On the path to 6G

Industry alignment and collaboration is key to bring it to life

Preben Mogensen, Nokia Bell Labs Fellow
EuCNC & 6G Summit 2022

Services to evolve from 5G, to 5G Advanced and 6G

2022 5G	5G-Advanced	6G 2030
High quality video (4K-8K)	XR - fully immersive user experience	Holographic transmissions
Object driven digital twinning (e.g. an engine)	Large scale digital reconstruction (e.g. a vertical farm)	Broad based digital twins with RT synchronous updates (e.g. smart city)
Data communication and control	Provide precise location and timing services that complement GNSS	Network with a 6th sense

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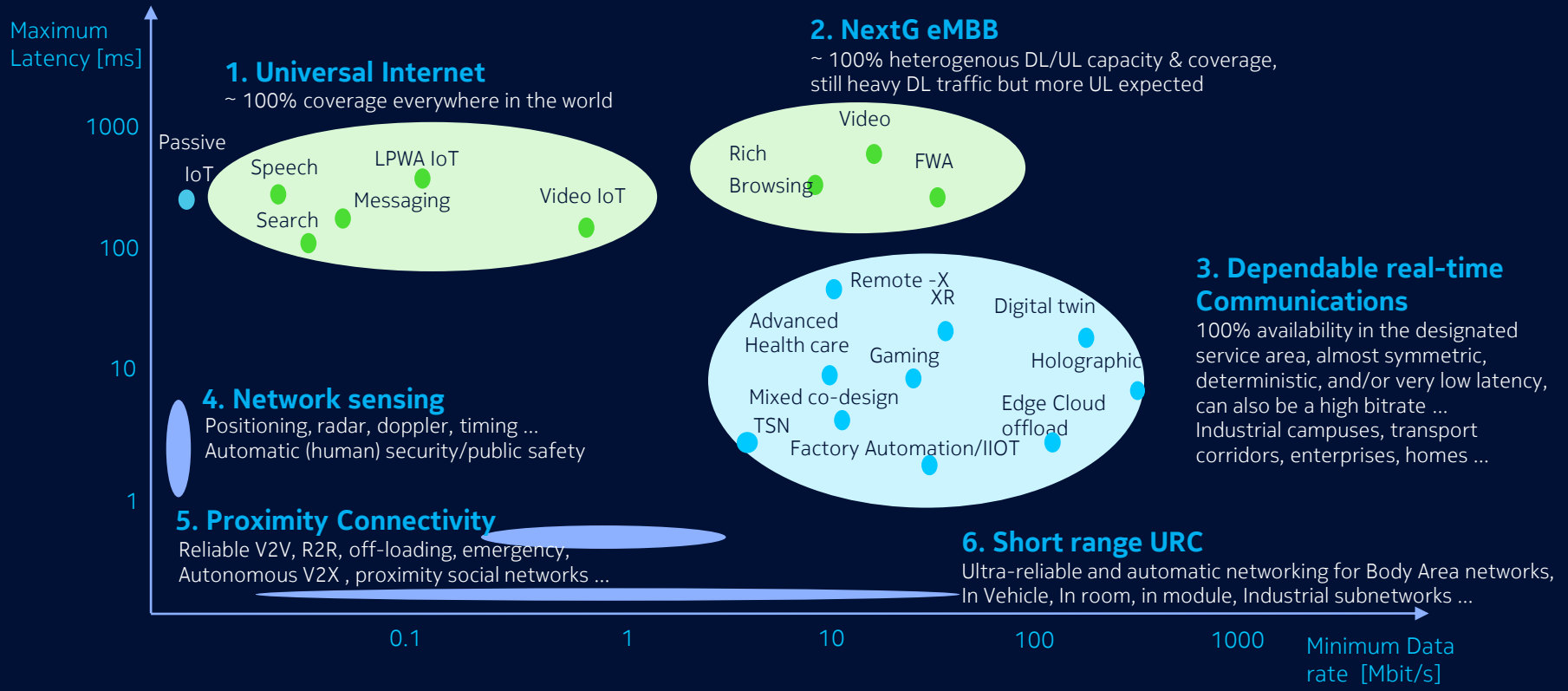
Key service categories driving the 6G development @ 2030



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6G technologies landscape
Nokia perspective

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5G-Advanced and 6G spectrum options

