Beyond-5G Thrusts for Intelligent Automation, Inc.

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Network and Security Division, IAI

www.i-a-i.com

Company Overview

- Founded in 1987
- Headquartered in Rockville, MD
- 240+ researchers and engineers
- Top 5 small federal R&D businesses for the last 10 years

- TS facility clearance
- 50,000+ sq. ft. state-of-the-art facilities including cleared spaces, R&D labs, manufacturing

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Future Vision (6G) vs. Current (5G)

Future 6G:

Physical Environment:

- Increased Speed (THz frequencies – lots more BSs/cells)
- Massive connectivity – IOT (lots more devices)
- ➢ Compare: Tactical Networks "congested and contested environments"

Internal Architecture:

- Latency (milliseconds -> microseconds) – 1000X
- Dynamic NF/Slicing configuration and orchestration using integrated MEC with 5GC
- "Multi-Mission" level requirements on management layer
- ➢ Dramatic increase in complexity: Need for automation

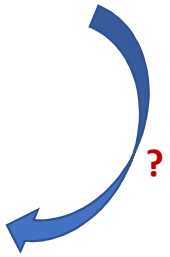
Proposed Solutions:

- Need for AI/ML algorithms across the board
  - For performance
  - For security

Current 5G:

- 3GPP Rel 15/16 provides basic standards for comms
- Commercial Deployments and UE/cellphone usage providing preliminary understanding of issues
- What about best-practices/standards for:
  - Implementation?
  - Automation – AI/ML

How will we get there (6G) from here (5G)?



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U.S. ARMY RDECOM

Research Context

ARL

Unified Land Operations → Prevailing in a Complex World

Large-scale, cluttered, contested urban environment

Future 6G Networks could be very similarly "congested and contested" to current Tactical Networks

- # devices / area
- Spectrum crowding
- No baseline for ML training

From ARO Adversarial ML Workshop 2017 (Tien Pham)

6G: Need for Holistic Security Across all Layers

- Adversary will utilize entire attack surface (PHY+MAC+IP+management)
- Need for coordinated Multi-layer security defense strategy
  - ➢ Monitoring & Response at all layers (data and links)
- What exactly are the threats at each layer?

Exactly how will this be done?

Need to be careful of having too much autonomy

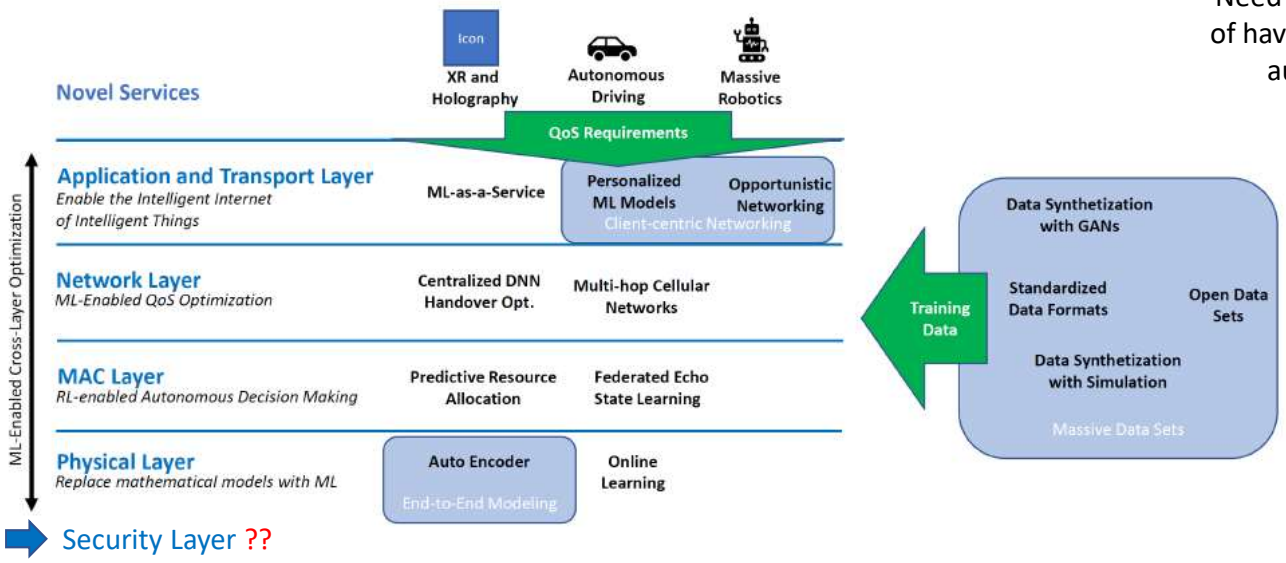

Figure 1: The role of ML in 6G networks.

