Precise One-way Delay Measurement with Common Hardwareand Software

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Outline

- Motivation
- Precise latency measurement
  - Challenges
  - Solutions
- Measurement setup
- Results
- Conclusion and outlook

Motivation

- Customers want to **evaluate & compare performance** of the systems they (want to) purchase
  - Themselves
  - By others (subcontractors / partners)
- Researchers want to publish quantitative results
- “ping” is the default latency evaluation tool, but is it accurate enough?
- More sophisticated solutions:
  - Complex so setup and/or
  - Require hardware support and/or
  - Expensive

➔ **Create easy to deploy and use measurement tool**

Precise latency measurement: challenges

- Specialized hardware
- Adjustments to operating system (OS)

- Non-real-time OS
- Multi-threading

- Time-sync for one-way latency measurements

- Cost / availability

Precise latency measurement: challenges & solutions

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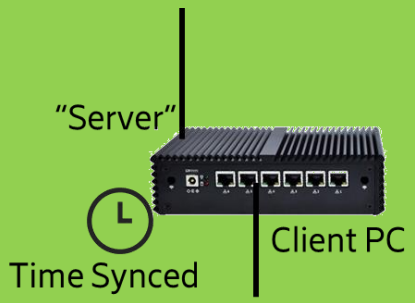
- Cost / availability

x64

- Busy-waiting:
  - while-loop, not "sleep"
- Single-thread:
  - Poll socket to receive
- No "print"

- Network namespaces

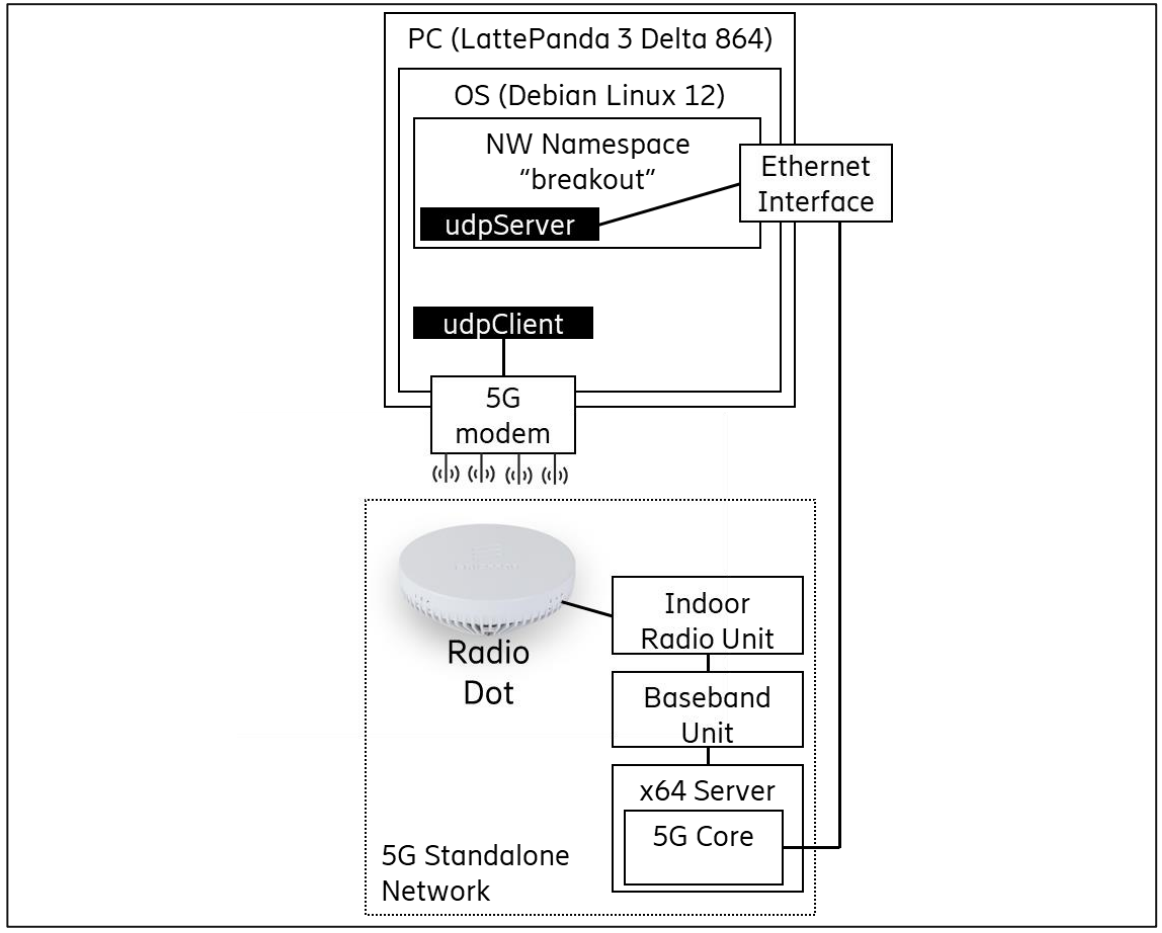


GitHub

Measurement setup

Parameter	Value
Subcarrier spacing	30 kHz
Transmission Time Interval	0.5 ms
Time Division Duplex (TDD) Pattern	DDSU
TDD Special Slot Configuration	13:3:0
Antenna	Ericsson Radio Dot 4479
Frequency and bandwidth	3.7 GHz, 100 MHz

