“No one can whistle a symphony. It takes a whole orchestra to play it.”

WILL AI/ML REVOLUTIONIZE THE NEXT GENERATION OF WIRELESS COMMUNICATION?

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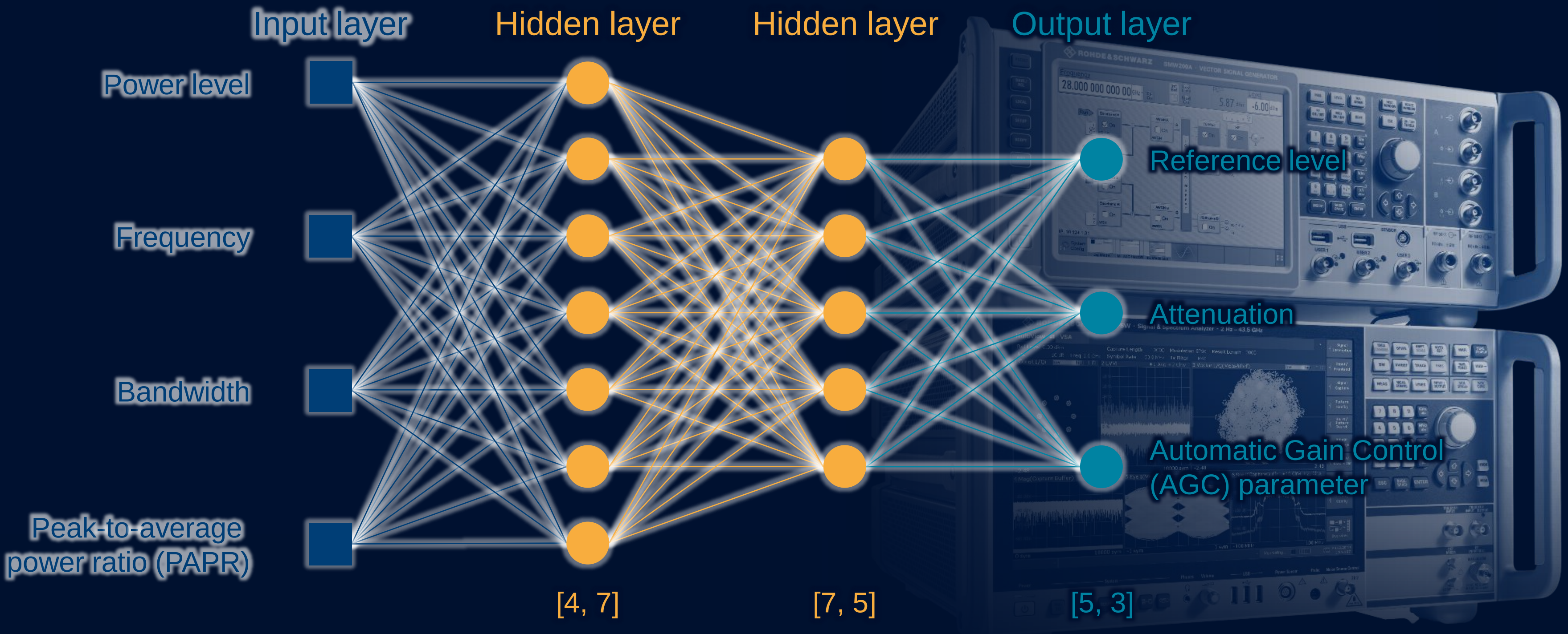
ROHDE&SCHWARZ

Make ideas real

AGENDA

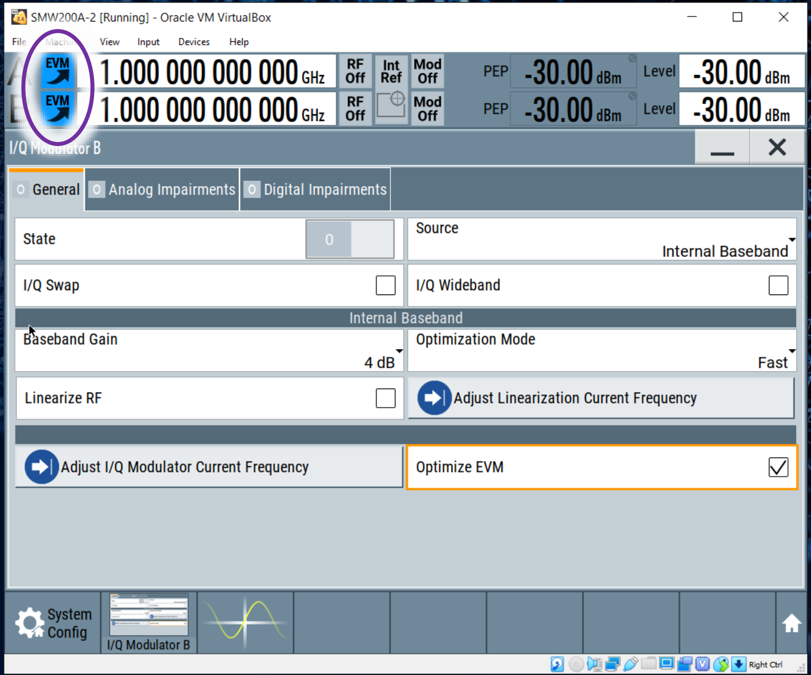
- Introduction and overview on 3GPP’s study items for AI/ML in Rel-18
- What role will AI/ML play in a future 6G communication standard? What is a neural receiver? Is there an evolution path?
- What role do test and measurement solutions play in this context?