From Ali et al. 2020 arxiv: https://arxiv.org/pdf/2004.13875.pdf (6G Wireless Summit 2020)

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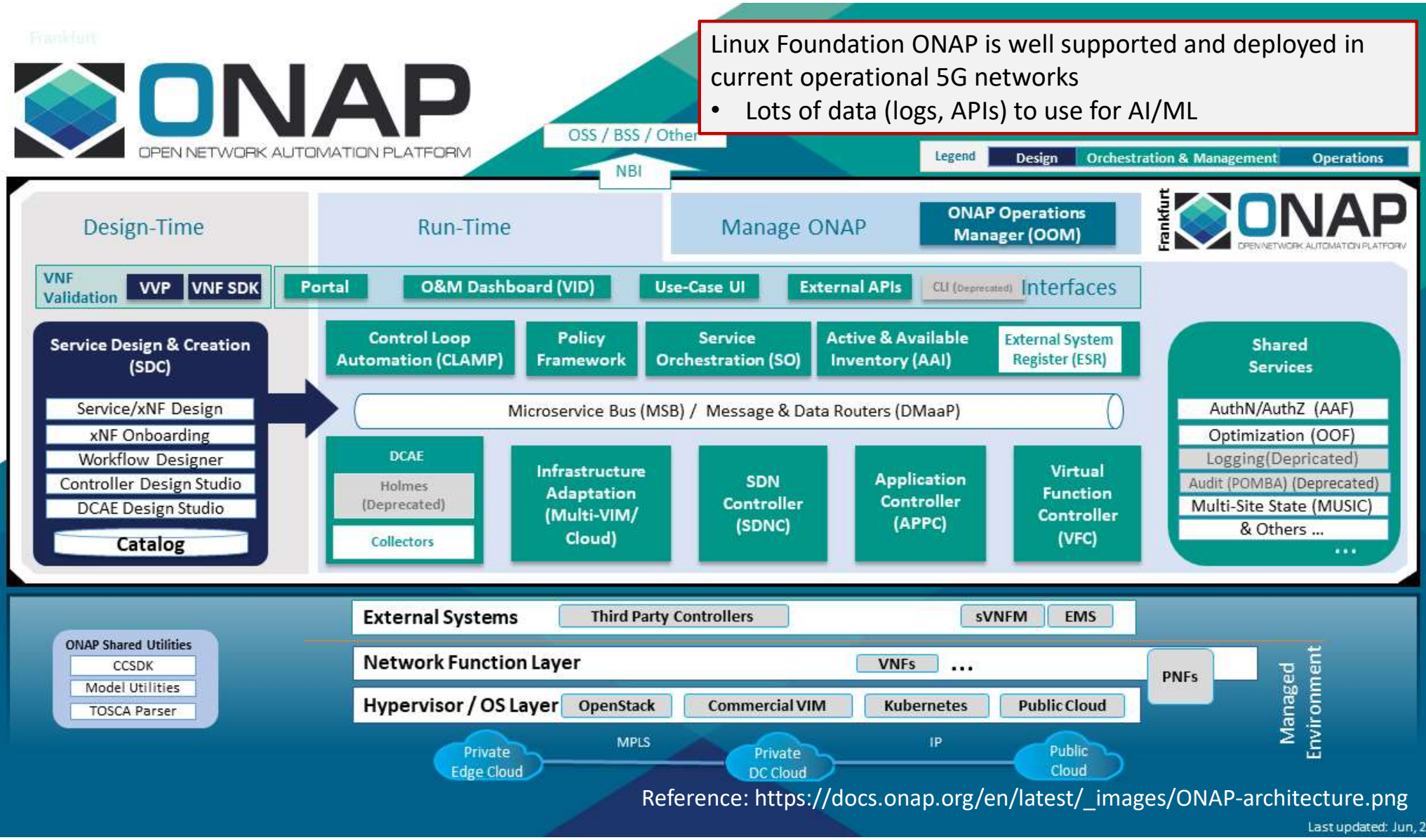
Linux Foundation ONAP is well supported and deployed in current operational 5G networks

