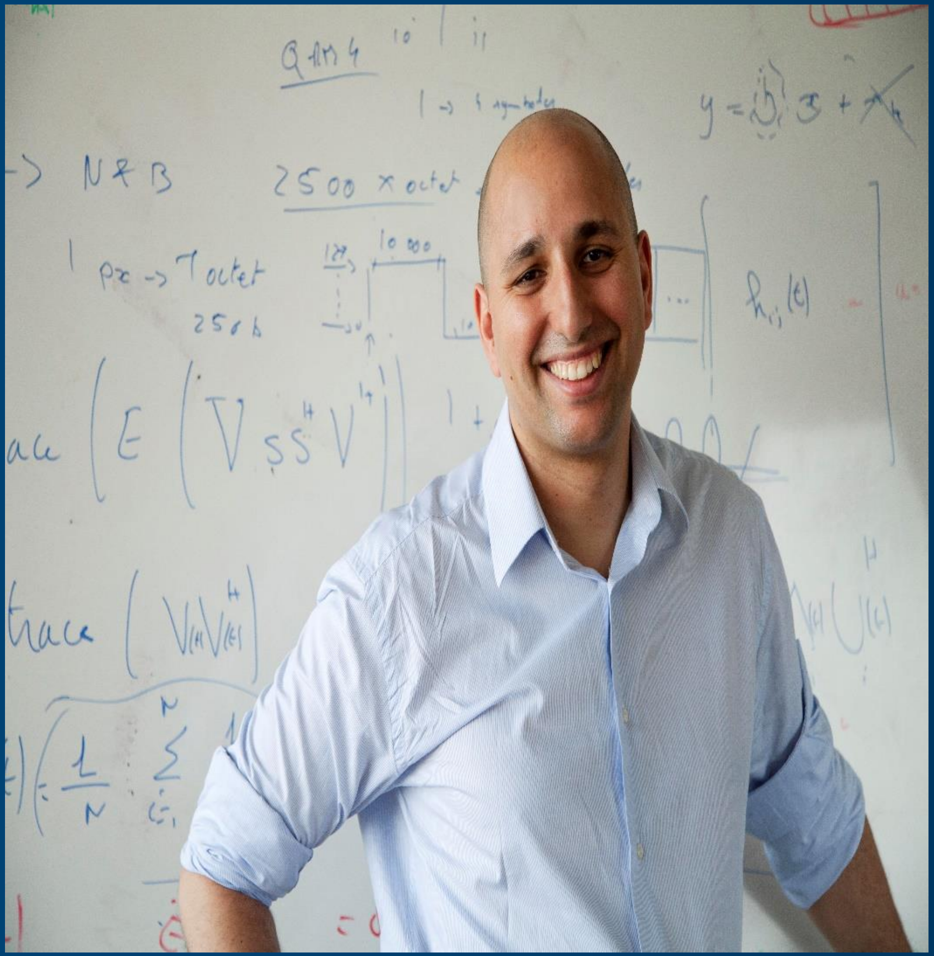
The Research Challenges for the Next Decade In Wireless Communications

Merouane DEBBAH
Director of the Mathematical and Algorithmic Sciences Lab, Huawei

Biography



- Director of the Huawei Mathematical & Algorithmic Sciences Lab
- IEEE and WWRF Fellow
- ERC Grant (2012-2017)
- 20 Best Paper Awards
- 200+ journal papers

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2030: Wireless for Intelligent Machines

"G" Waves

- 2G: Mobile for Voice
- 3G: Mobile for Visio-phony
- 4G: Mobile for Internet
- 5G: Mobile for Things
- 6G: Mobile for Machines?

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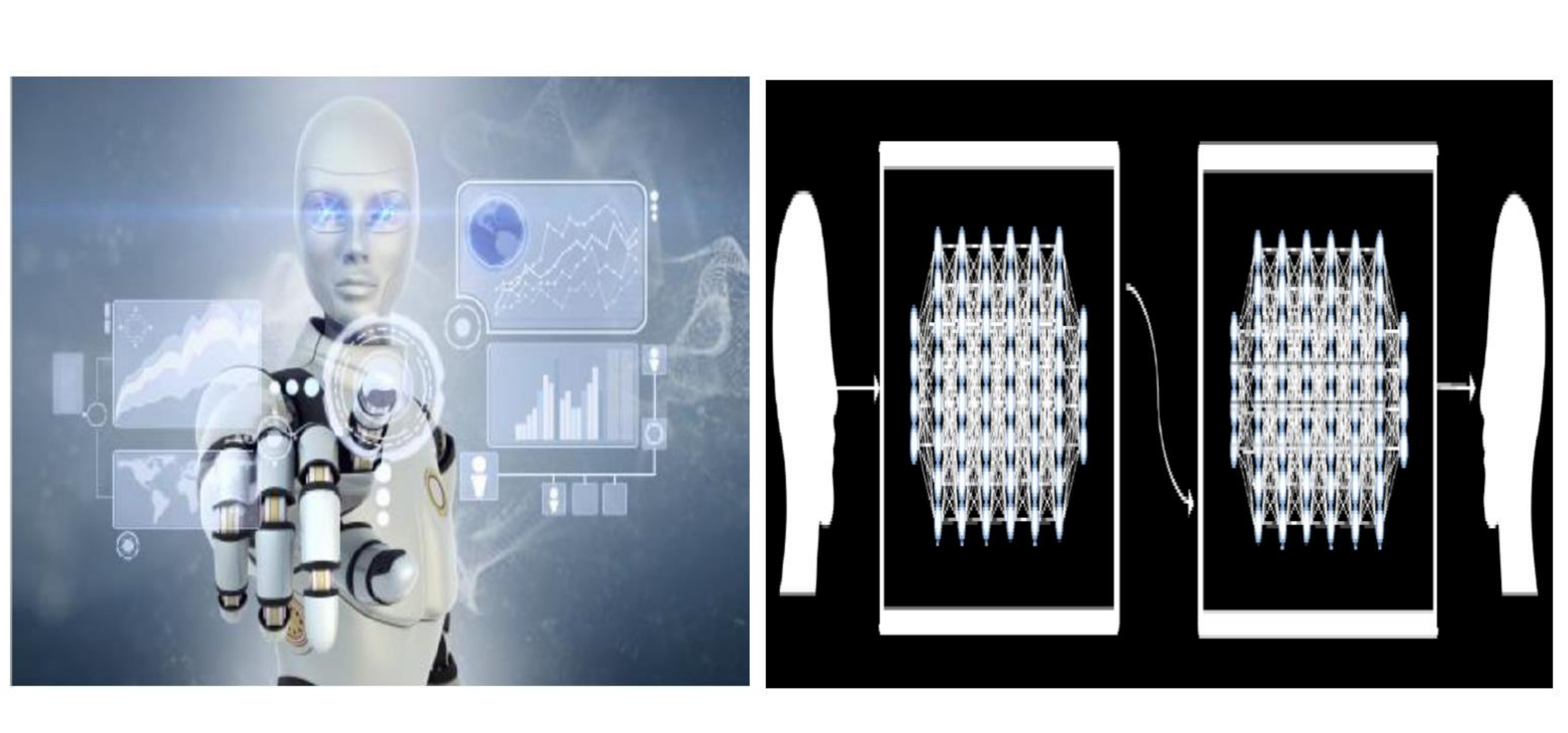
2035: The Internet of Intelligent Machines?



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We Are Entering a Hyper-connected Intelligent World

All Things Sensed

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 Computed

Network integrated AI to power new applications

Digital twins
Digital survival

Broadband | Data center | Cloud computing | Big data | IoT | Artificial intelligence