MACHINE LEARNING IS BASED ON NEURAL NETWORKS (NN)
HOW ABOUT BEST ERROR VECTOR MAGNITUDE (EVM)?



DOING "MACHINE LEARNING FOR THE SAKE OF MACHINE LEARNING" MAKES NO SENSE

► Optimizing instrument parameters related to EVM by push of simple button (not ML-based!)



STUDY ON ARTIFICIAL INTELLIGENCE/MACHINE LEARNING IN 3GPP RELEASES

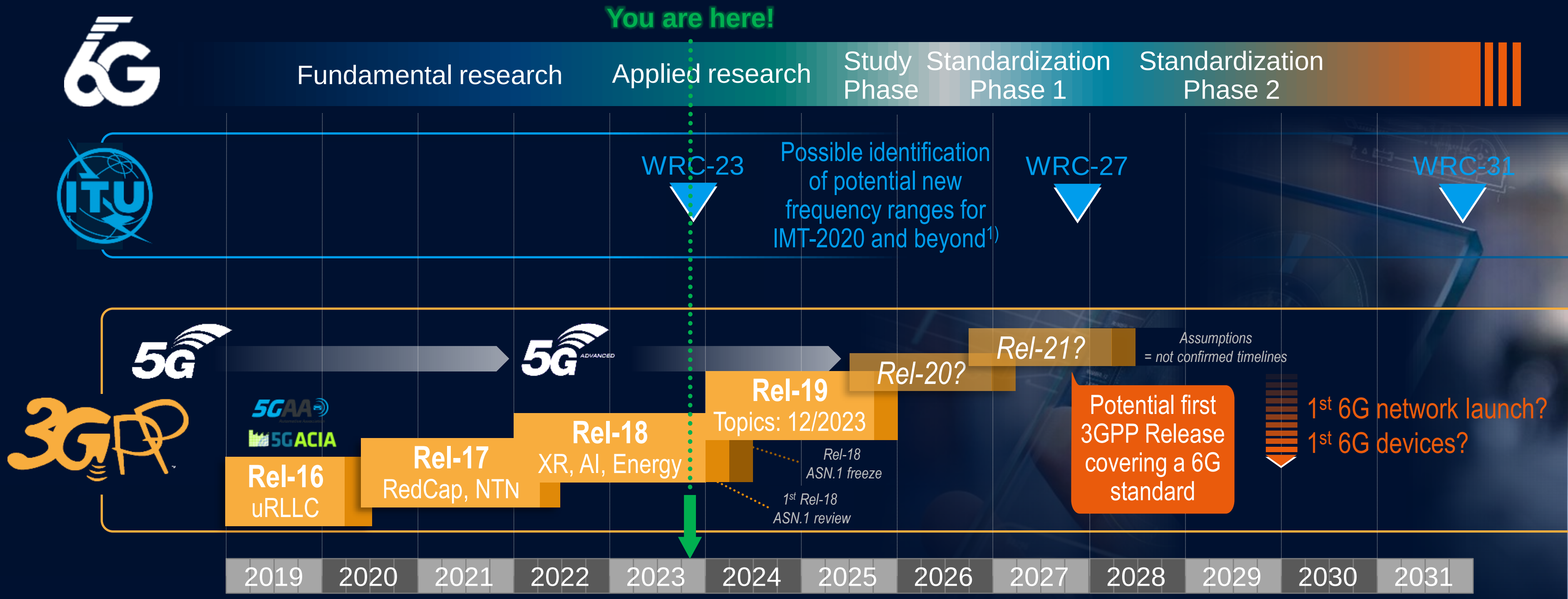
- AI/ML in 3GPP until "now" was mainly for data analytics:
  - 3GPP Rel-15/16/17: Network Data Analytics Function (NWDAF)
  - 3GPP Rel17: RAN3-led study on further enhancing data collection
- 3GPP Release 18: 5G-Advanced
  - SA1-led study on model transfer (TR 22.874), SA2-led study on 5G system support for AI/ML-based services (TR 23.700-80), SA4-led study on AI/ML for media (TR 26.927) and an SA5-led study on AI/ML management (TR 28.908); RAN3-led continuation based on findings in Rel-17 study item
  - AI/ML for NR air interface – 3GPP TR 38.843 V1.0.0 (2023-09)
    - Exploration of augmentation of the 5G air interface by AI/ML; study is scheduled throughout the complete release until the end of 2023, starting with three pilot use cases to assess performance in comparison to traditional methods and specification impacts:

    1. CSI feedback enhancements
       - Compression and prediction
    2. Beam management
    3. Positioning accuracy enhancements

Sources: https://arxiv.org/ftp/arxiv/papers/2305/2305.05092.pdf and https://www.3gpp.org/technologies/ai-ml-nr

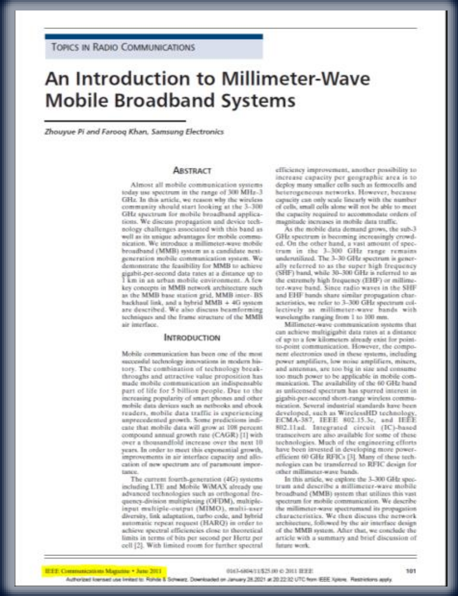
WHAT ROLE WILL AI/ML PLAY IN A FUTURE 6G WIRELESS COMMUNICATION STANDARD?

FIRST OF ALL: TIMELINES
FUTURE STANDARDIZATION AND REGULATORY ROADMAP



[1] *IMT-2020 systems are called 5G, The ITU has already started a new technology trend report to prepare the work on "IMT-2020 and beyond" that is likely to become 6G*

FIRST OF ALL: TIMELINES
IS THIS THE RIGHT TIME TO TALK ABOUT 6G? YES!


TOPICS IN RADIO COMMUNICATIONS

An Introduction to Millimeter-Wave Mobile Broadband Systems

Zhouyue Pi and Farooq Khan, Samsung Electronics

ABSTRACT

INTRODUCTION

IEEE Communications Magazine • June 2011

The support of mmWave was one of the revolutionary elements in 5G!

~4 years

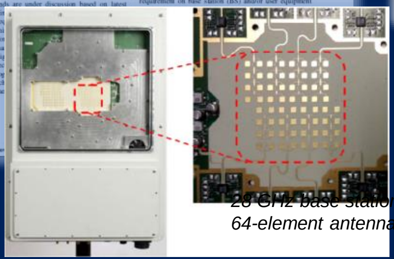

Millimeter-Wave Base Station for Mobile Broadband Communication

Farshid Aryanfar, Jerry Pi, Hongyu Zhou, Thomas Henige, Gary Xu, Shadi Abu-Surra, Dimitris Psychoudakis and Farooq Khan

Samsung Research America, Richardson, TX, 75082

I. INTRODUCTION

II. SYSTEM OVERVIEW


28 GHz base station with 64-element antenna array

~4+ years

5G

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5783993 (June 2011)
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7166778&tag=1 (June 2015)

6G RESEARCH AREAS FROM A T&M PERSPECTIVE

THz and "FR3"

