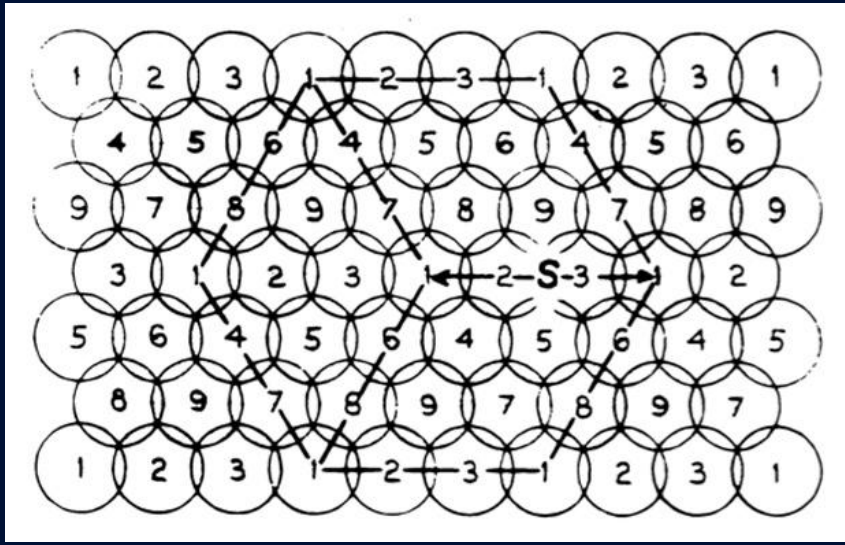

NOKIA Bell Labs
New value creation
driving a new generation network
Peter Vetter
Levi, March 26, 2019

The invention of cellular networks (1947)

0G



BELL TELEPHONE LABORATORIES
INCORPORATED

COVER SHEET FOR TECHNICAL MEMORANDA

SUBJECT: Mobile Telephony - Wide Area Coverage - Case 20564

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18-W.R.Young
19-K.Bullington
20-D.H.Ring

MM- 47-160-37
DATE 11 December 1947
AUTHOR D. H. Ring

~~XXXXXXXX~~
~~ABSTRACT~~

ABSTRACT

In this memorandum it is postulated that an adequate mobile radio system should provide service to any equipped vehicle at any point in the whole country. Some of the features resulting from this conception of the problem are discussed with reference to a rather obvious plan for providing such service. The plan which is outlined briefly is not proposed as the best solution resulting from an exhaustive study, but rather is presented as a point of departure for discussion and comparison of alternative suggestions which may be made.

The discussion in this memorandum is limited to some problems connected with the efficient utilization of a given frequency allocation for wide area coverage. Only a portion of the total allocation is available at any one point in the plan discussed. It is hoped that a future memorandum can be prepared dealing with the most efficient utilization of the frequency band assigned to a particular small area, i.e., methods of modulation, multiplexing, etc.

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The first mobile phone
1G

Martin Cooper –

First cell phone call in 1973

First cellular system trial 1978

Commercial launch 1984

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Democratization of mobile telephony
2G

Finnish Prime Minister - World first GSM call (1991)

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Every generation driven by new technologies and new application

	1G	2G	3G	4G	5G	6G
Era	1980s	1990s	2000s	2010s	2020s	2030s
Mobile Access	Analog 	GSM <2 GHz Δ=200kHz 	UMTS <2GHz Δ=5MHz 	LTE <6GHz Δ=nx20MHz 	5G <100GHz Δ=400MHz 	6G <THz Δ=5GHz
Fixed Access	POTS 	ISDN Δ=20kHz 	ADSL Δ=1MHz 	VDSL Δ=30MHz 	G.Fast Δ=200MHz 	FTTH Δ=10GHz
Platform	Analog	Digital	Circuit (ATM)	Packet (IP/Eth)	Cloud (SDN/NFV)	AI ?
Application	Voice	Voice	WAP	Web	IIoT	**?**
Unexpected Application	Fax	SMS/IoT	Web	Facebook Youtube	**?**	**?**

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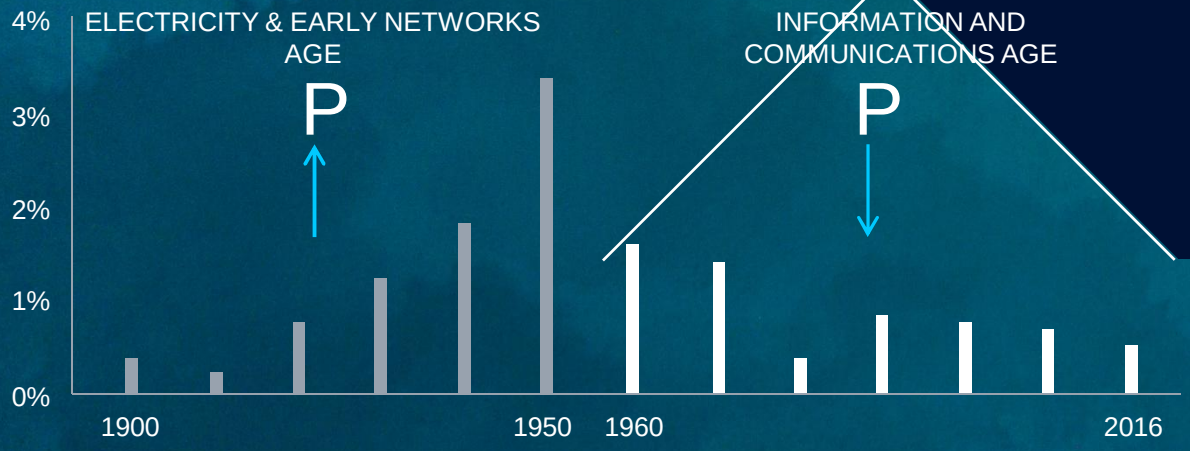
US Productivity Growth



