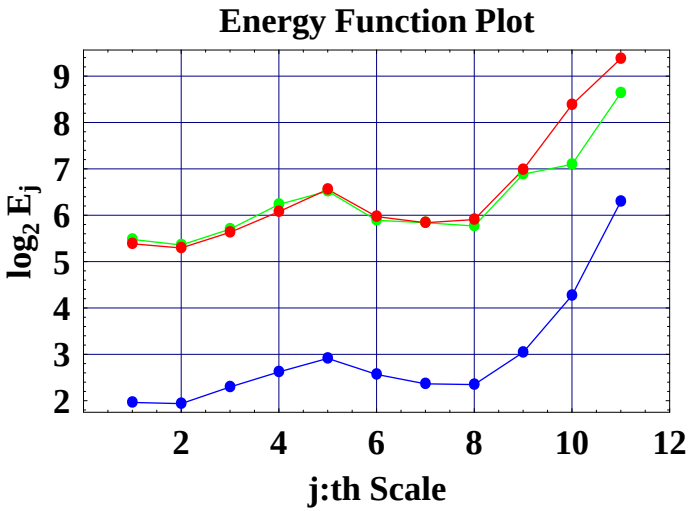


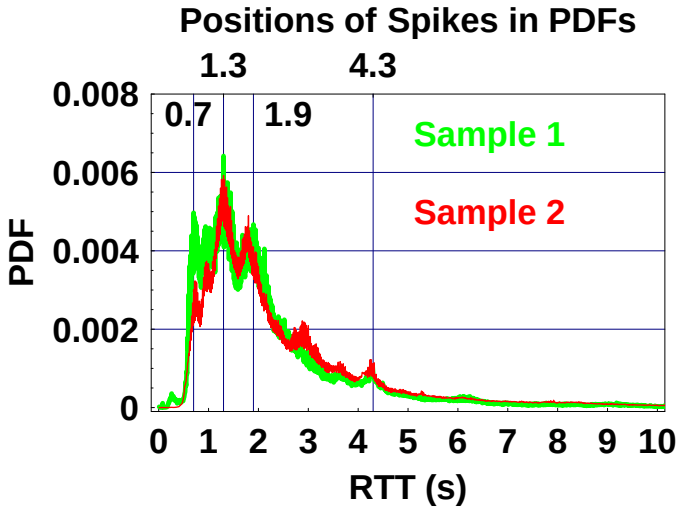




- An example of the effect of simultaneous TCP-connections from the *same* mobile.

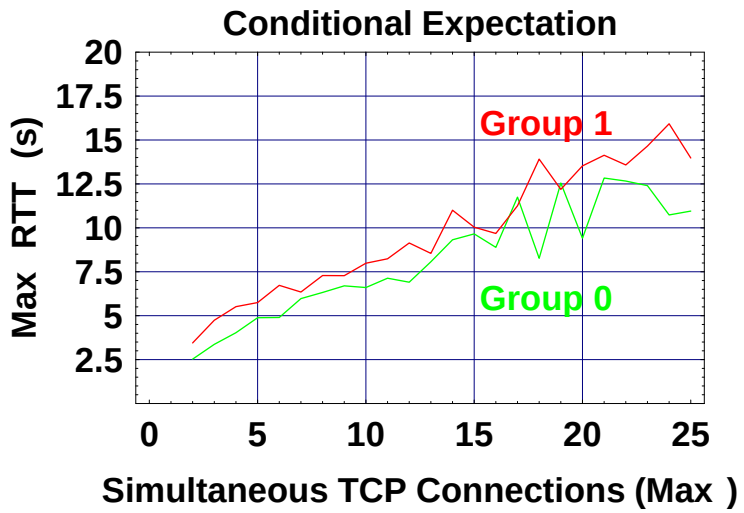
Macroscopic level: Dominating RTT values

