



# Institute for the Wireless Internet of Things at Northeastern University

Colosseum: A National Resource for at Scale  
Hardware-in-the-loop Emulation of Open,  
Programmable, and Virtualized Wireless Systems

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Platforms for Advanced  
Wireless Research



MITRE



N COLOSSEUM  
at Northeastern University



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Internet of Things  
at Northeastern University



## NEW NATIONAL RESOURCE FOR WIRELESS SYSTEMS RESEARCH

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- Massive \$20M+ wireless systems testbed developed by DARPA for Spectrum Collaboration Challenge
- Transferred to Northeastern University in November 2019
- Transfer to Northeastern and opening to community supported by NSF CCRI grant #1925601
- Joins NSF PAWR Ecosystem of wireless testing platforms
- Supports remote shared access
  - 5G (softwarization, slicing, security, Open RAN)
  - Spectrum Sharing
  - AI + Wireless
  - IoT



# COLOSSEUM: The World's Largest Network Emulator

Large-scale experimentation of wireless RF systems  
with hardware in the loop



- 21 racks of radios
- 171 high-performance servers w/ CPUs / GPUs
- 256 USRP X310s → 128 as user devices, 128 as part of Colosseum Massive Channel Emulator (MCHEM)
- 65,536 100 MHz emulated RF channels
- Full-mesh networking capability

# COLOSSEUM: The World's Largest Network Emulator

Large-scale experimentation of wireless RF systems  
with hardware in the loop



- Massive Computing and support resources: (CPU, GPU, FPGA)
  - 900 TB of Network Attached Storage
  - 320 FPGAs
- Diversified scenarios for better generalization of ML / AI models

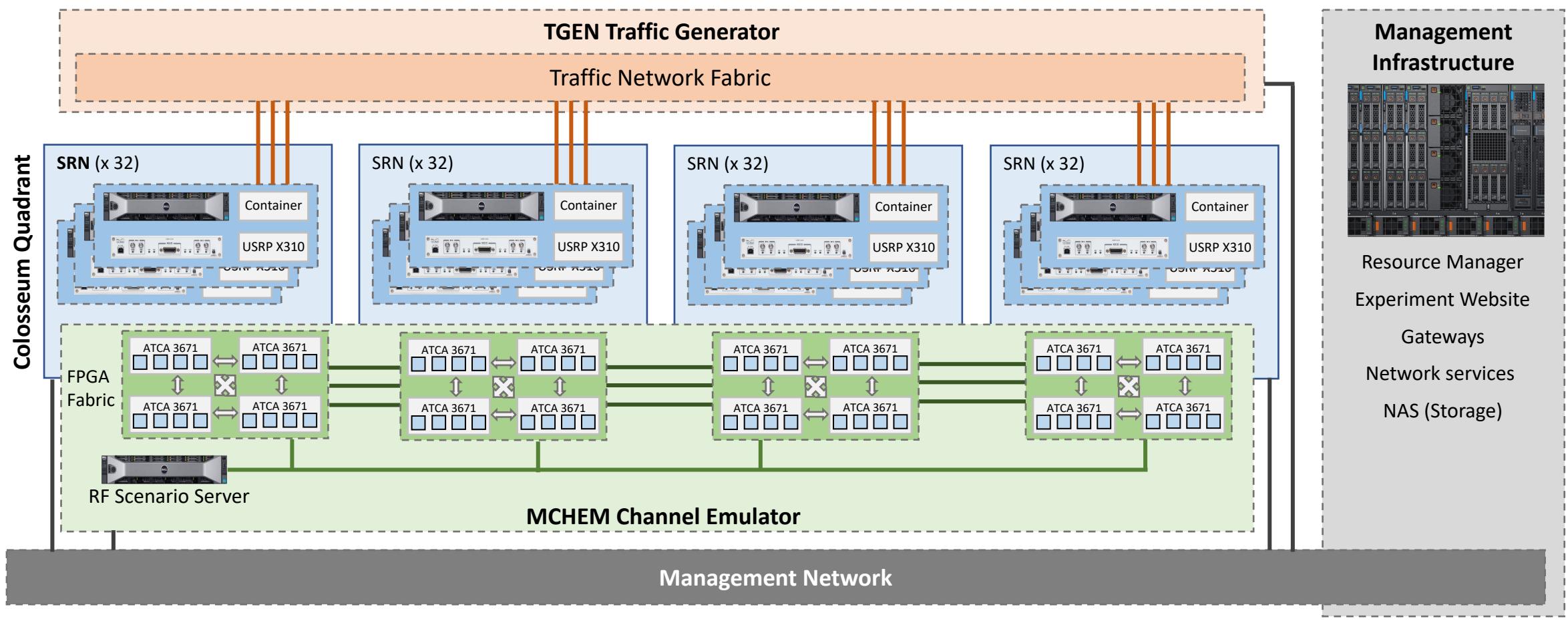
# COLOSSEUM: Much More Than a Supercomputer