STAGNATION IN PRODUCTIVITY GROWTH

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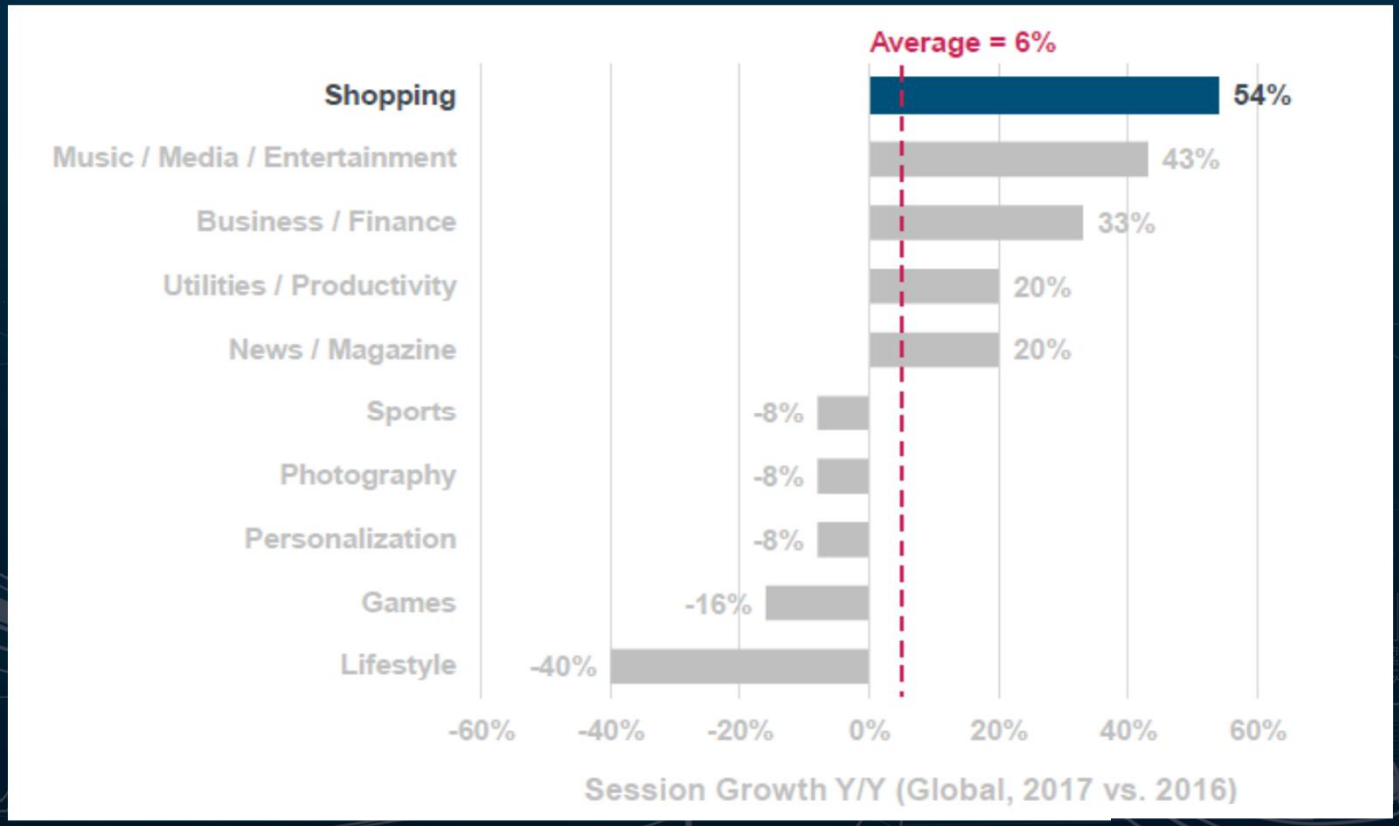
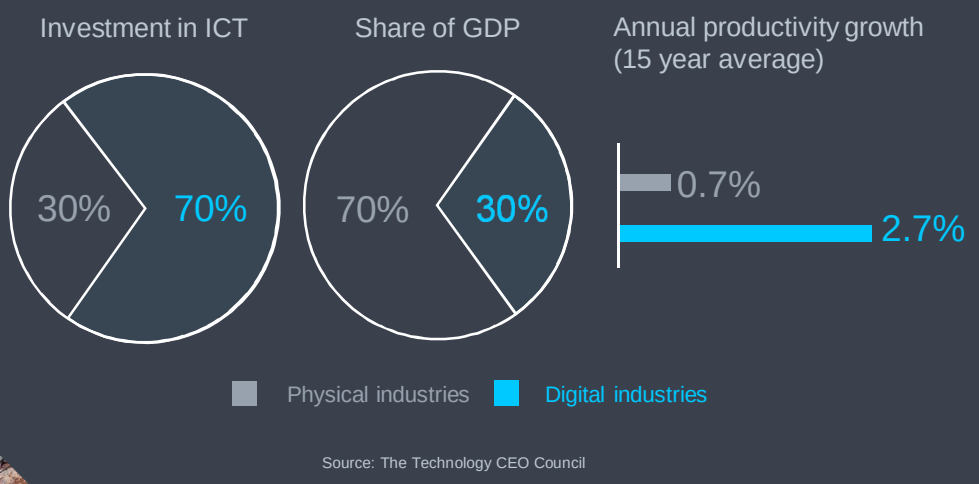
A change is gonna come: consumers now find consuming itself time-consuming

Growth in time spent on mobile devices



Source: Mary Meeker, Internet Trends 2018

TALE OF TWO INDUSTRIES



Source: The Technology CEO Council

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THE JOURNEY FROM INDUSTRIAL REVOLUTION 3.0 TO 4.0

er:

smartphones

w centralized clouds

E-commerce and social platforms

Best effort Internet connectivity

Industrial:

Myriad ‘things’