- Lots of data (logs, APIs) to use for AI/ML



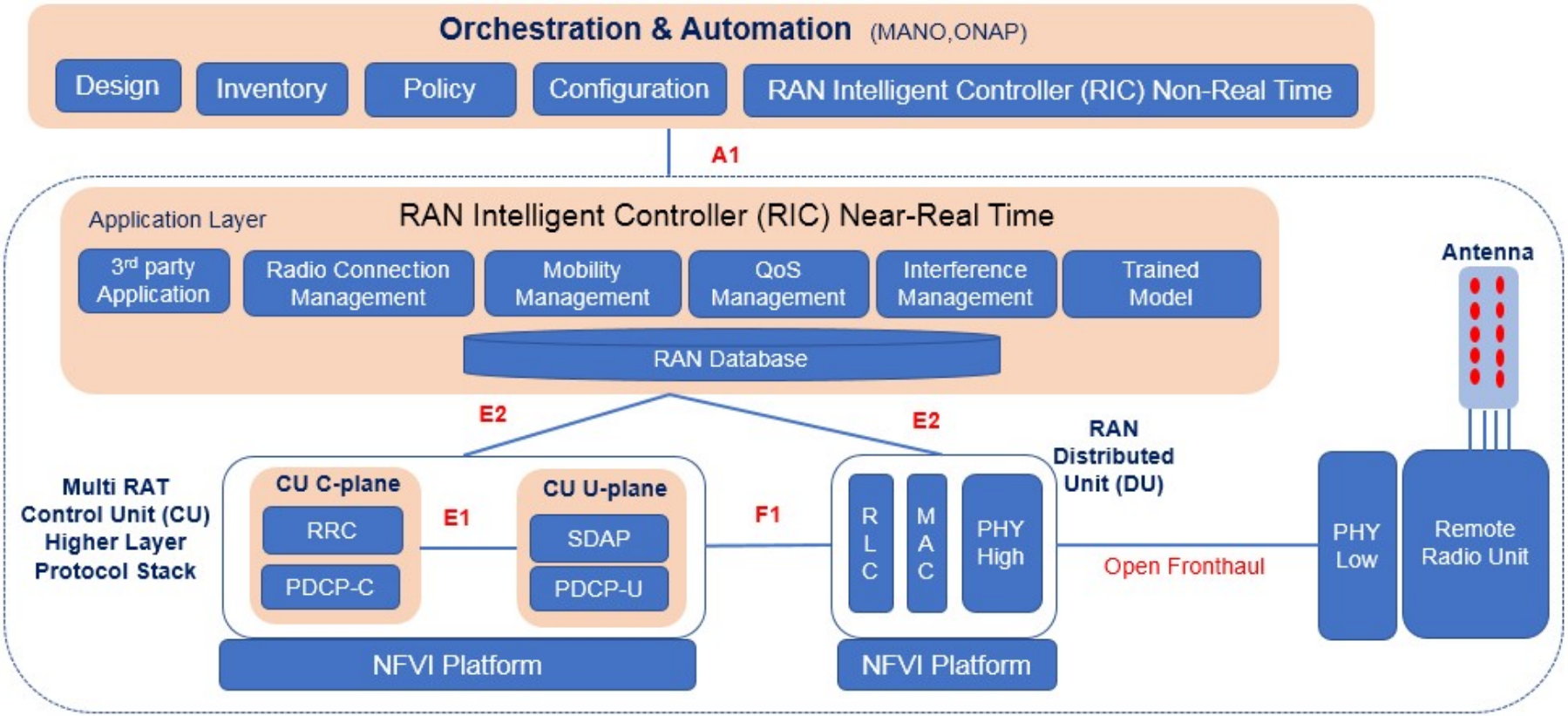
Reference: https://docs.onap.org/en/latest/_images/ONAP-architecture.png

Last updated: Jun, 2020

O-RAN Reference Architecture

O-RAN is also very well supported and is being adopted by many RAN providers and in Open Source

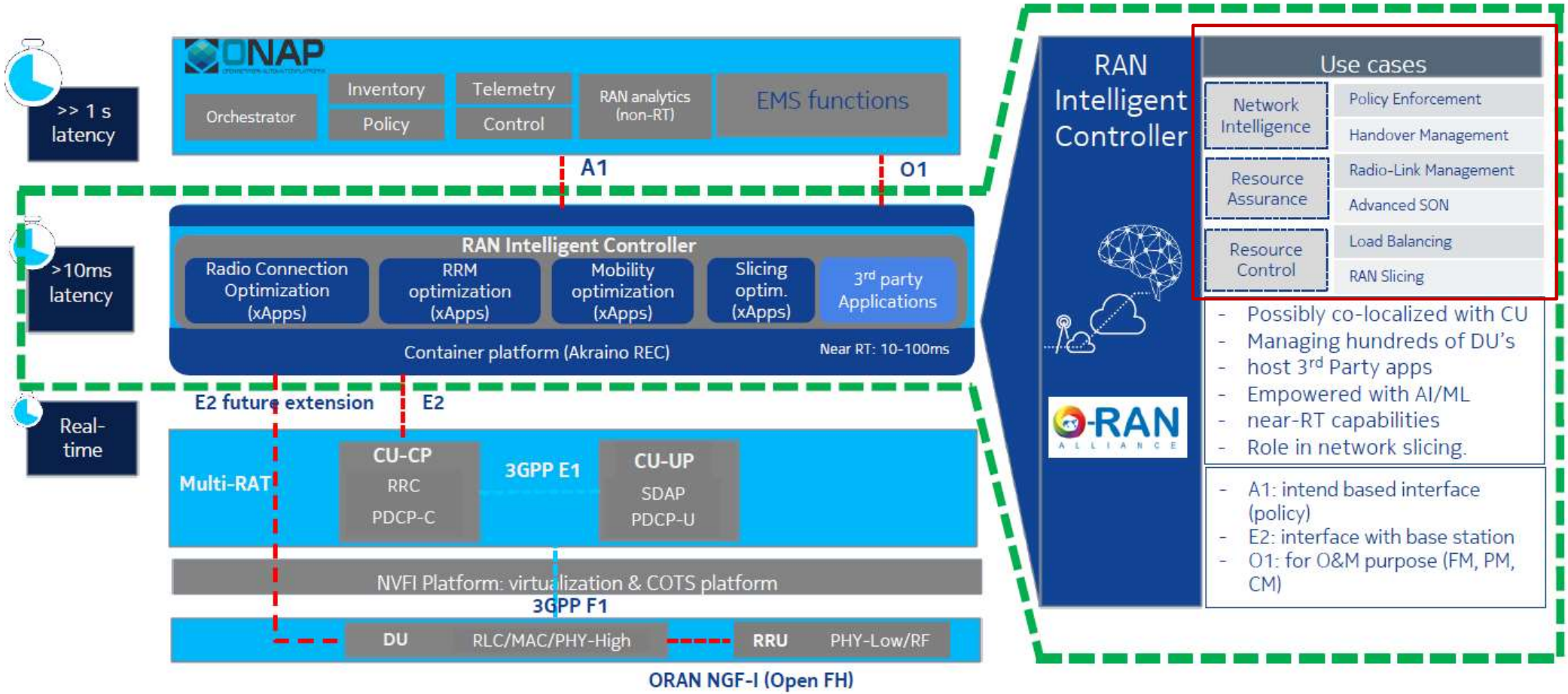
- Lots of data (logs, APIs) to use for AI/ML
- xAPP interface for 3rd part Apps



