PANEL

Chair
Timothy Pham, Chief Deep Space Network System Engineer, Jet Propulsion Laboratory - California Institute of Technology, USA

Panelists
Shintaro Mori, Fukuoka University, Japan
Eugen Borcoci, University Politehnica of Bucharest, Romania
Stan McClellan, Texas State University, USA

Evolution and Convergence

- The integration of terrestrial communications - satellites is the basic leap 5G/6G
- After 4G, the next generation of 5G was terrestrial wireless; 6G integrates 5G with satellite networks. In 6G 'roaming will be a problem. From here: 7G, wireless with roaming services.

  Basically, the difference between 5G / 6G is between features (and implicitly potential services)

a) transmission features; it's a matter of data-rate, end-to-end delay, max speed on mobile, THz communication

b) allowing new services: haptic, autonomic systems, AI-based applications; The last two here I think are listed only as marketing, because implicitly provided by 'transmission features'; maybe even 'haptic'

c) also, a plethora of (new, improved) services: health alerts, remote patient-care, instant-cognition, self-driving, real-time authentication, immersive Environments, advanced virtual reality, instant robot vision, tangible Internet, tactile Internet, etc. ...)

Evolution

https://www.researchgate.net/figure/Comparison-of-6G-with-4G-and-5G-communication-systems_tbl3_343090772

6G Wireless Communication Systems: Applications, Requirements, Technologies, Challenges, and Research Directions

Jul 2020

Mostafa Zaman Chowdhury Md. Shahjalal Shakil Ahmed Yeong Min Jang

Issue	4G	5G	6G
Per device peak data rate	1 Gbps	10 Gbps	1 Tbps
End-to-end (E2E) latency	100 ms	10 ms	1 ms
Maximum spectral efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility support	Up to 350 km/hr	Up to 500 km/hr	Up to 1000 km/hr
Satellite integration	No	No	Fully
AI	No	Partial	Fully
Autonomous vehicle	No	Partial	Fully
XR	No	Partial	Fully
Haptic Communication	No	Partial	Fully
THz communication	No	Very limited	Widely
Service level	Video	VR, AR	Tactile
Architecture	MIMO	Massive MIMO	Intelligent surface
Maximum frequency	6 GHz	90 GHz	10 THz

… Beyond..

7G (seventh-generation wireless) is the inevitable intelligent cellular technology.
7G networks will be able to use higher frequencies and provide substantially higher capacity and much lower latency in communications.
17.2 petabits per second

8G, arriving in 2048: 17.2 petabits per second, 3.65 petahertz frequencies,
435 milliseconds to download Avengers: Endgame in 4K

Until then, we are facing challenges on

- Networking and connectivity
- Aerial vehicles
- Earth’s satellites
- Networking complexity

Panel

Communications beyond the Thinking

(spatial, terrestrial, speed, 5G/6G, streaming, high data processing, protocols, etc.)

NexComm 2021

Panellist Position

6G- what new networking and connectivity promises ?

Eugen Borcoci, University POLITEHNICA Bucharest, Romania

eugen.borcoci@elcom.pub.ro

6G Goals

Roadmap to 2030

Architectural aspects

Networking and connectivity features

KPIs, Spectrum, physical layer

Network and connectivity research challenges

Panel
Communications beyond the Thinking
(spatial, terrestrial, speed, 5G/6G, streaming, high data processing, protocols, etc.)

NexComm 2021

Panellist Position

Survey on unmanned aerial vehicle-assisted information-centric wireless sensor networks for smart city applications

Shintaro Mori, Fukuoka University, Fukuoka/Japan smori@fukuoka-u.ac.jp

- Background, requirements, and technical issues in smart city applications
- Information-centric network (ICN) for wireless sensor networks (WSNs)
- Unmanned aerial vehicles (UAVs) assisted WSNs
- Remained issues, future works, and current studies in progress
  - Security and privacy in IC-IoT/IC-WSNs
  - Protocol in the network layer
  - Protocol in MAC layer and PHY layer
  - Smart city IoT systems as a service

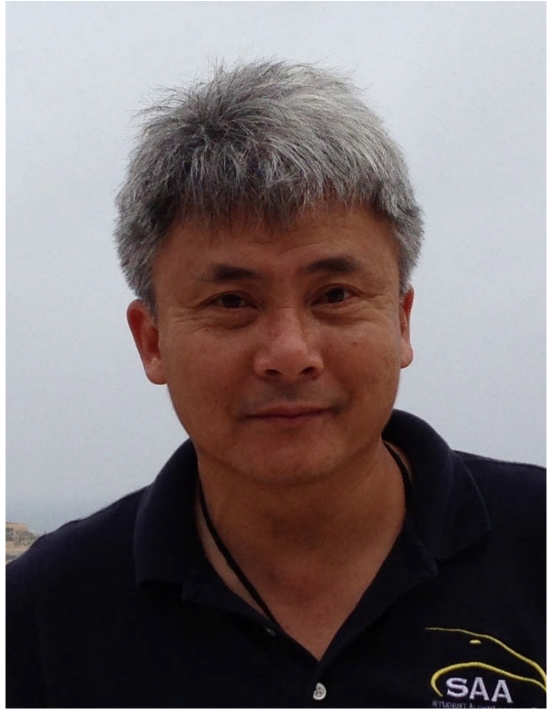
→ I will provide a survey about UAV-IC-WSNs for smart cities as a case study

→ I propose a combination of technologies among UAVs, ICNs, and WSNs to solve the challenges of the current frameworks

Panelist Position

Extending cost model of Earth satellite broadband services to future commercial lunar relay service?

Timothy Pham, Jet Propulsion Laboratory, California Institute of Technology, USA Timothy.Pham@jpl.nasa.gov



- Commercial viability of Earth satellite broadband services
- Would such viability be extended to lunar communication services?

Jet Propulsion Laboratory
California Institute of Technology

Panelist Position

Managing Complexity in Network Validation

Stan McClellan, Texas State University, USA stan.mcclellan@txstate.edu

- 900 MHz Licensed LTE and 5G
- 900/2400 MHz Unlicensed LoRA
- 3600 MHz Private LTE and 5G
- 700, 1700, 1900 MHz LTE/NB-IoT/Cat-M1 and 5G

→ Proliferation of Networking Standards = Complexity

→ Development / Demonstration / Validation Facility = Simplification

→ University / Industry Consortium Model = Valuable

Panel

Communications beyond the Thinking

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Panellist Position

6G- what new networking and connectivity promises ?

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Network and connectivity research challenges

Note: The 6G concepts, architectures and technologies are still open research issues. This panel position will present a summary of some 6G trends related to network and connectivity advances w.r.t. 5G, compiled from publicly available research papers and documents (see References)

Panel

Communications beyond the Thinking

(spatial, terrestrial, speed, 5G/6G, streaming, high data processing, protocols, etc.)

- **Eugen Borcoci : professor**
  - **University „Politehnica" of Bucharest (UPB)**
  - **Electronics, Telecommunications and Information Technology Faculty**
    - http://www.electronica.pub.ro
  - **Telecommunications Department**
  - **Address: 1-3, Iuliu Maniu Ave., 061071 Bucharest - 6, ROMANIA**
  - **E- mail address :eugen.borcoci@elcom.pub.ro**

- **Expertise:** teaching and research in specific domains of telecommunications and computer networks architectures, technologies and services:
  - network architectures and services, management/control/data plane, protocols, 4G/5G, QoS assurance, multicast and multimedia services over IP networks and heterogeneous access.