Multitude of edge clouds

Augmented intelligence control platforms

High performance networking

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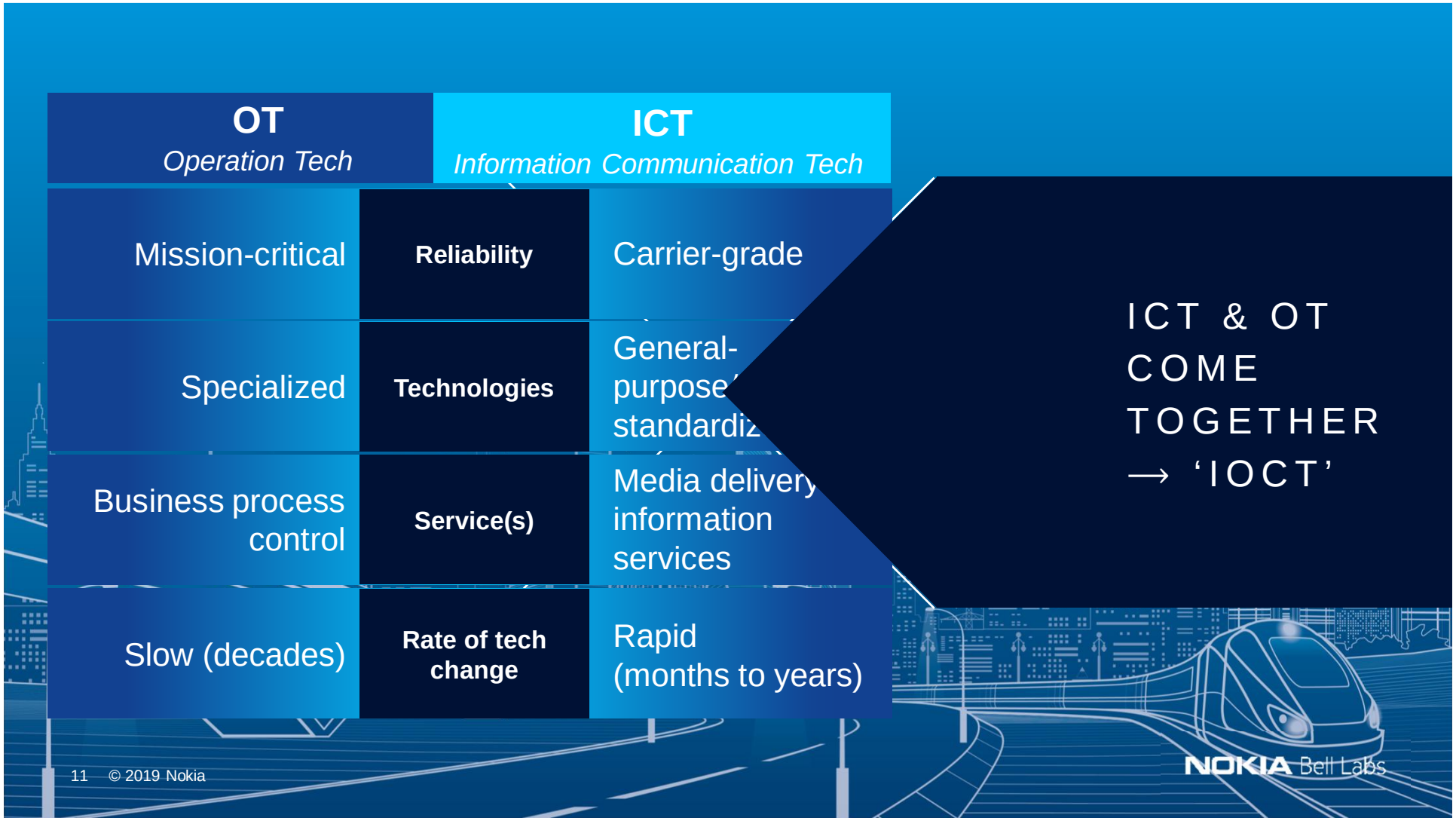
OT
Operation Tech
ICT
Information Communication Tech
Mission-critical
Reliability
Carrier-grade
Specialized
Technologies
General-purpose
standardiz
Business process control
Service(s)
Media delivery
information services
Slow (decades)
Rate of tech change
Rapid (months to years)
ICT & OT COME TOGETHER
⟶ 'IOCT'
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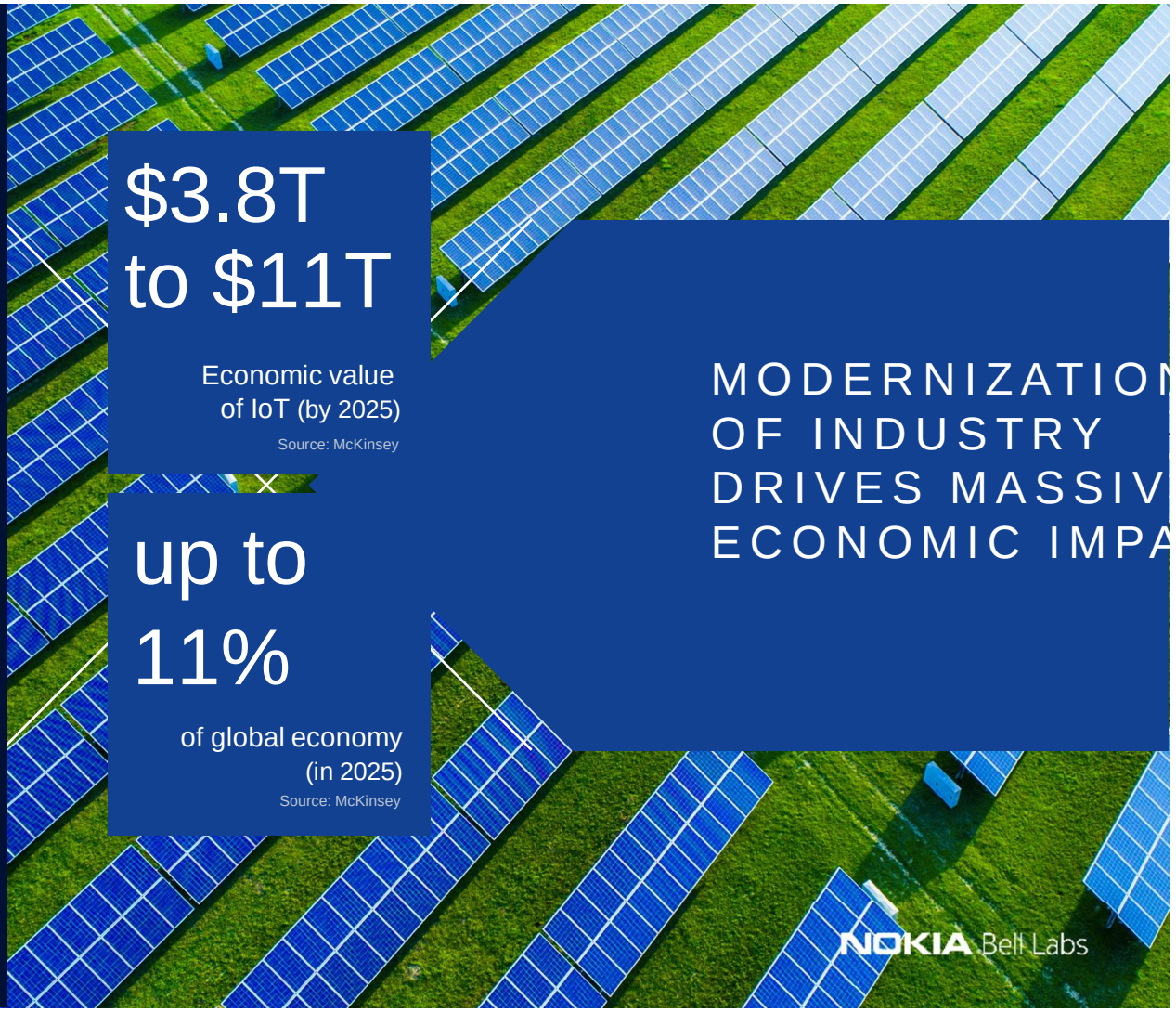
Industry	Sites
Transport venues & ports	50,000
Military bases	10,000
Warehouses	3,300,000
Industrial & manufacturing	10,710,000
Oil & gas	8,000
Power generation	47,6000
Water utility plants	140,000
Mining	54,000
Hospitals & labs	263,000
Total:	**14,582,600**