Parameter	Value
Packet size	50 Byte
Inter-packet spacing	20 ms
PC	Latte Panda 3 Delta 864
Modem	Quectel RM500q



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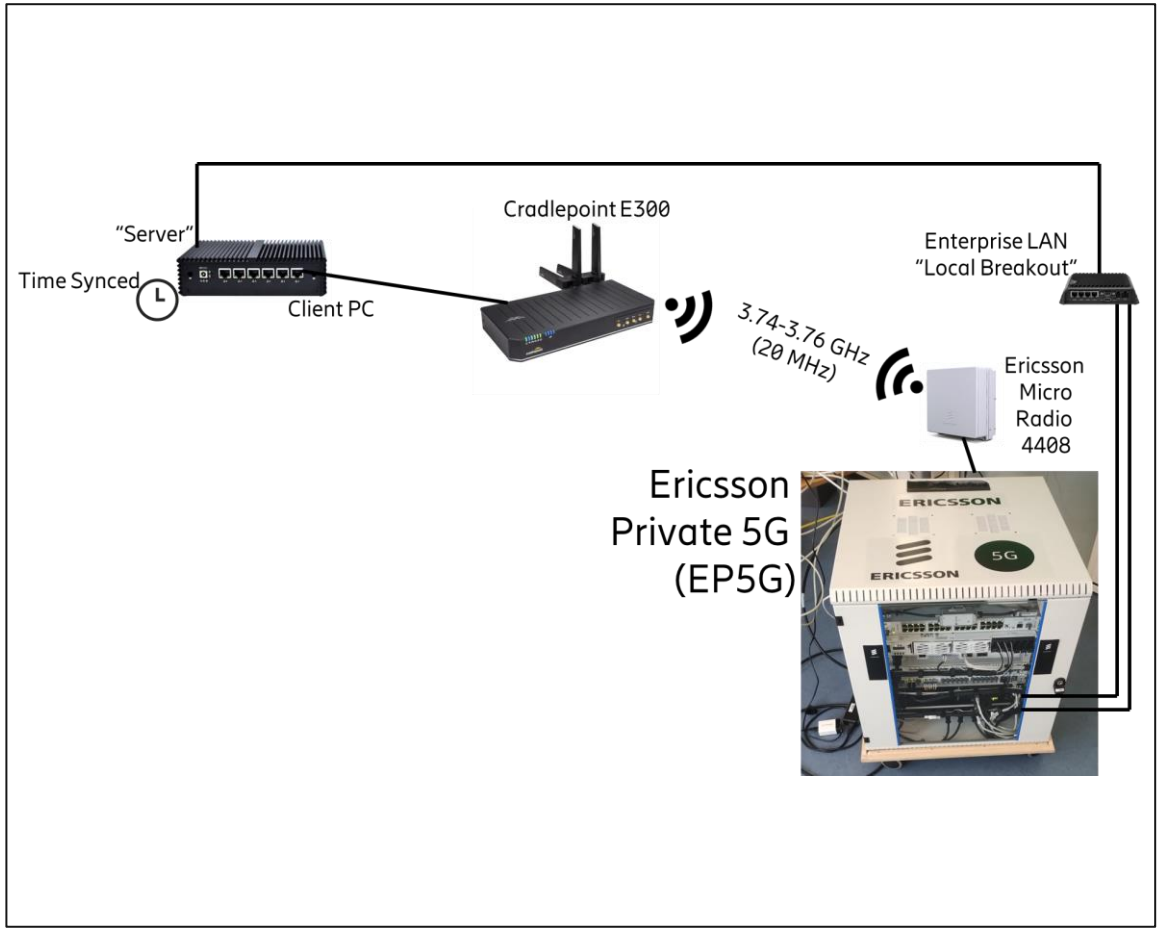
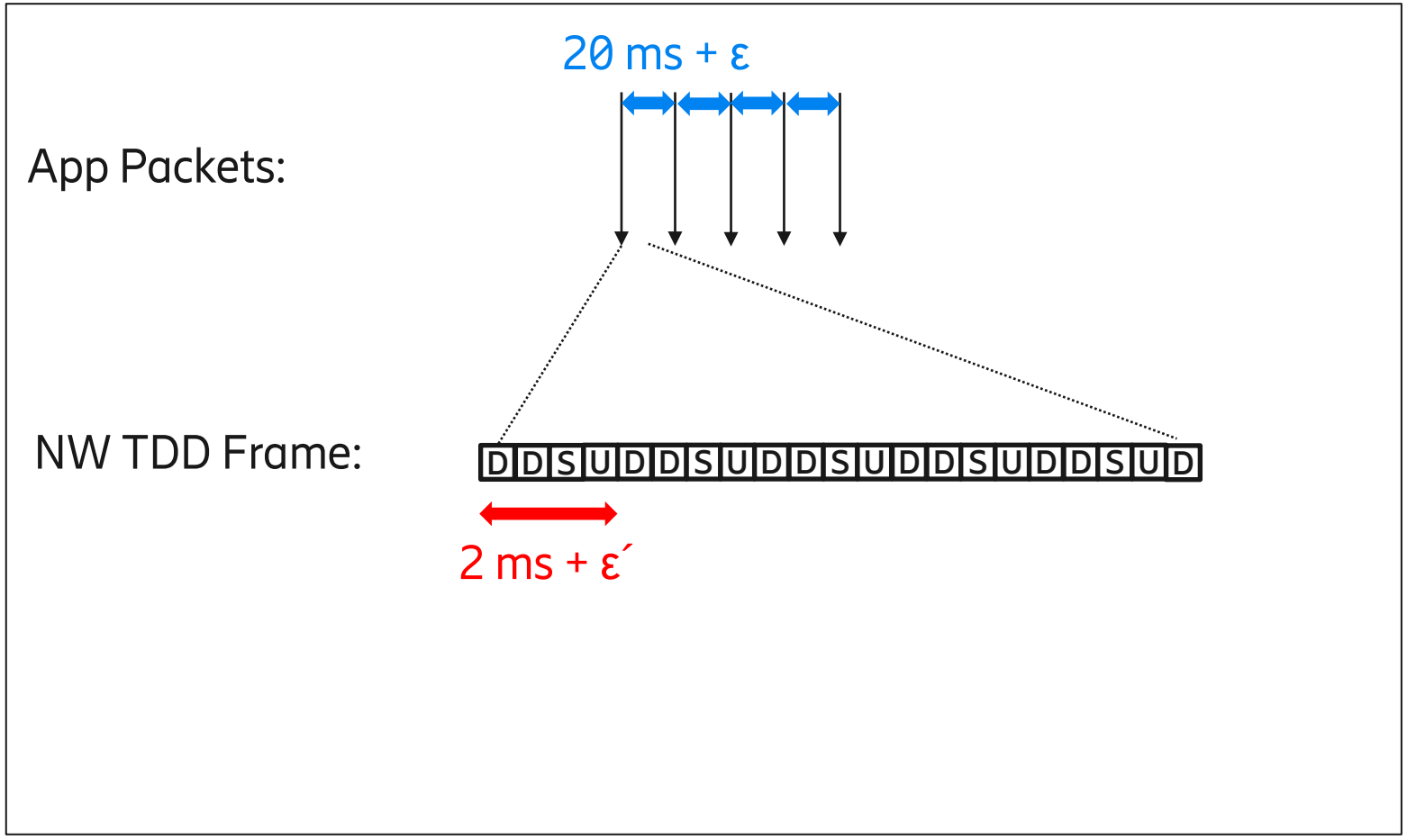
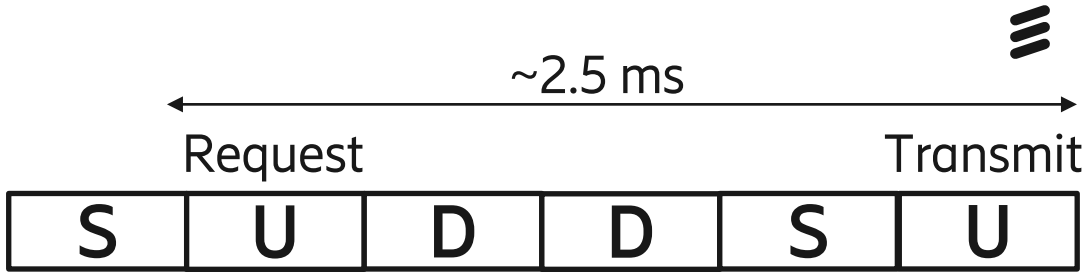


