



*Finnish Defence
Research Agency*

Military Communications in the Era of 5G/6G

Finnish perspective

WinnComm Europe 2019

**Research Manager
CDR (GS) Topi Tuukkanen
Finnish Defence Research Agency**



Outline

1. Tactical Networking Interoperability
2. From the World's First 6G Wireless Summit
3. Military Communication in the Era of 5/6G Mobile Communication
4. Way ahead



Tactical Networking Interoperability

Bold Quest 19.1 in Finland



* . Y872*

Ruotuväki, PL 25, 00131 HKI AKL-Posti Oy

BOLD QUEST

RUOTUVÄKI



THE OFFICIAL NEWSPAPER OF THE FINNISH DEFENCE FORCES

SPECIAL EDITION 12.4.2019 [online > WWW.RUOTUVAKI.FI](http://www.ruotuvaki.fi)

Welcome to Bold Quest 19.1





Bold Quest 19.1 in Finland



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Welcome to Bold Quest 19.1



- Bold Quest (BQ) is held for the third time outside the US.
- Bold Quest 19.1 is sponsored by the United States Joint Staff and led in cooperation with the Finnish Defence Forces.
- Bold Quest is a multinational series of events aiming to test and evaluate the command and control of joint fires, as well as the functional and technical interoperabilities of ground, sea and air-based ISR and joint fire systems.



Bold Quest 19.1 Schedule Outline

WEEK

17

APRIL 22

Deployment of
the troops

System integration

18

APRIL 29

Deployment of
the troops

System integration

19

MAY 6

Live/Virtual Ops
Integration

9.5. MEDIA DAY –
Riihimäki

20

MAY 13

Air/Ground
Operations

14.5. MEDIA DAY –
Rissala

21

MAY 20

Joint Fires

20.5. MEDIA DAY –
Rovajärvi

22.-23.5 DV Day

22

MAY 27

Redeployment



***World's First 6G Wireless Summit
Organized***



5G/6G Vision in Finnish Technical Magazine

TM **TEKNIKAN MAKASIINI** KRISTIINA KUUSMA KOONNEET ILPO SALONEN JA SAGA WIKLUND | MAKASIINI@TEKNIKANMAAILMA.FI

NÄKIJÄ MATTI LATVA-AHO, OULUN YLIOPISTO

6G-VERKKO AUTTAA TEKÖÄLYÄ

TIETOVERKOT Liikenne- ja viestintäministeriön huutokauppapäätös jakaa taajuuudet kolmelle operaattorille vaikuttaa pitkään. Lisenssit ovat voimassa vuoden 2033 loppuun.

"ELÄMME lukusajaa, koska Suomessa on maailman parhaat 5g-verkot. Harmi, että 2018 ministerio päätti jakaa 3,5 GHz:n taajuuslisenssit operaattoreille vanhaan malliin. Toivoin, että lisensoinnin osittaisella muutoksella olisi luotu uusi digiekosysteemi ja vauhditettu digitalisaatiota. Näin ei käynyt. 5g-verkosta hyötyvät operaattorien ehdoilla parhaiten kasvukeskukset, ei esimerkiksi syrjäseutujen etätuotehuolto, kuten olisi toivonut."

VUOSI 2023

"NÄKEMYS siitä, mitkä ovat 6g-verkon mahdollisuudet, on syntynyt. 5g:lle asetetut vaatimukset eivät ole hävinneet, vaan ne pysyvät ja vahvistuvat yhä kovempien teknisten vaatimusten myötä. Valtavia tietomääriä siirtyy lyhyellä viiveellä jo luotettavasti. Verkot ovat älykkäitä ja pystyvät tarjoamaan tilanteeseen optimoitua sisältöä ja palveluja. Langattomat verkot ovat yhtä keskeinen osa yhteiskunnan perusinfraa kuin vesi- tai sähköjohdot."

VUOSI 2028

"6G-VERKKOON kytkeydytään luotettavasti. Sensorit keräävät valtavasti dataa laitteista ja meistä kaikista. Langattomien yhteyksien ansiosta voimme olla toisissa aktiivisempia ja vaikka ostoksilla käydessä menee vähemmän aikaa. Langaton verkko auttaa tekoälyä, joka puolestaan tulee ihmisen avuksi. Tekoäly ei korvaa ihmistä. Ihmisen humaani tapa kerätä kokemuksia ja toimia kokemustensa pohjalta ei koskaan onnistu tekoälyä."

VUOSI 2033

MATTI LATVA-AHO
TKT, akatemiaprofessori Matti Latva-aho työskentelee Oulun yliopistossa 6g-lippulaivaohjelman johtajana. Hän on erikoistunut langattomaan tietoliikenteeseen ja on alallaan arvostettu tutkija.

TEKNIKAN MAAILMA 1/2019 15

- **Topic of the interview: “Artificial Intelligence will be helped by the 6G Wireless Networks”**
- **Interviewee: D.Sc. (Tech.), Academy Professor Matti Latva-aho, Director of the University of Oulu’s flagship 6G program, General Chair of the 1st 6G Wireless Summit in Finland**
- **Vision for the years 2023, 2028 and 2033 in Finland**



5/6G Vision in Finnish Technical Magazine

2023

We live in a luxury era because Finland has the world's best 5G wireless network. Regrettably, in 2018 the Ministry decided to allocate 3,5 GHz frequency licenses to operators based on the old distribution model. **I had hoped that altering the licensing process could have led to a new digital ecosystem and accelerated digitalization. This did not happen.** As such, instead of benefitting peripheral regions (e.g. through remote healthcare services), as I would have hoped, operator-managed 5G networks will advance growth centers.



