Smart City Connectivity and Applications

IEEE
Advancing Technology for Humanity

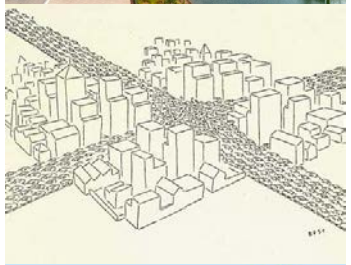
upna ISC Institute of Smart Cities

Tecnológico de Monterrey

Francisco Falcone

Global Context

UNESCO for Sustainable Cities

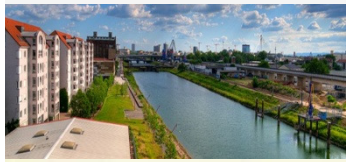


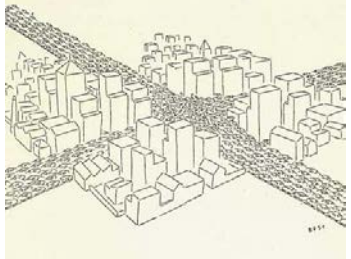
Today, more than half of humanity – 3.9 billion people – lives in cities. By 2050, cities will host 2.5 billion more urban dwellers, making the world almost 70% urban.

UNESCO is committed to enhancing the sustainability of cities through policy advice, technical assistance and capacity building, drawing on its longstanding normative and operational experience in the fields of education, sciences, culture, communication and development. Thanks to multi-disciplinary cooperation among all its sectors, as well as its broad network of experts across the globe, UNESCO has become a leading agency in the effective implementation of the New Urban Agenda and the 2030 Agenda for Sustainable Development.

- ❑ UNESCO Creative Cities Network
- ❑ UNESCO Global Network of Learning Cities
- ❑ Megacities Alliance for Water and Climate
- ❑ Disaster Risk Reduction and Resilience
- ❑ International Coalition of Inclusive and Sustainable Cities
- ❑ World Heritage Cities Programme
- ❑ Media and Information Literacy Cities
- ❑ UNESCO-Netexplo Observatory Cooperation on Smart Cities

EU Context





Comisión Europea

ES español

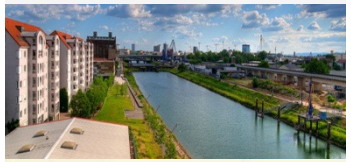
Home › Estrategia › Priorities 2019-2024

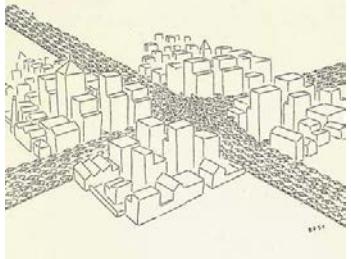
Las prioridades de la Comisión Europea

CONTENIDOS DE LA PÁGINA

Seis prioridades de la Comisión para 2019-2024

EU Context





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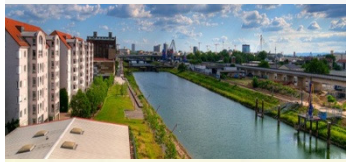

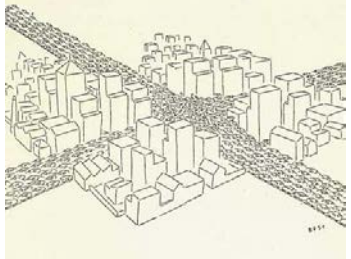

Comisión Europea

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Las prioridades de la Comisión Europea

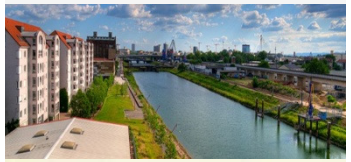
CONTENIDOS DE LA PÁGINA

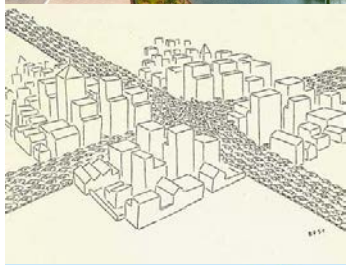
Seis prioridades de la Comisión para 2019-2024

