ICS/5GIC

What is Next ?

REGIUS
RAHIM TAFAZOLLI
DIRECTOR INSTITUTE FOR COMMUNICATION SYSTEMS (ICS), 5GIC

INSTITUTE FOR COMMUNICATION SYSTEMS

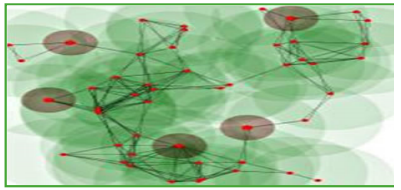
- WELL KNOWN RESEARCH INSTITUTE IN COMMUNICATIONS INTERNATIONALLY, PARTICULARLY IN EUROPE
- GOOD NETWORKING WITH INDUSTRY AND ACADEMIA
- GOOD AWARENESS OF STRATEGIC AND HOT RESEARCH AREAS –
  - TO SOME EXTENT WE ARE THE DRIVERS

Communication and Information Systems

- **Mobile Cellular**
  - 4G, 5G and….Beyond
- **WiFi**
  - .11g, n, ac, ax..
- **Non-Terrestrial Networks**
  - **Satellite Communications & Broadcast**
    - Broadband Fixed
    - Broadband Mobile- on the move
    - Broadcast- passenger vehicles
  - **Drone Communications**
- **Internet of Things**
- **Vehicle Communications**
- **Future Internet**



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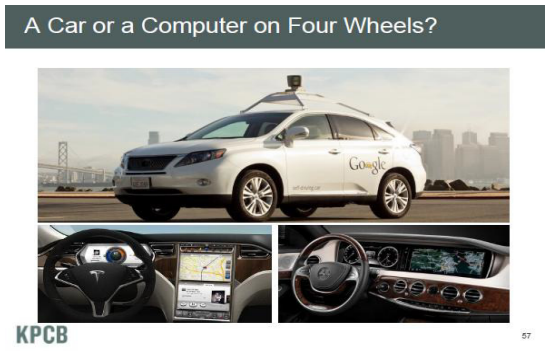
5G INNOVATION CENTRE
LARGEST OPEN INNOVATION CENTRE ON 5G

University of Surrey, 5GIC

COMMUNICATIONS & AUTOMATION

Connectivity + Intelligence (AI and Machine Learning)

Automation



Data to information transformation

Blurring boundaries between real and cyber worlds

Connected Devices of small and large sizes and capabilities

(robots, cars, sensors, actuators, smart phones ……. driverless cars)

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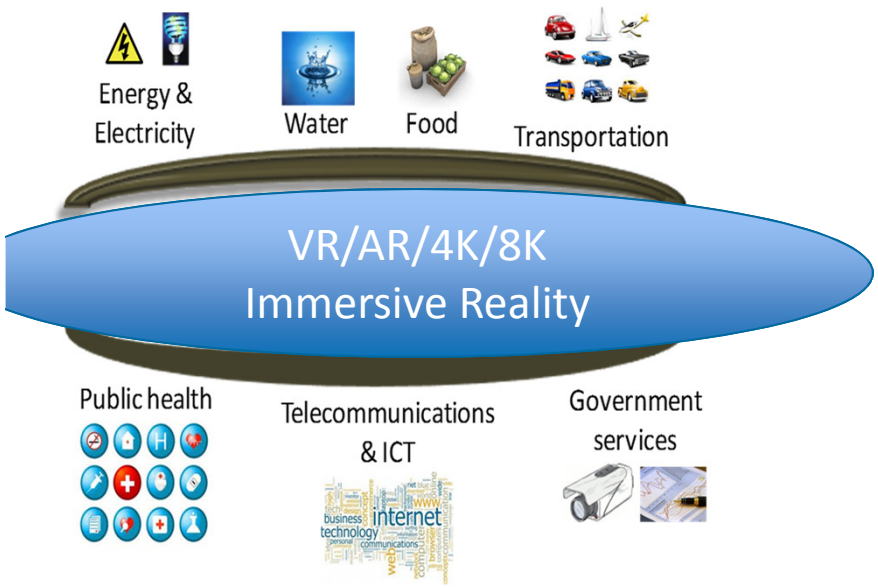
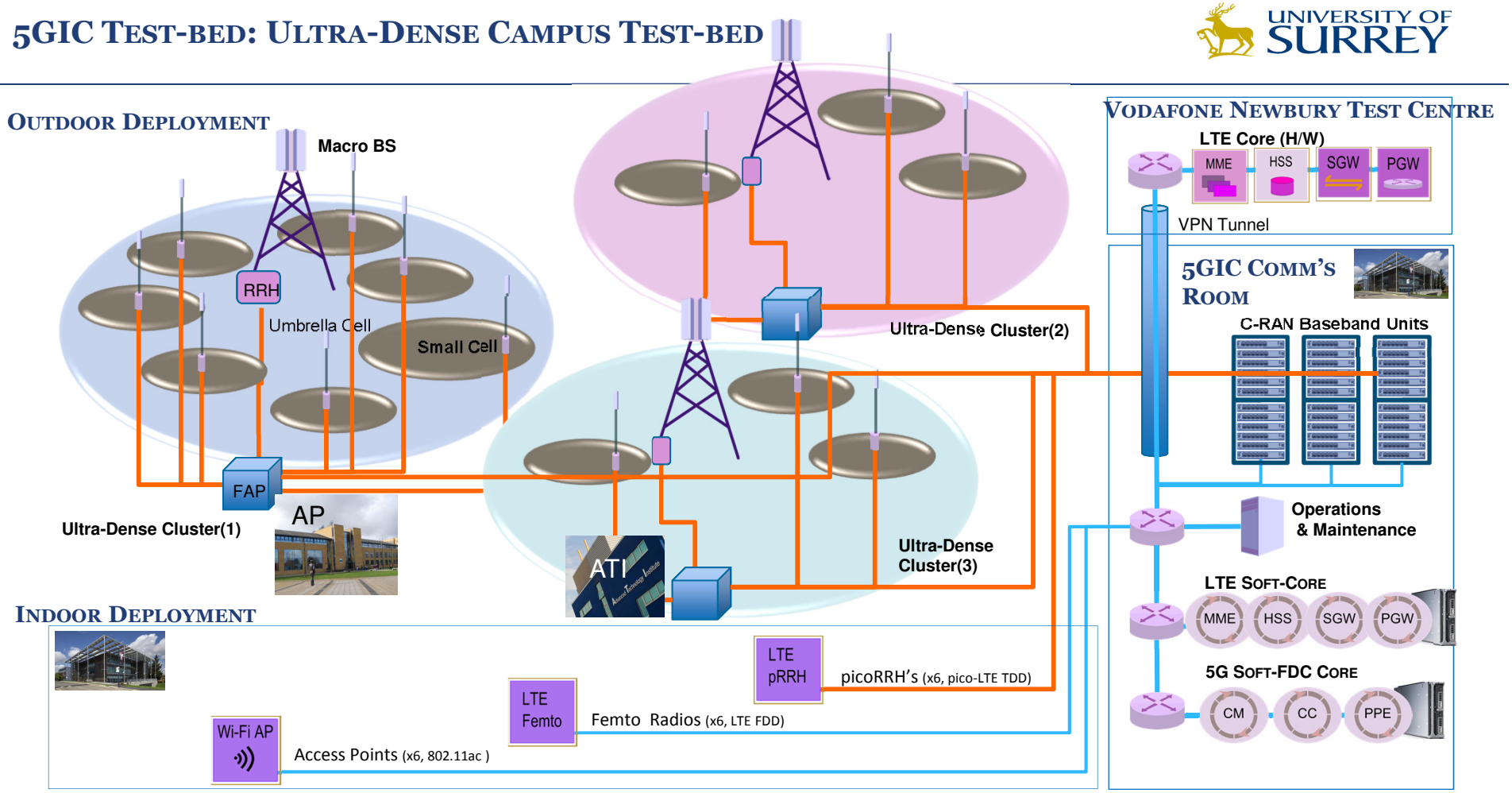
ONE NETWORK INFRASTRUCTURE SERVING ALL INDUSTRY SECTORS



