
5G 6G INNOVATION CENTRE
UNIVERSITY OF SURREY
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5.5G and 6G for 2030+
UK Spectrum Policy Forum Plenary
Overarching spectrum policy event
29th April 2021
REGIUS PROFESSOR
RAHIM TAFAZOLLI
DIRECTOR INSTITUTE FOR COMMUNICATION SYSTEMS (ICS), 5GIC, 6GIC

5G & 6G Standards Roadmap

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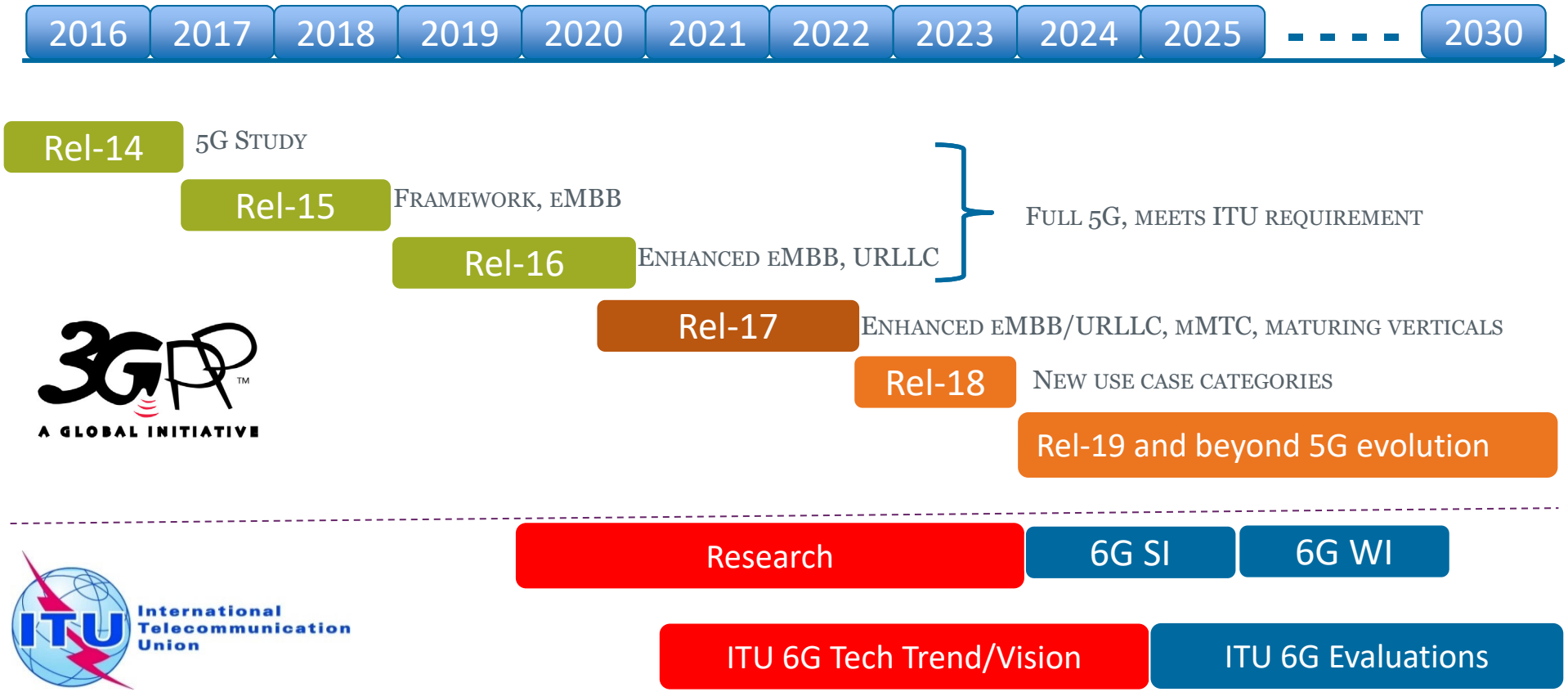

5G Release 15

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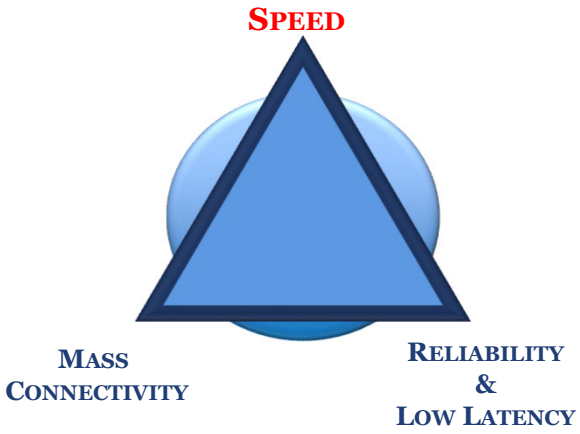
eMBB-Broadband to address 4G capacity crunch (400MHz to 52.6GHz)



Flexible Air Interface
- Numerology/slot/Frames/ BWP
- Wide BW/LF and HF/SUL

New Coding
- Polar codes for control
- LDPC for data

mmWave
- Beam based control/data
- Beam alignment and tracking

Network Slicing

Massive MIMO
- Large antenna ports
- Enhanced codebook

Ultra Low Latency
- Fast access and feedback
- Short frame duration and mini-slot