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- Artificial intelligence

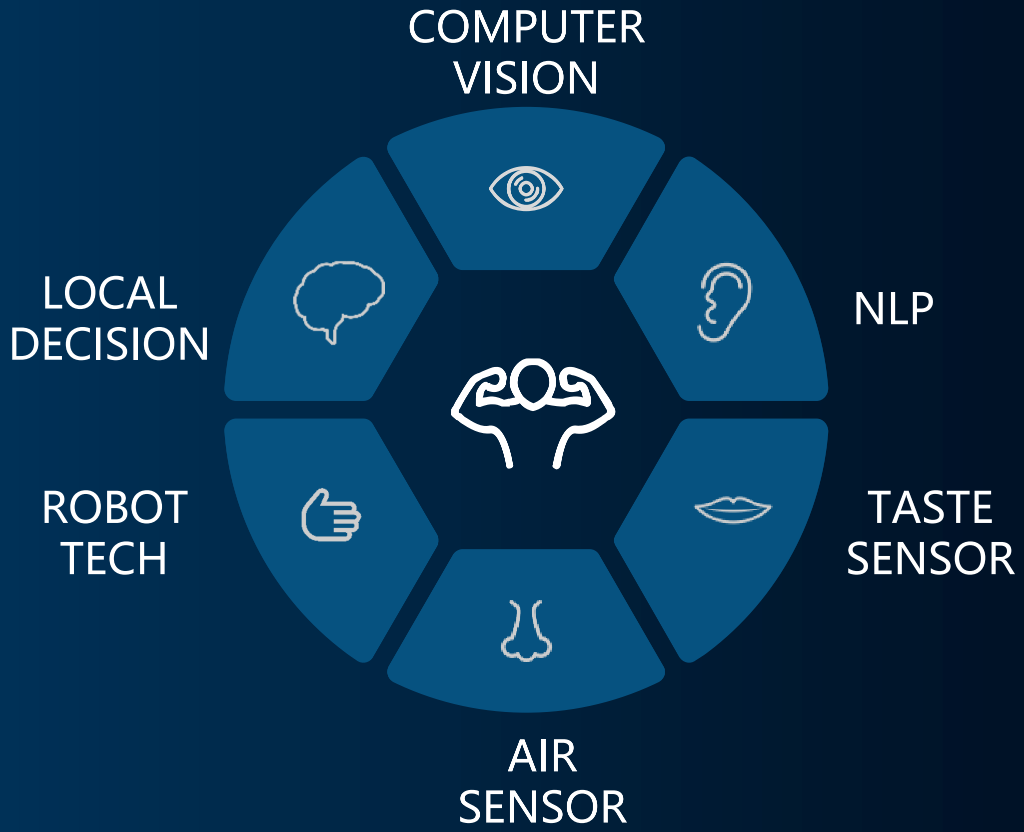
Better Perception

Naked Eyes

P30 Pro

Air Quality

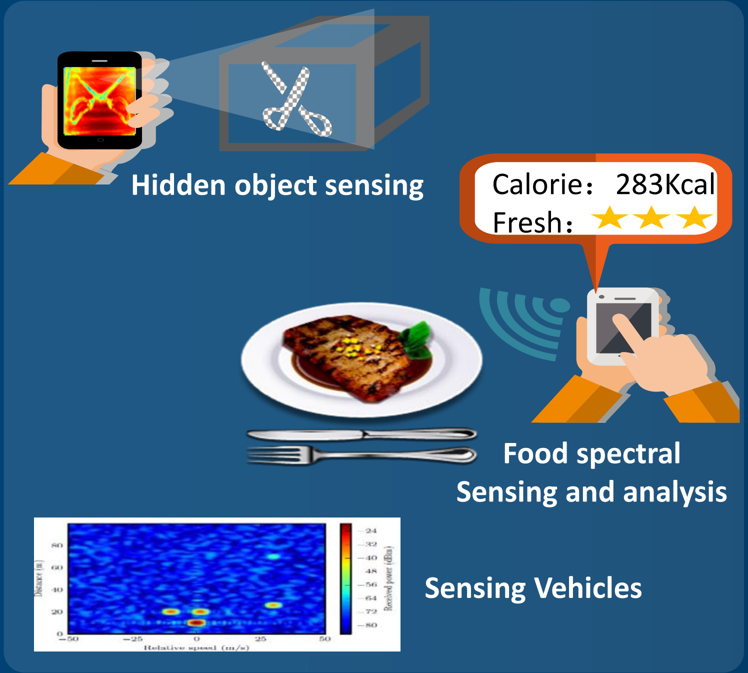
Blood Pressure



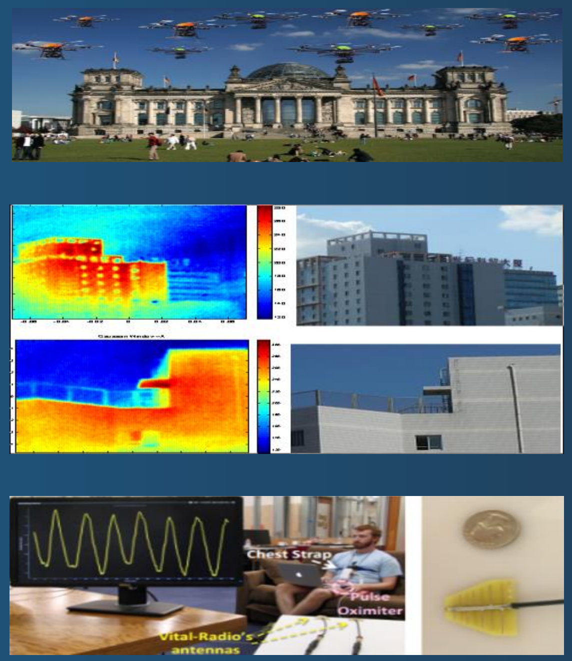
More Information, Better Service & Experience

Convergence of Wireless Transmissions and Sensing

Spatial Dimension | Chemistry | Biology | Medical



Terminal Sensing



Infrastructure Sensing

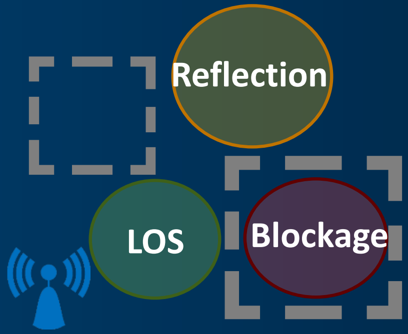
4D City Sensing reconstruction
(Traffic control)

