

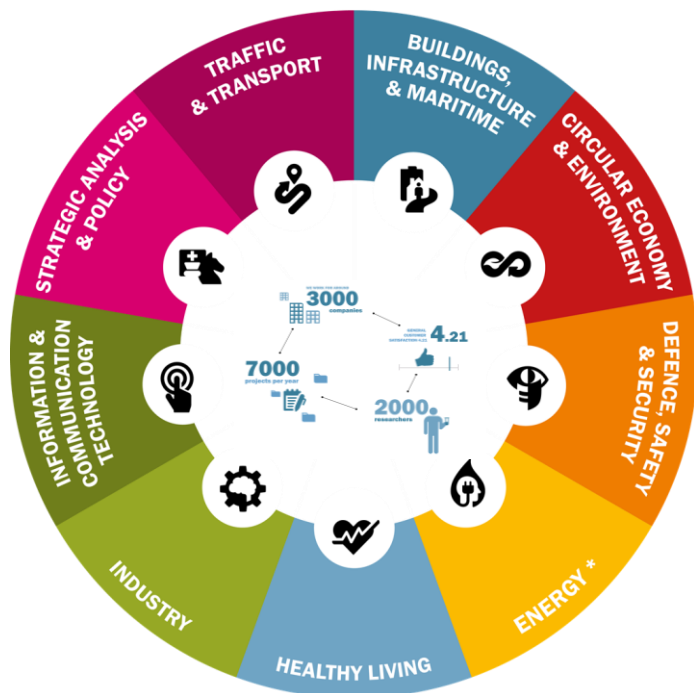
# › 5G TECHNOLOGIES IN MILITARY COMMUNICATIONS

C2COE Symposium “Get Connected” 2019 Brussels

June 26 – 27, 2019 | Marcel van Sambeek ([marcel.vansambeek@tno.nl](mailto:marcel.vansambeek@tno.nl))

**TNO** innovation  
for life

# ABOUT TNO



- TNO – Dutch Institute for Applied Scientific Research (est. 1932)
- Non-profit organization
- 2018 revenue: 482 M€ (45% government)
- > 3200 employees
- > 4800 projects per year, national and international
- TNO focuses on 9 domains

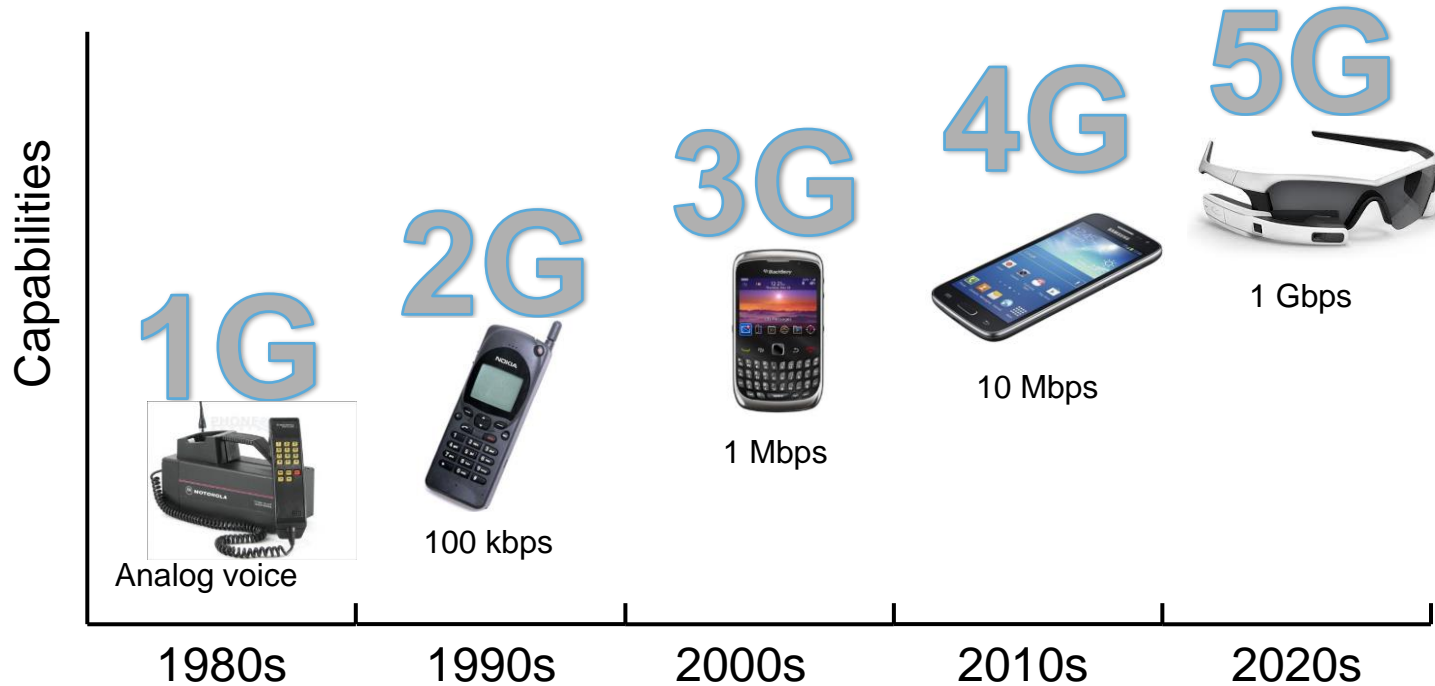
# OUTLINE

- › Introduction to 5G
- › 5G for verticals
- › 5G for military communications
- › Future work

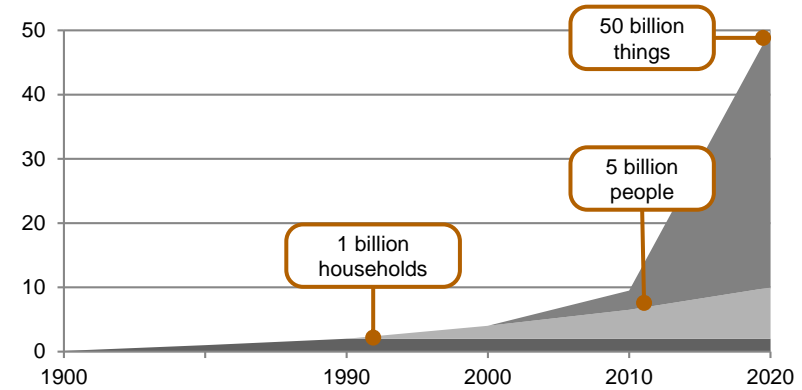
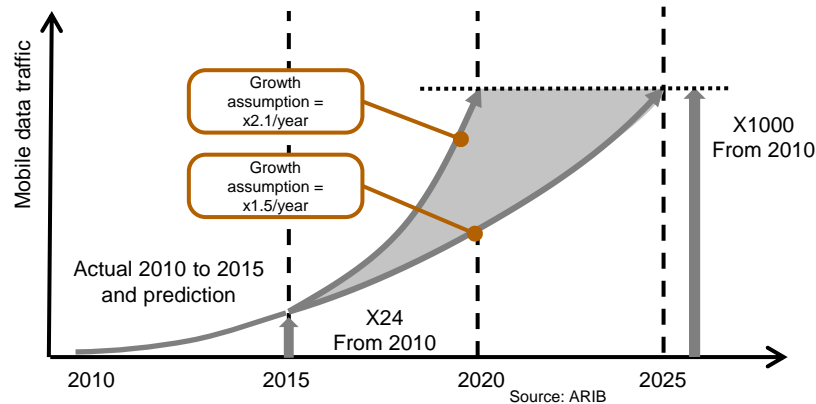
# OUTLINE

