Network Neutrality in Mobile Broadband

NeutMon

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Network Neutrality

- *Network Neutrality*: packets on the Internet should be processed impartially by ISPs and other operators, without regard to content, destination or source.

- In EU blocking, throttling, and discrimination of traffic by ISPs is not allowed. All traffic has to be treated equally, and no form of traffic prioritization can be enforced [1].

[1] BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules.

NeutMon

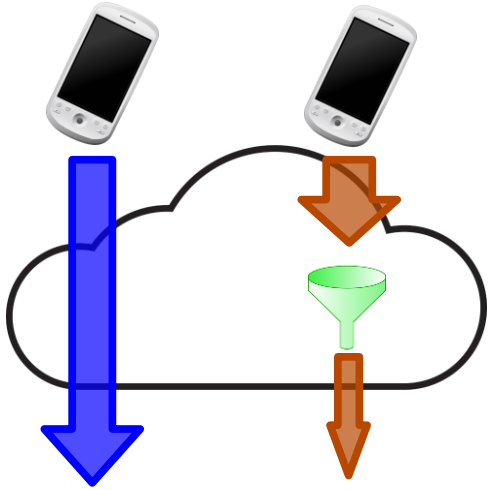
- NeutMon aims at
  - Studying the net neutrality problem in a mobile broadband scenario
  - Developing tools useful to detect possible violations
  - Collecting data about the neutrality level of EU mobile broadband providers
  - Analyzing collected data using techniques that take into account the specific characteristics of the considered environment

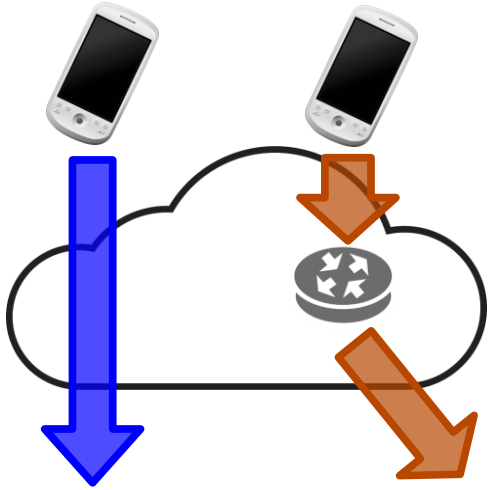
- Additional problems due to the wireless environment
  - Fluctuations originated by signal strength, retransmissions, number of users, mobility, etc



NeutMon

- NeutMon focuses on the detection of
  - throttling/blocking of Bit Torrent (BT) traffic
  - different forwarding rules for the different classes of traffic





- BT traffic is compared with random Control Traffic (CT)

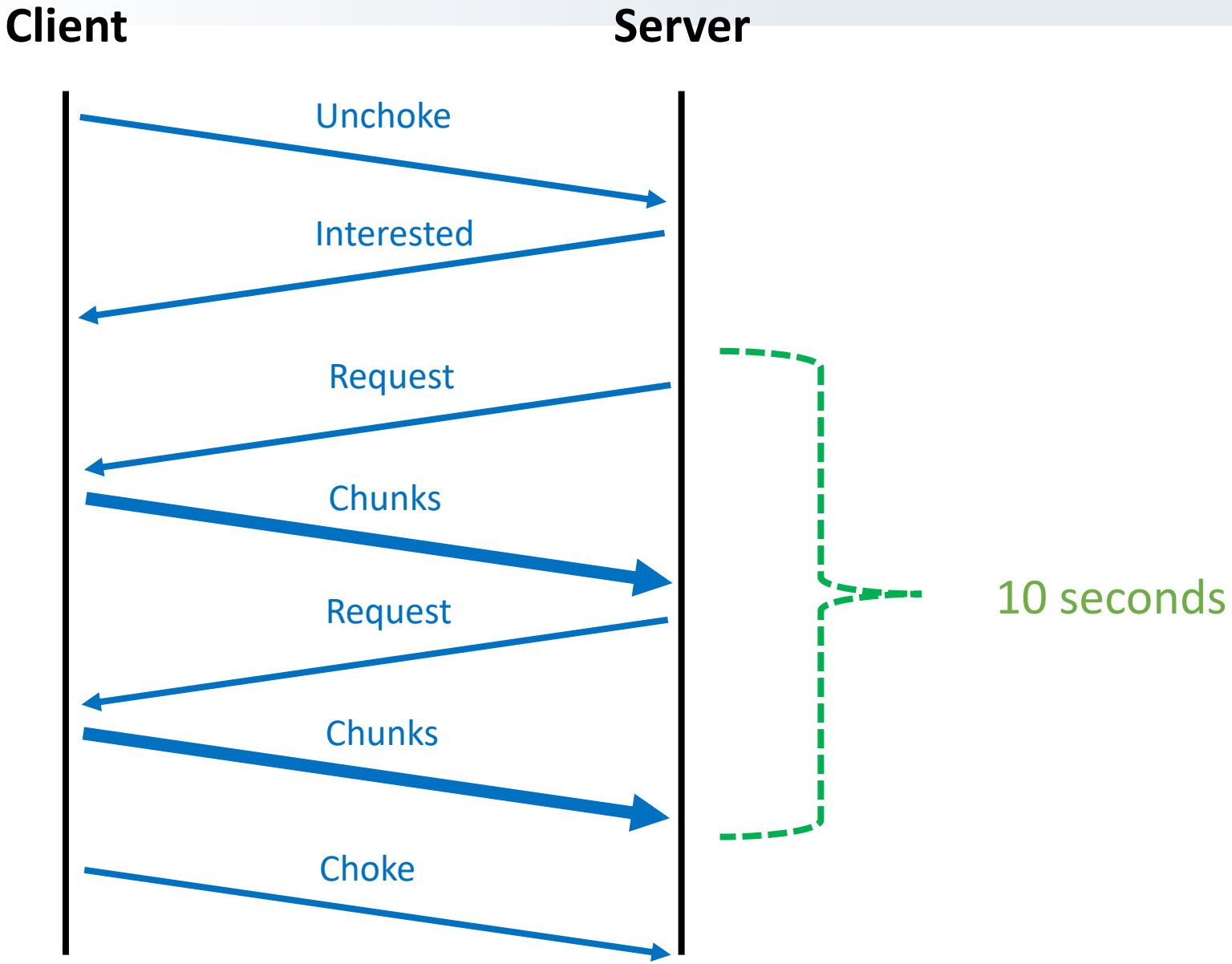
Implementation

- Two types of tests have been implemented:
  - Speed test
  - Traceroute test.

