Nokia 5G Journey

25th May 2017

Dr. Brian (Bong Youl) Cho, 趙奉烈
Head of Technology for APAC & Japan

Nokia 5G Radio Journey

2015	2016	2017
Year of **Vendor-Proprietary** 5G System	Year of **Transition** from Research/Proprietary to Commercial/Multi-vendor Interoperable 5G	Year of 5G **Standardization**

Nokia showed world first multi-vendor interoperable 5G demo with Intel

https://www.nokia.com/en_int/news/releases/2017/02/13/nokia-lays-key-5g-foundation-with-worlds-first-5gtf-connection

NOKIA intel

Nokia begins first key tests on 4.5GHz band with DOCOMO to develop 5G ecosystem in Japan

- Nokia works with NTT DOCOMO to test applications using 5G base station and the Intel® 5G Mobile Trial Platform end-user device
- Demonstrates potential of Nokia 5G FIRST to deliver enhanced broadband at vastly greater scale
- Showcase at 5G Tokyo Bay Summit 2017 signals start of 5G trials in the Tokyo area

24 May 2017

Last but not least, Nokia is a true 5G E2E Player

- Leader in **Transport**: e.g. IP and Optics (DWDM), G.FAST, GPON
- Leader in **Core**: e.g. Universal (Fixed/Mobile) Core with Shared Data Layer (SDL)
- Leader in **Edge Cloud**, i.e. MEC
- Leader in **Applications**, OZO, digital health and Worldwide IOT Network Grid

Nokia 5G Radio Journey

2015	2016	2017	2018	2019
Year of **Vendor-Proprietary** 5G System	Year of **Transition** from Research/Proprietary to Commercial/Multi-vendor Interoperable 5G	Year of 5G **Standardization**	Year of 3GPP 5G System **Development**	Year of Early 3GPP 5G **Commercialization**

Nokia showed world first multi-vendor interoperable 5G demo with Intel

https://www.nokia.com/en_int/news/releases/2017/02/13/nokia-lays-key-5g-foundation-with-worlds-first-5gtf-connection

NOKIA intel

5G

Radio	AirScale Radio Access AirScale Massive MIMO Adaptive antennas AirScale Cloud RAN
Core	Cloud Packet Core the foundation for 5G Next Generation Core
Transport	'Anyhaul' 5G transport including microwave, IP, optical and fixed access

		Nokia
Japan	Docomo	v
	KDDI	v
	Softbank	v
Korea	SKT	v
	KT	v
	LGU+	v
US	Verizon	v
	AT&T	v
	T-Mobile	v
China	CMCC	v
	CUC	v
	CTC	v

Last but not least, Nokia is a true 5G E2E Player

- Leader in **Transport**: e.g. IP and Optics (DWDM), G.FAST, GPON
- Leader in **Core**: e.g. Universal (Fixed/Mobile) Core with Shared Data Layer (SDL)
- Leader in **Edge Cloud**, i.e. MEC
- Leader in **Applications**, OZO, digital health and Worldwide IOT Network Grid

Nokia, as a **technology** company, focuses on **challenges**

Learning from USA 5G Field Trial – Density @28GHz

Propagation

Scenario	Cell Range
LOS	**2500m**
NLOS	**120m**

Penetration

Scenario	Loss
Drywall	**1.5dB**
Window	**6dB**
Double-E	**37dB**
Cement	**52dB**

Manhattan 1.5 x 1.5 km

LTE sites **69**

NR sites **168** (2.4xLTE)

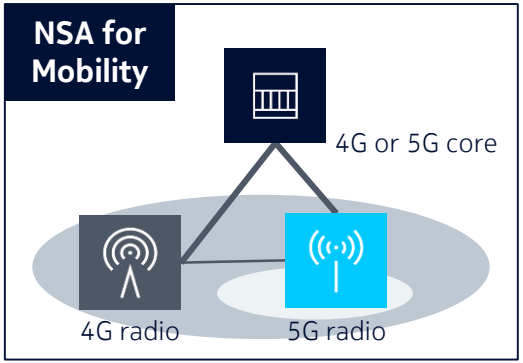
Increased density vs LTE

FWA

Nokia and KDDI trial 5G with AirScale radio for wireless ultra-broadband in megacities

