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Prototyping LTE-WiFi Interworking on a Single SDR Platform

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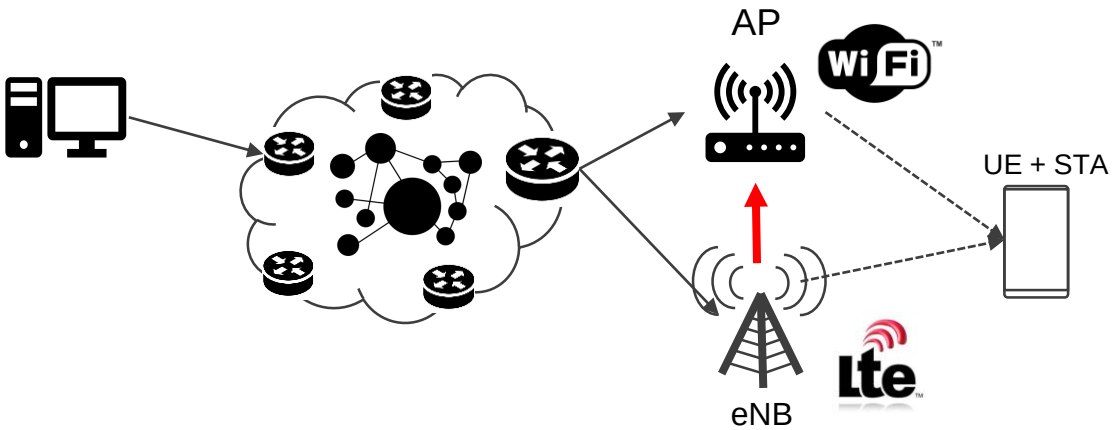
Future Wireless Communication System (aka 5G and beyond)

- Demand for higher throughput and/or lower latency
- Flexibility within radio access technology (RAT) such as LTE and WiFi
- Transparent End-to-End view involves interworking/coordination between different RATs

→ How to study/research these interworking technologies?



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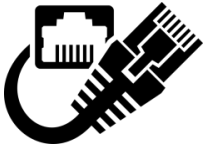
Open Source Protocol Stacks (Layer 2 and above)

OPNET

SRS SOFTWARE RADIO SYSTEMS

amarisoft

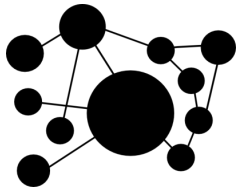


IP Networks

802.11

LTE UE

LTE eNB



LTE EPC

5G NR UE

5G NR gNB

WARP WIRELESS OPEN-ACCESS RESEARCH PLATFORM

Linux 802mac

ns-3 NETWORK SIMULATOR

OPEN AIR INTERFACE

OpenLTE

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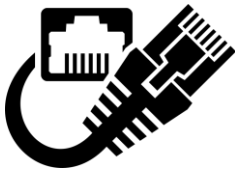
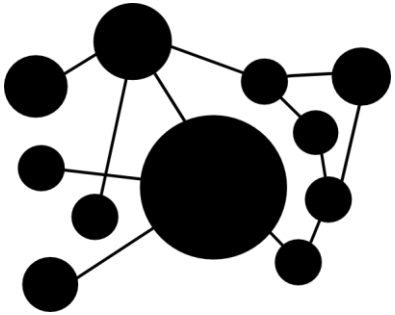
Network Simulator NS-3

- ✓ Open source (GNU GPLv2) discrete-event network simulator in C++
- ✓ Allows for simulating IP networks including routing algorithms
- ✓ Provides various wireless/IP simulation models including LTE, Wi-Fi, ...





Only simulation → Integrate SDRs, but how?