6G Peak capacity layers and high precision sensing

Localized high capacity & FWA

6G capacity expansion layer

Basic capacity layers, NTN & URLLC

Basic coverage & IoT

6G coverage expansion layer

Densification, Efficient design

Next-Gen Massive MIMO

Sub-THz

6G

D-band (130-174.8 GHz)
W-band (92-114.25 GHz)

>100GHz

mmWave

5G, 6G

57-71 GHz (unlicensed)
24-52 GHz (licensed)

5G-Advanced, 6G

7-20 GHz (shared)

~10GHz

Mid band

5G, 6G

2.5-7.1 GHz (licensed/shared/unlicensed)

4G, 5G, refarming to 6G

1.5, 1.8, 2.1, 2.3, 2.6 GHz (licensed/shared)

Low band

4G, 5G, refarming to 6G

600, 700, 800, 900 MHz (licensed)

<1GHz

6G

<1.5 GHz (licensed/shared)

6G 5G 4G

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Massive MIMO for higher site spectral efficiency

Low-cost/Low-power Radios/Arrays

Scale to very large arrays

Flexible Radios/Arrays

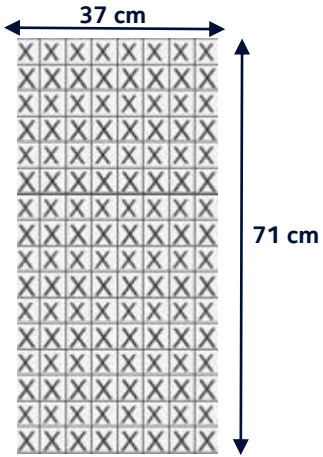
Multi-band, large bandwidth, waveform agnostic

Advanced Signal Processing Platforms & Algorithms

Increase spatial multiplexing efficiency

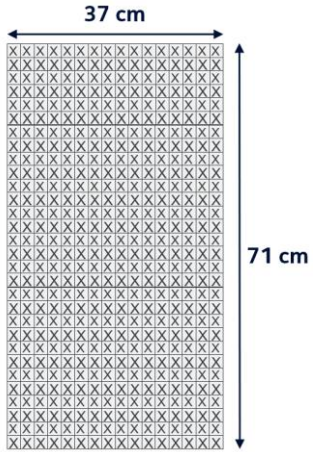
Coverage solutions

Beamforming and coupling to lower bands



256 radiator size @ 3.5 GHz

100 MHz, 160 MHz,…



1024 radiator size (7 GHz) is similar to the existing 3.5 GHz mMIMO antennas

100 MHz, 200, 400 MHz,…

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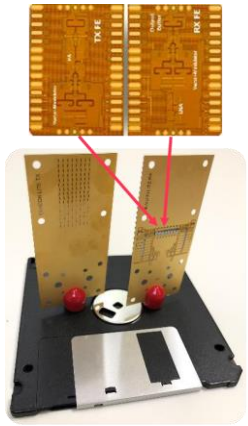
Sub-THz air interface for highest peak data rates

Efficiently providing ultra high bandwidth under challenging conditions

Ultra-high data rates

Future applications requiring
up to and beyond **100 Gbit/s**

Advanced HW components



World's first D-Band
Phased-Array-on-Glass

New PHY layer for sub-THz

- Low PAPR waveforms
- High gain antenna arrays
- Advanced beam forming for hybrid architectures