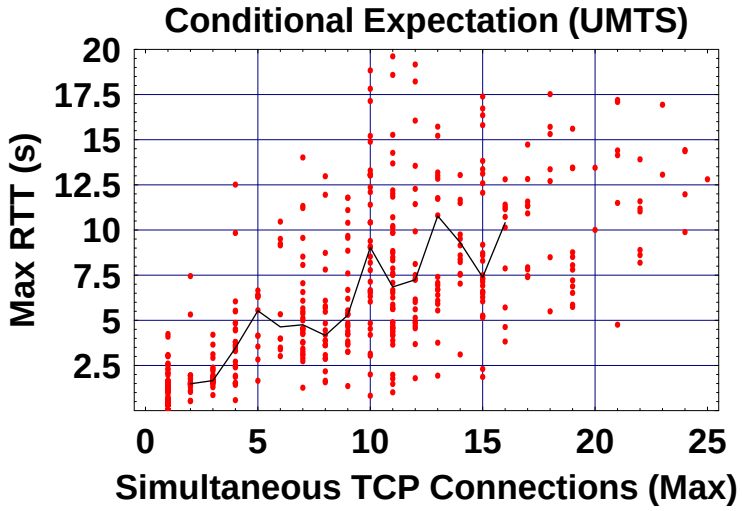




- A paper by Huang, Feldmann and Willinger used wavelets to detect network performance problems.
- Energy Function Plots (EFPs) using Haar wavelets showed local periodicity in the range $600ms - 5s$.
- PDF of aggregate RTT processes show that the probability mass essentially lies between the same $600ms - 5s$!
- The positions of spikes are due to deterministic reasons.
- The (backbone) network as a whole is not significantly congested during the busy hours.

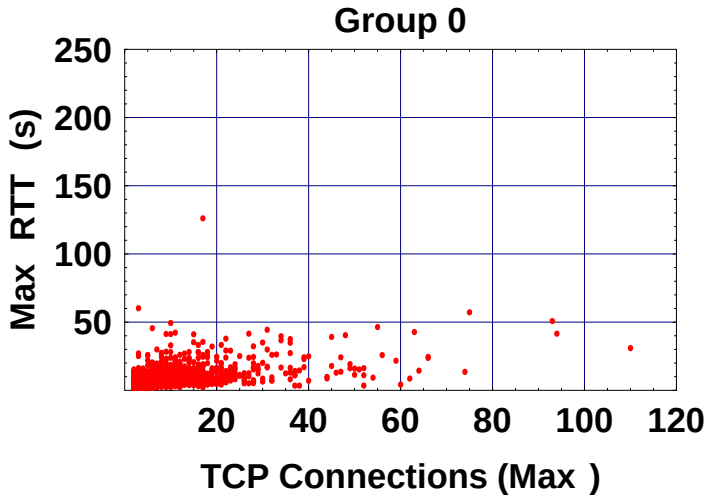
Macroscopic level: Self-congestion

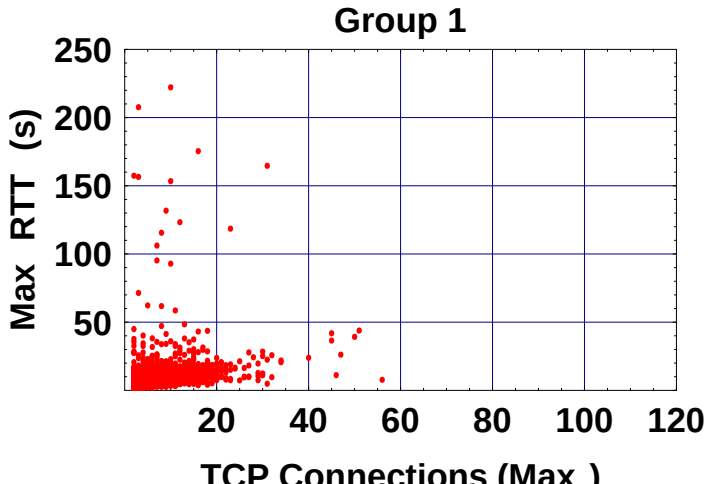




- Aggregate traffic from the same mobile.
- Group 0: The set of those mobiles that essentially did not send any data in the uplink.
- Group 1: At least one of the flows of the mobile in this group had non-trivial simultaneous uploading.
- Robust estimates of conditional expectation.
- For individual flows, self-congestion is due to simultaneous flows from same mobiles are the main reason for the observed RTT variability.

Macroscopic level: Uploading is more critical than simultaneous downloadings





- Group 0: The set of those mobiles that essentially did not send any data in the uplink.
- Group 1: At least one of the flows of the mobile in this group had a non-trivial simultaneous uploading.

Conclusions and further research topics

- Dominating RTT values told that the (backbone) network was not significantly congested during busy hours.
- Self-congestion and uploading are critical.
- Wavelets seem to be really a powerful tool.
  - EFP gave the same information about the congestion level of the network from the packet level data than the histogram of all RTTs, *i.e.*, **without reconstruction of TCP flows.**
- Usefulness of the Lomb periodogram?
  - TCP port 80 does not indicate the true application.
  - Distinguishing streaming applications from true file downloadings?
  - Could the ACK packets alone be used? (Without reconstruction of TCP connections)

- Poster (short paper) in Networking 2006 conference, May 15th-19th, Coimbra, Portugal.
- Questions?