From http://www.techplayon.com/open-ran-o-ran-reference-architecture/

What is RIC: architecture and key requirements

Sample O-RAN RAN optimization Apps



From: Thoralf Czichy, Near-RT RIC PTL presentation
https://wiki.o-ran-sc.org/display/RICP - ONS Europe, 2019

NOKIA

Acumos: Linux Foundation Open Source AI Framework

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AI

AI Foundation delivers third Acumos AI software release, which includes work with ONAP and O-RAN

by Mike Robuck | Nov 26, 2019 12:45pm

The LF AI Foundation releases third version of its Acumos AI Project software, which includes federation with ONAP and O-RAN. (Pixabay)

The LF AI Foundation has delivered its third software release for its Acumos AI Project, which includes integration with ONAP and O-RAN. The third release, which is called "Clio," includes features that were designed to more easily onboard AI models, as well as design and manage support for pluggable frameworks and enable federation with ONAP and O-RAN.

For Whitepaper, see
https://www.acumos.org/wp-content/uploads/sites/61/2018/03/acumos_open_source_ai_platform_032518.pdf

support for pluggable frameworks and enable federation with ONAP and O-RAN

Overview of IAI's Relevant 5G Efforts

IAI efforts help with Way Forward:
- AI/ML algorithms to overcome complexity
- Hardware products to help with 1000X better latency
- Situational Understanding of threats for 6G Holistic Security

- IAI 5G Testbed and Wireless RadioLab
  - Development and Validation of (automated) algorithms
  - Development of products based on accumulated R&D efforts
- Embedded AI/ML algorithms on FPGC platforms
- R&D of AI/ML algorithms
  - Increased performance and security of Tactical Networks
- Threats/Attacks on 5G networks – how to defend

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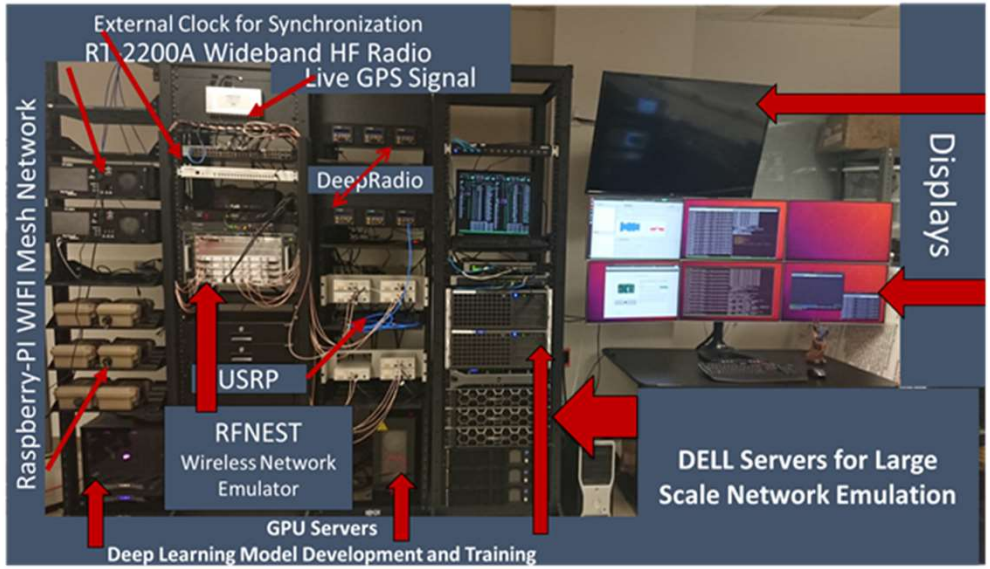
Wireless RadioLab and 5G Testbed

IAI's RadioLab with RF experiment and computation capabilities.



RadioLab is capable of generating rich sets of waveforms using different protocol and radio parameters such as beam patterns, bandwidth, modulations, etc.