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- Colosseum has **RF hardware in the loop**
- Not only a simulation environment: **real-time emulation with real radio signals, stacks and emulated channels**
- Combines in a **SINGLE** instrument
  - Fidelity of hardware channel emulators
  - Flexibility of a virtualized data center
  - Scalability of a network simulator
- Fully programmable
- \$20M+ investment by DARPA
- \$6M investment by NSF
- \$2M investment by Northeastern
- \$2M from MA

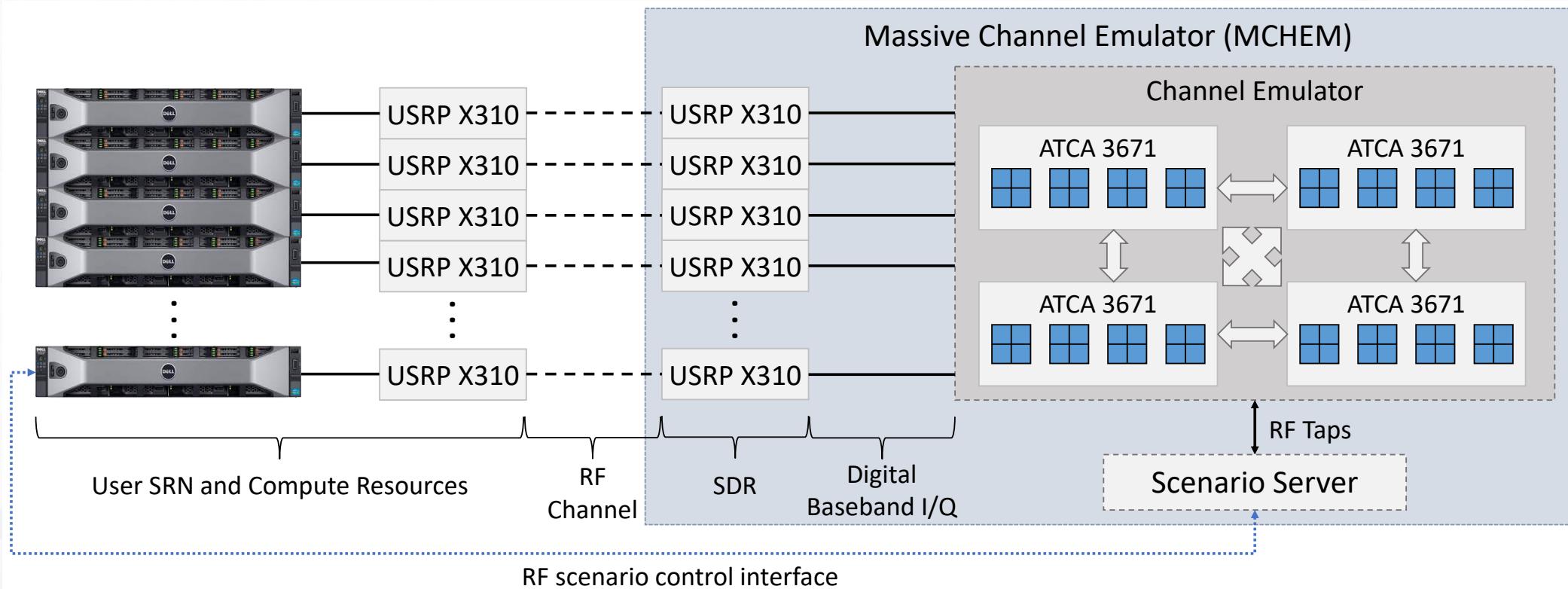


# Colosseum Architecture

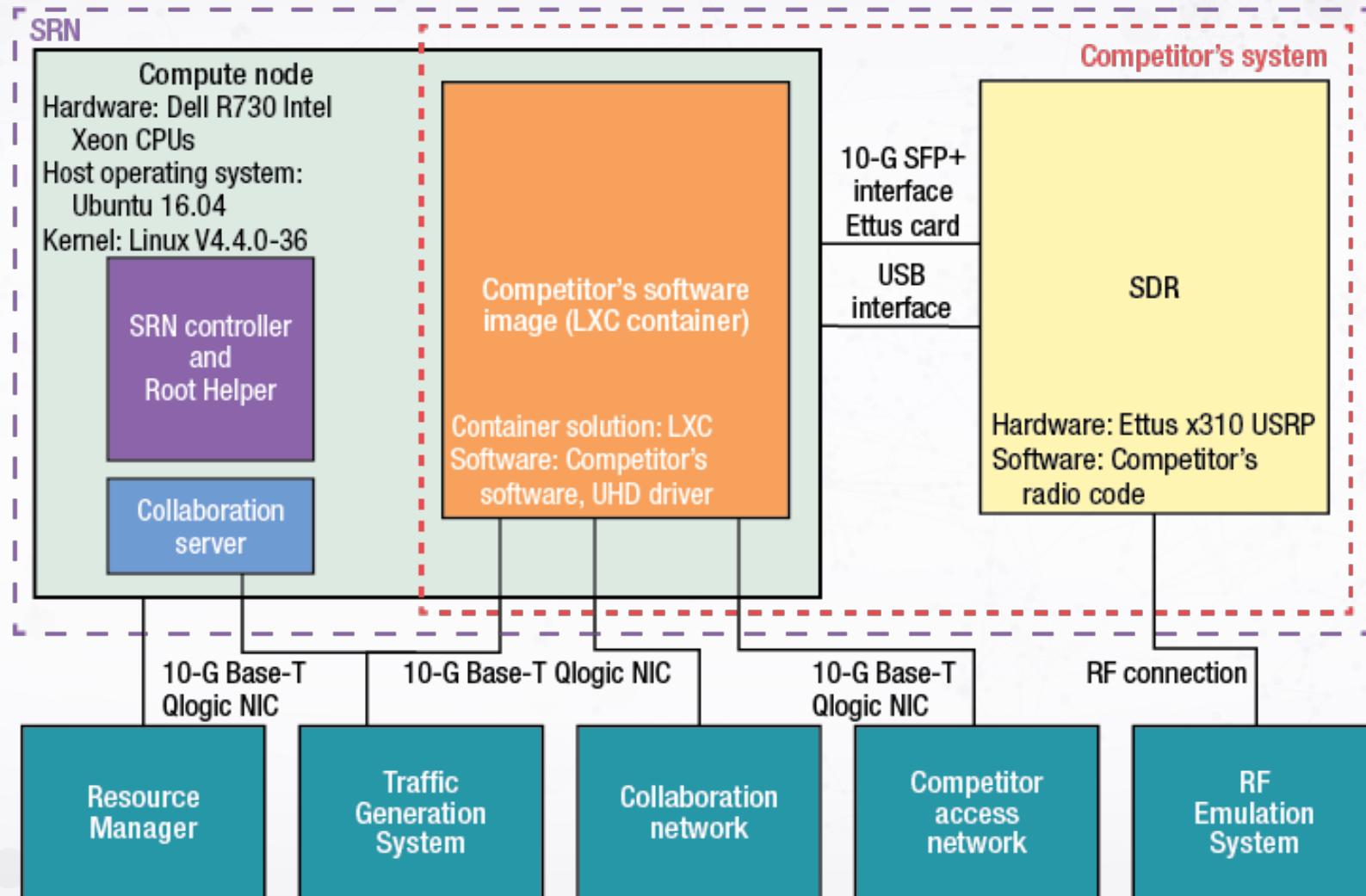


# Massive Channel Emulator (MCHEM)

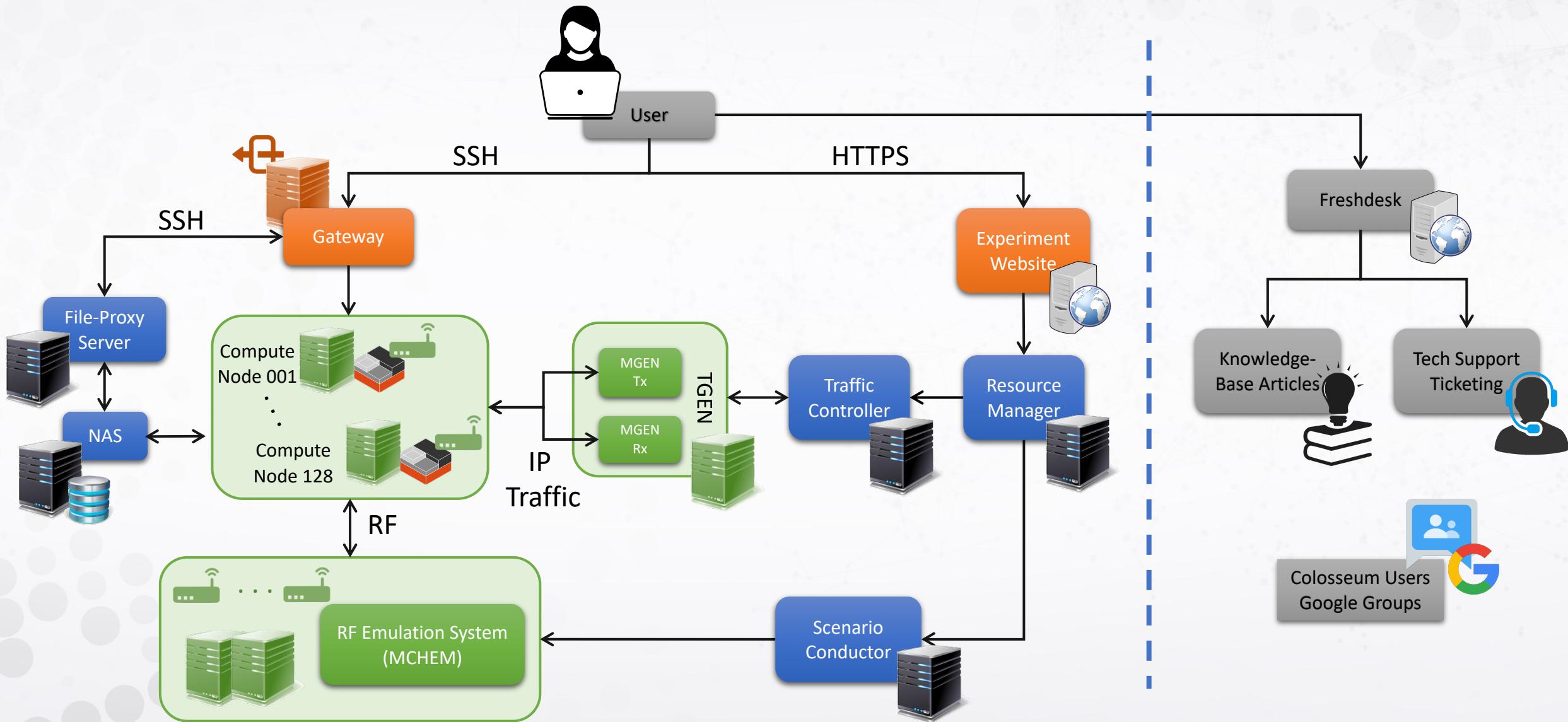
- Emulates in real time channels between 256 independent transmitters (65k channels)
- 512-tap channel model (sparse, 4 nonzero)
- Scenarios