SDR Integration

OSI Model

Layer 4
(Transport Layer)

Layer 3
(Network Layer)

Layer 2
(Data Link Layer)

L1-L2 API

Layer 1
(Physical Layer)

Integrity, ciphering, duplicate detect, SN, reordering, dual connectivity

Segmentation, reassembly, ARQ

Channel mux, adaptive resource scheduling (incl Beamforming), HARQ, access procedure, carrier aggregation

Coding, modulation, resource mapping, MIMO

Air transmission through EM waves

3GPP LTE/5G Protocol Stack

User Plane | Control Plane

IP

NAS

RRC

PDCP

RLC

MAC

L1-L2 API

PHY

RF + Antenna

GCC

SRS SOFTWARE RADIO SYSTEMS

OPEN AIR INTERFACE

ns-3 NETWORK SIMULATOR

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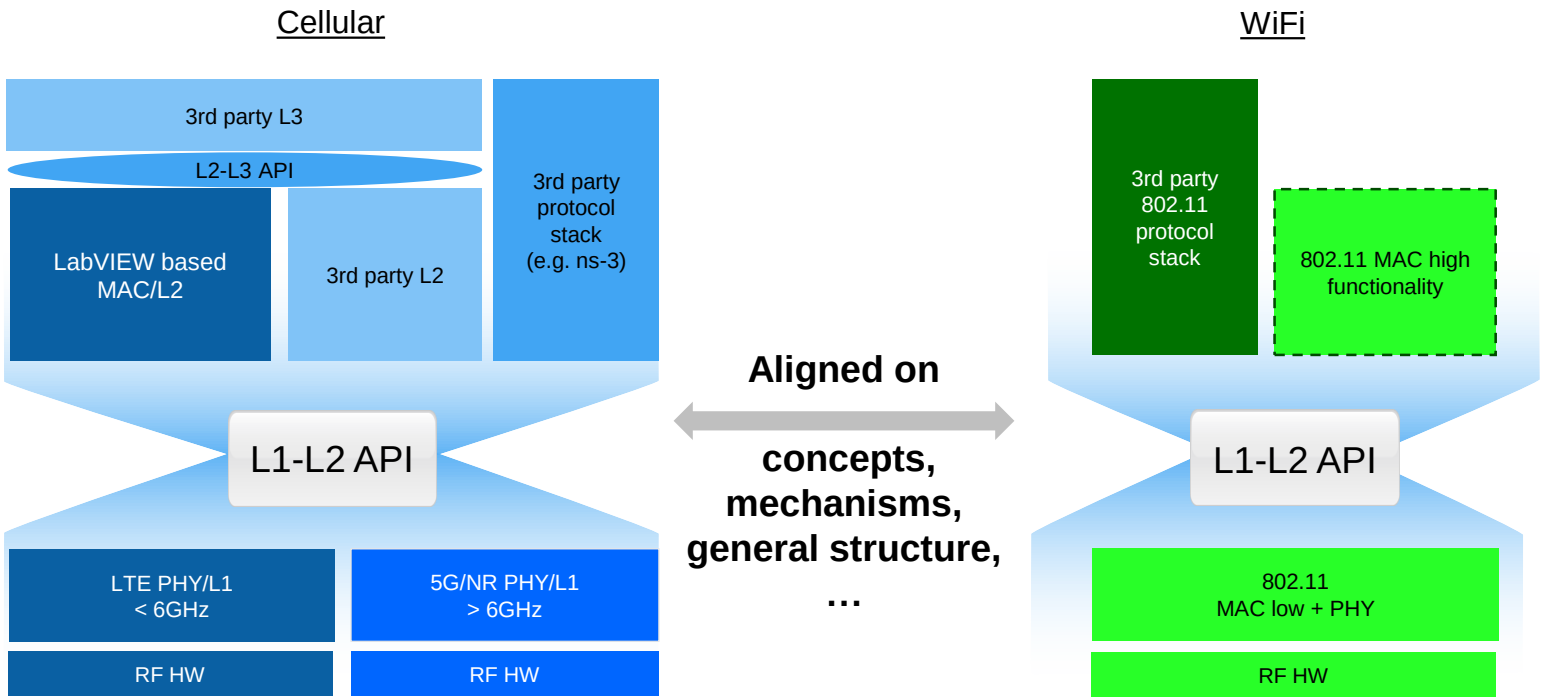
GNURadio THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

