

AI in the Air Interface: Promises and Challenges

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Artificial Intelligence : What is it and why is it important

- **Act Humanly:** The Turing Test
 - A human asks a machine questions and cannot tell if it's a machine
- **Think Humanly:** The Cognitive Modeling Approach
 - Requires that we understand how humans think
- **Think Rationally:** The “laws of thought” Approach
 - This study initiated the field of Logic
- **Act Rationally:** The Rational Agent Approach
 - Acts to achieve the best outcome (even in cases of uncertainty)



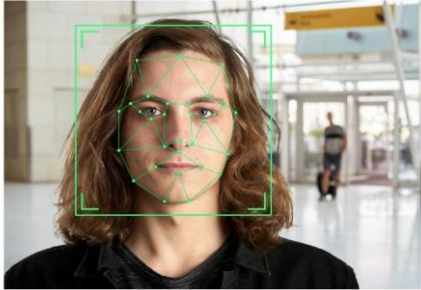
- Will scale over time and disrupt many industries
 - Like the transistor or internet search
- Enables broad access to technology and computing.
- Understandable, less rigid interface.
- The most important coding language may become ... colloquial spoken language
- Major industry segments are automating many expensive activities e.g. coding, customer service, medical image interpretation.

- Potential for creative innovation for/by non-technical people
- Can scale rational action in unreachable locations .. like space, or inside a human body..
- Will help the least skilled and accomplished workers the most, decreasing the gap between employees
- Economists are predicting it will add trillions of dollars to world GDP

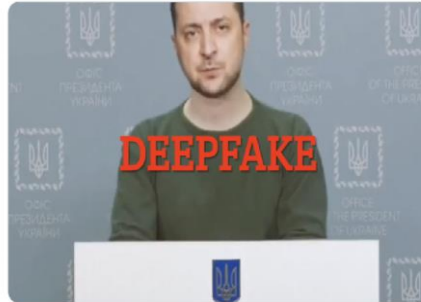
**The Foundations of Artificial Intelligence by Stuart Russell*

State of the Art

Image & Video



Facial Recognition Systems now have close to 100% accuracy

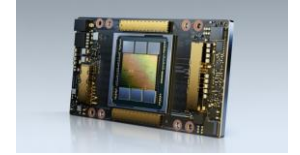


Deepfake creation and detection is a cat-and-mouse game



How many slices of pizza are there?
Is this a vegetarian pizza?

Rise of the GPU



- Dramatic improvements in size, performance and cost
- The use of AI to design better GPUs !
 - An example of AI reinforcing AI