Comparison: Global base stations sites: ~7M

Source: Harbor Research

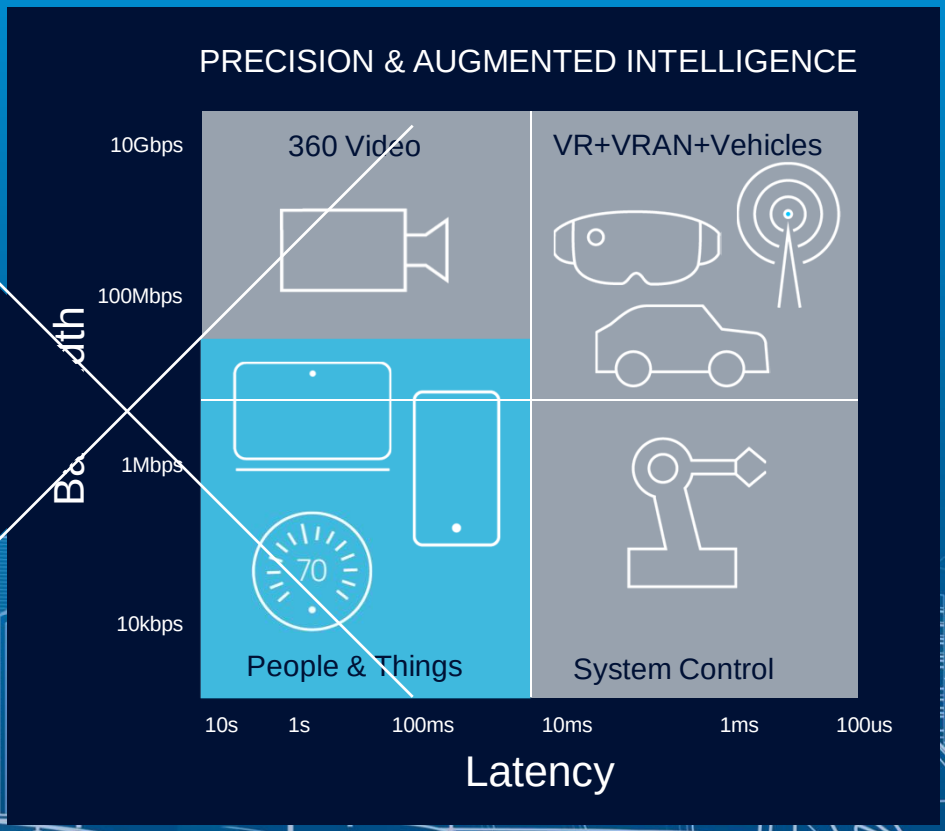


THE REQUIREMENTS FOR “IOCT”

Requirement	**“High-end” TSN examples** *(e.g. IEEE, SIEMENS, TI, Cisco, CERN White Rabbit)*	**3GPP R16 requirement** *(TR22.804), periodic communications*
#devices in common synchronization group	~ 100	Up to 300
Synchronization clock requirement	Sub nanosecond	< 1 µs, < 0.25us for PMSE*
Communication service availability	99.99-99.99999 %	99.999-99.99999 %
Message size	64-500 Bytes	20-1000 Bytes
Cycle time or transmission periodicity (CT)	31,25 µs – 1 ms	0,5 ms - 8 ms
Max. latency	Typ. <5-50% of CT, µs range	< 50% of CT, e.g. can be <1ms
Jitter (user plane)	0.1-100 ns	1 µs, 100 µs, often <50% of CT
Resolution in shared channel access	1 µs (e.g. GbE)	Symbol, slot, TTI (3GPP)

*) PMSE (Programme Making and Special Events) Systems include production tools for audio and video processing for Culture and Creative Industries.

