Building the foundations of 6G

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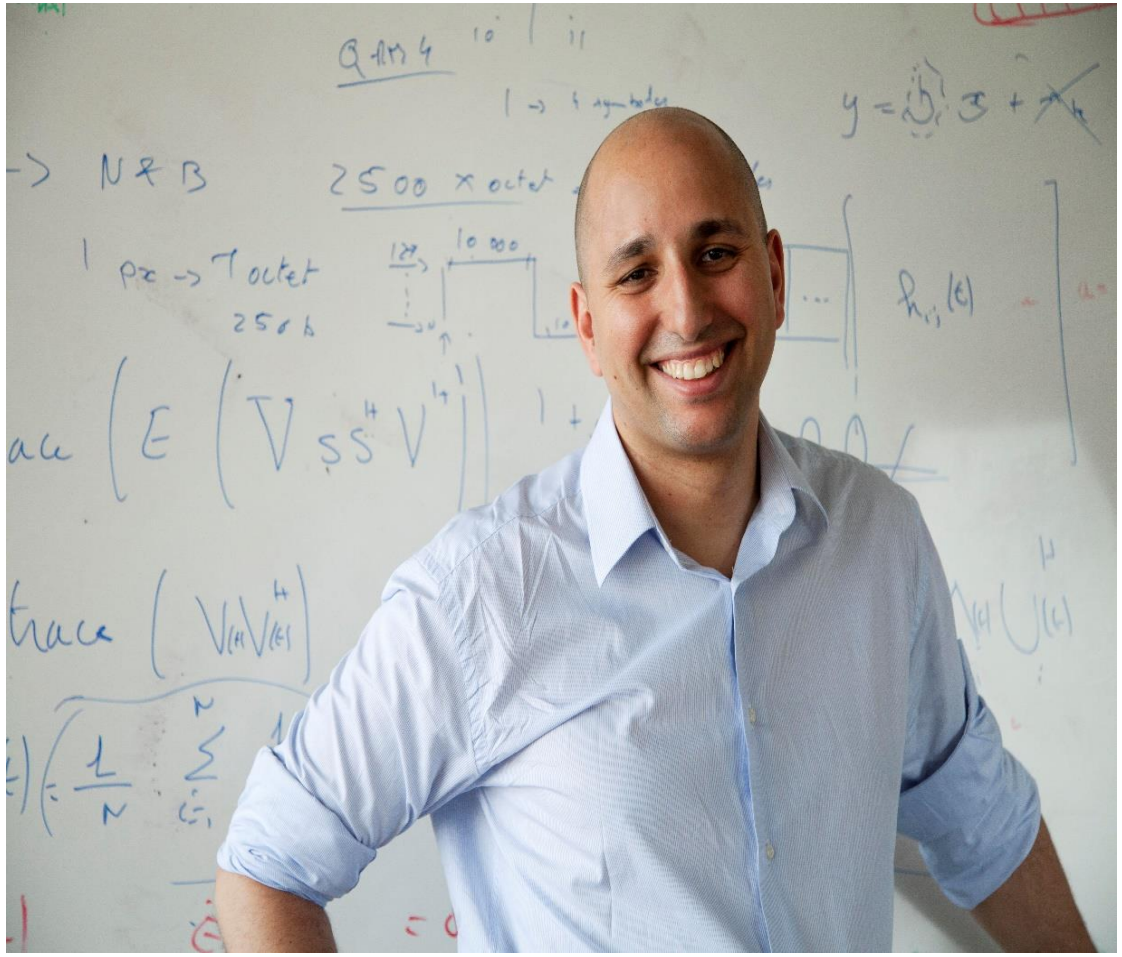


About the Researcher

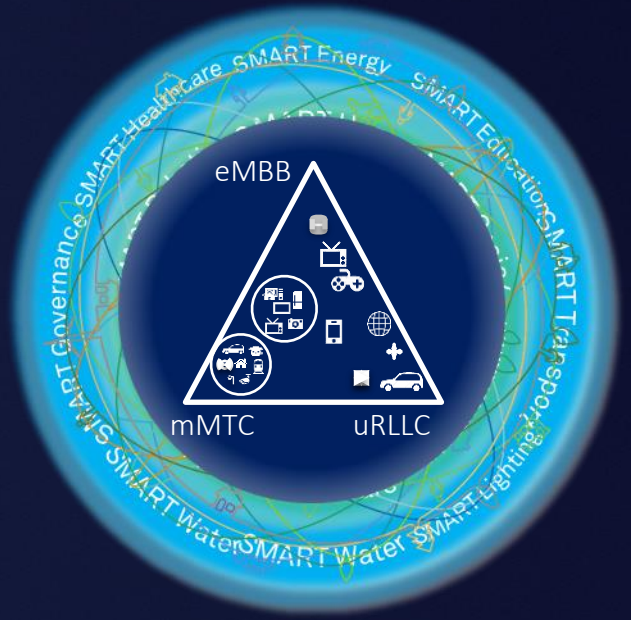
- Chief Researcher at the Technology Innovation Institute
- Professor at CentraleSupelec
- IEEE, EURASIP and WWRF Fellow
- Citations: 50000+, h-index: 100
- More than 20 Best papers Awards
- IEEE Signal Processing Society Distinguished Industry Speaker (2021-2022)
- Field of Research: 5G and beyond and AI

The 3rd Paradigm Shift of Mobile Industry is Going to Happen

198x

200x

2020~



Voice Era (1G)

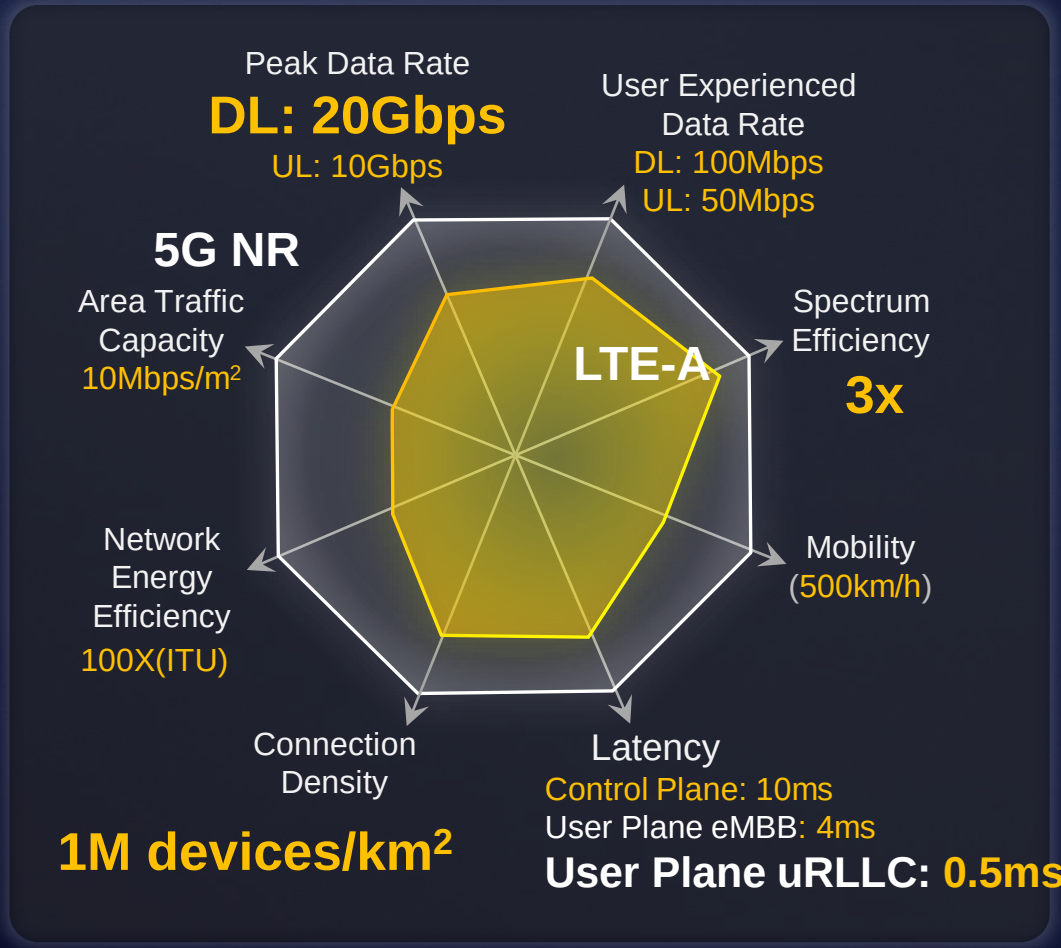
MBB Era (3G)