- **Programmable**
- **Resilient**
- **Low delay, high reliability**
- **1000x more capacity than 4G**
- **One Million connections per km^2**

5GIC Test-bed: Ultra-Dense Campus Test-bed



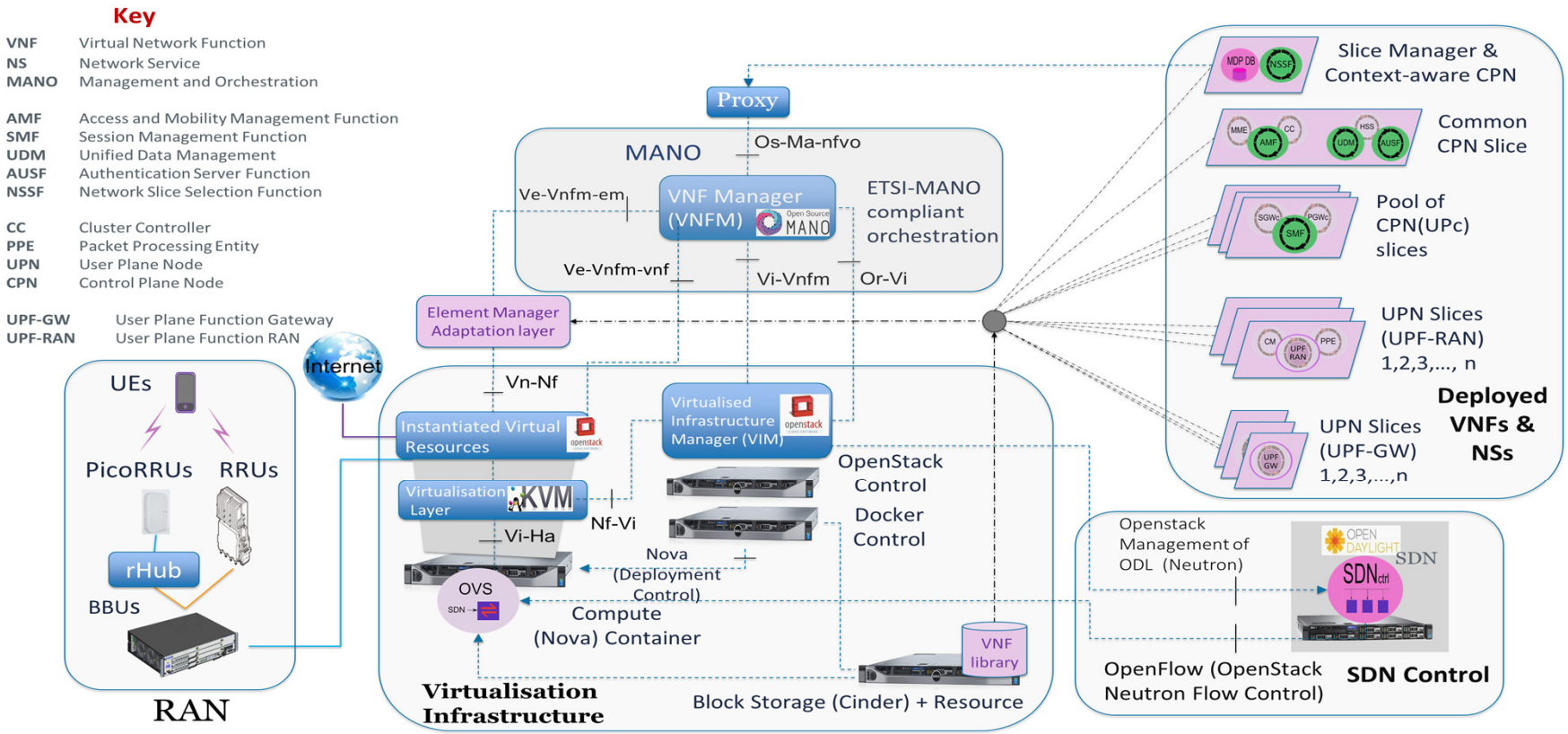
3GPP compliant

FLAT DISTRIBUTED CLOUD (FDC) CONTEXT-AWARE NETWORK ARCHITECTURE

FDC IS EFFICIENT, FLEXIBLE, SCALABLE, AGILE AND DYNAMIC FOR ALL PURPOSES

- **FLATTER THAN 4G CORE:** REDUCING THE NUMBER OF NETWORK LAYERS FROM THREE IN LTE TO ONE FOR 70% OF THE USE CASES, AND TWO FOR THE REMAINING 30%.
- **DISTRIBUTED:** PHYSICALLY DISTRIBUTED IN DIFFERENT RESOURCES ACCORDING TO MOBILE DEMANDS, AND INTELLIGENTLY DISTRIBUTED TO KEEP USER DATA CLOSE TO WHERE IT IS NEEDED.
- **CLOUD-BASED:** SCALABLE AND NOT SOLELY RELIANT ON LOCAL PHYSICAL RESOURCES
- **CONTEXT-AWARE:** META-DATA PROTOCOL (MDP), ENABLING AI DECISIONS BASED ON USER/NETWORK CONTEXTS

FDC-DYNAMIC NETWORK SLICING



HIGH CONNECTIVITY AND RELIABILITY

- **MASSIVE CONNECTIVITY**
  - >500% more connectivity than 4G