EVOLUTION TO MISSION-CRITICAL APPLICATIONS



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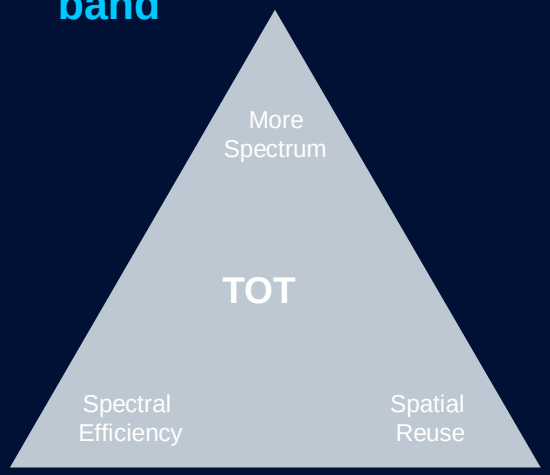
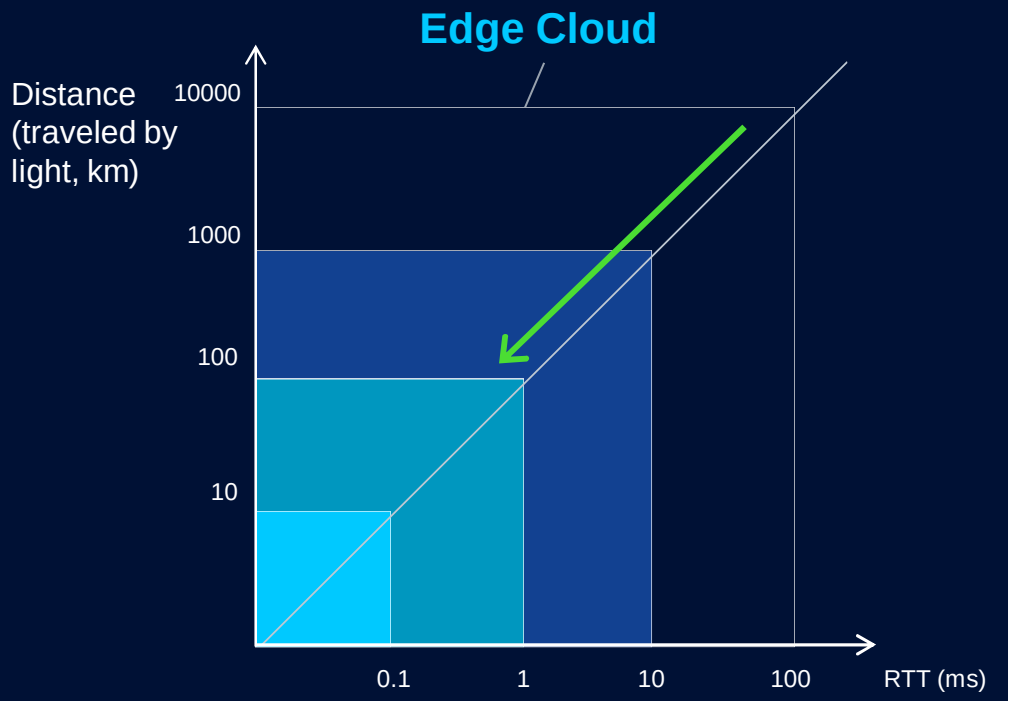
Physics will continue to dictate network and cloud performance





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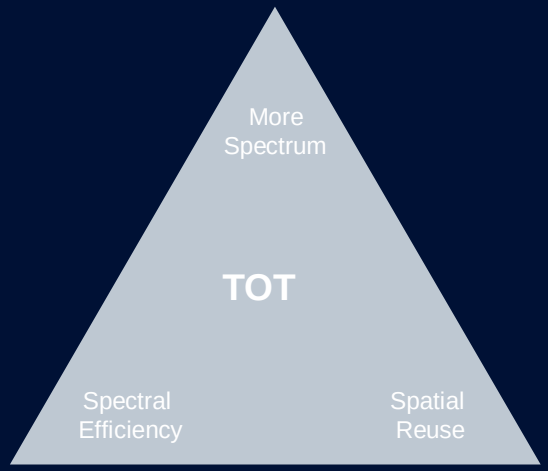
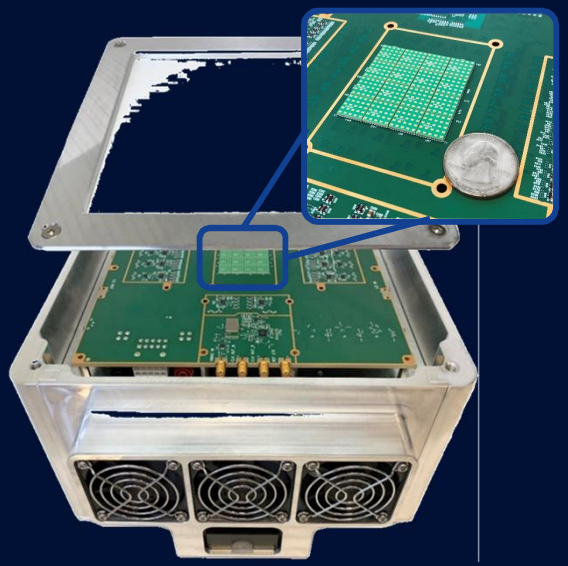
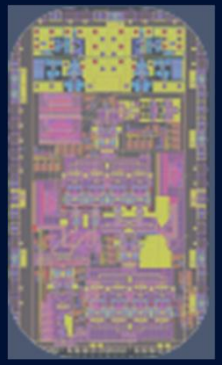
Improving capacity
New Spectrum

10s GHz → 100s GHz → THz





90 GHz prototype system



140 GHz RFIC

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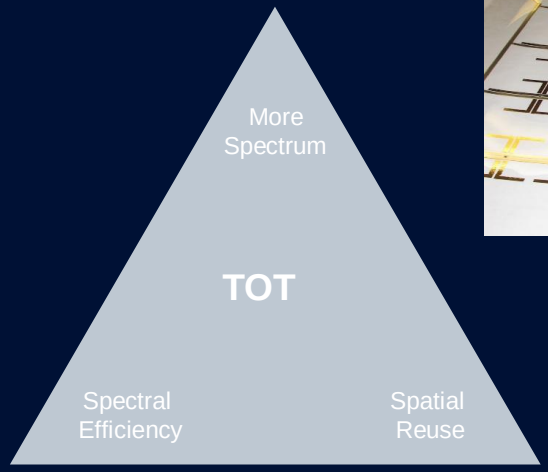
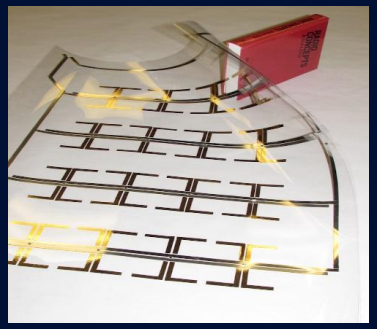
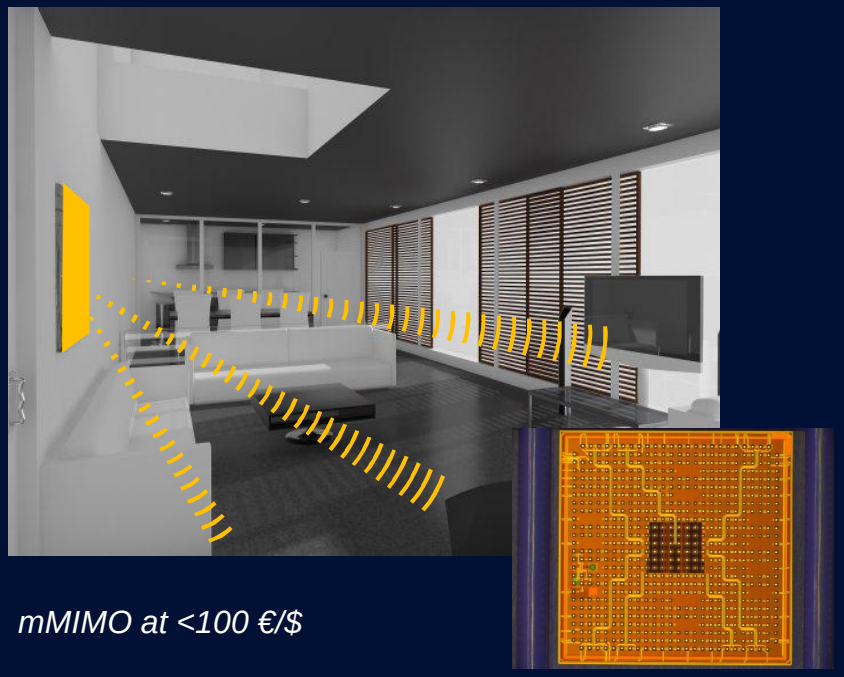
Improving capacity
Smaller Cells at Lower Cost







