Institute for the Wireless Internet of Things

at Northeastern University

Colosseum Use Cases

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Platforms for Advanced Wireless Research

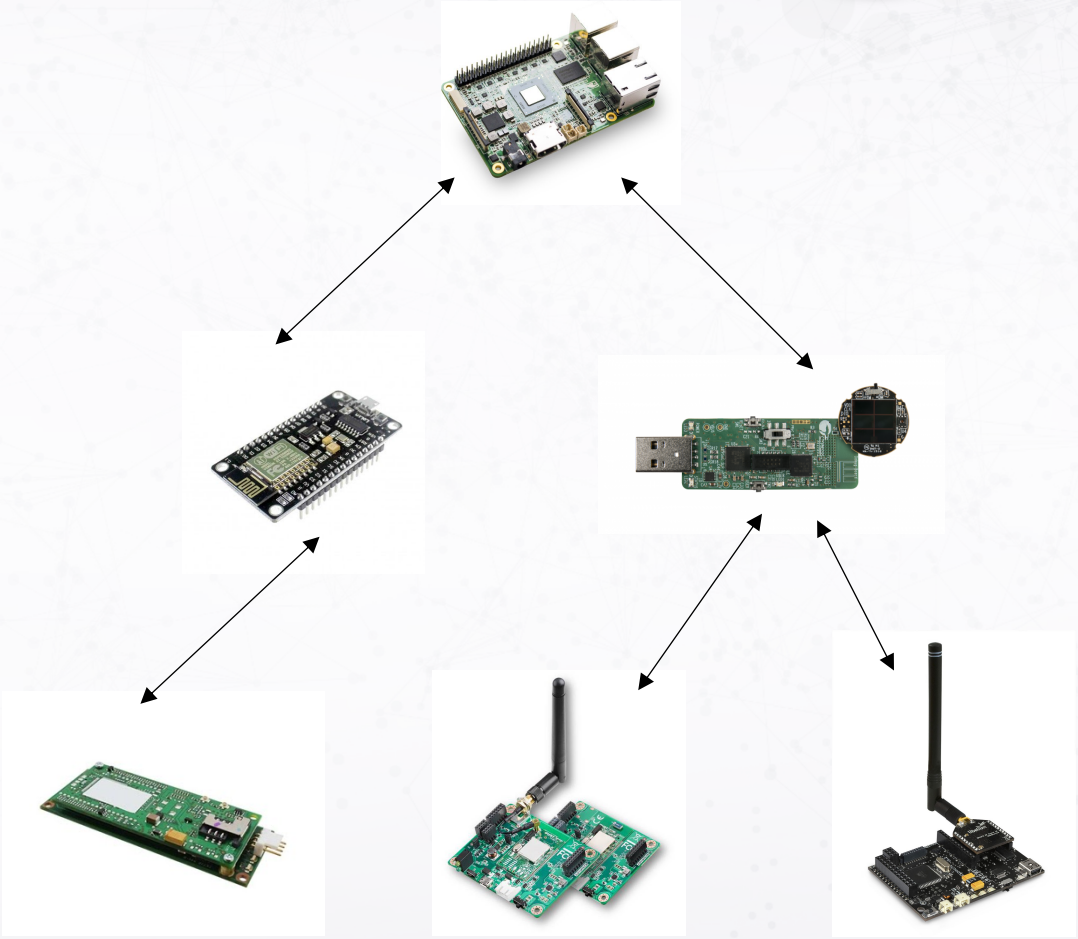
COLOSSEUM
at Northeastern University

Purpose of this section

- Provide an overview of use-cases and applications
- Map your research with what can be done on Colosseum

Large-Scale WiFi Experiments on Colosseum: Applications

- **Ad Hoc Networking**
  - Routing
  - Transport
  - MAC
  - Mobile WiFi hotspot
  - UAV communications (more later)
  - …
- **Massive** data collection at all layers of the protocol stack
- Define traffic patterns with **TGEN**
- Generate traffic inside your container



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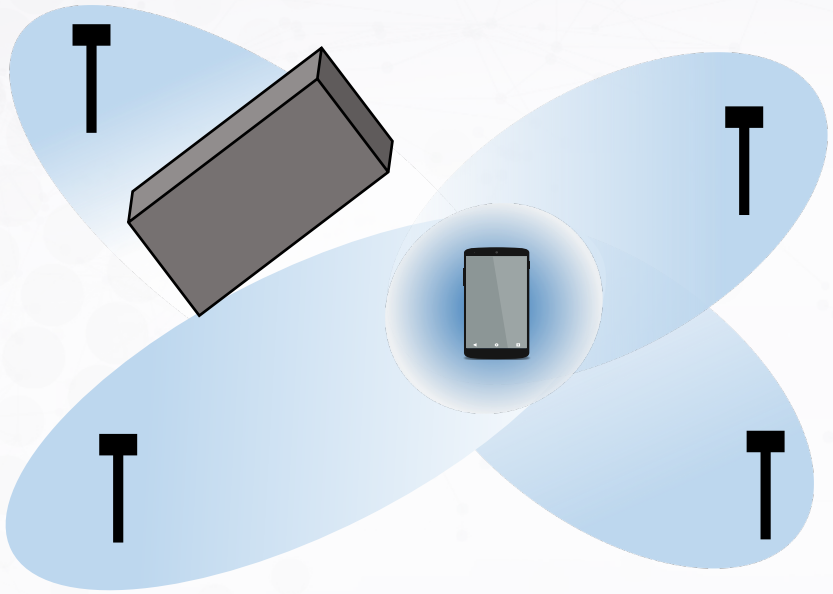
Large-scale WiFi Experiments on Colosseum: Resources