Text Generation

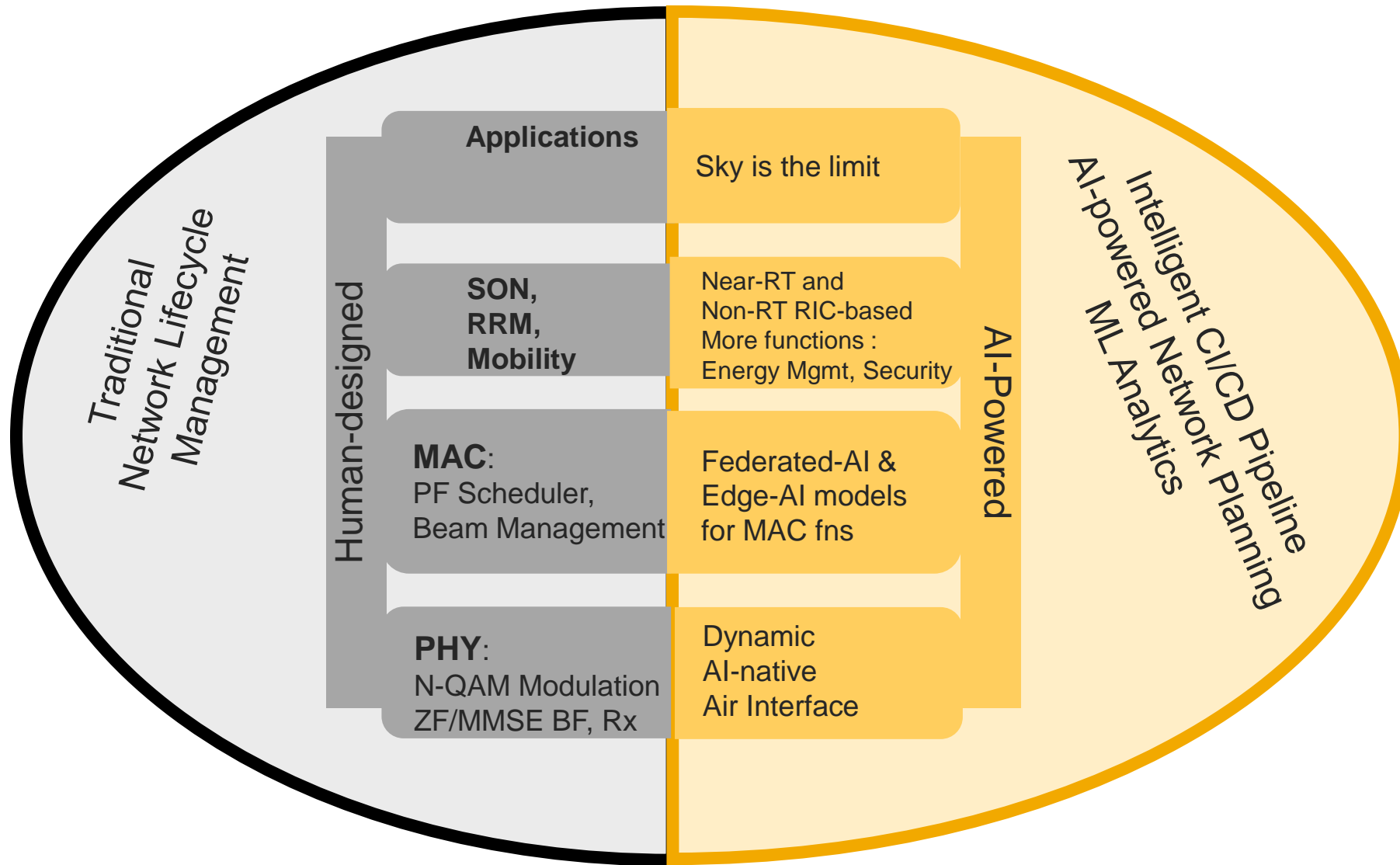
Explain to me the major accomplishments of Theodore Roosevelt's presidency.

- Large Language Models have progressed tremendously in just 3 years
 - GPT-2 (2019) - gibberish
 - GPT-3 (2020) – logical, with many factual errors
 - Chat-GPT (Nov 2022) – Accurate, still suffers from some hallucination

