

INTERNET OF SENSES

WHAT TO SENSE AND WHY

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PROFESSOR
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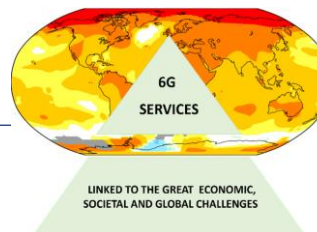
DIRECTOR INSTITUTE FOR COMMUNICATION SYSTEMS (ICS), 5GIC & 6GIC

5GIC: World's first 5G Centre

ART OF POSSIBILITIES



**WINNER OF ROYAL ACADEMY OF
ENGINEERING (RAENG) 2021
FOR BEST INDUSTRY-ACADEMIA
COLLABORATION**



WHY

How

WHAT

ENVIRONMENT

SOCIETY

ECONOMY

**ULTRA
ENERGY EFFICIENCY**

**ROBUST
PRIVACY & TRUST**

**SOLVE
DIGITAL DIVIDE**

FULL 5G CAPABILITY

CLEAR USE CASE

CLEAR BUSINESS CASE

4D VIDEO (TELEPORTATION)*

INTELLIGENT SURFACES

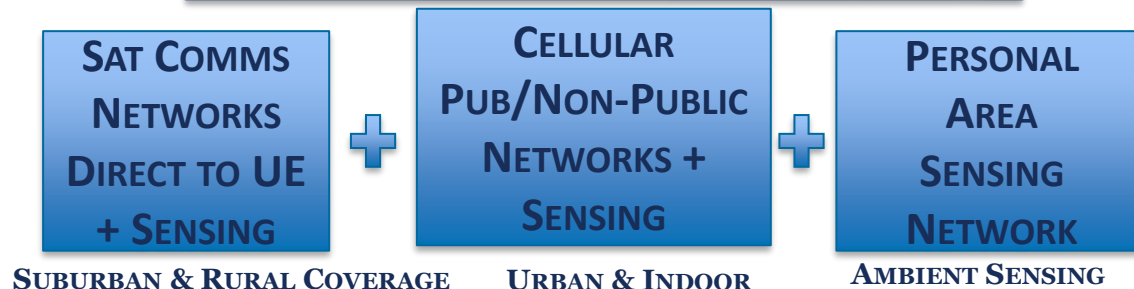
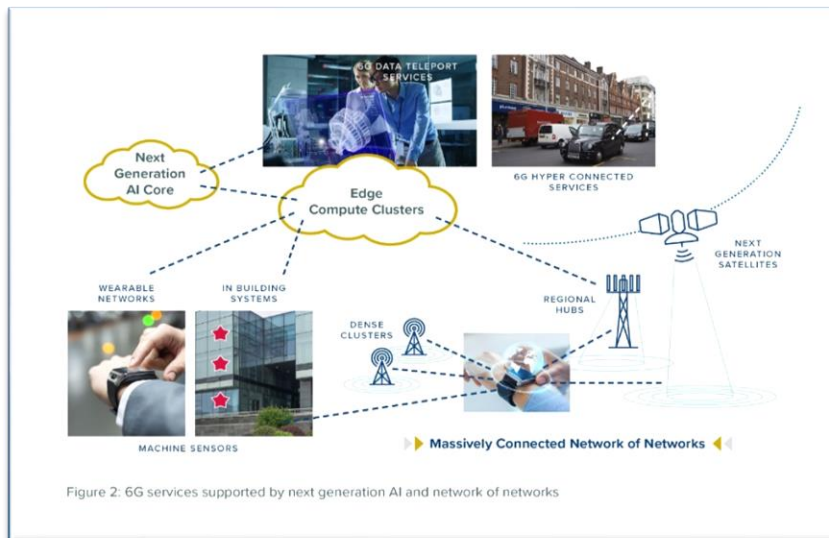
SENSING & SENSING NETWORK