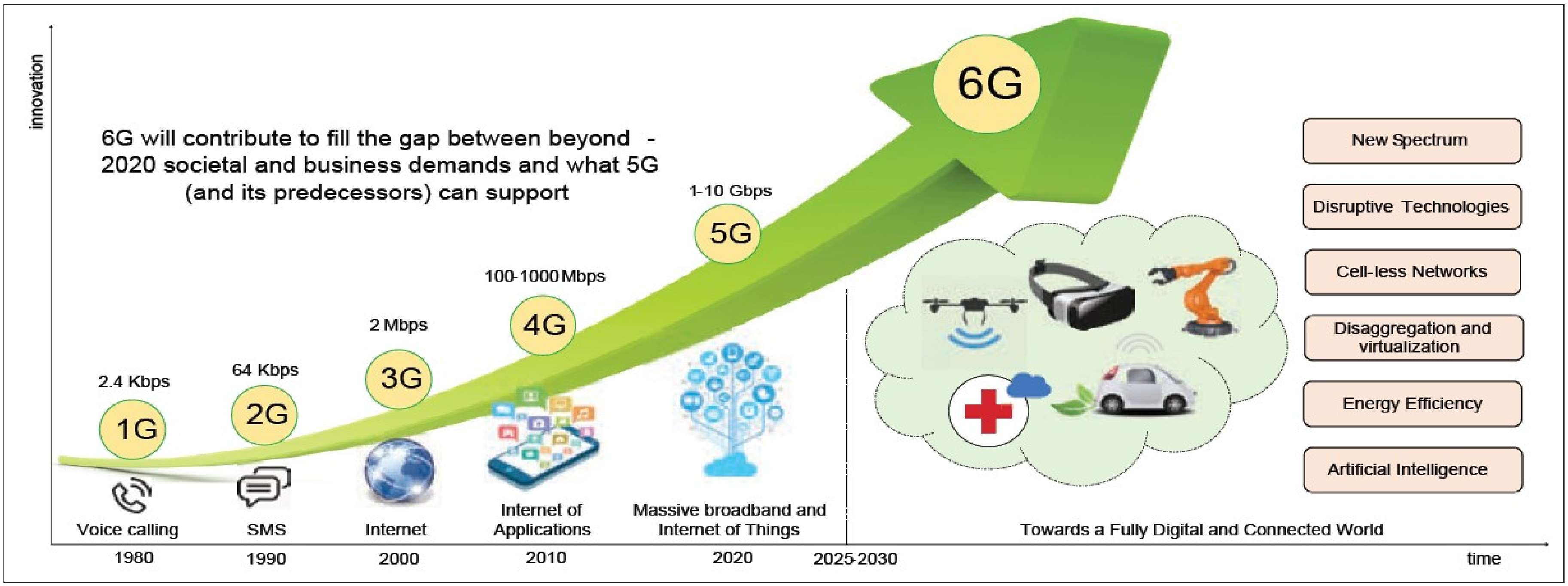
- **Recent research interest :** Software Defined Networking (SDN), Network Function Virtualization (NFV), Fog/edge computing, 5G networking and slicing, vehicular communications.

- Publications: 6 books, 4 textbooks and over 200 scientific or technical papers and scientific reports.

- UPB team leader in many national and int'l European research projects.

6G networking and connectivity

Historical and estimated 1G ..6G evolution



Source: M. Giordani, et al., "Toward 6G Networks:Use Cases and Technologies", IEEE Communications Magazine , March 2020

6G networking and connectivity

Why 6G?

- **Today- 5G is a strong technology intensively developed; however it has limitations w.r.t. future needs**

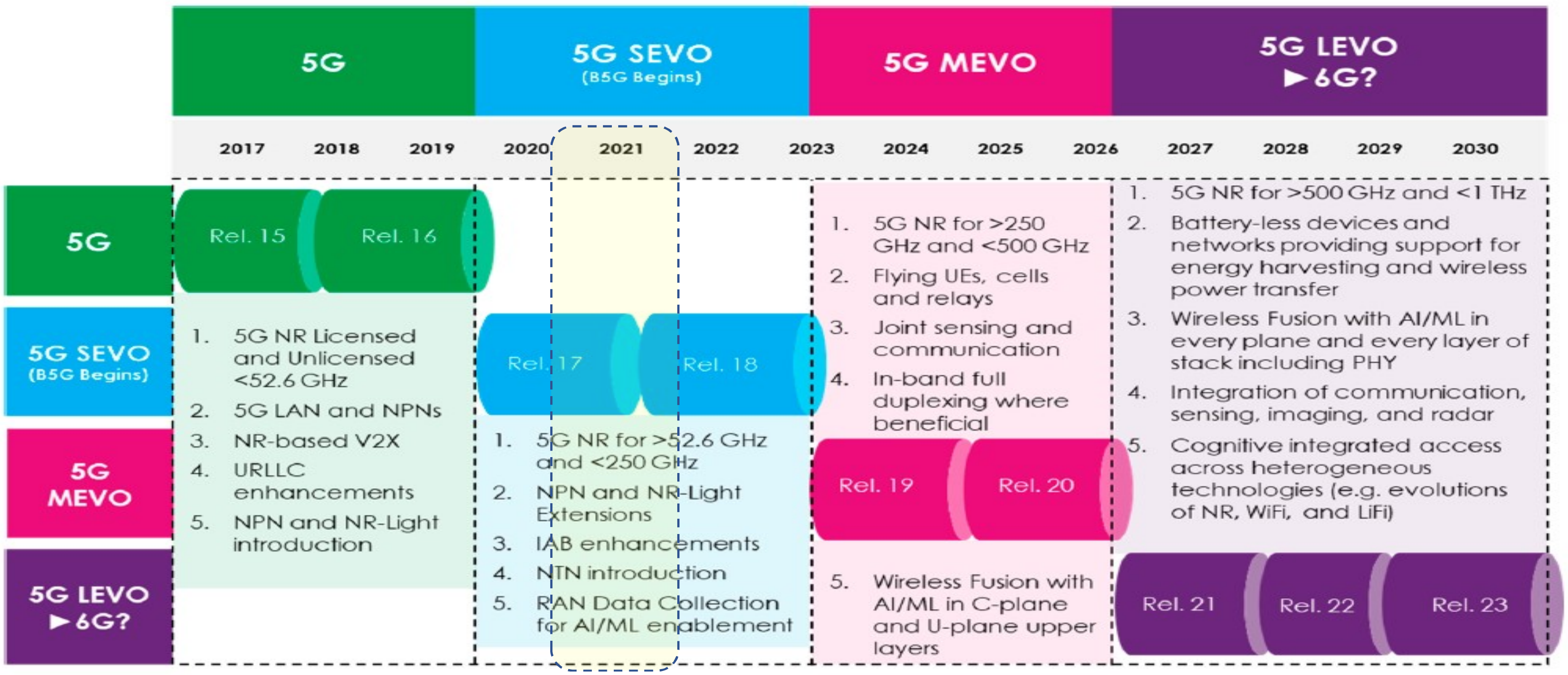
- ***6G Vision for 2030: the society will be data driven, served by near instant, unlimited wireless connectivity***
  - **6G goals:**
    - meet **novel network demands** (e.g., ultra-high reliability, high capacity and efficiency, and low latency) in a holistic fashion, answering the new needs of economic, social, technological, and environmental context of the 2030 era
    - **integration** of the space, aerial, terrestrial, and maritime communications into a robust network
    - **large range of applications and services**:
      - AR/VR, Holographic tele-presence (teleportation), eHealth, pervasive connectivity, Industry 4.0 and robotics, unmanned mobility, new devices replacing smart phones
      - Telepresence -high resolution imaging and sensing, wearable displays, mobile robots and drones, specialized processors, distributed AI, haptic communication
      - Autonomous connected vehicles , massive URLLC (mURLLC), human-centric services, bio-Internet of things (B-IoT), nano-Internet of things (N-IoT), mobile broadband reliable and low-latency communication

- **Open research issues related to 6G networking and connectivity :**

  - what candidate architecture and technologies : lower layer (physical, L2, L3) and also higher layers?