May 12, 2017

- Trial achieved speeds of more than 1Gbps over 5G with Nokia AirScale radio access on the 28GHz band to neighboring apartment



NOKIA

Nokia, as a **technology** company, focuses on **challenges**

Bring Massive MIMO to Massive Deployment

Items	Specification
Operating frequency	<6GHz
Instantaneous bandwidth	~100MHz
Modulation scheme	DL: up to 256QAM(?) UL: up to 64QAM
Number of antenna elements (a)	128
Number of TRX (b)	64T64R
Number of MIMO stream (c)	16

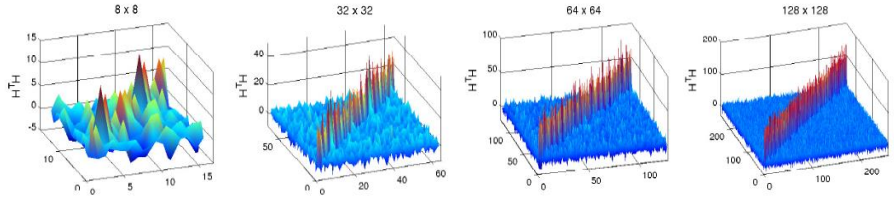
* note: (a) ≥ (b) ≥ (c)

Consideration

- Size, Weight, and Cost of unit
- Fronthaul cost & Baseband cost
- Coverage performance (DL/UL)
- Capacity performance
- Reliability (e.g. MTBF) and Safety
- …

Massive MIMO for "Channel Hardening"

- Under some conditions, when the number of BS antennas is large, **the channel becomes (nearly) deterministic**, and hence, **the effect of small-scale fading is averaged out**. The system scheduling, power control, etc., can be done over the large-scale fading time scale instead of over the small-scale fading time scale. This simplifies the signal processing significantly.
- In massive MIMO, as the number of base station antennas increases, and the number on single-antenna user terminals increases. **The correlation matrix becomes increasingly a diagonal matrix**.



[1] M. Hochwald, T. L. Marzetta, and V. Tarokh, "Multiple-antenna channel hardening and its implications for rate feedback and scheduling," *IEEE Trans Inform. Theory*, vol. 50, no. 9, pp. 1893–1909, 2004.

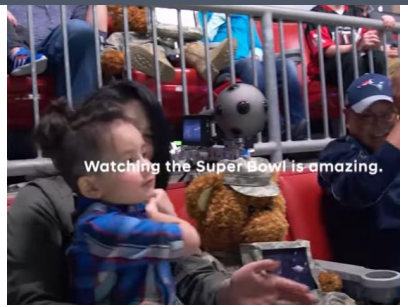
[2] T. Lakshmi Narasimhan and A. Chockalingam, "Channel Hardening-Exploiting Message Passing (CHEMP) Receiver in Large MIMO Systems," *IEEE WCNC* 2014

Consideration

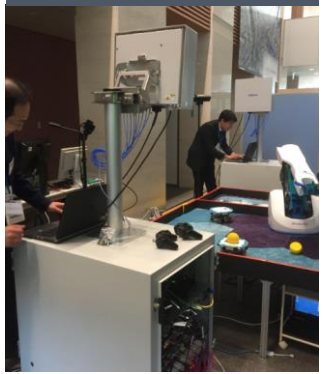
- Traffic model (full buffer, bursty traffic, etc)
- Interworking with scheduler, link adaptation, etc…

Nokia, as an **innovative** company, focuses on **end user benefit**

An interesting VR Live Streaming demonstrations

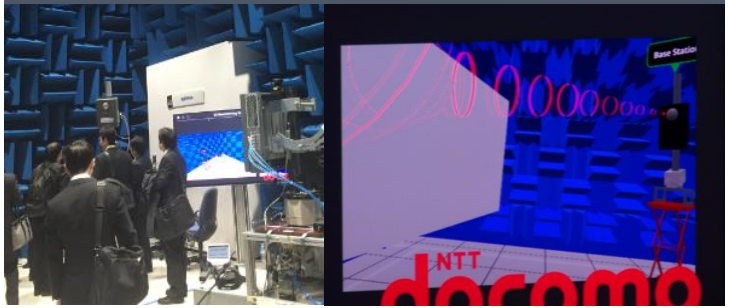


Robot arm control



Remote driving via 4G or 5G

“Dream goggle” for wireless engineer



Nokia, as an **open** company, works with industry to build **ecosystem**

CSP, IT, enterprise, and industry verticals

Open system interfaces and APIs

Standardization

3GPP
ETSI
IETF
ITU
IEEE Advancing Technology for Humanity

Open HW & SW reference architectures

OPEN Compute Project

TELECOM INFRA PROJECT

Multi-access Edge Computing (MEC)