  - 1st in the world, Nov 2018

- **NOVEL EDGE COMPUTING FOR QOE**

SOLUTIONS FOR HIGH CAPACITY

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5G Base station Plan with Airspan

NETWORK THROUGHPUT

Capable of Asymmetry configuration

- A-QAM
- MINT2
- SPARTAN
- Flexcore

MINT

LTE

10th Feb 2017, Demonstrated 5b/s/Hz/Antenna

4x4 8x8 128 x128 1024x1024

Size of MU-MIMO


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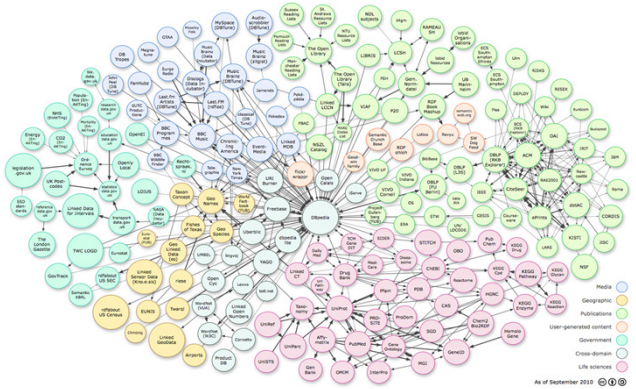
WHAT IS NEXT ?
IN 5 YEARS TIME



ARTIFICIAL INTELLIGENCE
&
ULTRA RELIABLE AND LOW LATENCY COMMUNICATION
&
MASS CONNECTIVITY

AUTOMATION

5G CONNECTIVITY + INTELLIGENCE (AI AND MACHINE LEARNING)

- LOGISTICS/TRANSPORT
- MANUFACTURING
- GAMES/ENTERTAINMENT
- UTILITIES
- HEALTH

AUTOMATION

First use case

- ZERO-TOUCH NETWORK MANAGEMENT AND OPERATION
  - FUTURE NETWORKS WILL BE TOO COMPLEX FOR HUMAN OPERATOR
    - AI + CONNECTIVITY + DATA

AUTONOMOUS NETWORKING

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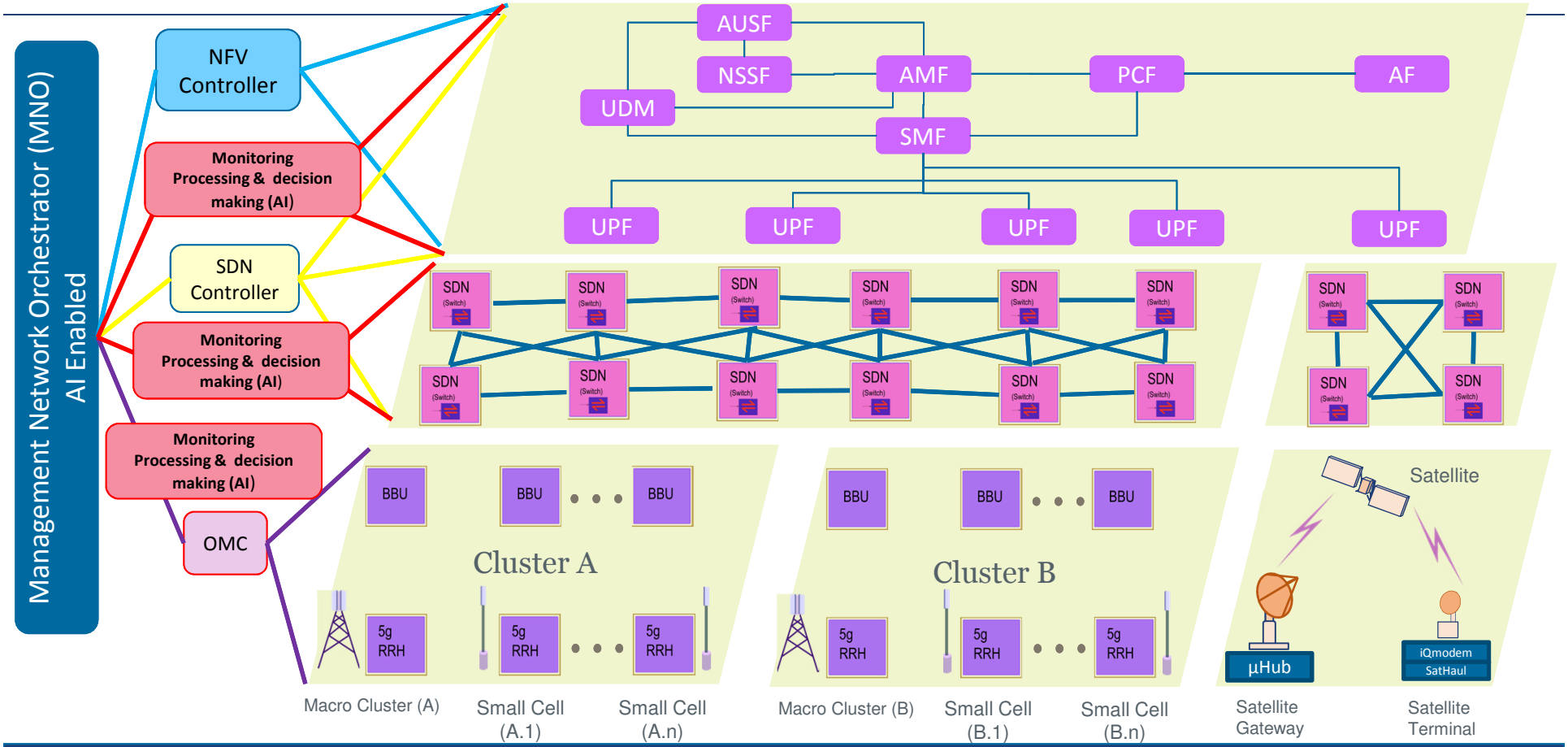