- Code available for download:
  - Accessible to users with Colosseum accounts
- Based on well-known Bastian Bloessl's IEEE 802.11 a/g/p
- LXC container ready for deployment on Colosseum
- Support for both **batch** and **interactive** mode
- Support for **TGEN in the loop**

Beamforming/Massive MIMO on Colosseum



Advantages:

- Spatial diversity
- Increased SNR / channel hardening
- Anti-jamming

Challenges:

- Coordinate and synchronize the transmission from the different antennas
- Channel estimation

Existing studies lack **experimental large-scale** evaluation of the benefits and challenges of beamforming / massive MIMO

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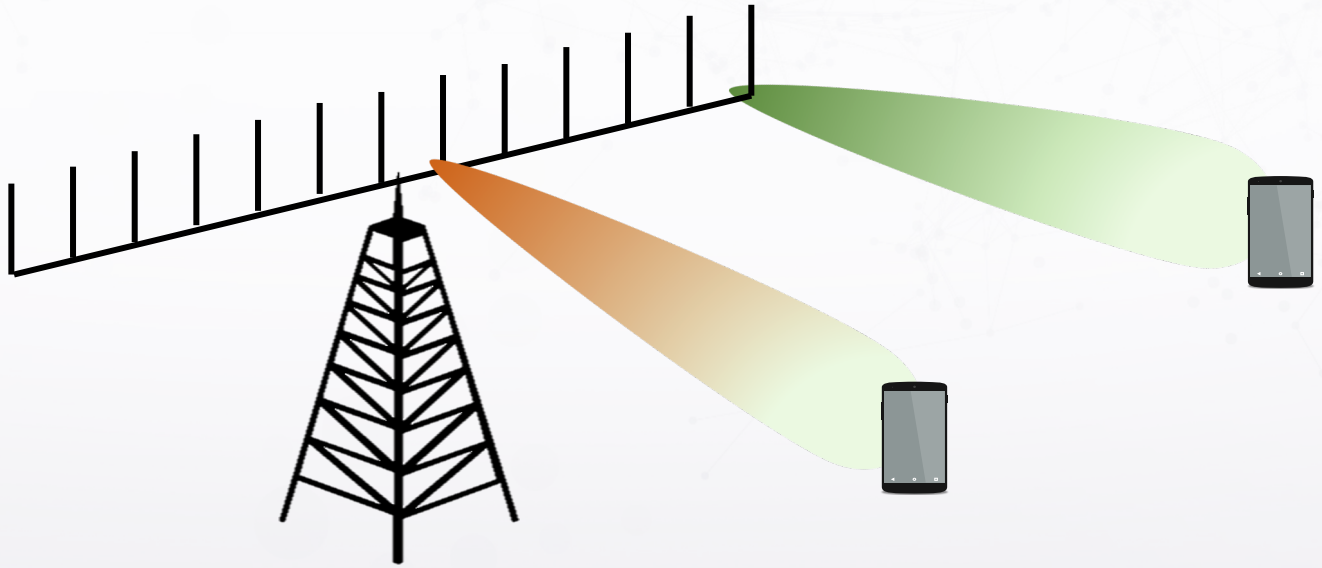
Beamforming/Massive MIMO on Colosseum

Use multiple SRNs to transmit / receive pre-coded signals

1. Colosseum supports this thanks to synchronization infrastructure in Quadrant 1
2. The scale of Colosseum enables new **massive MIMO** studies



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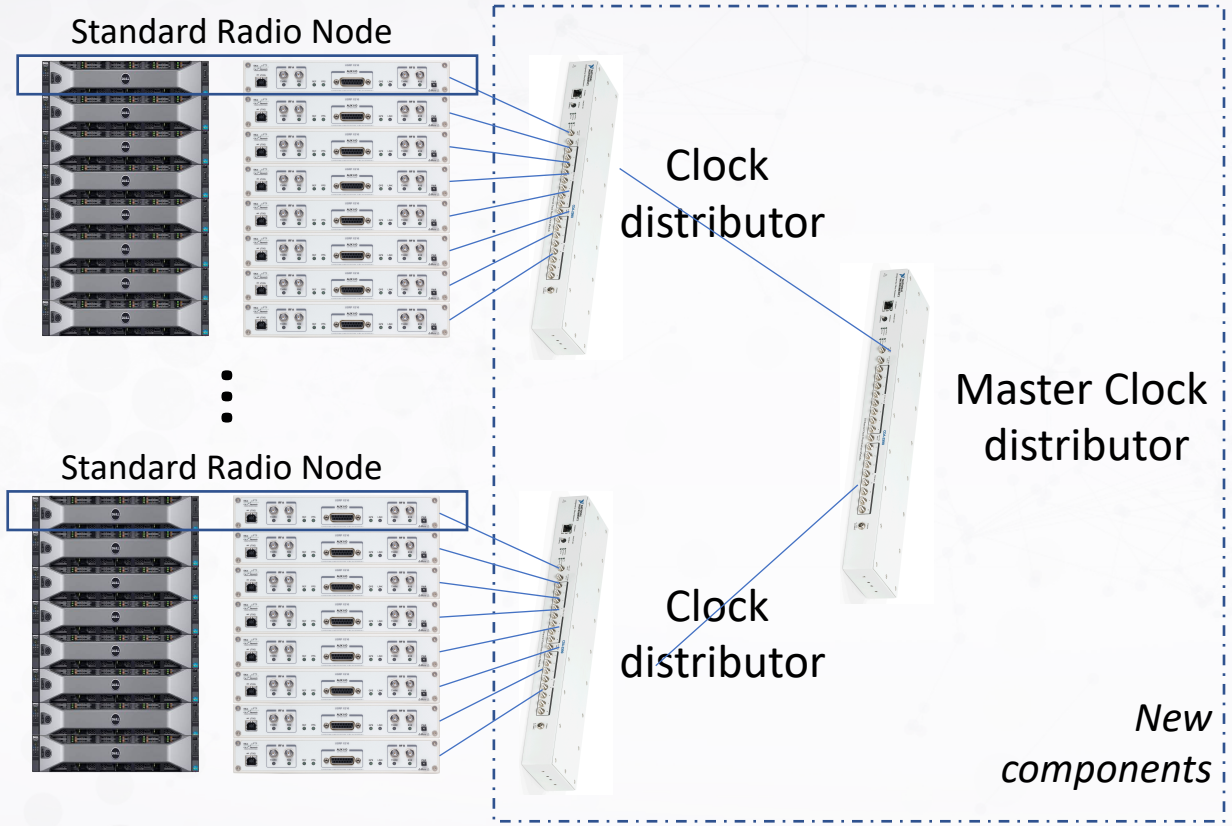
Beamforming on Colosseum - Infrastructure