Application Phase-drifting Against TDD Frame

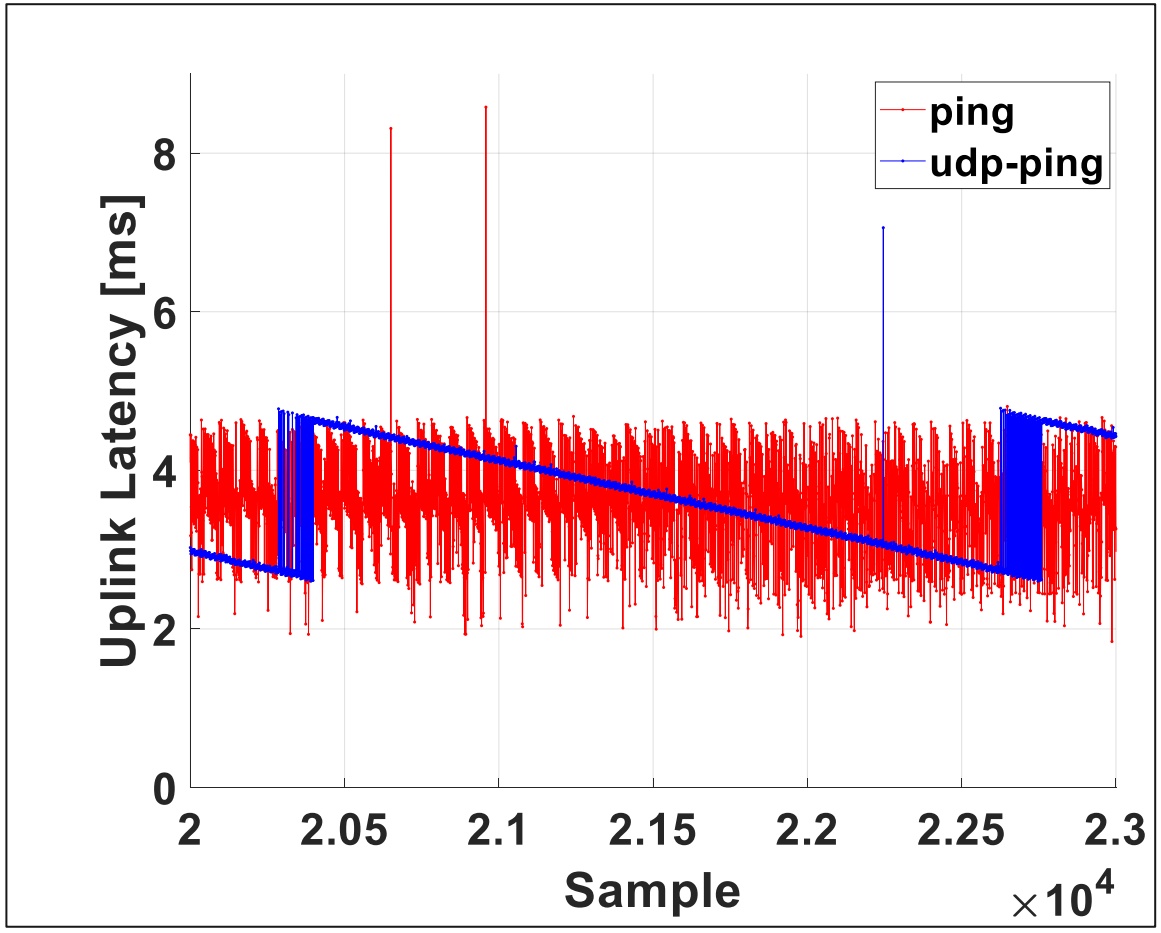
- Two decoupled systems will always “drift” (phase shift changes over time)
- Low variation of send intervals allows to systematically observe the drift
  - Network likely has more precise timing than application (ε’ « ε)
- Allows to systematically “probe” periodic effects