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# FIVE GENERATIONS MOBILE COMMUNICATION



# 5G TECHNOLOGY TO KEEP UP WITH GROWTH



- › At introduction of 5G, mobile operators have to handle 1000x more data traffic and to connect 10x more devices compared to at introduction of 4G
- › New 5G technology is needed to deliver additional capacity without an equivalent growth in costs

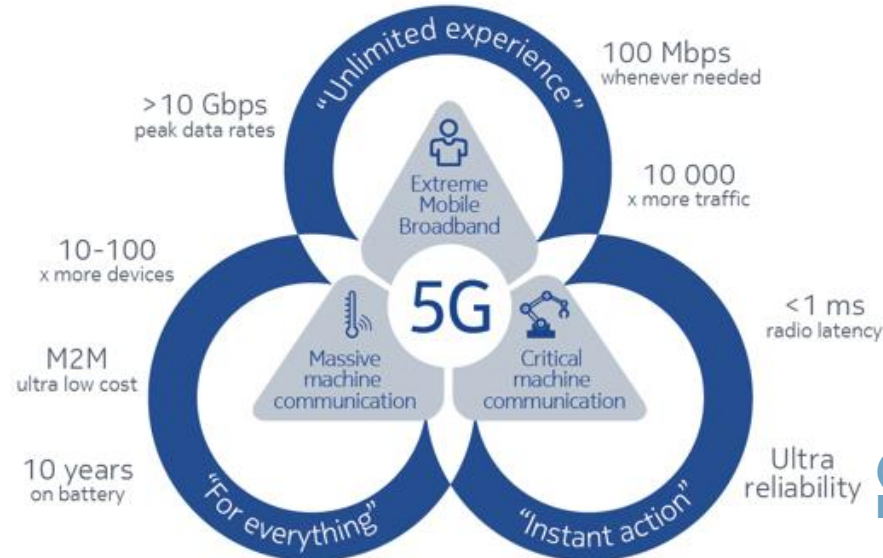
# 5G FOR THE DIGITAL SOCIETY

- › 5G is not just faster mobile Internet. The intention is also to provide communication for the digital society:
  - › Vertical sectors
    - › Intelligent Traffic / Automotive
    - › Health
    - › Industry
    - › Agriculture
    - › Logistics
    - › Energy
  - › Government
    - › Smart cities
    - › Public Safety



# 5G: THREE MAIN USE CASES

## (1) ENHANCED / EXTREME MOBILE BROADBAND



## (2) MASSIVE MACHINE-TYPE COMMUNICATION

## (3) ULTRA RELIABLE LOW LATENCY COMMUNICATION

Source: Nokia



# 5G MOBILE BROADBAND: EXPERIENCED DATA RATES REQUIREMENTS HIGHLY DEPEND ON SCENARIO



## Rural macro

50 Mbps DL / 25 Mbps UL  
100 users / km<sup>2</sup>



## Indoor hotspot

1 Gbps DL / 500 Mbps UL  
250000 users / km<sup>2</sup>



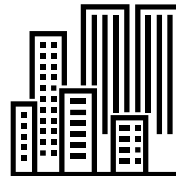
## High-speed train

50 Mbps DL / 25 Mbps UL  
1000 users / train  
Up to 500 km / h



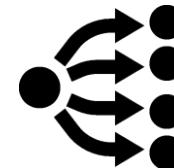
## Urban macro

50 Mbps DL / 25 Mbps UL  
100000 users / km<sup>2</sup>



## Dense urban

200 Mbps DL / 50 Mbps UL  
25000 users / km<sup>2</sup>



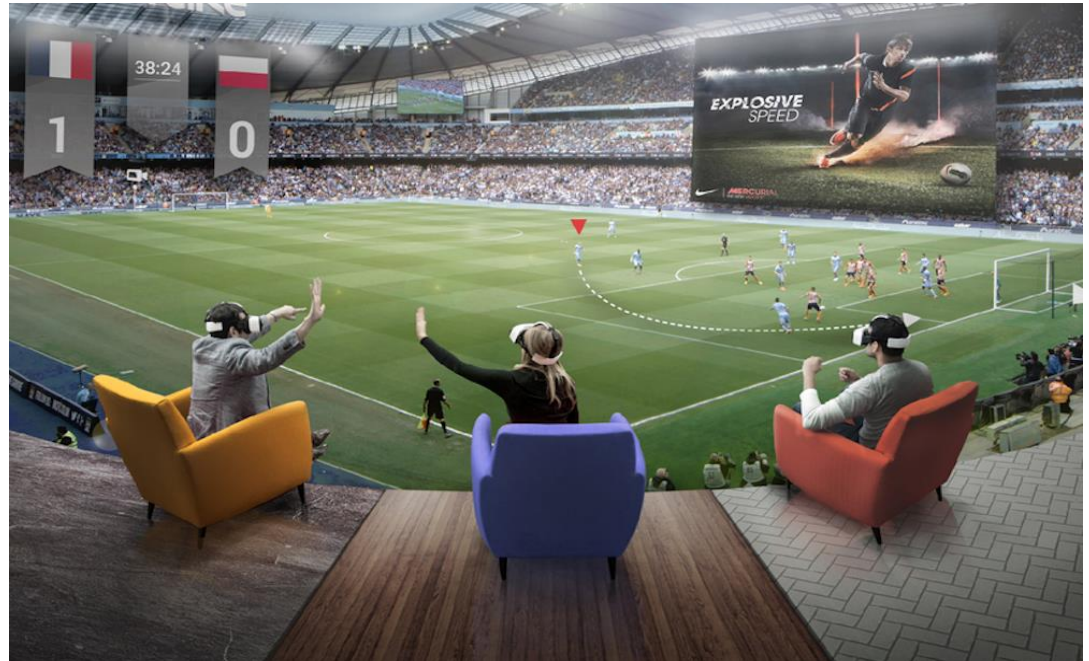
## Broadcast

Max 200 Mbps DL per  
channel

*Reference: 5Groningen roadmap  
Requirements from 3GPP TS 22.261*

## EXAMPLE: VIRTUAL REALITY

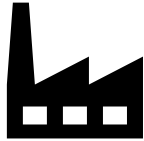
- › Is VR a killer app made possible through 5G?
  - › Gaming
  - › Social VR
  - › Immersive multimedia
  - › Conferencing
  - › Study / reference
- › Requirements:
  - › High data rates and/or
  - › Low latency