Analytics

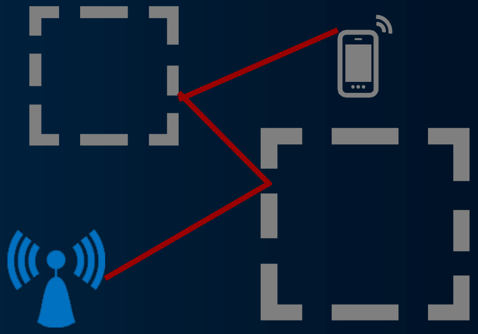
Sensing Assisted Transmission

Sensing Assisted PHY

1. Air Interface
Relative sensing



2. Reality mapping and Judging



3. Beam Forming tracking

Sensing Assisted Network

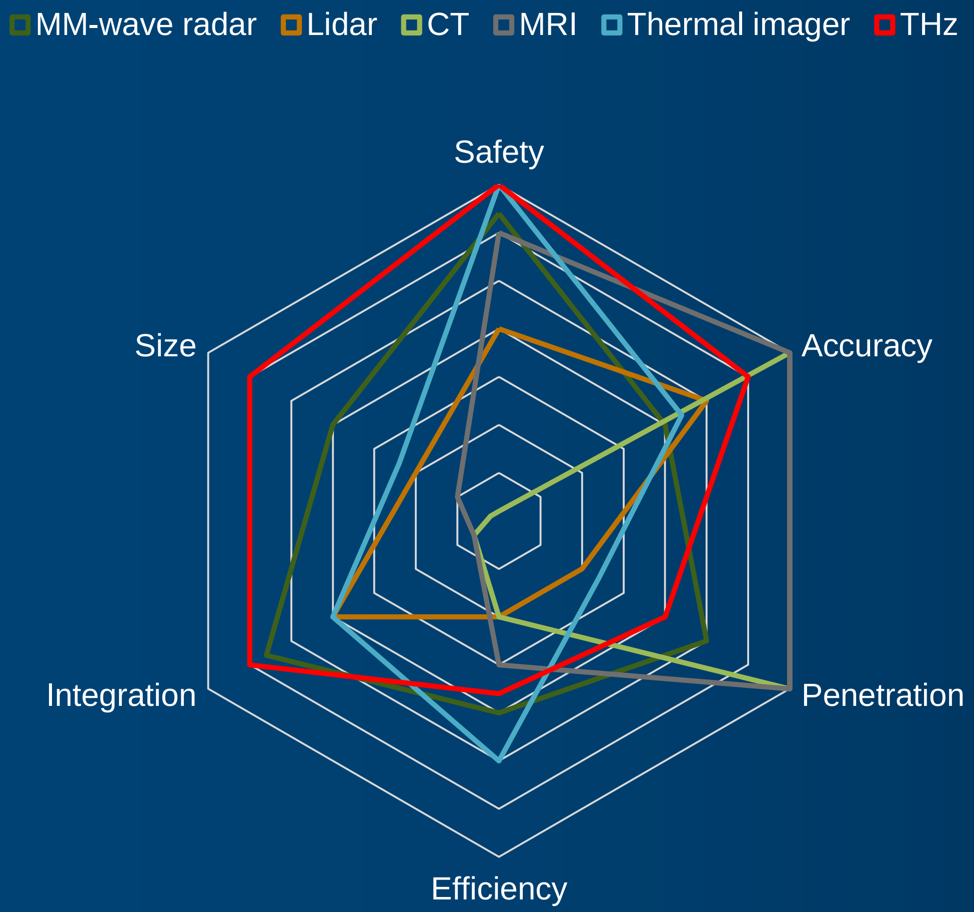
1. Environment sensing

2. Infrastructure and
traffic reconstruction

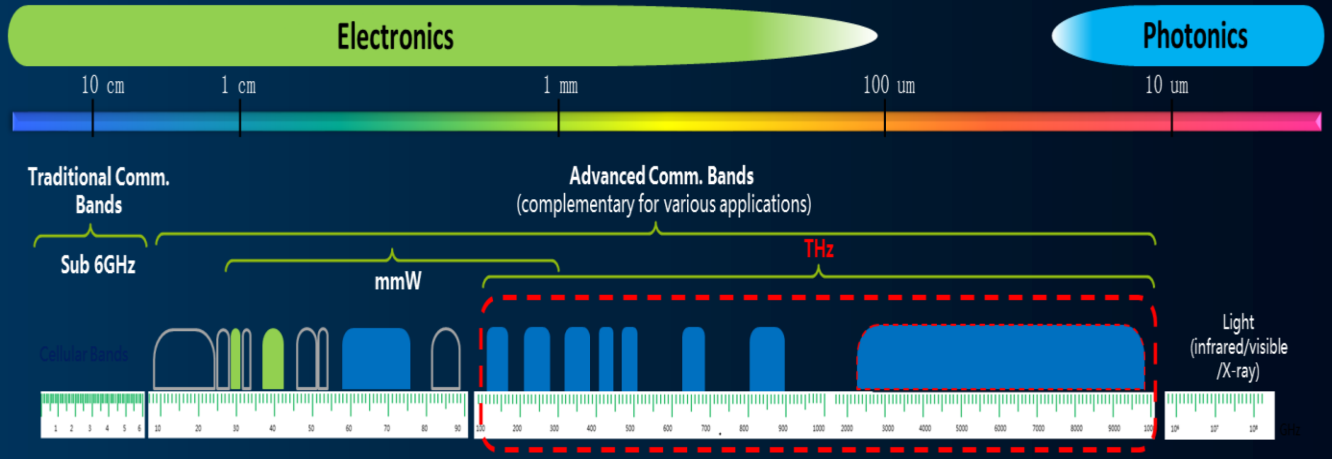
3. Network planning
and traffic steering

Sensing and Spectrum

TECHNOLOGY



Tera-THz Extend the Scope of Sensing



Ultra Bandwidth **Molecular Vibration** **Non-ionized** **Small Size**

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The Rise of AI: 1989-2019

2019 Turing Award

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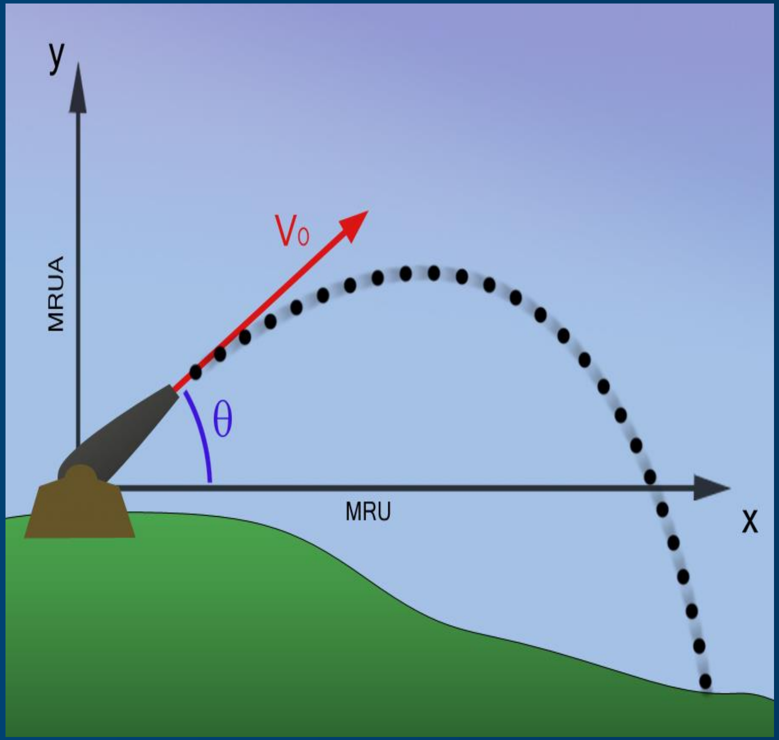
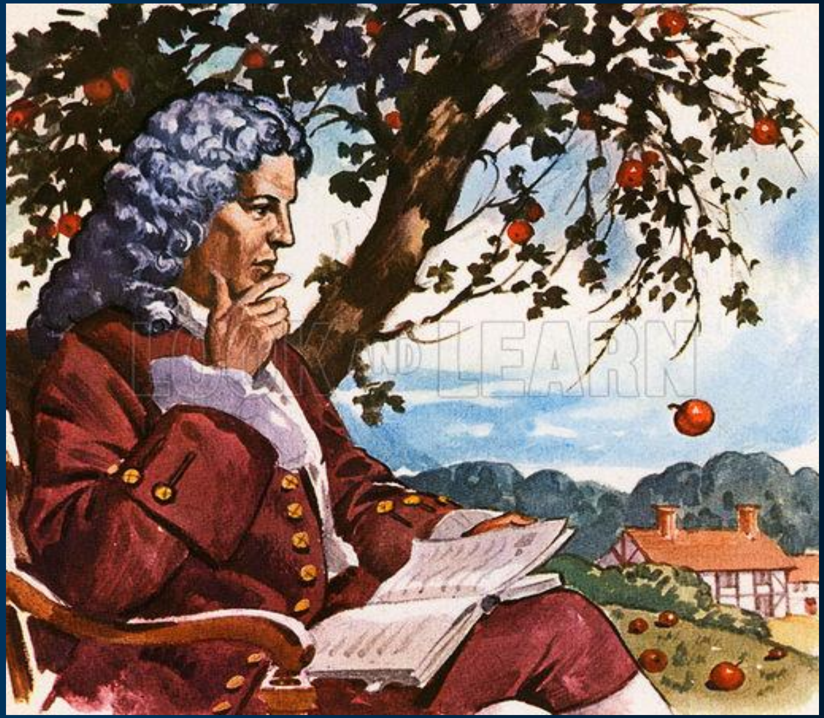
The Cost of Understanding





