



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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NEW NATIONAL RESOURCE FOR WIRELESS SYSTEMS RESEARCH

- 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

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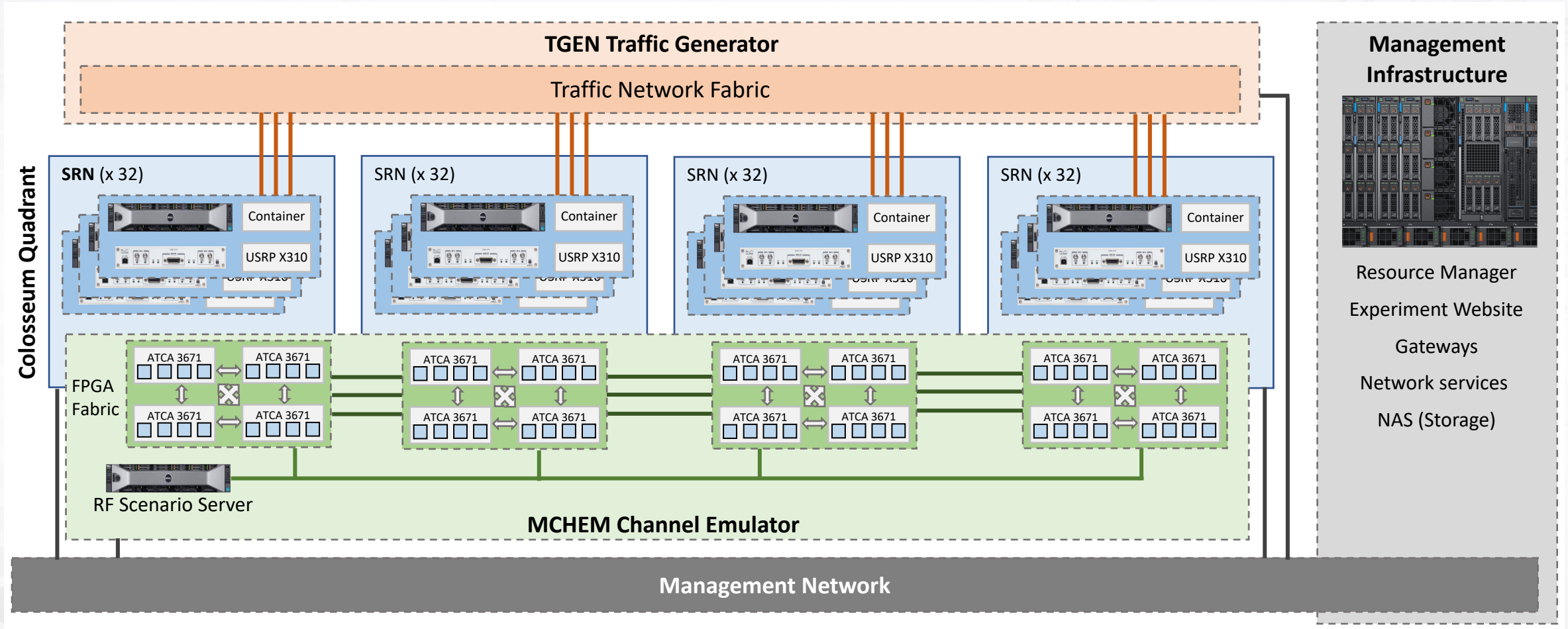
- Massive Computing and support resources: (CPU, GPU, FPGA)
 - 900 TB of Network Attached Storage
 - 320 FPGAs
- Diversified scenarios for better generalization of ML / AI models