Results: uplink latency

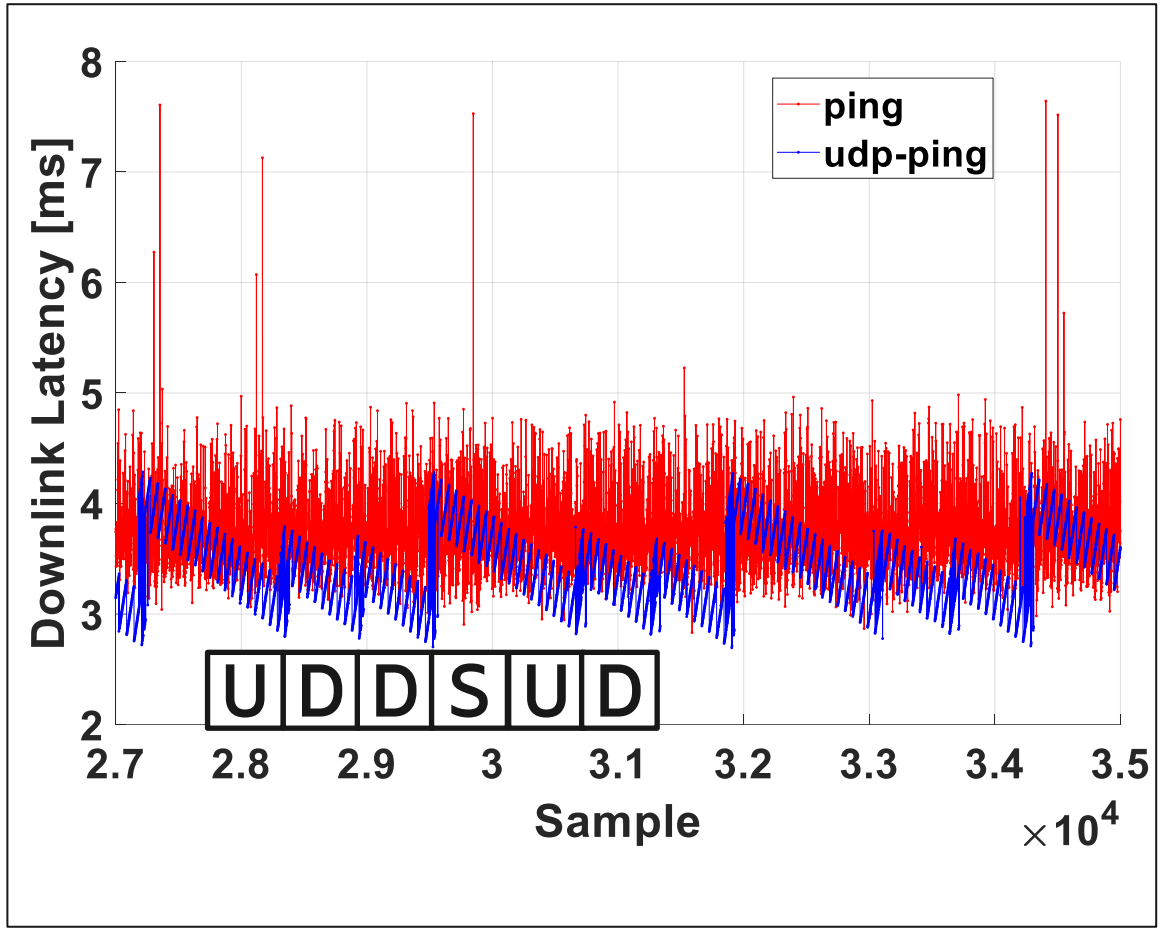


- *udp-ping* shows expected "swipe" through TDD frame
- *ping* does not clearly show such regular "swipe"
- Retransmission clearly visible in *udp-ping* result
  - Likely also in *ping* result
- *udp-ping*: 2.5 ms + 0.1 ms up to 4.5 ms + 0.2 ms
  - *ping* also shows lower values **(theoretically <2.5 ms impossible)**
  - Some jitter in sender app and/or base station at transition from lowest to highest delay