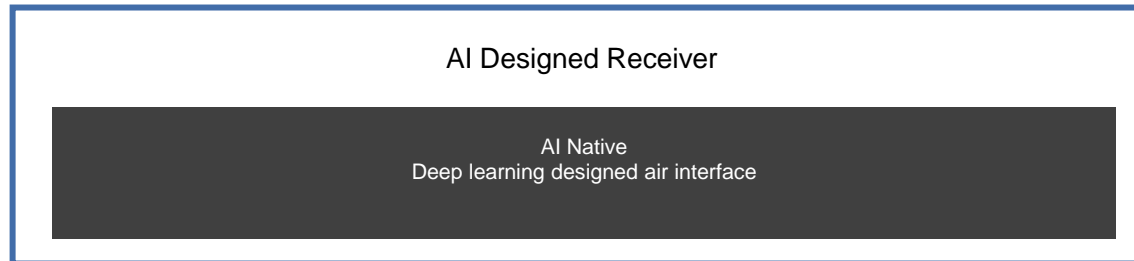
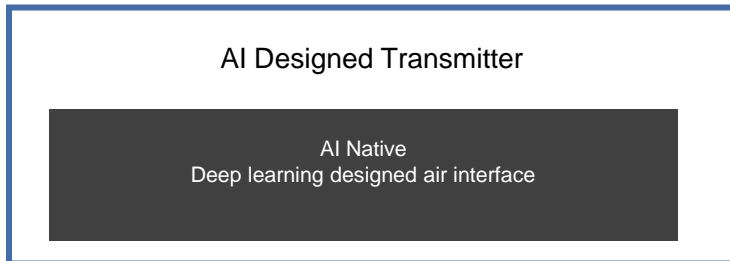
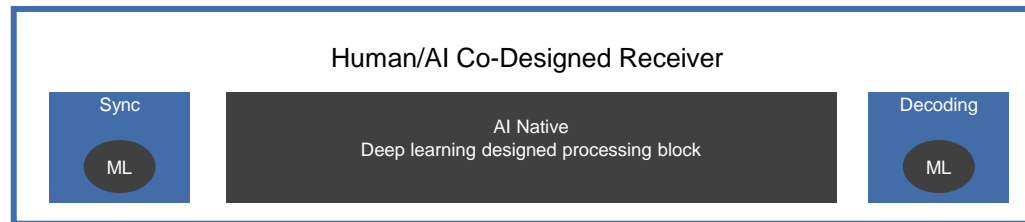
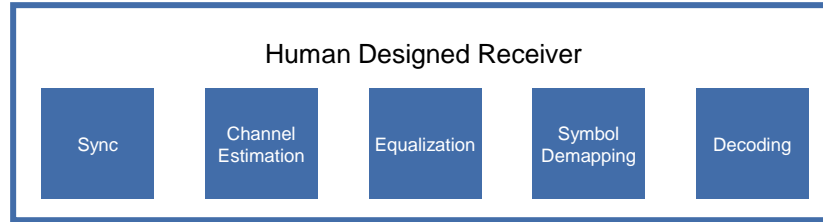
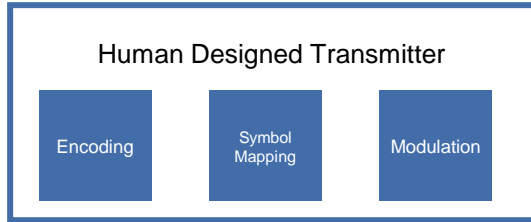
Language

- “No Language Left Behind” is capable of translating across 200 languages
- The Indic Language Translation has been a major recent accomplishment