NETWORK OF NETWORKS

* R. TAFAZOLLI, FUTURE WIRELESS WORLD, TEDx 2015

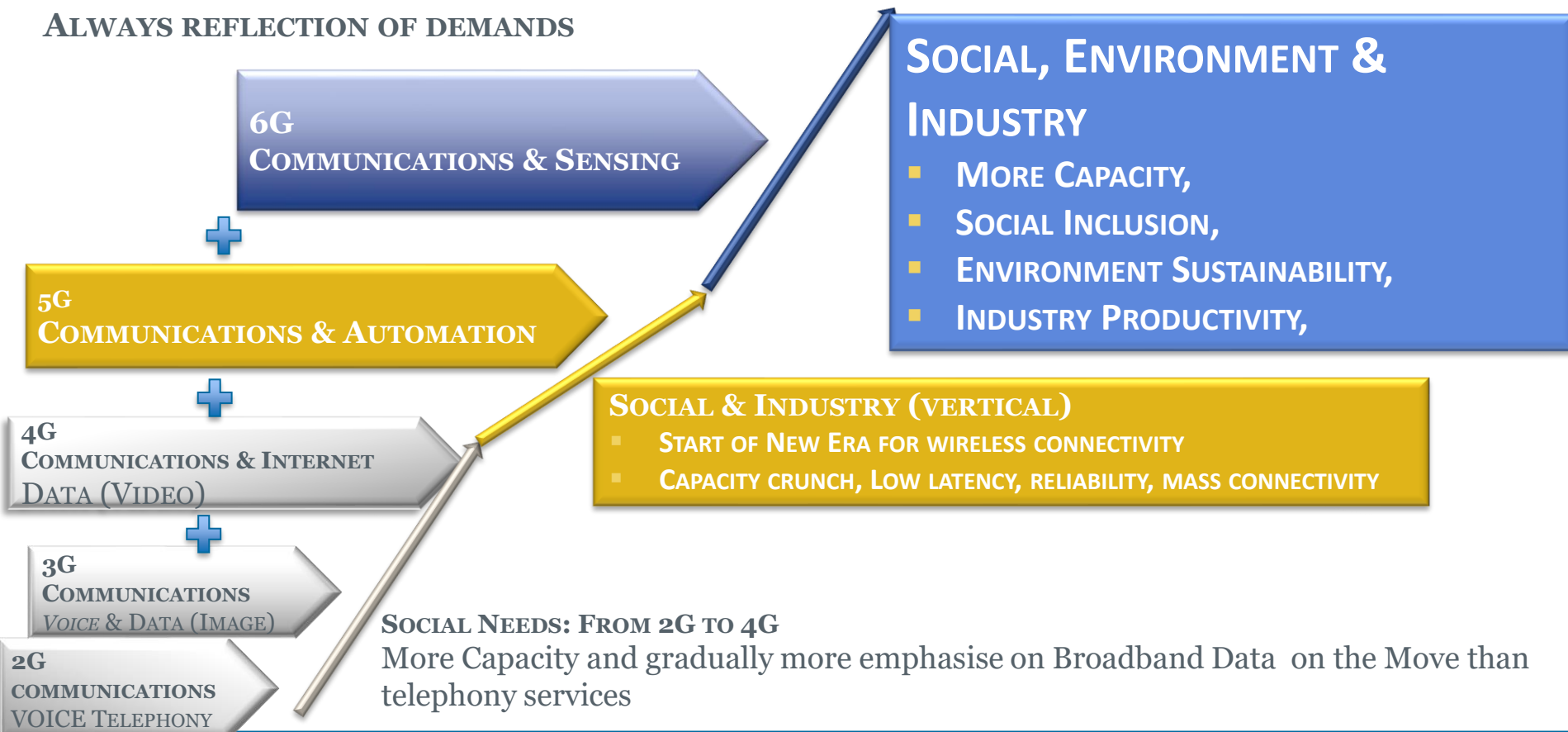
INTEGRATED COMMUNICATION & SENSING (ICS)