Open source software

OPNFV
ONAP
openstack.
ONOS
OPEN DAYLIGHT
vitrage
Linaro
OpenFastPath
LINUX FOUNDATION

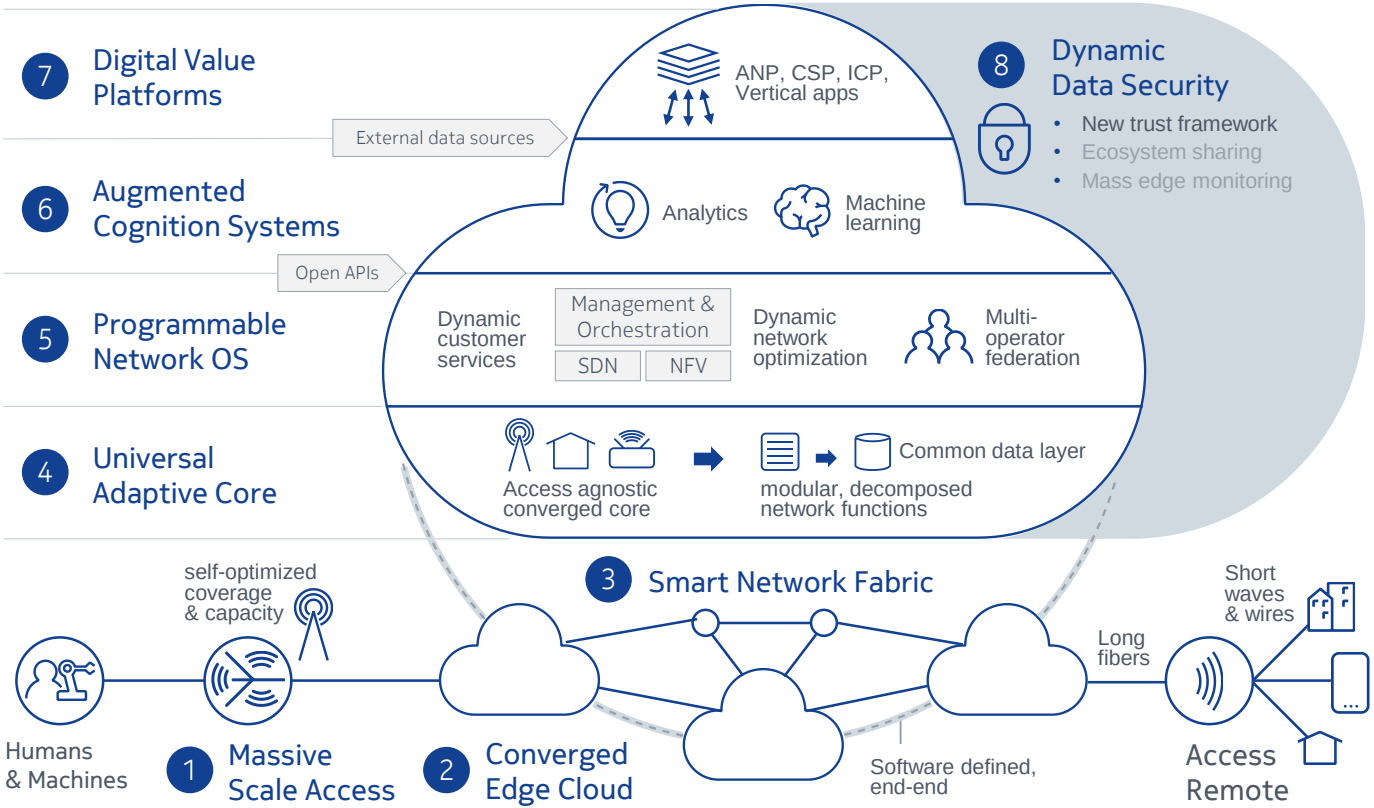
Nokia ecosystem

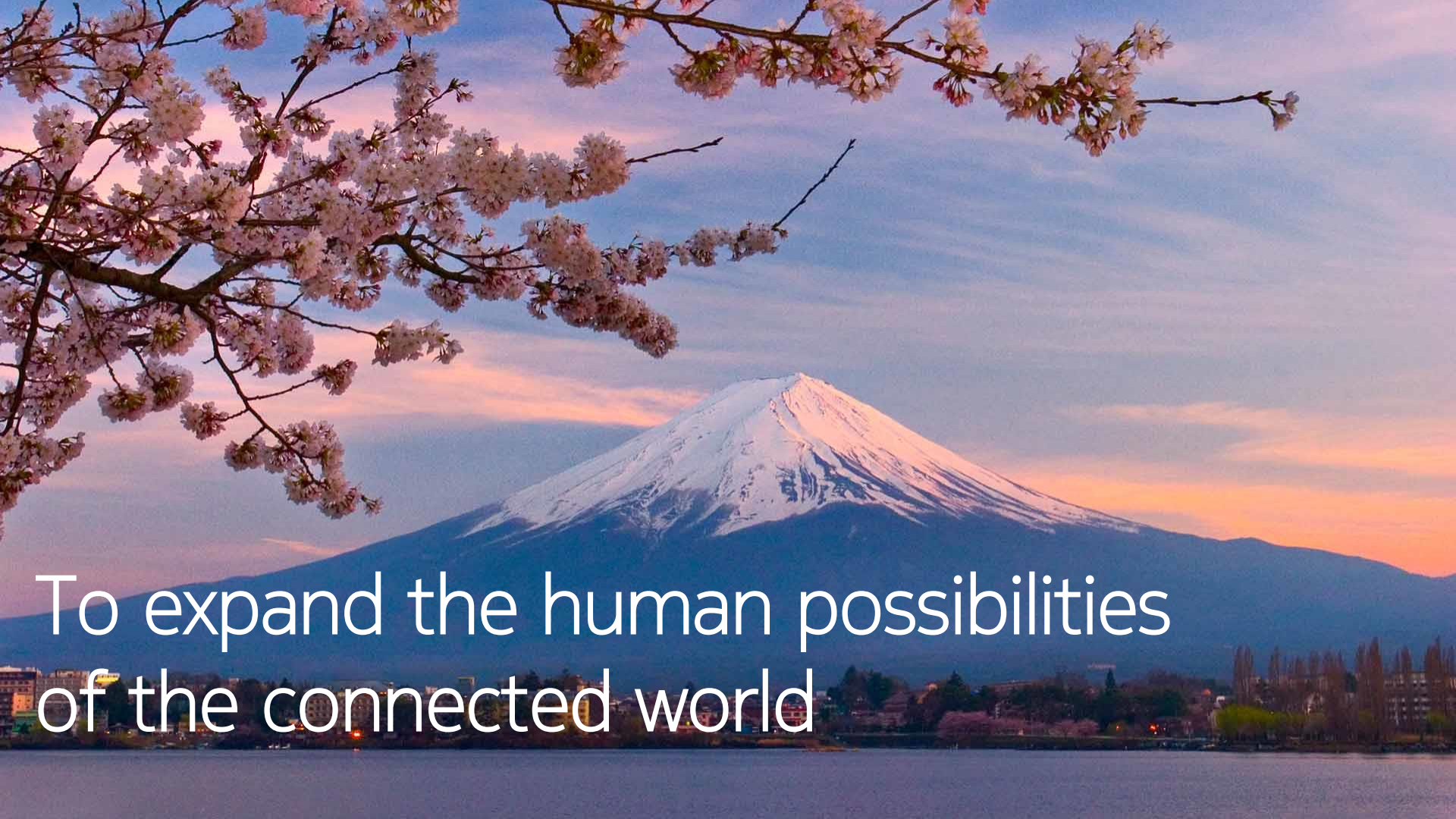
NOKIA

Products
Solutions
Services
Security
Analytics
Automation

NOKIA

Nokia, as an **E2E** company, delivers 5G **End-to-End** Network




To expand the human possibilities
of the connected world