MAC-PHY API Concept



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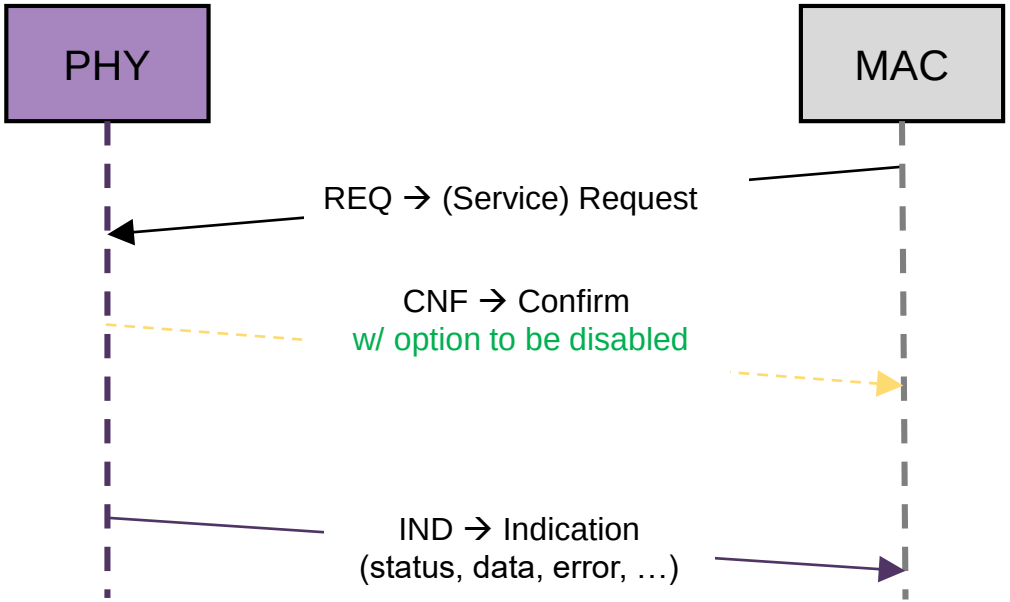
Potential of a general L1-L2 API

- Offers the **same ease of use** and mechanisms for different physical layer implementations.
- Enables very **flexible configuration** and E2E user data transmission.
- Enables **faster adoption, extension, migration and integration** of physical layer prototyping systems towards protocol and network level research & applications.
- Increases the level of **system abstraction**, because of no need to understand all details of the underlying physical layer.
- Offers a high level of **re-use** and increases the **transparency** of a complex wireless system.

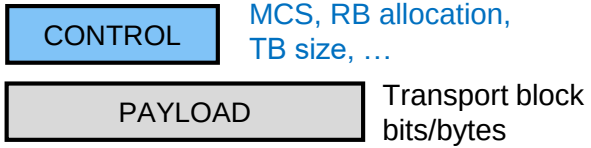
How does the L1-L2 API work?