mMIMO at <100 €/$

100s → 10s meters

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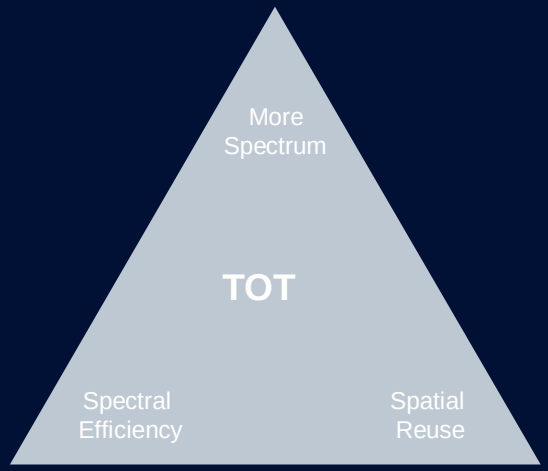
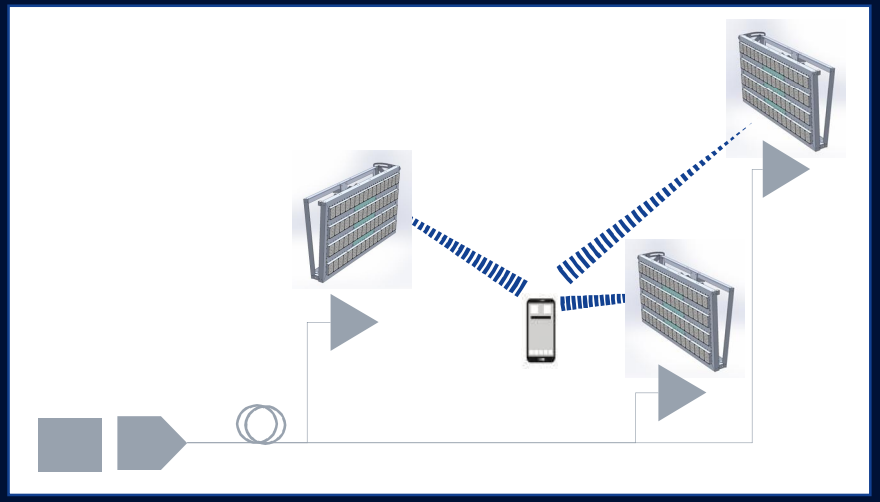
Improving capacity

Rearchitecting the total chain for efficiency of signal, energy and cost





<10 → >20 b/s/Hz

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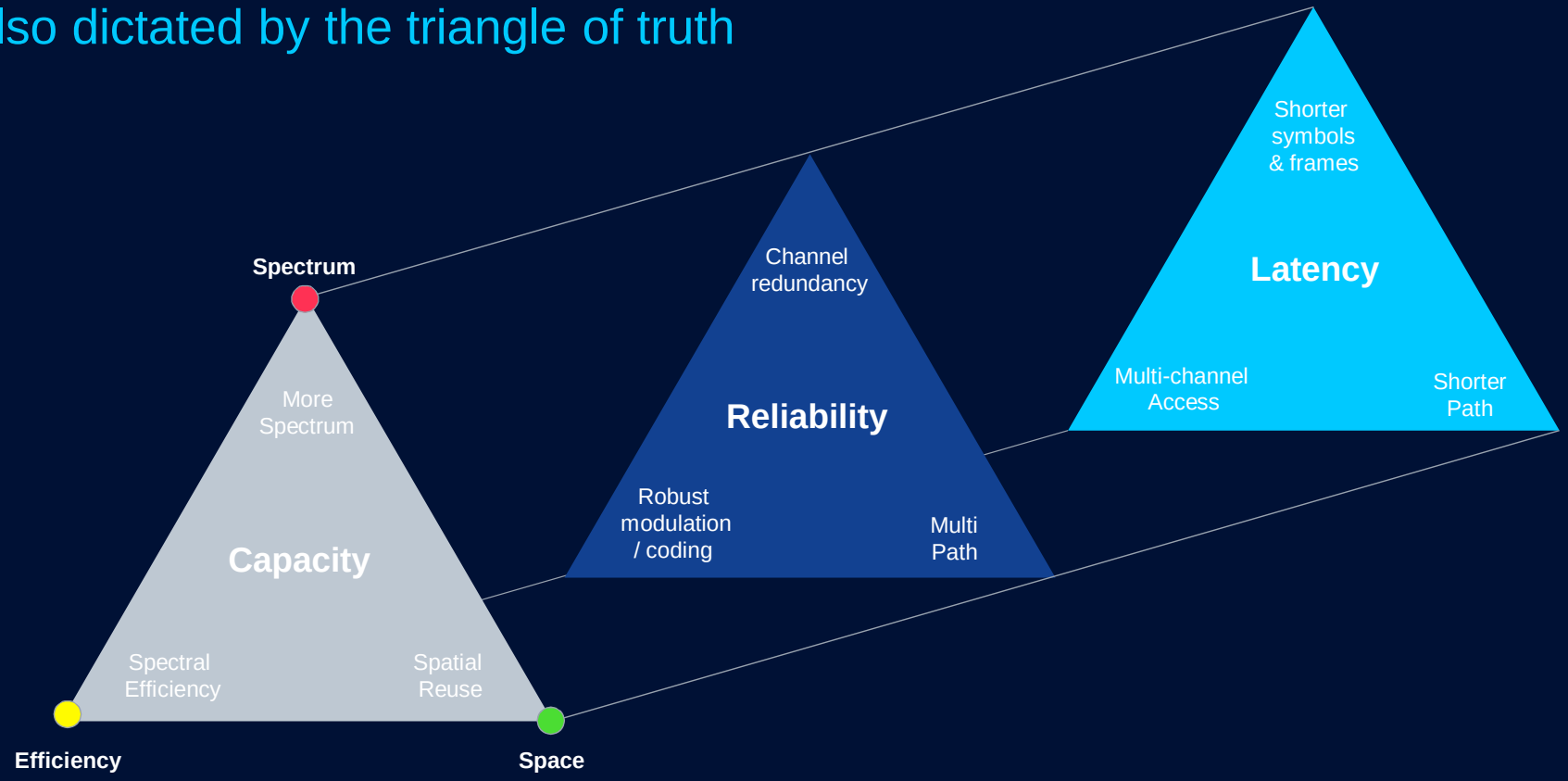
Improving the other critical parameters
Also dictated by the triangle of truth