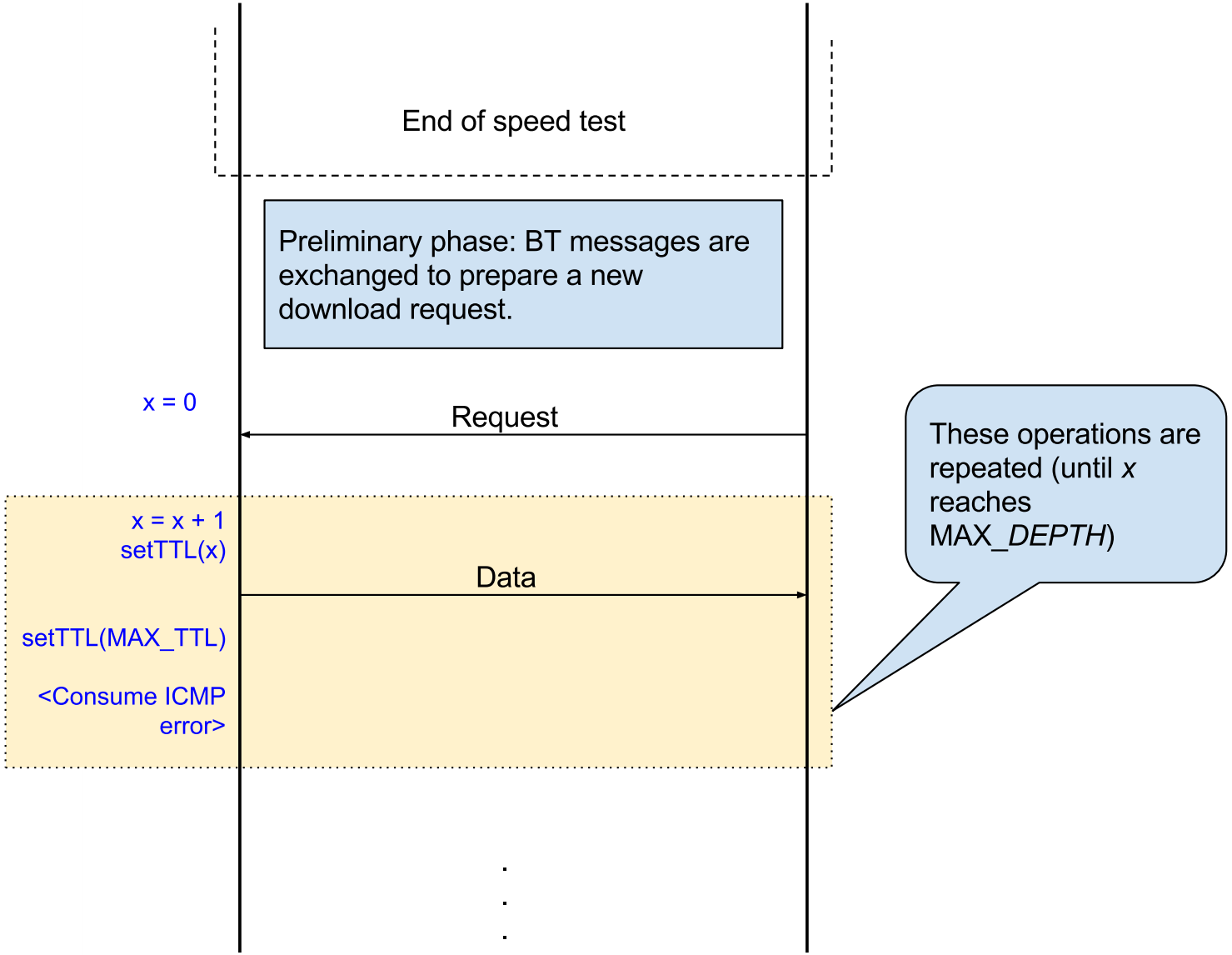
- Speed test: application-level throughput of the connection between the client and the server, for different classes of traffic.
- Traceroute test: network path that is traversed by different classes of traffic, between the client and the server.

- Each test is performed in both uplink and downlink directions and with the two classes of traffic (BT and CT).