L1-L2 API – General principles

Communication based on a common set of 3 message types



Example: TX REQ for data channel



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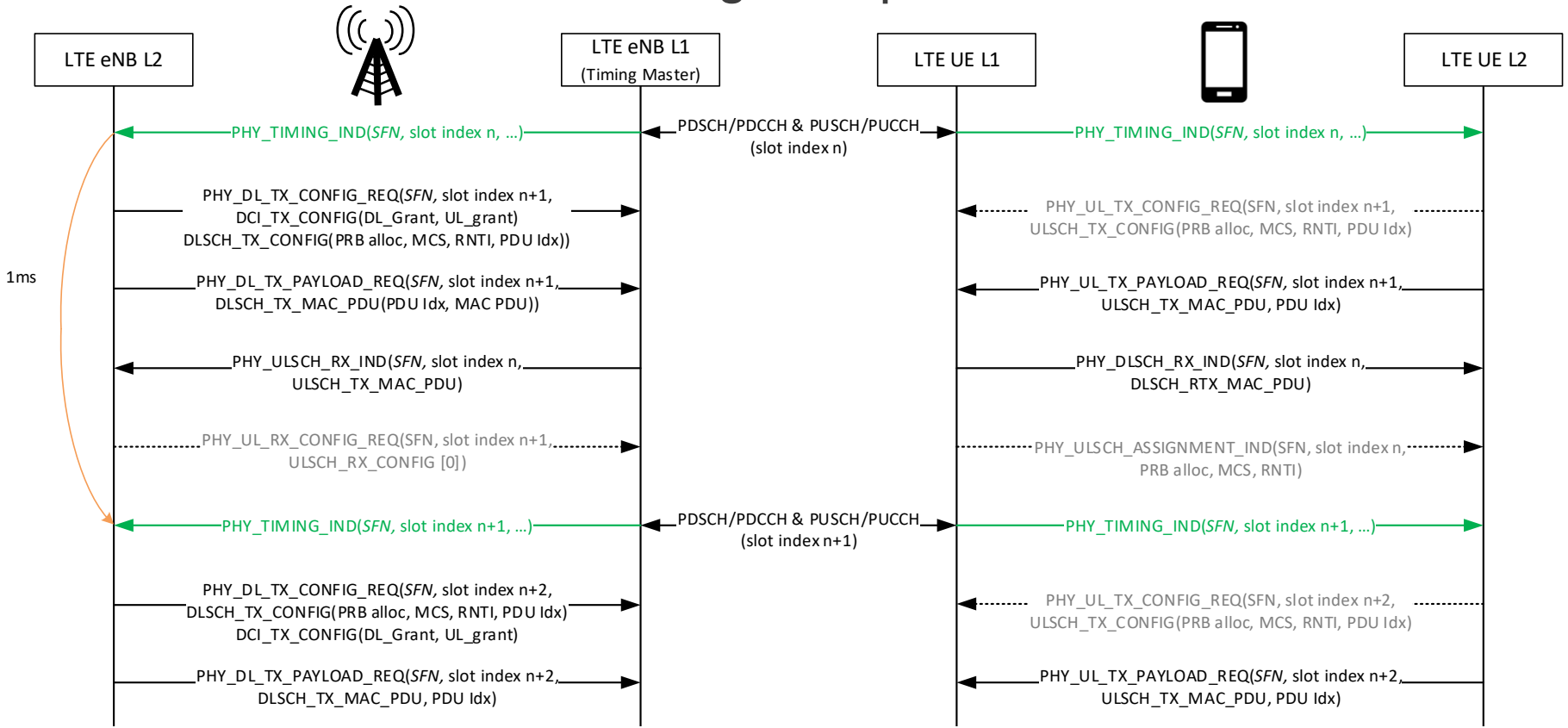
L1-L2 API in action - Message Sequence Chart