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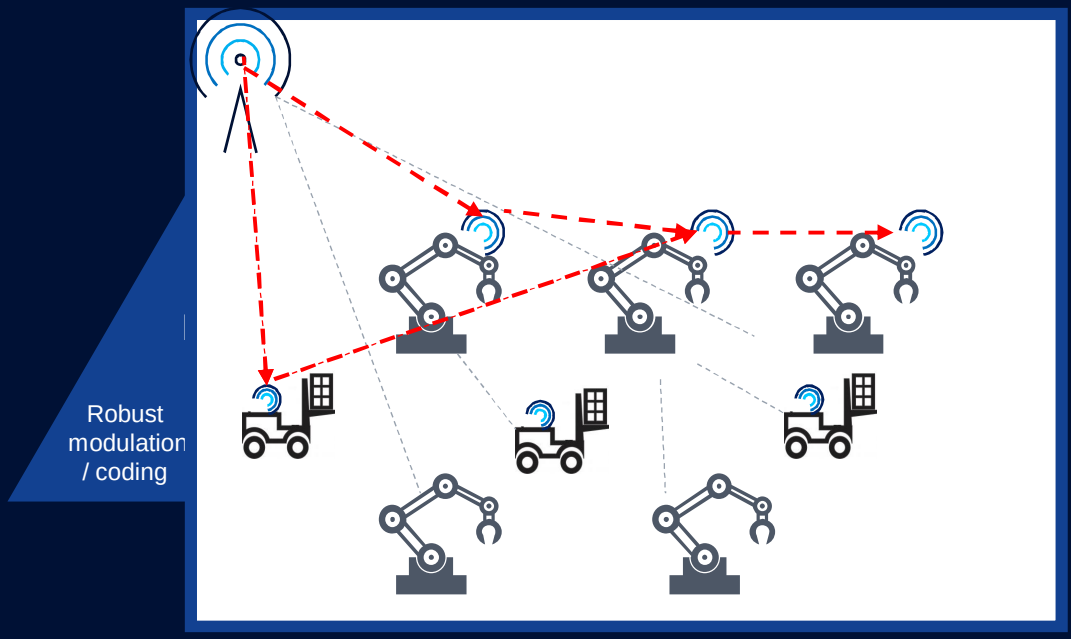
Improving Reliability

Nine “9s” at low cost with single access point



Path diversity

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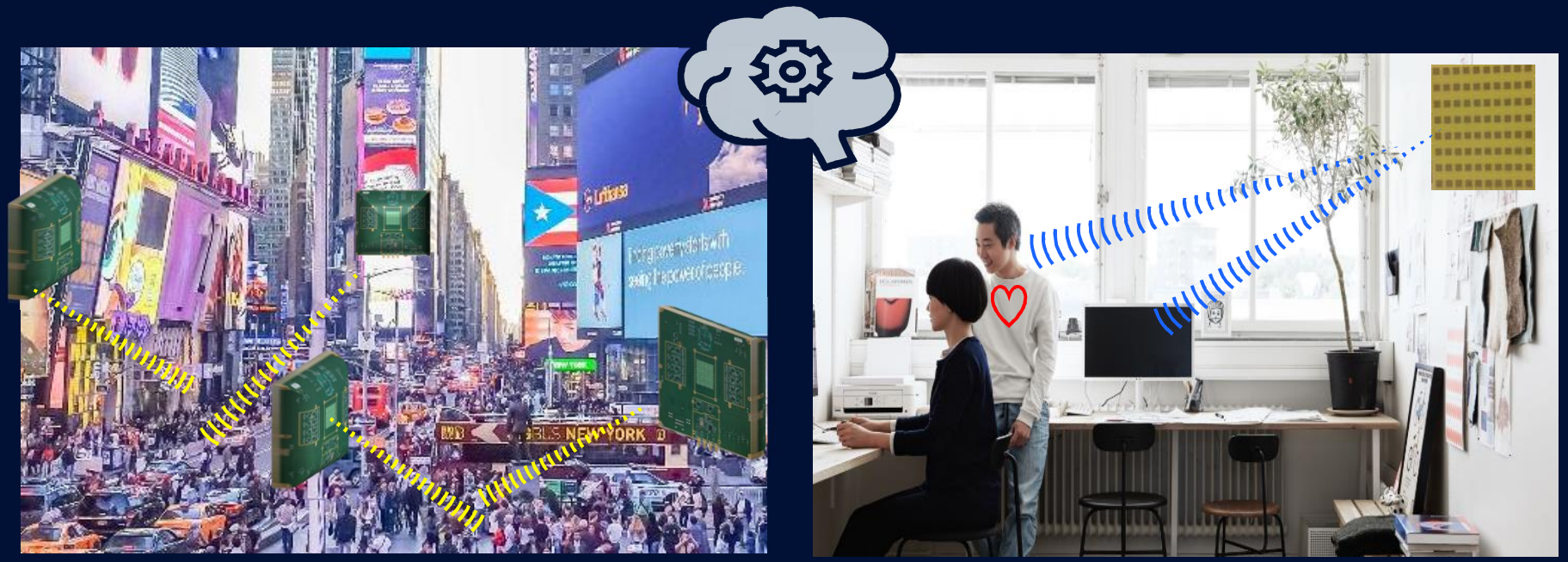
6G: A network with a 6th sense ?