Super Connected World (5G)

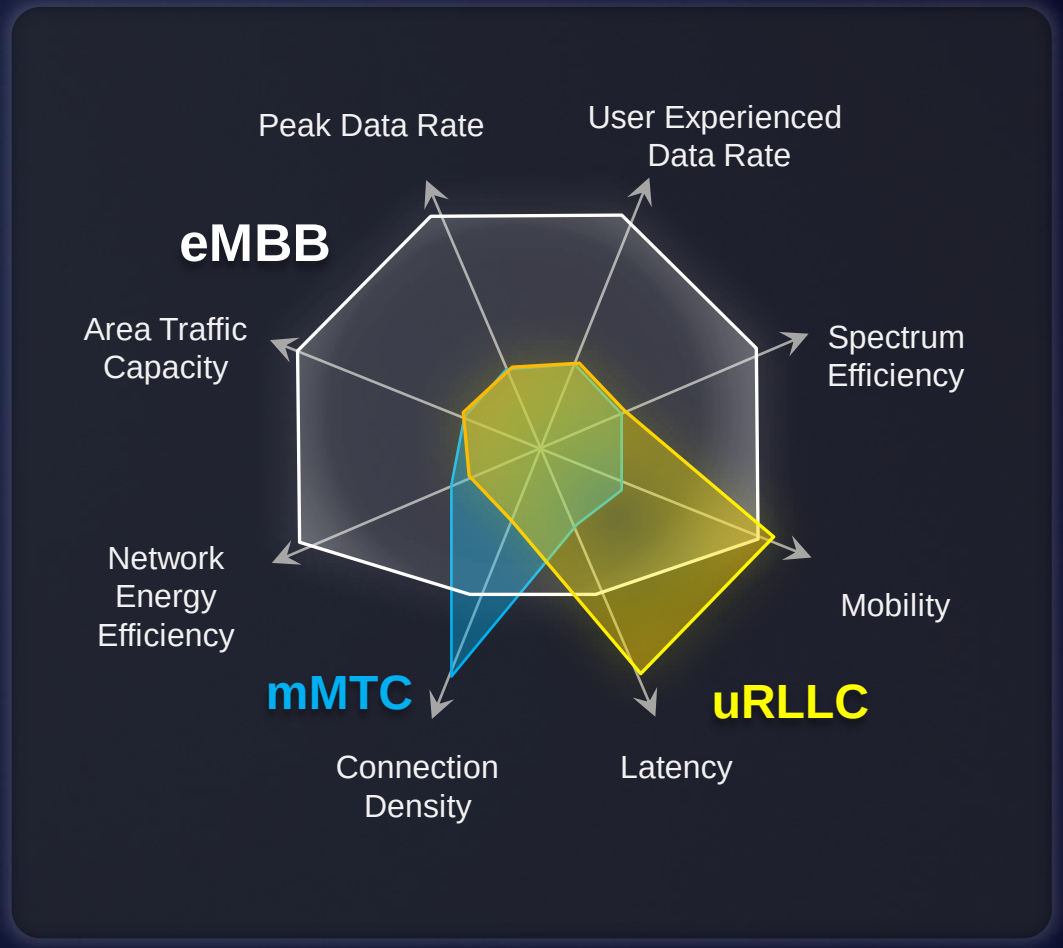
		eMBB + uRLLC + mMTC
Connectivity as a Service		Network Slice as a Service

5G Capability Requirements Defined by 3GPP

3GPP Standardization Targets for 5G NR



Requirements of Different Services



Source: 3GPP TR 38.913

R15 Enables Ultimate User Experience on eMBB

R15 Builds the Foundation of Commercial 5G Networks

2015 2016 2017 2018 2019 2020

RAN #80

2018.06.14
R15 frozen

R15：eMBB

R15 NSA | R15 SA | R15 Late Drop

R16：All ITU Scenarios (eMBB, uRLLC, mMTC)

R16

Key 5G Features of Release 15

5G Bandwidth
C band：~100MHz
mmWave：~400MHz

NR Air Interface
f-OFDM, Polar Code, LDPC,
UL & DL decoupling

Massive MIMO
4T4R->64T64R
CRS Free, Full Channel BF

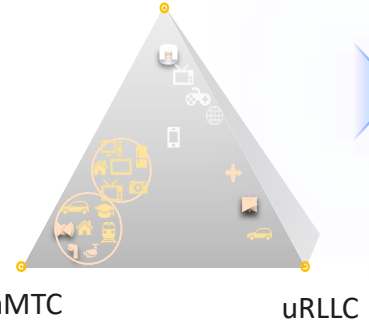
eMBB Devices
2T4R as >2.6GHz Basic
Config. HPUE with 26dBm

X 10
User Experience

X 20~30
Cell Capacity

- **5.5G is on the road…**

5G



eMBB
- Mobile video
- FWA

UCBC

Uplink centric broadband communication
- HD video uploading
- Machine vision

RTBC

Real-time broadband communication
- XR pro
- Holographic

Spectrum
(<100 GHz)