COLOSSEUM: Much More Than a Supercomputer

- 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

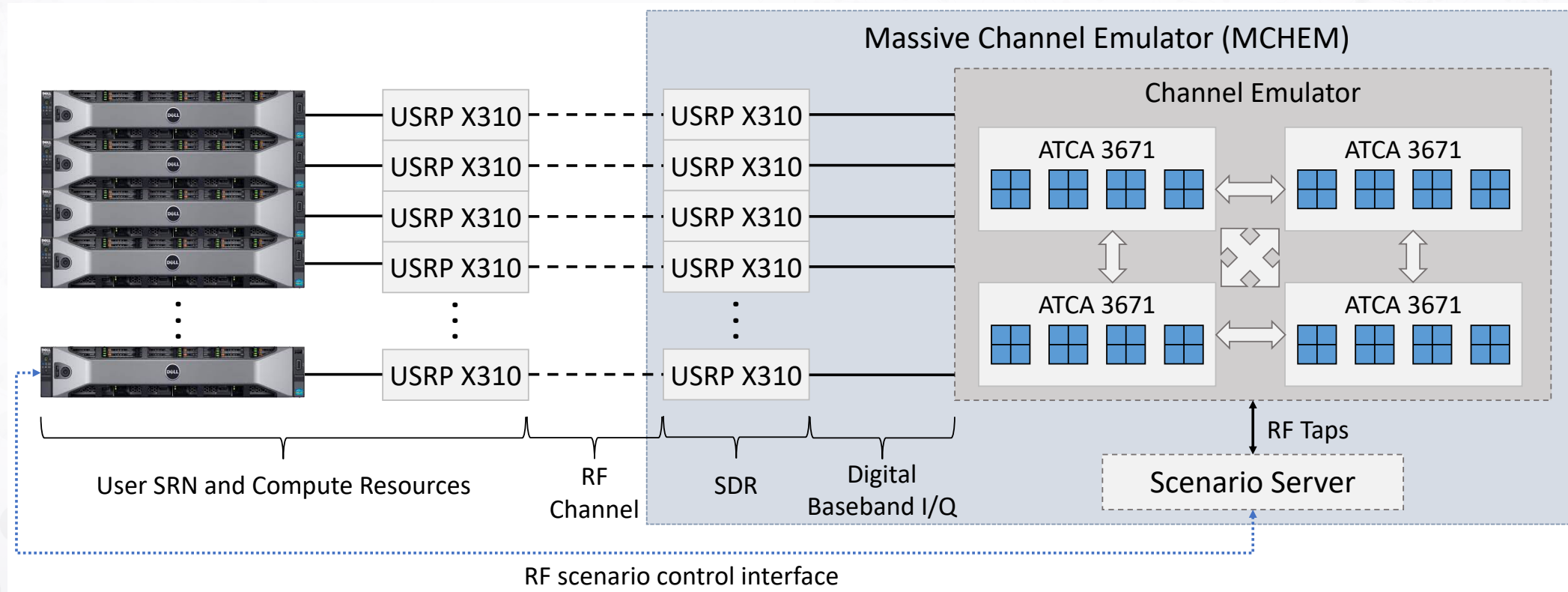


Colosseum Architecture

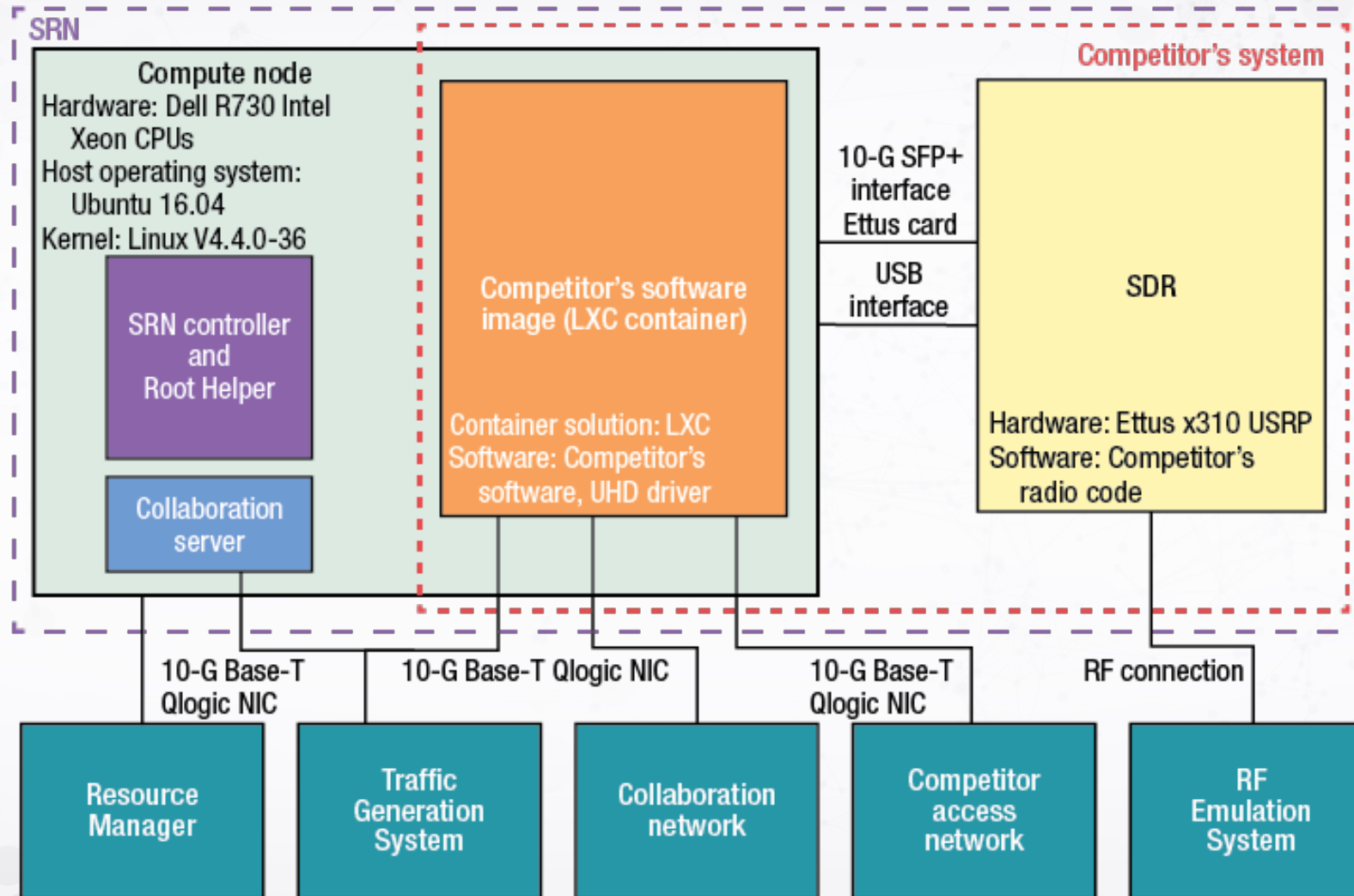