The value of ambient intelligence



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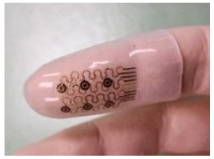
AUGMENTED DIGITAL HUMAN 'SYSTEM'

Augmented distributed computing system

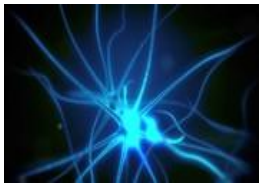
Augmented physical actuation systems

Augmented intelligent thinking systems

Augmented hyperspectral sensory devices



Augmented digital nervous system



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Research Direction for the network 2030

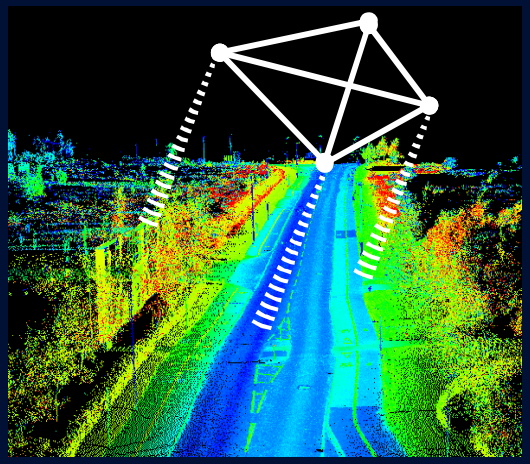
Preparing the network for the era of human and machine augmentation

Hyper Specification

- One network platform customizable for highly specialized uses

Hyper Capable

- Vastly expanding across all dimensions using spectrum up to THz



Hyper Sensing

- 6th Sense: Inferring state and meaning to augment humans and machines

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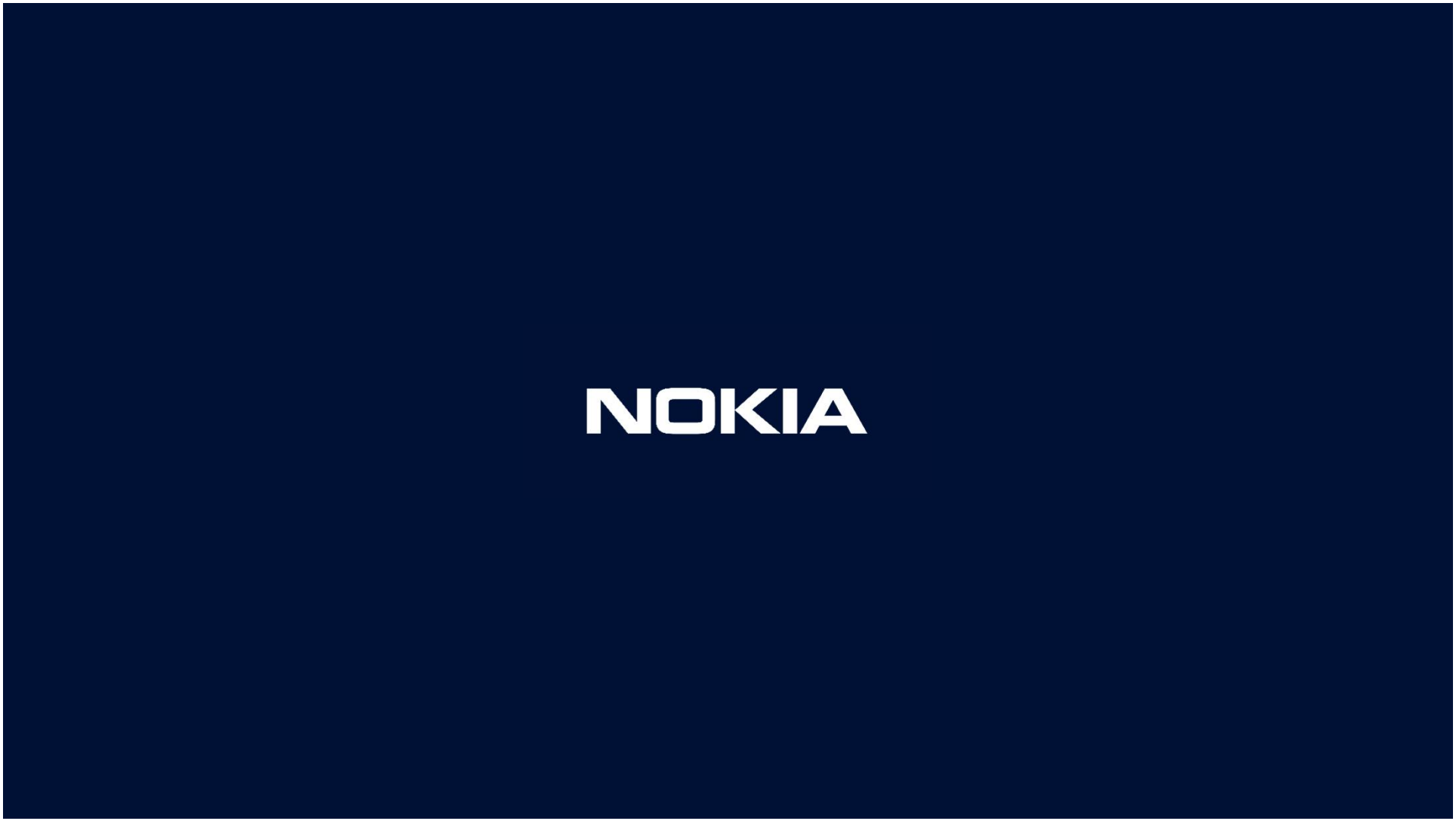
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