5/6G Vision in Finnish Technical Magazine

2028

A perception of the 6G wireless network's possibilities has been established. Rather than disappear, the demands on 5G have both persisted and increased as technical demands expand. Huge amounts of data are transferred quickly and reliably. **Intelligent networks are capable of providing optimal content and services on a situational basis.** Wireless networks play as central a role in society's infrastructure as do water and electric lines.

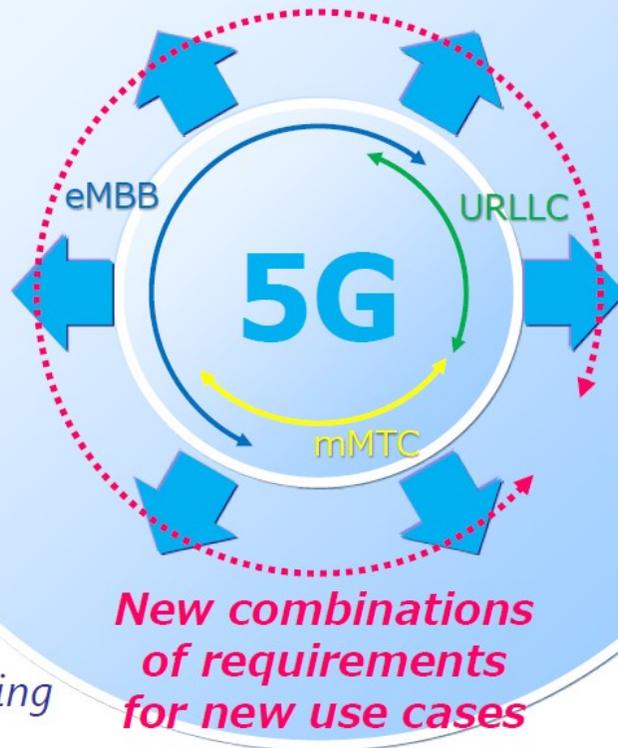


5/6G Vision in Finnish Technical Magazine

2033

We are reliant on the 6G wireless network. Sensors gather a tremendous amount of data from all devices and individuals. Wireless connections enable us to work more actively and to shop more time-efficiently. **The wireless network supports artificial intelligence,** ? which, in turn, aids humans. Artificial intelligence does not, however, replace people. Artificial intelligence will never replace humans' humanistic manner of gathering experiences and using these experiences to inform their actions.

5G evolution & beyond



Extreme high data rate/capacity

- Peak data rate > 100Gbps exploiting new spectrum bands
- > 100x capacity for next decade

Extreme coverage

- Gbps coverage everywhere
- New coverage areas, e.g., sky, sea, space, etc.

Extreme low energy & cost

- Devices free from battery charging
- Affordable mmW devices

Extreme low latency

- E2E very low latency
- Always low latency

Extreme high reliability

- Guaranteed QoS for wide range of industry use cases

Extreme massive connectivity

- Massive AI devices
- High-precision positioning

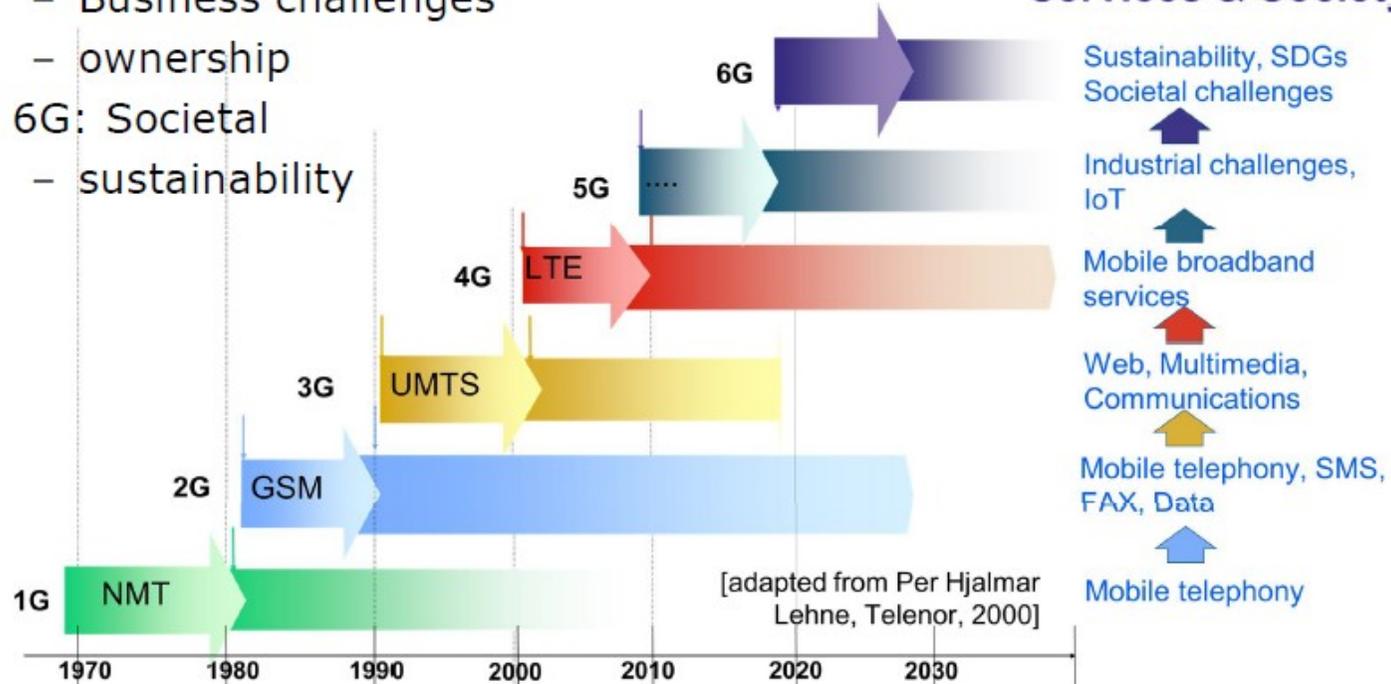
New combinations of requirements for new use cases