IN A NETWORK-OF-NETWORKS INFRASTRUCTURE



MOBILE SYSTEM GENERATIONS EVOLUTION

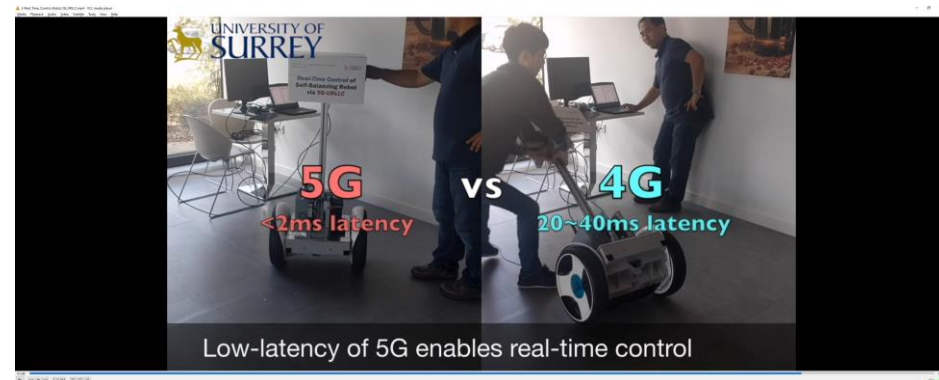
ALWAYS REFLECTION OF DEMANDS



TIME AND FREQUENCY SYNCHRONISATION

- 5G CAPABLE OF WIRELESS LATENCY $<1\text{ms}$ 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