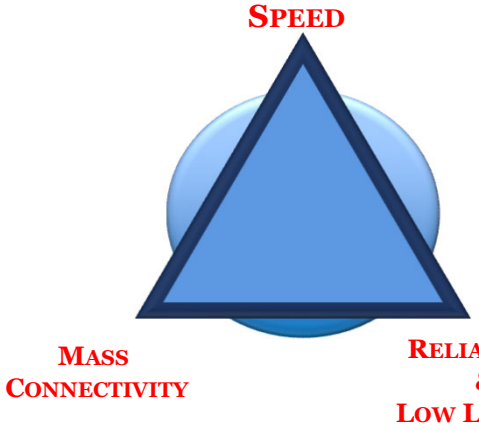
Forward Compatibility

CU/DU Splits

Security baseline

5GNR Release 16 (400MHz to 52.6GHz)

Completed 2020



Mobile

- MIMO Enhancement
- IAB
- Mobility Enhancement
- UE Power Saving

Vertical

- URLLC Enhancement
- V2X
- Positioning (~3m)
- Industry IoT
- IoT Slicing Security

5G Release 17: Extension to 71GHz

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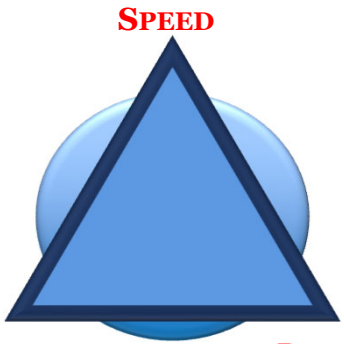
Enhancements: ongoing



Sub-3GHz FDD enhancements
- FDD MIMO enhancement
- Efficient multi-carrier Operation and DSS

IoT enhancements
Reduced Capability Devices (REDCAP)
IIoT/URLLC/Positioning enhancement
NB-IoT 16QAM DL/UL and RLF-based mobility

Net Slicing
AI/ML-enabled Net management

NTN (LEO, GEO)

Coverage and UL enhancements
- Indoor coverage
- Outdoor coverage

Verticals
- Sidelink performance enhancement (V2X)
- Sidelink relaying
- Broadcast/multicast

Positioning (~30cm)

Security enhancement

FDD 30% Throughput
UPLINK 70% Throughput
URLLC 10x Outage
mMTC 10x #of Connections

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2020
Q4

People Centric
234M connections
Worldwide [Ref]

2025

People Centric
1.8B connections
worldwide [Ref]
&
Machines Centric

Capacity & Reliability enhancements
&
Automation (AI/ML), Edge Computing

[Ref]: GSMA

6G Vision-From 5G/6G Summit in Nov 2020

Vision Theme	Number of Speakers (out of 7)
Fusion of Virtual and Physical Worlds	6
Coverage as an explicit 6G goal	6
Spectrum Efficiency	6
AI	5
6G to address the great societal challenges	5
Energy efficiency	5
Comprehensive target KPIs	2
Holography	1
Intelligent Surfaces	5
Security and Trust	5

- Sensing and actuation
- THz Communications
- Huge amount of computing and Processing + People generate more contents
  - Alternative to Von Neumann Architecture
  - Collaborative ML/AI
- Fibre slower than mega constellation sat
- Multi-lateral trust, more important in IoT
- Sub-cm geo-location
- High quality time for synchronisation

6G Vision from 5G/6G Summit

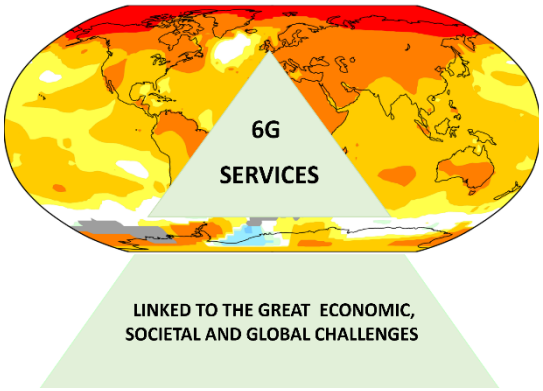
- CONSIDERING 5G EVOLUTION IN R17, 18 AND POSSIBLY 19 AND 20:

  5G + AI ≠ 6G

New Approach to 6G

6GIC vision

- Start with clear use case with clear business case
- Don't set any KPIs e.g, speed etc..
- Consider 5G capabilities and its future evolution
- Fully consider social and industry challenges
  - Productivity
  - Sustainability
  - Digital Divide