6G networking and connectivity

3GPP viewpoint : Roadmap to 2030 ; SEVO, MEVO, LEVO, 6G – Short, medium, long term evolution , 6G



AI – Artificial Intelligence
C-Plane – Control Plane
KPI- Key Performance Indicators
Li-Fi -Light Fidelity
NR- 5G New Radio
NPN-5G Non-Public Network
NTNs - Non-Terrestrial Networks
ML – Machine Learning
PHY- Physical Layer
RAN – Radio Access Network
UE- User Equipment
U-Plane - User Plane
URLLC- Ultra Reliable Low Latency Communication
V2X – Vehicle to Everything

Source: A. Mourad et al., "A Baseline Roadmap for Advanced Wireless Research Beyond 5G", Electronics 2020, 9, 351; doi:10.3390/electronics9020351 www.mdpi.com/journal/electronics

6G networking and connectivity

6G Architectural innovative aspects

Enabling Technology	Potential	Challenges	Use cases
Innovative network architectures			
Multi-connectivity and cell-less architecture	Seamless mobility and integration of different kinds of links	Scheduling, need for new network design	Pervasive connectivity, unmanned mobility, holographic telepresence, eHealth
3D network architecture	Ubiquitous 3D coverage, seamless service	Modeling, topology optimization and energy efficiency	Pervasive connectivity, eHealth, unmanned mobility
Disaggregation and virtualization	Lower costs for operators for massively-dense deployments	High performance for PHY and MAC processing	Pervasive connectivity, holographic telepresence, industry 4.0, unmanned mobility
Advanced access-backhaul integration	Flexible deployment options, outdoor-to-indoor relaying	Scalability, scheduling and interference	Pervasive connectivity, eHealth
Energy-harvesting and low-power operations	Energy-efficient network operations, resiliency	Need to integrate energy source characteristics in protocols	Pervasive connectivity, eHealth
Intelligence in the network			
Learning for value of information assessment	Intelligent and autonomous selection of the information to transmit	Complexity, unsupervised learning	Pervasive connectivity, eHealth, holographic telepresence, industry 4.0, unmanned mobility
Knowledge sharing	Speed up learning in new scenarios	Need to design novel sharing mechanisms	Pervasive connectivity, unmanned mobility
User-centric network architecture	Distributed intelligence to the endpoints of the network	Real-time and energy-efficient processing	Pervasive connectivity, eHealth, industry 4.0

Source: M. Giordani, et al., "Toward 6G Networks:Use Cases and Technologies", IEEE Communications Magazine , March 2020

Panel

Communications beyond the Thinking

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6G networking and connectivity

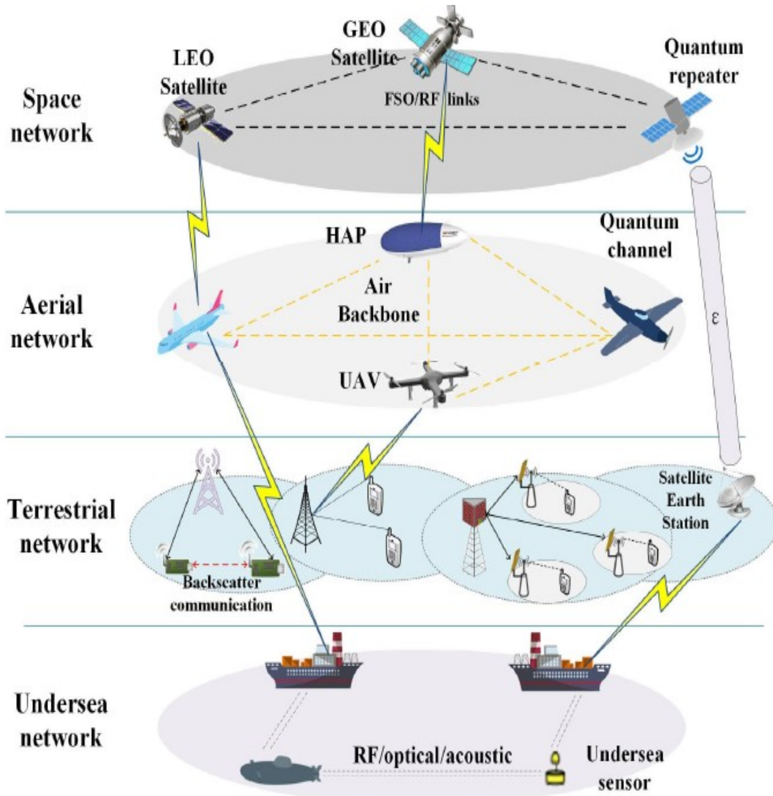
Integrated Space Aerial,

Terrestrial and Undersea

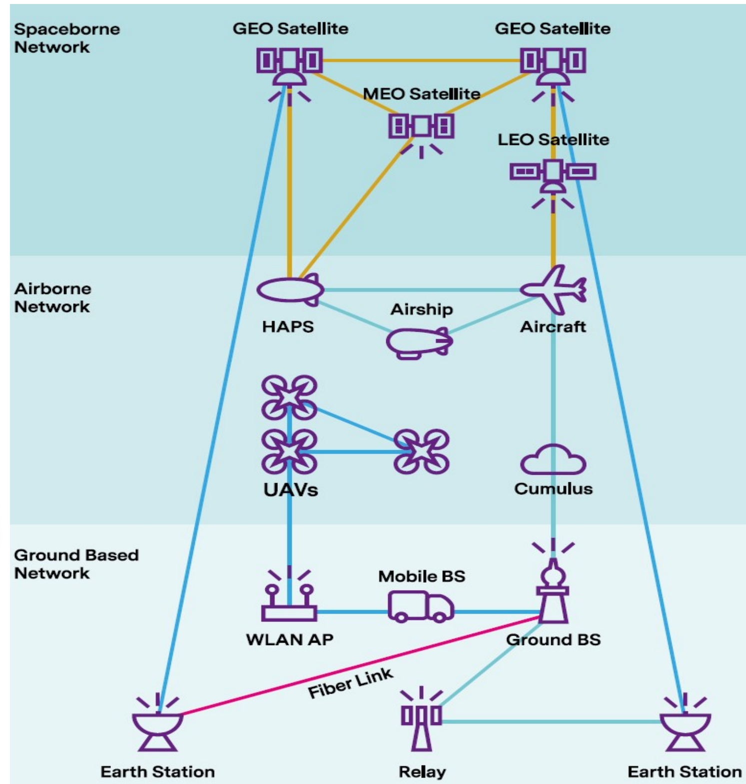
Network

Ubiquituous 3d coverage

LEO- Low Earth Orbit
MEO- Medium Earth Orbit
GEO- Geostationary Earth Orbit
HAP- High Altitude Platforms
UAV- Unmanned Aerial Vehicle