Speed test

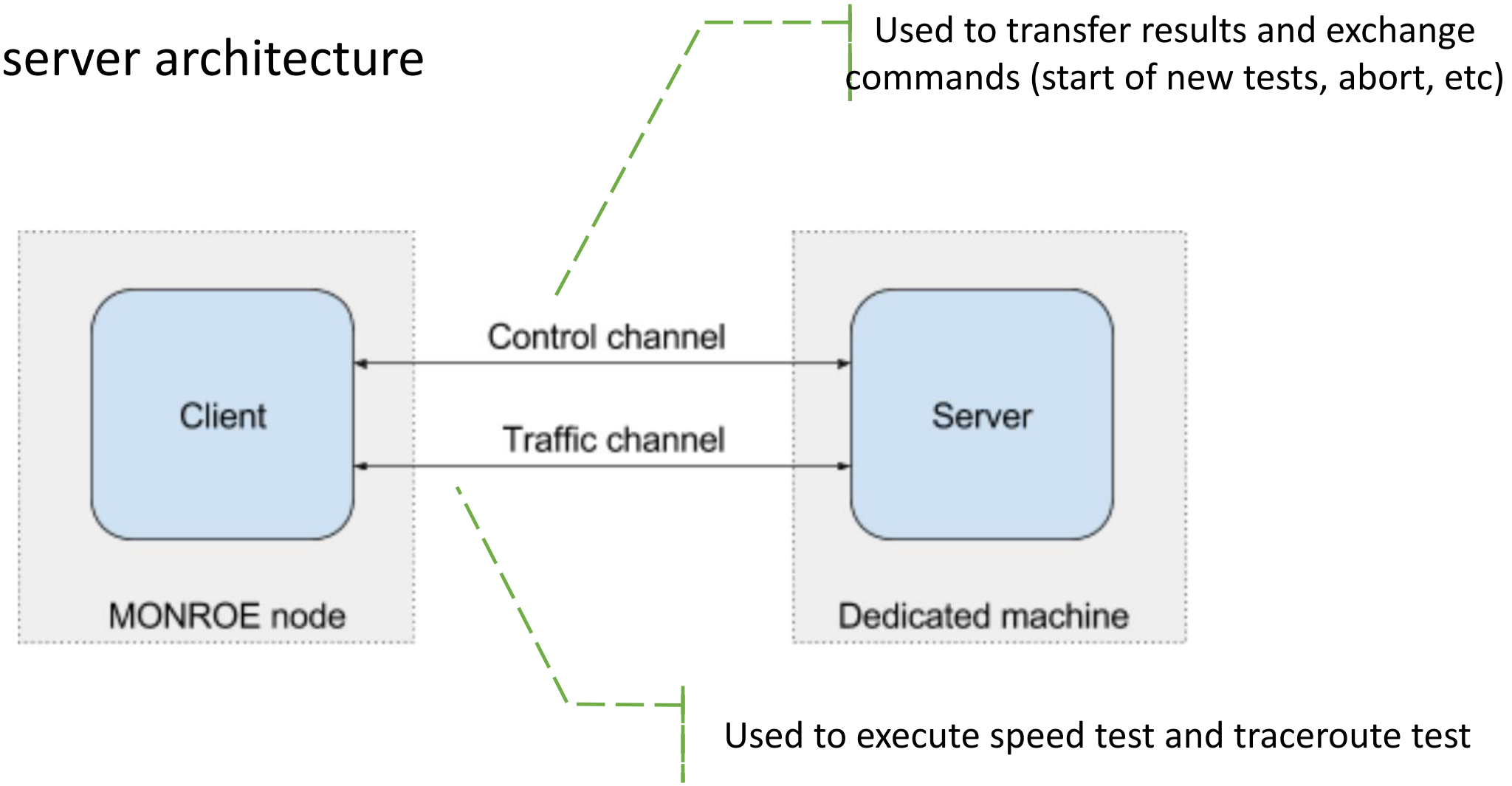

Client
Server
Unchoke
Interested
Request
Chunks
Request
Chunks
Choke
10 seconds

Traceroute test



Architecture

- Client-server architecture



Implementation

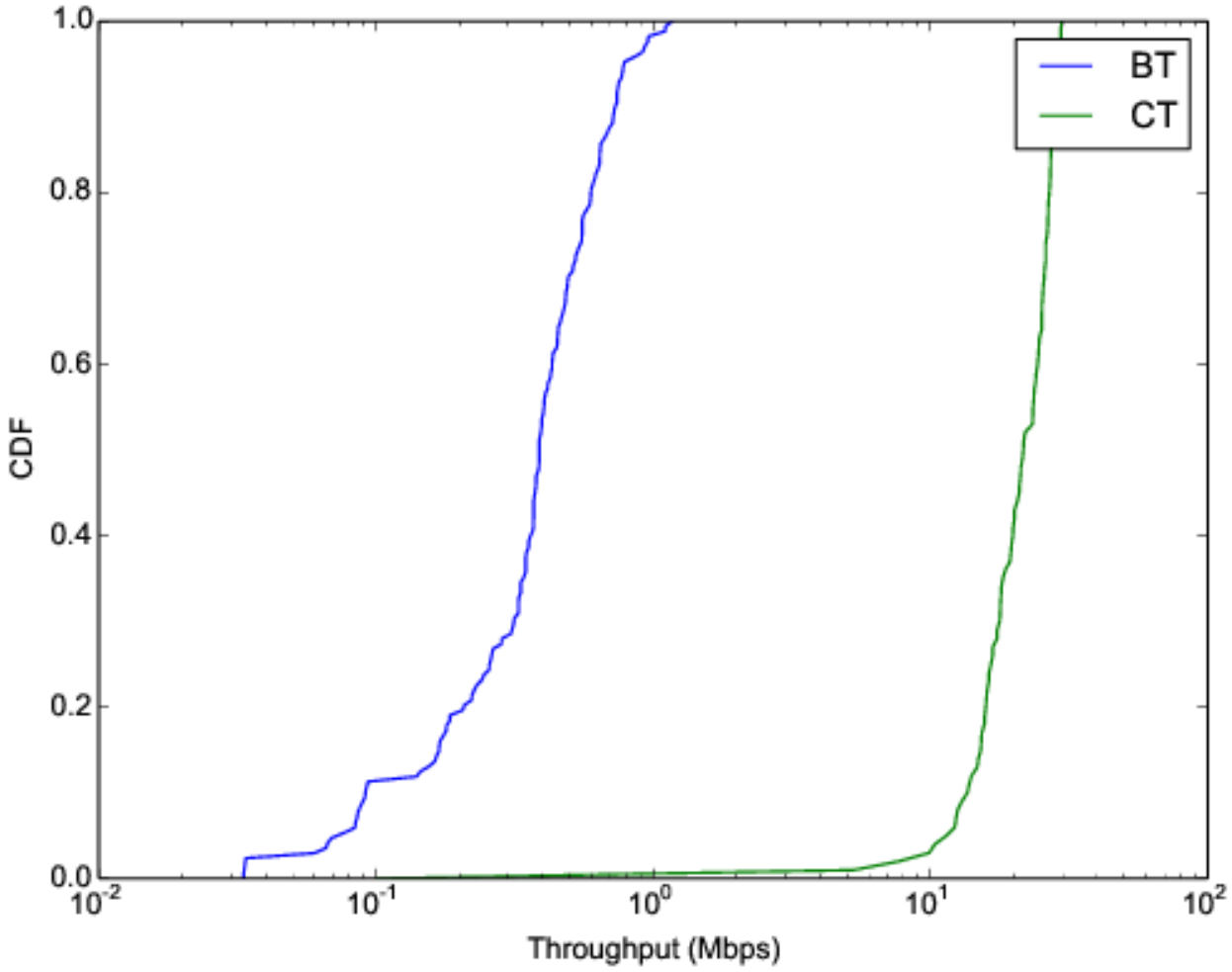
- The server processes the requests coming from a single client at a time
  - done to avoid interferences during the measurement phase caused by cross-traffic and increased load;
  - clients that desire to carry out a measurement when the server is busy are queued, and they will be served as the current measurement completes.

Experiments

- First phase: *wide-range experiments*
  - Purpose: collect preliminar information about all operators covered by MONROE (13)
  - Scheme:
    - Four time slots: 02, 08, 14, 20
    - Three executions per time slot
    - Speed test: 10 seconds
- Second phase: *focused experiments*
  - Purpose: collect additional evidences against suspect operators
  - Scheme:
    - Twelve executions in 24h
    - Speed test: 30 s

Results of wide-range experiments (speed)

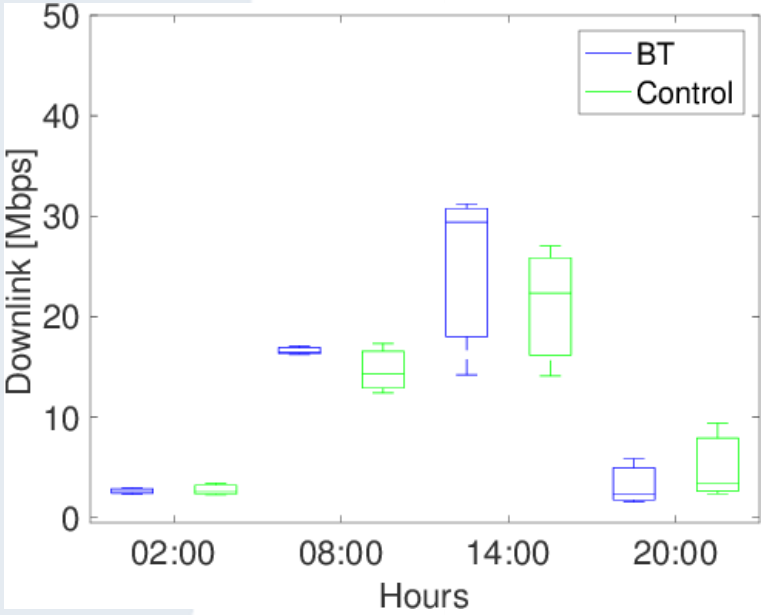
- Some cases of differentiation are particularly evident even at first sight.
- Example: CDF of measured throughput for Vodafone Italy collected at 02:00:



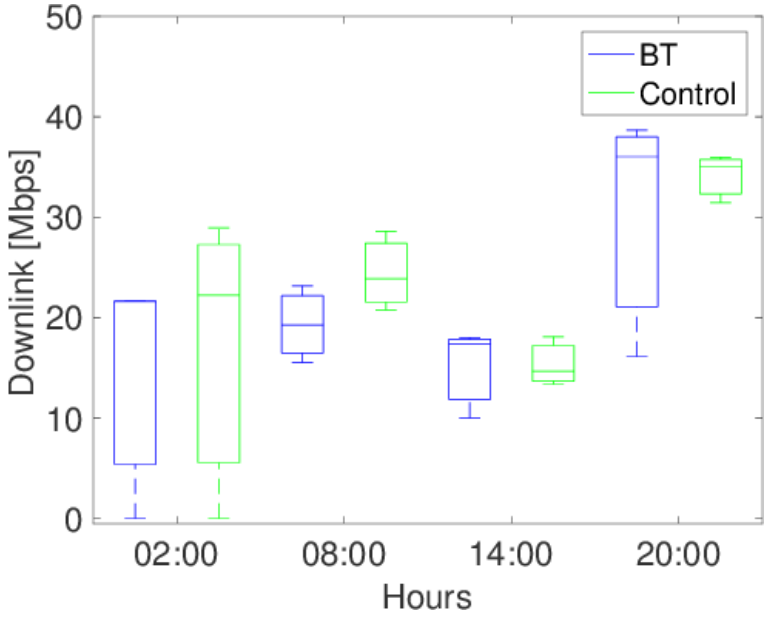
Results of wide-range experiments (speed)

- Downlink mean throughput values obtained by BT and CT by all operators at the different time slots.
- Italy:

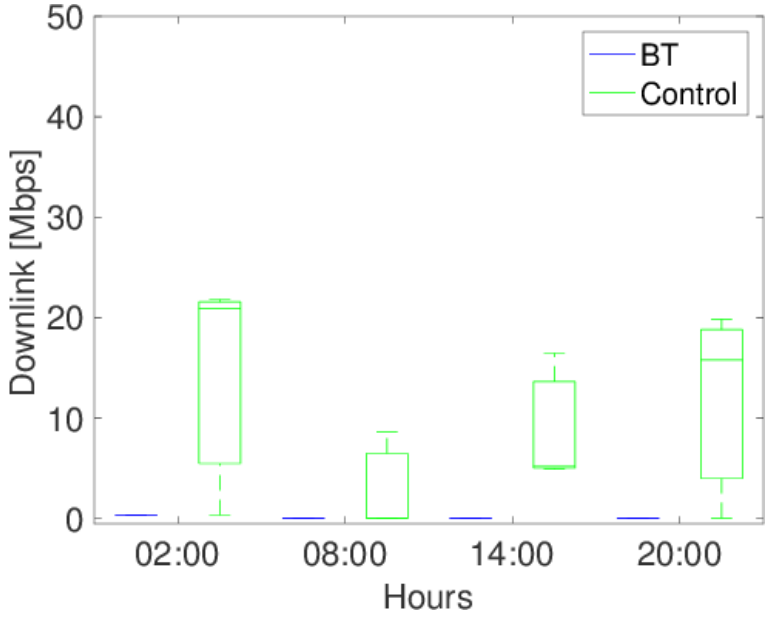
Blu Wind



TIM



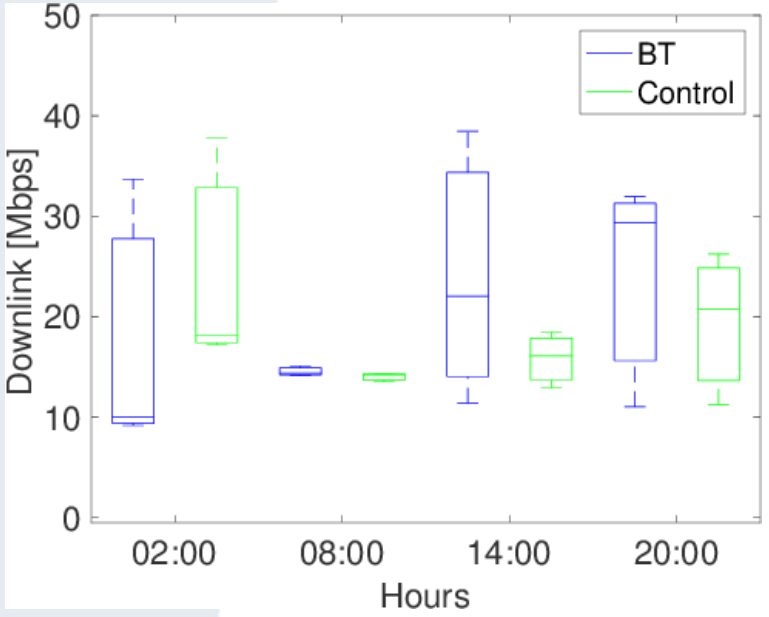
Vodafone Italy



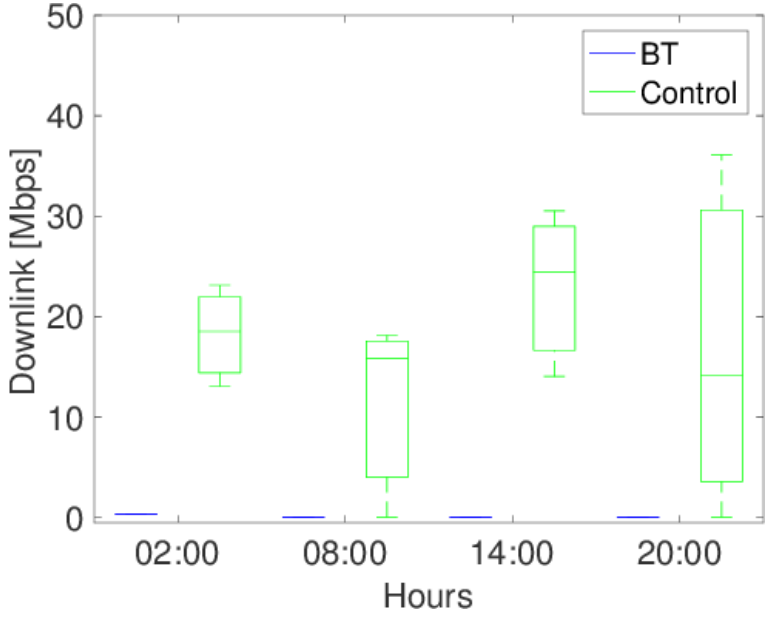
Results of wide-range experiments (speed)

- Downlink mean throughput values obtained by BT and CT by all operators at the different times.
- Spain:

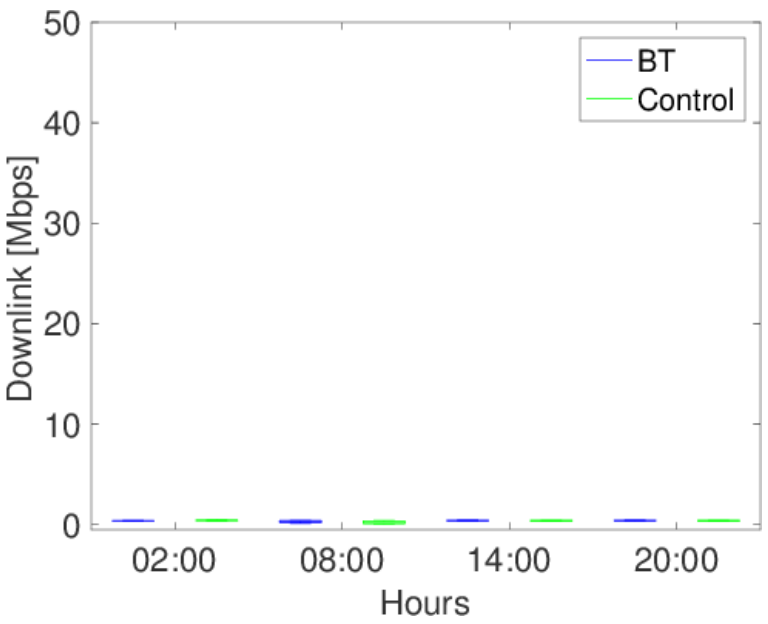
Orange



Vodafone Spain



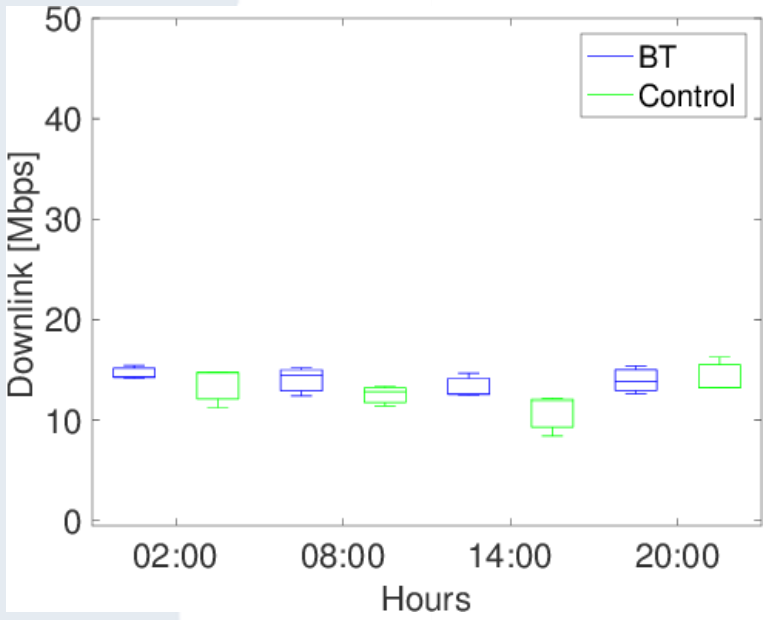
Yoigo



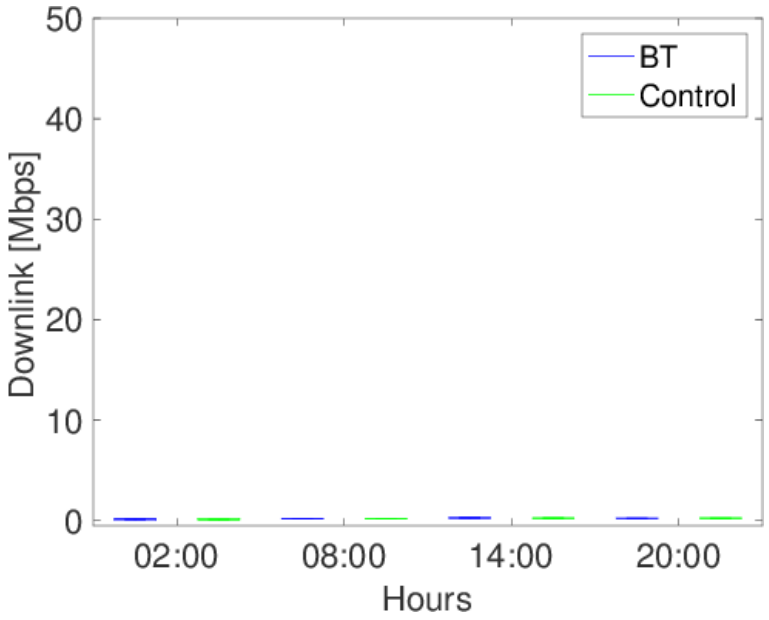
Results of wide-range experiments (speed)

- Downlink mean throughput values obtained by BT and CT by all operators at the different times.
- Sweden:

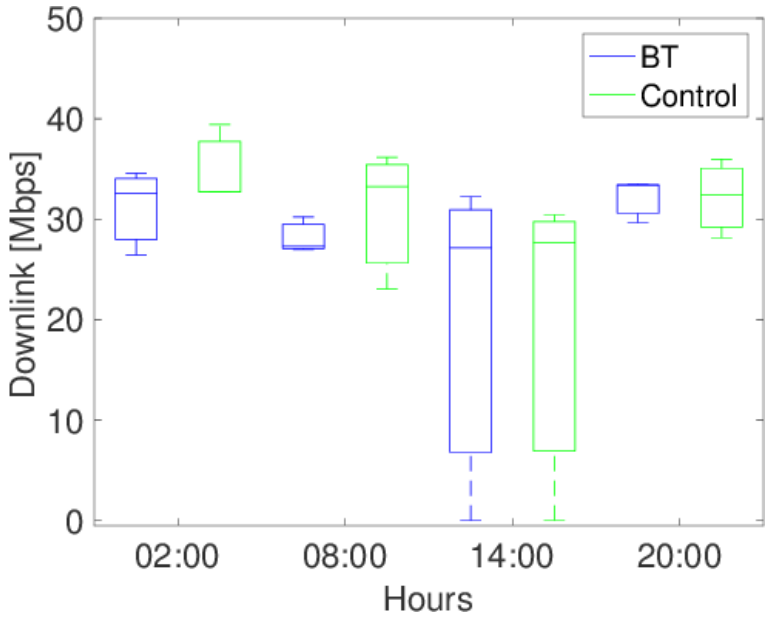
H3G



Telenor (Vodafone)



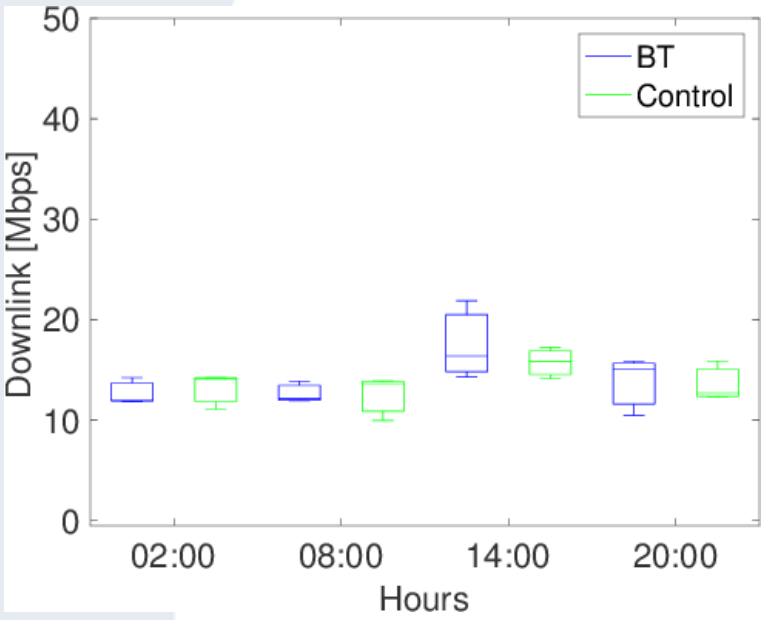
Telia mobile



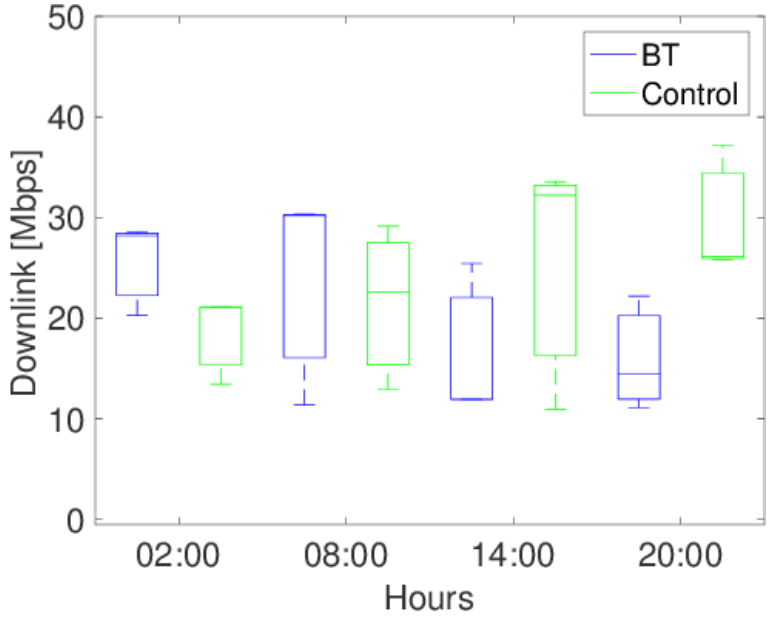
Results of wide-range experiments (speed)

- Downlink mean throughput values obtained by BT and CT by all operators at the different times.
- Norway:

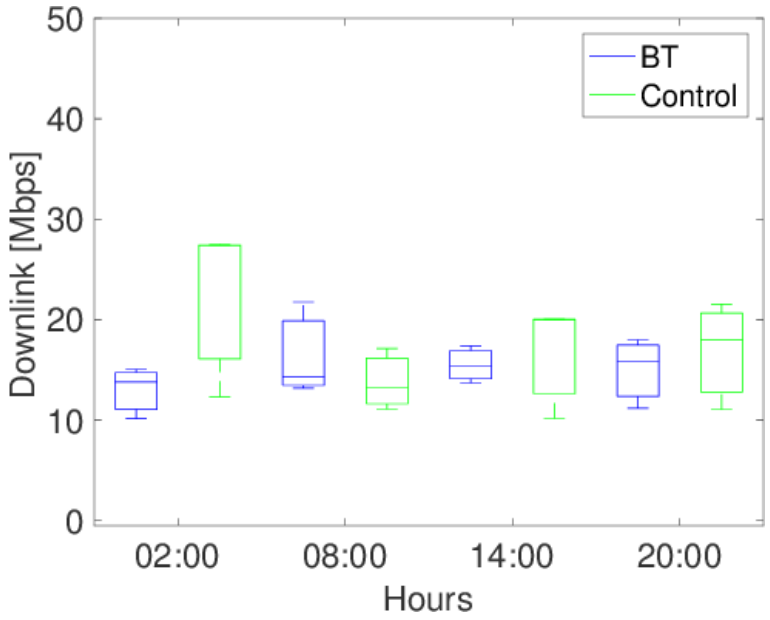
ICE Nordisk



Telenor

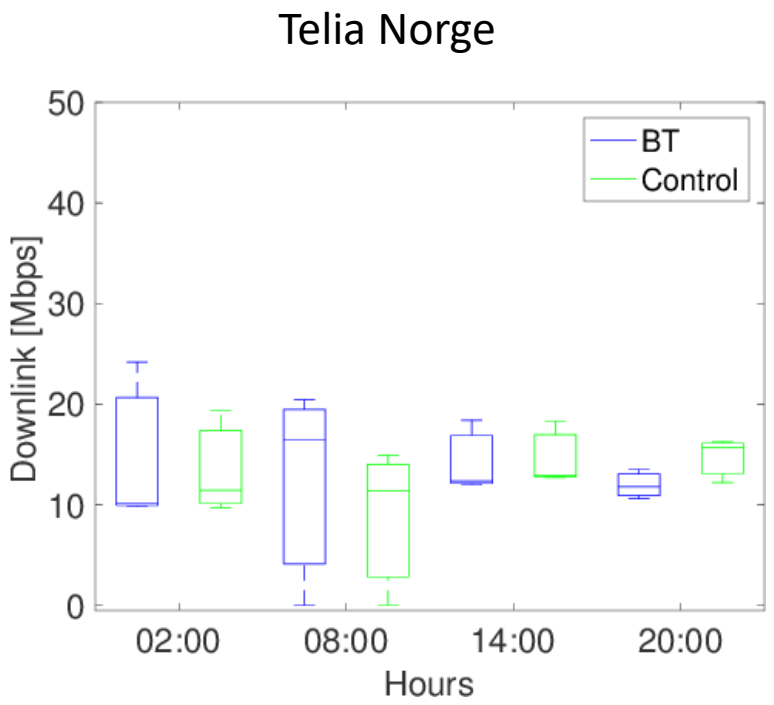


Telia mobile



Results of wide-range experiments (speed)

- Downlink mean throughput values obtained by BT and CT by all operators at the different times.
- Norway (cont.):



Results of wide-range experiments (speed)

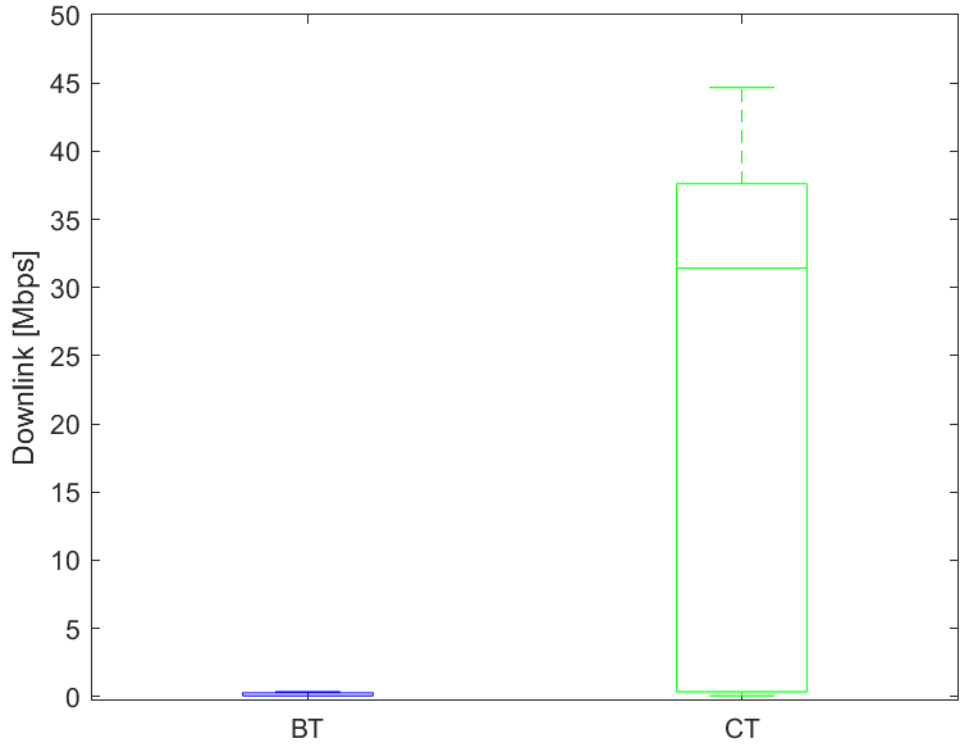
Country	*Operator*	*Port 6881 blocked*	*Throttling*
Italy	TIM	0%	None
	Vodafone	86.4%	BT (sometimes CT)
	Blu Wind	41.2%	BT and CT
Norway	ICE	0%	None
	Telenor	0%	None
	Telia Mobile	0%	None
	Telia Norge	0%	None
Spain	Orange	0%	None
	Vodafone	73.9%	BT (sometimes CT)
	Yoigo	100%	BT and CT
Sweden	H3G	0%	None
	Telenor (Vodafone)	58.3%	BT and CT
	Telia Mobile	0%	None

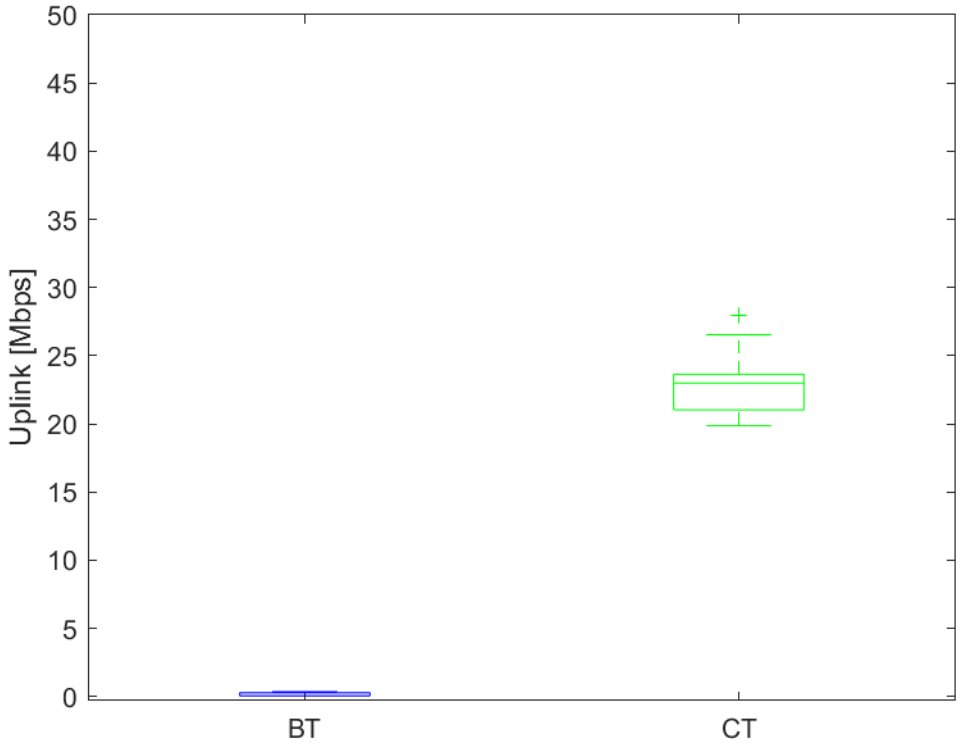
Analysis tool

- The analysis tool compares the distribution of CT and BT instantaneous throughput (averaged on *d* second intervals)
  - Kolmogorov-Smirnov test
  - False positives (network reported as non neutral when it is neutral) if *d* small