5G Operational system

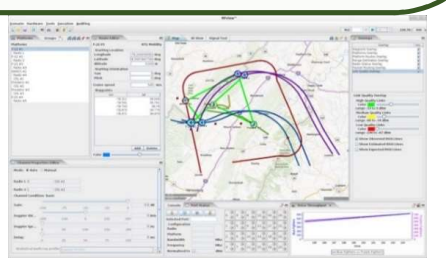
Amari Callbox
(5G NR RAN/Core, 5G UE)

5G Development: OpenSource:

- OpenAirInterface 5G (gNB/eNB)
- Free5GC (5G core)
- ONAP
- Coming: ORAN & MEC

5G

IAI's RFnest: network channel emulator (adds pathloss, fading, Doppler, multipath effects to RF signals)



IAI's RFview: Scenario generation and control of RFnest

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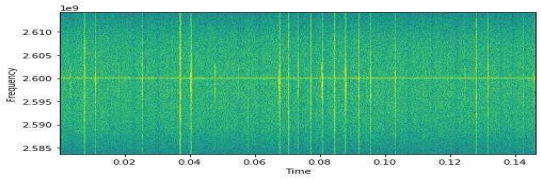
RadioLab Resources: In-House Radios and RF Data

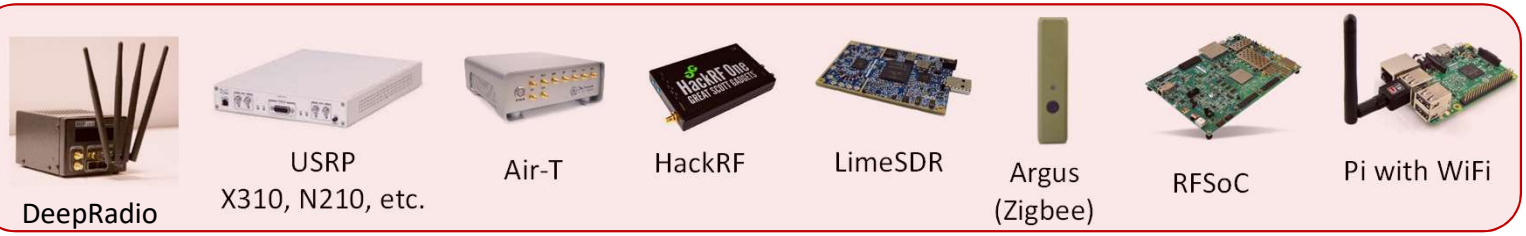
In-house available commercial and tactical radios generate and collect RF data as needed for Tactical Network Research



RF Data: available commercial (e.g., 5G/LTE/WiFi) and tactical (e.g., SRW) RF data sets.

Tactical Radios

mmWave radios



sub-6GHz radios

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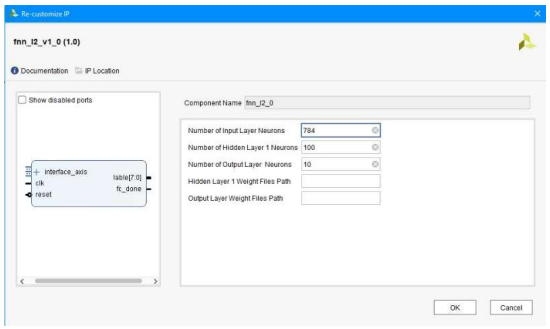
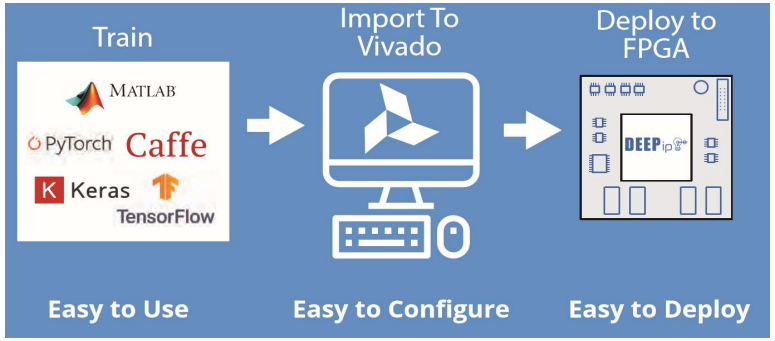
Embedded Implementation

- Implement algorithms on **embedded platforms** for **fast** decisions in **microsecond-millisecond time** frame.
- **Hybrid** embedded implementation **FPGA**, **embedded GPU**, and **ARM** supported by radio platforms for sub 6-GHz and mmWave.
  - Classical signal processing operations such as FFT on FPGA.
  - Inference with FNNs and simple CNNs on FPGA using IAI's DeepIP (DNN IPs for FPGA's in Xilinx's Vivado Design Suite).
  - Inference with complex CNNs and RNNs, & training/retraining of DNNs on embedded GPU (Nano/Xavier) and ARM.