# Standard Radio Node (SRN)



# Colosseum Architecture



# Who Can Use Colosseum?

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- **NSF-supported researchers** can access Colosseum free of charge
- We provide basic support and documentation, scenario creation on a best effort basis
  - Tell us what you are trying to accomplish, and we will direct you to an existing scenario, or we will try to work with you to develop a new one
- **DoD researchers (i.e, ARL, AFRL, NRL)** can access Colosseum for free for two years
- Industry and other researchers: talk to us ([colosseum@northeastern.edu](mailto:colosseum@northeastern.edu)), we are developing a fee structure for use by communities that are not currently contributing to Colosseum operations

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# Open, Programmable, and Virtualized 5G Systems on Colosseum

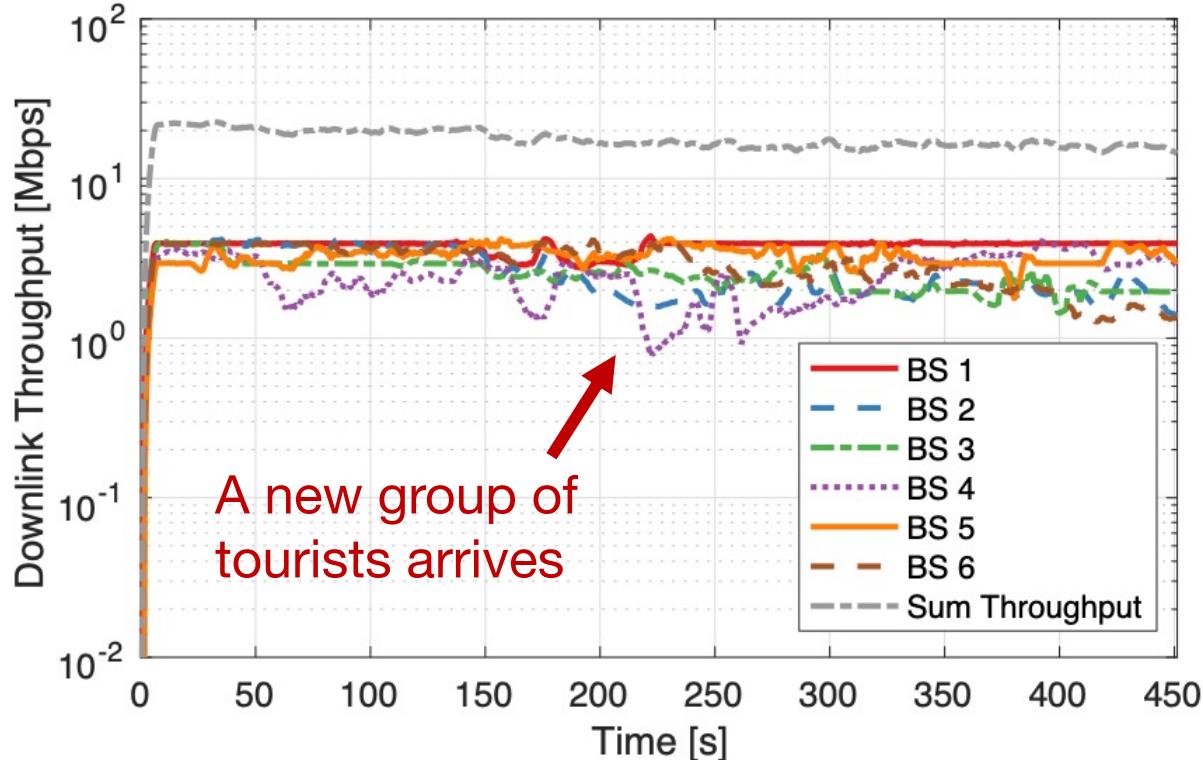
# Colosseum for NextG wireless research

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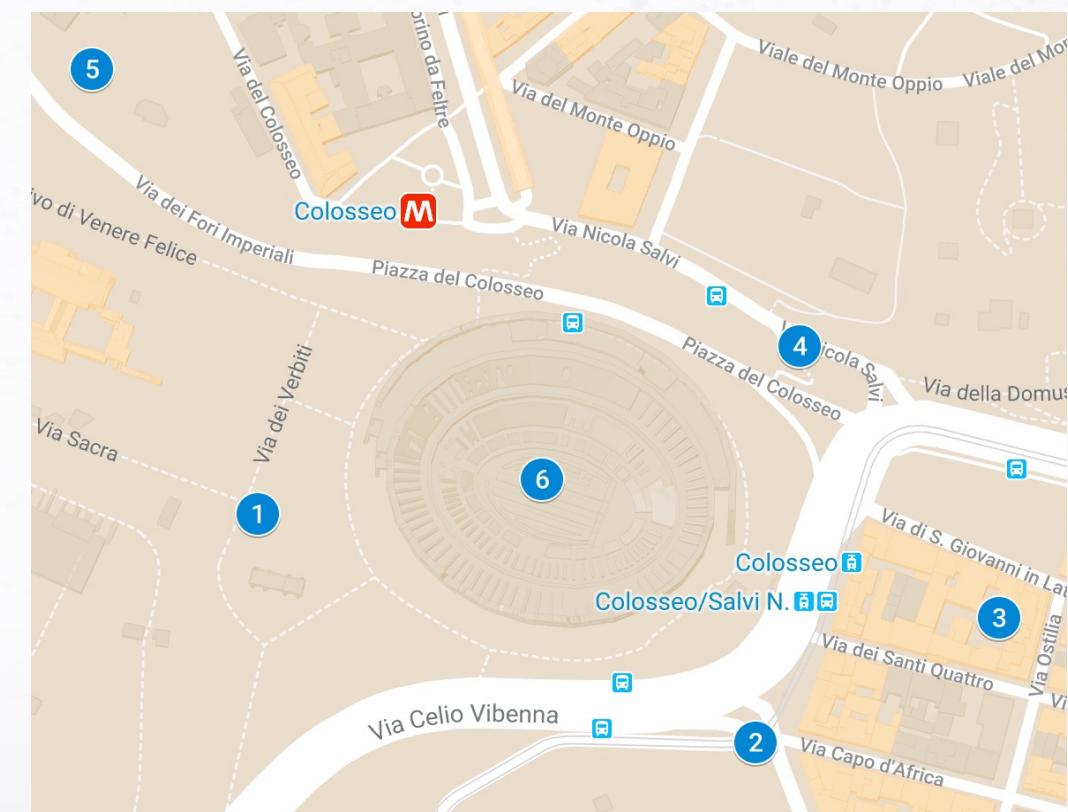
- Virtualize cellular networks
  - Scenarios designed for cellular deployments
    - Star topologies with base stations and users
    - Customizable source traffic profiles
  - Software profiles:
    - srsRAN and SCOPE (more on this in a few minutes)
    - OpenAirInterface 5G RAN and core (more on this tomorrow)

# Colosseum 5G Capabilities

- Cellular network with multiple interfering base stations and users
- Pedestrian user mobility
- Real-world scenario with base station locations in Rome, Italy (next to the actual Colosseum)
- Traffic can be customized