Paradigm Shift in Wireless Comm: The Promise of AI

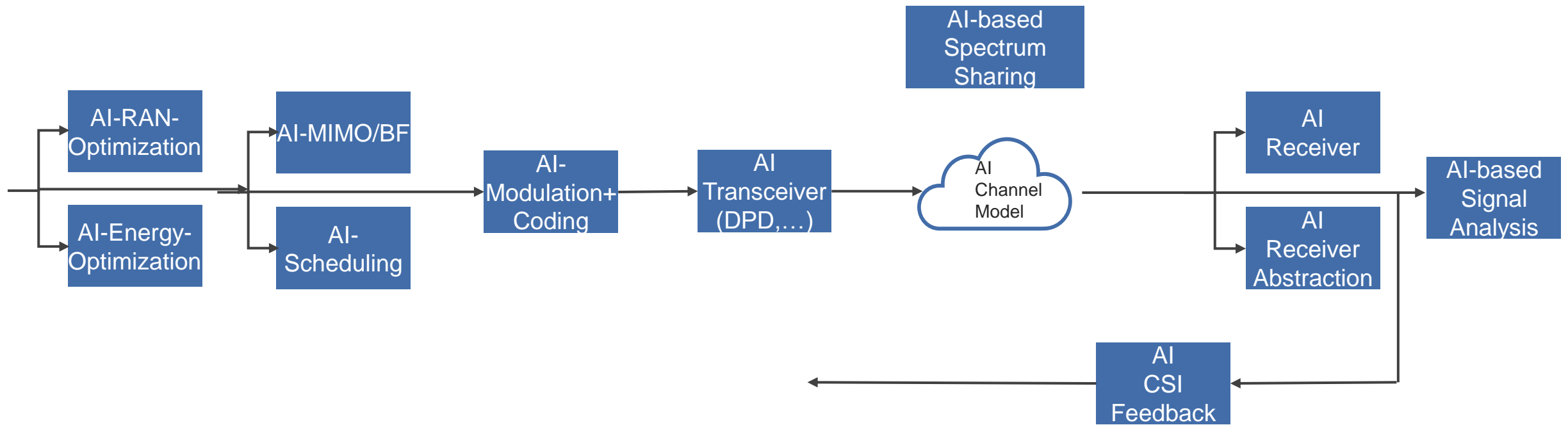


AI in the Air Interface

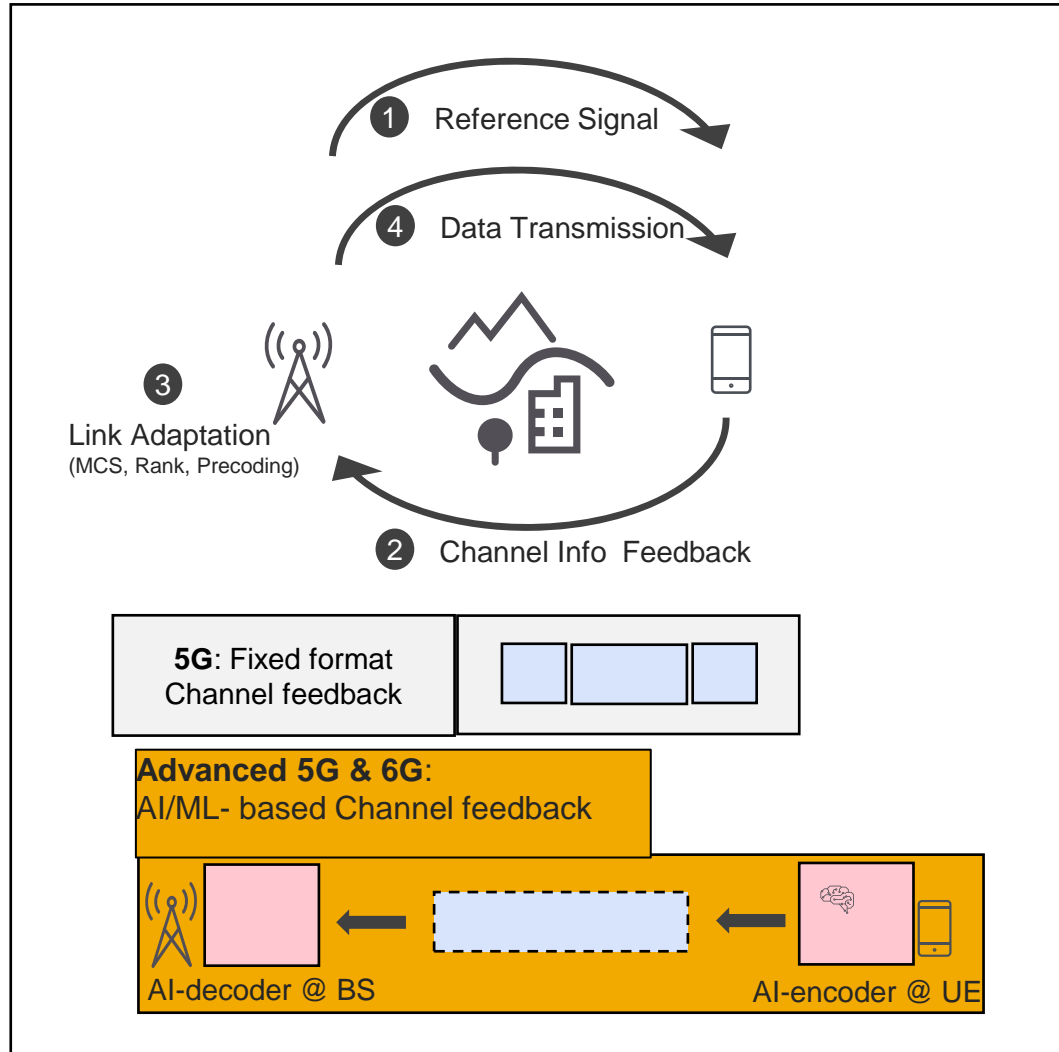


6G ?