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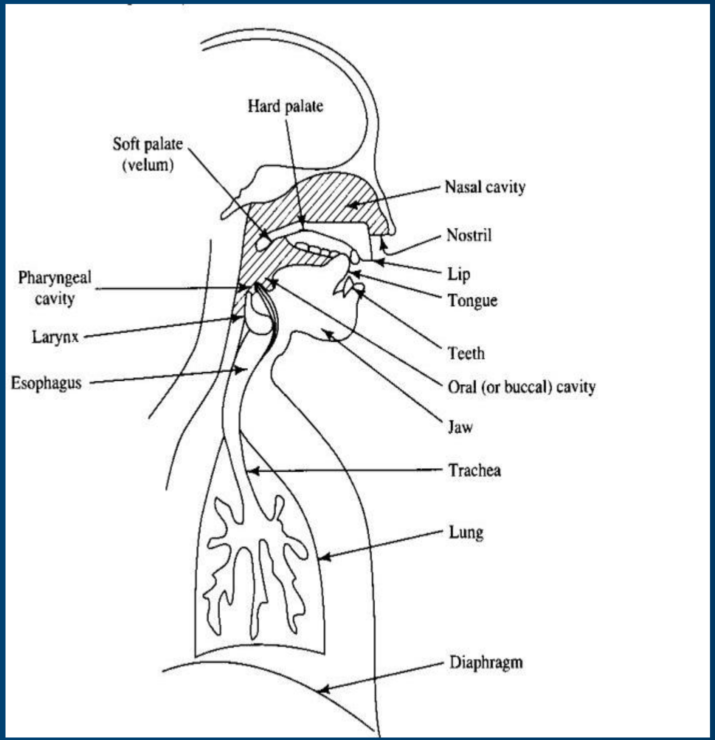
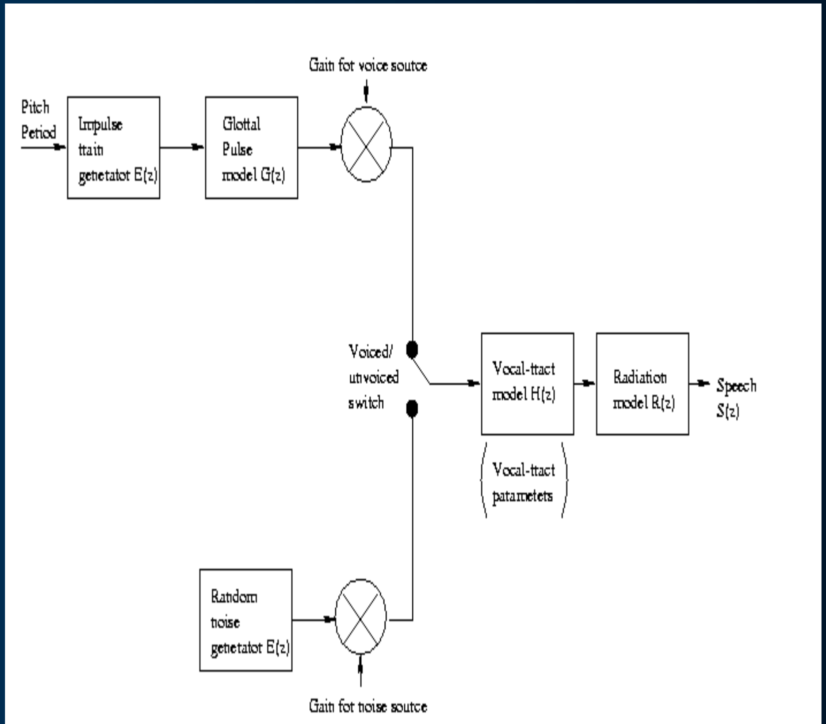
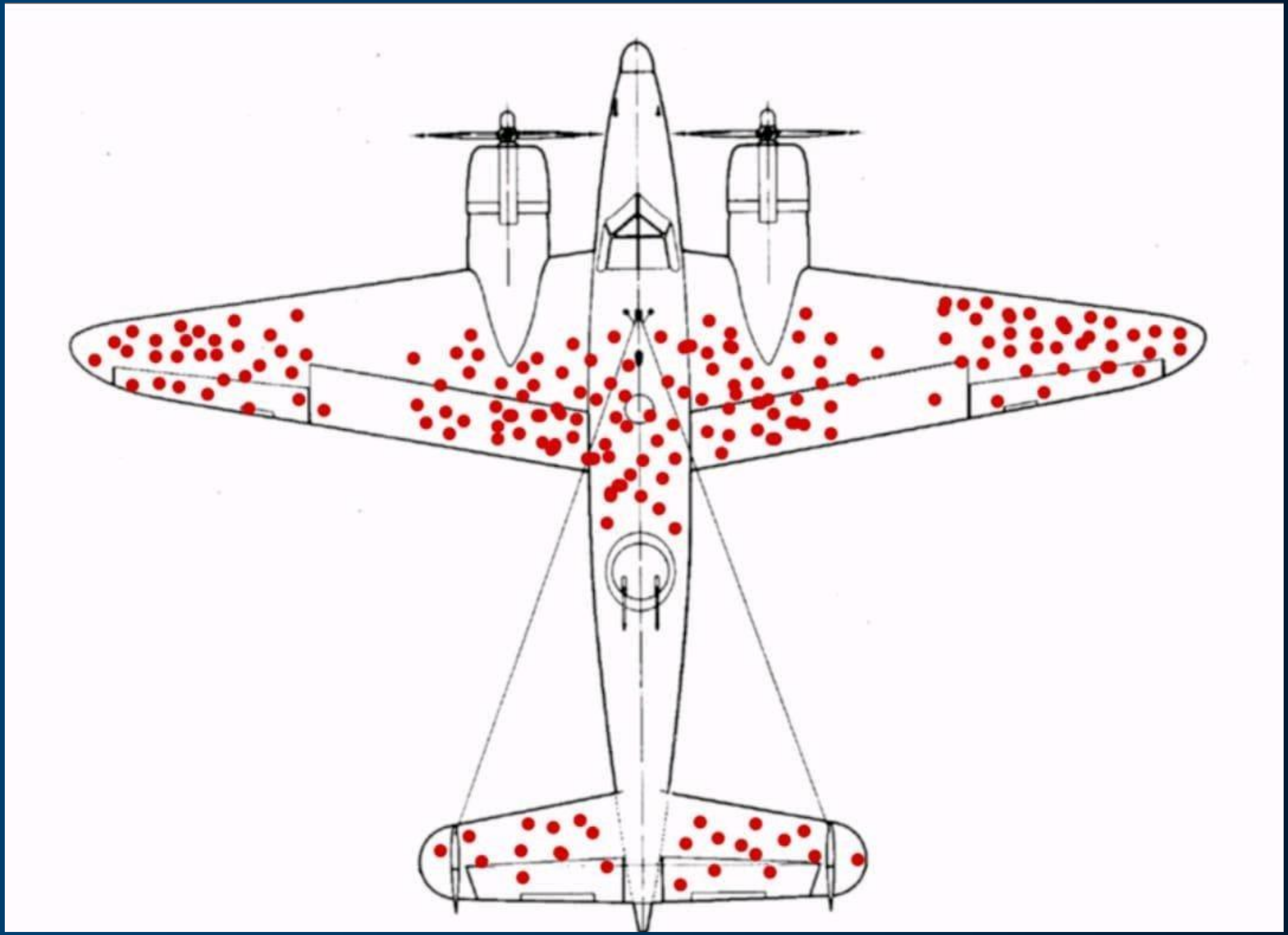
The Limits of Modelling





New Paradigms for Data



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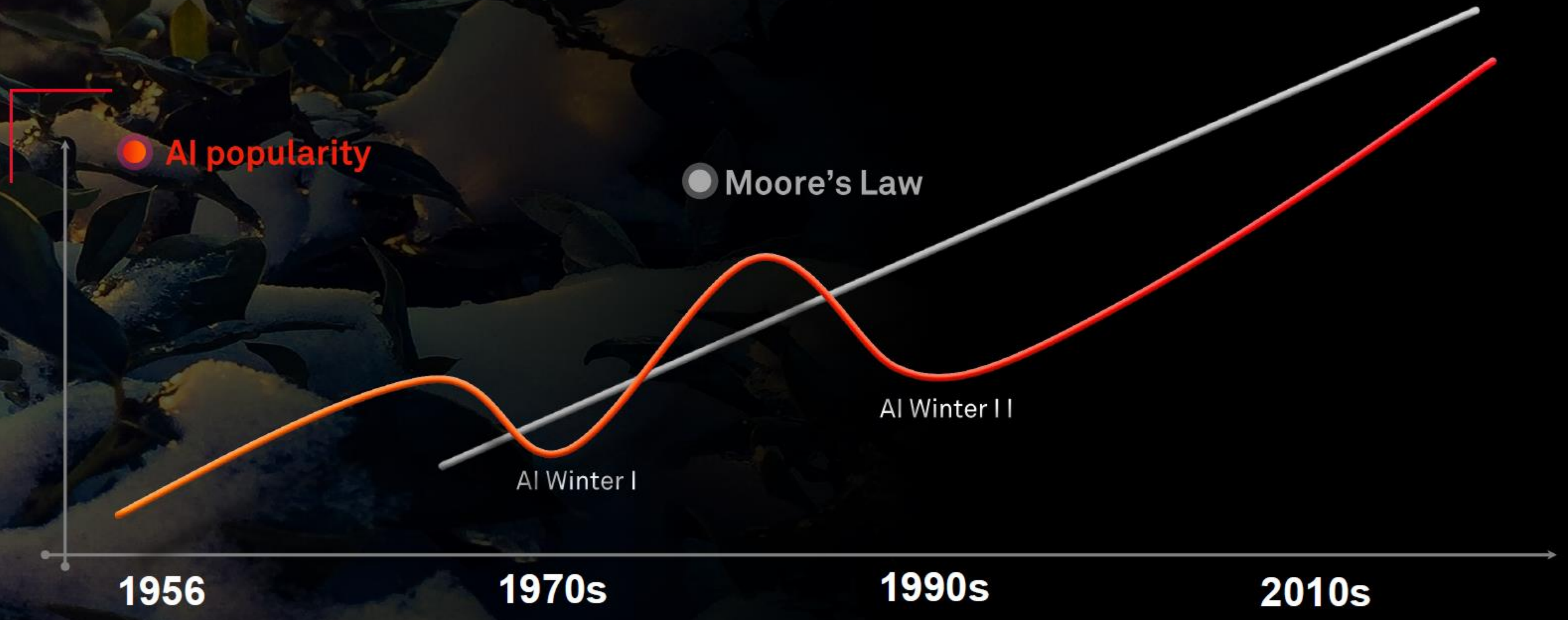
AI: Overall outcome of 60 years of development in ICT



AI in Telecommunication

Computers and Automata*

CLAUDE E. SHANNON†, FELLOW, IRE

C. E. Shannon first became known for a paper in which he applied Boolean Algebra to relay switching circuits; this laid the foundation for the present extensive application of Boolean Algebra to computer design. Dr. Shannon, who is engaged in mathematical research at Bell Telephone Laboratories, is an authority on information theory. More recently he received wide notice for his ingenious maze-solving mechanical mouse, and he is well-known as one of the leading explorers into the exciting, but uncharted world of new ideas in the computer field.