Source: T.Huang, et al., "A Survey on Green 6G Network: Architecture and Technologies", IEEE Access, VOLUME 7, 2019, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8922617



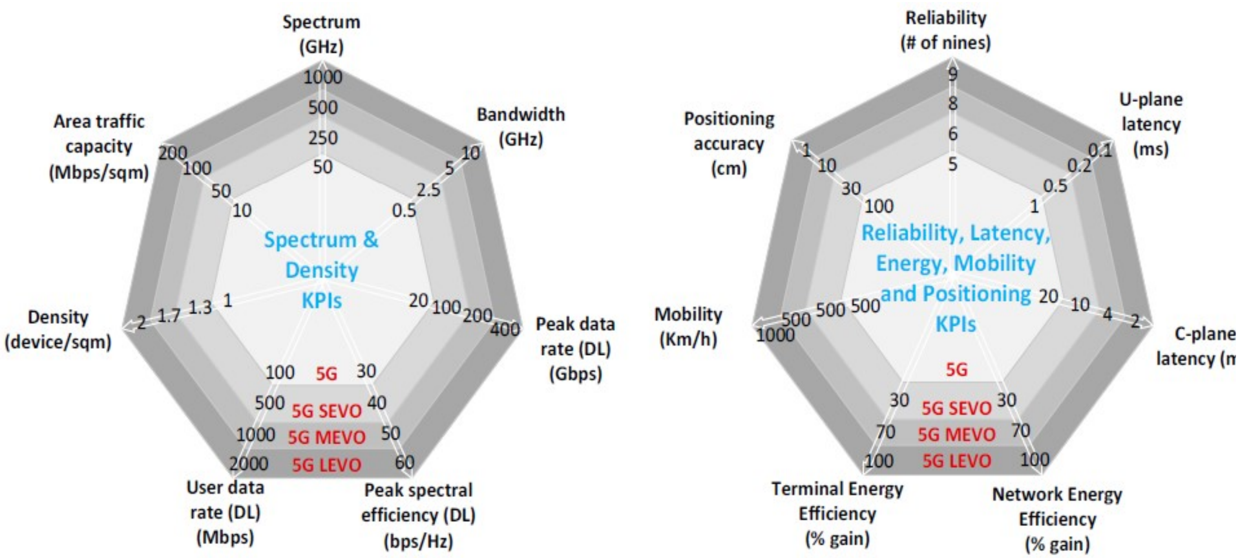
Source: 6G FlagShip, "WHITE PAPER ON BROADBAND CONNECTIVITY IN 6G", 6G Research Visions, No. 10 June 2020, Univ. of Oulu

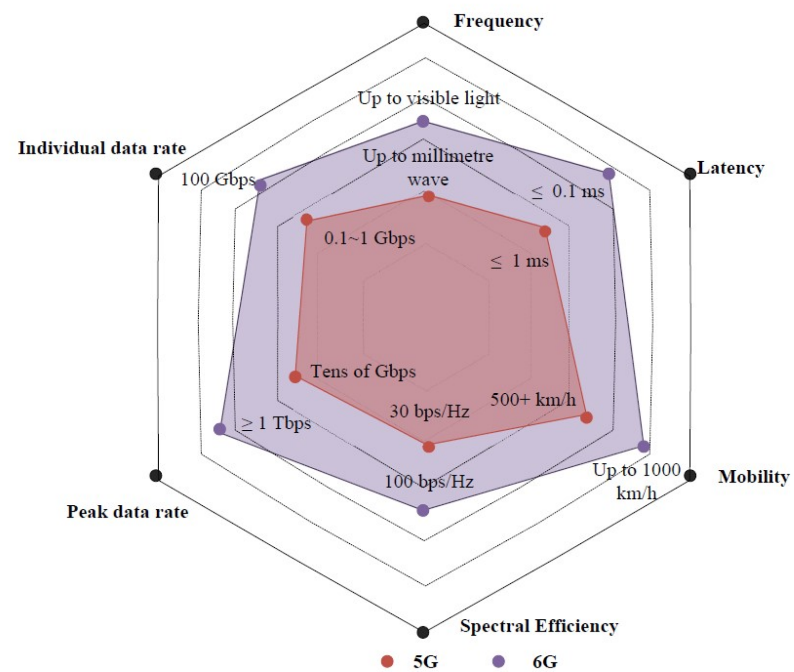
6G networking and connectivity

- **Novel 6G networking technologies**
  - **Nanonetworking**
    - N-IoT is based on molecular communication; Different materials, such as graphene and meta materials can be used to build nanometer-range devices
    - physical design for molecular communication is a challenging task
  - **Bionetworking**
    - B-IoT using biological cells are used for communication using IoT
    - Novel routing schemes to be developed for B-IoT and N-IoT compared with traditional IoT
    - Efficient nano-devices and bio-devices must be developed for N-IoT and B-IoT
  - **Optical networking**
  - **3D networking**
    - drone-based user devices and drone-based base stations to enable communication networks
    - novel models (including routing) must be devised for a 3D network (it is substantially different compared with a 2D network)

6G networking and connectivity

5G, 5G SEVO, 5G MEVO, 5G LEVO, 6G comparison





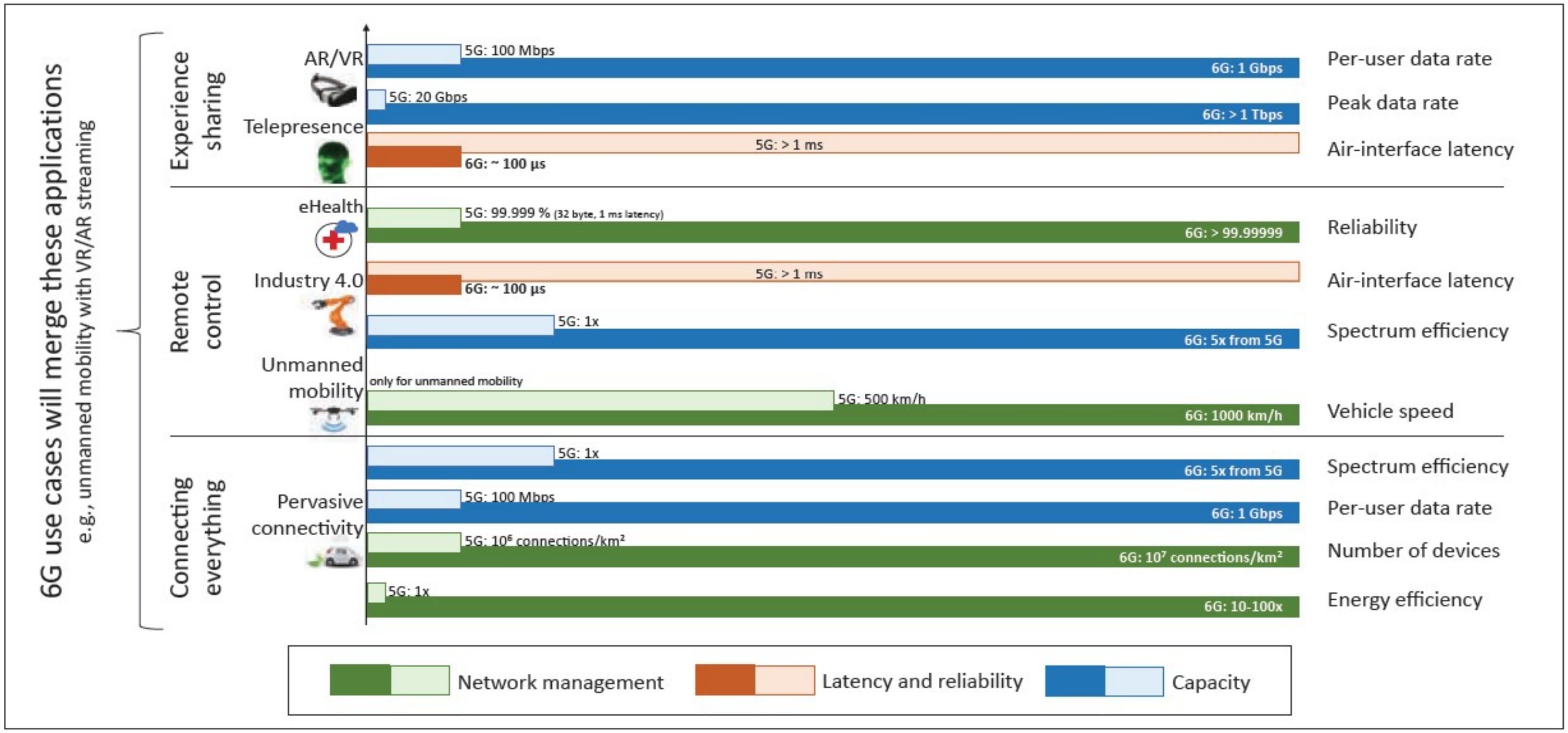
Source: A. Mourad et al., "A Baseline Roadmap for Advanced Wireless Research Beyond 5G", Electronics 2020, 9, 351; doi:10.3390/electronics9020351 www.mdpi.com/journal/electronics