mMTC
- REDCAP
- NB-IoT

URLLC
- Reliability & latency
- IIoT-Adv

HCS

Harmonized communication and sensing
- V2X
- Positioning

Hundreds of billions of connections over 5G

XR pro

V2X

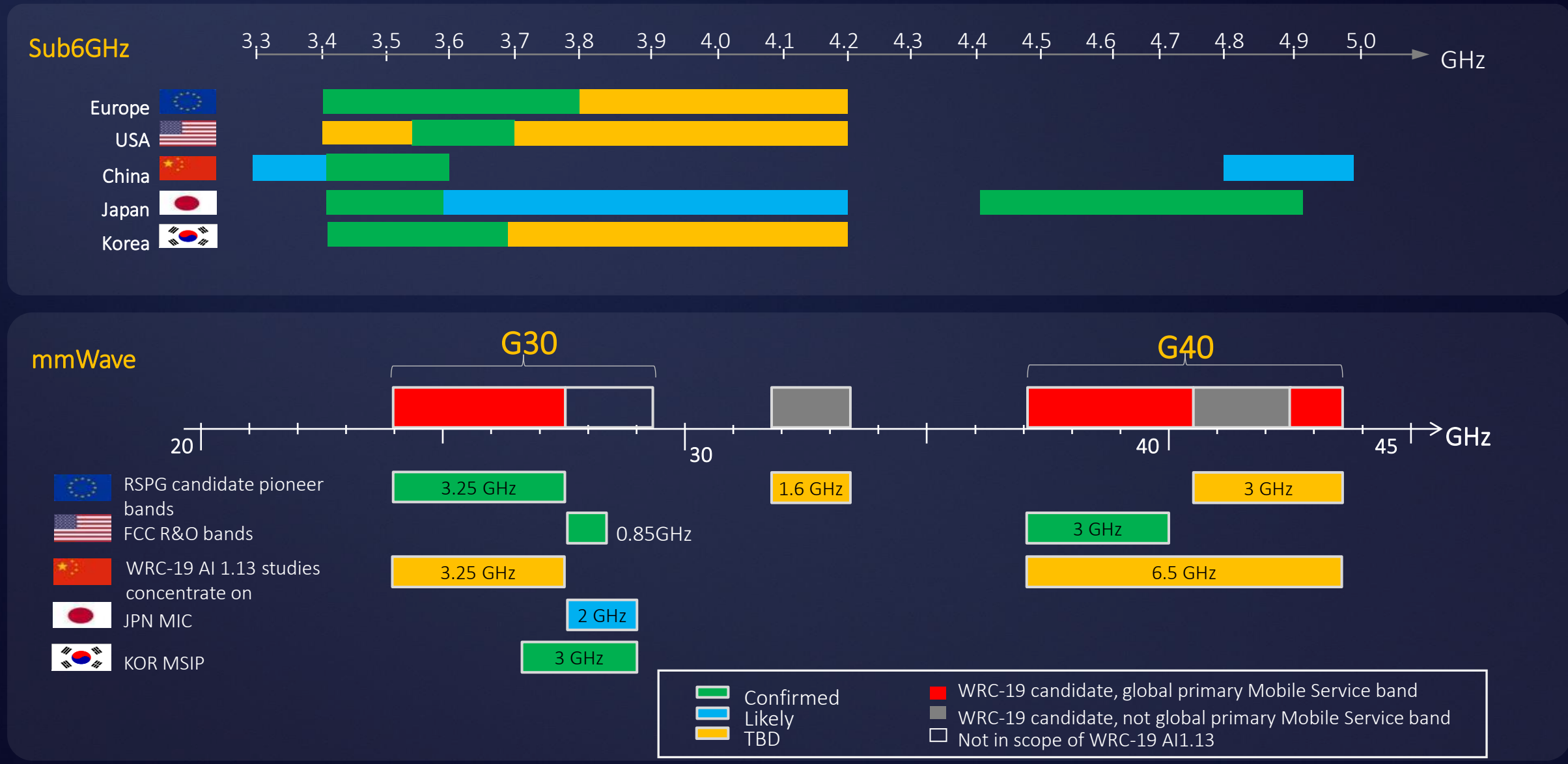
Machine vision

High-precision positioning

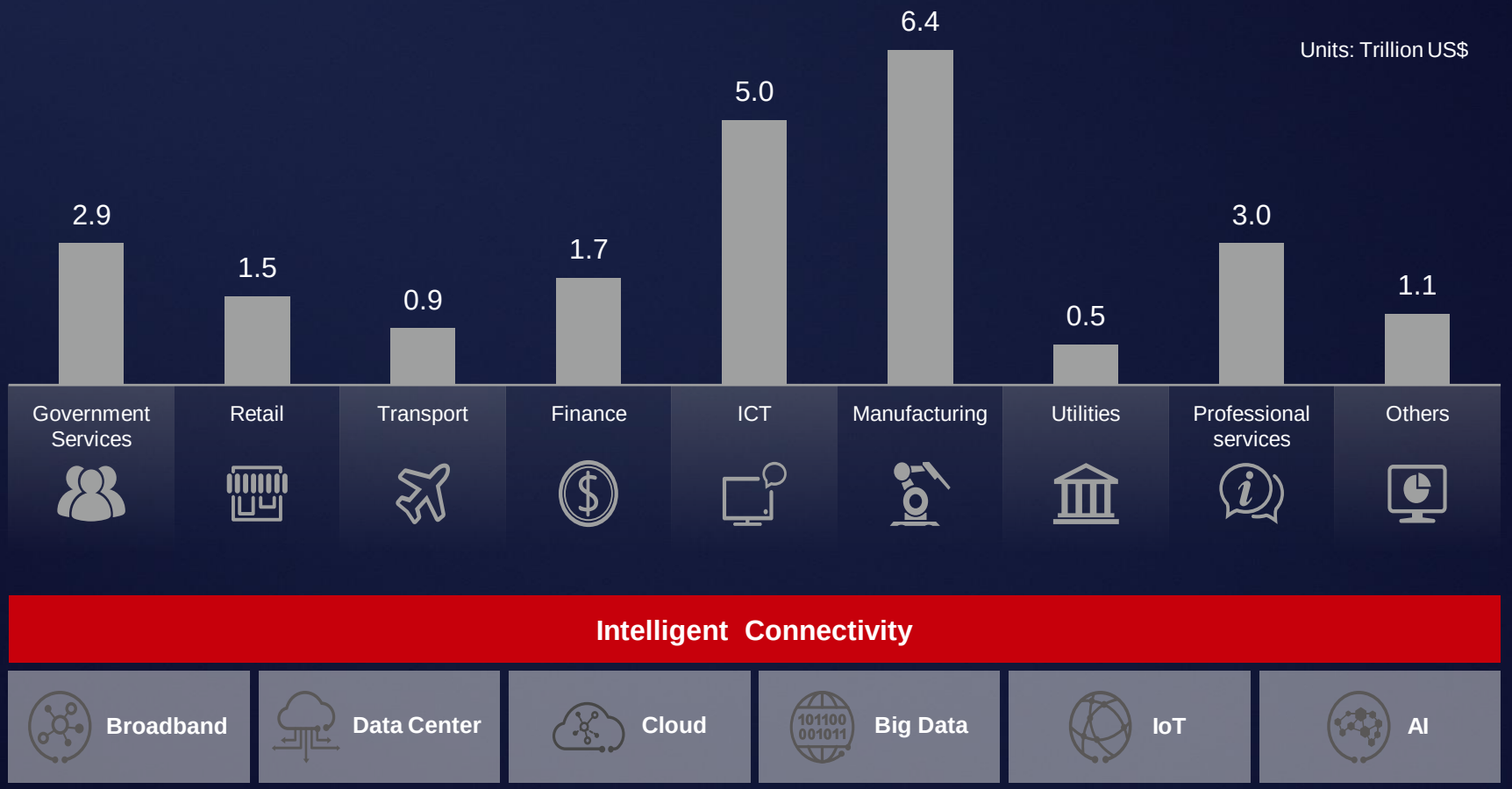
…

New opportunities worth tens of billions of dollars in each scenario

C-band/G30/G40 Potentially Global Harmonized as New Bands

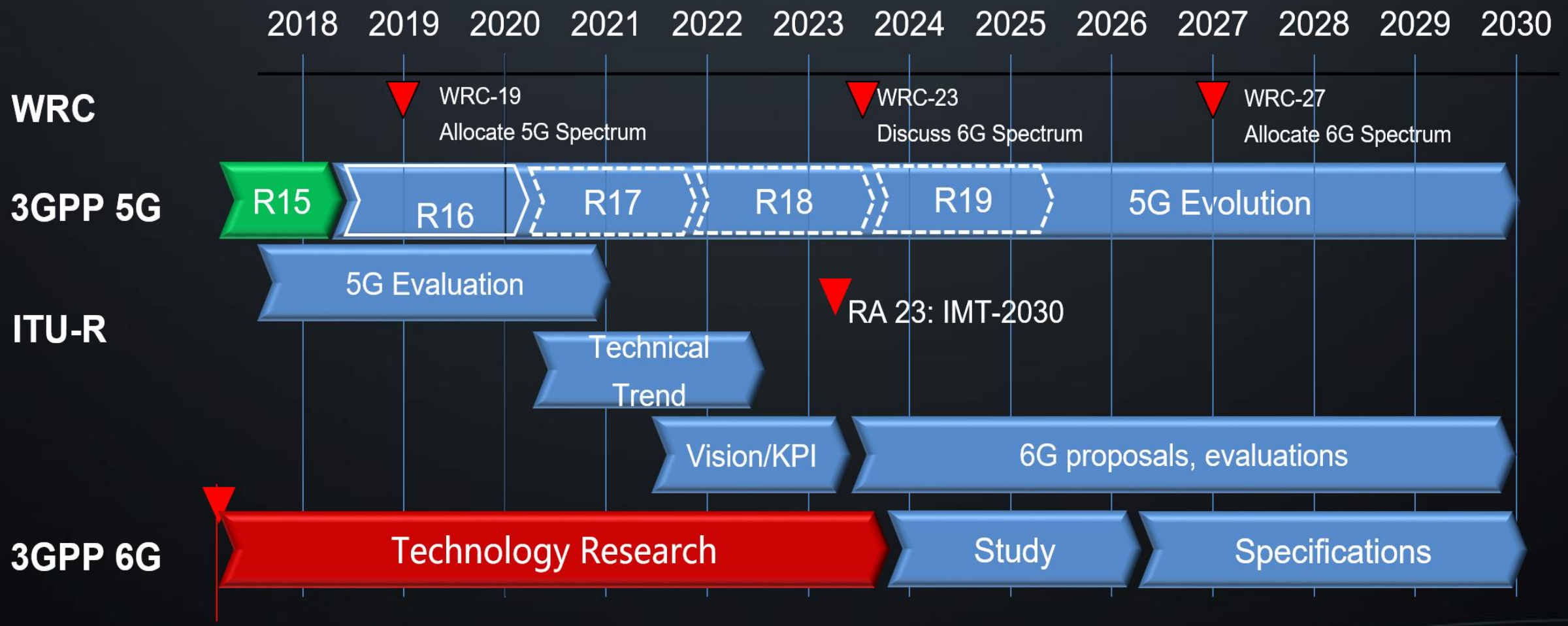


2025: Tapping into the Opportunities of Digital Economy Valued at US$23 Trillion



Standardization Roadmap

The success of 6G remains a single global standard



- 5G NR will continue evolving to several more use cases effectively
- 6G will emerge to serve new use cases with fundamental new technologies

6G for what?