Joint communication & sensing

Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces

Photonics, Visible Light Communication

Multiple access, new waveforms, channel coding

Ultra-massive MIMO

New network topologies, distributed computing

Full-duplex communication

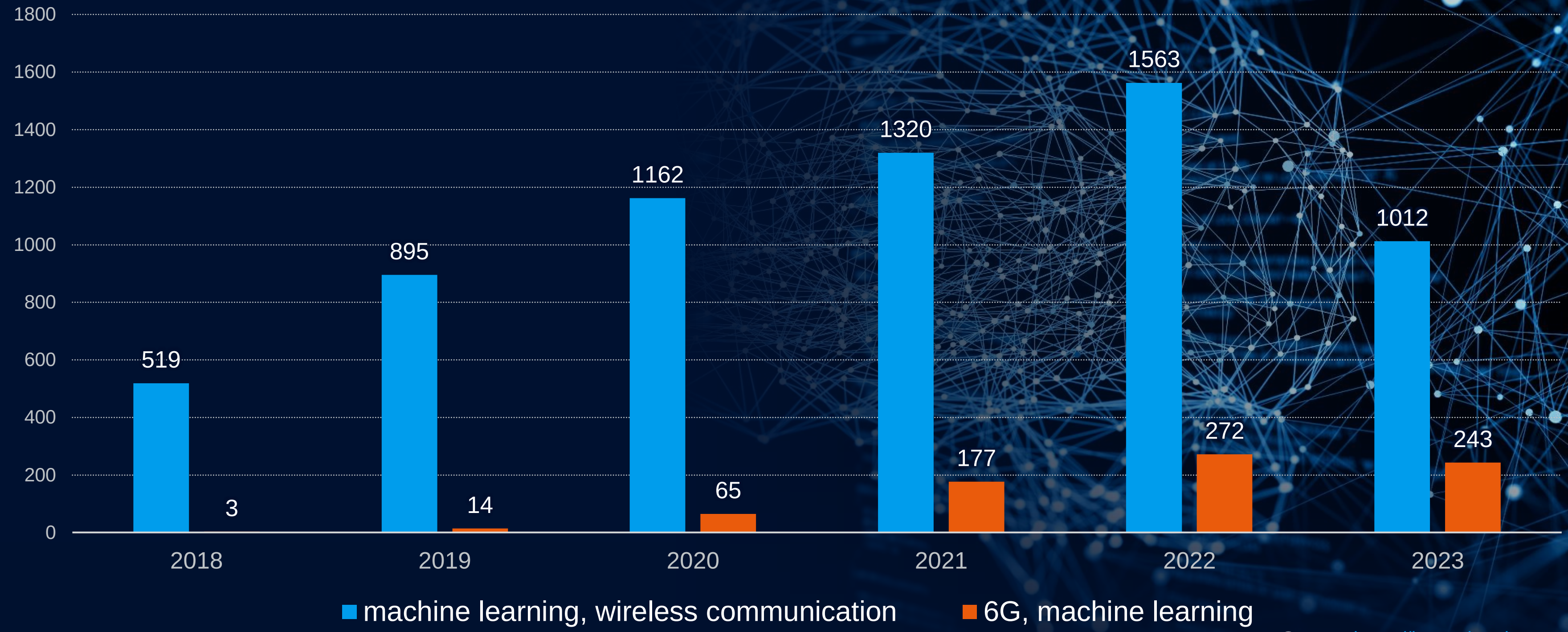
Security & Trustworthiness

A high-level overview of all these research areas is provided in one of our #THINKSIX videos.

6G RESEARCH AREAS FROM A T&M PERSPECTIVE

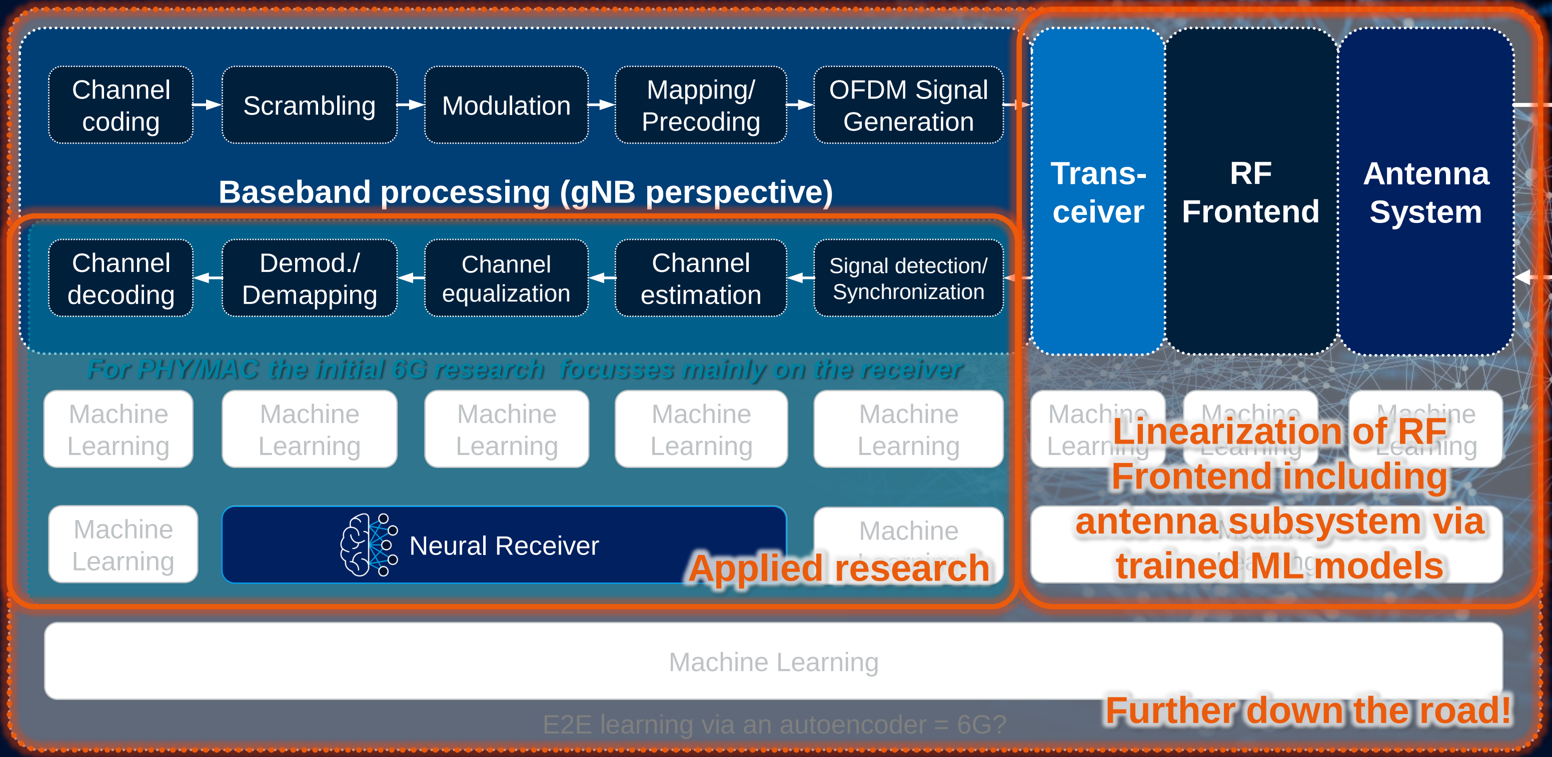
A high-level overview of all these research areas is provided in one of our #THINKSIX videos.