Massive Channel Emulator (MCHEM)

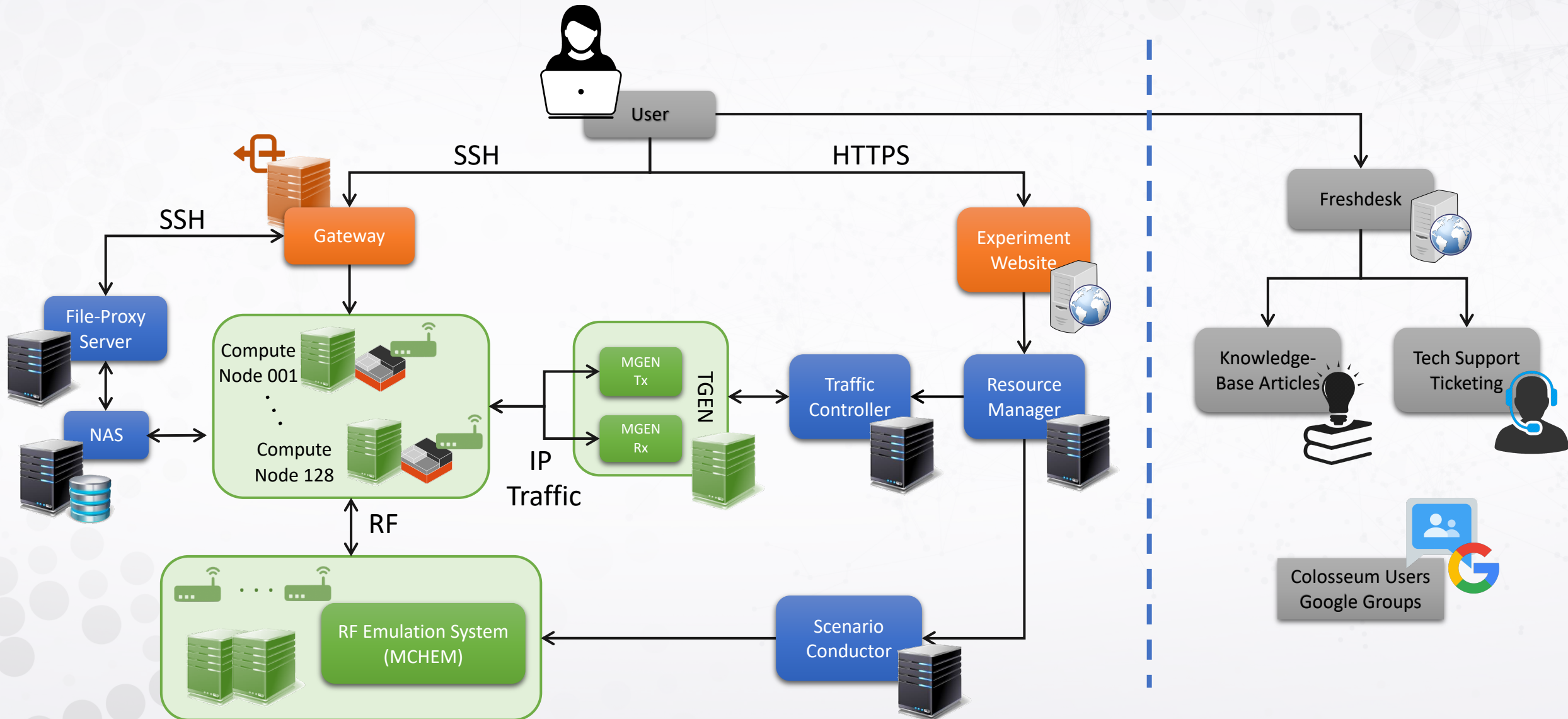
- Emulates in real time channels between 256 independent transmitters (65k channels)
- 512-tap channel model (sparse, 4 nonzero)
- Scenarios