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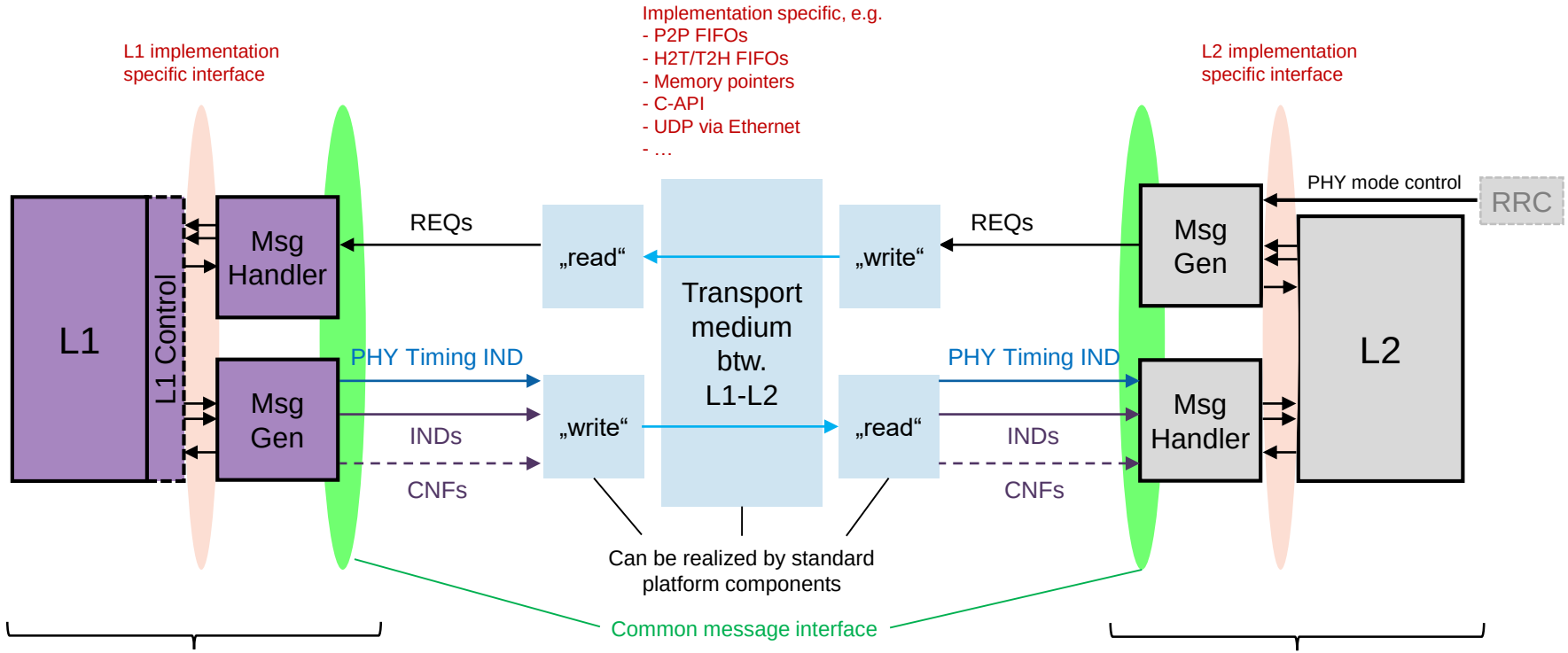
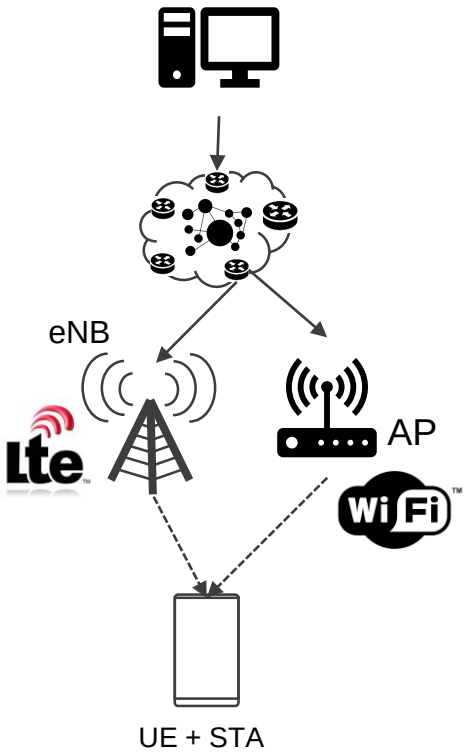
L1-L2 API – Interfaces and Modules