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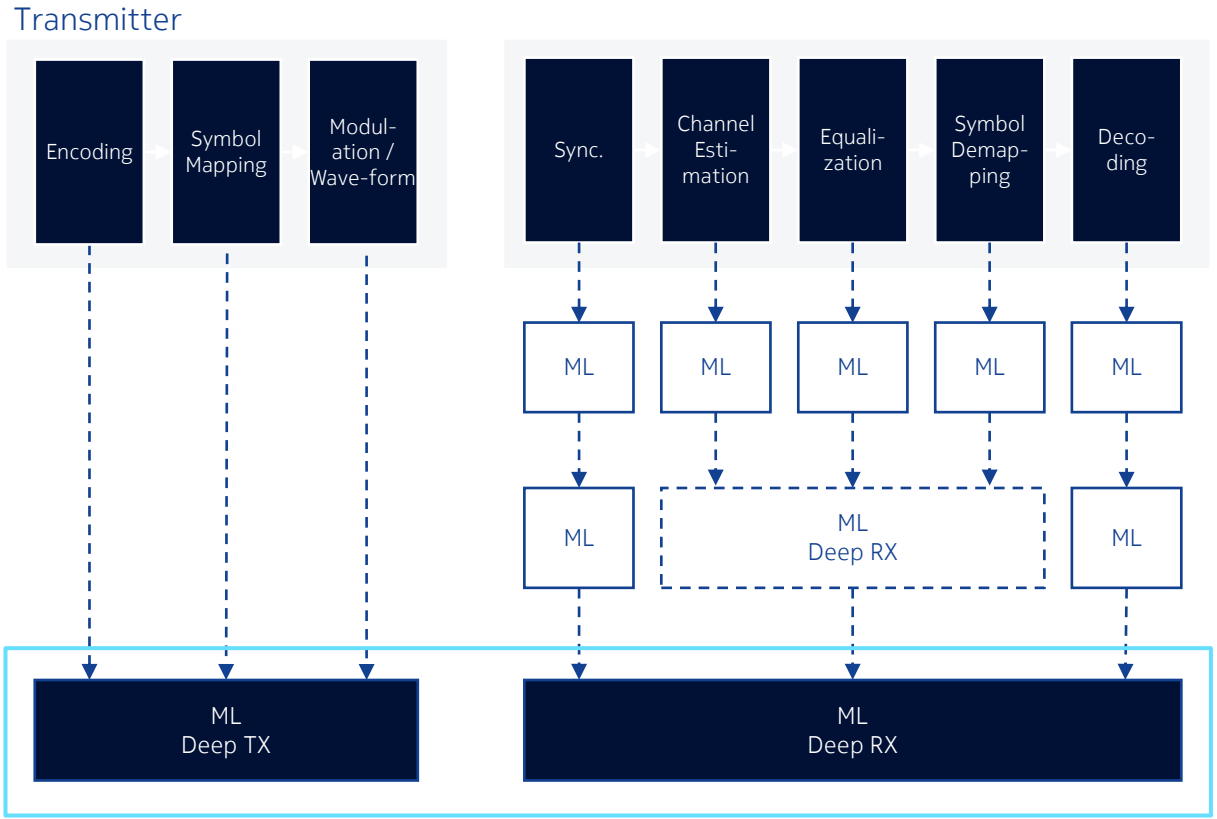
Roadmap to optimized 6G AI native air interface



5G

The classical architecture

5G-Advanced

ML replaces/enhances individual processing blocks

5G-Advanced

ML replaces multiple processing blocks

6G

ML designs part of the PHY itself

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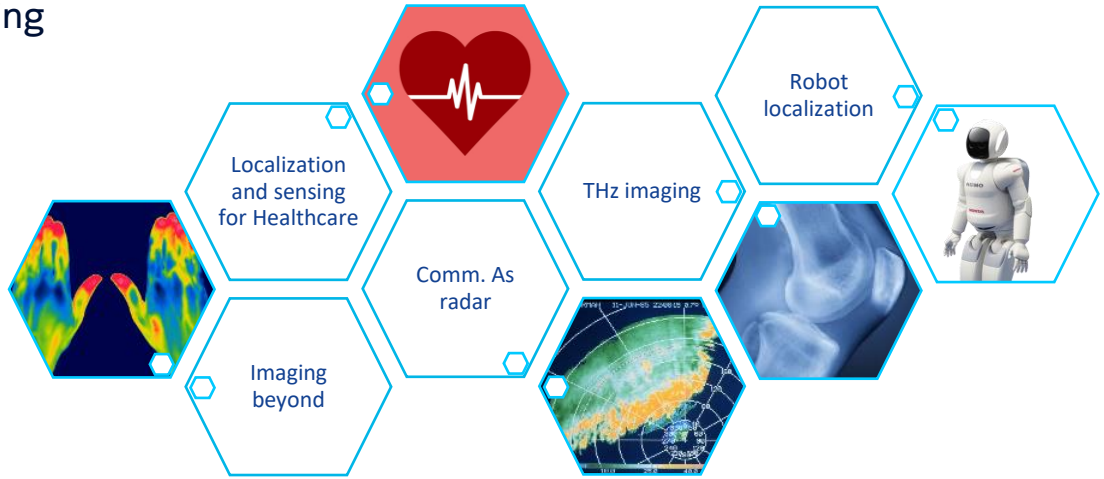
6G network (&device) with a 6th sense