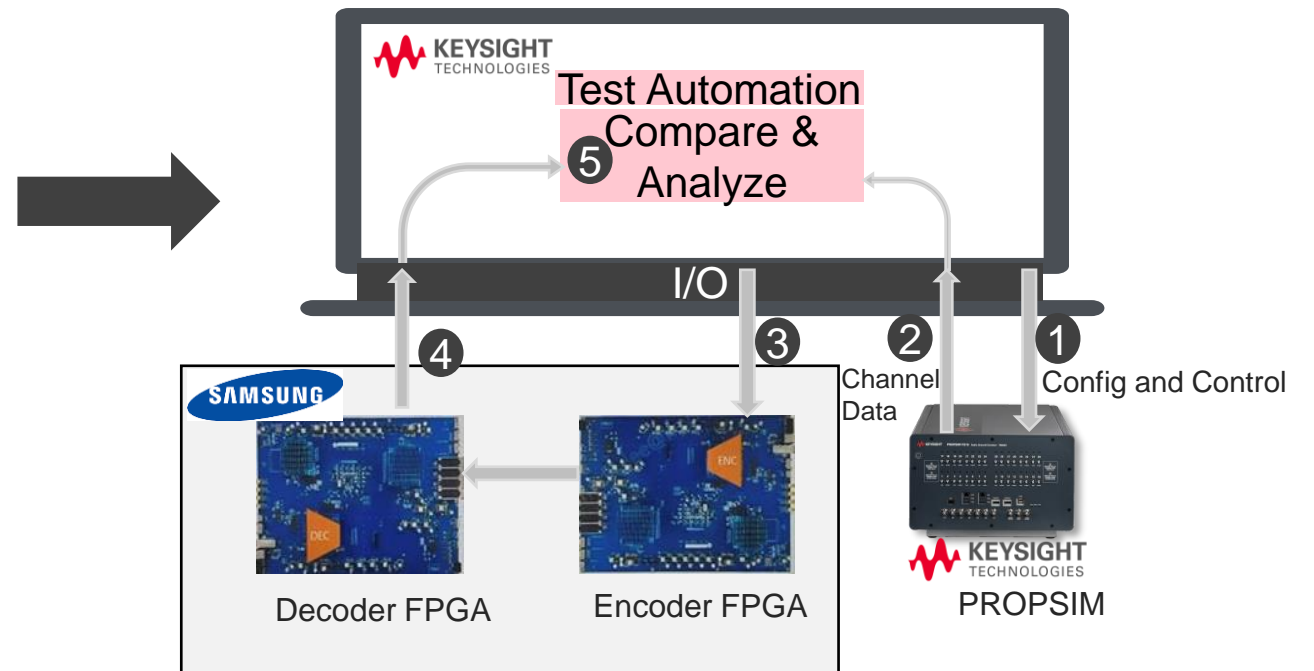
The diverse facets of AI in the RAN and air interface