# ULTRA-RELIABLE LOW LATENCY COMMUNICATIONS

## REQUIREMENTS HIGHLY DEPEND ON SCENARIO

Reference: 5Groningen roadmap  
Requirements from 3GPP TS 22.261



### Discrete automation - motion control

1 ms latency  
99,9999% reliability  
100 x 100 x 30 m



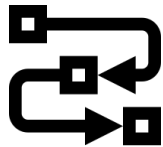
### Intelligent transport systems

*Platooning* < 3 ms latency  
*Cooperative manoeuvres* < 10 ms latency  
99,9999% reliability  
2km along road



### Drones & remote farm machinery

10 to 30 ms latency  
99,9 to 99,9999% reliability  
Several km<sup>2</sup> area



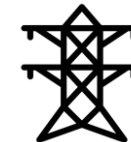
### Process automation

50 ms latency  
99,9 to 99,9999% reliability  
300 x 300 x 50 m



### Remote medication & surgery

10 to 100 ms latency  
99,9999% reliability  
Wide range of coverage areas



### Smart Grid: Electricity distribution

5 to 25 ms latency  
99,9 to 99,9999% reliability  
100 to 200 km along power line

# EXAMPLE: 5G FOR INTELLIGENT TRANSPORT

- › Vehicle-to-vehicle (V2V) & vehicle-to-infrastructure (V2I) communication improves safety and traffic flow
- › Step 1 to inform driver, step 2 for automated / autonomous vehicles
- › Requirements:
  - › Low latency
  - › Direct communication
  - › High availability
  - › Privacy & security



'cooperative driving' challenge at the NL A270 testbed

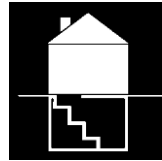
June 27 2019

# MASSIVE MACHINE TYPE COMMUNICATION

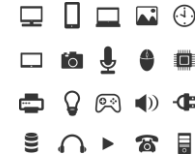
## 4G IOT TECHNOLOGY ALREADY FULFILLS MOST OF THE REQUIREMENTS



**Throughput**  
A few kbps to  
1 MBps



**Coverage**  
Extreme indoor coverage



**Density**  
1 million per km<sup>2</sup>



**Battery life**  
10+ years



**Mobility**  
Idle mode mobility and/or  
connected mode mobility



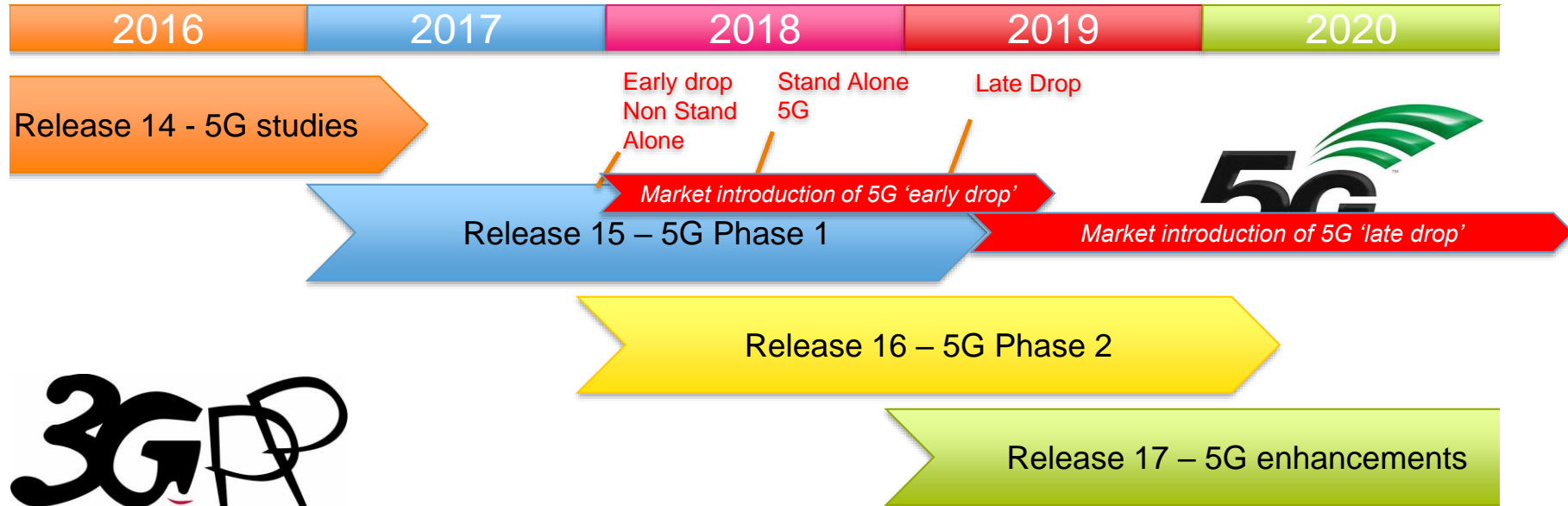
**Cost**  
Few Euros per device

# EXAMPLE: 5G FOR SMART CITIES

- › Small devices / sensors
- › Requirements:
  - › Low power, long battery standby time
  - › Coverage everywhere, also under ground
  - › Many devices



# 5G STANDARDS: 3GPP MULTI RELEASE TIME PLAN



A GLOBAL INITIATIVE

## 5G RELEASE CONTENTS

**5G**

Release 15

- eMBB
- New Radio
- 5G Core

**5G**

Release 16

- URLLC
- Critical IoT
- eV2X

**5G**

Release 17

- What's in store?