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WHAT IS NEXT ?
IN 10 YEARS TIME

What is Not possible?

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All science fiction films and books published so far are technically implementable

One could say; how about Teleportation?

WHAT MAKES US US?

OUR PHYSICAL BODY OR OUR CONSCIOUS?

ANSWER: IT IS OUR CONSCIOUS

WE ARE OUR 5 SENSES

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

Ref [2] : Rahim Tafazolli, Keynote NEAT Workshop, SIGCOMM 2018, Budapest

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Holoportation + Sensual Information = Teleportation

TELEPORTATION

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DO NOT NEED TO TRANSMIT OUR PHYSICAL BODIES

ALL NEEDED IS TO HAVE MULTI-SENSORY INFORMATION TRANSMITTED FROM:

PLACE B TO PLACE A (CONTRARY TO CURRENT THINKING)

SIMPLEST FORM OF TELEPORTATION

RXer TXer

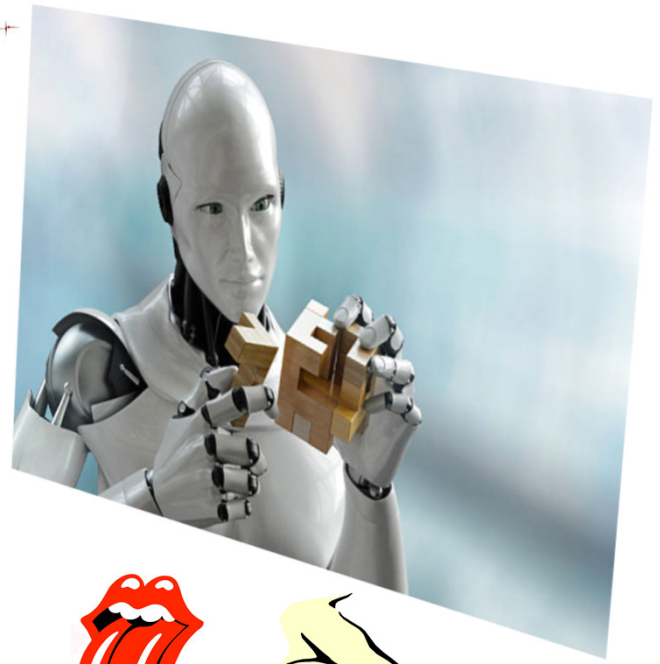
Sensual Info

TELE-INTERACTIONS

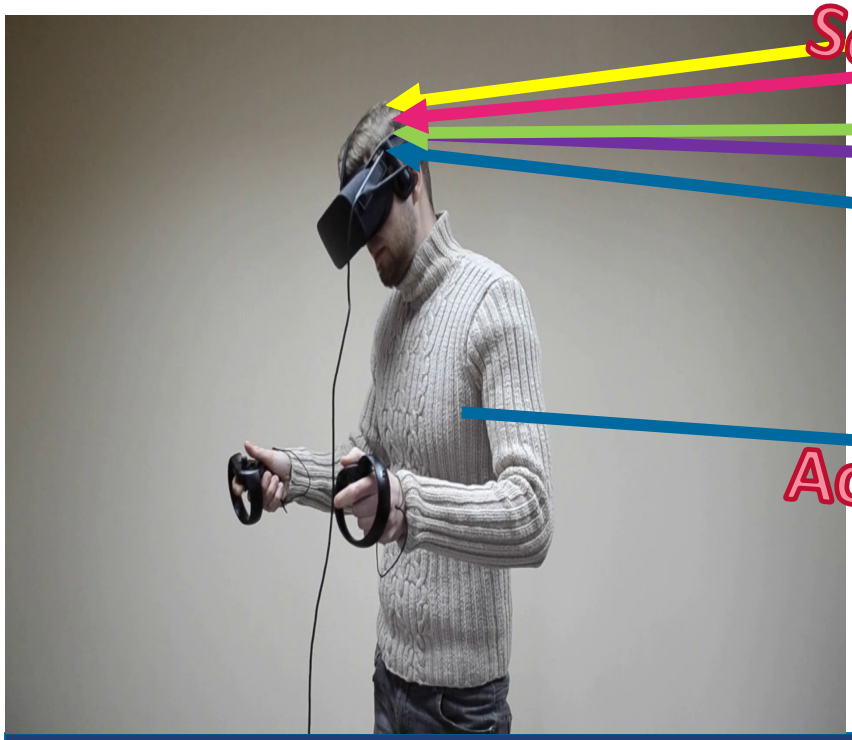
RXer

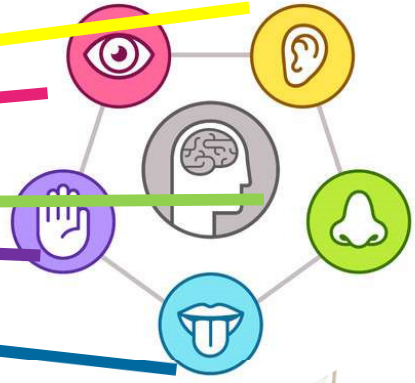
TXer

Sensual Info



REAL-TIME TELE-INTERACTIONS





Sensual Info

Actuation Info

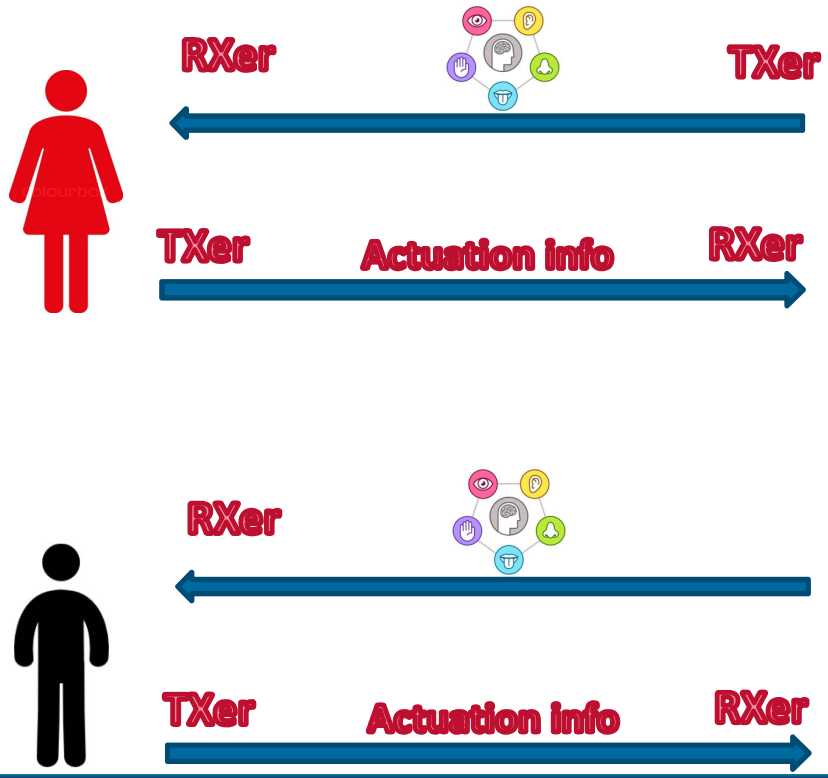
REAL-TIME INTERACTIONS VIA HOLOPORTATION

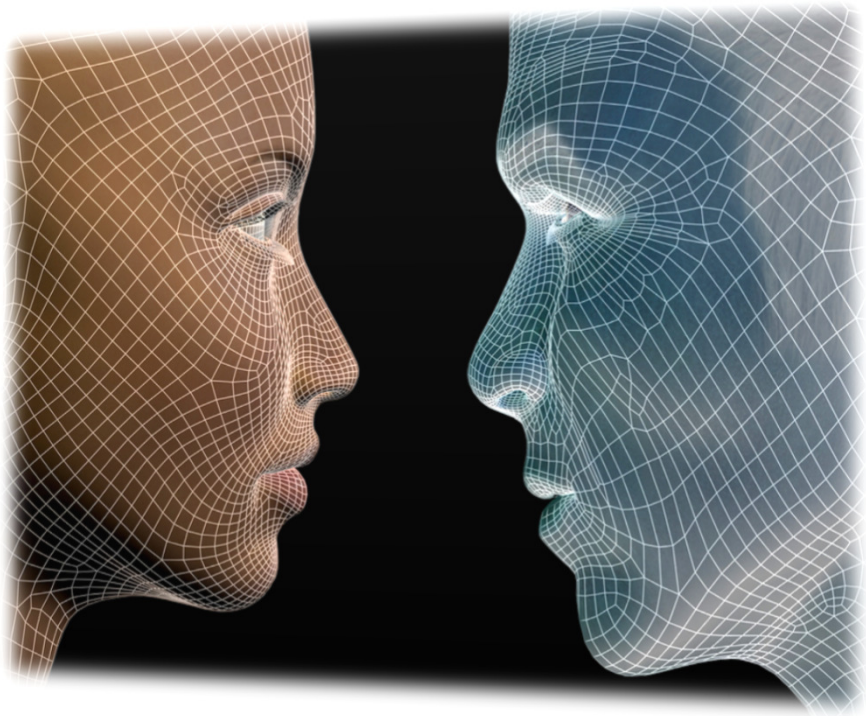
RXer TXer

TXer RXer

Holoportation

REAL-TIME INTERACTIONS IN CYBER SPACE





SOCIAL NETWORKING IN CYBER SPACE

INTERACTIONS BETWEEN PEOPLE IN CYBER SPACE

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

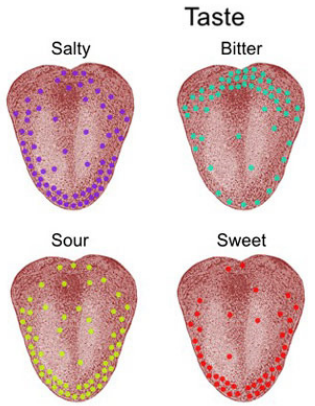
- Per inch^2 ~ 20 to 50 Mbps → For one average size Hand: ~ 1Gbps
- Latency <100 ms,
  - for natural delay with the brain touch function

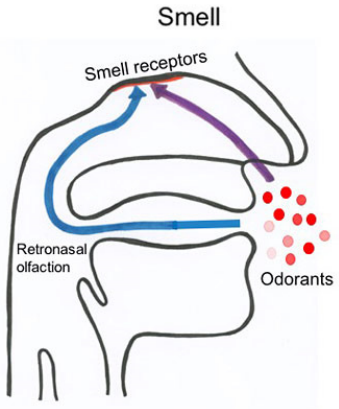
Taste

- Chemical Reactions
- Bit rate and Latency ?