- Initial deployment with
  - One Colosseum quadrant
    32 Standard Radio Nodes (Server + USRP X310)
  - Synchronized clock/PPS with 5 Octoclocks
  - Using UHD drivers to synchronize I/Q samples among different SRNs

- Work in Progress: The container is currently being developed

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(Some) Limitations of Current 4G and 5G Networks

- Monolithic architectures, hardware based
  - Hard to **update, improve, reconfigure**
  - **Vendor lock-in**
- Hard to programmatically control, especially at large scale
- Manual Configuration and Optimization (theory/application gap)
- **Can't support increasing** traffic demands

Example applications:

- Resource allocation / scheduling
- Network slicing
- Spectrum sharing

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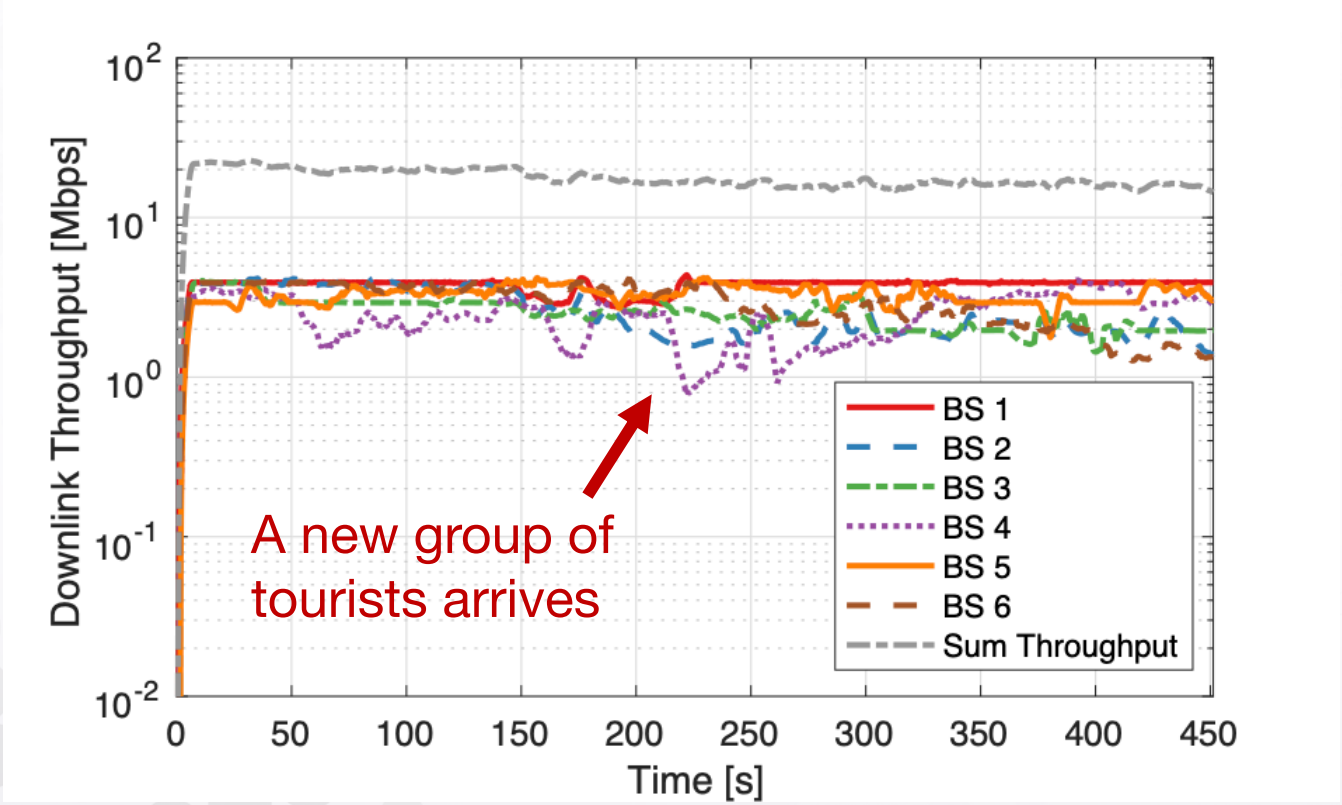
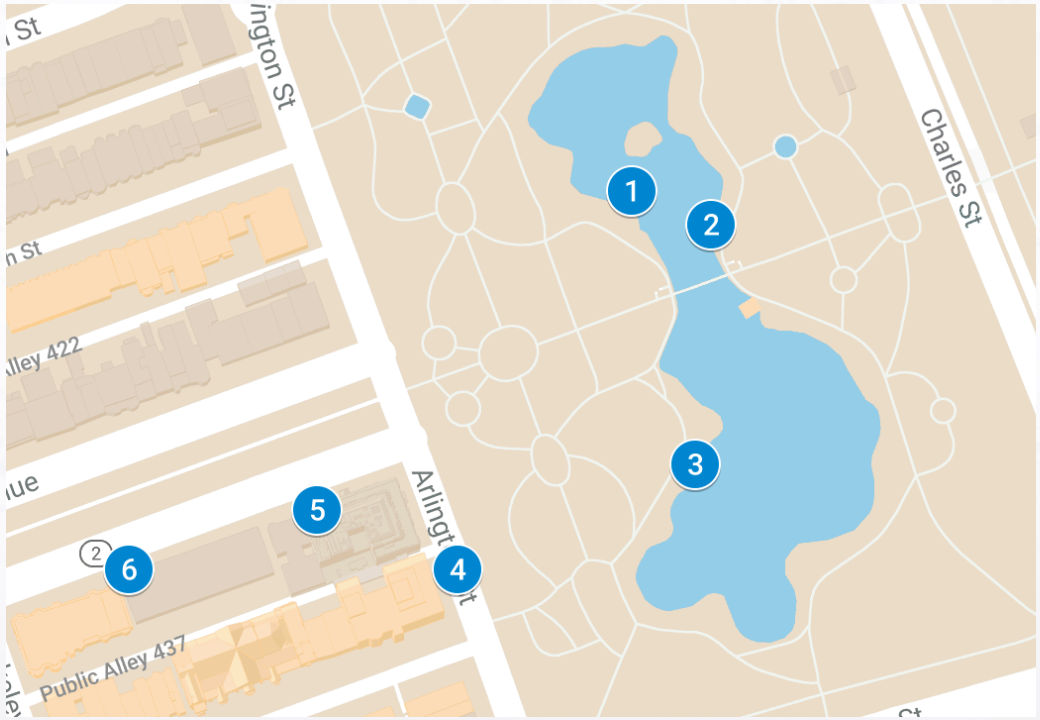
Colosseum 4G/5G Capabilities: An Example