Global Collaboration a must for success in AI Technologies



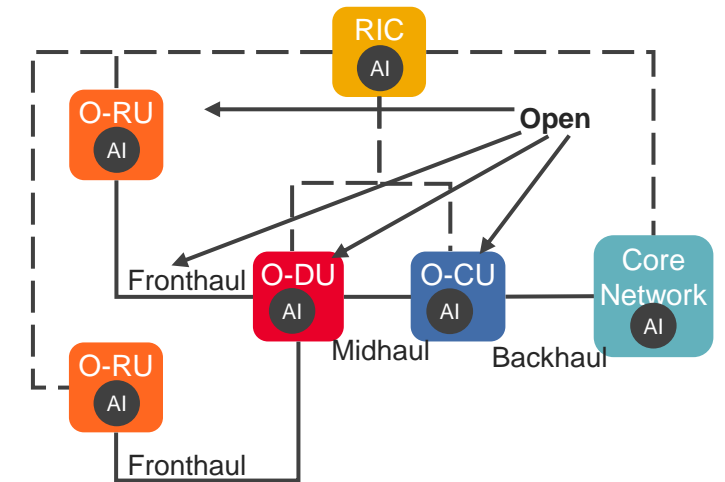
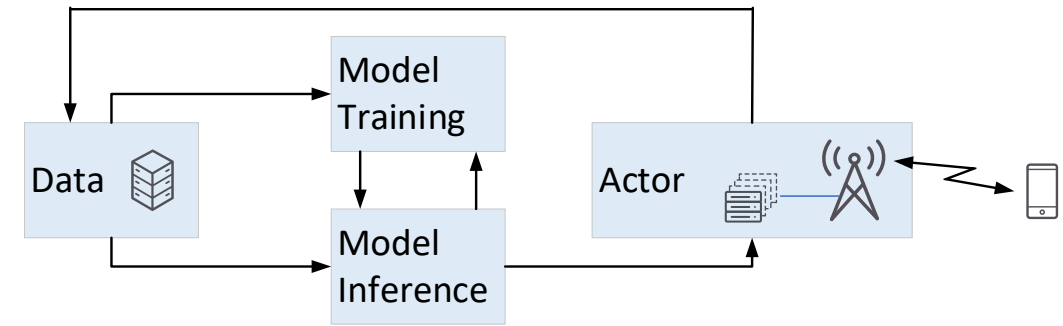
Keysight & Samsung collaboration was successful in creating a framework to demonstrate and study AI-based CSI-Compression



Many more such collaborative efforts are planned for 6G Technologies

AI/ML In the Network

- Tremendous complexity in wireless systems => no closed analytical models that are solvable with reasonable computing power / time
 - RAN optimization problems are ripe for AI/ML solutions
- New nodes in disaggregated RAN to enable AI/ML approaches to network optimization
 - Near RT-RIC (xAPP), Non-RT-RIC (rAPP)
- AI-native architecture being planned, both in HW and SW
 - AI-friendly HW arch for DU, CU
 - Enabling Edge AI, Distributed & Federated AI models
- Large array of use cases where AI/ML approaches are being attempted
 - RAN Performance
 - Energy efficiency
 - Mobility and handover
 - Application latency / jitter
 - Scheduling
 - Beam Management
 - Massive MIMO
 - 6G ?
 - Security
 - Data Poisoning
 - Rogue Network Element Detection
 - Threat pattern analysis
 - FCAPS / Analytics
 - Network/RF/Spectrum planning
 - Root Cause Analysis
 - Troubleshooting
 - Anomaly detection



Standards' Discussions

3GPP Study Item	Inputs	Outputs	Models Used
Beam Management	L1 RSRP of set B + and beam information	Predictions of all beams	CNN, DNN, Fully Connected, U-NET
Positioning Accuracy	CIR	TOA	CNN
CSI Optimization	SVD of sub-band/Channel Normalization	Precoding Vector per SB	Transformer, EVCSInet, CNN

3GPP RAN4 Major topics

- Interoperability and testability of AIML for NR air interface
 - How do different vendors incorporate Test Equipment Vendors, and model obfuscation?
- General aspects of AIML for NR air interface
 - Data Collection for training and inference, how to do it?
 - What are performance testing goals?
 - What are KPIs for the RAN1 study items, which are specific to the study items

The Contours of the AI/ML Solution

Type of Learning

- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning
- Deep Learning
- Transfer Learning
- Federated Learning