*Start of introduction of 5G services and products*

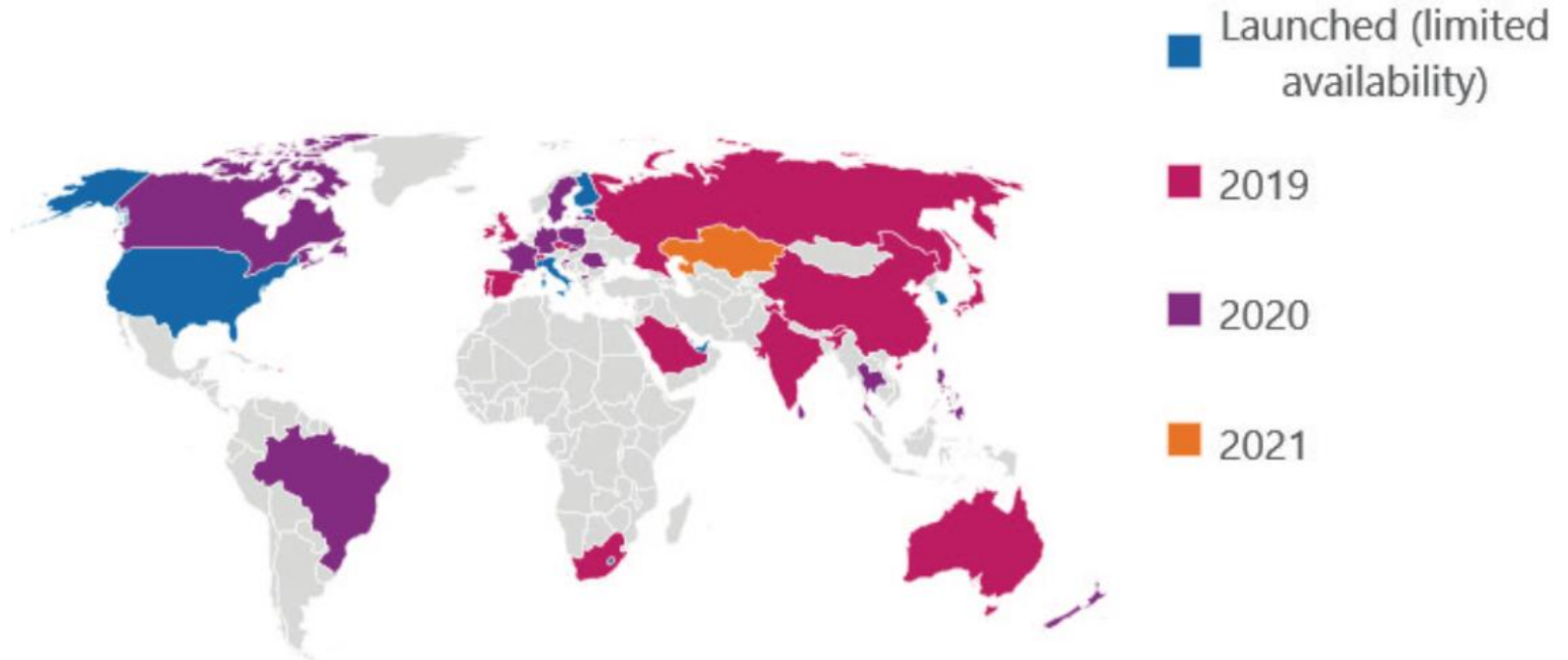
2019 - 2020

2021 - 2022

2023 - 2024



# EXPECTED 5G INTRODUCTION



# SWISSCOM FIRST COMMERCIAL NETWORK

## Where 5G has gone live.

We are bringing 5G to the city, the country and everywhere in between.  
Available across Switzerland by the end of the year.



Lützelflüh



Bern



Davos



Geneva



Zurich



Burgdorf



Basel



St. Moritz



Estavayer-le-Lac

All these places have partial 5G provision that is being continuously expanded.



# OUTLINE

- › Introduction to 5G
- › **5G for verticals**
- › 5G for military communications
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# 5G: CURRENT VERTICAL USE CASES



Automotive



Public Safety



Railway



Maritime



Satellite integration



Industry

# NEW RELEASE 17 VERTICAL USE CASES



Audio-Visual production



Interactive Services



Medical



Logistics



Unmanned Aerial Vehicles

# VERTICALS: INVOLVEMENT OF NEW SECTORS



# 5G FOR PUBLIC SAFETY

- › Mission critical use of public mobile networks
  
- › Requirements:
  - › Priority – voice ... and data
  - › Availability - even in case of disasters
  - › Coverage - also across borders
  - › Broadband - high bandwidth for data, video
  - › Secure



# 3GPP: MISSION CRITICAL SERVICES

## Standardization of Mission Critical Services:

- › LTE / 4G Release 13: Push-to-talk for mission critical communication (MCPTT)
- › LTE / 4G Release 14: MCPTT enhancements and support for data and video
- › 5G Release 15: Interworking MC services and integration with legacy systems

## Underlying technologies:

- › Group-based communication
- › Device to Device communication, without network infrastructure
- › QoS: priority in radio network for new MC services (voice, data and video) and pre-emption of voice calls
- › Shared use of radio networks (frequencies, base stations), option for dedicated core network and/or MC service platform

First deployments live, e.g. USA (FirstNet), UK and via BroadWay project (EU)







## EXAMPLE: FirstNET

FirstNet is an independent authority within the U.S. Department of Commerce.

- › 2001: Public safety identifies a need, triggered by communication challenges on 9/11
- › 2001 - 2012: Public safety advocates for its dedicated network
- › 2012: Congress creates the First Responder Network Authority
- › 2012: Consulting with public safety nationwide
- › 2016 - 2017: Forming an innovative public-private partnership

FirstNet awarded an innovative 25-year contract to AT&T in March 2017

- › 20 MHz of federally owned spectrum and \$6.5 billion in initial funding
- › AT&T to deploy and operate a nationwide high-speed broadband network for public safety over 25 years.
- › AT&T will invest about \$40 billion over the life of the contract to build, operate, deploy, and maintain the Network
- › AT&T can use FirstNet's spectrum when it is not being used by public safety for other, commercial purposes
- › Public Safety organizations have individual contracts with AT&T for FirstNet services, with standard smart phones

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# 5G TECHNOLOGIES FOR MILITARY COMMUNICATIONS

- › Initial study by NATO STO
  - › NATO STO Task Group IST-ET-096
  - › Technical Report: “5G Technologies: A Defense Perspective”
  - › NATO partners from USA (lead), DEU, NLD, TUR
- › New NATO STO IST task group to be started by NATO STO
  - › New decision in October, already 2x rejected
  - › Detailed study on use of 5G and adaptations in 5G standards
- › EDA white paper on 5G (in preparation)

NORTH ATLANTIC TREATY  
ORGANIZATION



AC/323()