Standard Radio Node (SRN)



Colosseum Architecture



Who Can Use Colosseum?

- **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), we are developing a fee structure for use by communities that are not currently contributing to Colosseum operations

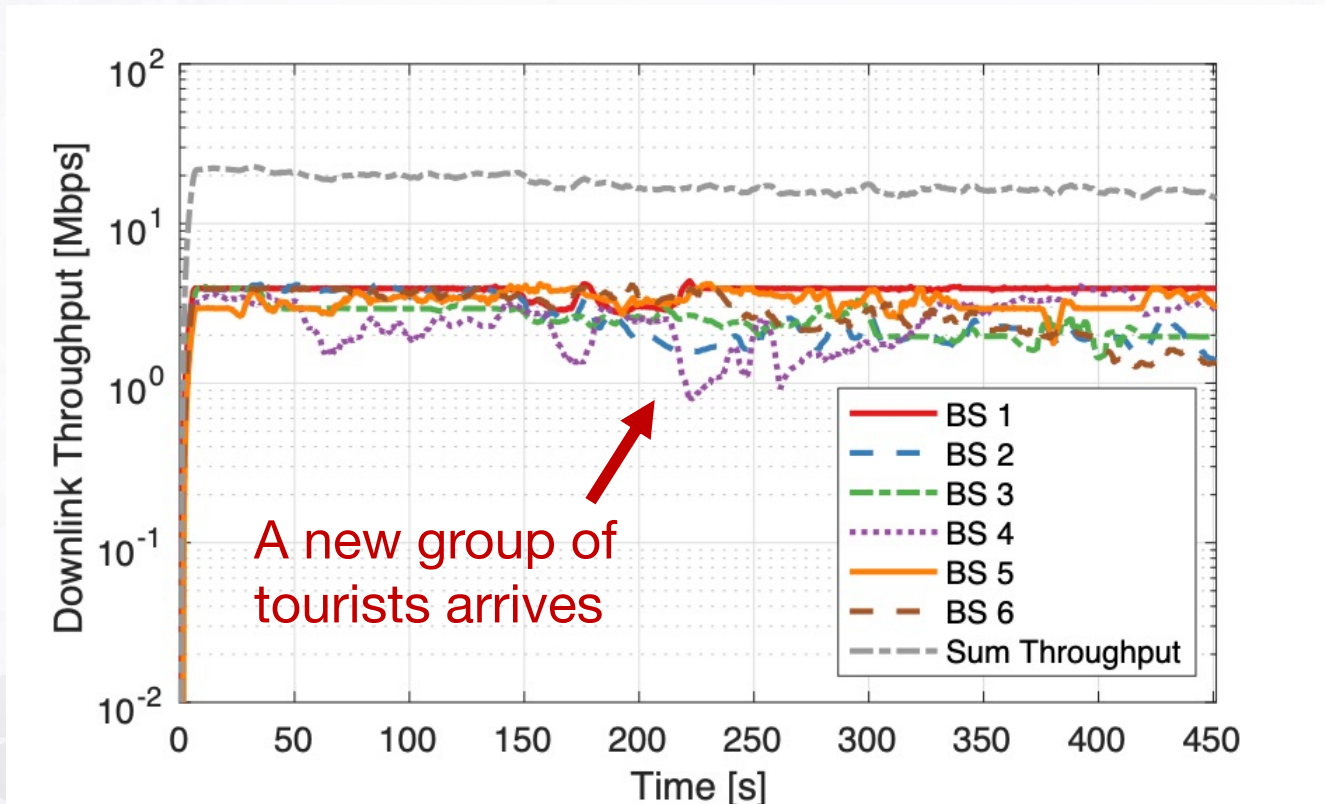
Open, Programmable, and Virtualized 5G Systems on Colosseum