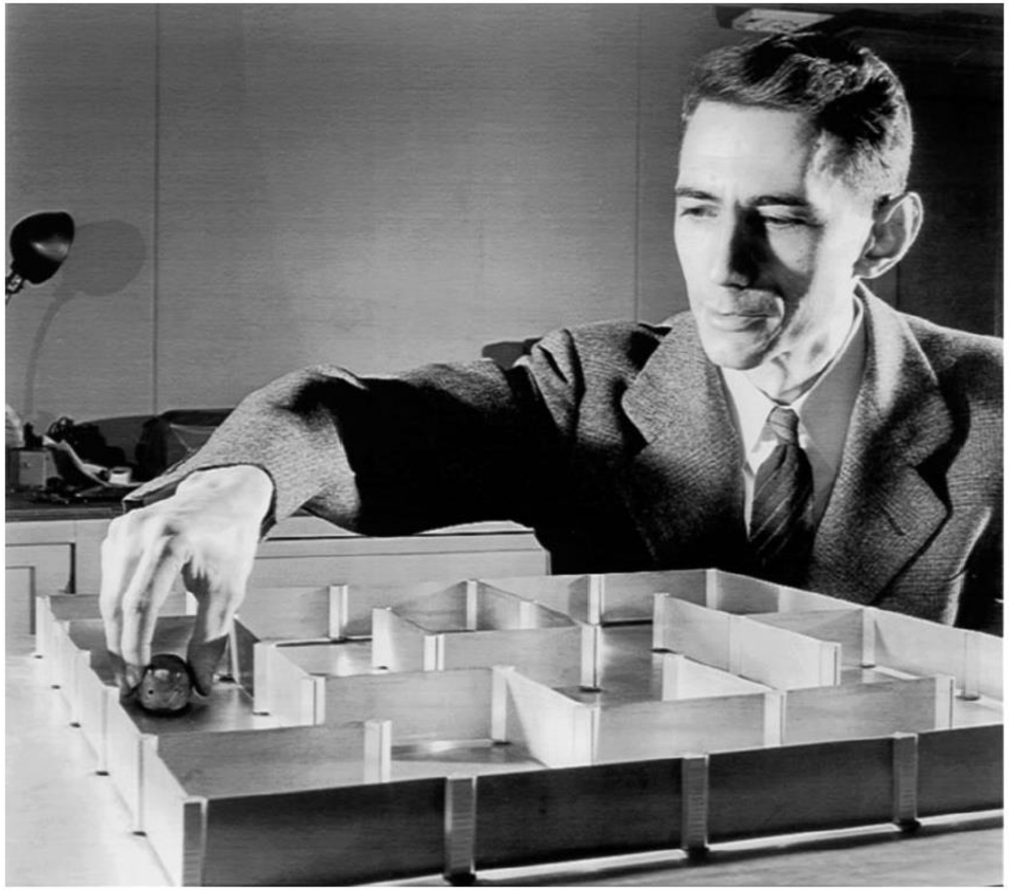
The Editors asked Dr. Shannon to write a paper describing current experiments, and speculations concerning future developments in computer logic. Here is a real challenge for those in search of a field where creative ability, imagination, and curiosity will undoubtedly lead to major advances in human knowledge.—*The Editor*

Summary—**This paper reviews briefly some of the recent developments in the field of automata and nonnumerical computation. A number of typical machines are described, including logic machines, game-playing machines and learning machines. Some theoretical questions and developments are discussed, such as a comparison of computers and the brain, Turing's formulation of computing machines and von Neumann's models of self-reproducing machines.**

* Decimal classification: 621.385.2. Original manuscript received by the Institute, July 17, 1953.
† Bell Telephone Laboratories, Murray Hill, N. J.

Introduction

SAMUEL BUTLER, in 1871, completed the manuscript of a most engaging social satire, *Erewhon.* Three chapters of *Erewhon*, originally appearing under the title "Darwin Among the Machines," are a witty parody of *The Origin of Species*. In the topsy-turvy logic of satirical writing, Butler sees machines as gradually evolving into higher forms. He considers the classification of machines into genera, species and vari-



Why now?

Massive amounts of data that can be used to train Machine Learning models are being generated, for example through daily creation of billions of images, online click streams, voice and video, mobile locations, and sensors embedded in the Internet of Things devices.

Computing capacity has become available to train larger and more complex models much faster. Graphics processing units (GPUs), originally designed to render the computer graphics in video games, have been repurposed to execute the data and algorithm crunching required for machine learning at speeds many times faster than traditional processor chips.

Key Trend Emerging: Specially design chips and Hardware for Machine Learning workloads (Tensor Units).

Machine-learning algorithms have progressed in recent years, especially through the development of deep learning and reinforcement-learning techniques based on neural networks.

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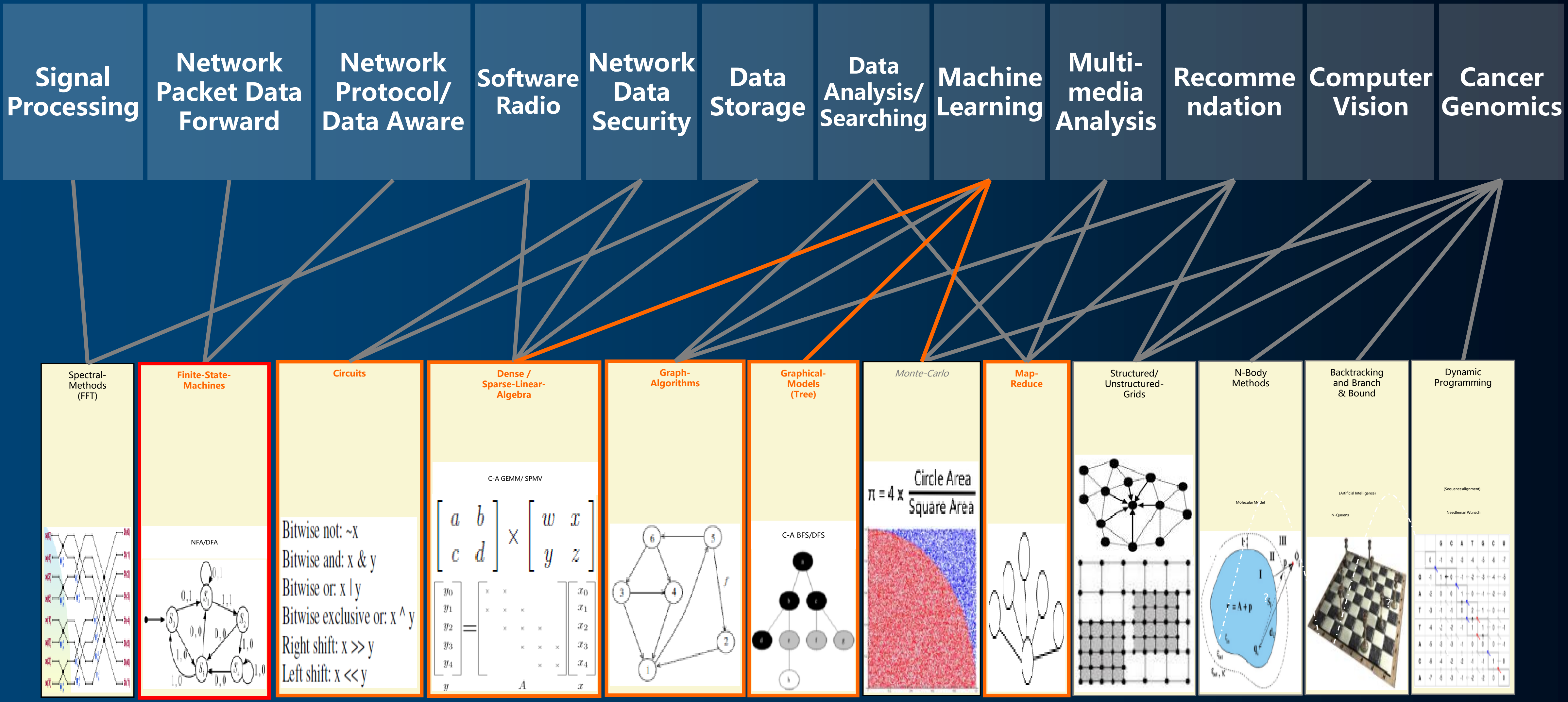
New Paradigms for Algorithms



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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

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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