Results of focused experiments (speed)

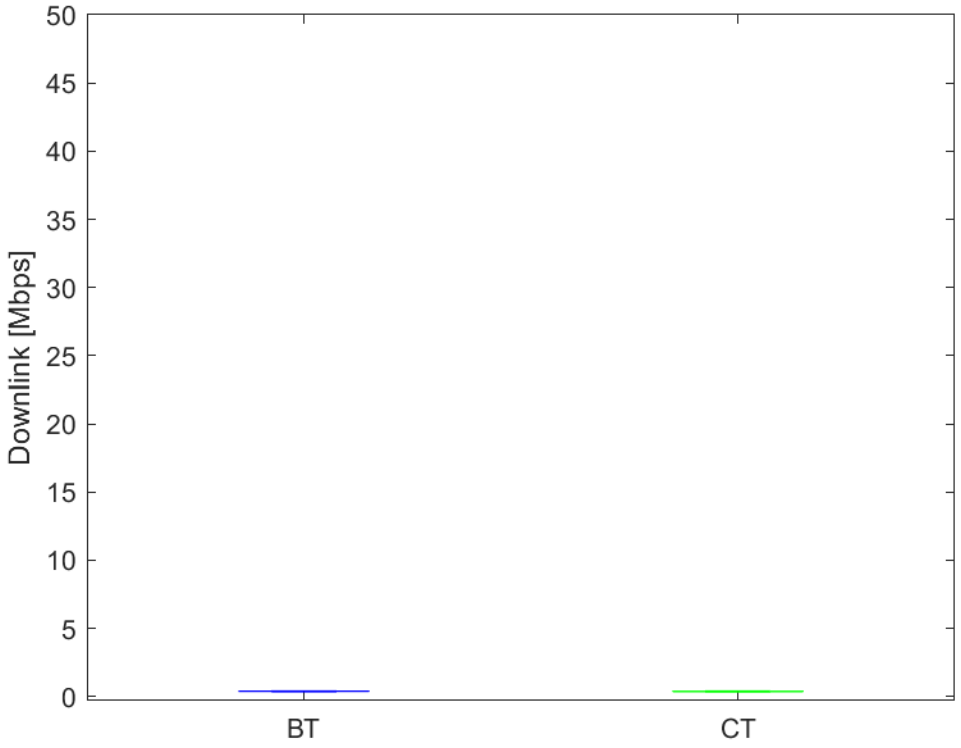
- Vodafone spain

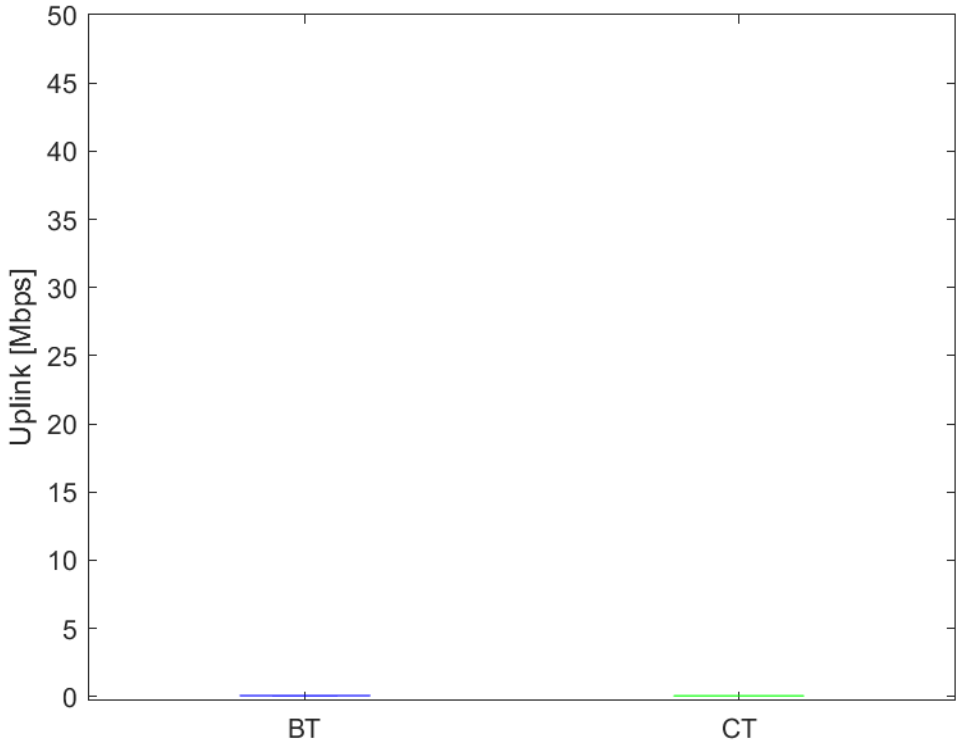




Results of focused experiments (speed)

- Yoigo spain





Analysis of traceroute data

- Problem: different traceroutes may traverse multiple paths and still this could not be a case of differentiation, as network operators apply load balancing based on criteria such as port numbers and other fields of the IP/TCP headers (usually the 5-tuple fields).
- We sent flows that are “externally” similar as much as possible (same ports, same addresses).
- We collected different traceroutes for each operator and for each class of traffic.

Analysis of traceroute data

- For each class of traffic (BT/CT) and traffic direction (UL/DL), we merged all the traceroutes.
- We obtain a data structure that, for each traceroute hop, shows the set of interfaces traversed by one class of traffic in one direction.

- For example for BT-UL we can have:

```
Hop 1: {IP1, IP2, IP3}
Hop 2: {IP4}
Hop 3: {IP5, IP6}
Hop 4: *
Hop 5: {IP7, IP8}
...
```

Analysis of traceroute data

- For each traffic direction we computed the intersection and differences between the sets of BT and CT at each hop.
- We identified at each hop which are the exclusive interfaces discovered by just one of the two classes of traffic (if any).