Source: Y.Zhao, et al., A Comprehensive Survey of 6G Wireless Communications INTERNET OF THINGS JOURNAL, 2020, arXiv:2101.12475v1 [cs.NI] 29 Jan 2021

6G networking and connectivity

KPIs for some use cases – comparison 5G/6G

- significant improvements with respect to 5G



Source: M. Giordani, et al., "Toward 6G Networks:Use Cases and Technologies", IEEE Communications Magazine , March 2020

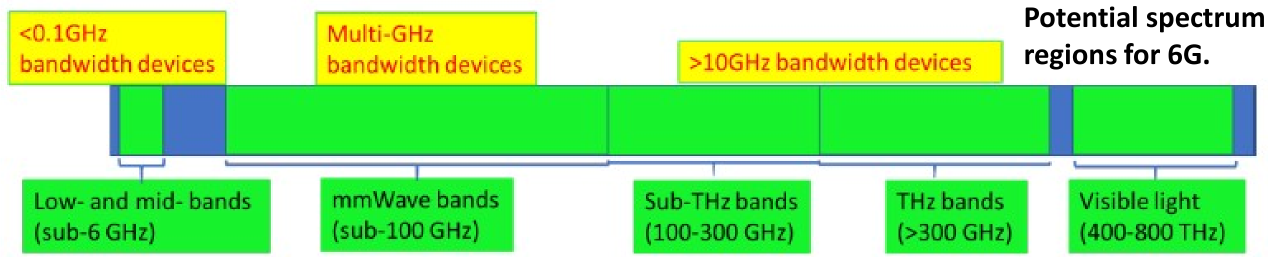
6G networking and connectivity

6G Spectrum, physical layer features

- 5G : sub-6 GHz and 24.25 to 52.6 GHz
- 6G: expansion to potential new bands from low-bands to low THz and visible light region

Enablers at the Infrastructure Level

- Ultra-Massive MIMO and Holographic Radio
    - Beamforming beyond the Beam-Space Paradigm
    - Holographic Radio
- Intelligent Reacting Surfaces
- User-Centric and Scalable Cell-Free Networking
- Integrated
    - Access and Backhaul
    - Space and Terrestrial Networks
    - Broadcast and Multicast Networks



Potential spectrum regions for 6G.

KPI	5G	6G
Peak data rate	20 Gb/s	1 Tb/s
Experienced data rate	0.1 Gb/s	1 Gb/s
Peak spectral efficiency	30 b/s/Hz	60 b/s/Hz
Experienced spectral efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mb/s/m^2	1 Gb/s/m^2
Connection density	10^6 devices/km^2	10^7 devices/km^2
Energy efficiency	not specified	1 Tb/J
Latency	1 ms	100 μs
Reliability	$1\text{-}10^{-5}$	$1\text{-}10^{-9}$
Jitter	not specified	1 μs
Mobility	500 km/h	1000 km/h

Source: N.Rajatheva et al., "White Paper on Broadband Connectivity in 6G- Research Visions", https://arxiv.org/pdf/2004.14247.pdf

6G networking and connectivity – some research challenges

- Increased hardware complexity
- Low power circuits with high-performance processing capabilities
- Intelligent wireless energy harvesting
- Seamless coexistence of multiple RATs, AI-based adaptive transceivers
- Dynamic radio resource allocation
- Pre-emptive scheduling in massive connectivity
- Security and Privacy- distributed models
- Flexible network slicing
- Intelligent cell-less architecture
- Integration of space, air, terrestrial and maritime communications
- AI-based management and control

THANK YOU !

Panelist Position

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IARIA ICN 2021
@Porto, Portugal

Survey on unmanned aerial vehicle-assisted information-centric wireless sensor networks for smart city applications

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福岡大學
FUKUOKA UNIVERSITY

IARIA

Biography

Shintaro Mori received his B.S., M.S., and Ph.D. degrees from Kagawa University in 2007, 2009, and 2014, respectively. Since April 2014, he has been with the Department of Electronics Engineering and Computer Science, Faculty of Engineering, Fukuoka University, Japan, where he is currently an assistant professor. His research interests include cross-layer design and wireless sensor networks. He is a member of IEEE, IEICE, ISSJ, and RISP.

For more information, please see my website:

https://cross-layer.com/

Background

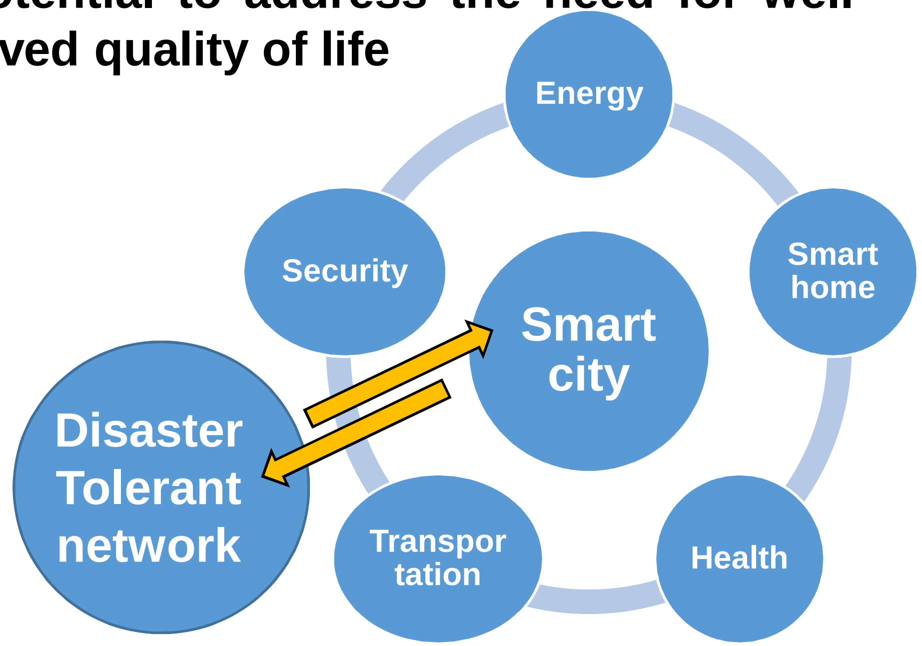
- I will provide a survey about UAV-IC-WSNs for smart cities as a case study