Smell

- Smell and Taste are inter-related





Overall Technical requirements

- Bit rates al least several Tbps/person
- Latency <1ms (guaranteed) between sensing and actuation
- Geo-Location accuracy better than 1cm and update rate < 1ms
- Synchronisation within 10ms, for natural feel

Network 2030

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No reason for Internet and Mobile Networks being different:

- What should be the starting point- 5G Core or Current Internet?
- If 5G Core, no tunnelling after tunnelling of protocols

Future network must be designed (architecture and protocols) by default with:

- Mobility
- Wireless connectivity

and

- Stateful and Memoryful
  - Context aware
  - New Signalling architecture
  - Multiple and synchronised Routing protocols
  - Distributed protocols/computing/storage

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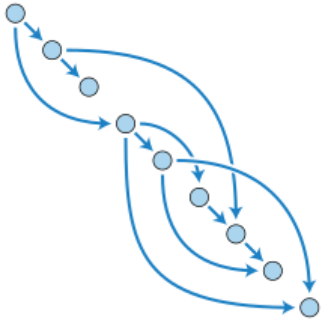
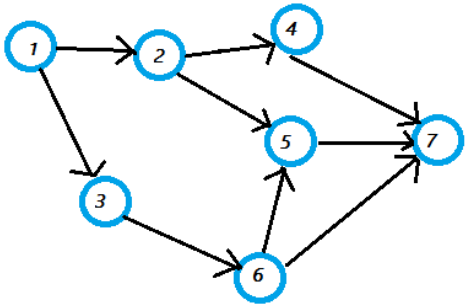
DISTRIBUTED LEDGER TECHNOLOGY



- BITCOIN, CRYPTOCOIN,…BUT NOT LIMITED TO THESE
- DIFFERENT ACYCLIC GRAPHS FOR DIFFERENT APPLICATIONS AND NETWORK FUNCTIONS
- ENABLES SYNCHRONISATION BETWEEN CONTENTS UPDATES. DISTRIBUTED CLOUD PLATFORMS, SECURITY, RESILIENCE
- COMBINED WITH HIGHLY ACCURATE DISTRIBUTED TIME MECHANISMS (E.G NPL), FOR REAL TIME COMPUTING/SIGNAL PROCESSING



MEMORYFUL NETWORKING

- CURRENT NETWORKS DON'T KEEP HISTORY OF PREVIOUS TRANSACTIONS, SPECIALLY IN SIGNALLING
- SIGNALLING IS ALWAYS REPEATED OVER AND OVER
- SIGNALLING IS MAJOR SOURCE OF DELAY, BANDWIDTH & ENERGY CONSUMPTION

RETHINK:

- RADIO RESOURCE CONTROL
- MOBILITY MANAGEMENT
- AUTHENTICATION PROCEDURES
- DEVICE/USER CONTEXTS

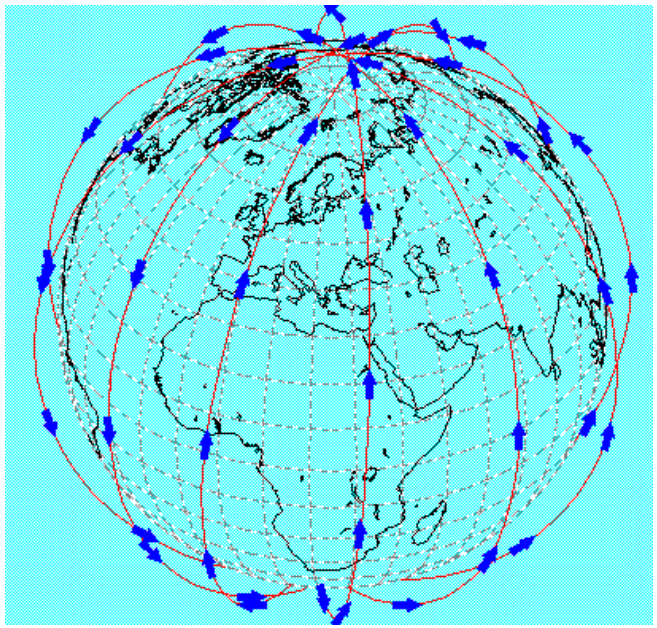
NEW INFRASTRUCTURE

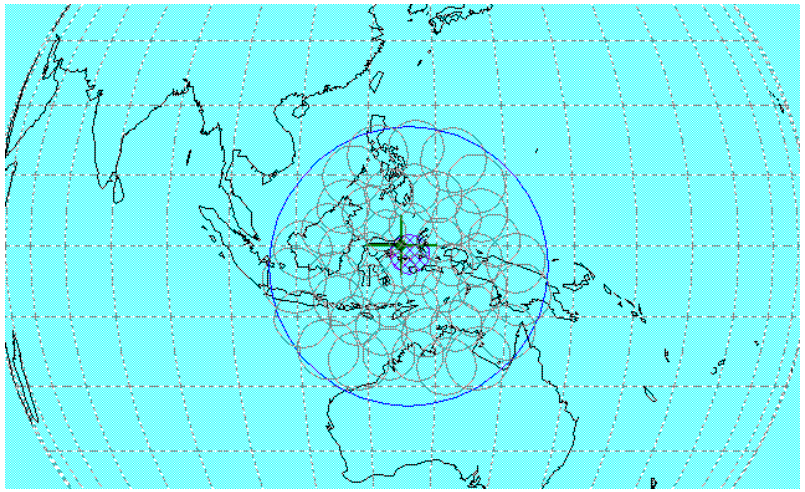
NETWORK 2030 INFRASTRUCTURE

Space-Terrestrial Seamless converged infrastructure

FIXED/MOBILE/INTERNET/DRONES/SATELLITE

NON-TERRESTRIAL NETWORKS





OPPORTUNITY:
ECONOMY OF SPACE COMMUNICATIONS NOW COMPARABLE TO TERRESTRIAL

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

Current Massive constellations Plans

	ONEWEB	SPACEX	LEOSAT
sats	640	4000	80-100
Alt(km)	1200	1100	1400
Tbps	5-10	8-10	0.5-1
$B	2	10	3
User speed	50 Mbps	?	1-2Gbps
Lat(mS)	20-30	20-30	50
Service	BB/Mobility	BB/Backhaul, ??	Mob/Backhaul/enterprise

Some of the proposed mega constellations projects

Operator	Orbit	Number of Satellites
SpaceX Ku-band	LEO	4,425
Boeing Q/V-band	LEO	2,956
OneWeb Ku-band	LEO	648
Kepler	LEO	140
Telesat Ka-band	LEO	117
Theia	LEO	112
LEOSat	LEO	108
O3b	MEO	60
Boeing Ka-band	LEO	60
ViaSat Ka-band	MEO	24

MEGA-CONSTELLATION-NETWORK 2030

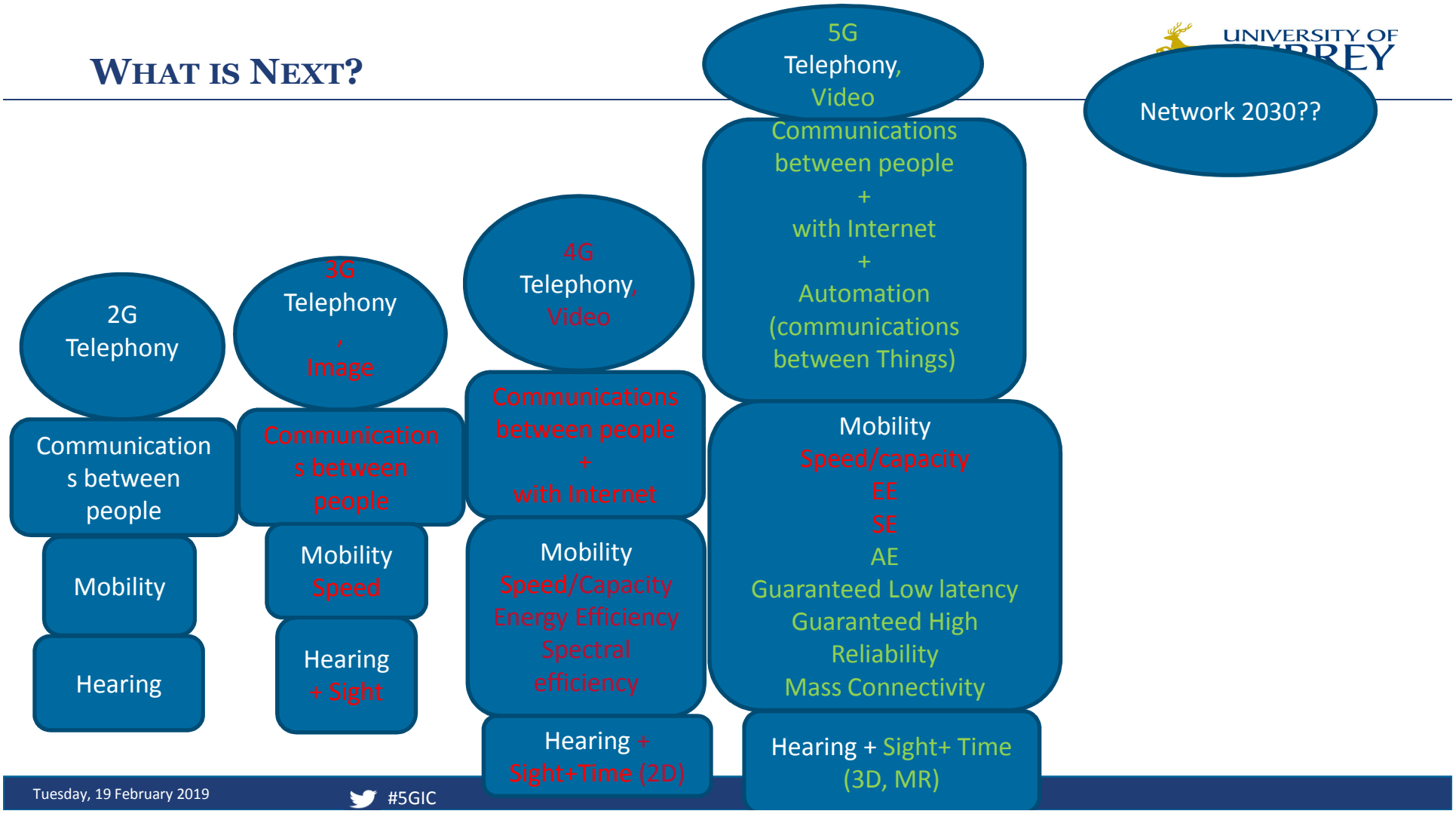
- OVERALL COST HAS TO BE SAME AS TERRESTRIAL FOR SAME (COVERAGE AND CAPACITY)

TECHNICAL CHALLENGE :