- Cellular network w/ srsLTE: 6 interfering base stations w/ 24 users
- Downlink video streaming
- Pedestrian user mobility
- Real-world scenario with base station locations in Boston Public Garden



Downlink throughput



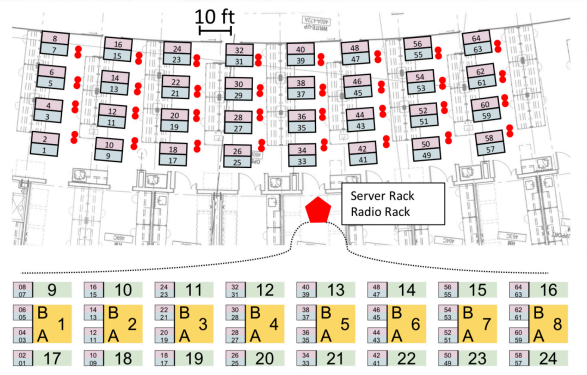
Base station locations

Example: 5G Validation Pipeline

- Initial design and testing at-a-scale on Colosseum w/ different scenarios
- Validation on real-world indoor environment
- Experiment over realistic RAN deployments on PAWR city-scale platforms

Test 4G/5G container on emulated scenarios

Validate in real wireless environment



Test over real-world RAN

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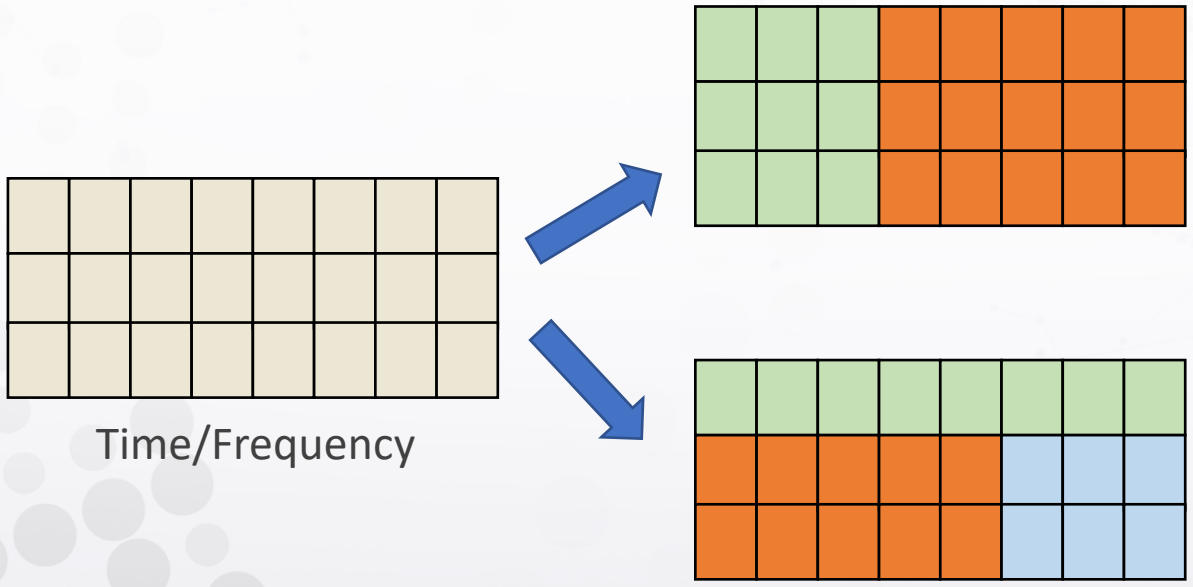
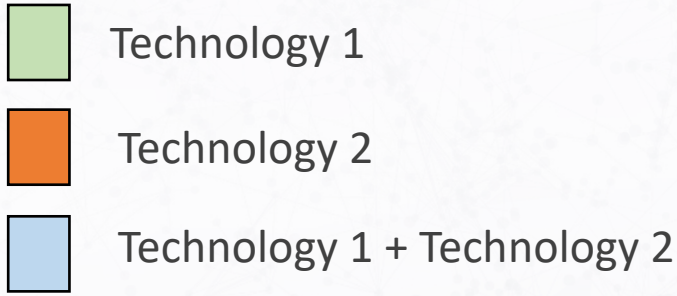
Spectrum sharing