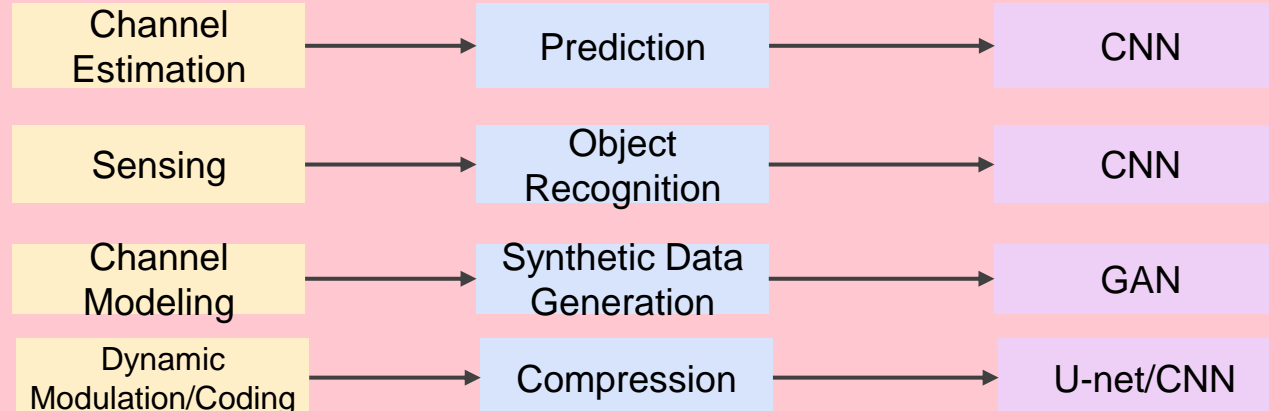
Type of Outcome

- Prediction
- Classification
- Anomaly detection
- Pattern / Object Recognition
- Natural Language Proc.
- Recommender System
- Generative AI