NUMBER OF PUBLICATIONS IEEE *Xplore*®



Source: https://ieeexplore.ieee.org/

TOWARDS AN AI-NATIVE AIR INTERFACE FOR 6G



ML applied to individual processing blocks

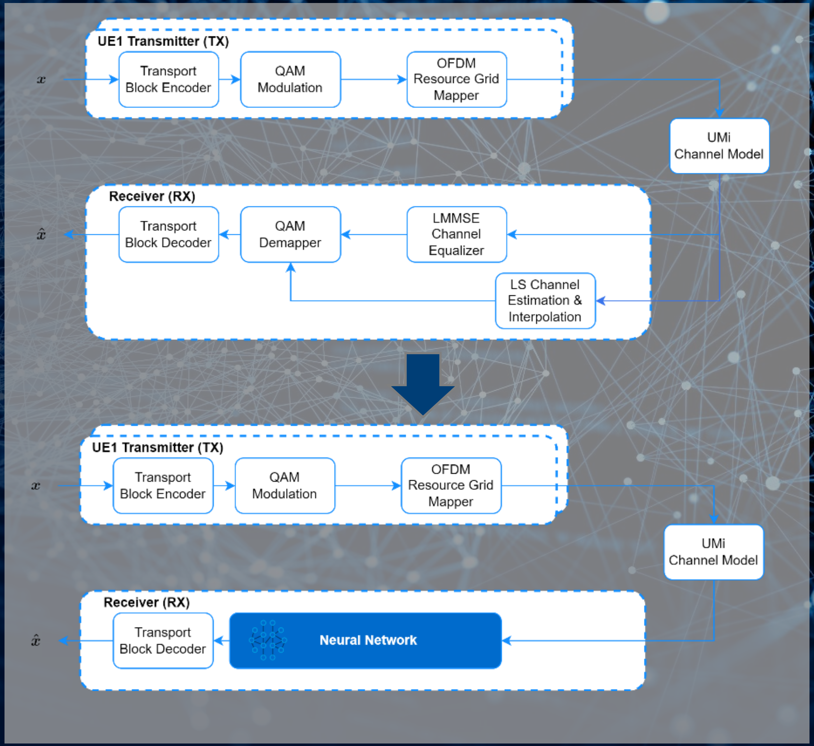
ML replaces multiple processing blocks

ML used to jointly optimize TX, RX and baseband processing;