- Rapid urbanization is a worldwide trend
  - There is a significant increase in the number of inhabitants in urban areas compared to the rural/countryside population

- Population management as urban density increase globally
  - To consider more managing resources in cities
  - To allocate optimal resources in urban centers

- The smart city concept has great potential to address the need for well-managed, reliable, flexible, and improved quality of life

- Aim of smart city applications
  - Improving the quality of life for residence people
  - Increasing efficient public and private resource utilization
  - Reducing pollution, nuisances, and crime.
  - Monitoring to reduce disaster damages



Background

- Requirements from smart city applications
  - Smart city applications generate a huge amount of IoT data (big data).
  - IoT data must be effectively collected, processed, and analyzed for continuous and non-disruptive provisioning

- Technical issues in traditional smart city frameworks
  - Every IoT device has different constraints and specifications, which raise a problem as interoperability (due to processing power capability, size, memory, battery life), and cost (unavailability (because of constraint-oriented environments) and heterogeneity)
  - Conventional networks on standard protocols and algorithms act as a potential bottleneck for handling dynamic data transmission
  - Forwarding such IoT data may lead to network congestion, which in most cases is managed using TCP/IP
  - Various communication application programming interfaces can also be targeted with diverse side-channel and denial of service attacks
  - If no infrastructure support (poor wireless environment), the data collection of sensors has great difficulty

- Information-centric network (ICN) for wireless sensor networks (WSNs)
- Unmanned aerial vehicles (UAVs), such as drones, assisted WSNs

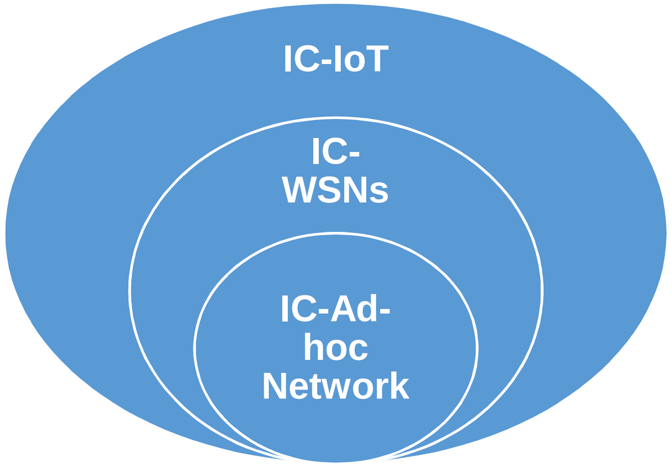
ICN for WSNs

- **Why do we introduce ICN to WSNs?**
  - **ICNs are designed based on named content instead of addresses**
  - **ICNs are being realized as a promising architecture compared to address-based networks, such as the current Internet**
  - **ICNs access the content via a name-based routing and characterize an in-network caching in intermediate nodes for efficient data delivery**

- **Advantages for IC-WSNs**
  - **An in-network caching scheme can efficiently handle to delivery of the information from unavailable nodes and minimize retrieval delay**
  - **A naming scheme can offer better name management and provide easy information retrieval**
  - **ICN can provide a better hand-off mechanism for mobile devices**

- **Familiar ICN frameworks**
  - **DONA, CCN/NDN, PURSUIT, and NetInf**

- **IC-IoT versus IC-WSNs**
  - **IC-WSNs are deployed with a specific goal and work under a single domain.**
  - **IC-IoT can communicate via the Internet and exploit for other uses.**



UAV for WSNs

- UAVs are expected to be widely deployed in the future for enabling a proliferation of various applications
  - UAVs can work for personnel hobbies, observation, surveillance, and aeronautical photography
  - UAVs can provide aerial delivery, disaster rescue, and remote sensing

- UAV deployment for WSNs
  - UAVs dispatch to harvest sensing data from the observation area and have superior flexibility and mobility for data collections
  - UAVs can provide a low-cost solution (satellites have cost expensive), and help (complement) deploy IoT devices in cellular coverage

- Advantage of UAV usages
  - IoT devices are often deployed at rural places (poor wireless networks)
  - UAVs adopt for energy-efficient data transmission when sensors are sparsely spread over a wide area
  - UAVs enable short-range communication with ground nodes via an air-to-ground line-of-sight link (which increases transmission reliability)

- Note that UAVs promote and utilize to improve coverage quality in 5G and beyond cellular networks.

Remained works

- **Security and privacy in IC-IoT/IC-WSNs**
  - **Wireless nature of the communication medium**
  - **Inherent limitations of IoT devices, e.g., heterogeneity, scalability, location, and provider**
  - **ICN model's content-centric specifications, e.g., in-network caching scheme, face cache pollution attacks**
  - **Key management (validation) and distribution method may increase running costs and communication overheads.**

→ We try to solve by using blockchain technology[1][2]

- **Protocol in the network layer**
  - **Addressing will be limited to neighbor connectivity, i.e., end-to-end communication should be considered based on content name, PIT, and forwarding information for dynamic communications in IoT/WSNs.**

→ Sorry, I'm not familiar…

---

[1] S. Mori, "Caching Data Protection Scheme for Information-Centric Wireless Sensor Networks," *Proc. IARIA the 19th Int. Conf. Networks (ICN 2020)*, pp. 50–54, Lisbon, Portugal, Feb. 2020.
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Remained works

- **Protocol in MAC layer and PHY layer**
  - **Exploring dynamic spectrum sharing among licensed/unlicensed**
  - **Investigating new massive machine-type communication technologies for real-time, spectrum hungry, reliability, and availability for UAV-IC-WSNs/IoT/Ad-hoc networks**

→ We try to develop a cooperative scheme[3][4]
→ We believe that a multi-radio multi-channel technology is a promising solution to support higher data transmission and network performance[5]

Another specific theme in smart cities

- **Smart city IoT systems as a service, i.e., data and API are treated as a commodity by market participants**
  - **The information involves many parties, stakeholders, and entities such as individuals, businesses, and government agencies with their objectives, which needed to be economical properly (monetization)**

→ Sorry, I'm not familiar…, but I am a little interested..

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Extending Cost Model of Earth satellite broadband services to future commercial lunar relay service?

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Biography

Tim Pham is the Chief System Engineer of the NASA Deep Space Network. His interest is in system engineering and system development. Besides DSN system engineering work, he also supports the CCSDS activities in Cross Support Transfer Services and the ground system development at the Morehead State University.

Tim has published several papers on antenna arraying, spacecraft tracking, system modeling and performance analysis. He co-authored the book "Antenna Arraying Techniques in the Deep Space Network". He is recipient of the NASA Exceptional Service Medal, NASA Exceptional Achievement Medal, several NASA New Technology and Space Act Awards, and the IARIA Fellow.