SCIENCE AND TECHNOLOGY  
ORGANIZATION



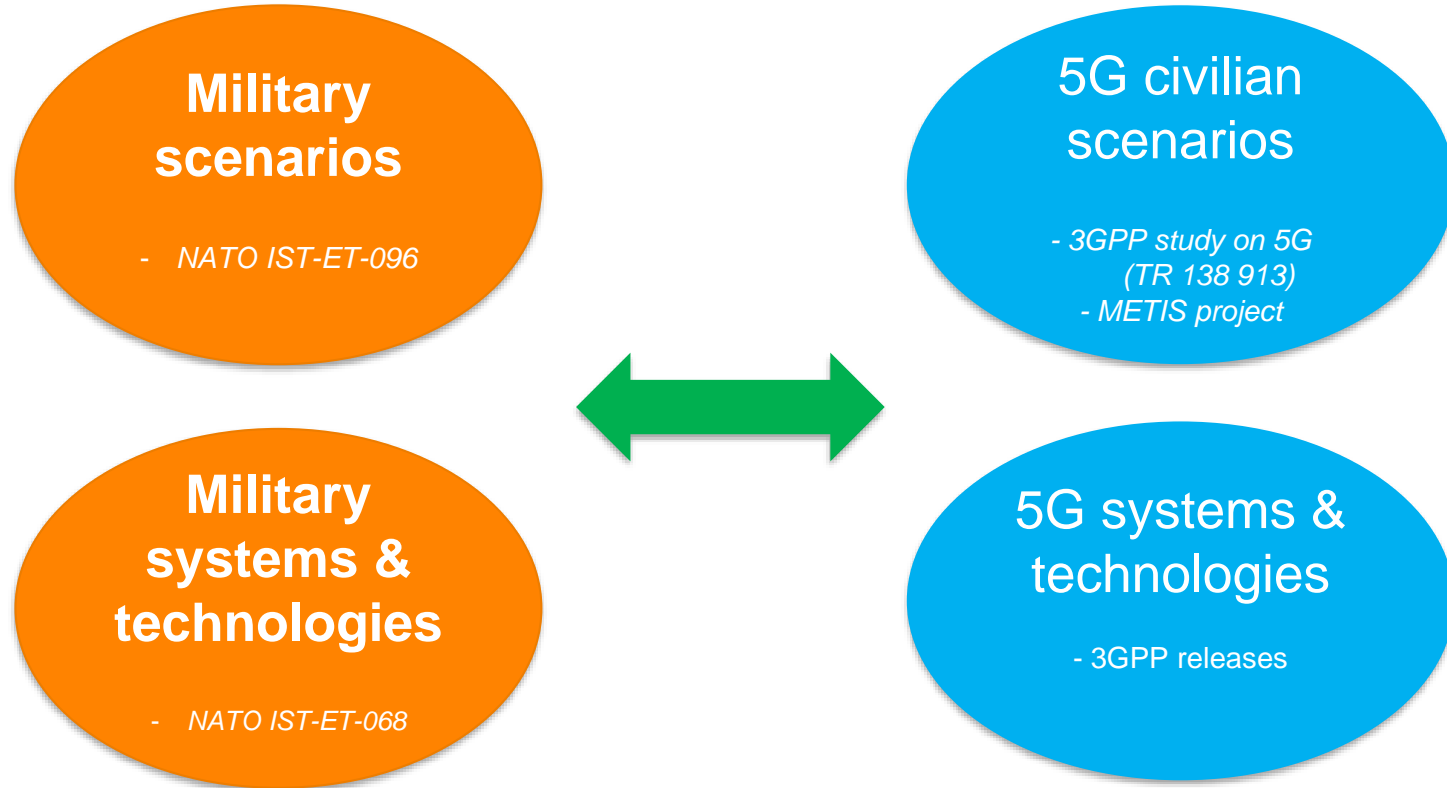
www.sto.nato.int

STO TECHNICAL REPORT

IST-ET-096

## 5G Technologies: A Defense Perspective

Pre-Release Report of Task Group IST-ET-096



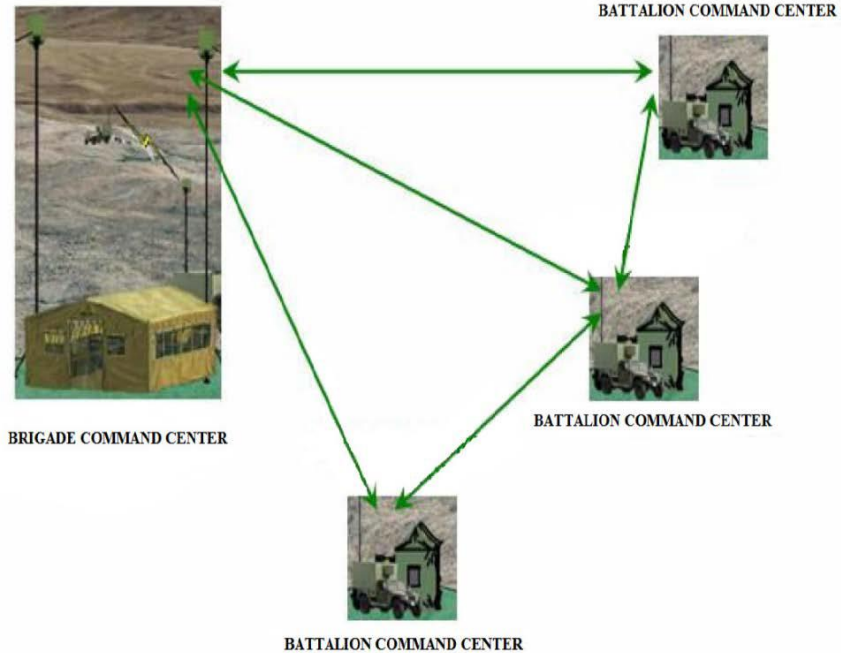
## Military scenarios

- NATO IST-ET-096

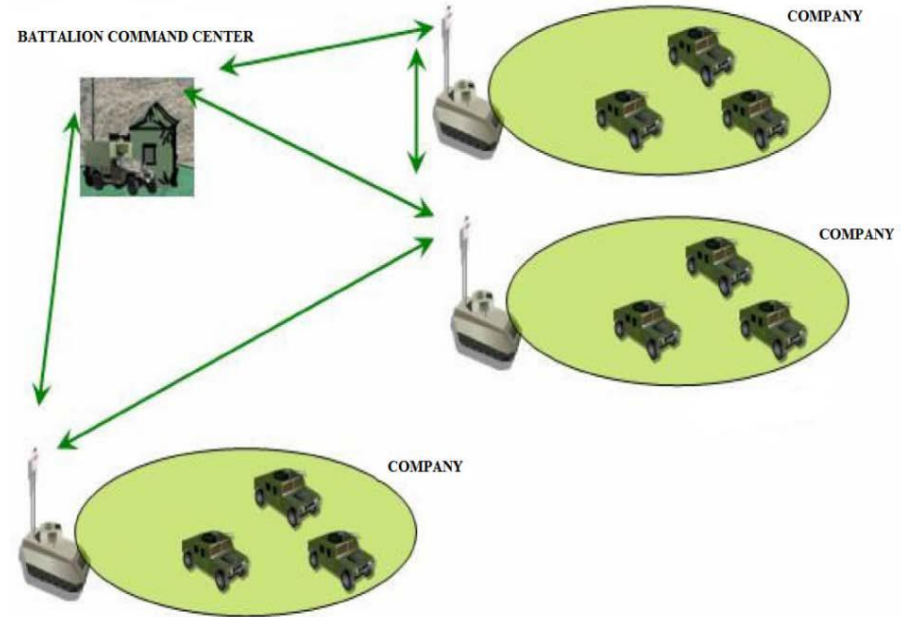
Five scenarios from IST-ET-096:

- *Scenario 1:* Wireless communications between command & control (C2) center at Battalion and Brigade level
- *Scenario 2:* Wireless communications between C2 center at Company and Battalion level
- *Scenario 3:* Wireless communications infrastructure inside a Command Post - rapid deployable Command Post
- *Scenario 4:* Fixed infrastructure - limited mobility Company-level communications.
- *Scenario 5:* Full mobility Company-level communications (e.g. ad-hoc MANET)

Scenario 1: Wireless communications between command & control (C2) center at Battalion and Brigade level



Scenario 2: Wireless communications between C2 center at Company and Battalion level



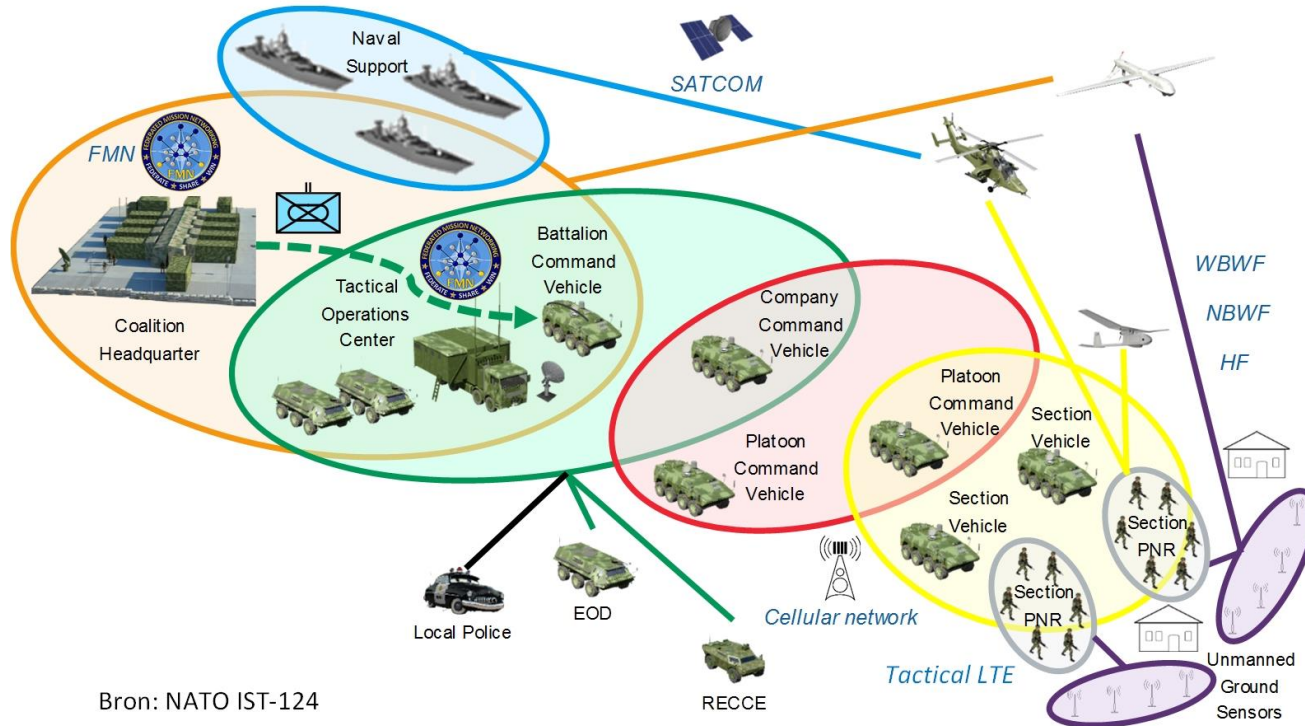
## Military systems & technologies

- NATO IST-ET-068

### Types of military communication systems:

- **Tactical communication systems**
  - Used by mobile land forces below level of a Brigade HQ
  - Wide range of battlefield, joint, and combined systems
- **Overlaid public / civilian communication systems**
  - Used for additional redundancy, capacity and reliability to the tactical communication system or act as an alternate channel
  - Managed, operated, and maintained by an external organization (MNO)
- **Strategic wireless and Beyond-Line-of-Sight (BLOS)**
  - Used for long-range mobile forces or platforms such as aircraft, surface ships or submarines

## HETEROGENEOUS NETWORKS



Bron: NATO IST-124



## 5G systems

- Evolvement of LTE and LTE-Advanced
- Main categories: eMBB (>10 Gb/s), URLLC (<1 ms), mMTC (1 M/km<sup>2</sup>)
- 3GPP Release 15, 16 17
- Verticals: public safety (mission critical services)

## 5G technologies

- 5G Radio technologies
  - 5G New Radio and mmWave
  - Massive MIMO (Multiple Input Multiple Output) arrays
  - Network sharing (RAN)
  - D2D communications
- 5G Core technologies
  - Softwarization: 5G core to support SDN / NFV
  - Distributed network, edge computing
  - Cloud technologies
  - Network slicing

**5G civilian  
scenarios**

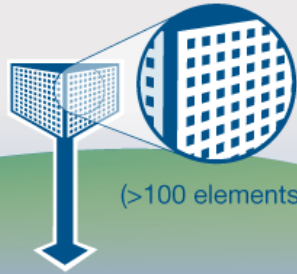
**5G systems &  
technologies**

# 5G BASE STATIONS WITH BEAMFORMING

## BASE STATIONS



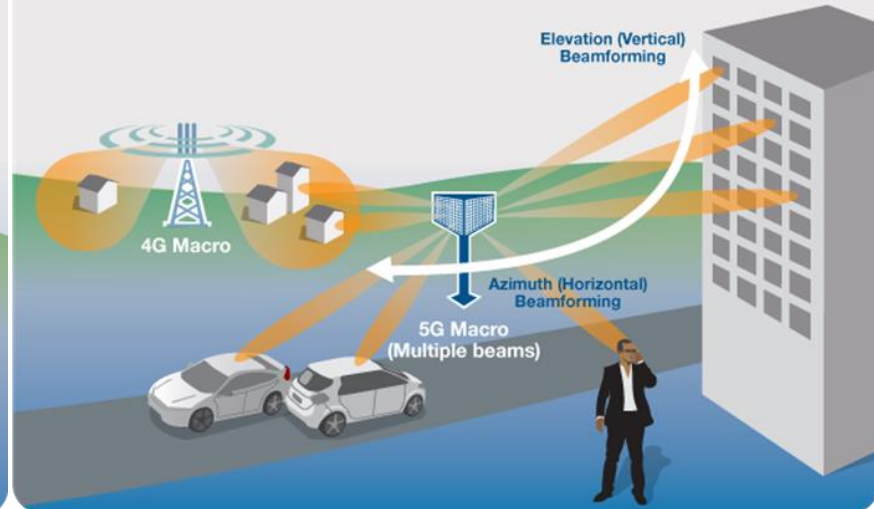
4G Sector Antenna



(>100 elements)