DEEP ip
Deep Learning on FPGA Fabric

XILINX
ALLIANCE PROGRAM
MEMBER





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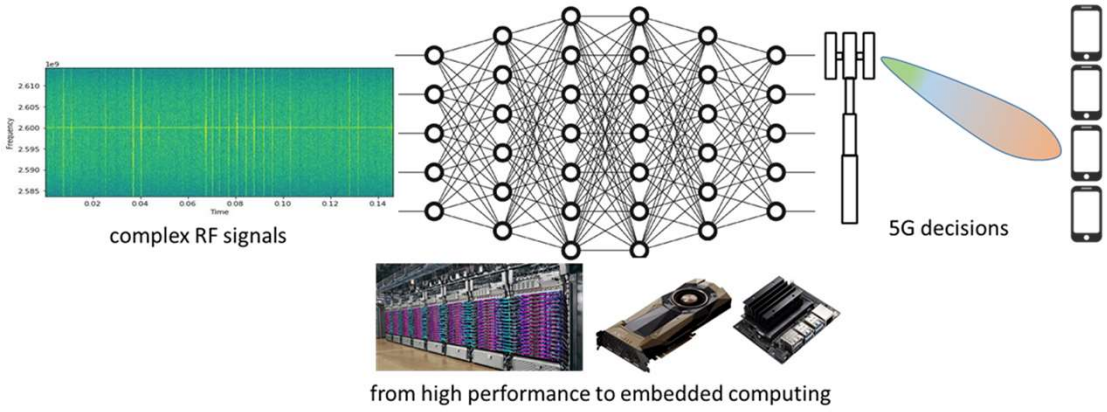
R&D – Algorithm Development in 5G

5G Expertise

- Dynamic Spectrum Sensing
- 5G RAN/wireless Security
- Network Slicing
- Virtualization and 5G Core Security
- Open Source Software
- Orchestration and Management
- 5G Testbed



5G ML Focus Areas/Publications

- 5G Fast initial access
- 5G Beam tracking/prediction and handover
- Intelligent surfaces for 5G and beyond
- 5G RAN slicing
- Covert 5G communications
- 5G UE authentication
- 5G RAN security

Use machine learning / deep learning to solve complex 5G tasks only when expert knowledge and analytical methods are shown to be insufficient.

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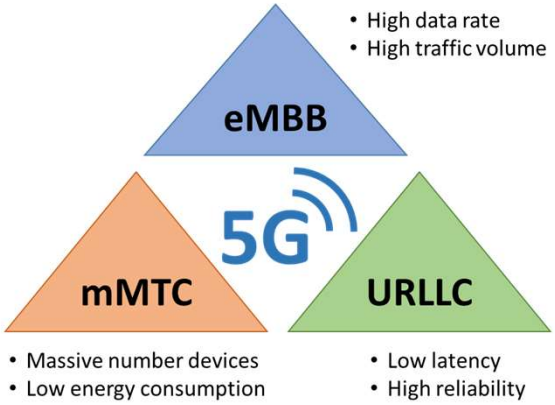
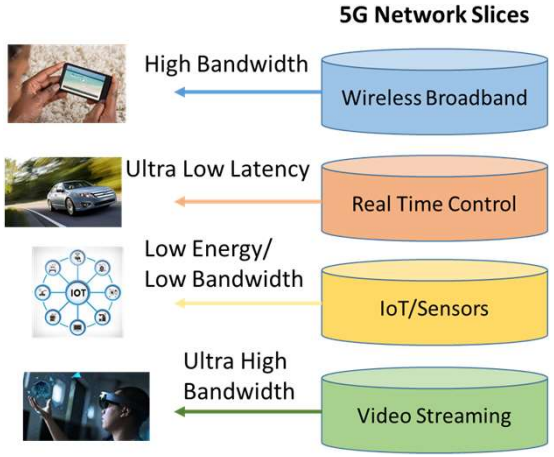
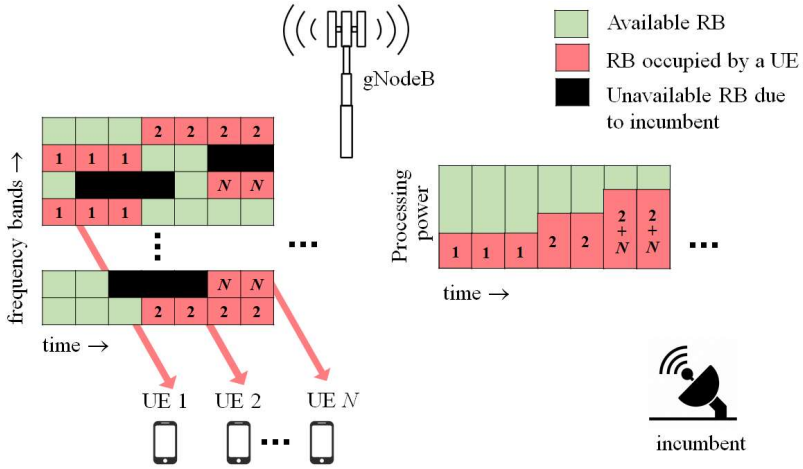
Network Slicing

- Network slicing to multiplex virtual network services on the same physical infrastructure.
- Our focus: Network slicing optimization for **Near-RT Radio Intelligent Controller** (NRT-RIC).
  - Admission control and resource allocation for network slice requests.
  - Reservation and deep reinforcement learning algorithms.
  - Supports spectrum sharing (CBRS band).
  - Secured against attacks (jamming and stealth attacks).