- 5G WAS NOT DESIGNED WITH GUARANTEED TIME SYNCHRONISATION IN MIND

NEW USE CASES WITH INTERACTIVITY

5G

ENABLED BY LOW LATENCY AND RELIABILITY

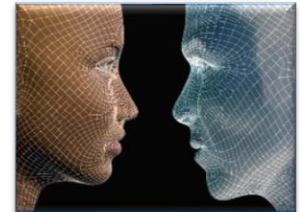
- CONNECTED VEHICLES
- MANUFACTURING
- GAMES/ENTERTAINMENT
- HEALTH

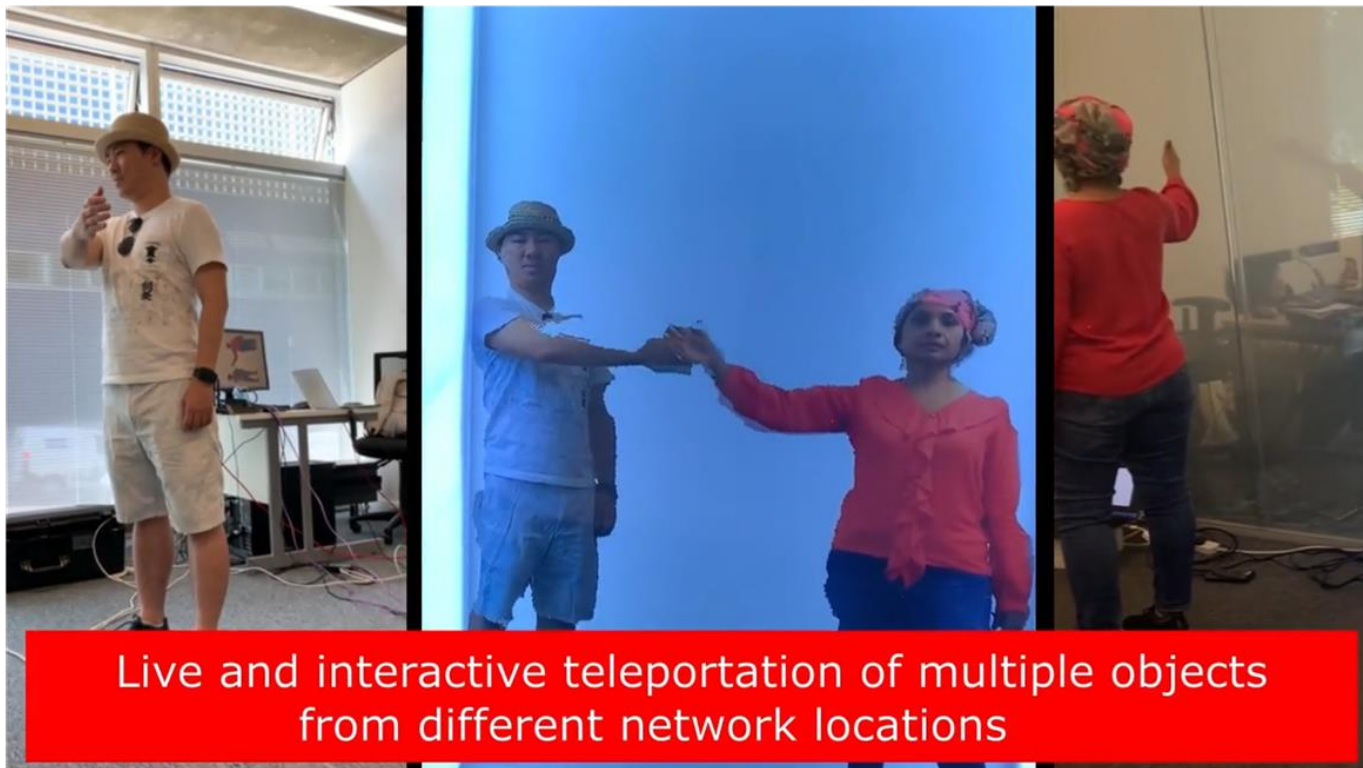


6G

ENABLED BY LOW LATENCY + TIME SYNCHRONISATION + SENSING INFORMATION

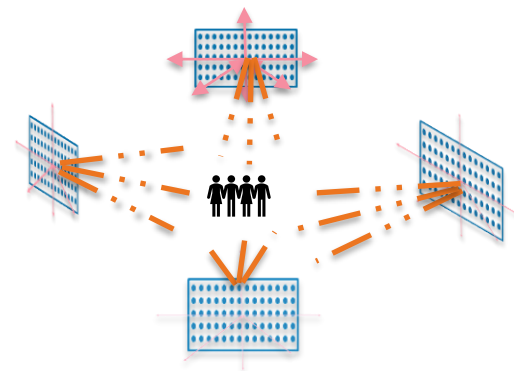
- DRIVER-LESS AND COOPERATIVE DRIVING
- COOPERATIVE MANUFACTURING
- NEW GENERATION OF ENTERTAINMENT
- INTERACTIVE TELECARE
- TELEPORTATION





TIME AND FREQUENCY SYNCHRONISATION BENEFITS

- **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**
- **AND MANY MORE....**



6G is Communications with Eye

- **AFFECT EFFICIENCY AT ALL LAYERS OF COMMUNICATIONS: PHY, MAC, NET,..& SYSTEM**
- **ENERGY & SPECTRUM EFFICIENCY**
- **ENABLE SMARTER APPLICATIONS**
- **TWO BROAD CATEGORIES OF SENSING:**
 - **SYSTEM LEVEL**
 - **USER LEVEL (AMBIENT INFORMATION)**