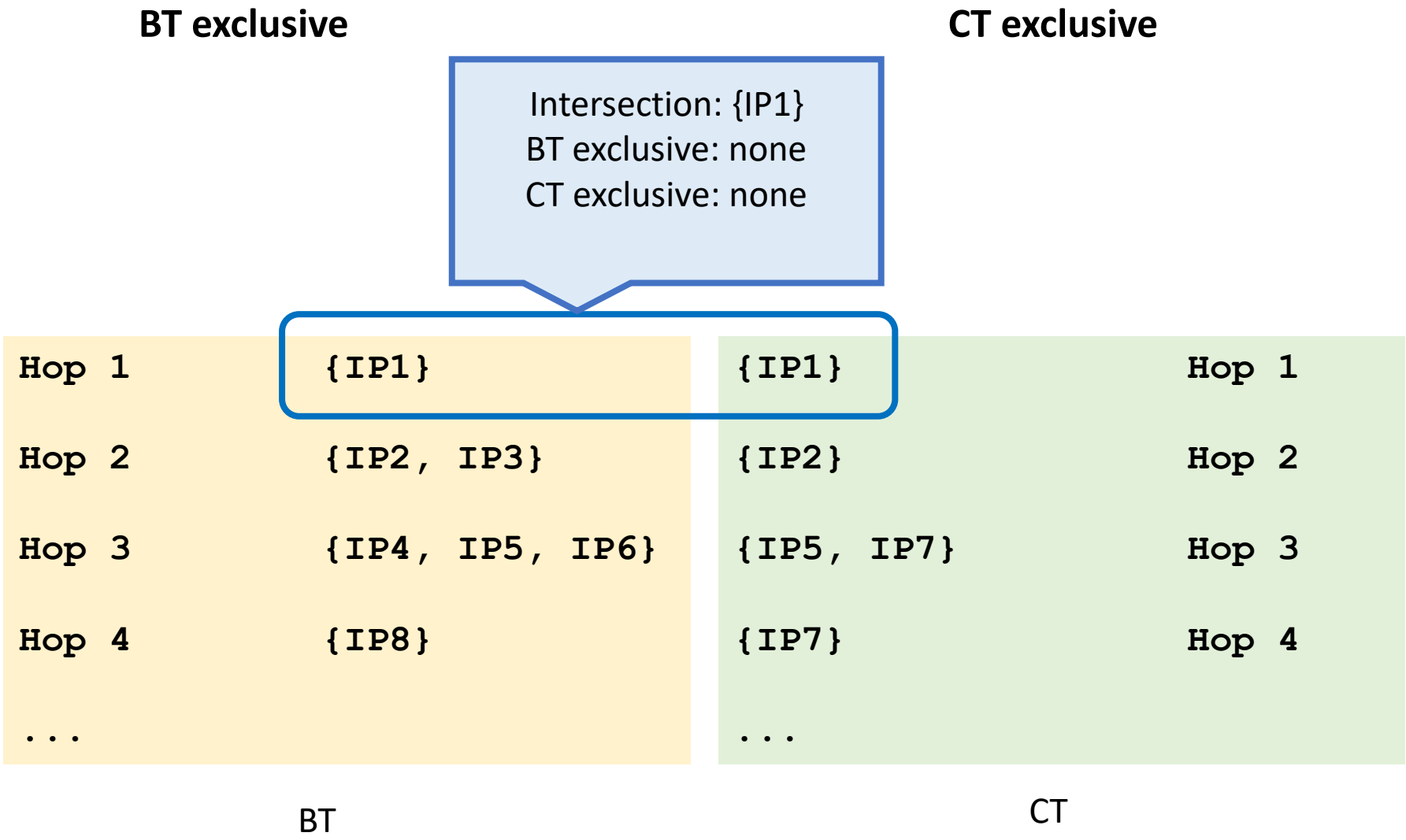
Hop 1	{IP1}
Hop 2	{IP2, IP3}
Hop 3	{IP4, IP5, IP6}
Hop 4	{IP8}
...	

BT

{IP1}	Hop 1
{IP2}	Hop 2
{IP5, IP7}	Hop 3
{IP7}	Hop 4
...	

CT

Analysis of traceroute data



Analysis of traceroute data

BT exclusive
Hop1: -

CT exclusive
Hop1: -

Hop 1	{IP1}
Hop 2	{IP2, IP3}
Hop 3	{IP4, IP5, IP6}
Hop 4	{IP8}
...	

BT

{IP1}	Hop 1
{IP2}	Hop 2
{IP5, IP7}	Hop 3
{IP7}	Hop 4
...	

CT

Analysis of traceroute data

BT exclusive
Hop 1: -
Hop 2: {IP3}

Intersection: {IP2}
BT exclusive: {IP3}
CT exclusive: none

CT exclusive
Hop 1: -
Hop 2: -

Hop 1	{IP1}	{IP1}	Hop 1
Hop 2	{IP2, IP3}	{IP2}	Hop 2
Hop 3	{IP4, IP5, IP6}	{IP5, IP7}	Hop 3
Hop 4	{IP8}	{IP7}	Hop 4
...		...	

BT

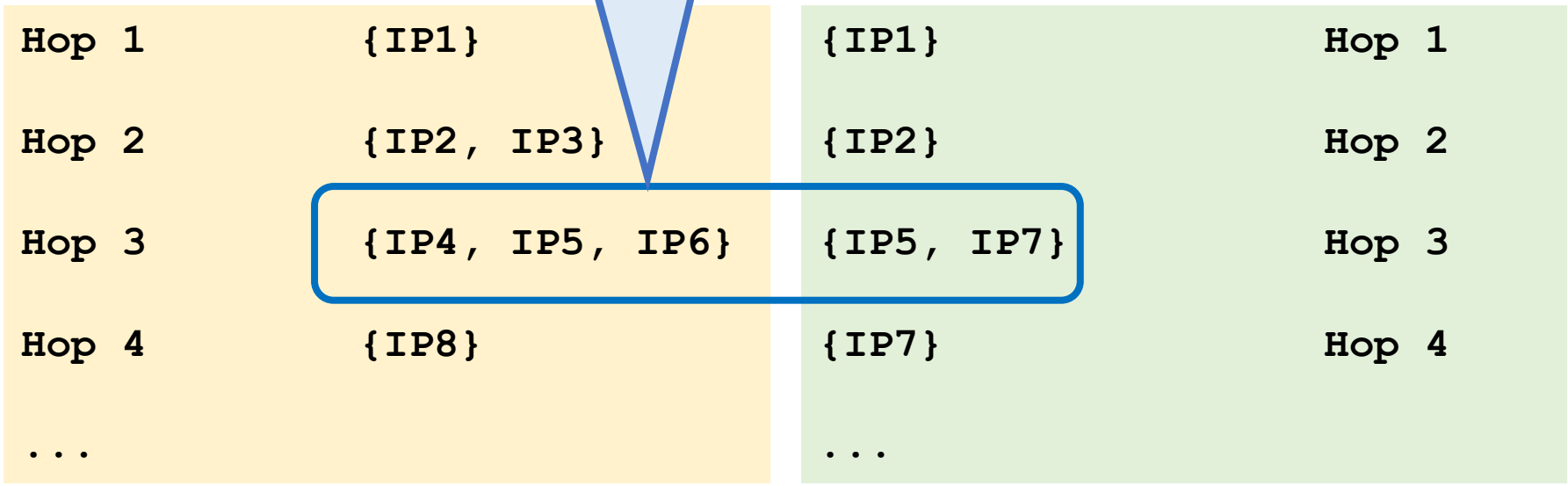
CT

Analysis of traceroute data

BT exclusive
Hop 1: -
Hop 2: {IP3}
Hop 3: {IP4, IP6}

Intersection: {IP5}
BT exclusive: {IP4, IP6}
CT exclusive: {IP7}

CT exclusive
Hop 1: -
Hop 2: -
Hop3: {IP7}



Results of wide-range experiments (traceroute)

- We computed the percentage of exclusive interfaces out of the total for each hop.
  - If the percentage is low, the differences between the two sets could be due to load balancing.
  - If the percentage is high it is more likely that the differences between the two sets could be due to different paths applied by operators to different classes.

Results of wide-range experiments (traceroute)

- Some results (Italy):

TIM
UL:
Hop 9 BT exclusive: 25%, CT exclusive: 40% (likely load balancing)
DL:
no difference

Vodafone
UL:
no difference
DL:
no difference

Wind (Blu)
UL:
Hop 4 BT exclusive 86%, CT exclusive 80%
Hop 7 BT exclusive 83%, CT exclusive 80%
DL:
Hop 8 BT exclusive 30%, CT exclusive 50% (could be load balancing)

Advancement status

- Implementation of software for collecting measurements — **complete**
- Collection of measurements
  - Wide-range — **complete**
  - Focused — ongoing
- Tools for analyzing data — **complete**
- Mechanisms for reducing traffic during speed test — ongoing

  (not included in the proposal)