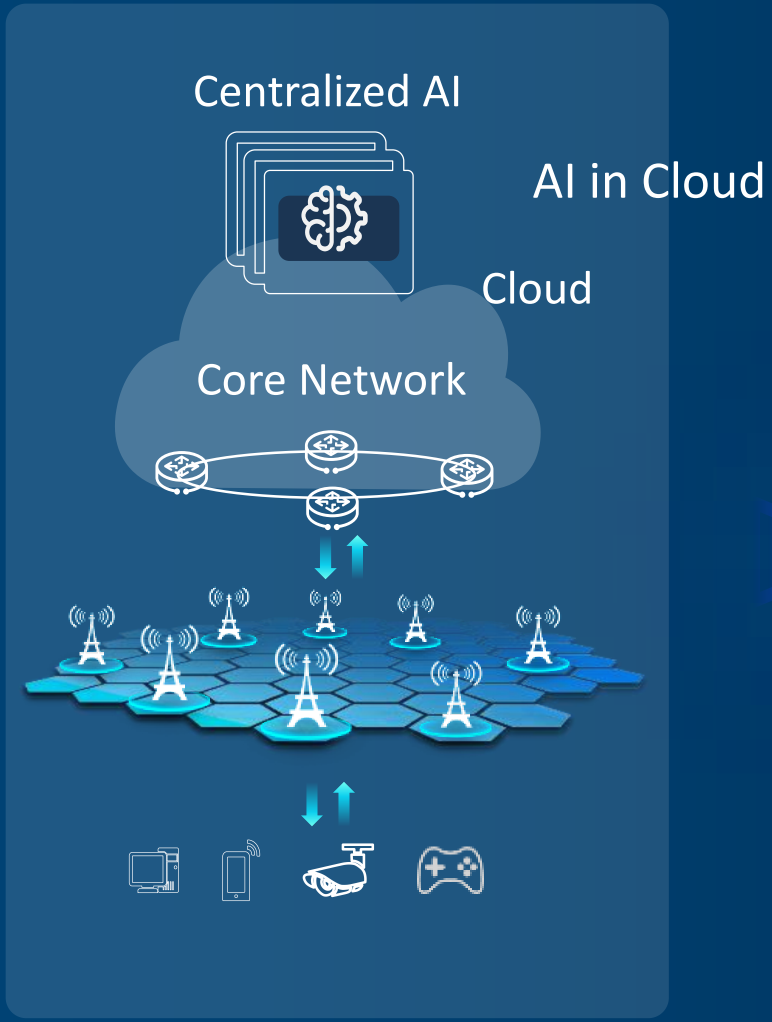
Cooperative Training/Inference

Edge
Local 本地

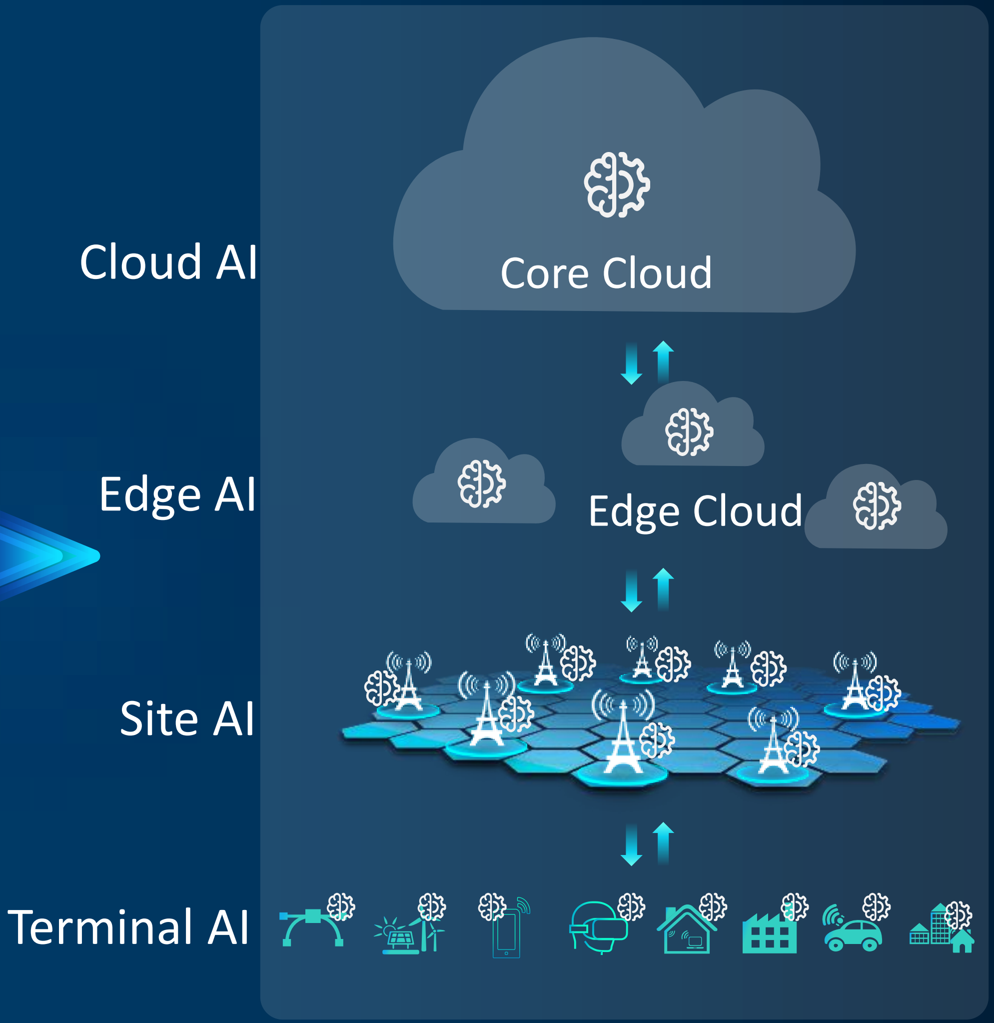
Cooperative Training/Inference

Cloud 云
Large-scale 大规模

New Paradigms for Networks



Current Cloud and AI



Integrated Cloud, Network & AI

L5 Full Scenario
(Intent-Driven)

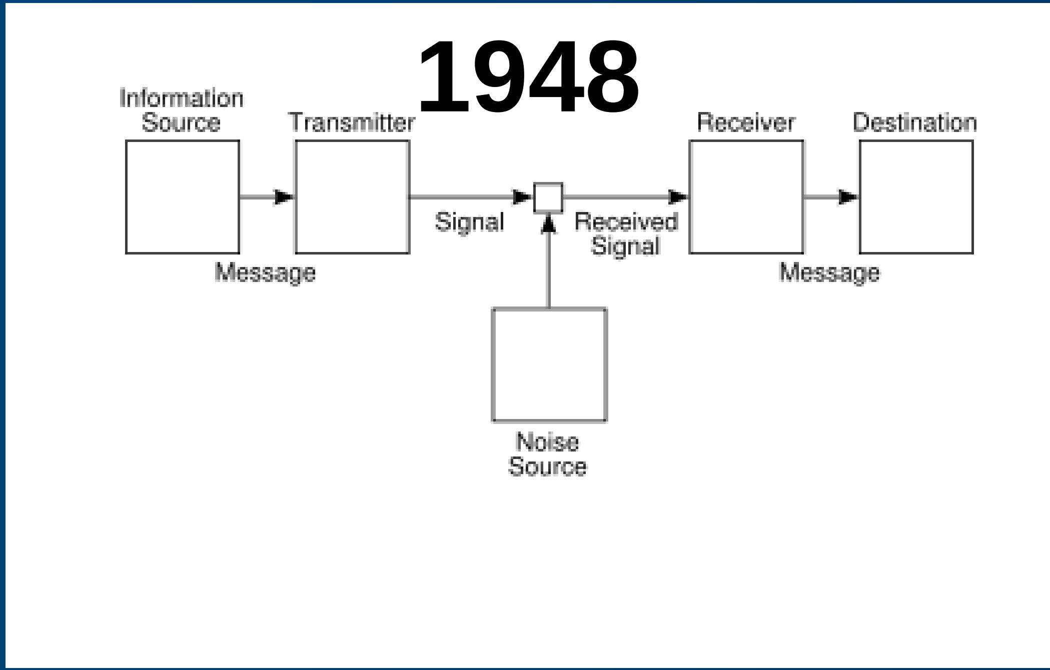
L4 Service Scenario
(Autonomy)

L3 Single-Scenario
(Conditional Automation)

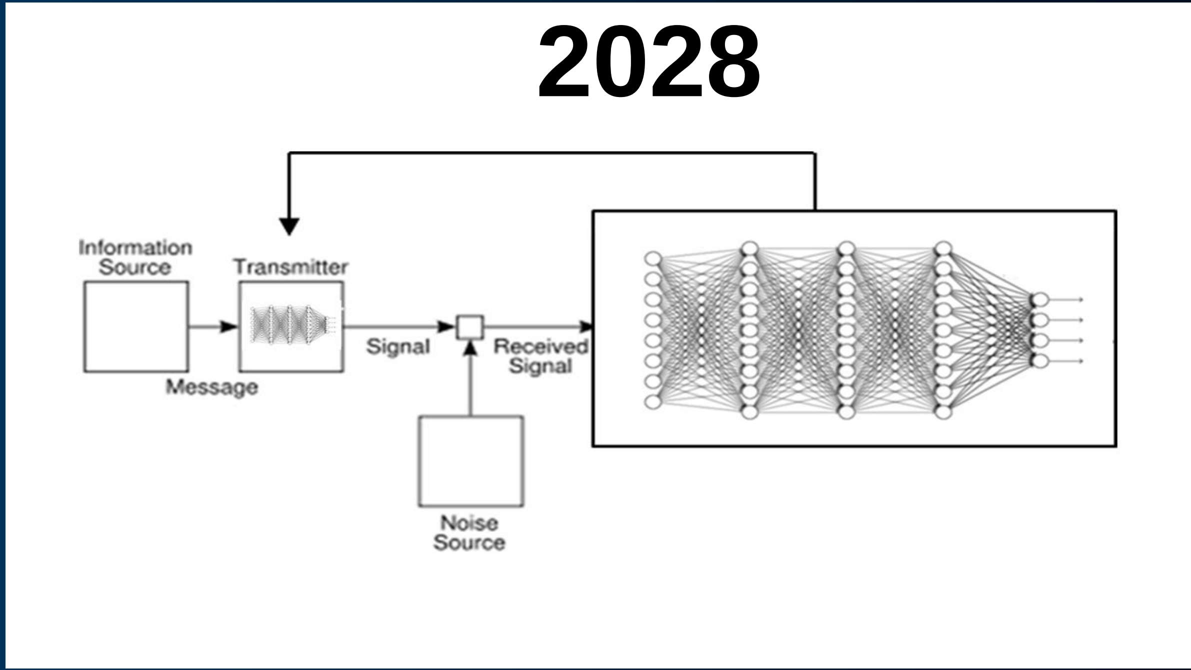
L2 Task
(Partial Automation)