WIRELESS EVOLUTION- MEDIA PERSPECTIVE

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Use case with Business Case

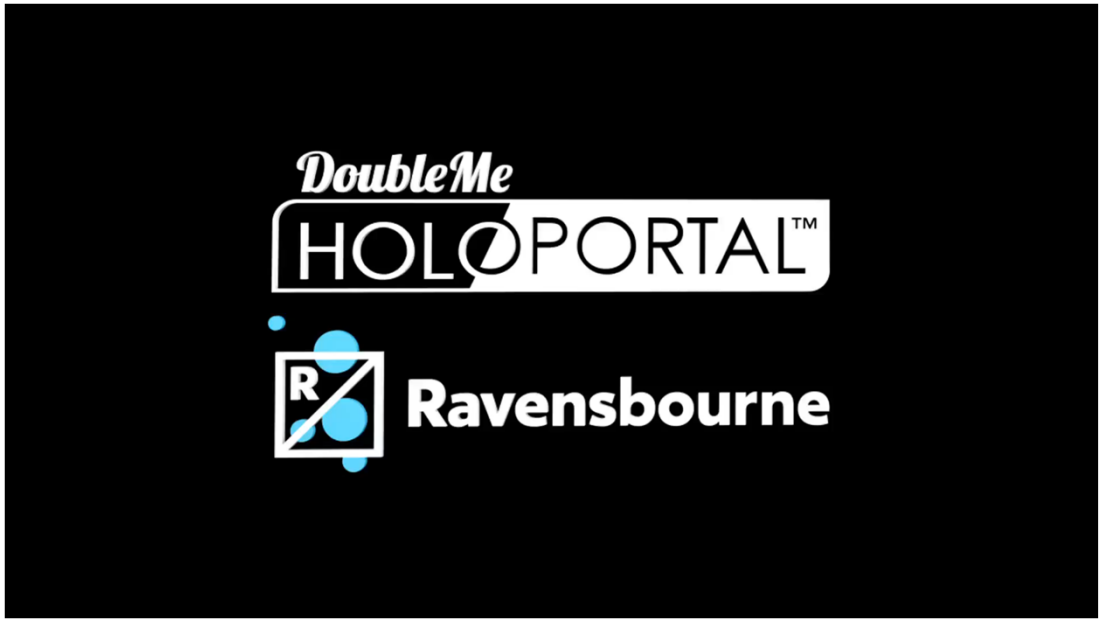
- 2G-----PHYSICAL WORLD- **TEXT, RINGTONES**
- 3G---PHYSICAL WORLD- **IMAGE**
- 4G---= = = = = = = = – **2D VIDEO**
- 5G- VIRTUAL AND PHYSICAL WORLDS - **3D VIDEO**
- 6G- VIRTUAL AND PHYSICAL WORLDS INTERACTIONS **4D VIDEO**

4D Video enables Interactive VR

3D Video+ Ambient Information=4D Video

Ref [1] : Rahim Tafazolli, first presented in TEDx in 2015, Cyprus

Fusion of Virtual and Physical Worlds



Holoportation + Sensual Information = Teleportation

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1G TO 5G ENABLED TRANSMISSION/RECEPTION:

ONLY TWO OF HUMAN SENSES

- HEARING: AUDIO (2D, 3D)
- SEEING: VIDEO (3D)

WHAT IS MISSING FROM HOLOPORTATION:

- INTERACTIVITY
- OTHER 3 HUMAN SENSES (TOUCH, SMELL, TASTE)

ENABLING TECHNOLOGIES FOR TELEPORTATION:

- TIME SYNCHRONISATON,
- HIGH ACCURACY MOVEMENT,
- AMBIENT INFORMATION INCLUDING TOUCH AND …

Simplest form of Teleportation

RXer TXer

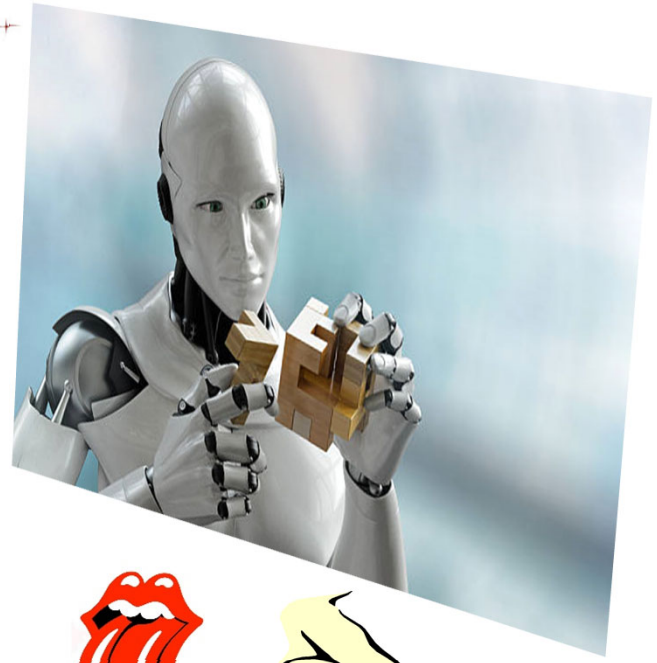
Sensual Info

TELE-INTERACTIONS

RXer

TXer

Sensual Info



Real-time Interactions between Real and Virtual worlds

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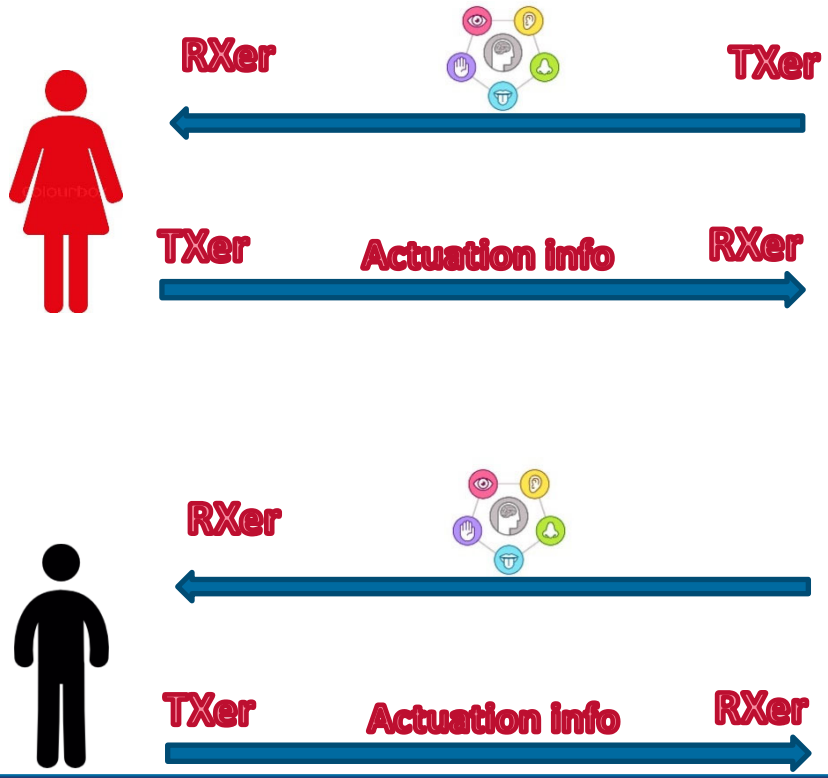
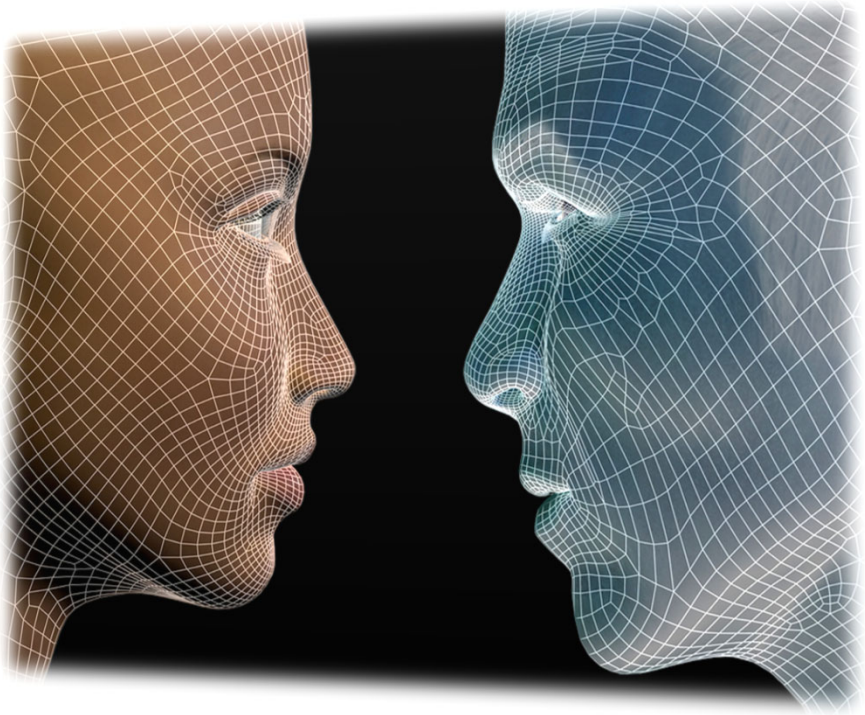
RXer TXer

TXer RXer

Holoportation

Real-time Interactions in Virtual World





Fusion of Virtual and Physical Worlds

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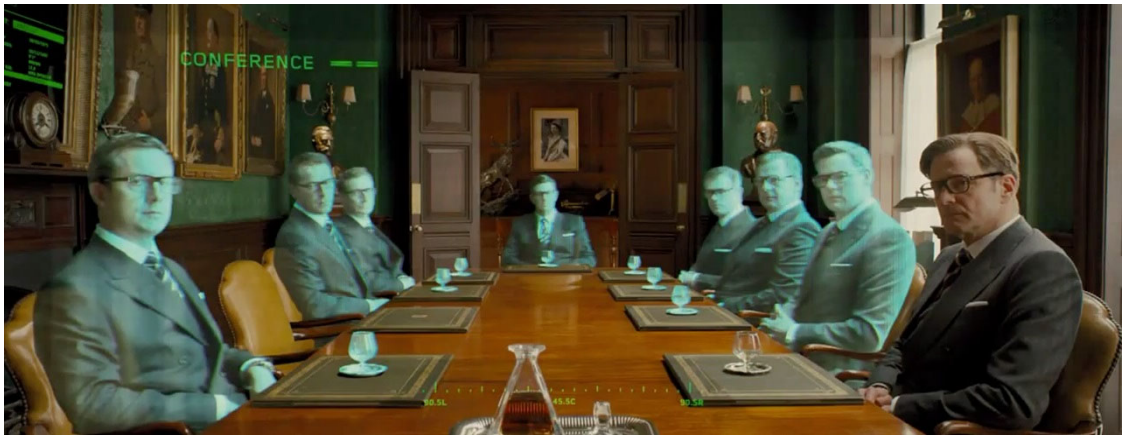
Enabled by high accuracy time synchronisation