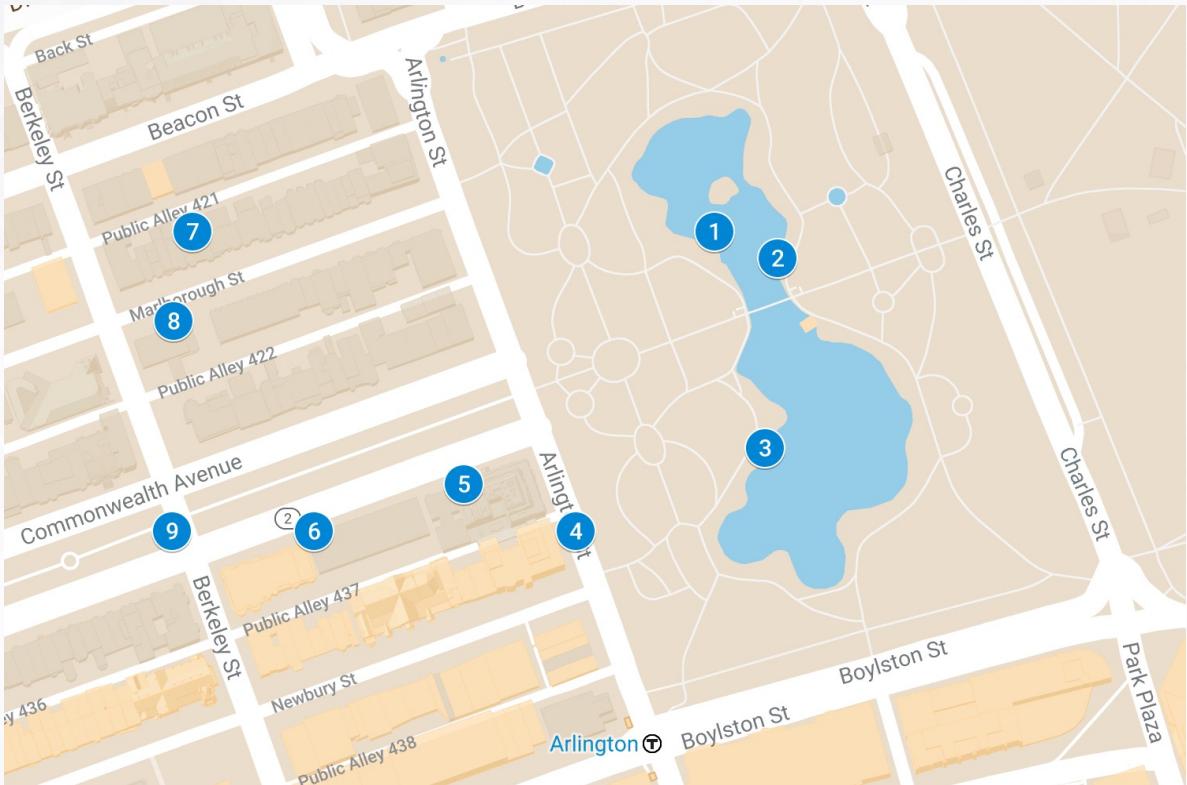


Example of Downlink throughput experiment

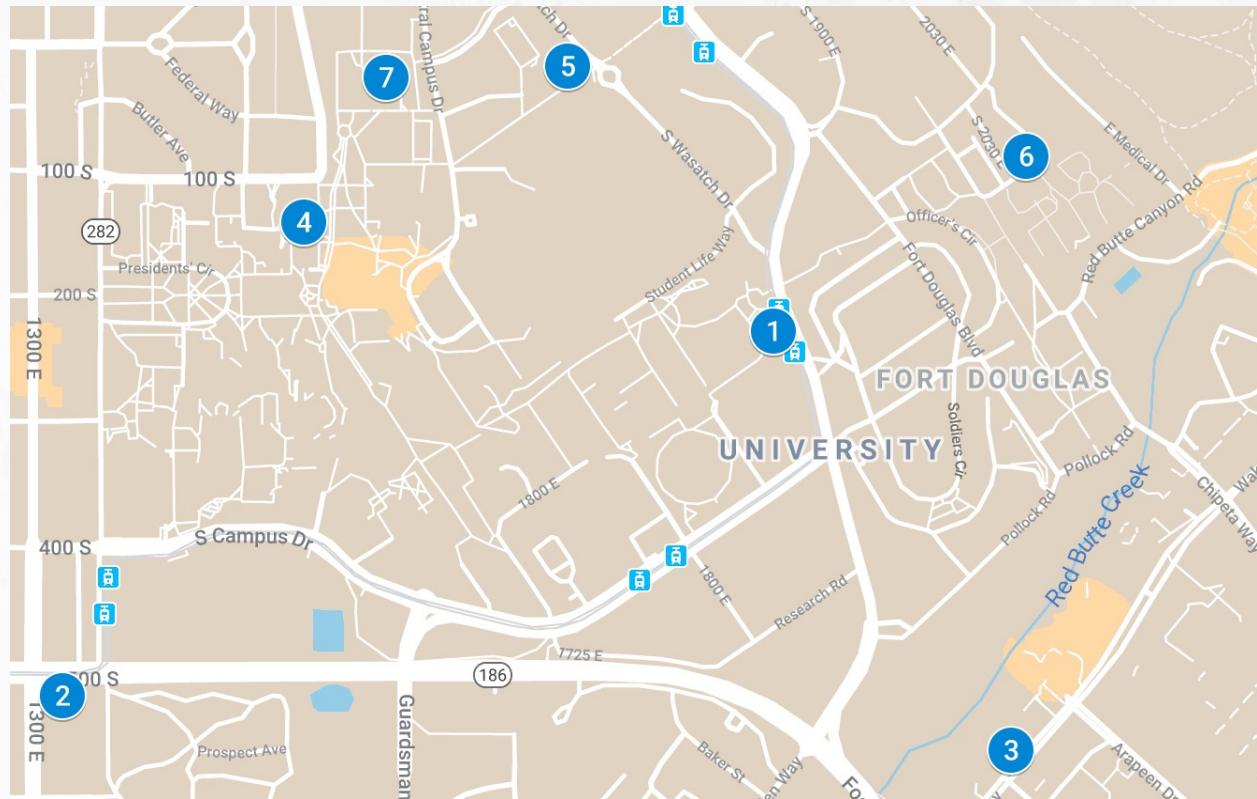


Base station locations

# Additional Colosseum 5G Scenarios



Boston Public Garden, Boston, MA



POWDER PAWR – University of Utah Campus, Salt Lake City, UT

\* Blue circles represent the base station locations, users move with random patterns

# Traffic Scenarios - TGEN

- Scenarios include pre-defined traffic through TGEN
- TGEN is based on Multi-GENerator (MGEN)
  - <https://github.com/USNavalResearchLaboratory/mgen>
  - Tool to generate TCP/UDP traffic
  - Open-source
  - Specify:
    - Duration
    - Type of traffic
    - Bitrate
    - Etc.