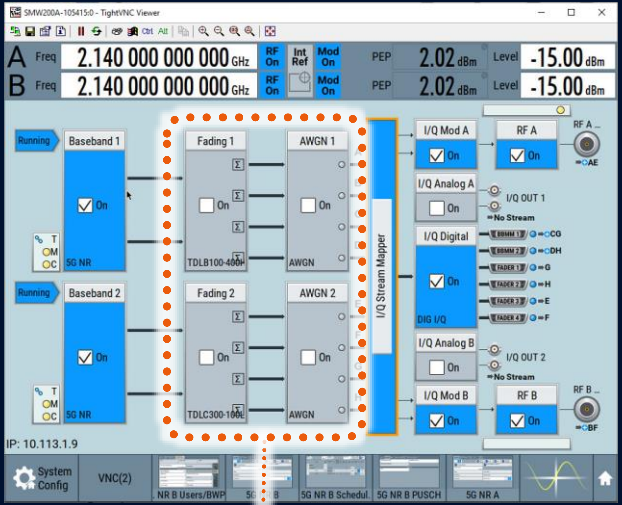
ML designs part of 6G PHY/MAC itself

NEURAL RECEIVER TESTBED

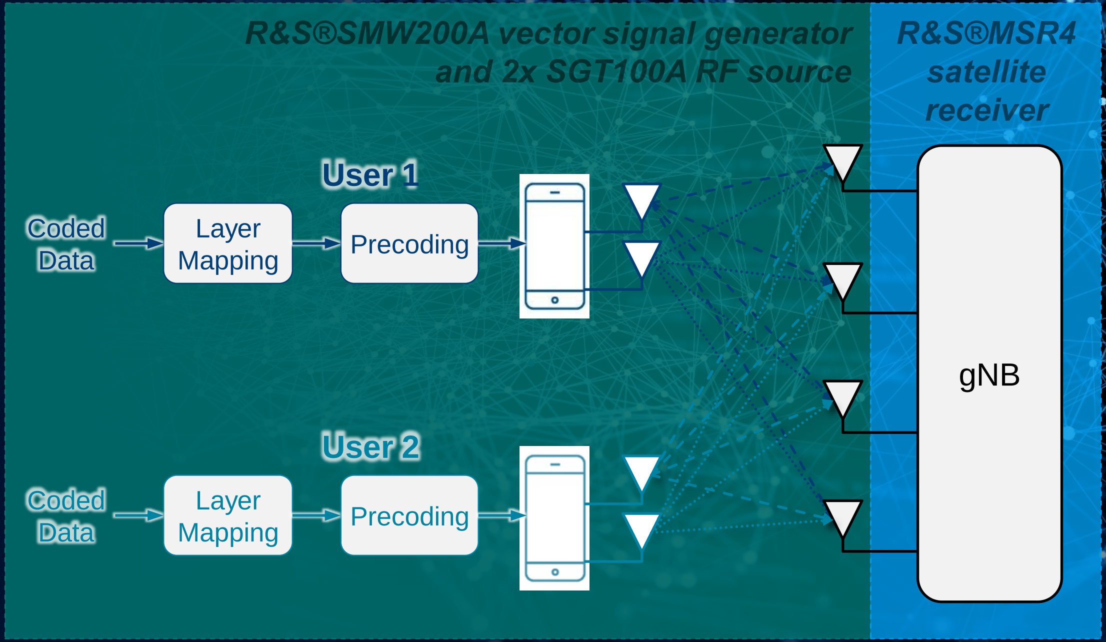
- Neural receiver: replacing conventional Digital Signal Processing (DSP) by AI/ML models
- Partnered up with **NVIDIA** to build industry-first neural receiver testbed
- 5G NR signal generation, receiving, pre-processing by **Rohde&Schwarz test & measurement solutions**
- Design of a neural receiver based on NVIDIA's **SIONNA™** open software framework: MIMO detection, channel estimation, equalization, demapping