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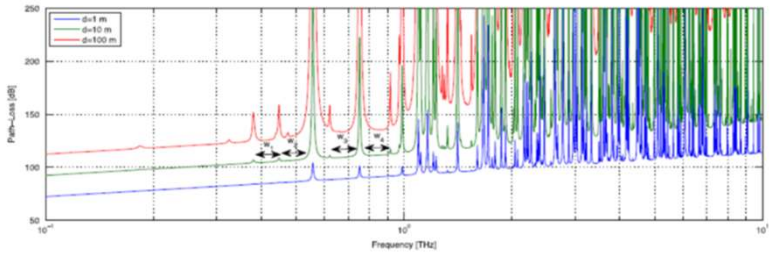
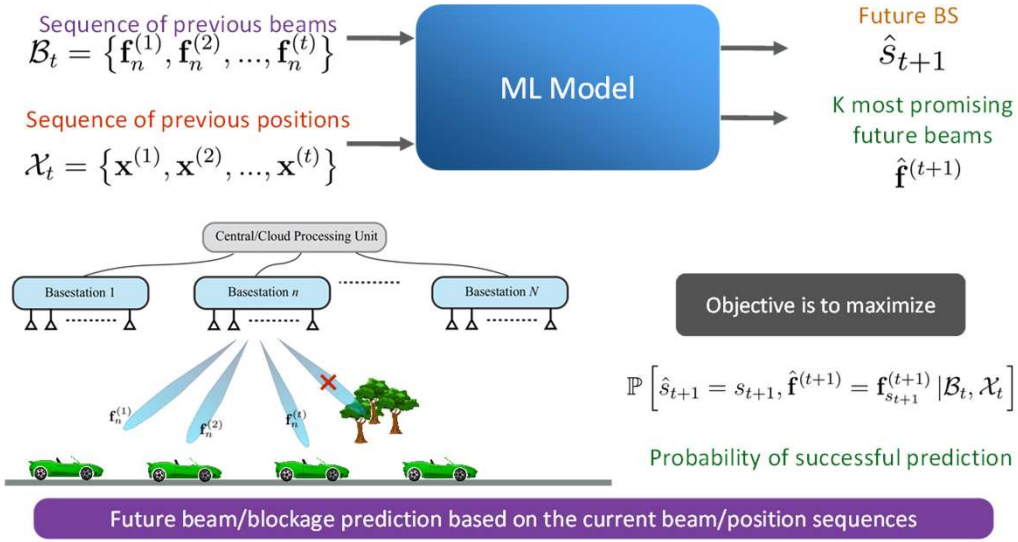
TeraHertz Communications

- THz provides unprecedented rates not supported in 5G and before.
  - Highly-directional and secure transmissions.
  - Ultra-low latency (e.g., Augmented reality / virtual reality).
- Challenge: Link maintenance and support of high mobility.
- ML/DL-based fast beam training, beam switching and handoff.



- Spreading and absorption loss.
- Sensitive to blockages.
- Experience with NS3-TeraSim



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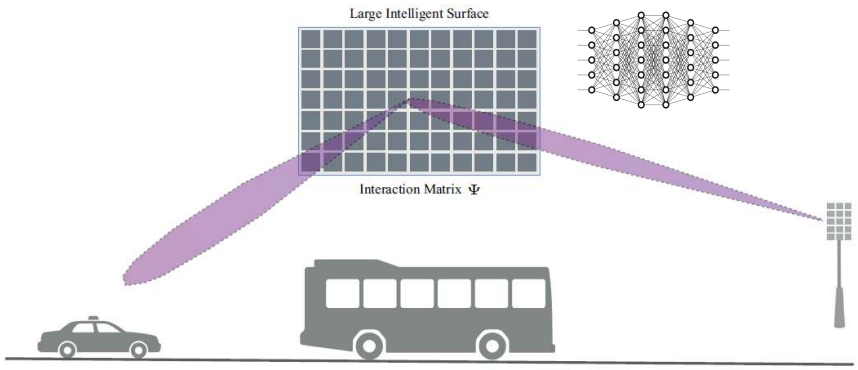
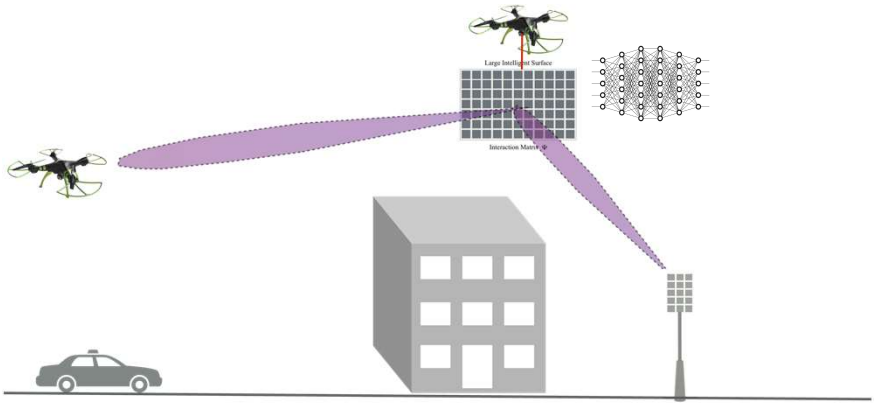
Reconfigurable Intelligent Surfaces (RISs)

- Reflect and focus the signals towards the intended receivers.
- Can enhance coverage in mmWave & THz systems in face of blockages.
- ML/DL to configure RISs for fast beam training, beam switching and handoff.
- In the process of fabricating sub6-GHz and mmWave RISs and integrating them with our 5G ecosystem testbed.