- **Trend:** With the **ever-increasing number of connected devices** and new technologies, **coexistence** is essential to overcome spectrum scarcity

- **Challenge:** Can several transmissions **coexist** on the same spectrum band **reliably**?
  - **Licensed/Unlicensed**
  - **Cognitive** radio



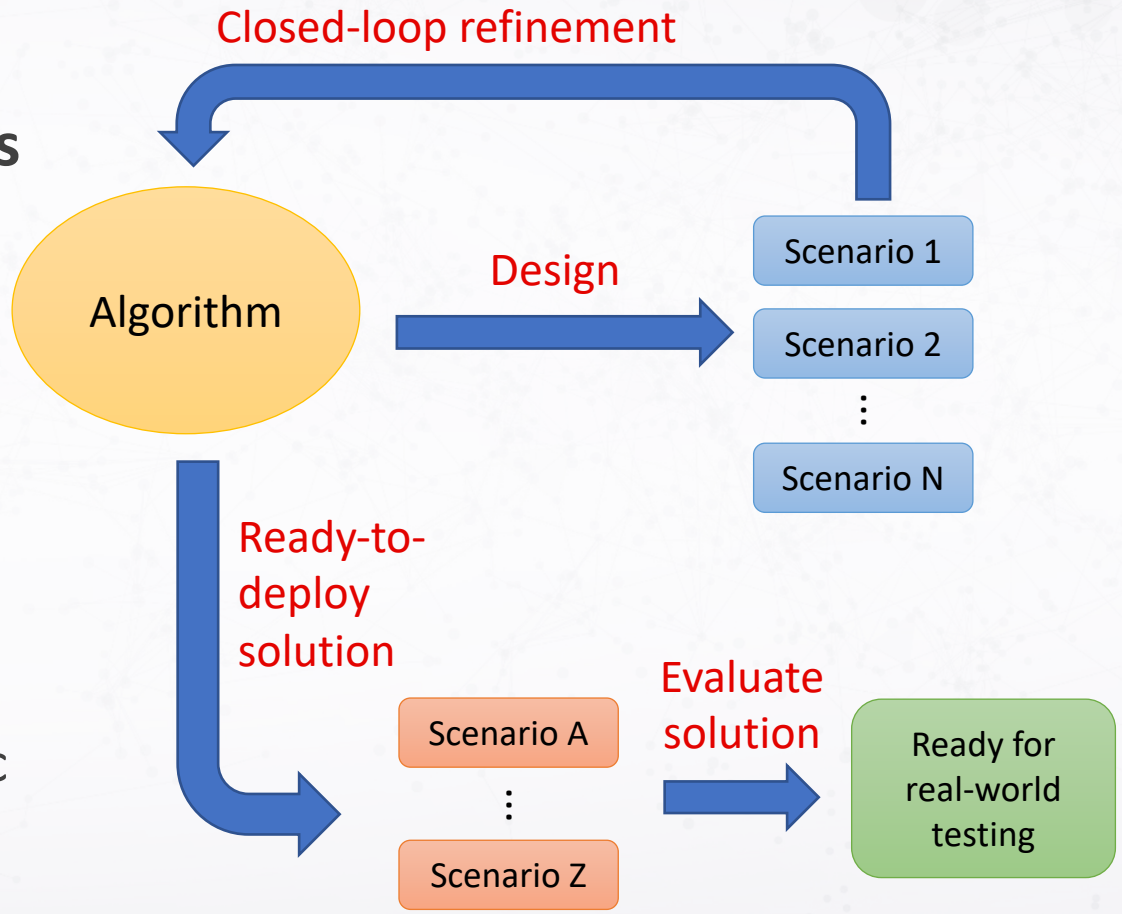


Which one is **better**?