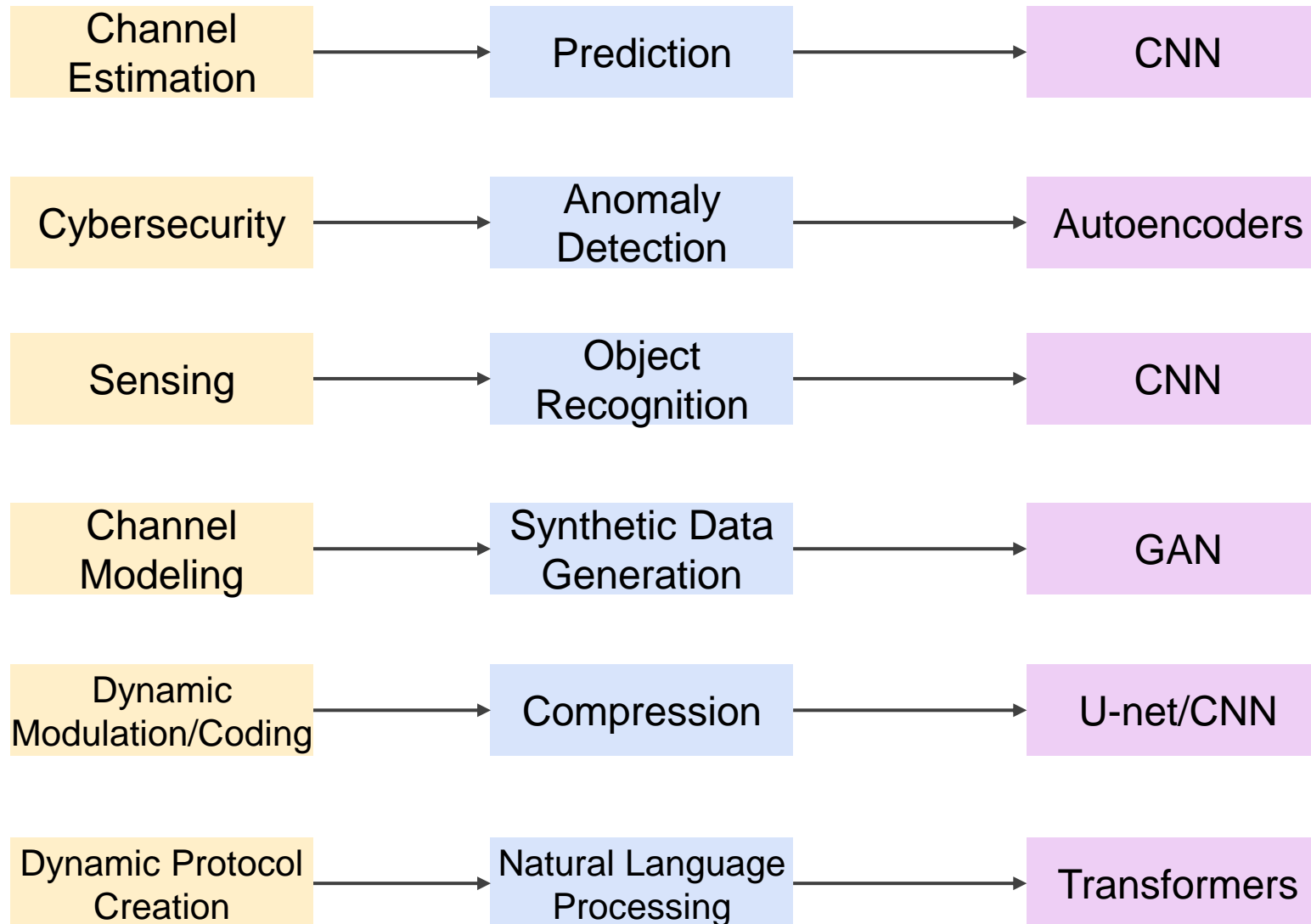
Type of Model

- CNN (Convolutional Neural Network)
- Transformers
- Auto-encoders
- GAN
- Diffusion

Some exemplary use-cases

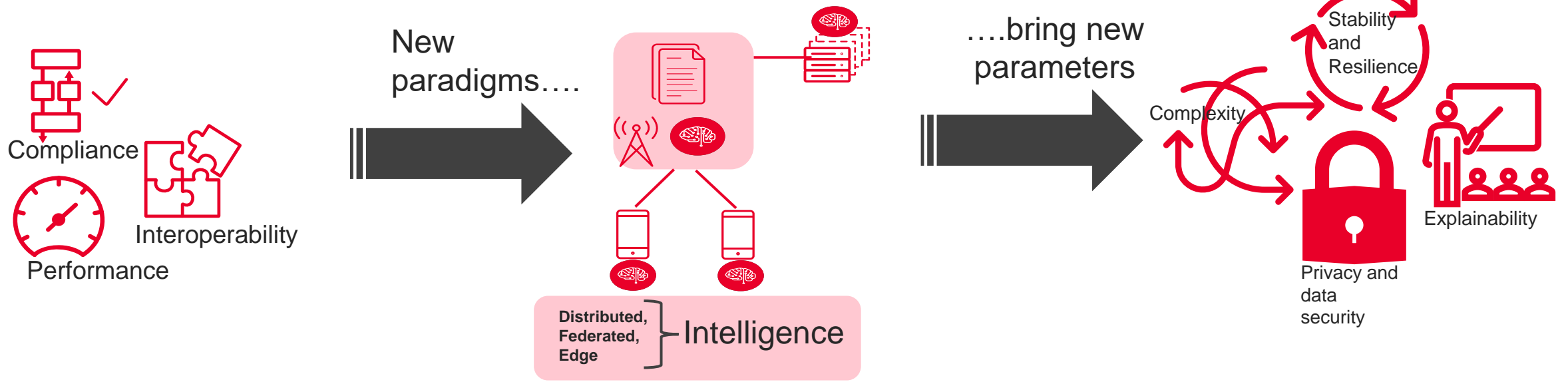


ML Tasks with Communications



Test and Measurement in an AI world

99% of resources used to build AI
< 1% go to testing AI .
Dr. Hinton thinks it should be 50-50



Challenges for AI/ML in the RAN

- Selecting the truly useful applications of AI from the 'hype' cycle is important
- Lack of data availability slows down innovation
- Inter-vendor cooperation and inter-working mechanism still unclear for AI-based systems
- Generalization of ML over dynamic conditions
 - i.e. How curated does the model need to be based on the conditions observed at the edge?
- Lack of well described and well understood test methodology