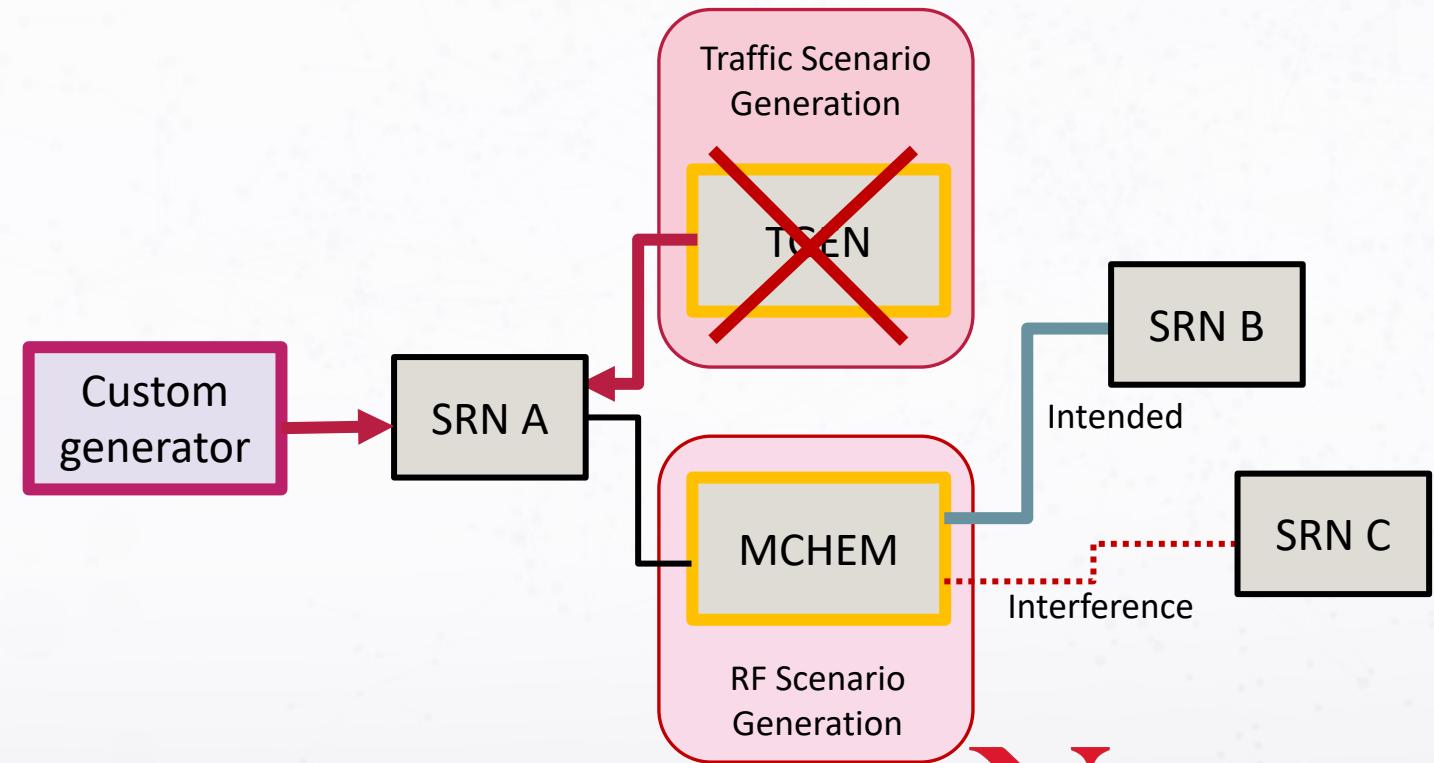
*Example*

Stage	Duration	Link SNR	Offered Traffic / Flow
0	15 sec	20 dB	NaN
1	120 sec	20 dB	1.25 Mbps
2	120 sec	15 dB	1.25 Mbps
3	120 sec	10 dB	1.25 Mbps
4	120 sec	5 dB	1.25 Mbps
5	120 sec	20 dB	1.25 Mbps
6	15 sec	20 dB	NaN

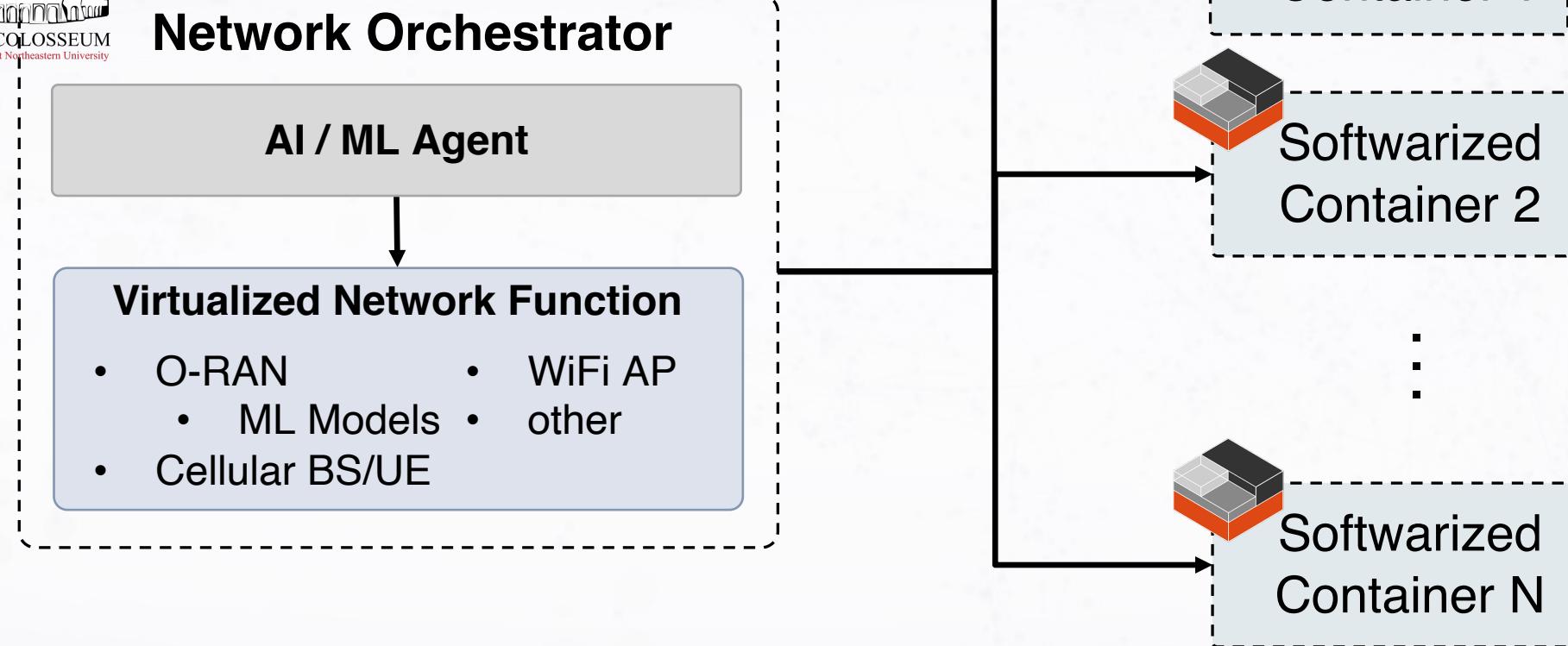
Label	Value
Version	Practice
RF ID	9988
RF Description	Single tap; large scale
Scenario BW (MHz)	10
Traffic ID	99880
Traffic Description	Streaming UDP
Center Frequency	1000.0 MHz
Number of Incumbent Nodes	0
Number of Competitor Nodes	10

# Traffic Scenarios - Customization

- Users can use custom traffic generators
- Examples:
  - iPerf2
  - iPerf3
  - Netperf
  - MTR
- TGEN gets bypassed



# Colosseum as Enabler for AI/ML



- Prototype AI/ML solutions at-a-scale on emulated RF and traffic scenarios
- Validate in real-world wireless environment