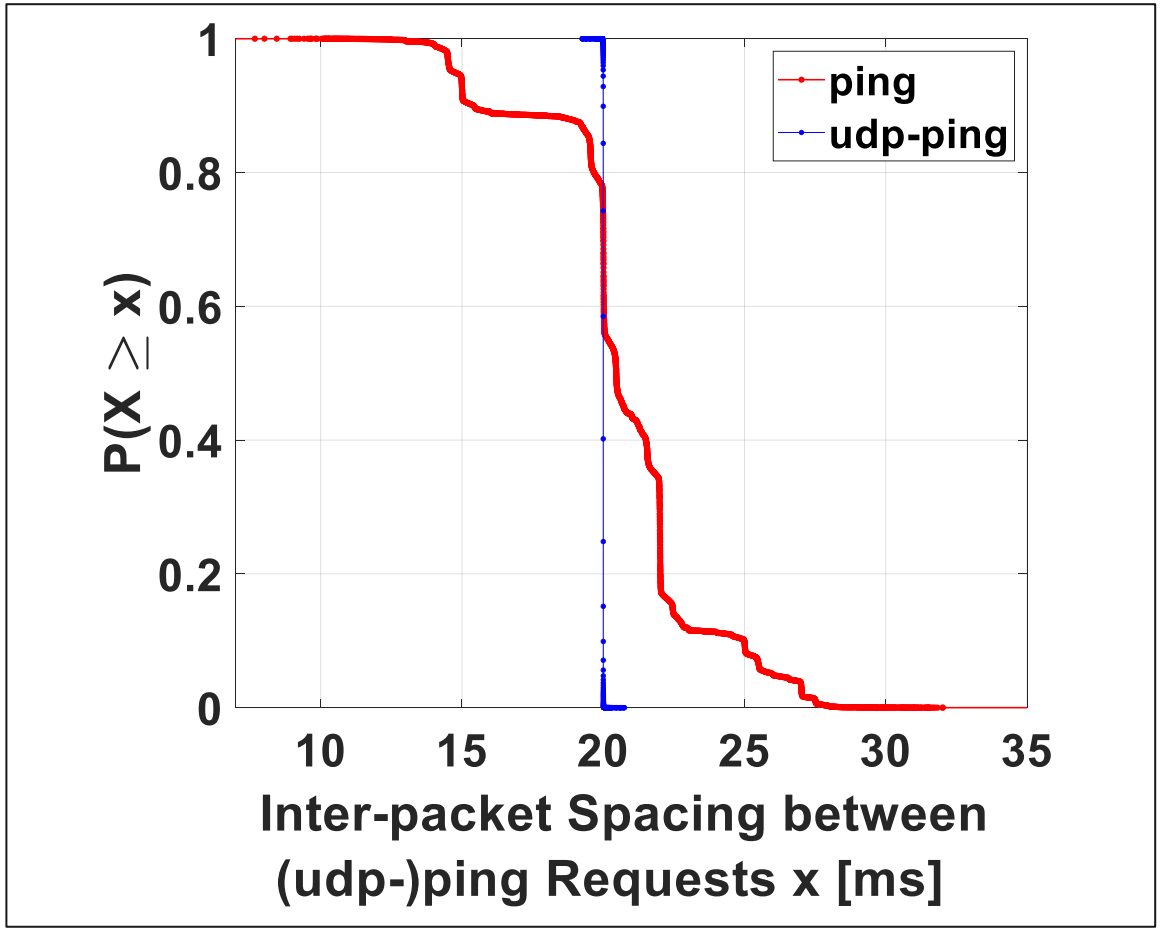
Results: downlink latency

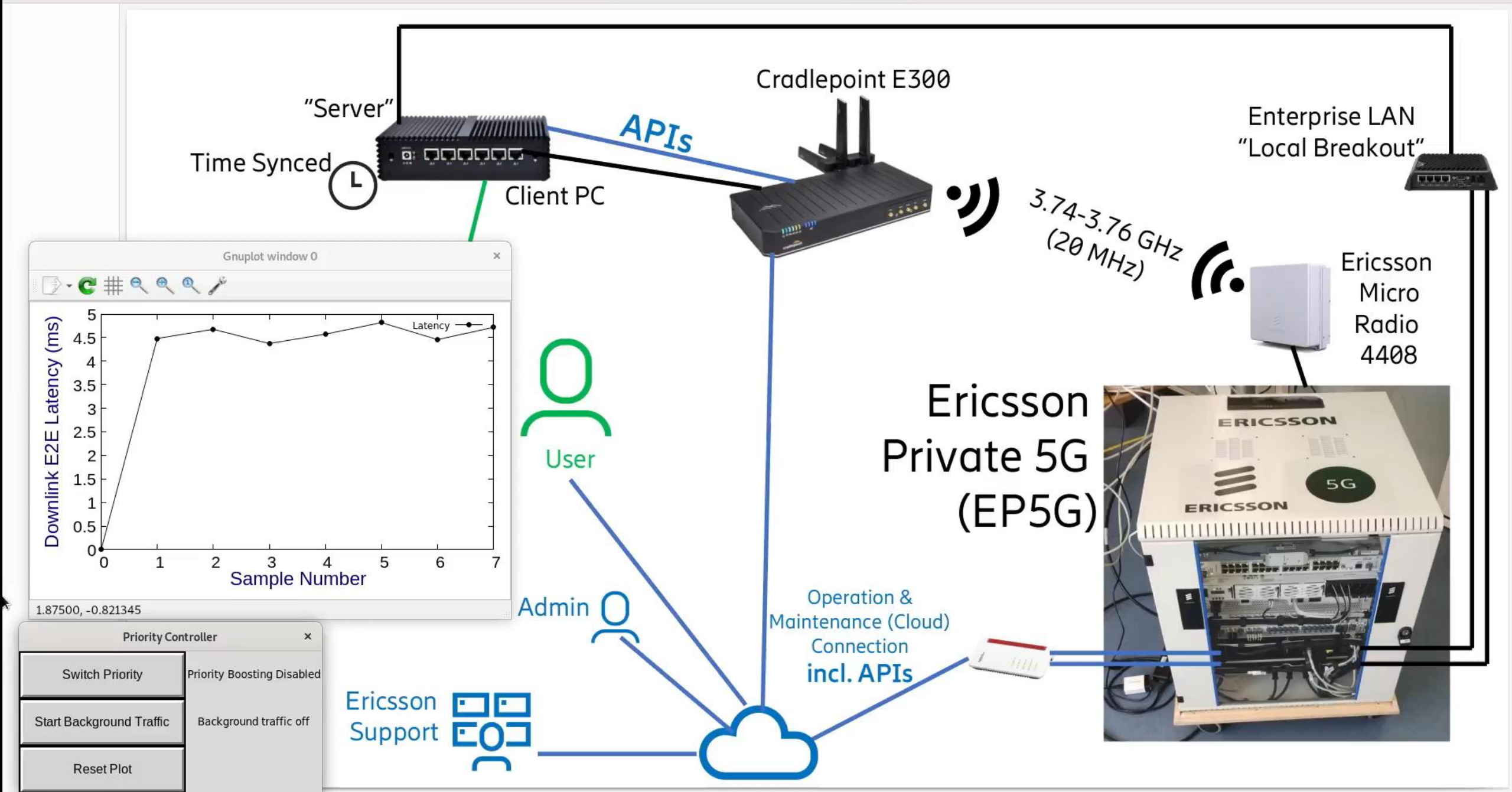
- *ping* again more random **and often larger latency**
- *udp-ping* reveals two stages of "tooth saws" from "swiping"
  - Larger one from TDD pattern
  - Smaller one from unknown source
    - Likely periodicities in base station or modem processing
- Theoretical minimum: 0.5 ms
- Actual minimum: 2.7 ms (+2.2 ms)
  - Processing at base station
  - Processing at receiving modem



Results: inter-packet spacing

- *udp-ping* transmits almost exactly every 20 ms
- *ping* is ±5 ms accurate for 80% (10% - 90%) of the measurements
- Further inaccuracies from deriving timestamp and printing result possible for *ping*