6G: Digitisation of the Society

- 1G-3G: Speed, flexibility
- 3G-4G: Service view
- 5G: Industrial
 - Business challenges
 - ownership
- 6G: Societal
 - sustainability

Sustainability: Killer app for 6G

Ultra-long battery life,
Charging, Indoor/Outdoor
Services & Society



©Sudhir Dixit

6G Wireless Summit in Levi, Finland, 24-26 March 2019

Sudhir DIXIT, PhD, Life Fellow IEEE

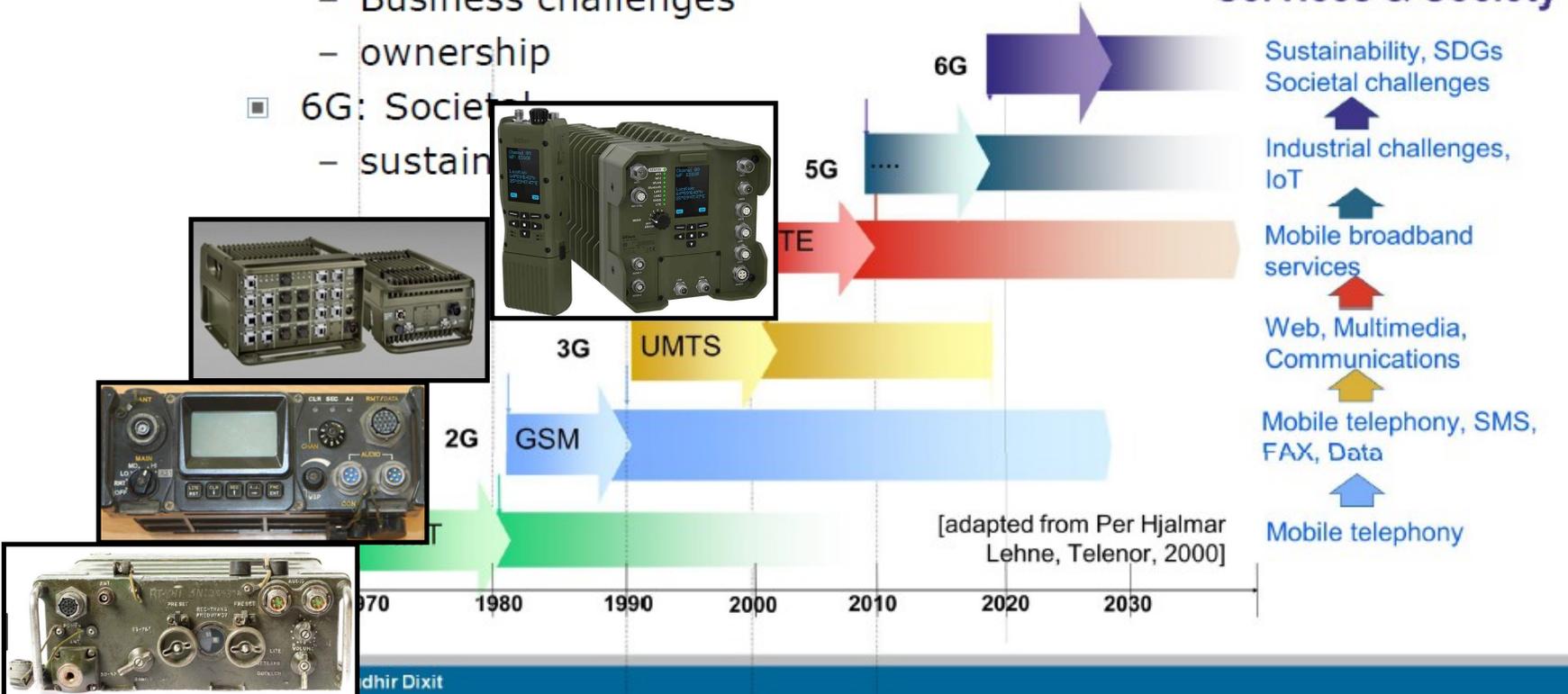
Realizing wireless internet connectivity for all through B5G leading to 6G – Digital Inclusion: The Killer App for 6G