Spectrum sharing on Colosseum

Opportunity:

- Generate **heterogeneous RF/traffic scenarios**
- **Design adaptive** solutions:
  - Optimization / Data-driven
  - Minimize impact on licensed users
  - Spectrum hole detection
- **Validate** algorithms on unseen scenarios
  - Ensure algorithms are not scenario-dependent
  - Test different algorithms on the same RF/traffic scenarios for fair comparison



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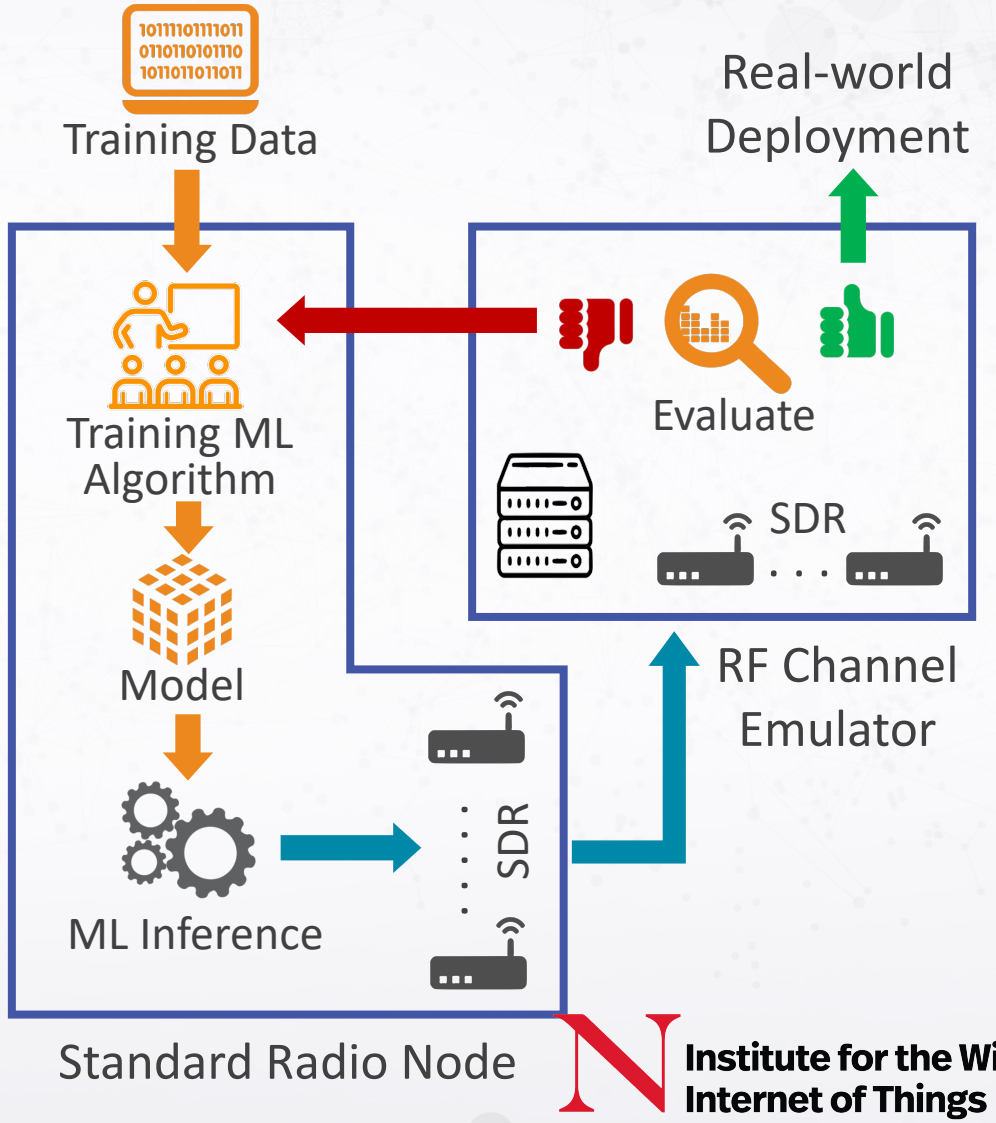
Fusion of Artificial Intelligence and Internet of Things

- **Trend:** IoT applications are getting **smarter** by incorporating Artificial Intelligence
- **Challenge:** **Large-scale in-field deployment** of IoT devices to train and test with AI algorithms is challenging, time consuming and often expensive
- **Opportunity:** Colosseum provides a unique platform where the power of **AI meets the real-time wireless IoT** emulations whether it be WiFi, Cellular or LPWAN
  - X310 Software Defined Radio
  - Powerful computation nodes equipped with GPUs
  - FPGAs for embedded AI-IoT testing