"Server"
Time Synced
Client PC
APIs
Cradlepoint E300
Enterprise LAN
"Local Breakout"
3.74-3.76 GHz
(20 MHz)
Ericsson
Micro
Radio
4408
Ericsson
Private 5G
(EP5G)
User
Admin
Ericsson
Support
Operation &
Maintenance (Cloud)
Connection
incl. APIs
Gnuplot window 0
Downlink E2E Latency (ms)
Sample Number
Latency
1.87500, -0.821345
Priority Controller
Switch Priority
Priority Boosting Disabled
Start Background Traffic
Background traffic off
Reset Plot

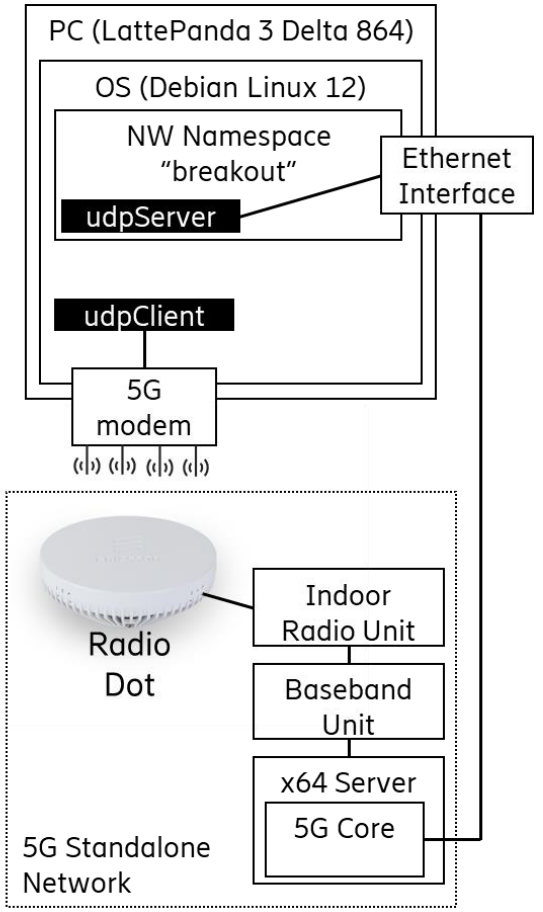
Conclusion and outlook

Conclusion

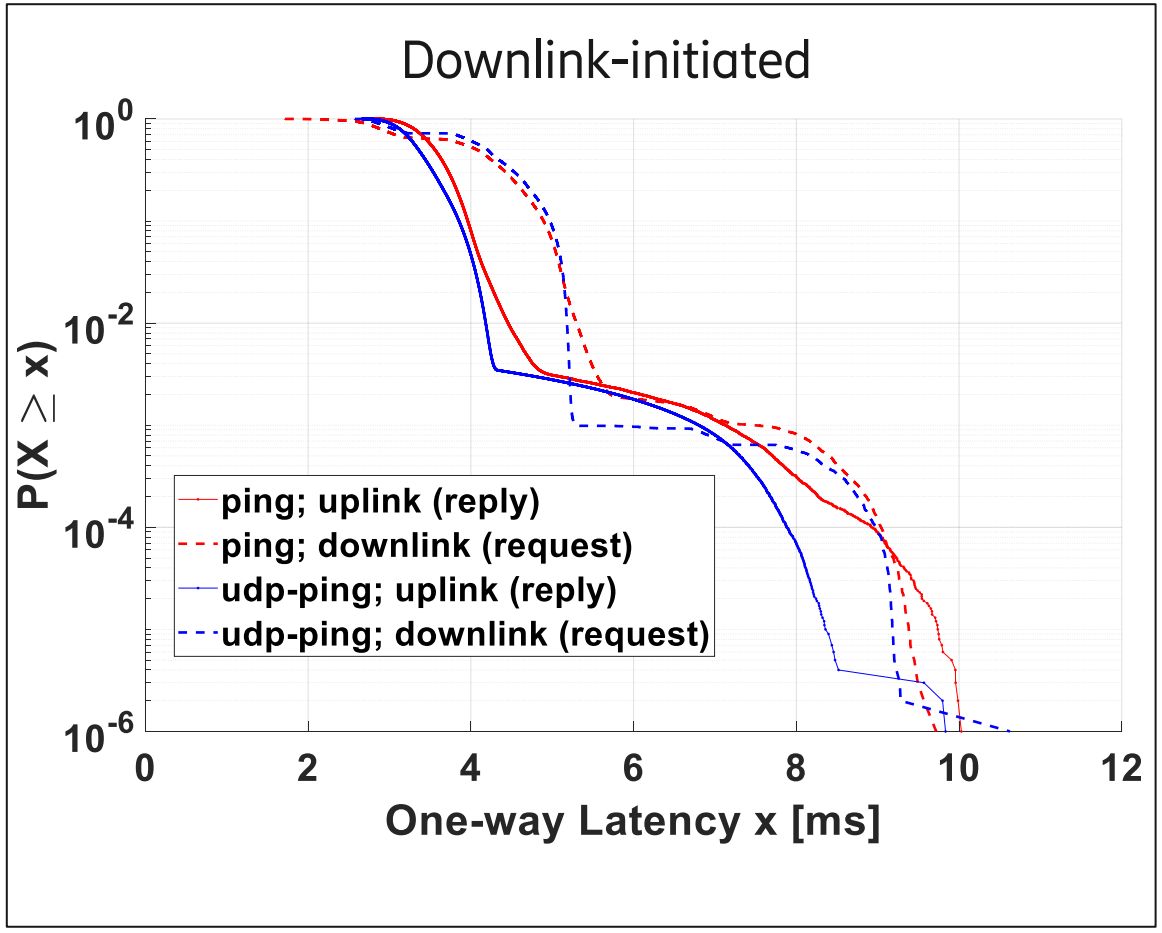
- We developed and **published** a measurement tool and setup more precise than “ping”
- udp-ping enables one-way latency measurement with sub-millisecond precision