- Un Pacto Verde Europeo
- Una Europa Adaptada a la Era Digital
- Una economía al servicio de las personas
- Una Europa más fuerte en el mundo
- Promoción de nuestro Modo de Vida Europeo
- Un nuevo impulso a la democracia europea

Spain Context

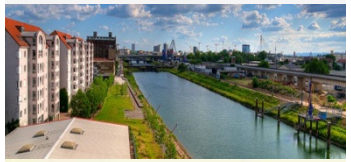
AGENDA URBANA ESPAÑOLA

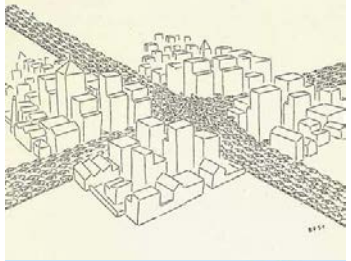




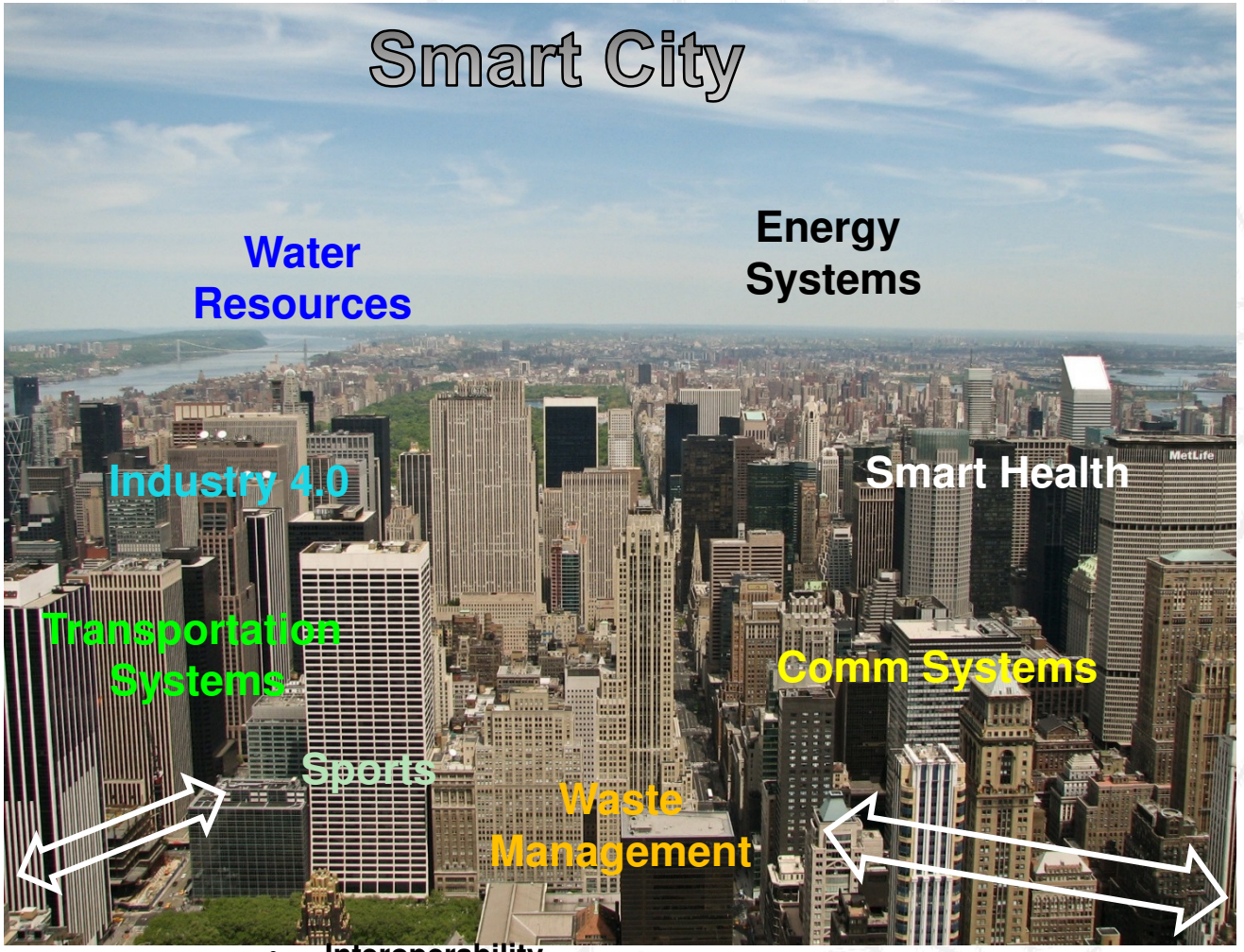
- Objetivo Estratégico 1: Ordenar el territorio y hacer un uso racional del suelo, conservarlo y protegerlo.
- Objetivo Estratégico 2: Evitar la dispersión urbana y revitalizar la ciudad existente.
- Objetivo estratégico 3: Prevenir y reducir los impactos del cambio climático y mejorar la resiliencia.
- Objetivo estratégico 4: Hacer una gestión sostenible de los recursos y favorecer la economía circular.
- Objetivo estratégico 5: Favorecer la proximidad y la movilidad sostenible.
- Objetivo estratégico 6: Fomentar la cohesión social y buscar la equidad.
- Objetivo estratégico 7: Impulsar y favorecer la Economía Urbana.
- Objetivo estratégico 8: Garantizar el acceso a la Vivienda.
- Objetivo estratégico 9: Liderar y fomentar la innovación digital.
- Objetivo Estratégico 10: Mejorar los instrumentos de intervención y la gobernanza.