6G: Digitisation of the Society

- 1G-3G: Speed, flexibility
- 3G-4G: Service view
- 5G: Industrial
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Sustainability: Killer app for 6G

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6G Wireless Summit in Levi, Finland, 24-26 March 2019

Sudhir DIXIT, PhD, Life Fellow IEEE

Realizing wireless internet connectivity for all through B5G leading to 6G – Digital Inclusion: The Killer App for 6G

Wireless solutions are critical to sustainable development



6

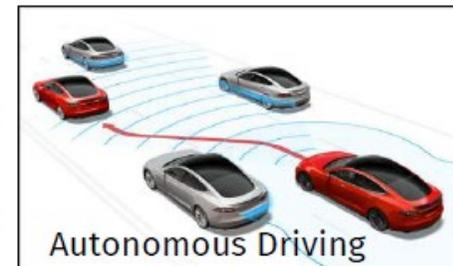
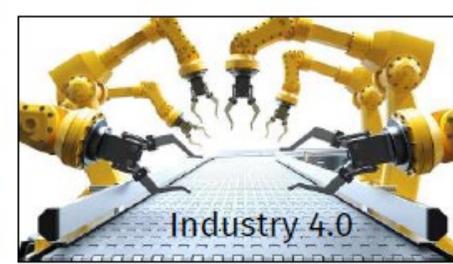
Sustainability targets set by UN for 2030

Sudhir Dixit

6G Wireless Summit in Levi, Finland, 24-26 March 2019

Sudhir DIXIT, PhD, Life Fellow IEEE

Realizing wireless internet connectivity for all through B5G leading to 6G – Digital Inclusion: The Killer App for 6G



6G will include 5G evolved capabilities and more...
In the end it is about service and value creation

Open and flexible

- Over the first 30 years of mobile communication we only invented 3 services:

Voice, SMS & Mobile broadband

- During the last 5 years we have been creating: **LPWA, IoT, V2X, UAV, URLLC, TSC, NTN.**

- Continuing the **acceleration of new services** likely demands a new paradigm of standardization versus profiles

Sustainable

- Both the opportunities and and fear of 5G is already a major topic in the public and industry.
- We need to increase focus on sustainability:

- Energy consumption
- Batteri life-time
- Electromagnetic Fields
- Recycling of equipment
- Cost
- Environmental integration
- Social inclusive

Intelligent and smart

- Future networks will offer both Edge AI and network sensing:

A combination of these will drive new value paradigms.

Trusted

- New operator and customer paradigms sets new demands to security and privacy:

- Potentially introduce an external user-trusted privacy and security broker.

Future X - Architecture Vision for 5G evolution and beyond

RAN

THz frequencies
 Extreme URLLC and TSC
 Network as a sensor

Cloud Native Architecture

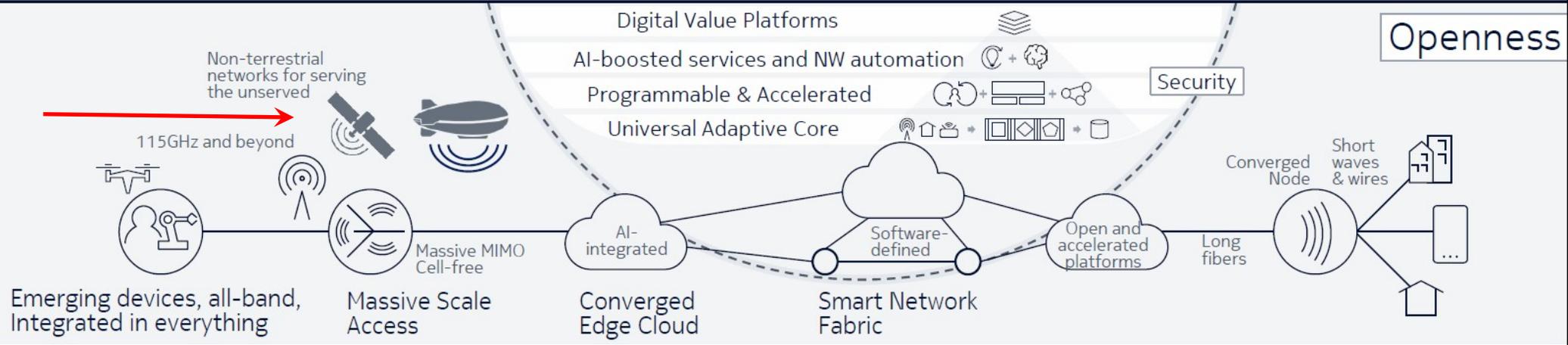
Web Scale Capacity and Programmable
 Multi Vendor Mashup Services
 Open platforms and interfaces