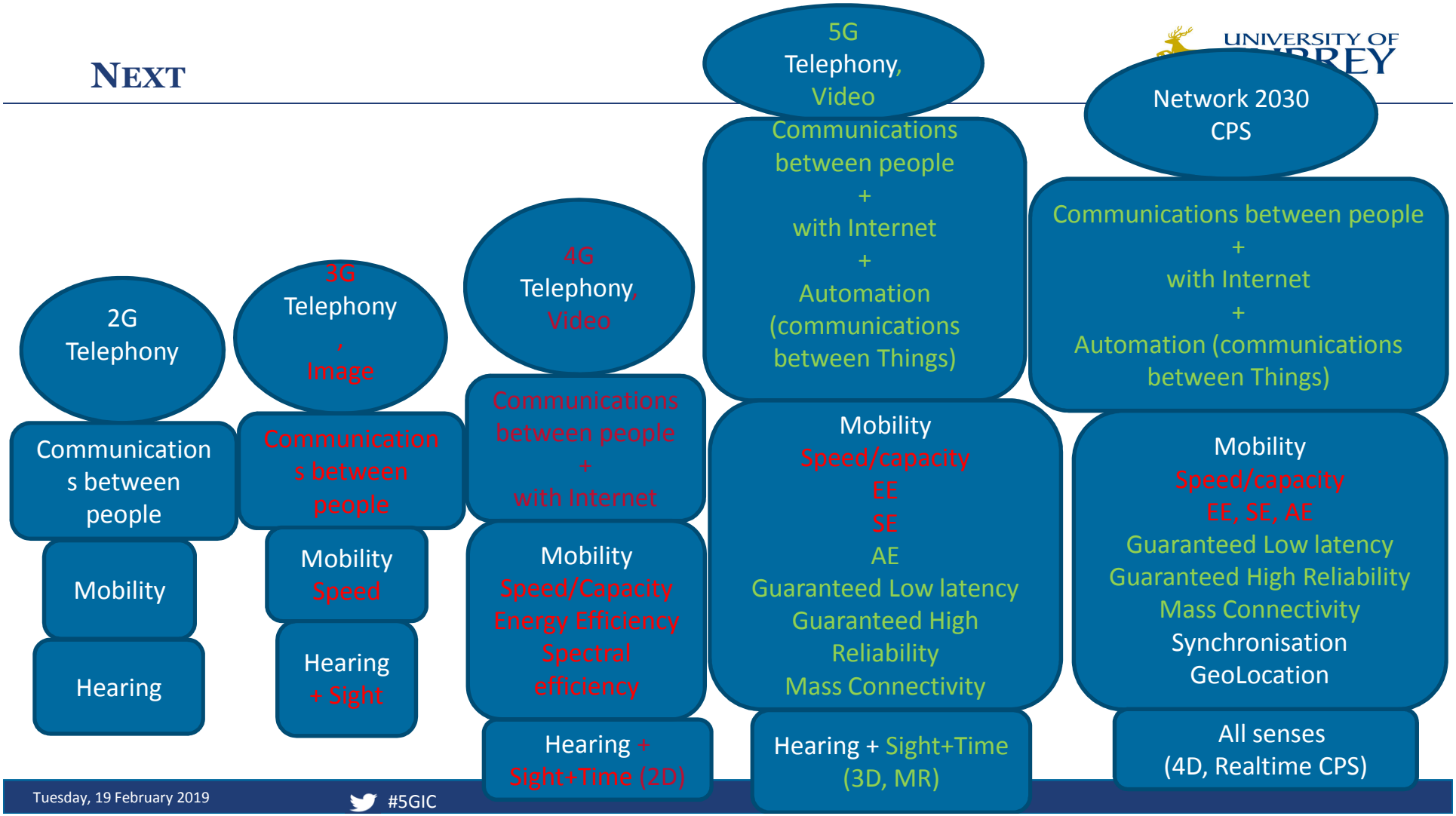
Direct Communications between UE to satellite and/or Terrestrial

- NEED NEW SATELLITE TECHNOLOGIES
- ANTENNA TECHNOLOGIES
- NEW CONSTELLATION DESIGN
- SEAMLESS INTEGRATION WITH TERRESTRIAL NETWORKS

WHAT IS NEXT?


2G
Telephony
Communication
s between
people
Mobility
Hearing
3G
Telephony
,
Image
Communication
s between
people
Mobility
Speed
Hearing
+ Sight
4G
Telephony,
Video
Communications
between people
+
with Internet
Mobility
Speed/Capacity
Energy Efficiency
Spectral
efficiency
Hearing +
Sight+Time (2D)
5G
Telephony,
Video
Communications
between people
+
with Internet
+
Automation
(communications
between Things)
Mobility
Speed/capacity
EE
SE
AE
Guaranteed Low latency
Guaranteed High
Reliability
Mass Connectivity
Hearing + Sight+ Time
(3D, MR)
Network 2030??

NEXT


2G
Telephony
Communications between people
Mobility
Hearing
3G
Telephony
,
Image
Communications between people
Mobility
Speed
Hearing + Sight
4G
Telephony,
Video
Communications between people
+
with Internet
Mobility
Speed/Capacity
Energy Efficiency
Spectral efficiency
Hearing + Sight+Time (2D)
5G
Telephony,
Video
Communications between people
+
with Internet
+
Automation (communications between Things)
Mobility
Speed/capacity
EE
SE
AE
Guaranteed Low latency
Guaranteed High Reliability
Mass Connectivity
Hearing + Sight+Time (3D, MR)
Network 2030
CPS
Communications between people
+
with Internet
+
Automation (communications between Things)
Mobility
Speed/capacity
EE, SE, AE
Guaranteed Low latency
Guaranteed High Reliability
Mass Connectivity
Synchronisation
GeoLocation
All senses
(4D, Realtime CPS)

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THANK YOU