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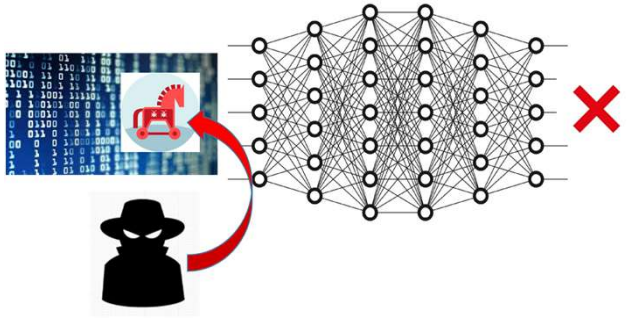
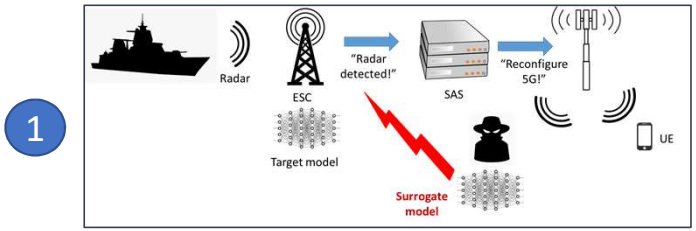
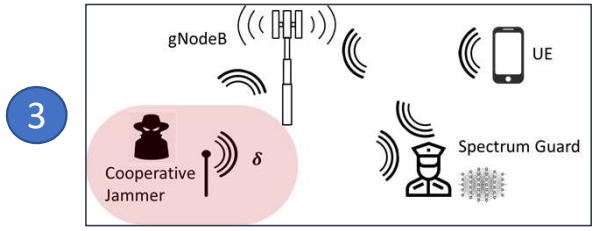
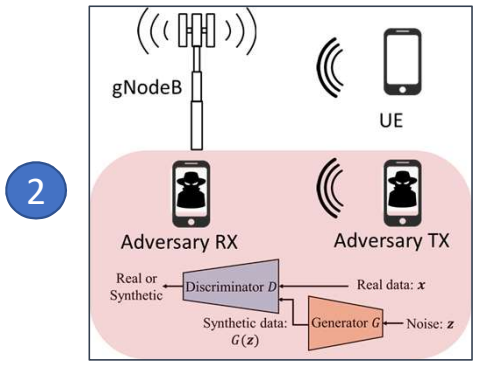
Adversarial ML as New Attack Surface for 5G

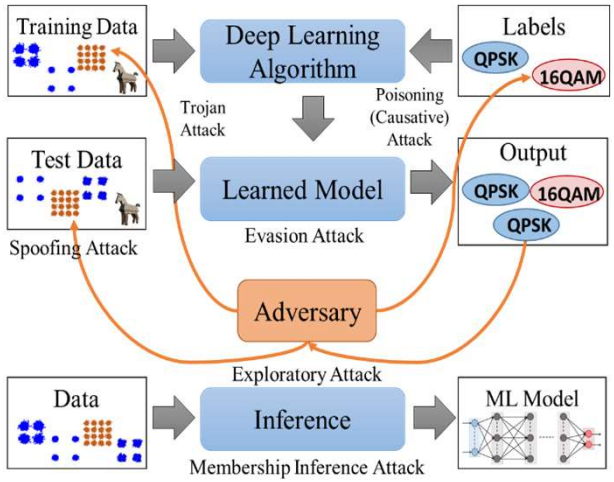
- Adversaries may **tamper with the learning process** and **fool deep learning algorithms** to make errors in decisions.
- Deep learning is sensitive to errors in training & test inputs.
  1. Fool environmental sensing capability (ESC) for 5G-incumbent spectrum sharing by manipulating spectrum sensing over the air.
  2. Fool ML/DL classifier for PHY authentication of 5G UEs.
  3. Generate covert 5G communications (not detectable by ML/DL).











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From Research to Transition

- Team of 50+ research scientists and engineers working on wireless communications, networking and security.
- Over 70 publications on 5G, ML/DL, wireless communications and security since 2015.
- Executed over 50 DoD projects in these areas since 2015.
- Executed numerous field tests (Ft. Dix, Stockbridge, Yuma, etc.).
  - Example: CyberBlitz field test of DeepRadio to detect wireless threats and configure tactical radios.
- IAI builds commercial products:

DEEP radio

DEEP ip
Deep Learning on FPGA Fabric

DeepCircuit
Configurable Deep Learning Framework on FPGA

Scraawl®
Actionable Insights from Analytics

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