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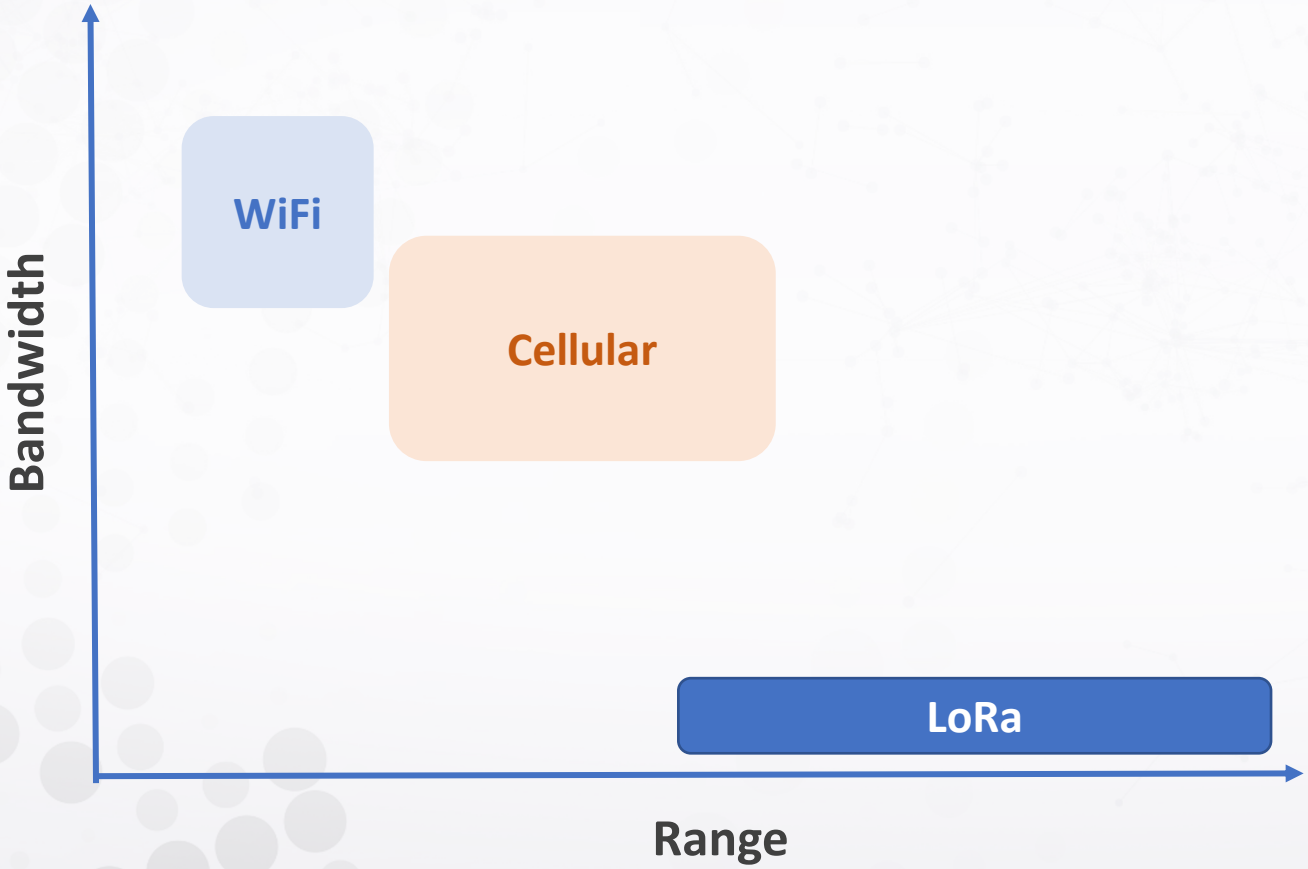
Motivation for LoRa