5G Massive MIMO

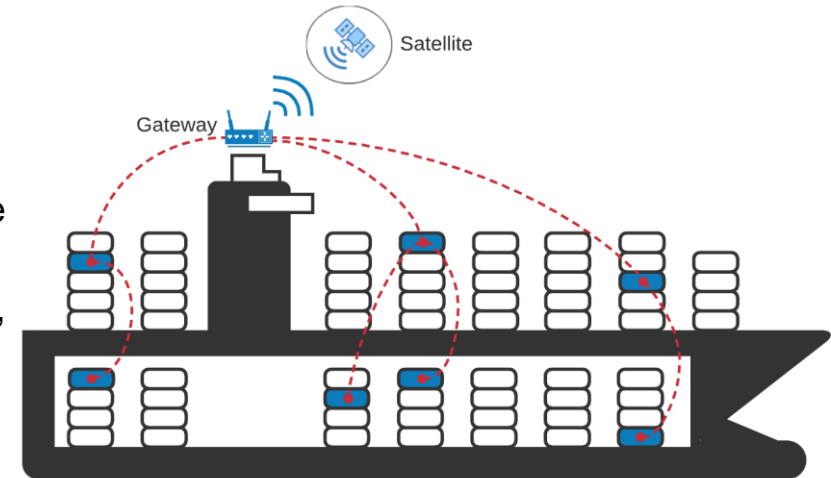
## MIMO BEAMFORMING



# 5G (AND 4G) SIDELINK COMMUNICATION

## DIRECT COMMUNICATION BETWEEN DEVICES

- › Relaying
  - › Indoor coverage can be an issue (metallic environment in factories, mmWave communication for multimedia applications)
  - › Planning an indoor network is not always possible (e.g. cabling in existing houses, containers)
  - › Relay can be more powerful (e.g. satellite access, or ambulance that has better antenna and battery)
- › Direct UE-to-UE communication
  - › Direct communication between devices (e.g. drone to controller, or PC to beamer) can offload the network and be more energy efficient



# 5G NETWORK SLICING

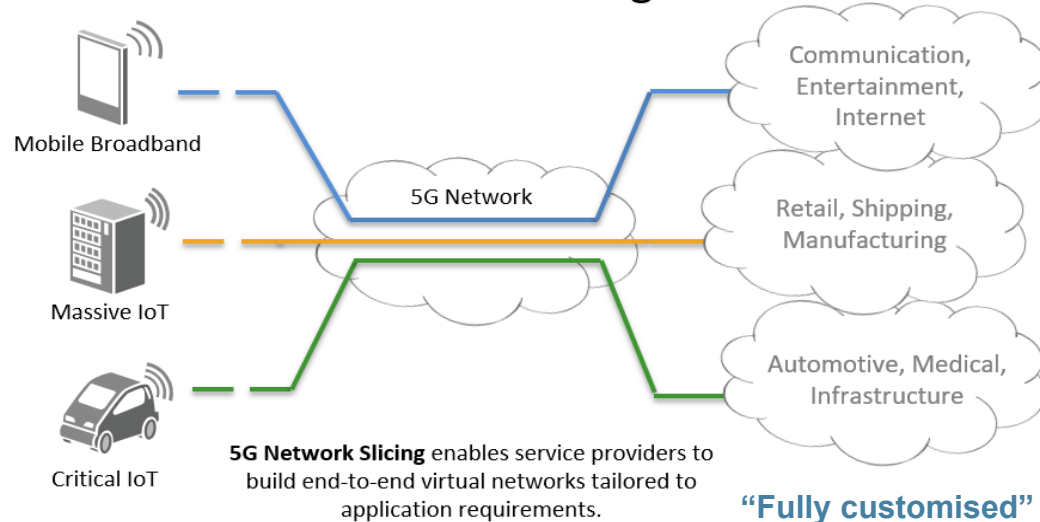
## The 4G Network



4G enables voice, text, and data services, but not the range of use cases that the future requires and 5G will enable. 5G will not only be faster, it will be more flexible.

