5GEM (5G Emulator)

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Agenda

• Who is EpiSci?
• What is 5GEM?
  • Terminology
  • Objectives of 5GEM
• 5GEM Architecture
• Emulation Benefits
• Added/New Features
  • Results
EpiSci delivers novel and explainable multi-agent autonomous capabilities for mission critical applications.
Diverse, Highly-Skilled, & Expert Workforce

TEAM BACKGROUND

- EpiSci has 40+ FT/PT employees and contractors who collaborate across the United States & South Korea.
- 80% of the team has advanced degrees in CS, EE, & AI/ML.
- Our elite team of scientists, researchers and engineers solve large-scale problems by bridging the gap between rapid advances in machine learning and prototyping, integrating, and deploying Tactical AI in next-generation autonomous systems.
- We pride ourselves on creating cutting-edge technologies that enhance national security and growing a team built on a foundation of trust, innovation, and teamwork.

EDUCATION

- PhD: 38%
- Masters: 39%
- Bachelors: 23%

CLEARANCES

- Uncleared: 48%
- Secret: 40%
- TS SCI: 9%
- Top Secret: 3%

Note: EpiSci’s San Diego headquarters has SECRET level facility clearance and is in the middle of upgrading to TOP SECRET.
## Terminology for 5GEM (5G Emulator)

<table>
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<tr>
<th>UE = CELL PHONE (RADIO)</th>
<th>eNB = LTE BASE STATION</th>
<th>PHY Emulator</th>
<th>OAI = OPEN SOURCE LTE/5G+ CODE</th>
<th>NFAPI = INTERFACE BETWEEN MAC/PHY</th>
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| LTE                      | UE                      | • Vendor specific  
                          |               | • Real-time emulator of mobile network systems  
                          |               | • Software-based implementation of LTE and 5G system  
                          |               | • An external network interface Allows you to virtualize the MAC layer |
| 5G (SA)                  | NR UE                   | • Performance depends on radio resource management  
                          |               | • Allows us to model channel conditions in real time  
                          |               | • Full protocol stack  
                          |               | • Follows 3GPP standards |
| Both (NSA = 5G/LTE)      | NSA UE                  |              |                                |                                  |
Objectives

- Illustrate the importance of a fully virtual layer 1 (L1) system:
  - Improved validation tests
  - Performance evaluation of various protocols utilizing behavioral models
- Showcase added features to OAI, both LTE and NR
- Showcase added nFAPI features/bug fixes for both LTE and NR
- Demonstrate fully scalable models (25-35 LTE UEs and 5-10 NR UEs) with an emulated L1
  - We will showcase applications of the virtual L1
5G OAI Block Diagram

IP Packets

Linux IP Stack
NAS
SDAP
RRC
PDCP
RLC
MAC
UE UDP Socket
PHY

NR UE

Open-Source Proxy
BYPASS

UE UDP Socket
PHY

NR UE

PHY

NR UE

N2

NGAP

GTPv1u

F1AP

X2AP

NAS

N3

RRC

SDAP

PDCP

RRC

SDAP

RRC

SCTP

UDP

IP

Ethernet

Ethernet

gNB

Data

Network

5GCN

User Plane

Control Plane

N1

NRF

UDM

AUSF

SMF

UDSF

UPF

PCF

SPGW-U

NEF

UPF

AUSF

UDSF

UPF

PCF

SMF

AMF

UDM

NRF

NRF

UDM

SMF

AUSF

SPGW-U

NEF

NEF

NRF

UDM

SMF

AUSF

SPGW-U

NEF

NEF

NRF

UDM

SMF

AMF

From

5G OAI Block Diagram

https://github.com/EpiSci/oai-lte-5g-multi-ue-proxy
EpiSci's Open-Source Proxy

- UE UDP Socket
- Open-Source Proxy
- PHY
- BYPASS
- PNF
- PHY

https://github.com/EpiSci/oai-ite-5g-multi-ue-proxy

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Benefits of a PHY Emulator

- Evaluation of various protocols
- Evaluation of various behavioral models
- Analysis of various wireless environments (e.g., MIMO, SISO, etc.)
- Evaluation of various wireless network applications

Experimental Methodology

- Development of new wireless network protocols
- Isolating error-prone/variable portion of protocol stack
- Allows for high-layer protocol stack development without adverse affects from PHY/RF layers

Industrial Networking

- Controlled signaling environment
- Repeatability
- Automated test environment
- Real-time
- Configurable
- Scalability

Development Process
BACK UP SLIDES
Newly Added Features

nFAPI Additions

- Creation of the nFAPI interfaces
- VNF/PNF Synchronization
- The UE PNF was ported into the proxy to allow for a distributed UE environment.
- Timing improvements were made by adjusting the VNF based on periodic timing information

OAI Features

- Several queuing mechanisms were added to the UE for packet processing from the nFAPI interfaces.
- Handling of UE specific packets (i.e., filtering at the PDU level based on the RNTI)
- The Contention Based Random-Access (CBRA) procedure was modified for bypassing the PHY layer.
- The Contention Free Random-Access (CFRA) procedure was added for the Non-Standalone (NSA) UE.
- Accurate scheduling the PDSCH and PUSCH PDUs based on the required slot demanded by the gNB.

Bug Fixes

- ACK/nACK multiplexing
- gNB ULSCH scheduler
- Fixed incorrect nFAPI pointer math
- Updated UE MAC and stub to handle late packets without detrimentally impacting the system.
- Buffer sizes, socket options, and packet-segmentation metrics were improved.