- Low bandwidth, long range, low power = suitable for IoT



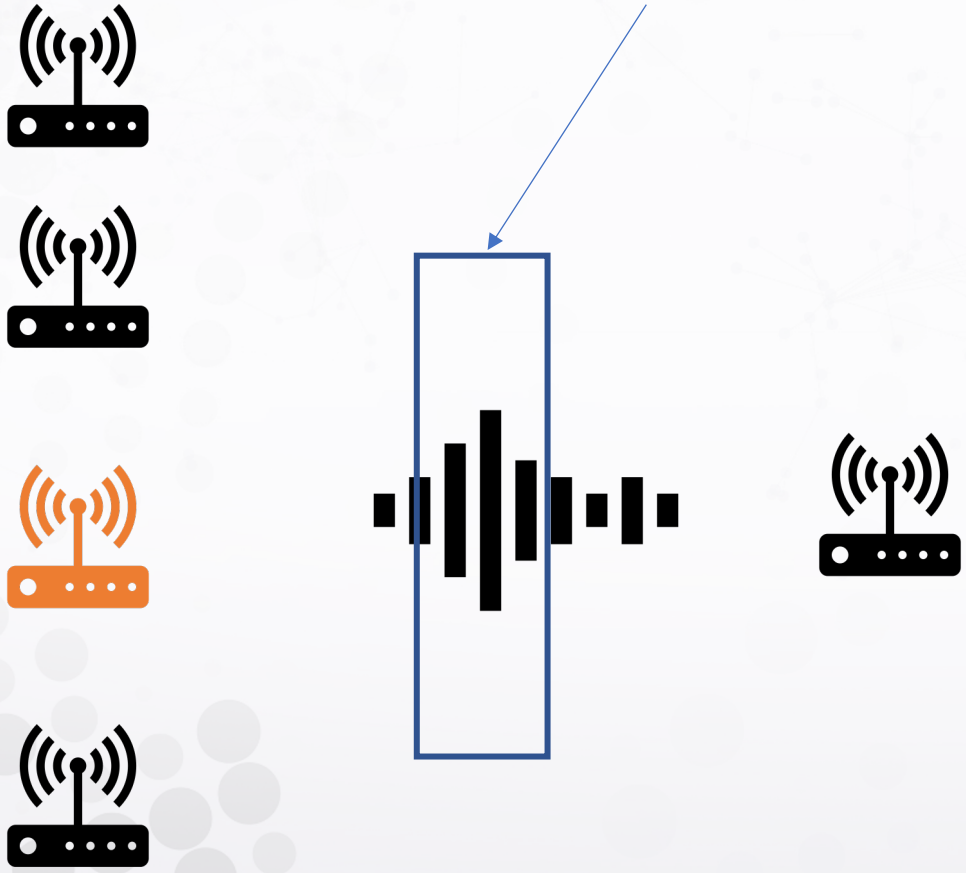
LoRa Gateway

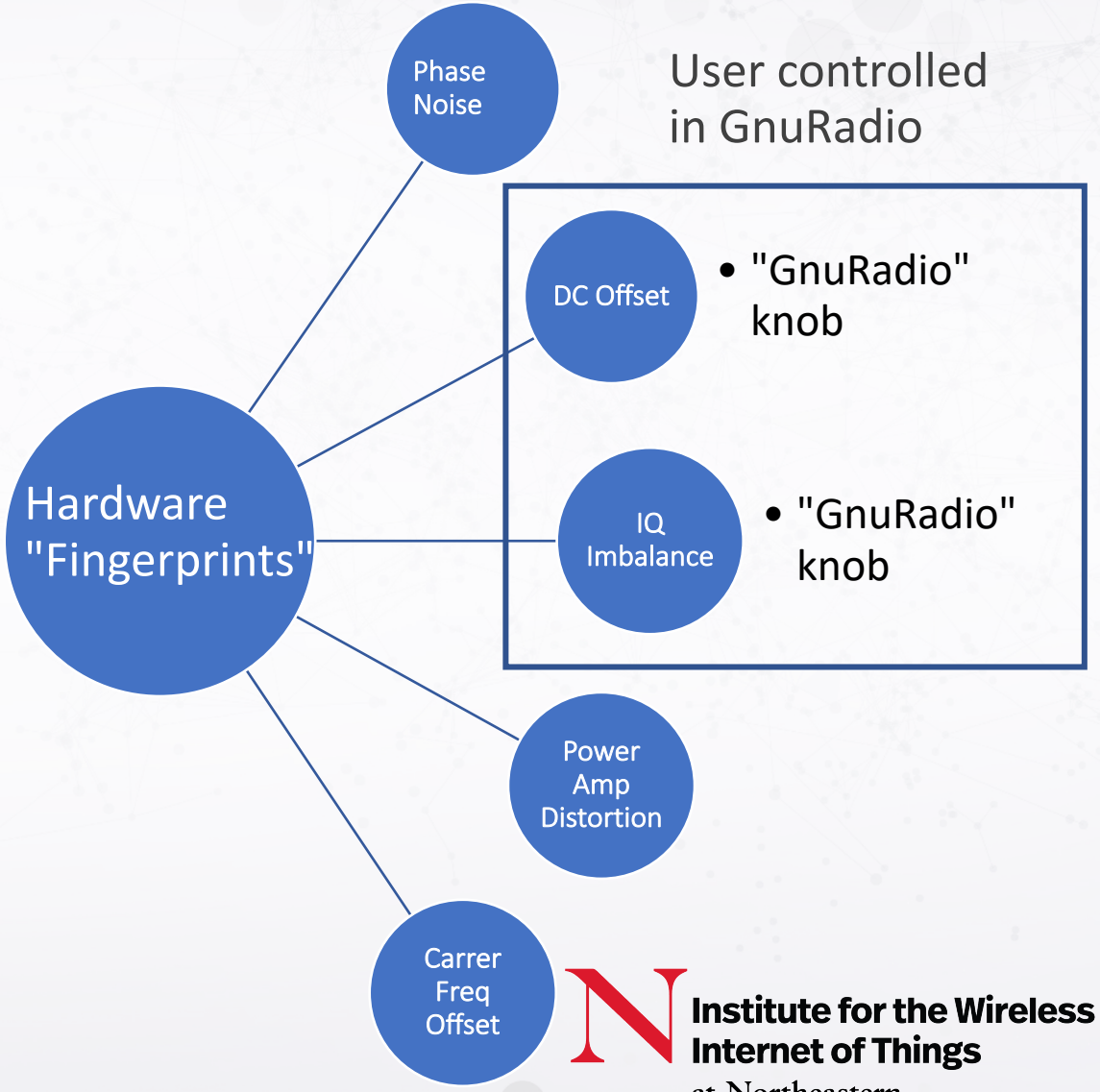
LoRa Tx

- GnuRadio PHY "gr-lora" available from Bastille Threat Research Team on GitHub

RF Fingerprinting

- Deep Learning for detecting unique Tx-signatures
  - raw in-phase (I) and quadrature-phase (Q) samples





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Mesh Networking+

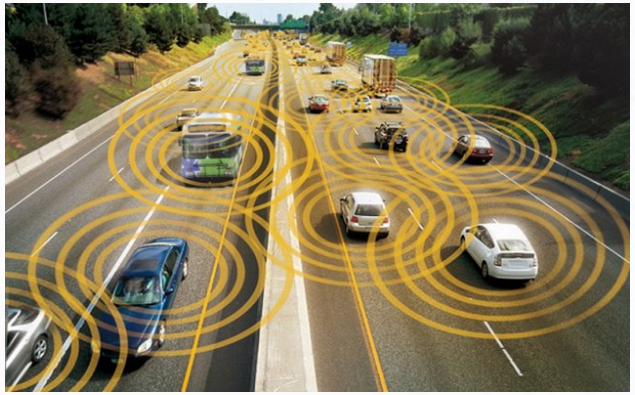
Mesh Networking

Colosseum **bridges the gap** between study scenario and experimental validation!

- Experiments fully represent the deployment scenarios
- ~Unlimited network deployments

Mobile Networks

Nodes **mobility** can be fully configured at the start of the emulation



- Wide range of large-scale **mobile testing scenarios** with real radios

UAV Networks

Possibility to configure **aerial channels**!

- Large-scale **aerial mobile deployments** with real radios

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