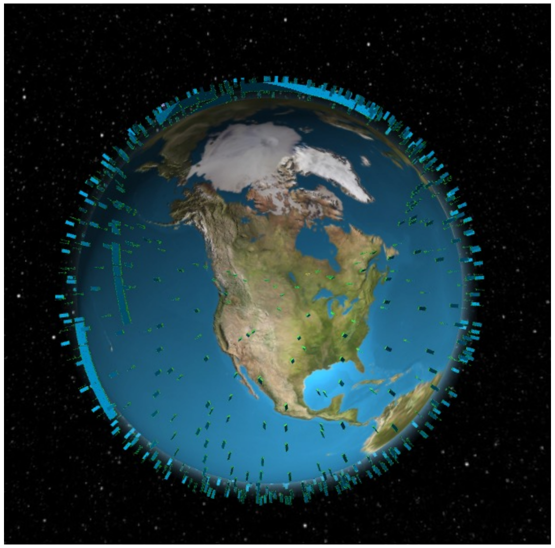
Panelist Position

Extending cost model of Earth satellite broadband services to future commercial lunar relay service?

- Commercial viability of Earth satellite broadband services
- Would such viability be extended to lunar communication services?

Earth Satellite Broadband Services

- Characteristics of low Earth orbit satellite broadband system
  - Low Earth orbit
    - Low latency and higher bandwidth compared to geosatellites
    - Large number of satellites (tens of 1000s) required for sufficient coverage
- Business model
  - Cost reduction (e.g. SpaceX) via [1]
    - vertical integration with launch provider
    - reusable low cost rockets
    - rideshare program offered to other payload customers
  - High revenue expected from large potential customer base
    - ~160M Americans lack of broadband access [2]



https://platform.leolabs.space/visualization

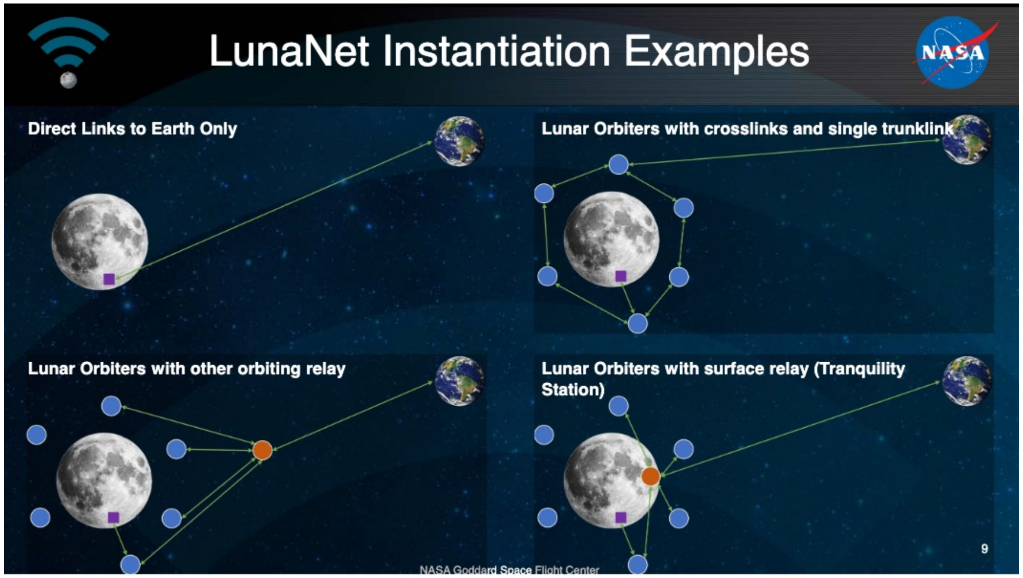
[1] https://spacenews.com/op-ed-can-spacex-profit-on-certain-starlink-launches/
[2] https://blogs.microsoft.com/on-the-issues/2019/04/08/its-time-for-a-new-approach-for-mapping-broadband-data-to-better-serve-americans/

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

Considerations on Future Lunar Network

- Sustaining presence on the moon requires an internet-like communications among lunar “residents” and with Earth
  - Commercial, government, international partners
  - Orbiters, rovers, astronauts, habitats
- Three key services
  - Networking
  - Position, navigation and timing
  - Science utilization

- Commercial viability requires
  - Low cost in launch and operation
  - Large customer base or good business base
- Will the future hold true?



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Communications Beyond the Thinking

Managing Complexity in Network Validation

NexComm 2021 - Panel 1
Porto, Portugal, April 18-22, 2021
(https://www.iaria.org/conferences2021/NexComm21.html)

Stan McClellan
Texas State University, San Marcos TX, USA

Stan McClellan

stan.mcclellan@txstate.edu

Professional Experience

- Co-Director, Connected Infrastructure Initiative (CIEDAR), Texas State University
- Professor, Ingram School of Engineering, Texas State University (2008 – Present)
- Director, Ingram School of Engineering, Texas State University (2013 – 2018)
- CTO & co-Founder, Power Tagging Technologies (2008-2010)
- Chief Architect – Systems & Solutions, ZNYX Networks (2006 – 2008)
- Technical Director & Distinguished Technologist, Hewlett Packard (2000 – 2006)

Publications & Activities

- Smart Cities in Application: Healthcare, Policy, and Innovation. Springer. 2019
- Smart Cities: Applications, Technologies, Standards and Driving Factors. Springer, 2017.
- The Smart Grid as an Application Development Platform. Artech House, 2017.
- “Smart City Applications,” IEEE GreenTech 2018, Apr. 2018.
- “The Smart Grid as an Application Deployment Platform,” IEEE GLOBECOM, 2014.
- “Cyber Security & Threat Management for the Smart Grid,” IEEE ICC, June 2012.
- “Security & Network Management in the Smart Grid,” 4th IEEE Computer & Communication Workshop (CCW), Oct. 2010.

Position Statement

- 900 MHz Licensed LTE and 5G
- 900/2400 MHz Unlicensed LoRA
- 3600 MHz Private LTE and 5G
- 700, 1700, 1900 MHz LTE/NB-IoT/Cat-M1 and 5G