SYSTEM-LEVEL SENSING: ENVIRONMENT CONTEXT INFORMATION

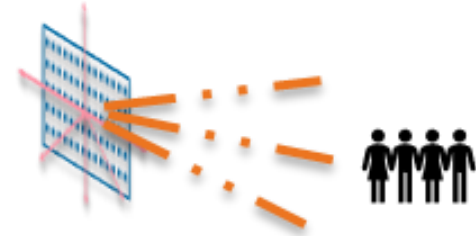
Traffic Sensing



Camera

Interference Management

Traffic Location and Mobility Sensing



Resource Management, Beam Forming and Tracking

EM Sensing



Intelligent Surfaces
with Metamaterial

Coverage Extension

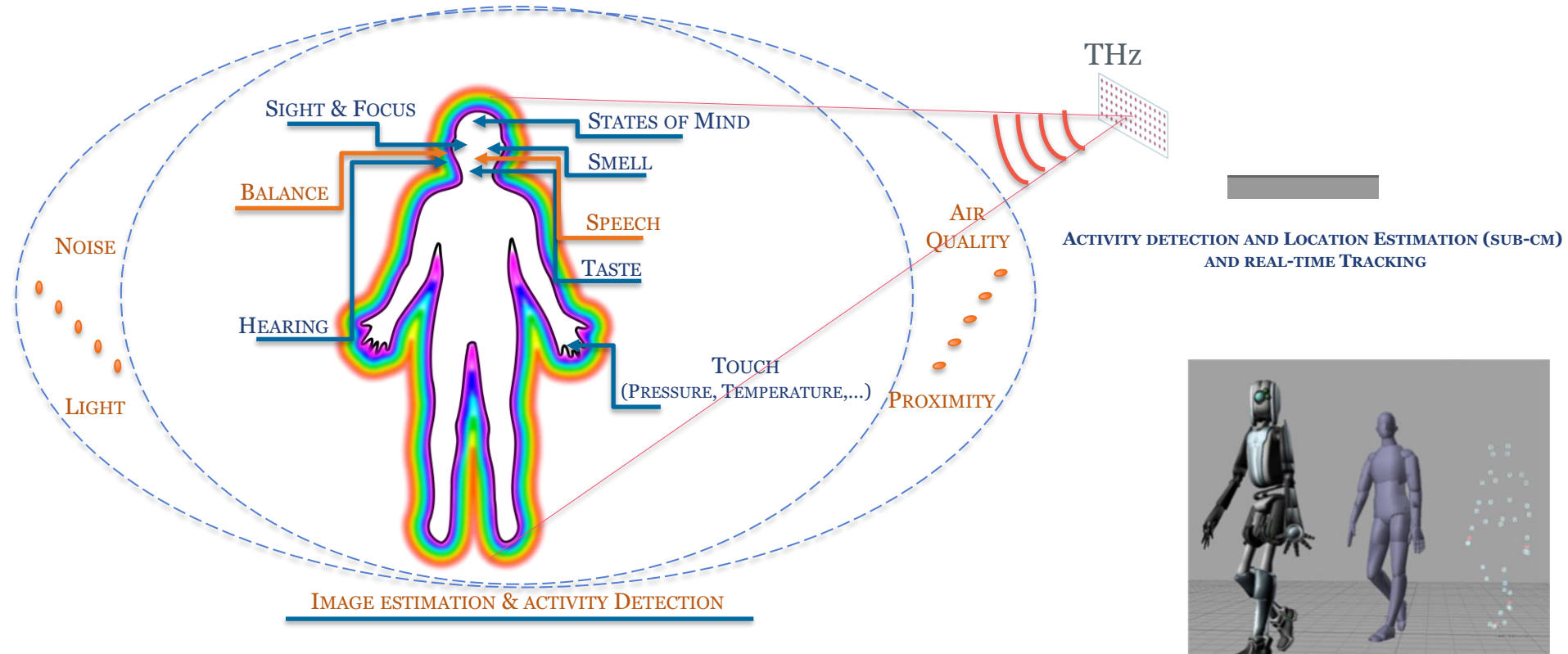
Change of Environment (Channel) Sensing



Camera
Radar/Lidar

Channel Equalization

USER-LEVEL SENSING: USER CONTEXT INFORMATION



THz IMAGING

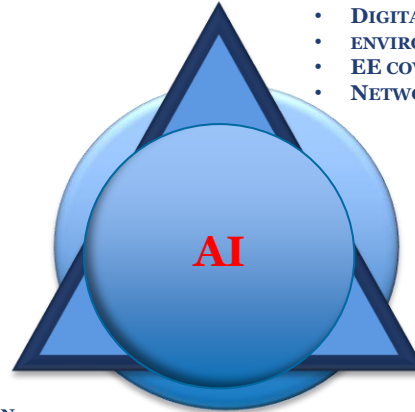
- Sub-THz components for transmitter and receiver
- Wearable sensor networking & Wearable material
- Integration between short/wearable networks with wide-area cellular networks and User equipment (UE)
- Edge processing and computing and task offloading between UE and networks
- Integration of sensing information with communications
- Standard data models and semantic descriptions of sensory data
- Privacy preserving and bilateral (distributed) authentication protocols between sensor nodes
- Federated AI
- High quality time synchronisation
-

INTEGRATED COMMUNICATION AND SENSING IN NETWORK OF NETWORKS



COVERAGE

- DIGITAL INCLUSION,
- ENVIRONMENT SUSTAINABILITY,
- EE COVERAGE EXTENSION
- NETWORK OF NETWORKS



SYNCHRONISATION

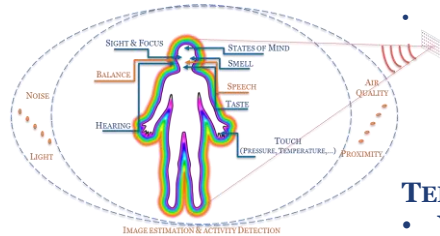
- 4D VIDEO, PHYSICAL & VIRTUAL WORLDS
- INTERACTIVITY DRIVERLESS TRANSPORTATION
- INTERACTIVE E-HEALTH,....
- INTERACTIVE ROBOTICS



SENSING & GEO-LOCATION

(HUMAN AND ENVIRONMENT AND NETWORK SENSING)

- ENVIRONMENTAL INFORMATION
- NATURAL INTERACTIVITY BETWEEN PHYSICAL & VIRTUAL WORLDS
- RESOURCES EFFICIENCY
- MANY NEW SMART SERVICES,



TELEPORTATION:

- VR + SYNCHRONISATION+ USER LEVEL SENSING

THANK YOU

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