*La Agenda Urbana Española (AUE) es un **documento estratégico**, **sin carácter normativo,** y por tanto de adhesión voluntaria, que, de conformidad con los criterios establecidos por la Agenda 2030, la nueva Agenda Urbana de las Naciones Unidas y la Agenda Urbana para la Unión Europea persigue el logro de la sostenibilidad en las políticas de desarrollo urbano. Constituye, además, **un método de trabajo y un proceso** para todos los actores, públicos y privados, que intervienen en las ciudades y que buscan un desarrollo equitativo, justo y sostenible desde sus distintos campos de actuación*





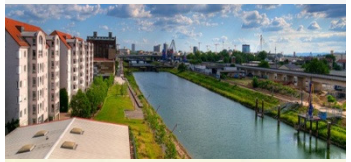
Resource Management

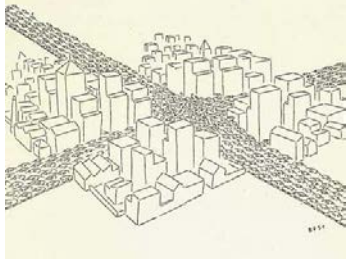


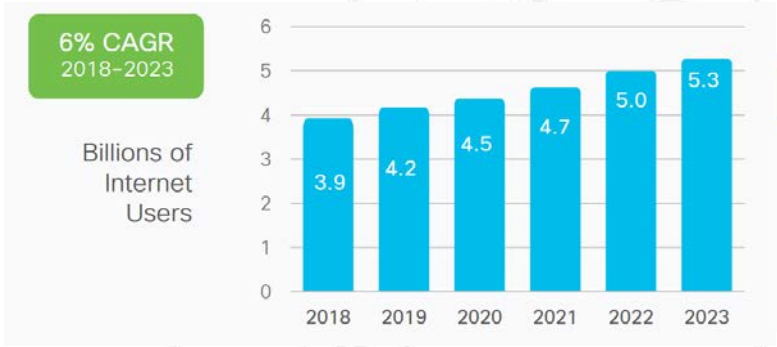
Open Government

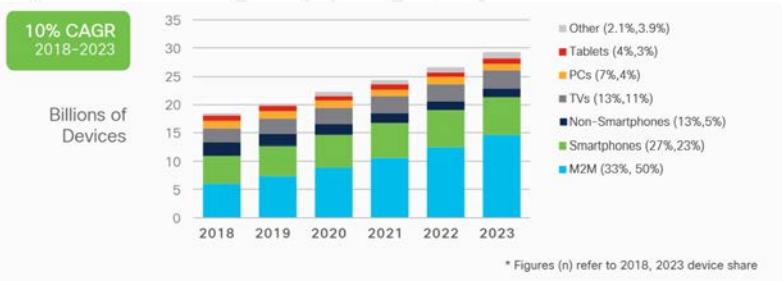
- Interoperability
- Big Data Management
- Seamless Interaction
- User Centric: Usabilty and Adoption