TEST SCENARIO: 5G NR PUSCH MU-MIMO
NUMBER OF USERS, MIMO MODE AND NUMBER OF LAYERS

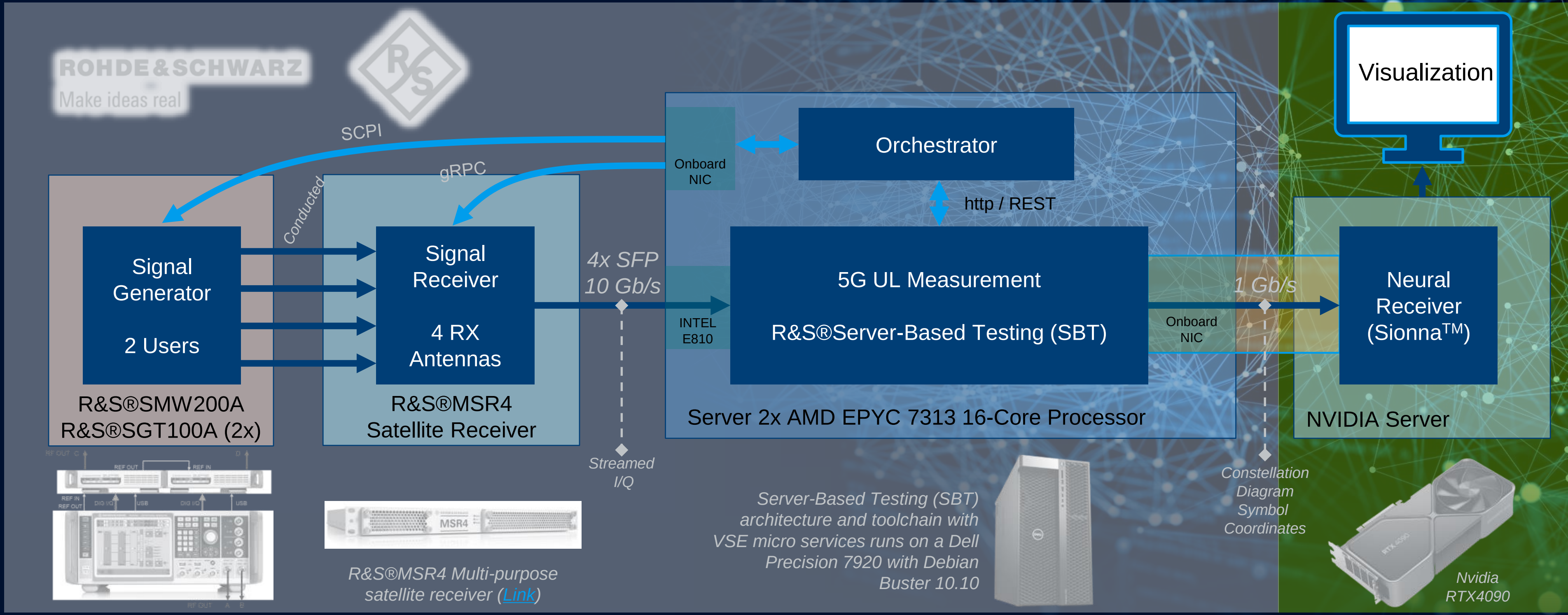


Both users independently faded, independent noise settings

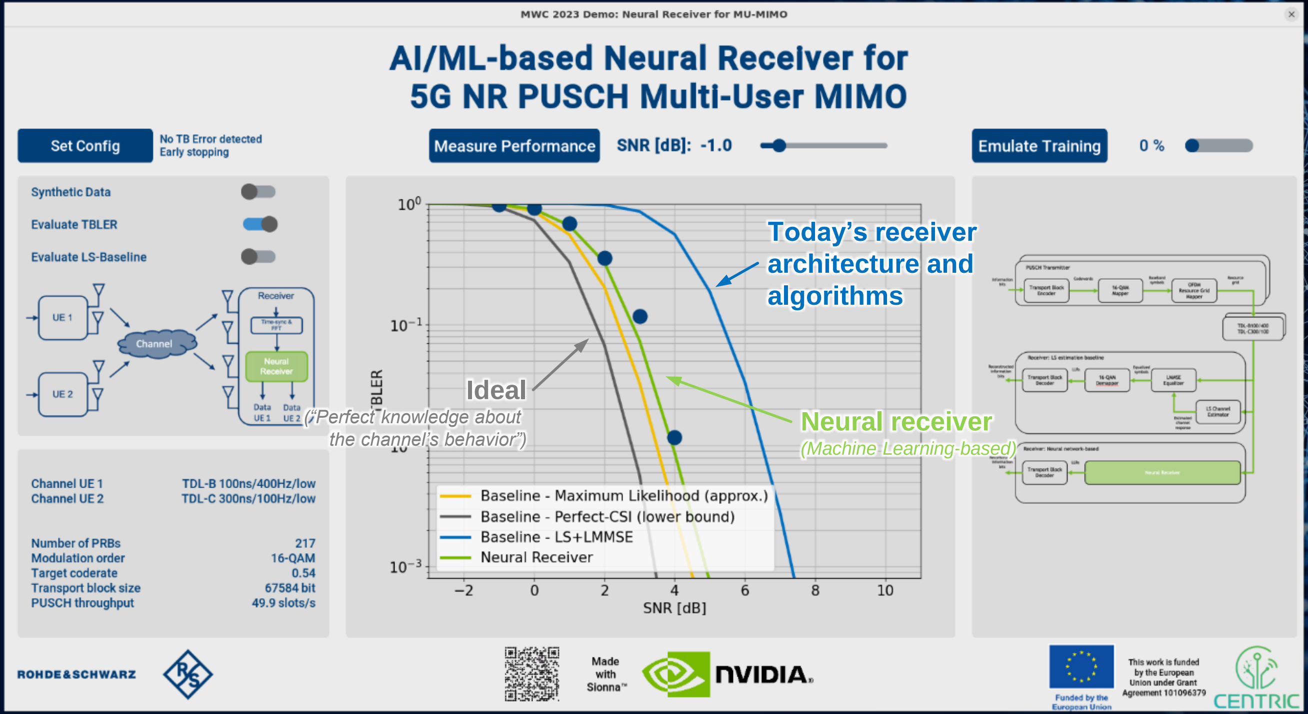


Both users transmit simultaneously on 80 MHz signal bandwidth (PRB 217), 16QAM modulation
DMRS symbols 2 and 11, User#1 on even-numbered subcarriers, user#2 on odd-numbered subcarriers