**“One size fits all”**

## 5G Network Slicing

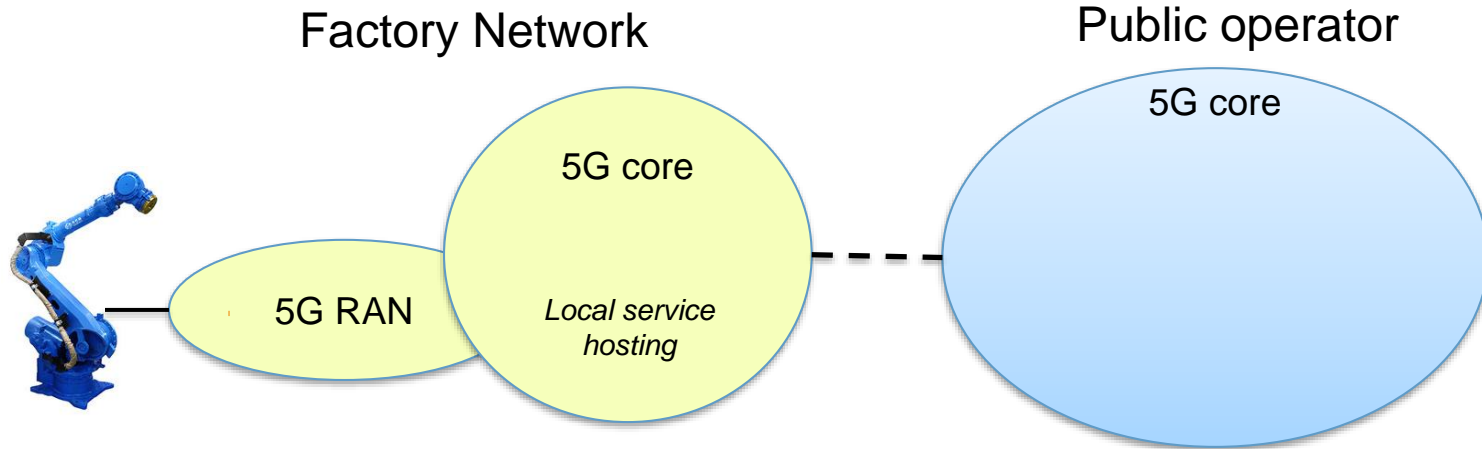


# 5G DISTRIBUTED NETWORK



# 5G IN NON-PUBLIC NETWORKS

## DEDICATED NETWORKS FOR DEDICATED APPLICATIONS

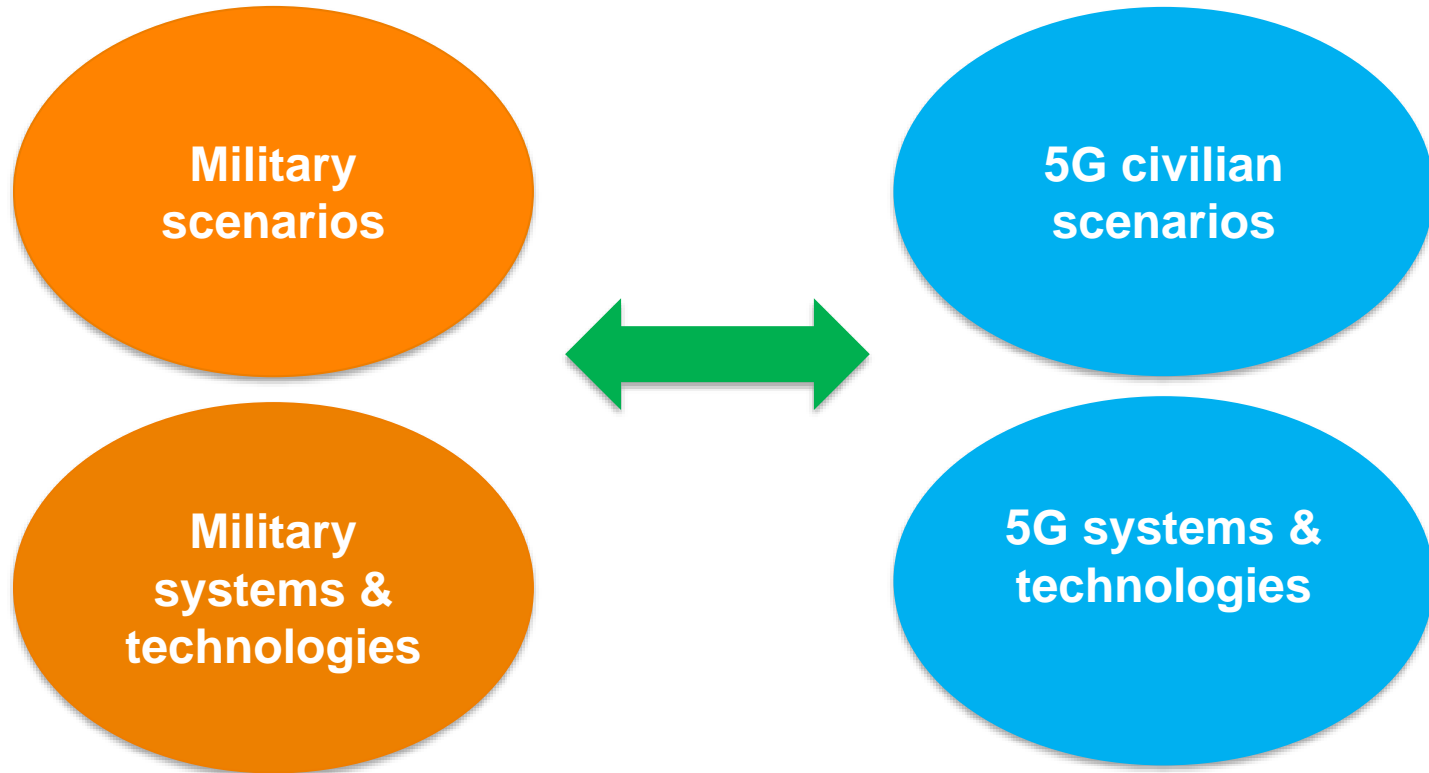


### Private networks

- Extreme low latency
- 3<sup>rd</sup> party services

### Possible relation with public operator

- Roaming
- Dual SIM cards



# MILITARY SCENARIOS AND 5G: INITIAL IDEAS

## › **Deployed Mobile Networks (5G in tactical networks)**

- › Dedicated vs shared (between coalition partners) vs public networks (e.g. for public safety)
- › Commercial (licensed) spectrum vs military spectrum (special handsets)
- › Vendor/supplier of equipment for military use has higher requirements for the supply chain

## › **Mix-of-means**

- › Military radios for robustness (EW), with limited capacity / data throughput
- › Mobile Networks (5G) when possible, with high capacity / data throughput
- › Virtual / Augmented Reality for information overlay in 5G networks
- › Routing mechanism on application level between those networks/radios necessary

## › **High volume sensors**

- › Military sensors in and around compounds could benefit from IoT developments in the mobile networks



# 5G TECHNOLOGIES FOR MILCOM: INITIAL IDEAS

## › 5G mMIMO and beamforming

- › Civil 5G: Beam towards the UE of interest; nulling towards other UEs
- › 5G Milcom: nulling towards red-forces based on their (GPS) location

## › Peer-to-peer communication

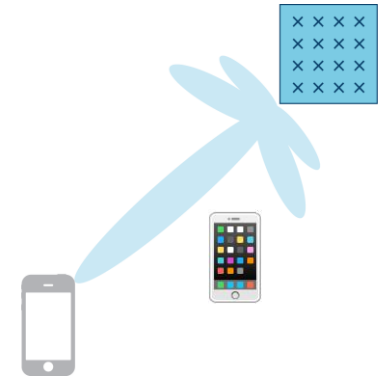
- › Civil 5G: Device2Device (D2D, relaying) for Public safety
- › 5G Milcom: Use for D2D communication among soldiers in areas with no network coverage

## › SaT5G

- › Civil 5G: Satellite (HAPS) communications make integral part of 5G
- › 5G Milcom: Exploit SaT5G for connectivity in remote areas.

## › Network slicing

- › Civil 5G: service-specific network sharing
- › 5G Milcom: MoD as an operator, to provide military network slices to different forces, all over the same expeditionary 5G infrastructure



# OUTLINE

- › Introduction to 5G
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- › **Future work**

## FUTURE WORK

- › Approval / support to start NATO STO group on 5G for detailed study on benefits of 5G in Milcom
  - › Description of military use cases and requirements
  - › Mapping of 5G technologies on Milcom
  - › Identify missing elements in 5G specifications (R15/16/17)
  
- › Involvement in future work for 5G standardization (R17) for missing capabilities
  - › Disaster relief in a war zone or natural disaster areas
  - › Network sharing options in 5G, supported by softwarization and cloud technologies
  - › SatCom, etc.
  
- › Involvement of vertical / industrial partners in 3GPP on service and product development
  - › EDA white paper on 5G
  - › Public safety can be used as example: relative small market size, active participation of stakeholders, long lead times of 5-10 years

› THANKS FOR YOUR ATTENTION

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for life