Multi-party Physical and Virtual Interactions

Interactions between people in Virtual World

High Quality Holoportation Requirements

	Dimension	Bit Rate
Tile	4x4 inches	30 Gbps
Human	77x20 inches	4.62 Tbps

Colour, FP (full parallax), 30fps
Ref: N.Peyghambarian, University of Arizona

Other Senses

Touch

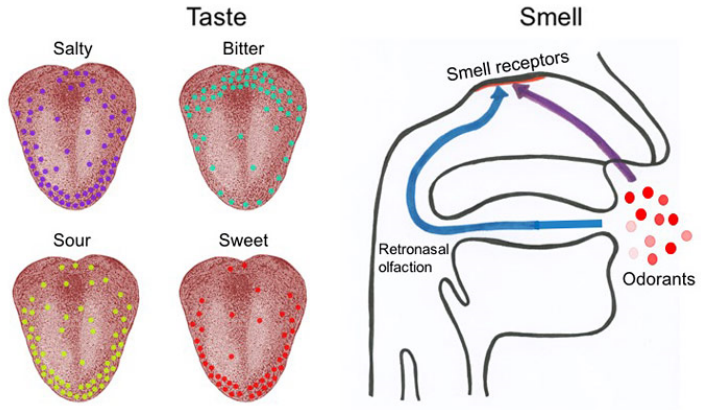
- Per inch^2 ~ 20 to 50 Mbps → For one average size Hand: ~ 1Gbps
- Latency <100 ms,
  - for natural delay with the brain touch function

Taste

- Chemical Reactions
- Bit rate and Latency ?

Smell

- Smell and Taste are inter-related



Latency vs Synchronisation

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- 5G capable of wireless latency <1ms for a single flow (session)

- Synchronisation is time difference between DIFFERENT flows generated by DIFFERENT objects that need INTERACTION with each other in REAL TIME
  - Example:
    - Objects: Two/more robots in a factory that need to work collaboratively (in Physical World)
    - Interactions between virtual and physical worlds (many applications)

- 5G was not designed with guaranteed time Synchronisation in mind

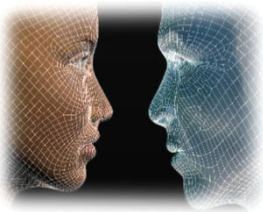
Digital Transformation: Society and Industry

5G
Enabled by Low latency and reliability

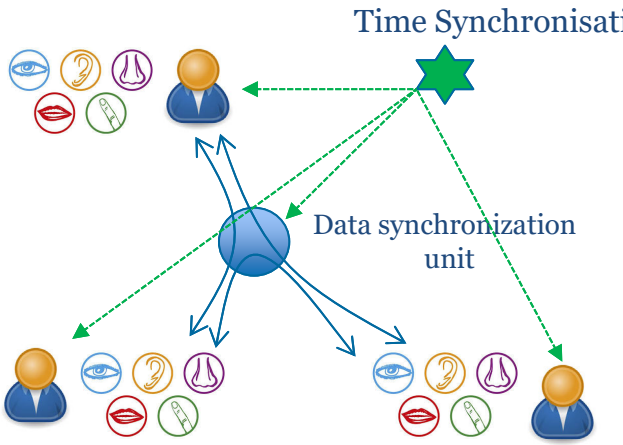
- **Examples:**
  - Connected vehicles
  - Manufacturing
  - Games/Entertainment
  - Health

6G
Enabled by Low latency and Time synchronisation

- Driver-less and cooperative driving
- Cooperative Manufacturing
- New generation of entertainment
- Interactive Telecare
- Teleportation



TIME SYNCHRONISATION: FUSION BETWEEN VIRTUAL & PHYSICAL WORLDS



LOW TIME JITTER ESSENTIAL

MULTI-CELL SYNCHRONISATION FOR TDD (5G) AT TIME SLOT LEVEL (SUB-MS)

- BETTER INTERFERENCE MANAGEMENT UP & DOWN LINKS FROM DIFFERENT CELLS AND BETWEEN DIFFERENT NETWORKS (MINIMISE GUARD-BANDS)

- **DISTRIBUTED MMIMO (FUTURE NETWORK)**
  - IN CELL-FREE ARCHITECTURES ALL DISTRIBUTED MMIMO SHOULD APPEAR AS ONE PHYSICALLY CO-LOCATED UMMIMO (TIME AND FREQUENCY SYNCH)

- **FAST SPECTRUM SHARING AT PACKET LEVEL**

RECONFIGURABLE

REFLECTING SURFACE

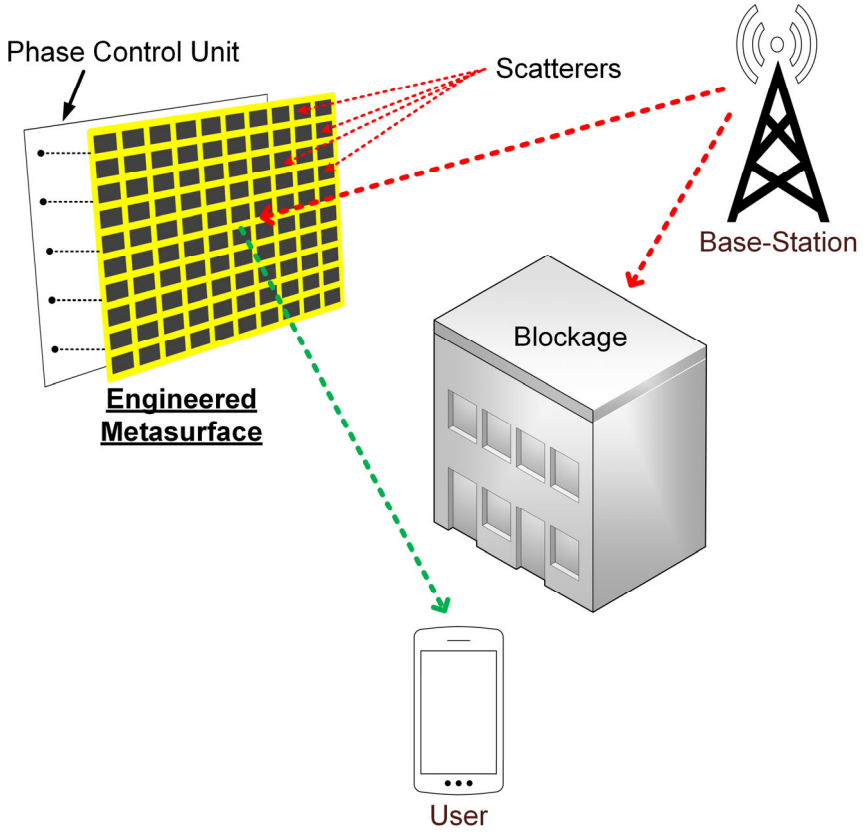
SOME USE CASES:

OUTDOOR 2 OUTDOOR

OUTDOOR 2 INDOOR

INDOOR 2 INDOOR

RECONFIGURABLE REFLECTING SURFACE -HOLOGRAPHY



- METASURFACE CONSISTS OF SEVERAL CONDUCTIVE PRINTED PATCHES (SCATTERERS)
- SIZE OF EACH SCATTERER IS A SMALL PROPORTION OF THE WAVELENGTH OF THE OPERATING FREQUENCY.
- MACROSCOPIC EFFECT OF THESE SCATTERERS DEFINES A SPECIFIC SURFACE IMPEDANCE AND BY CONTROLLING THIS SURFACE IMPEDANCE, REFLECTED WAVE FROM THE METASURFACE SHEET CAN BE MANIPULATED.
- EACH INDIVIDUAL SCATTERER OR A CLUSTER OF THEM CAN BE TUNED IN SUCH A WAY THAT THE WHOLE SURFACE CAN RECONSTRUCT EM WAVES.
- TUNABILITY MAY BE PERFORMED BY USING LIQUID CRYSTALS, GRAPHENE, VARACTORS, MICROELECTROMECHANICAL SYSTEMS (MEMS) OR PIN DIODES.

6GIC- World's first working RRS based on Holography Principle

Static RRS

- Thickness: 3mm
- Unit cells: 11000
- Beams: 2 reflected beams towards $\pm 45^{0}$
- Measured Gain: 20 dB
- Bandwidth: 400MHz (3.3 GHz- 3.7 GHz)
- Input power: ZERO

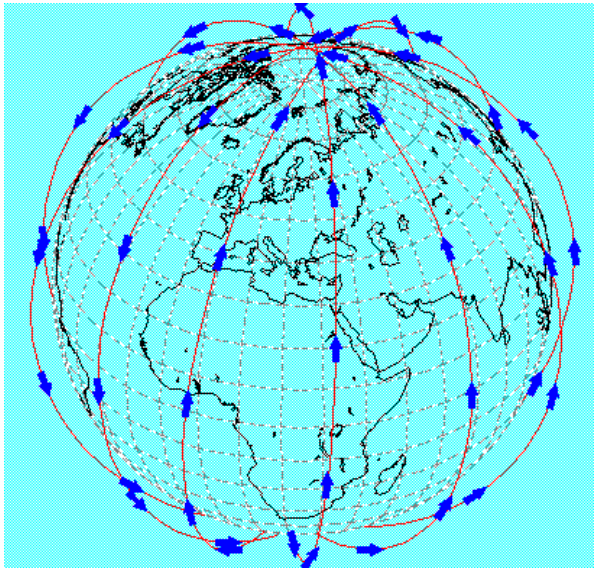
Dynamic RRS

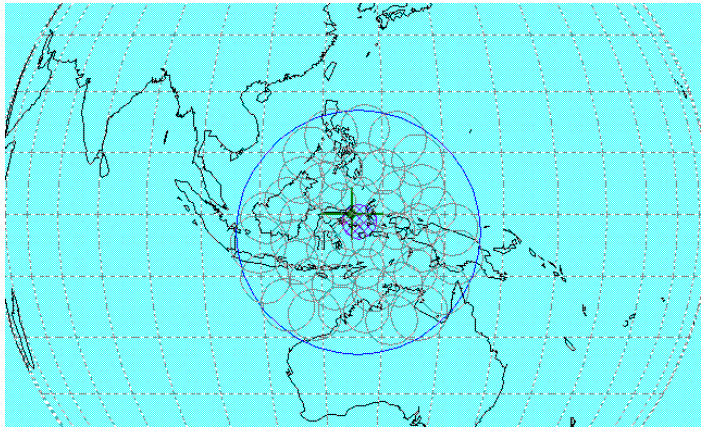
- Substrate Thickness: 1.524mm
- Unit cells: 3000
- Measured Gain: 17dB
- Bandwidth:700MHz (3.1 GHz- 3.8 GHz)

RRS-Demo

NON-TERRESTRIAL NETWORKS: OVERCOMING DIGITAL DIVIDE

COMPLEMENTARY ROLE





CHALLENGE:
DIRECT COMMUNICATIONS BETWEEN UE TO SATELLITE AND/OR TERRESTRIAL

6G FOR 2030+

INTEGRATED

COMMUNICATION
&
SENSING

(ICS)