Colosseum for NextG wireless research

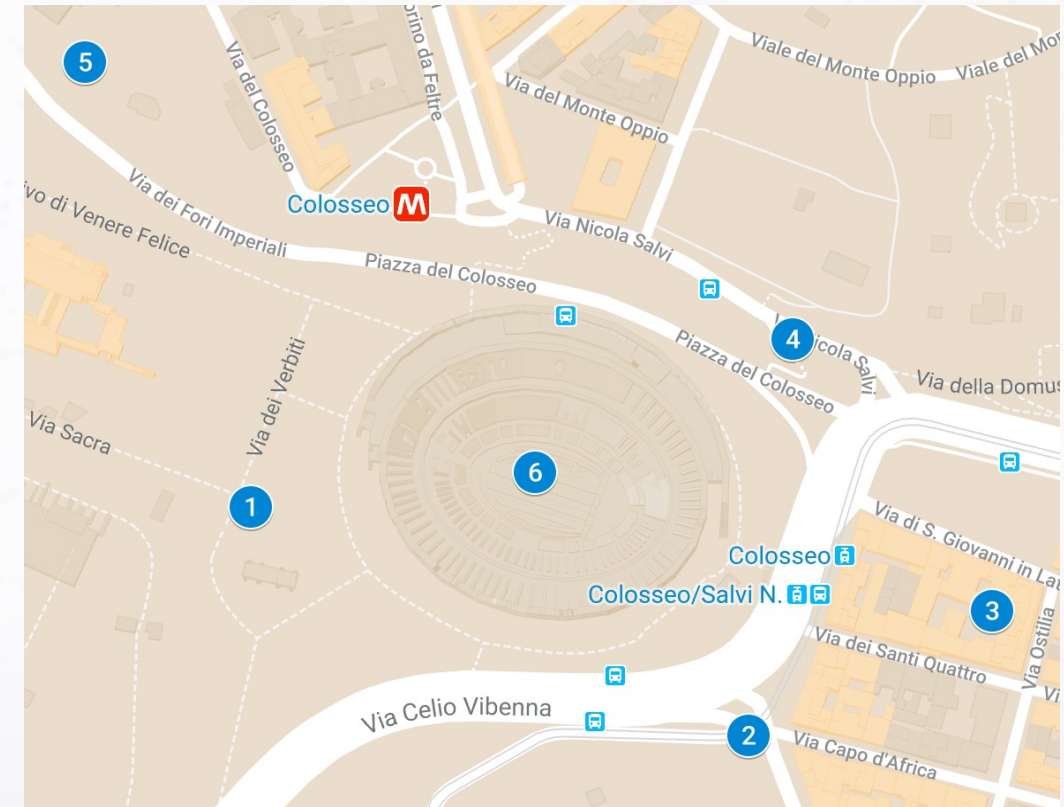
- Virtualize cellular networks
 - Scenarios designed for cellular deployments
 - Star topologies with base stations and users
 - Customizable source traffic profiles
 - Software profiles:
 - srsRAN and SCOPE (more on this in a few minutes)
 - OpenAirInterface 5G RAN and core (more on this tomorrow)