Zero-Touch optimization and automation

Multitenant and demand-time driven network slicing b2b

Embedding ML/AI into Architecture

Pervasive across the architecture



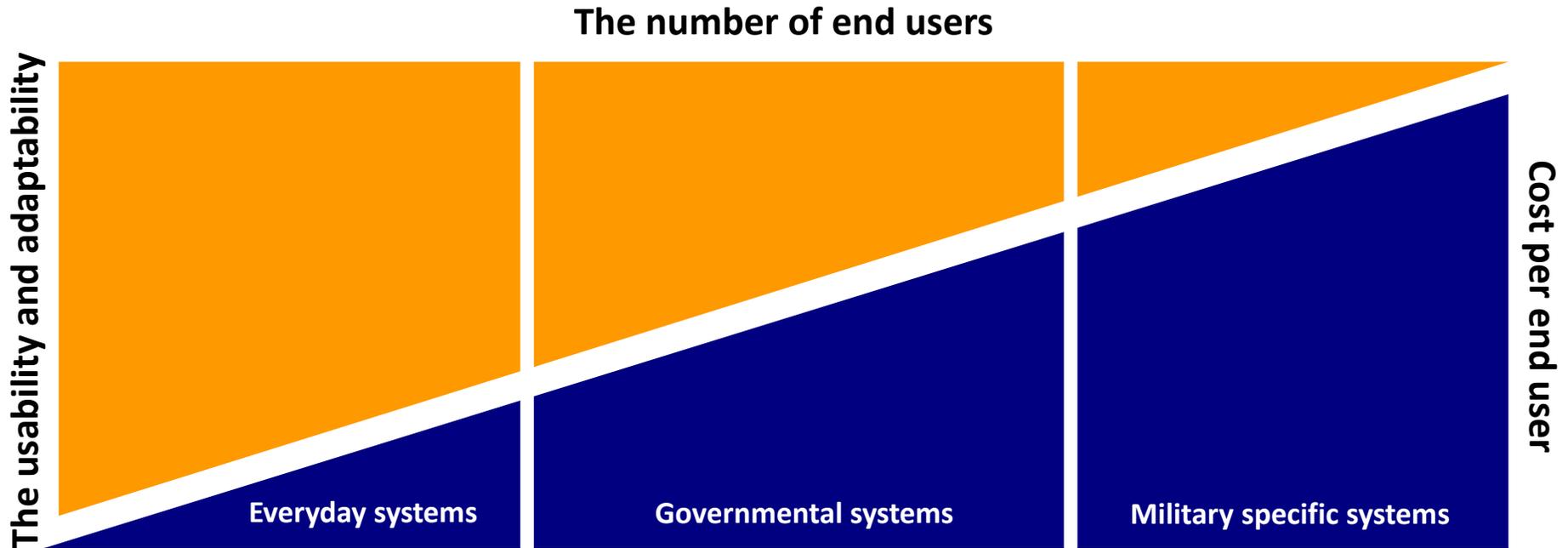
6G Wireless Summit in Levi, Finland, 24-26 March 2019
 Preben Mogensen, Nokia Bell Labs
 5G Evolution: A View on Cellular Technology Beyond 5G



Military Communication in the Era of 5G/6G Mobile Communication



Heterogeneous building blocks of military communication



OE A

- *Mobile communication*
- *BYOD = Bring Your Own Devices*

OE B

- *Public safety communication + deployable base-stations, basestations in the air etc*
- *Mobile communication*