NEURAL RECEIVER TESTBED
DEMONSTRATED @ MWC BARCELONA 2023



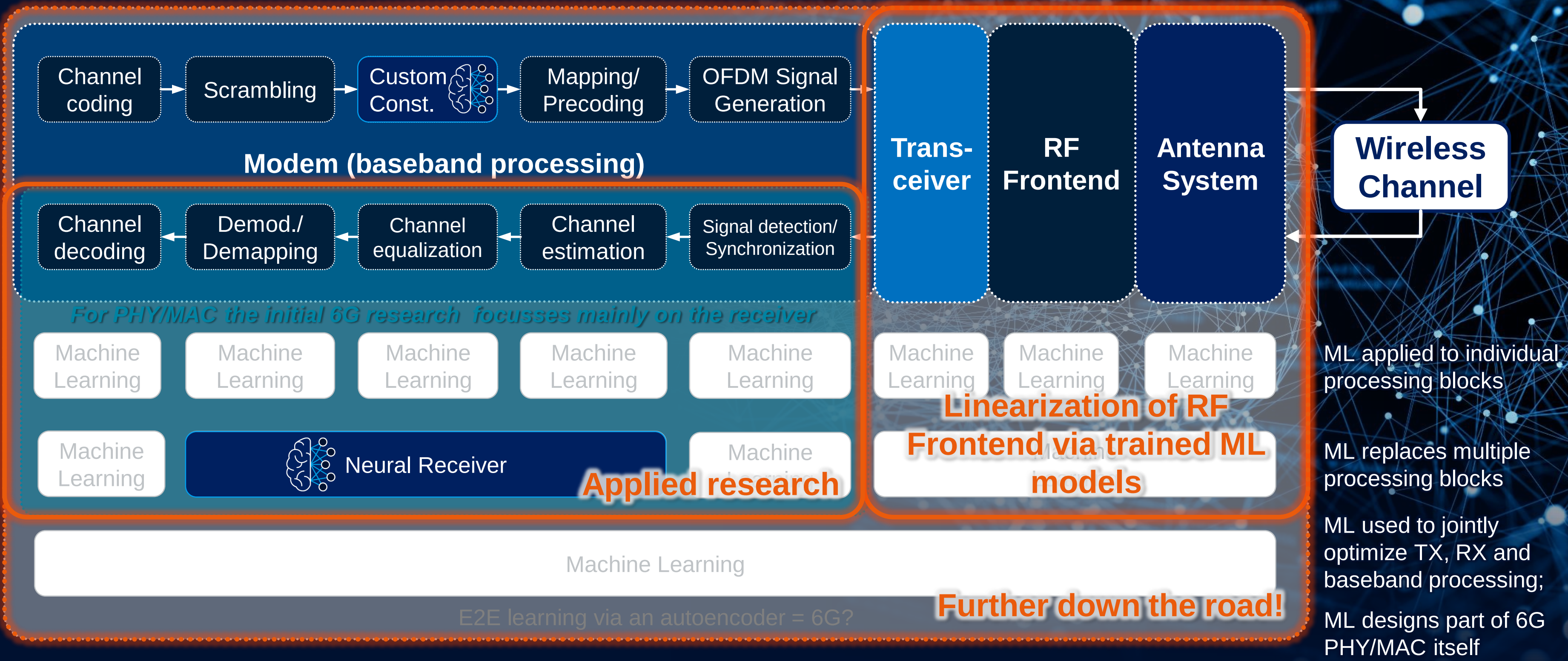
HARDWARE-IN-THE-LOOP VALIDATION OF A NEURAL RECEIVER IMPLEMENTATION



6G NEURAL RECEIVER TESTBED
APPLICATION VIDEO

► YouTube link: https://youtu.be/BQyxBYzdg5k

ENHANCING THE NEURAL RECEIVER?
TOWARDS AN AI-NATIVE AIR INTERFACE FOR 6G



6G NEURAL RECEIVER TESTBED DEMO

ADOPTION OF AI/ML WILL REQUIRES ADAPTATION OF NEW TESTING METHODOLOGIES AND TEST PROCEDURES

- 3GPP Rel-18 and 19 lay the foundation for an AI/ML framework in 3GPP that 6G may build on.
- We demonstrated first promising results of replacing traditional signal processing blocks and classic signal processing algorithms with trained machine learning models
- Still a long way to go; several research challenges are currently under investigation by multiple research projects worldwide, e.g.:
  - Processing power, power consumption, etc.: implementation in GPU vs. FPGA or ASIC?
  - Training with synthetic data only? How to move to entirely real-world data-driven models?
  - Wireless radio channel characteristic representation in the form of fading profiles vs. real-time channel
  - Local adaptation of default models: “online training” in the field = site-specific neural receiver model
- The R&S testbed for neural receiver can help to validate performance of initial concepts before putting them into silicon.

THANK YOU!
QUESTIONS?

“No one can whistle a symphony. It takes a whole orchestra to play it.”

Halfrod E. Luccock (1885-1960)