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

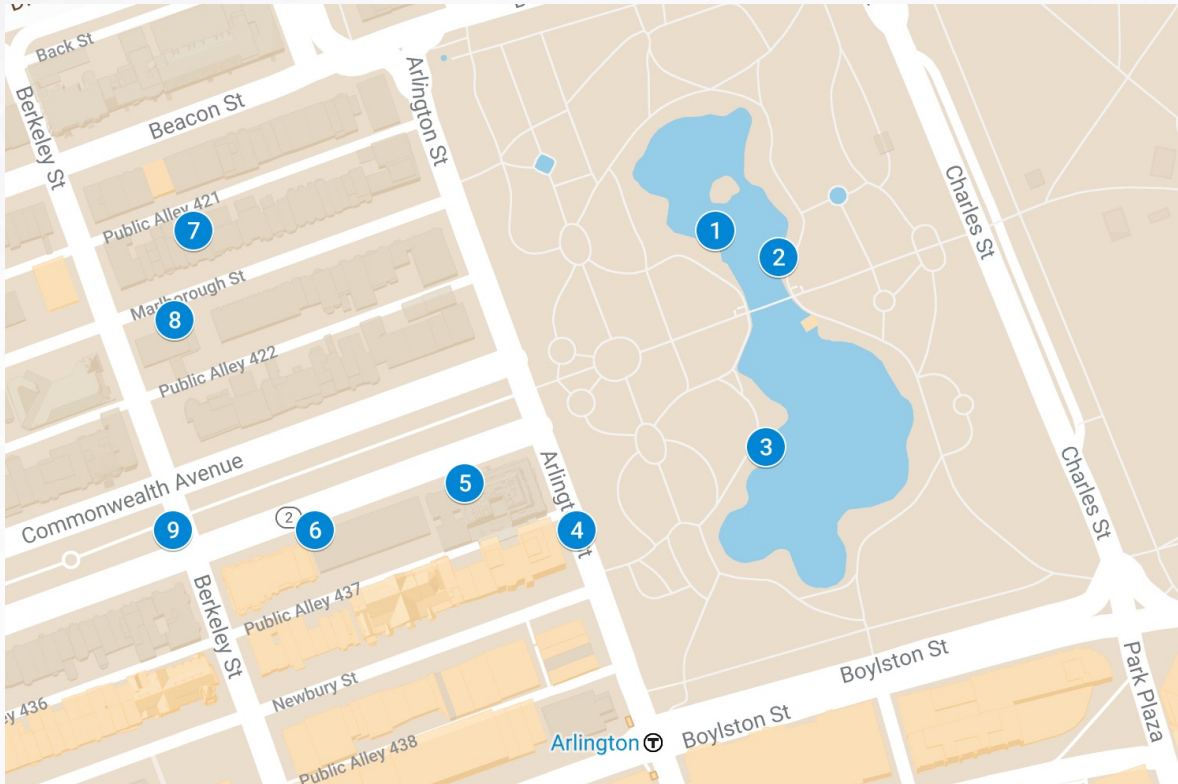


Example of Downlink throughput experiment

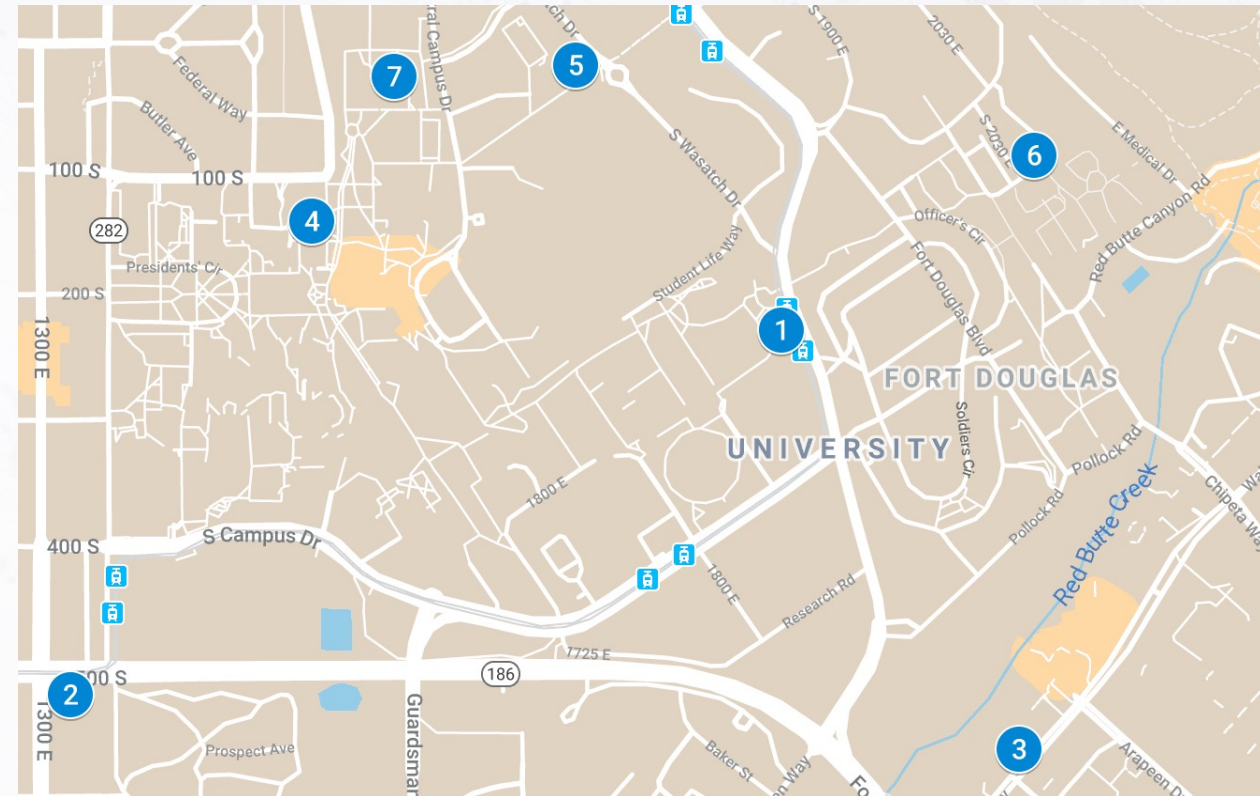


Base station locations

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.