OE C

- *Finnish C4I System M18*
 - *Easy of use, auto-configuration, EPM capability*

Critical Communications

Tactical Communications

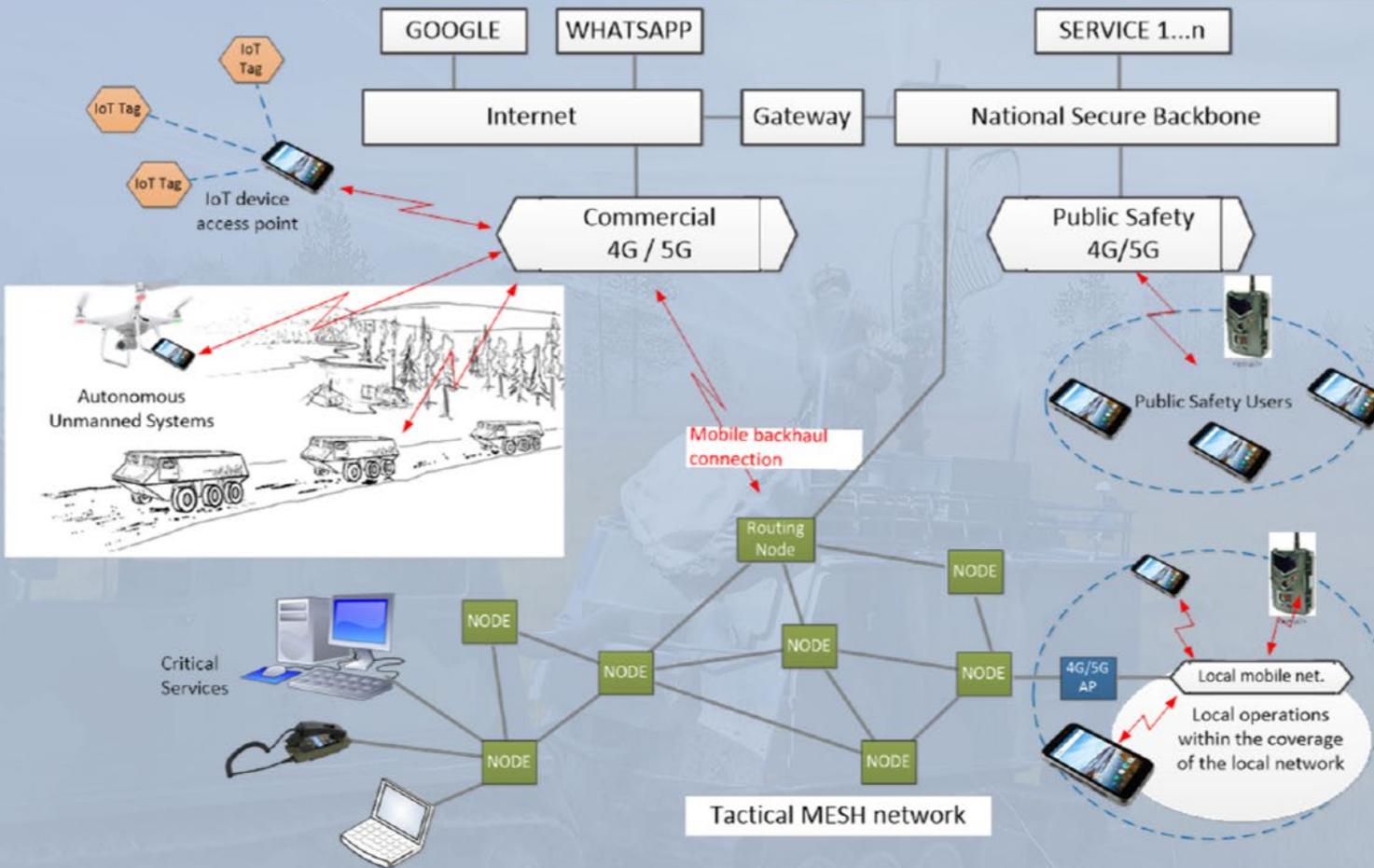
- Communications for command and control (C2) applications, sensors and real time situation awareness in tactical operations
- Specialized tactical waveforms
- MESH topology
- 4G/5G utilized as a backhaul and as a complementary solution

Public Safety Communications

- Communication and situational awareness for police, fire fighters and rescue officers in field operations
- TETRA based solution utilized, operational ~2030
- 4G/5G based solutions emerging, operational in ~2022

Secure Communications

- Governmental institutions and enterprises
- Requiring higher level of certified security in mobile communications



- Resiliency
- Cyber security
- Dynamic spectrum access



5G/6G R&D will push ahead military communication

- Network-Assisted Device Collaboration
 - Mesh/Multi-Hop Network
 - Full Duplex
 - Integration of Communication + Sensing
 - ML/AI Enabled Proactive Network Design
 - Integration of Non-Terrestrial Networks
 - Even higher Frequency (e.g. 140 GHz, THz)
 - On-demand Mobile Base stations
 - Extreme Positioning (cm level)
 - Extreme Coverage of Rural
 - Ambient Backscatter Communications
 - Quantum Backscatter Communications
 - Augmented distributed computing system
 - Augmented digital nervous system
 - Augmented intelligent thinking systems
 - AI-Powered Cloud Computing
 - AI-Powered Device Processing
 - Holograms & UI
 - Flexible network topologies
- The volume of 5G/6G Research and Development will be tremendous.
 - Above are listed, by way of example, some technologies mentioned in World's First 6G Wireless Summit organised in Finland.
 - All those technologies can be used also in military communication. For example, if AI/ML is used in commercial 5G/6G networks to maximise the performance of the heterogeneous 4G/5G/6G networks, in the heterogeneous military network the optimized performance can be for example jamming resistance.





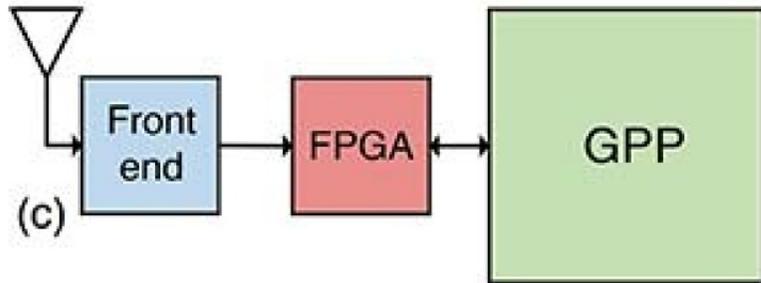
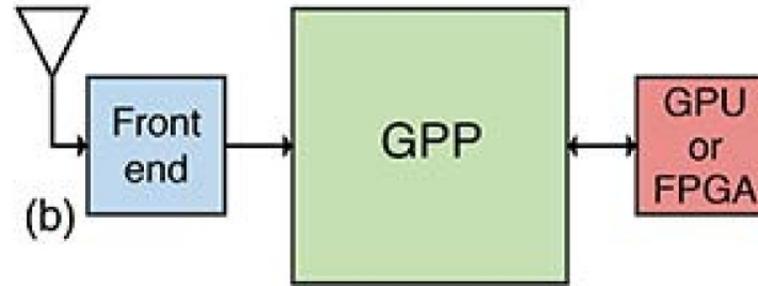
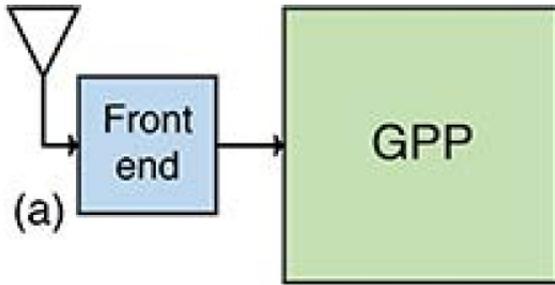
5G/6G aided next generation military communication