- **Extremely Immersive Experience**
- **Haptic: a new dimension of human perception**
- **Sensing and Imaging**
- **Industry 4.0 with Connected Intelligence**
- **Smart Urban Life**
- **3D Full coverage of the earth**
- **Native AI with Communications**
- **Green and Sustainable development**

2030 Key Requirements

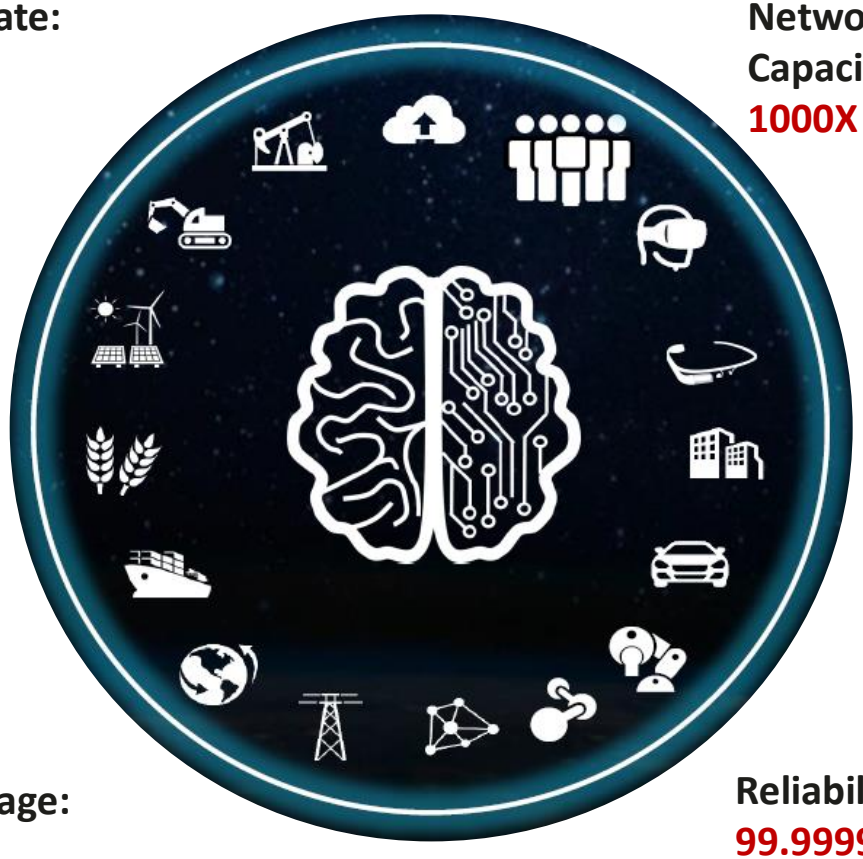
Peak Rate:
1Tbps

Guaranteed Rate:
10-100Gbps

Network Capacity:
1000X w.r.t. 2020

Energy Efficiency:
10X w.r.t. 2020

Air Interface Jitter:
+/-0.1ns



Sensing Battery Life:
20 Years

Position Accuracy:
50cm outdoor, 1cm indoor

Device Density:
10millions/km^2

Air Interface Latency:
+/-0.1ms

Network Coverage:
167dB

Reliability:
99.99999%

6G enables a Hyper-connected Intelligent World

All Things Sensing

Sensing the physical world, mapping it to digital signals

Temperature, space, and touch
Sense of smell, hearing, and vision

All Things Connected

Data goes online to power machine intelligence

Ubiquitous connections, wide connections, multiple connections, and deep connections

All Things Intelligent

Network integrated AI to power new applications

Digital twins
Digital survival

We Are Entering a Hyper-connected Intelligent World

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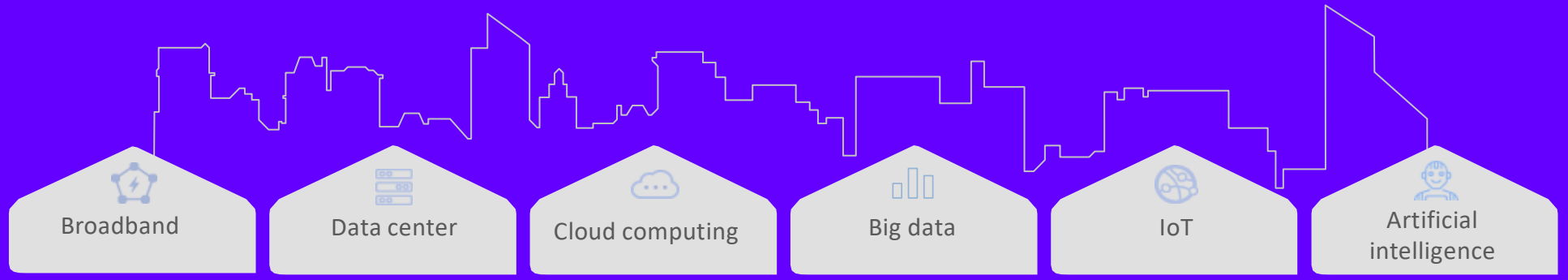


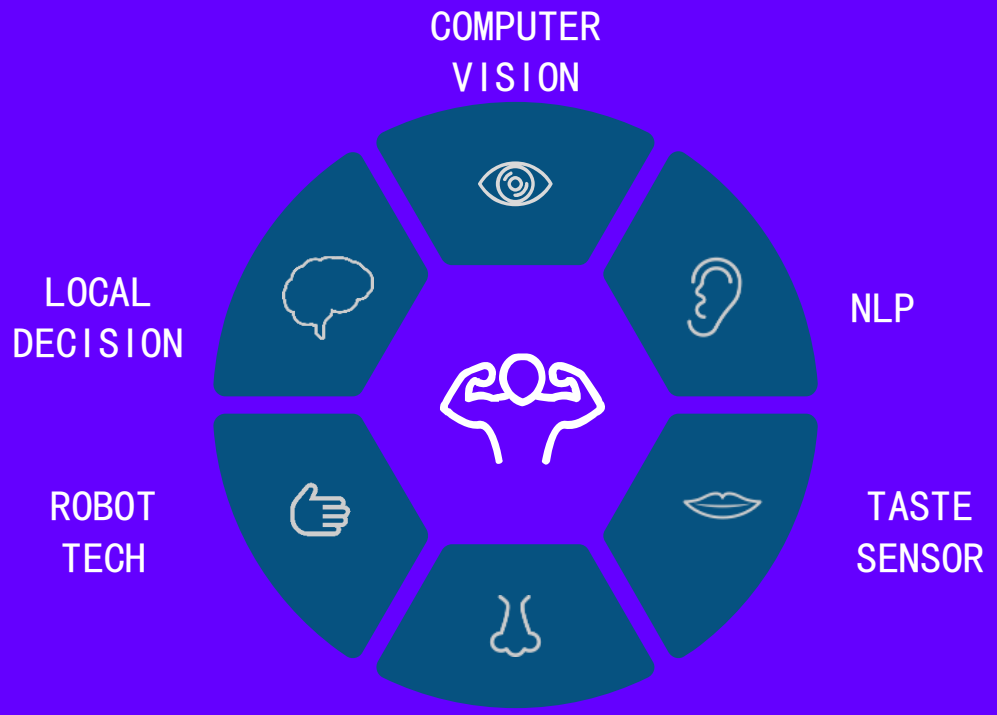
Better Perception

Naked Eyes

P30 Pro

Air Quality

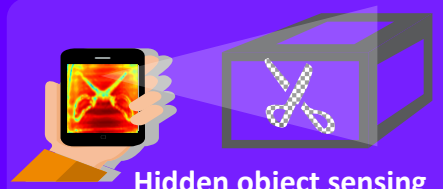
Blood Pressure



More Information, Better Service & Experience

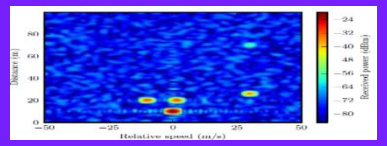
Convergence of Wireless Transmissions and Sensing