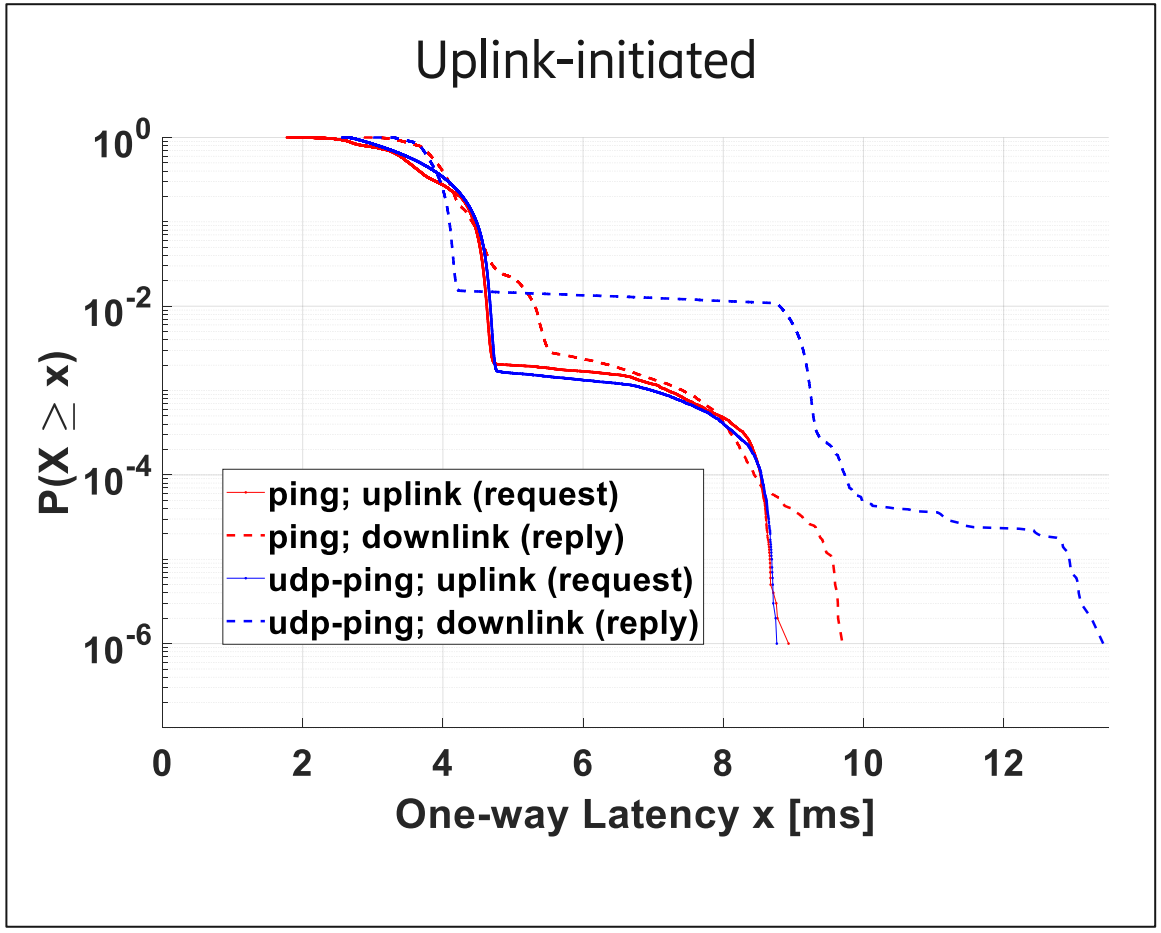
Next steps

- **Use it to measure as many systems as possible**
- **Combine with network-side observations**
- Compare with MoonGen
- Evolve for throughput measurements (first version available on request)



Backup


Downlink-initiated
P(X > x)
One-way Latency x [ms]
ping; uplink (reply)
ping; downlink (request)
udp-ping; uplink (reply)
udp-ping; downlink (request)


Uplink-initiated
P(X > x)
One-way Latency x [ms]
ping; uplink (request)
ping; downlink (reply)
udp-ping; uplink (request)
udp-ping; downlink (reply)