- 5G/6G will bring new tools to offer in in **OE A** and **B** better priority for military and public safety users (e.g. network slicing and QoS mechanisms)
- ANN/ML/DL in signal processing will enable change from **static** performance to **dynamic** performance
 - Information coding (autoencoder), channel equalizer, modulator/demodulator, MIMO signal processing, error correction, interference canceller etc
- Tenets of better jamming resistance in **OE C**
 1. Use spread spectrum communication + jitter everywhere (FH, synchronization etc.)
 2. Static → dynamic frequency management → more frequencies available in crisis
 3. Take benefit ANN/ML/DL in signal processing
 4. Redundancy of communication systems and used frequency bands
 5. Take benefit of SDR and Cognitive radio technology → update constantly the performance of the waveform during the life cycle of the radio and the waveform → need for **more efficient waveform development tools** (backup slides)





Evolving SDR technology (1)

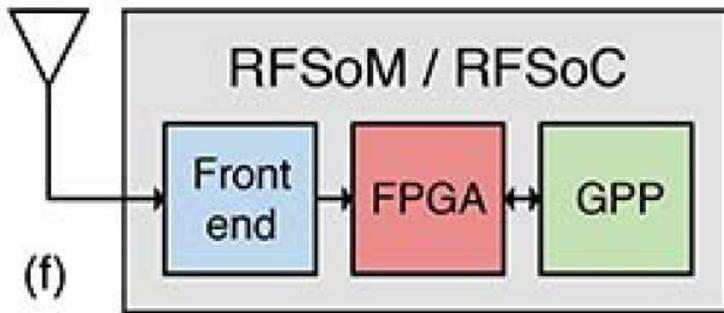
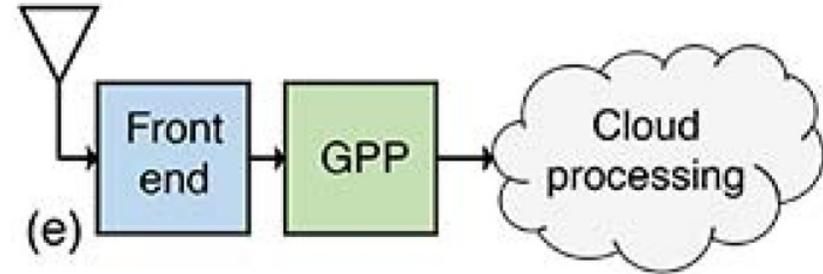
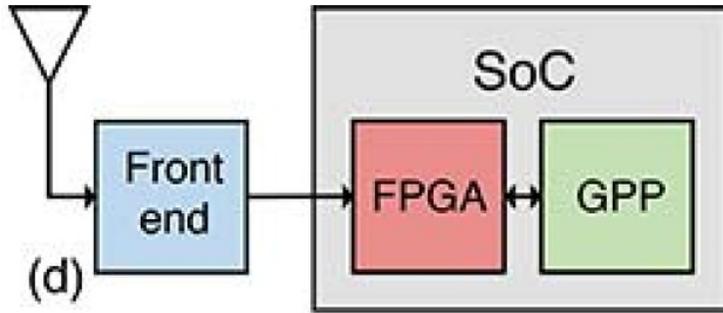


- *First generation SDR implementation technology at the time when SCA was specified*
- *Separate GPP, FPGA, GPU and DSP components*
- *C++ and VHDL were predominant programming languages in embedded devices like radio*
- *It was natural to choose source code portability as a methodology to enhance more effective programming i.e. program code portability and software component reuse.*

Pictures: <http://gpsworld.com/innovation-the-continued-evolution-of-the-gnss-software-defined-radio/>



Evolving SDR technology (2)