Spatial Dimension | Chemistry | Biology | Medical



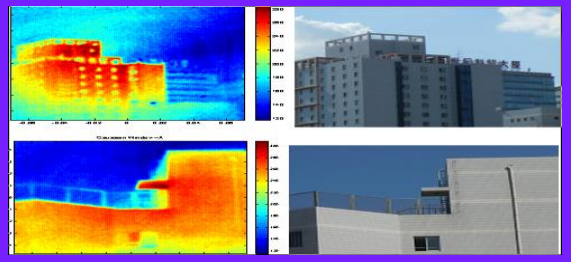
Hidden object sensing

Food spectral
Sensing and analysis



Sensing Vehicles

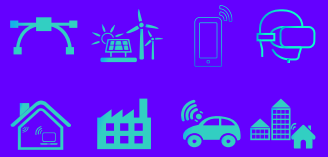
Terminal Sensing



Infrastructure Sensing

4D City Sensing reconstruction
(Traffic control)

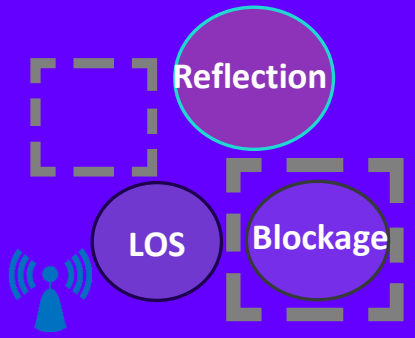
Analytics



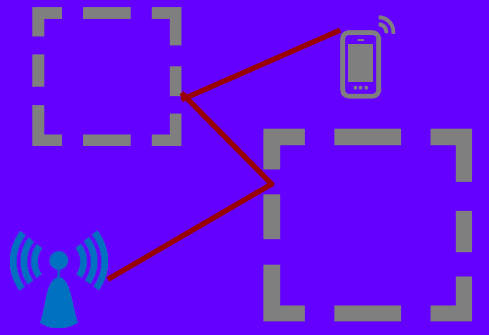
Sensing Assisted Transmission

Sensing Assisted PHY

1. Air Interface
Relative sensing

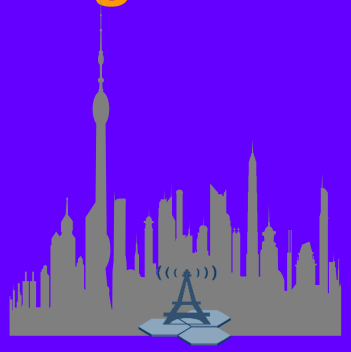


2. Reality mapping and Judging

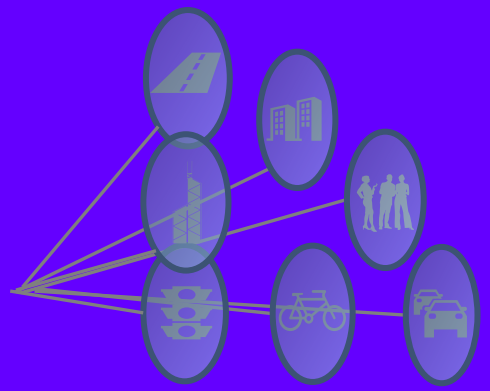


3. Beam Forming tracking

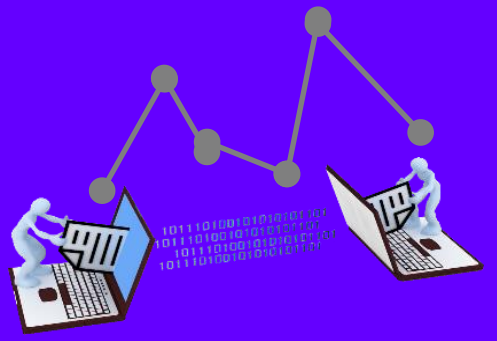
Sensing Assisted Network



1. Environment sensing



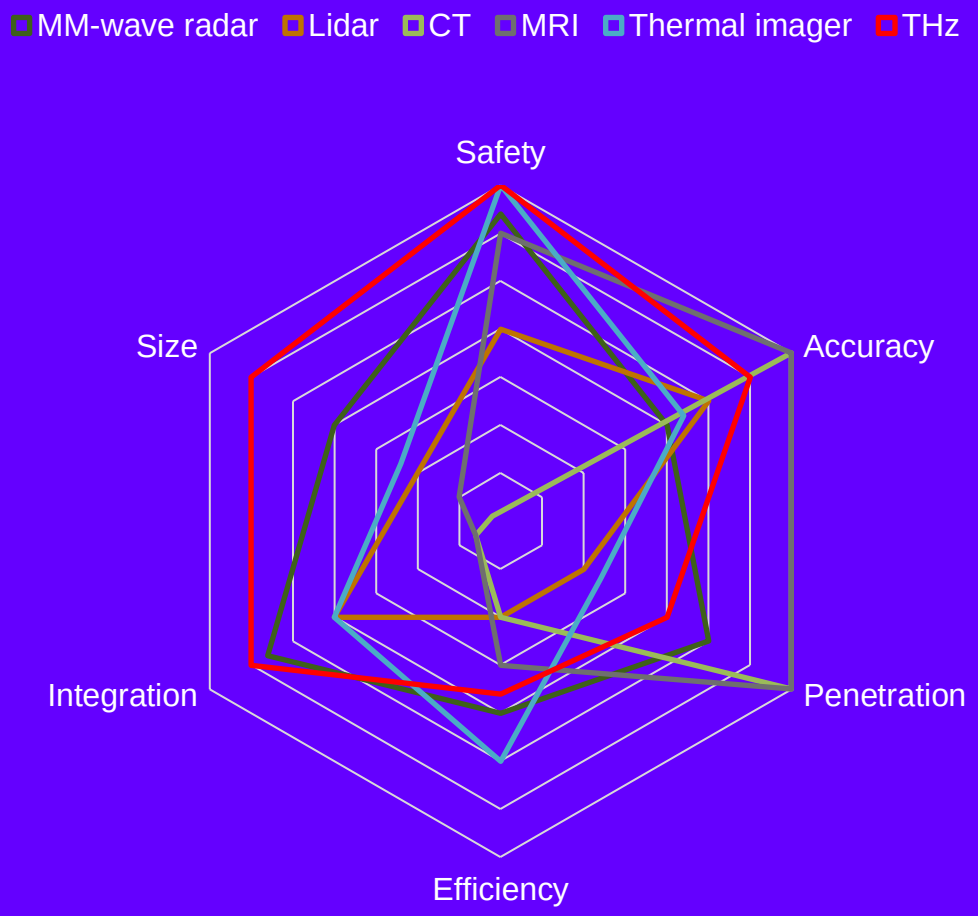
2. Infrastructure and
traffic reconstruction



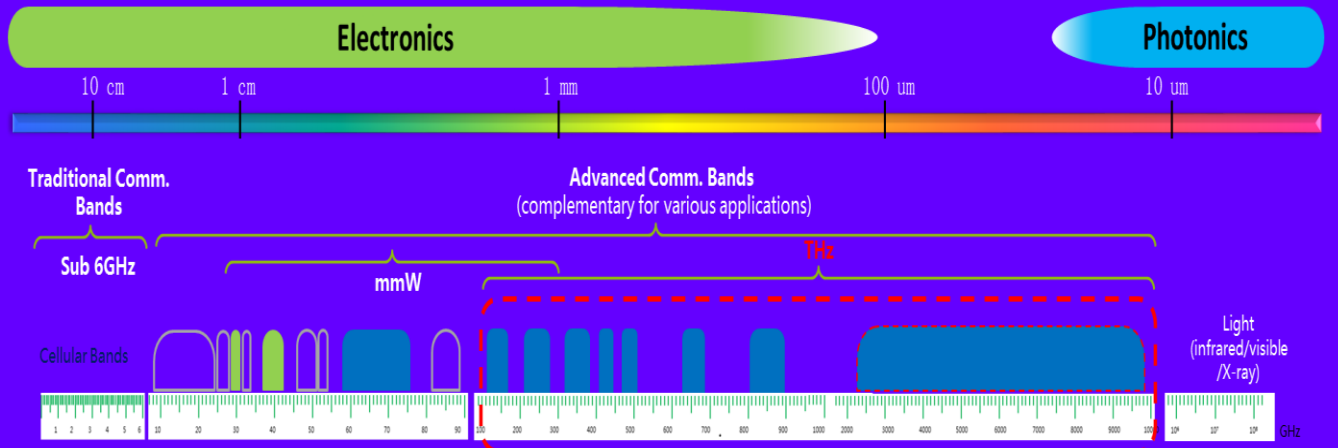
3. Network planning
and traffic steering