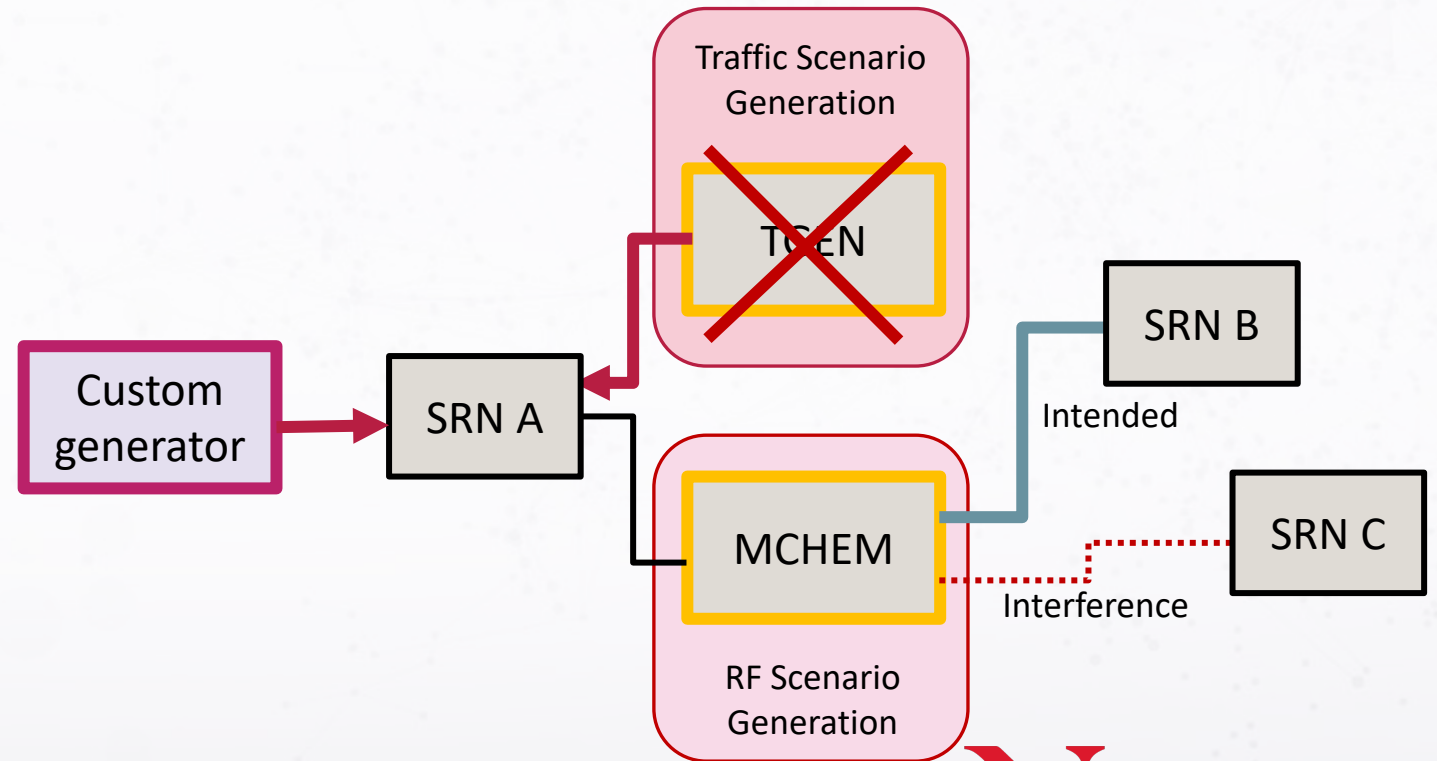
Example

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

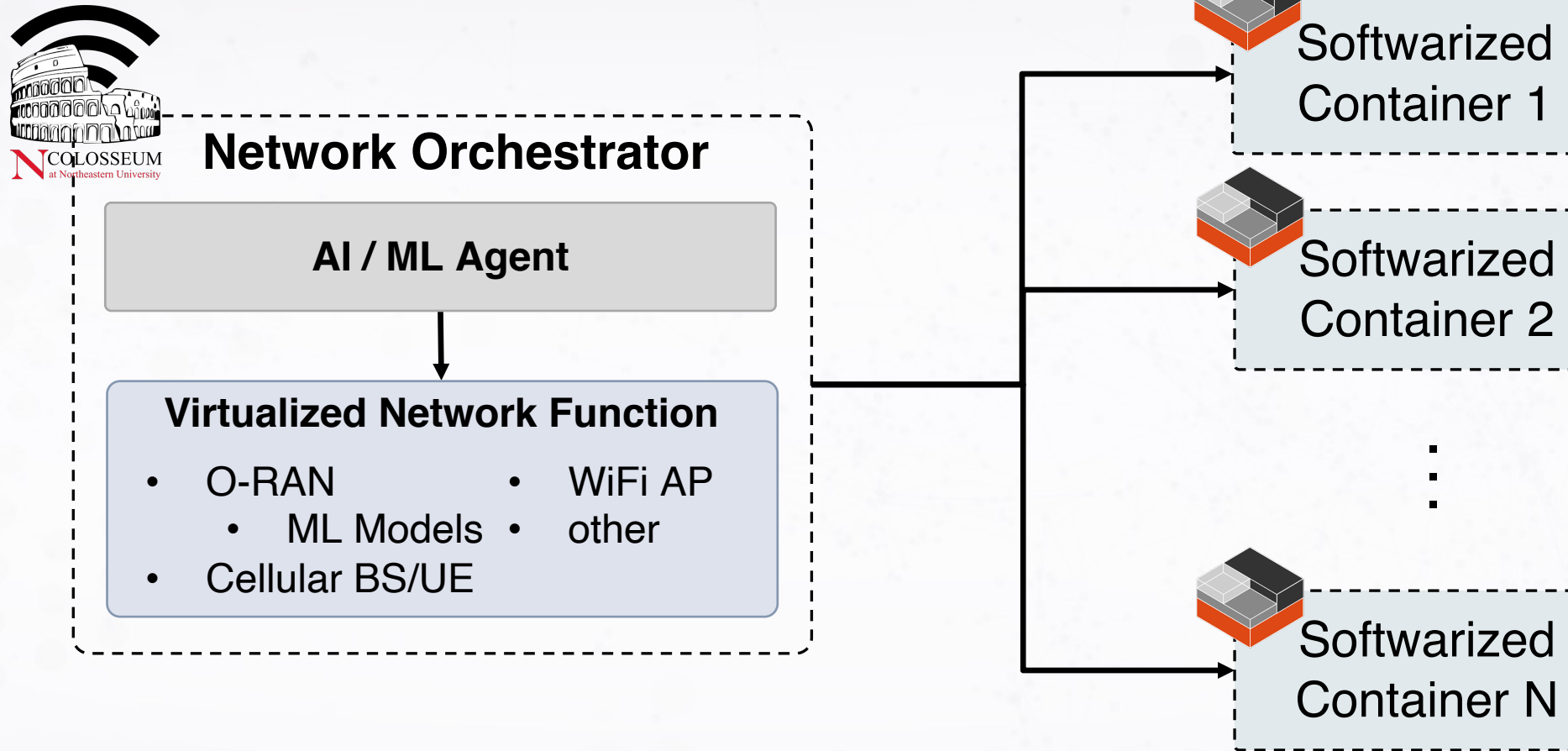
Label	Value
Version	Practice
RF ID	9988
RF Description	Single tap; large scale
Scenario BW (MHz)	10
Traffic ID	99880
Traffic Description	Streaming UDP
Center Frequency	1000.0 MHz
Number of Incumbent Nodes	0
Number of Competitor Nodes	10

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