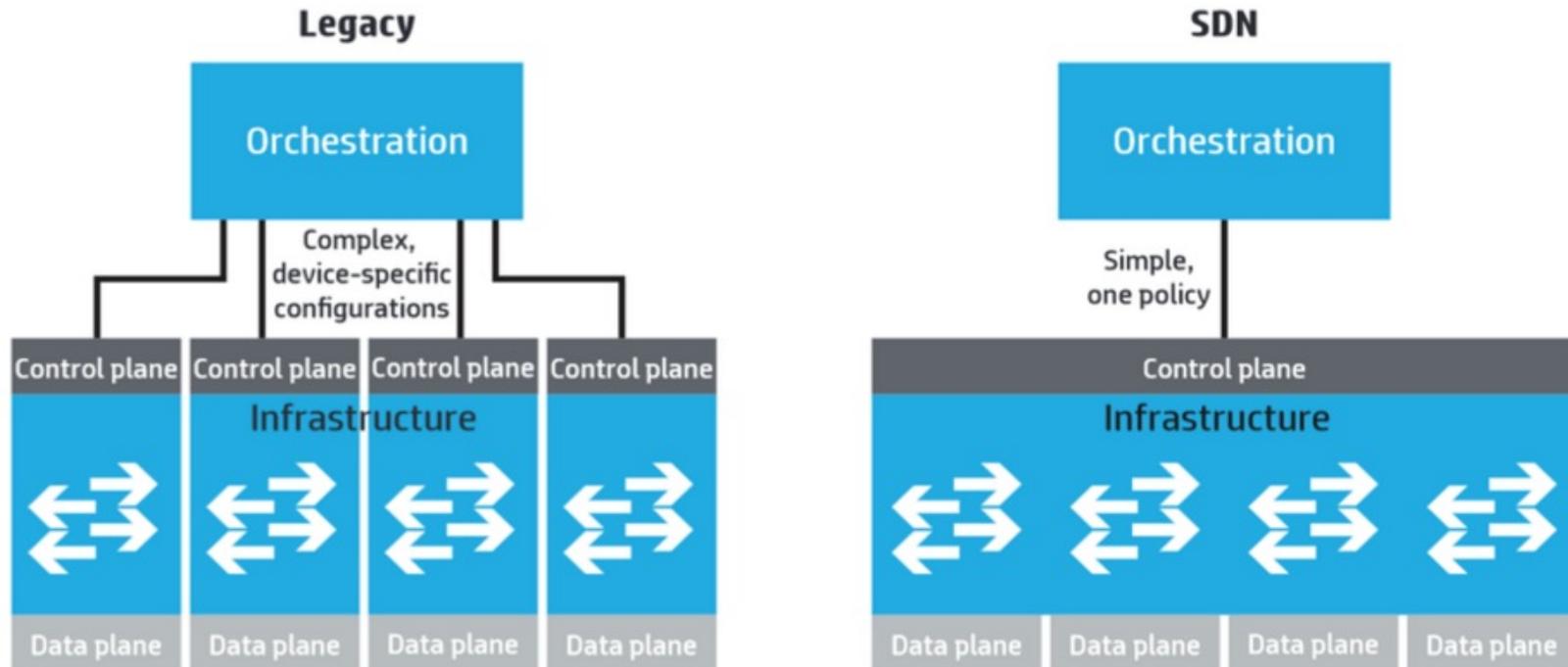
RFSoSM = radio-frequency system on module
RFSoSC = radio-frequency system on chip

- *Situation today and in future. SoC integrates FPGA, GPP and even RF Front End on same chip/module*
 - *Cloud computing*
 - *It is impossible to integrate all parts of SCA on the chip. SoC manufacturer offers efficient higher level modelling tools (like HLS and OpenCL) to implement signal processing algorithms*
- *Enables move from “source code portability to WF design flow portability”*

Pictures: <http://gpsworld.com/innovation-the-continued-evolution-of-the-gnss-software-defined-radio/>



5G- welcome to OE A&B communication!



- Easier utilization of national communication infra for critical communication (CC)
 - Network Slicing – **“high priority highway for CC”**
- Advanced mobile networks
 - Higher data rates, **new tools for security, advanced priority mechanisms**, NFV
 - Massive MIMO Beamforming → **better LPI/LPD/AJ**
 - Low delay → **time critical MIL communication** (Radar data)
 - IoT communication → Sigfox, Lora type of **communication for sensors**



New approach to WDE (Waveform Development Environment)

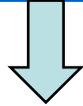
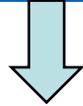
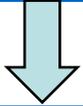
MDD
ECLIPSE
4G, 5G
HLS
OpenCL
GNU&USRP
- LabView
- Vivado
- RFNoC™
SoC
MPSoC
RFIC
etc.



High level modelling of the waveform on every OSI layer
- HLS, OpenCL, Matlab/Simulink, State machine toolbox, Opnet, C++ etc.
- High level models including timing/synchronisation



Automatic generation of the code from higher level models



RFIC

SoC, MPSoC, etc



Real time over-the-air validation



Lower waveform design/porting cost

High Level Modelling Tools and Automatic Code Generation Tools are used to emulate/simulate, debug, verify and validate the functionality of waveform at every stage of the design.



Military wireless R&D way ahead

Civilian 5G / 6G research funding exceeds military R & D and will drive several relevant technologies

Military oriented R & D to focus on military niches:

- 1) Infrastructureless => e.g. MANETs
- 2) Electronic warfare
 - LPI / LPD / AJ
 - Dynamic Spectrum Access
- 3) Security
- 4) Interoperability
- 5) Long system life cycles
 - MIL STDs vs 5G 18mth cycle of Releases?



National way ahead

FDF is equipping troops with SDR radios and waveforms. This results in better communication capability and better international interoperability (for FIN the role of FMN is essential). Our new SDR is an ideal platform for cognitive radio.

Different operating environments (A, B, C) of FDF lead to different communication solutions. The seamless communication across OEs is essential.

SDR technology and WDE tools are constantly developing. Will this will bring more efficiency to SDR waveform development?

HF-communication is essential and important part of military communications. Development of Future WBHF would be an excellent cooperative effort.



Thank you !

For more information contact:

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