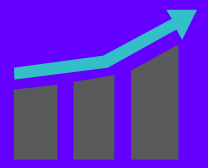
Sensing and Spectrum

TECHNOLOGY

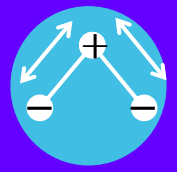


Tera-THz Extend the Scope of Sensing



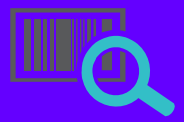


Ultra Bandwidth



Molecular Vibration

Non-ionized



Small Size

We Are Entering a Hyper-connected Intelligent World

All Things Sensed

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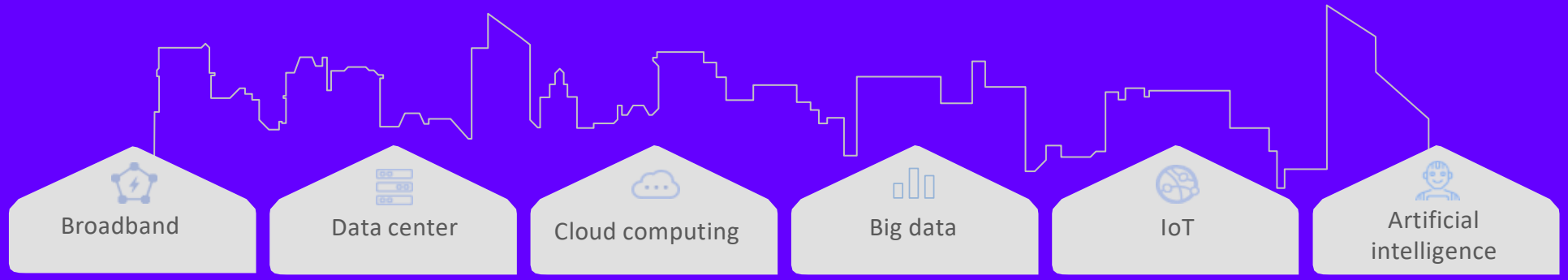
Temperature, space, and touch
Sense of smell, hearing, and vision

All Things Computed

Network integrated AI to power new applications

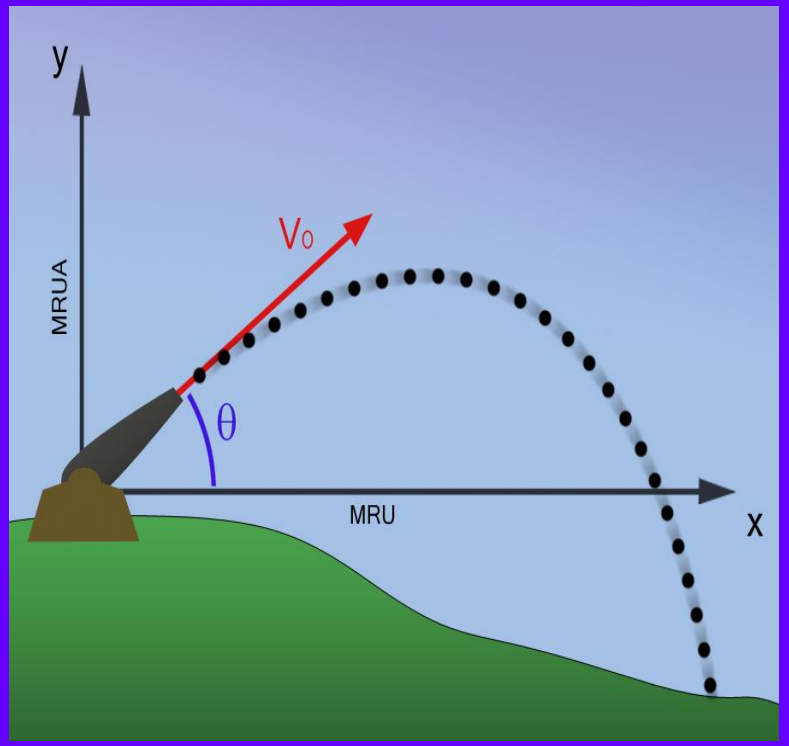
Digital twins
Digital survival



The Rise of AI: 1989-2019

2019 Turing Award

The Cost of Understanding



New Paradigms for Computing

	Device				Edge		Cloud
	Earphone	Always-on	Smartphone	Laptop	IPC	Edge Server	Data Center
Compute	20 MOPS	100 GOPS	1-10 TOPS	10-20 TOPS	10-20 TOPS	10-100 TOPS	200+ TOPS
Power budget	1 mW	10 mW	1-2 W	3-10 W	3-10 W	10-100 W	200+ W
Model size	10 KB	100 KB	10 MB	10-100 MB	10-100 MB	100+ MB	300+ MB
Latency?	< 10 ms	~10 ms	10-100 ms	10-500 ms	10-500 ms	ms ~ s	ms ~ s
Inference?	Y	Y	Y	Y	Y	Y	Y
Training	N	N	Y	Y	Y	Y	Y
Chip	Ascend-Nano	Ascend-Tiny	Ascend-Lite	Ascend 310	Multi Ascend		Ascend 910

New Paradigms for Networks

Mobile AI: What is the right architecture?