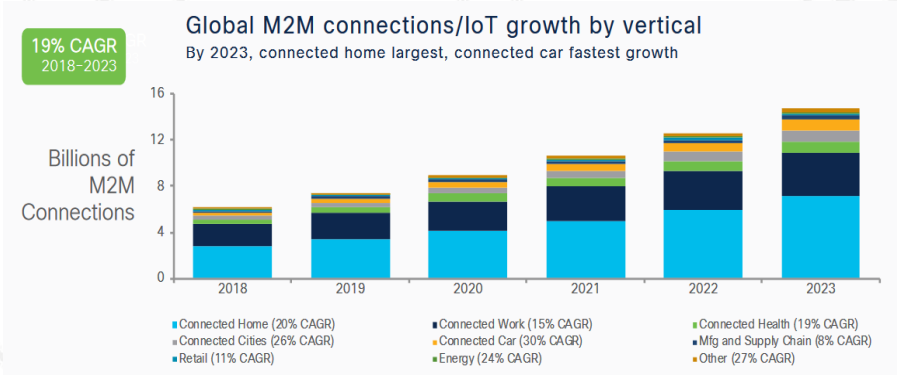
Network Traffic Evolution









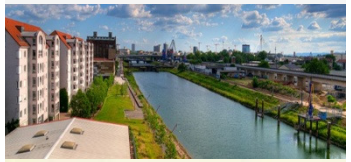
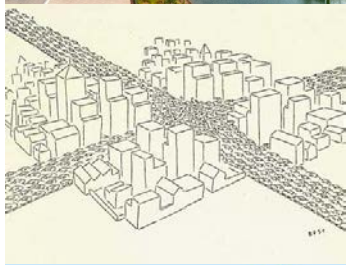


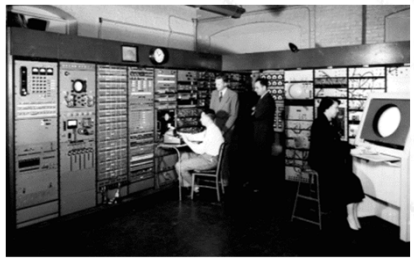
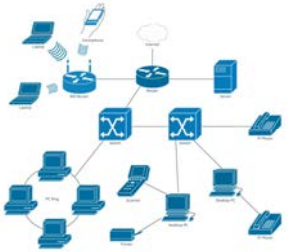
CISCO VNI: https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf)

IoT

- Where does IoT come from?
- It can be seen as an evolution of Internet, starting from connection of end devices evolving towards contextual environments.
  I. NW connections
  II. Internet
  III. Mobile Internet
  IV. Mobile Internet & Users
  V. Internet of Things