IN A
NETWORK-OF-NETWORKS
INFRASTRUCTURE

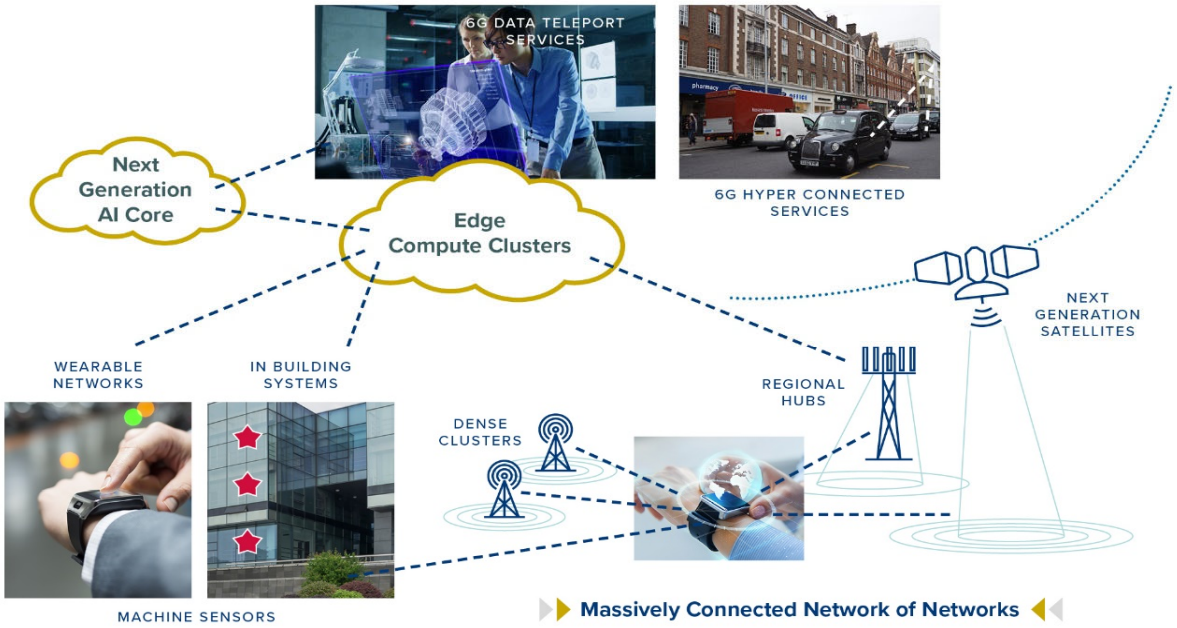


Figure 2: 6G services supported by next generation AI and network of networks

Integrated Communication and Sensing (ICS)

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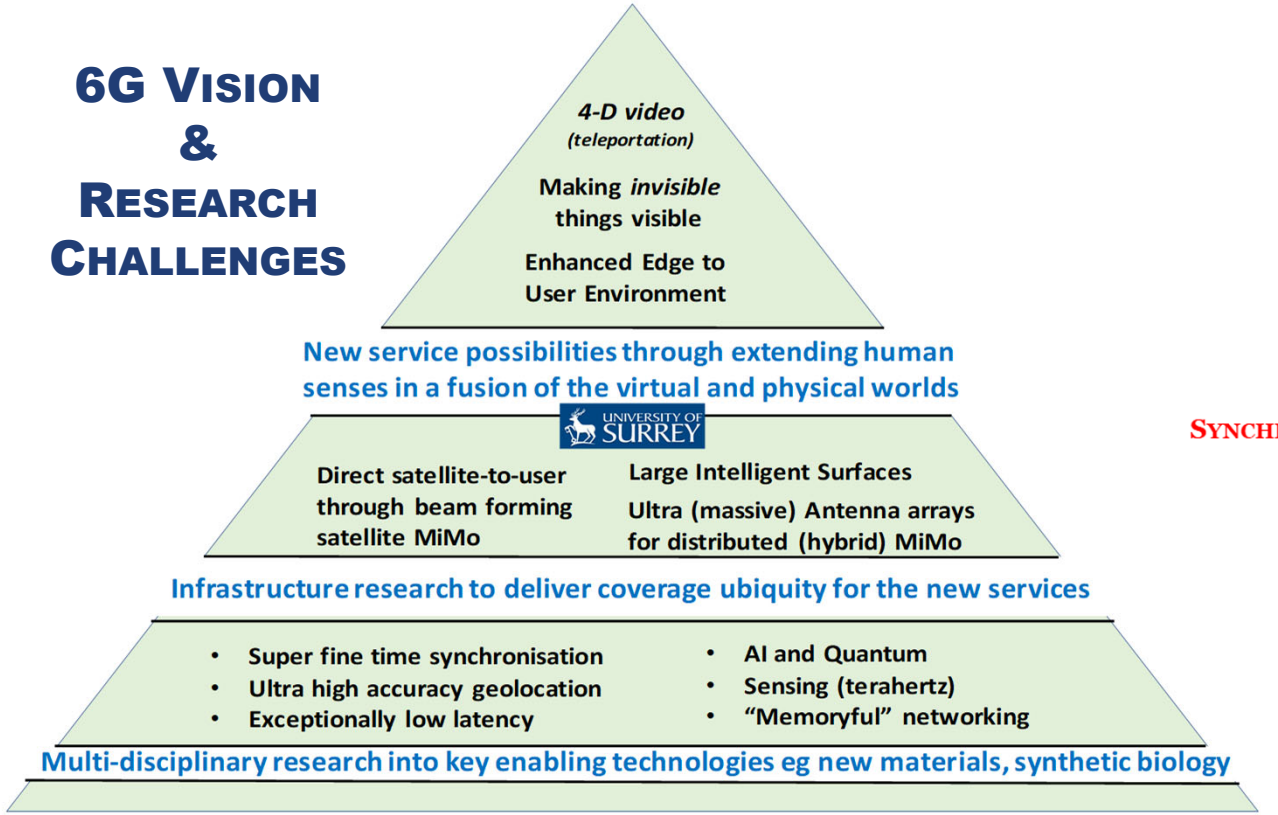
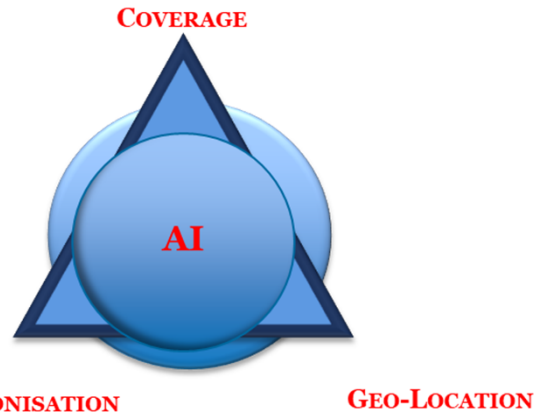
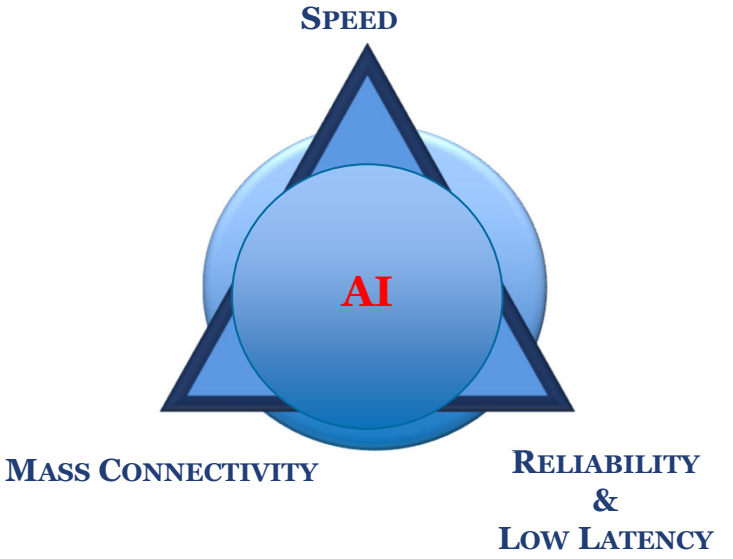
Figure 1: 6G vision supported by new cross-functional research and development programme