To be provided by L1 compliant with common API

To be provided by L2 compliant with common API

LTE-WiFi Prototyping Setup with USRP-2974



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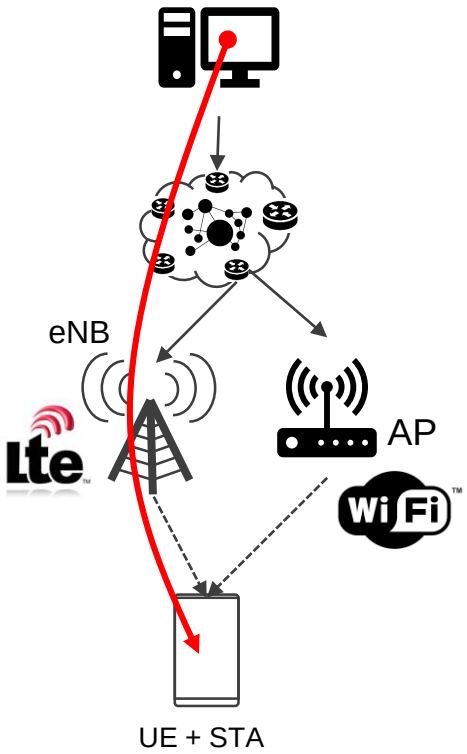
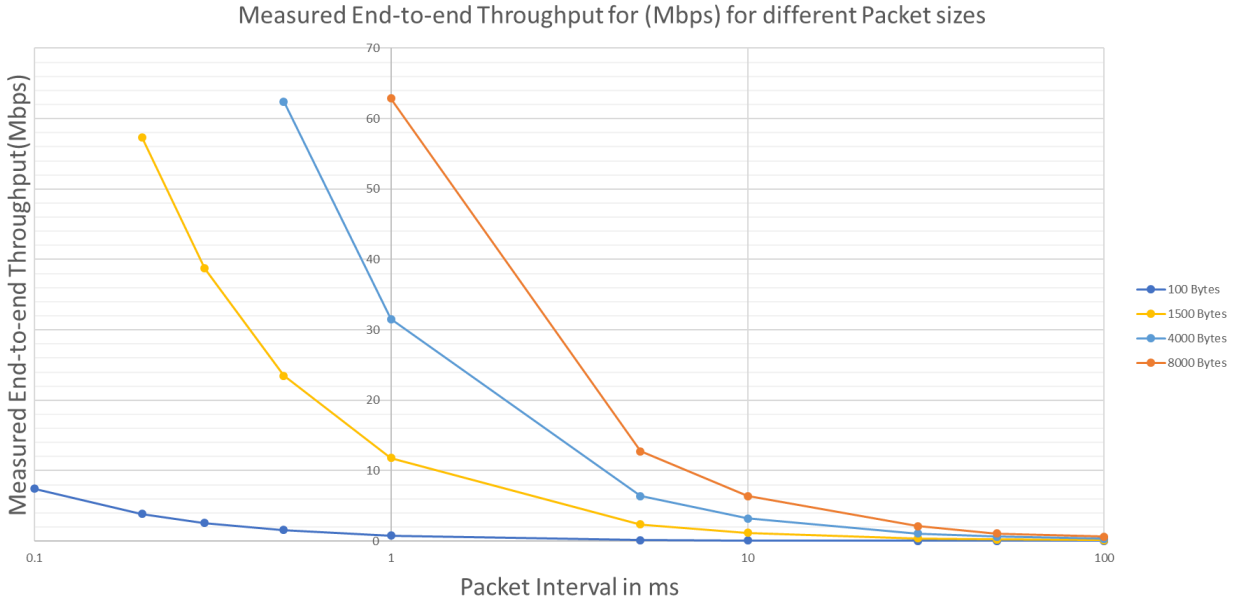
Measurement of End-to-End Throughput





- Close to capacity limit of LTE PHY layer
- Throughput Increase compared to pure software-based PHY

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Conclusions and Outlook

- Generalized API specification to connect PHY and MAC of different RATs
- Interworking research is possible with ns-3 and attached real-time SDR
- Implementation is used in EU-funded research project ORCA (https://www.orca-project.eu)
- Enhanced ns-3 with L1-L2 API implementation available under https://github.com/ni/NI-ns3-ApplicationExample

Next steps:

- Maintain and further extend based on community/research needs
- Investigation and application to other higher layer stacks like Open Air Interface
- Investigation and application to other physical layers like 5G GFDM PH TUD

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Thanks!