L1 Functionality
(Expertise Based)

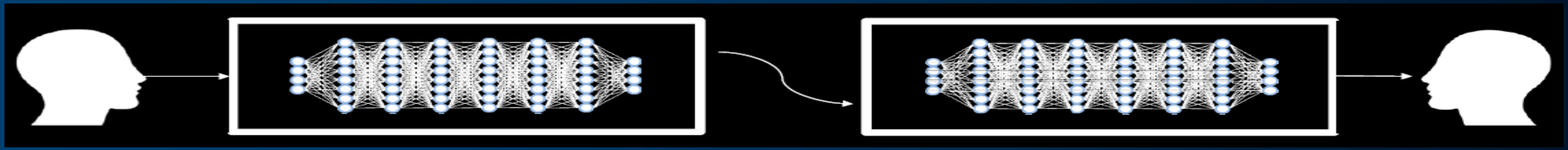
Smart Communications



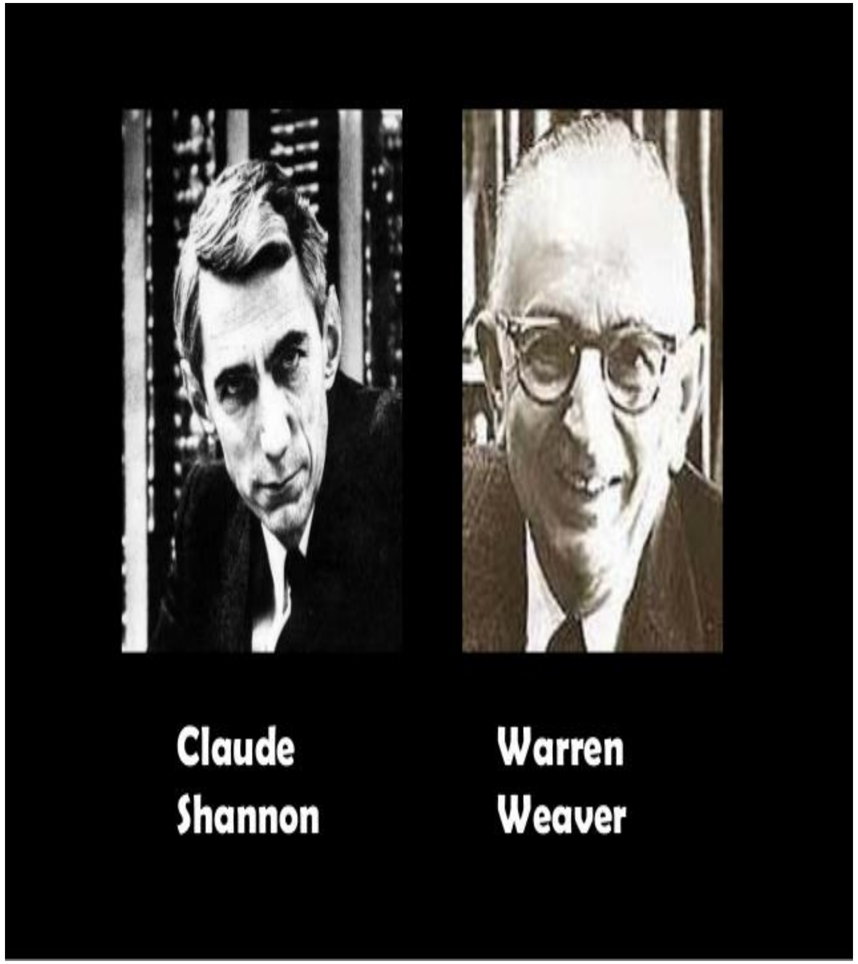
Shannon 1.0



Shannon 2.0



Semantic Communications



1.2. Three Levels of Communications Problems

Relative to the broad subject of communication, there seem to be problems at three levels. Thus it seems reasonable to ask, serially:

LEVEL A. How accurately can the symbols of communication be transmitted? (The technical problem.)

LEVEL B. How precisely do the transmitted symbols convey the desired meaning? (The semantic problem.)

LEVEL C. How effectively does the received meaning affect conduct in the desired way? (The effectiveness problem.)

in

RECENT CONTRIBUTIONS TO THE MATHEMATICAL THEORY OF COMMUNICATION 1
Warren Weaver, The Rockefeller Foundation

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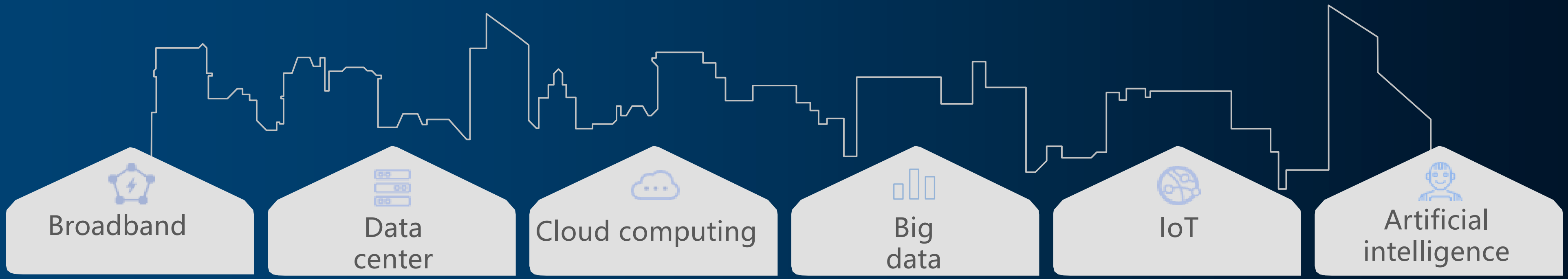

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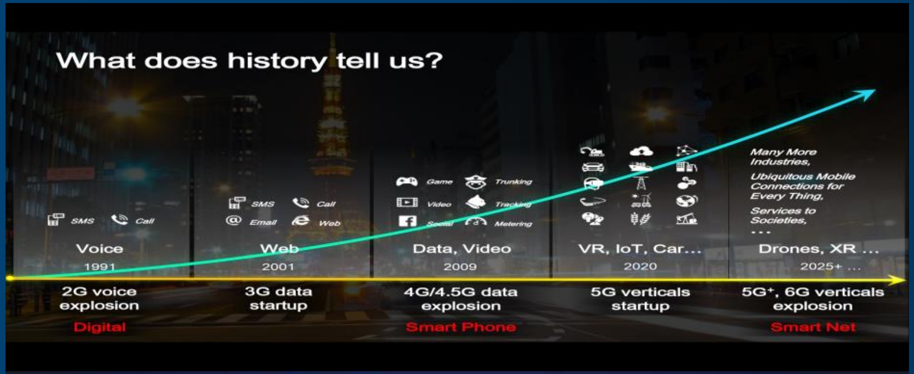
Better Connection

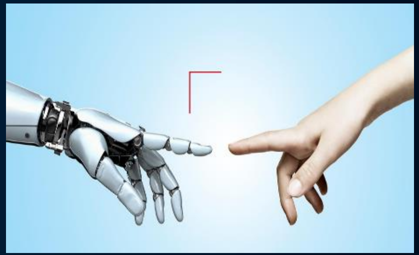


Information Everywhere

Holoportation & Edge Intelligence (4.62Tbps)

Autonomous / Flying Transportation (4T/day)

Digital Industry and Robotics (<<1ms)