Reactive Environment connected to Users & Systems

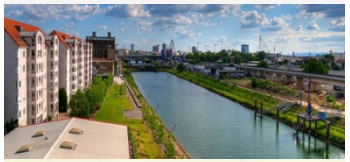



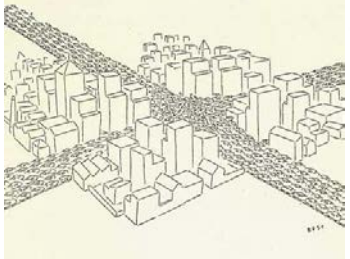




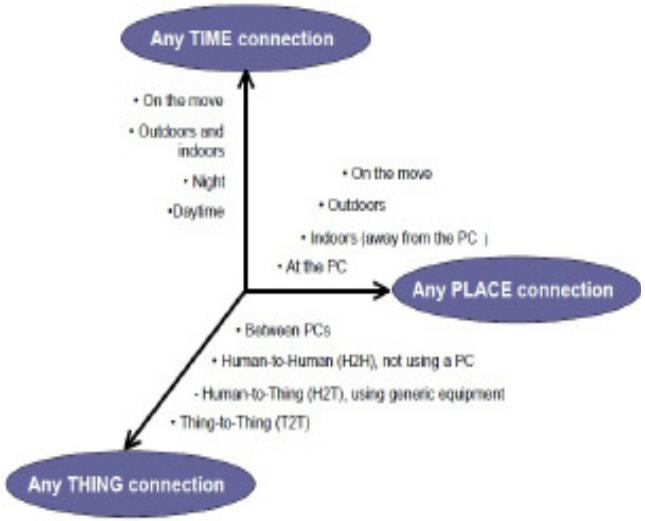
C. Perera et al., "A Survey on Internet of Things From Industrial Market Perspective", IEEE Access, January 2015

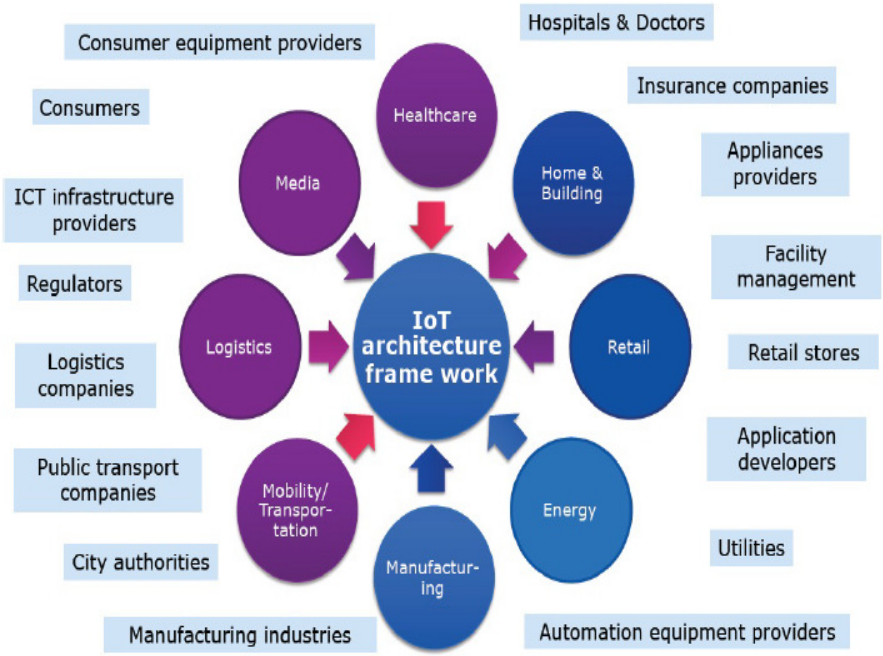
IoT

- According to the definition of Sundmaeker et al., *IoT will allow objects and people to be connected at any time, place, with anything and with anyone, using any path or network and any service.*