My Brain Hurts

→ Proliferation of Networking Standards = Complexity

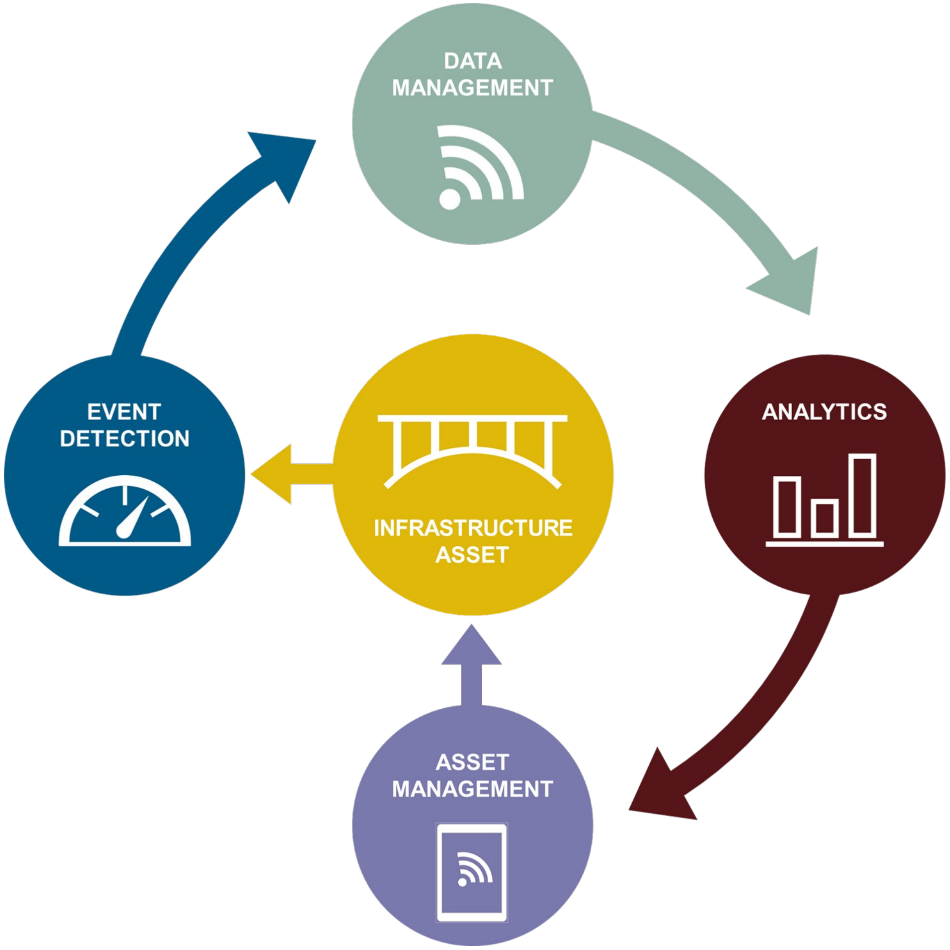
→ Development / Demonstration / Validation Facility = Simplification

→ University / Industry Consortium Model = Valuable

Technology Enhanced Infrastructure

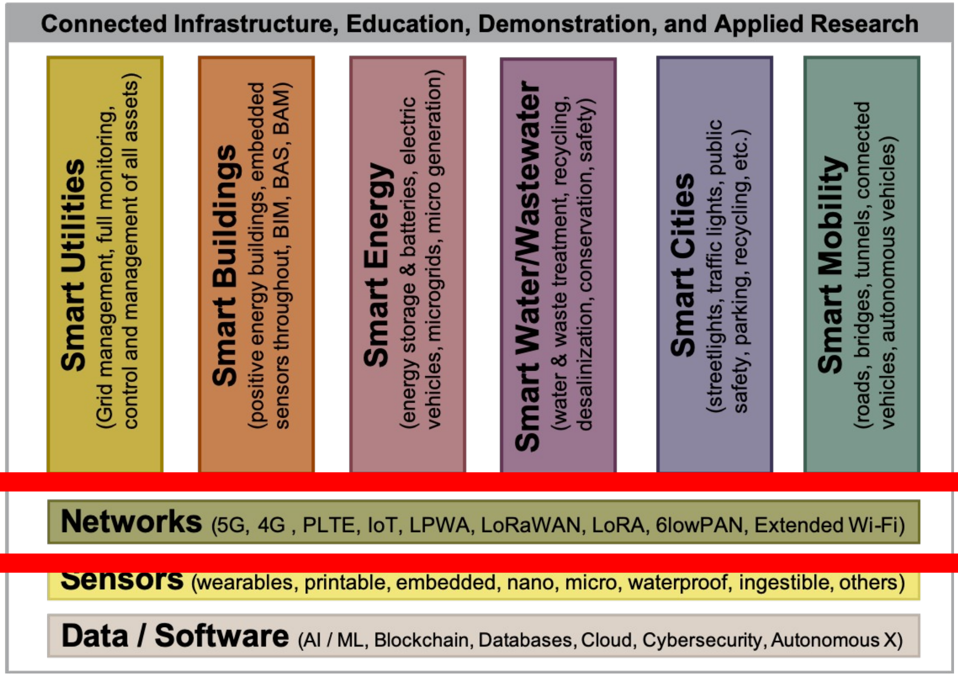
STOP!

The network is a key element, but is not a central focus



CIEDAR Consortium

Networks are a key element of "Smart" Technologies



An open, multi-use, scalable, adaptable testbed is critical

- Platform for Targeted Research, Development, Demonstration, and Validation of "Smart" Tech
- Integrate Industry, Government, Municipalities, Academia, Startups, and Others
- Development and Prototyping at-scale

CIEDAR: Smart Networks Lab

- LTE, 5Ge, 5G, 6G, LPWA, LoRAWAN, LoRA, NB-IOT, IEC61850
- Goose, DNP3, 6LowPAN, Extended Wi-Fi, WiSUN, Wirepass, RF-Mesh
- Private LTE/5G 900 MHz FCC-licensed
- Wirepass & Wi-SUN 900 MHz unlicensed
- LoRA WAN 2.4 GHz unlicensed

Licensed by US FCC

Private LTE Leaders

Experimental Licenses on 900 MHz*

Ameren

SDGE

A Sempra Energy utility®

Exelon.

Private LTE: Wide range of use cases for Electric and Gas.

Southern Company

NewYorkPower Authority

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

Dominion Energy

Xcel ENERGY

TEXAS STATE UNIVERSITY®

The rising STAR of Texas

*Experimental Licenses as recorded on file at the FCC

Anterix

- Working with industry partner Anterix
- Texas State University is one of only nine (9) entities in the US licensed for a 900MHz wireless network
- The network will be used for multiple Private LTE projects and prototypes

Current Projects: ALERRT Center

- Scenario
  - Real-life training for municipal first-responders in active-shooter situations
  - Records streaming position and attitude data from a collection of inertial measurement units (IMU) attached to participants in an active shooter training scenario
  - Critical elements require time-based positional data: participant location, relative attitude of weapon/hands, torso/shoulders, and head/face
  - Visual motion capture not acceptable due to multiple instances of occlusion during scenario and dynamic deployment requirements

- Prototype / Testing Issues
  - The non-real-time (caching) nature of the data streaming is not optimal, and should be provided in real-time to a centralized visualization facility for other participants or observers.
  - The scalability of the solution has not been addressed. Typically, 50+ participants would be included in a live scenario. Network stability and functionality under these conditions needs to be examined.
  - The system architecture of the prototypes is first-generation, and needs to be revisited and optimized for battery life, throughput, ease of use, and so on.
  - IMU reconciliation (drift) needs to be addressed in very tight operational boundaries

Current Projects: Network Optimization

- Scenario
  - Drones present a dynamically mobile radio area network (RAN) to users
  - Mobile RAN accommodates changing environmental situations or to optimize network throughput
  - Drone remains virtually tethered to a fixed base station via a pre-existing broadband wireless link (Private LTE)
- Applications
  - Inspection of electrical infrastructure (towers, remote locations, etc.)
  - Active shooter scenarios with secure “pop-up” wireless network, dynamically provisioned (“sliced”) from pre-existing network
  - Reconciling “digital divide” issues related to network access by under-served populations

Near-Term Projects

- Other Projects
  - 5,000 Embedded Wireless Sensors in 30,000 sq. ft. Building
  - 5G for DERMS Real-Time Control of Distributed Energy
  - Virtual NOC Management for ISO/RTO/TDSP/IOU/MUNI/COOP
  - 30,000 Sensors BlueTooth Mesh Network within a Smart Building
  - 96 miles Electric Shuttle System with Autonomous Navigation
  - Power Management, GIS, Location Services with Applied AI/ML

Thank You!

More information on CIEDAR:

- https://hillviews.txstate.edu/issues/2020/bobcat-strong/project-ciedar.html
- https://www.marc.txstate.edu/CIEDAR.html
- https://vimeo.com/445306772