Big Data

Training

Update

Unified training and inference framework

Consistent Development Experience

Cooperative Training/Inference

Device 端
Light 轻量

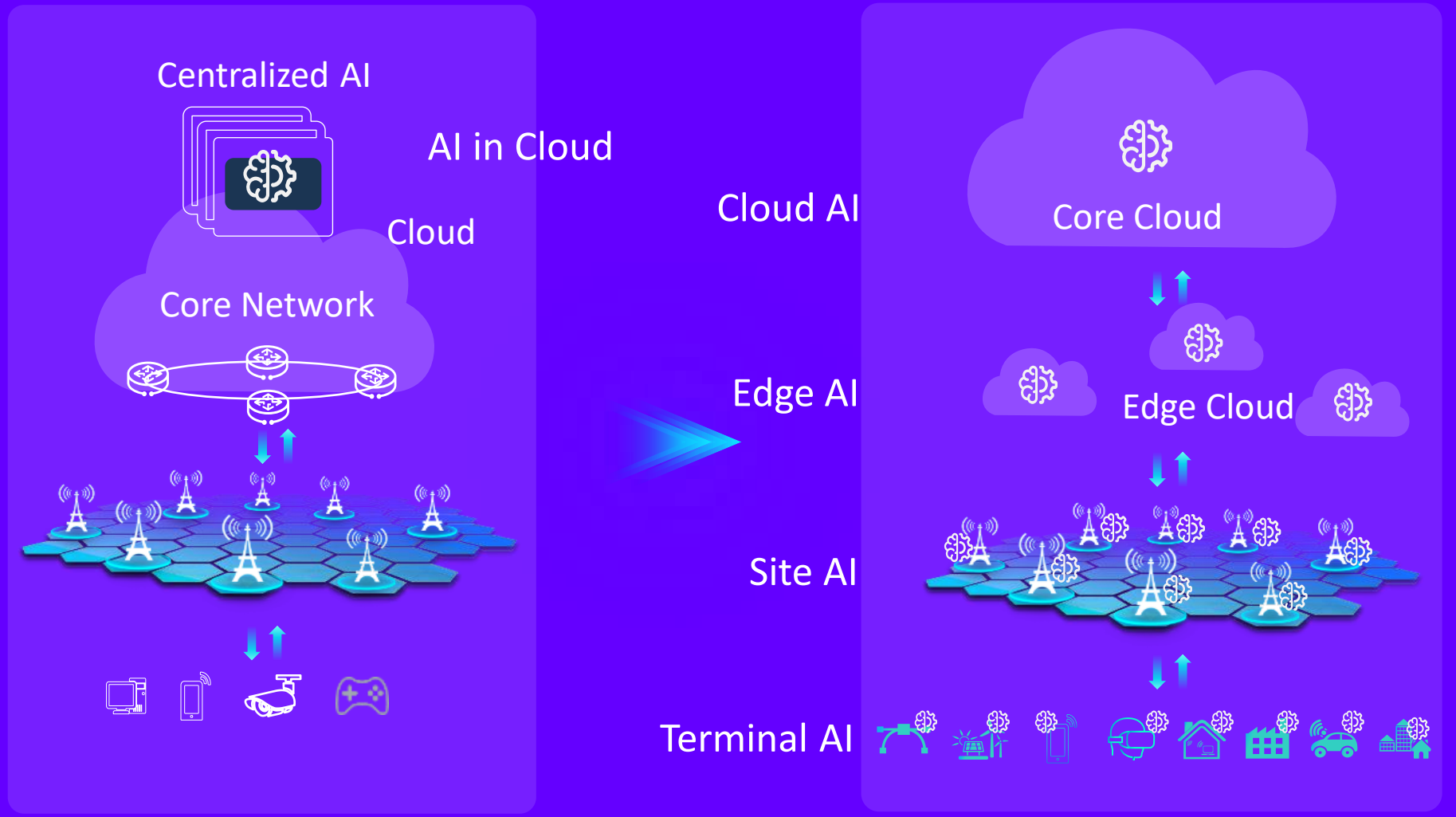
Cooperative Training/Inference

Edge
Local 本地

Cooperative Training/Inference

Cloud 云
Large-scale 大规模

New Paradigms for Networks



Current Cloud and AI

Integrated Cloud, Network & AI

L5 Full Scenario
(Intent-Driven)

L4 Service Scenario
(Autonomy)

L3 Single-Scenario
(Conditional Automation)

L2 Task
(Partial Automation)

L1 Functionality
(Expertise Based)

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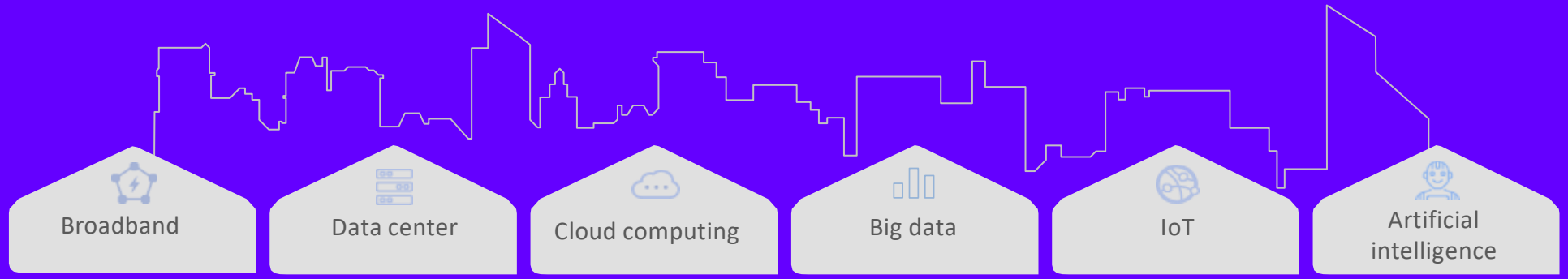
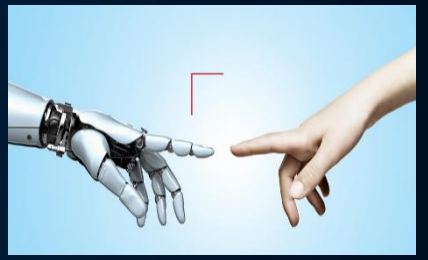


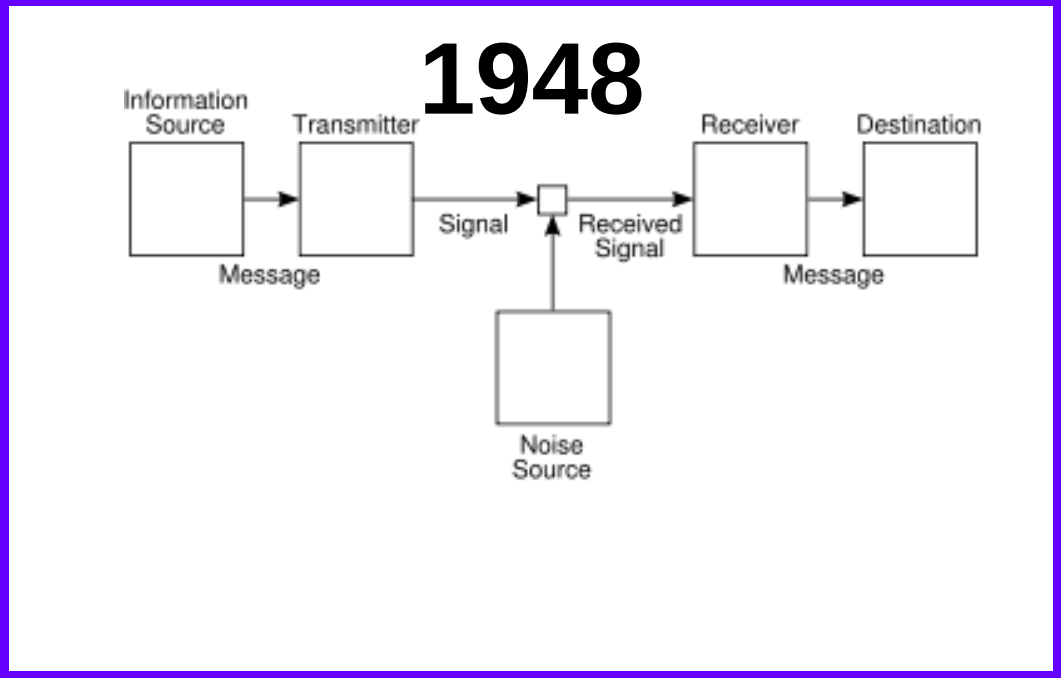
Better Connection

Information Everywhere

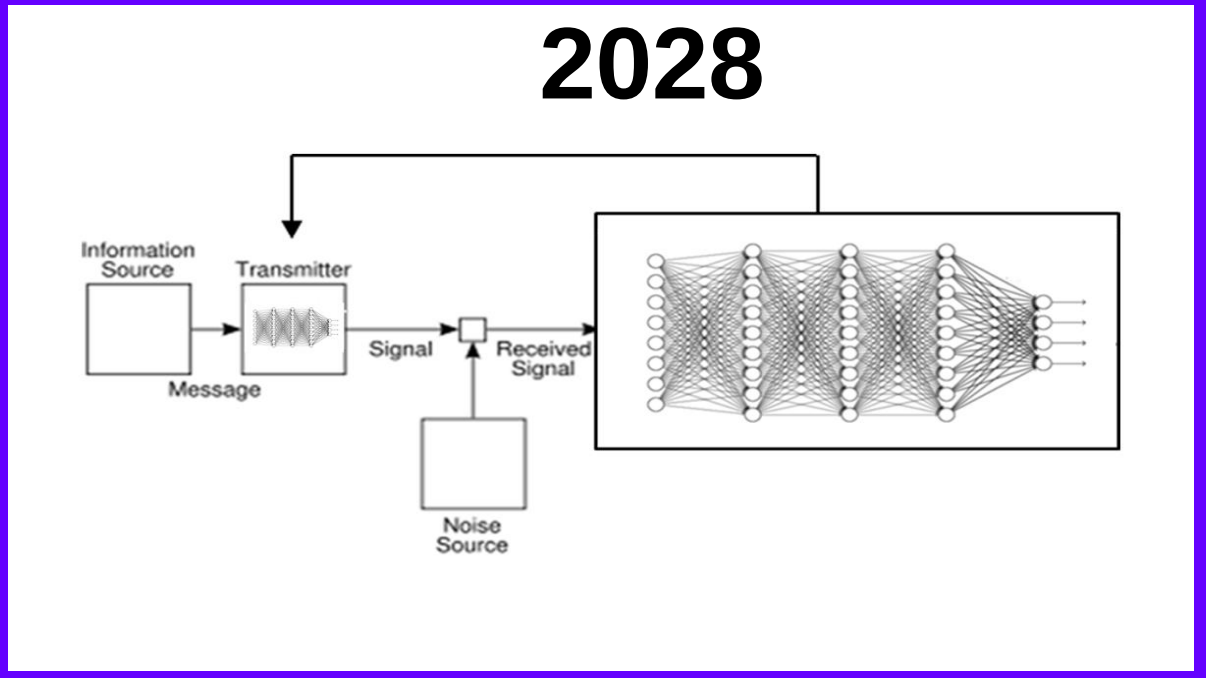
Holoportation & Edge Intelligence **(4.62Tbps)**		
Autonomous / Flying Transportation **(4T/day)**		
Digital Industry and Robotics (<<1ms)		