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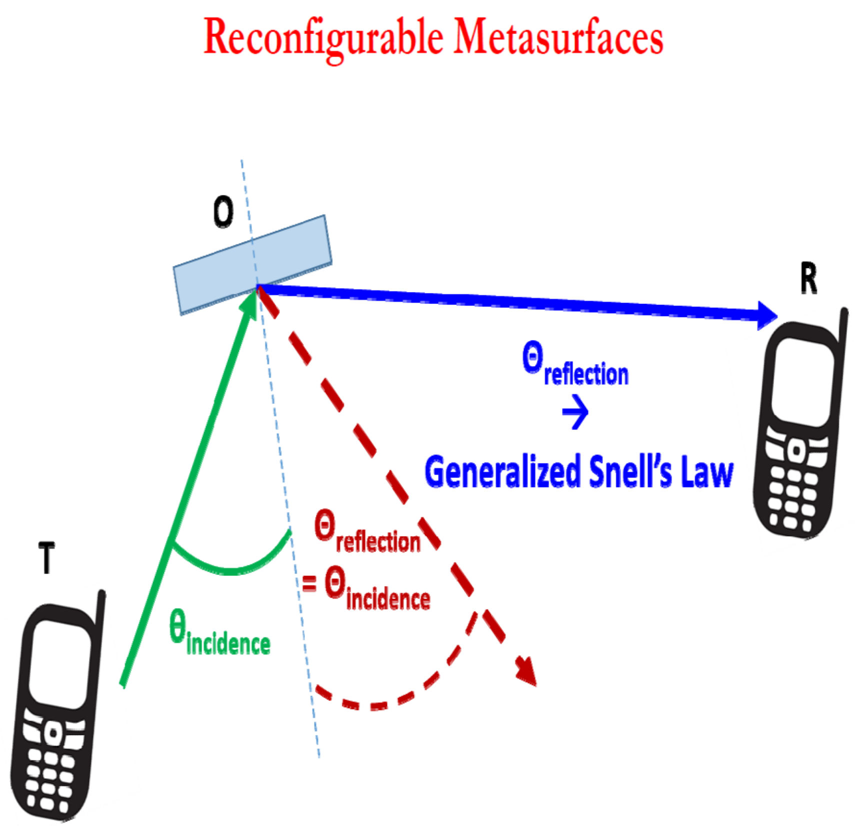
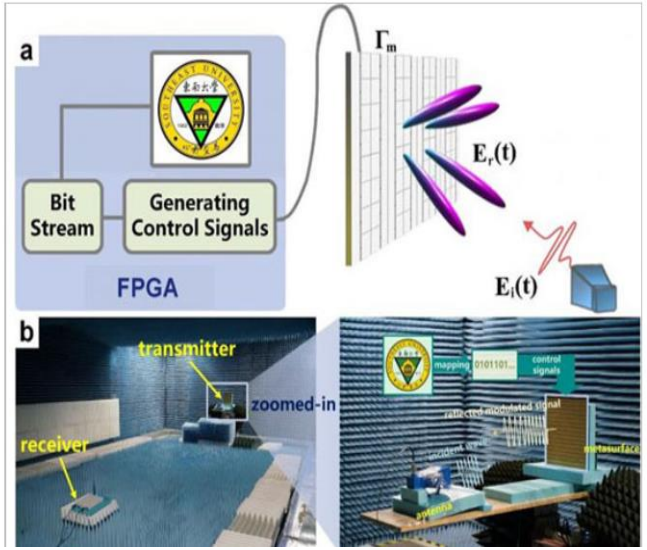
New Electromagnetic Channel Models



Metasurface for Nonlinear Manipulation Could Simplify Wireless Communication

Scientists have developed a metasurface that enables efficient manipulation of spectral harmonic distribution, and have proposed a novel architecture for wireless communication systems based on this time-domain digital coding metasurface. According to the scientists, the metasurface could simplify the architecture of communication systems, while yielding excellent performance for real-time signal transmission. Scientists from the State Key Laboratory of Millimeter Waves, the National Mobil Communication Research Laboratory, and the Photonics Initiative, Advanced Science Research Center located in New York make up the team.



(a) Schematic of the proposed BFSK wireless communication system based on the time-domain digital coding metasurface. (b) Experimental scenario of the BFSK wireless communication system. (c-d) The received messages by the BFSK wireless communication system for different receiving angles, showing stable communication abilities. Courtesy of Science China Press.

Optical nonlinear phenomena are typically

From Connected Things to Connected Intelligence

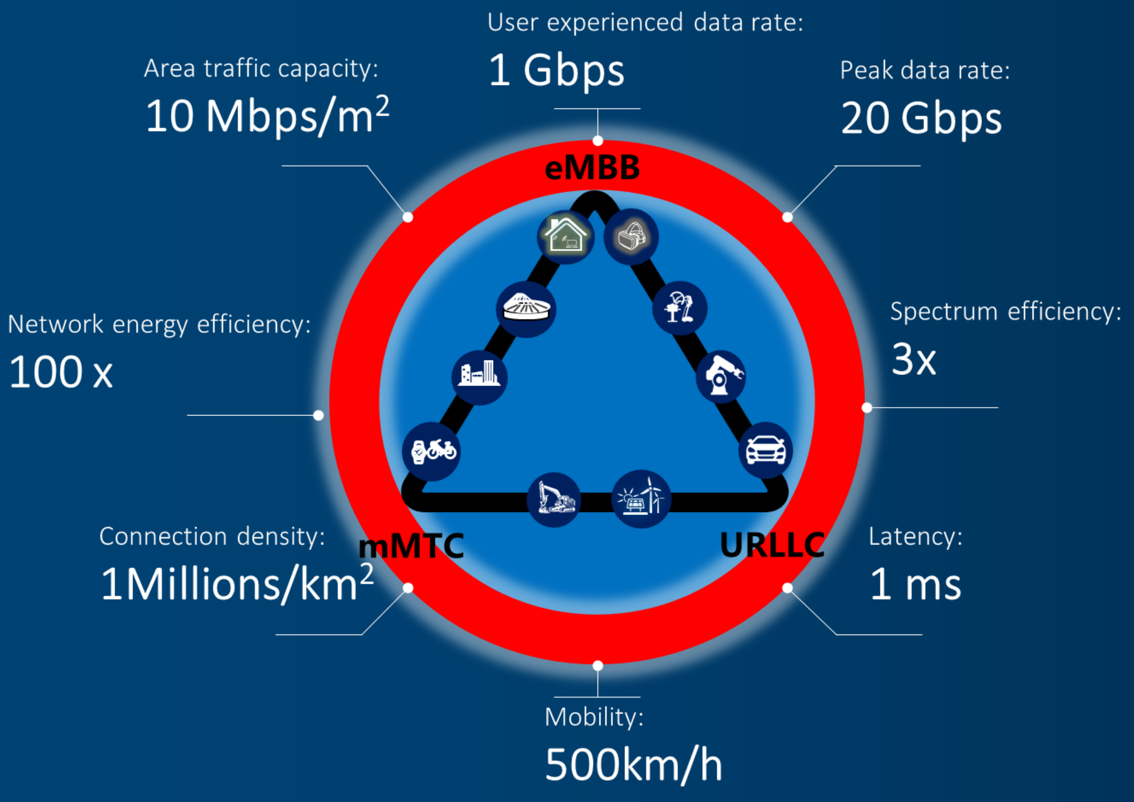
2020

2030

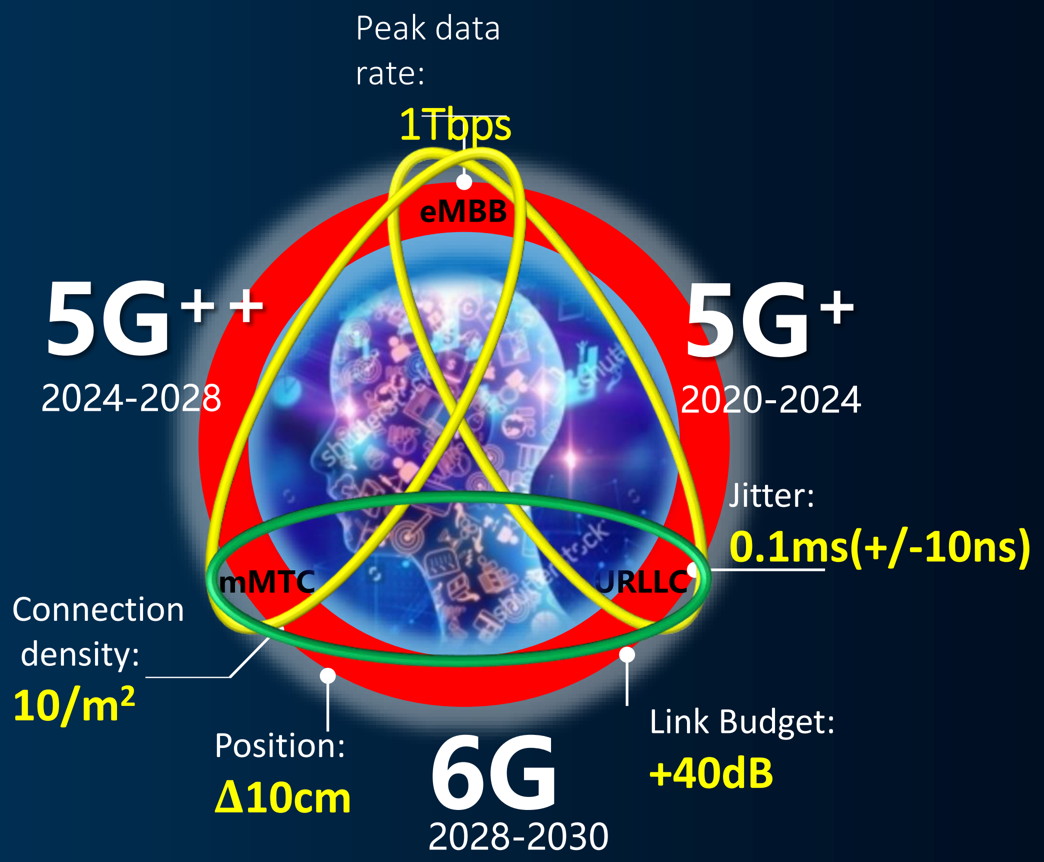
5G is Now

Standardization Timetable

Beyond 5G



2020



2030

THANK YOU

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