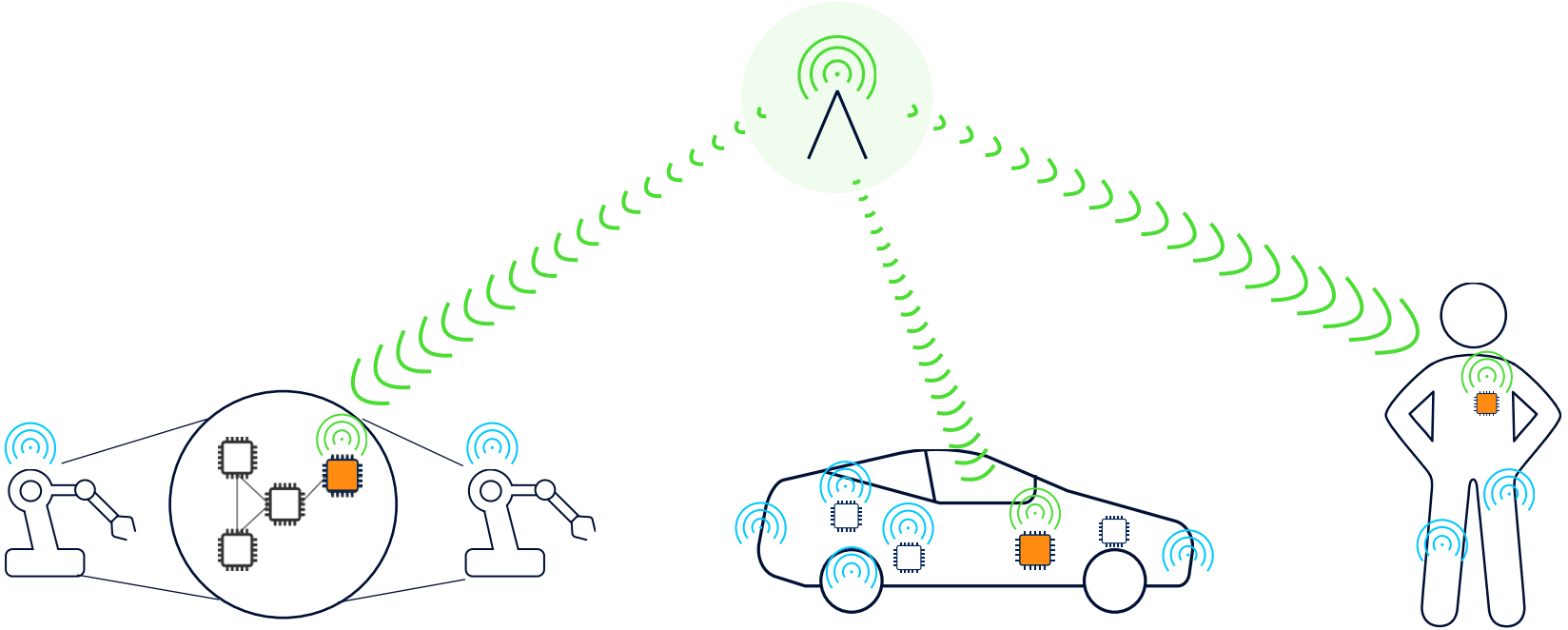
Simultaneous communication and sensing

- Waveform multiplexing
- Resource allocation
- Beam sweeping
- CSI based sensing
- High precision localization in NLOS



6G extreme connectivity

The end-point is a network for life-critical communication



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6G architecture themes

Het-Cloud	New RAN-Core functionality	Cognitive Networking	Automated Management and Orchestration
Data and Information Architecture	Deep Slicing	6G Subnetworks	Mesh / Cell-less