HUAWEI

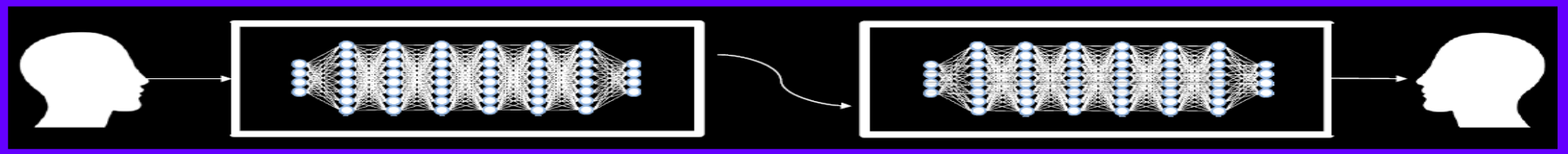
Smart Communications



Shannon 1.0



Shannon 2.0



Smart Channels

Title: Optimal Communication Channels in a Disordered World with Tamed Randomness

Authors: Philipp del Hougne[1]*, Mathias Fink[1], Geoffroy Lerosey[2]

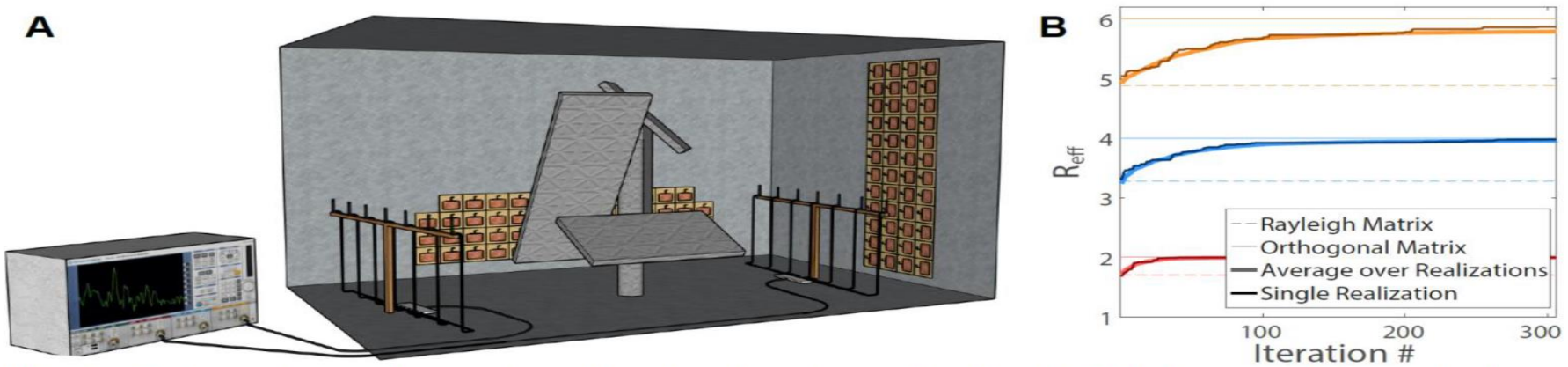
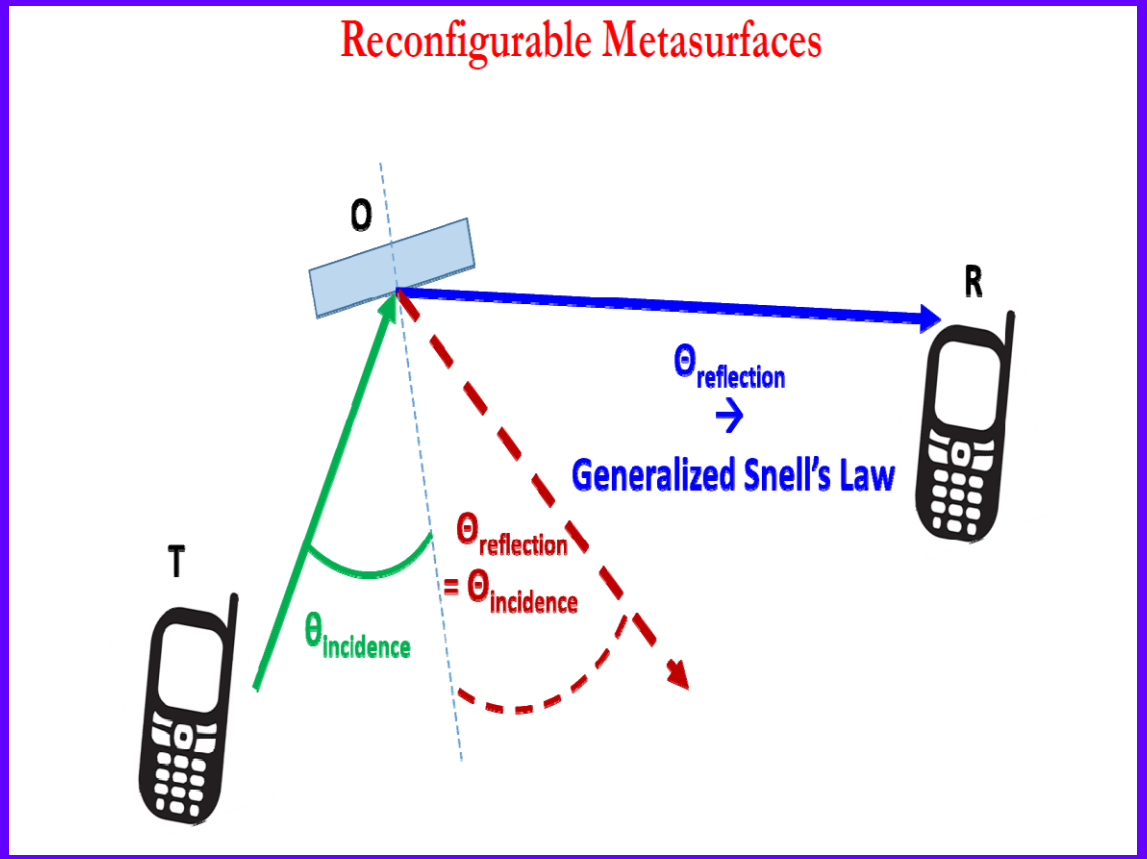


Fig. 1. (**A**) Experimental setup in a disordered cavity under Rayleigh fading conditions. A phase-binary metasurface reflect-array partially covers the cavity walls; appropriately configured, it physically shapes the channel matrix measured between the two antenna arrays and imposes perfect channel orthogonality. (**B**) Iterative optimization of channel diversity. The evolution of R_{eff} over the course of the optimization is given for a single realization, as well as averaged over 30 realizations, for n=2,4,6 (red, blue, yellow). Benchmarks for Rayleigh fading and perfect orthogonality are indicated, see legend.

Smart Channels



Di Renzo *et al.*

Smart Radio Environments Empowered by AI Reconfigurable Meta-Surfaces: An Idea Whose Time Has Come

Marco Di Renzo[1*], Merouane Debbah[2], Dinh-Thuy Phan-Huy[3], Alessio Zappone[4], Mohamed-Slim Alouini[5], Chau Yuen[6], Vincenzo Sciancalepore[7], George C. Alexandropoulos[8], Jakob Hoydis[9], Haris Gacanin[10], Julien de Rosny[11], Ahcene Bounceu[12], Geoffroy Lerosey[13] and Mathias Fink[11]

From Connected Things to Connected Intelligence

2020

2030


TII
Technology
Innovation
Institute