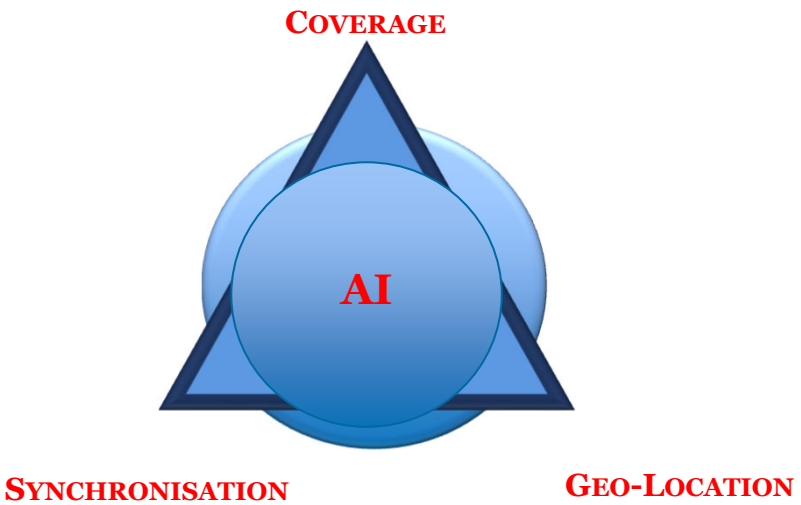
6G Vision & Research Challenges





What Next?





2020-2026

2030+

UK Leadership in Innovation

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Lesson learnt from the past

- Fix Frequency band(s)
- New Frequency Bands: consider moving downwards in spectrum rather than always upwards
- 6GHz is important as 5G extension band
- Develop channel models (THz, specially 0.1-10THz)
- Channel Model for uMassive distributed MIMO

Standardisation

- Start with a use case with clear business case
- Don't set target KPIs
- (Network of Networks)-Not only wide area cellular but combination of short-range and wide area with Intelligent surfaces Integration of ambient information into communication
- Geo-location
- Time/frequency synchronisation, Time distribution
- AI-enabled Phy layer, AI-enabled networking

Maximum Impact

- Telecom Eco-system Diversification; focus on Technology Innovation
- Establish a UK 6G Alliance: industry, academia bring national, international projects and results and share findings
- Joint collaborative research between industry-academia at low TRL
- Opportunity in 6G : 6GHz as new mid-band. Innovation in THz communications and components
- Adopt seriously multidisciplinary research for 6G from start

THANK YOU

https://www.surrey.ac.uk/sites/default/files/2020-11/6g-wireless-a-new-strategic-vision-paper.pdf