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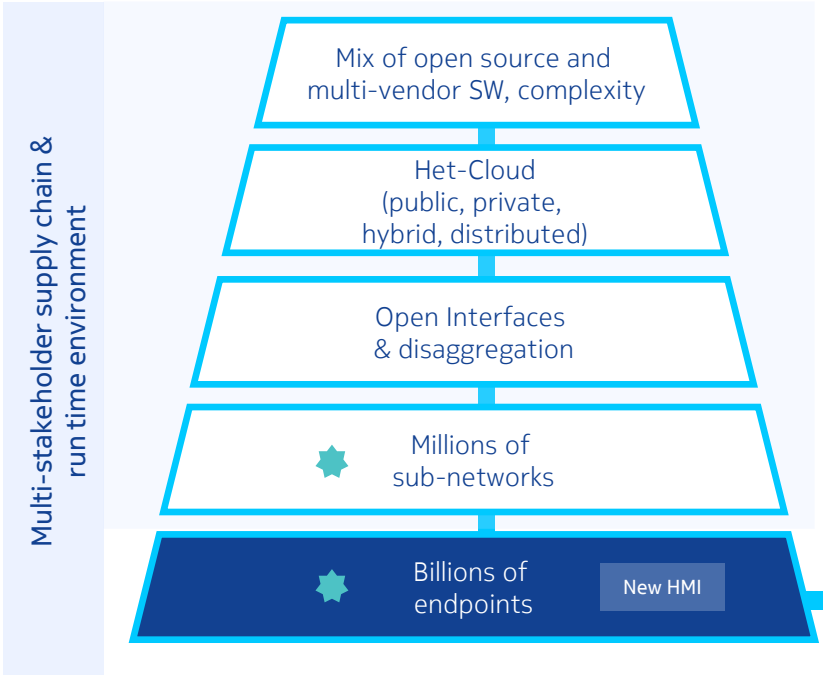
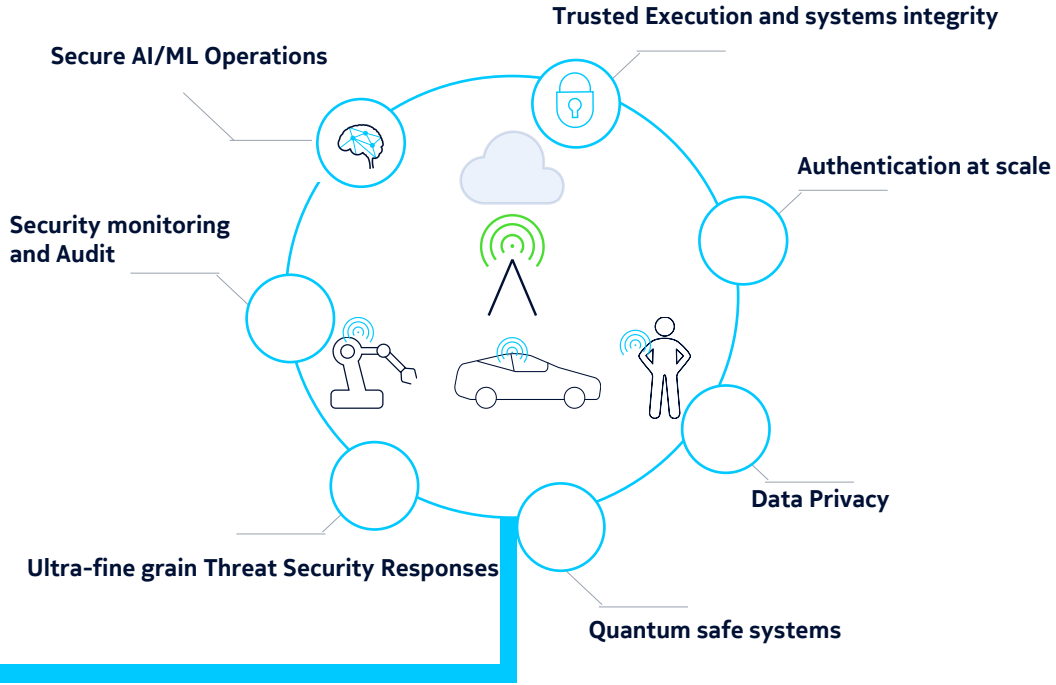
6G security and trust

Mitigate the exploding threat surface



Technology enablers



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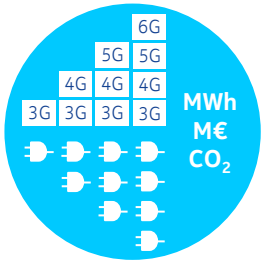
Energy efficient design and deployment is key for 6G

Data traffic boom continues



Double digit annual growth in energy costs and CO_2 emissions

Mobile Network Operators increasingly setting long term sustainability targets to reduce CO_2 emissions *

Financing sector prioritizes investments for businesses reducing CO_2 emissions **

* http://sciencebasedtargets.org/
** https://www.nordea.com

How to support x20 traffic increase @ ½ Energy ?

- **Technology**
- **Features**
- **Deployment**

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Let us create 6G together