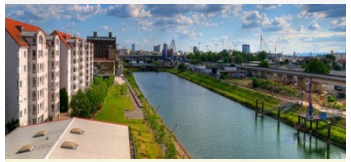


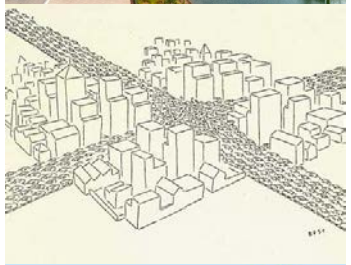


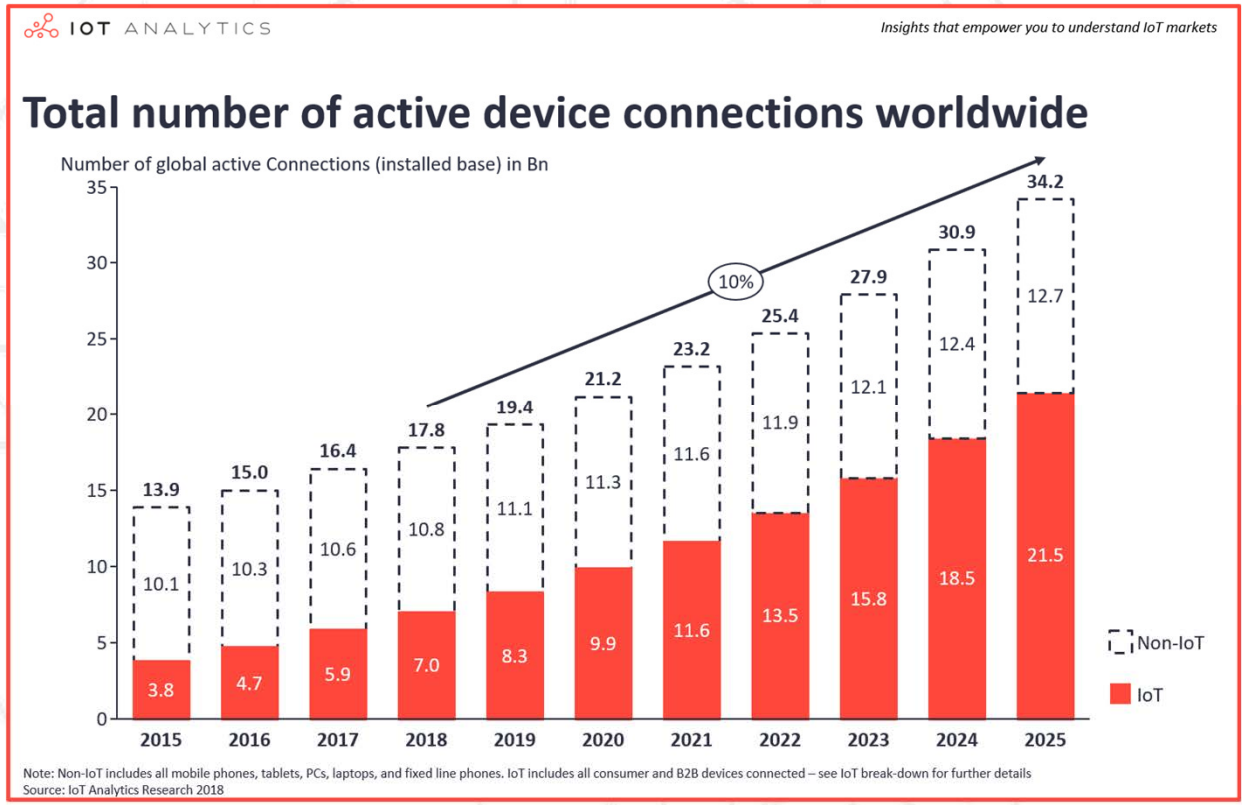
http://iot.ieee.org/images/files/pdf/IEEE_IoT_Towards_Definition_Internet_of_Things_Revision1_27MAY15.pdf

Communications: IoT Context

- Why is it interesting to consider IoT?







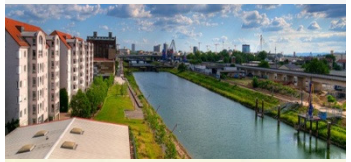
FORTUNE BUSINESS INSIGHTS

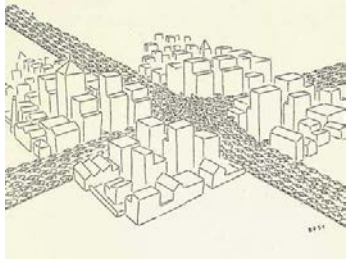
Internet of Things (IoT) Market to Reach USD 1,102.6 Billion by 2026; Rising Usage of AI & Machine Learning to Boost Growth: Fortune Business Insights™

IoT Market Analysis By Component (Devices, Connectivity, IT Services, Platforms), By Application (Consumer Electronics, Retail, Manufacturing, Transportation, Healthcare) And Segment Forecasts To 2022 Grand View Research

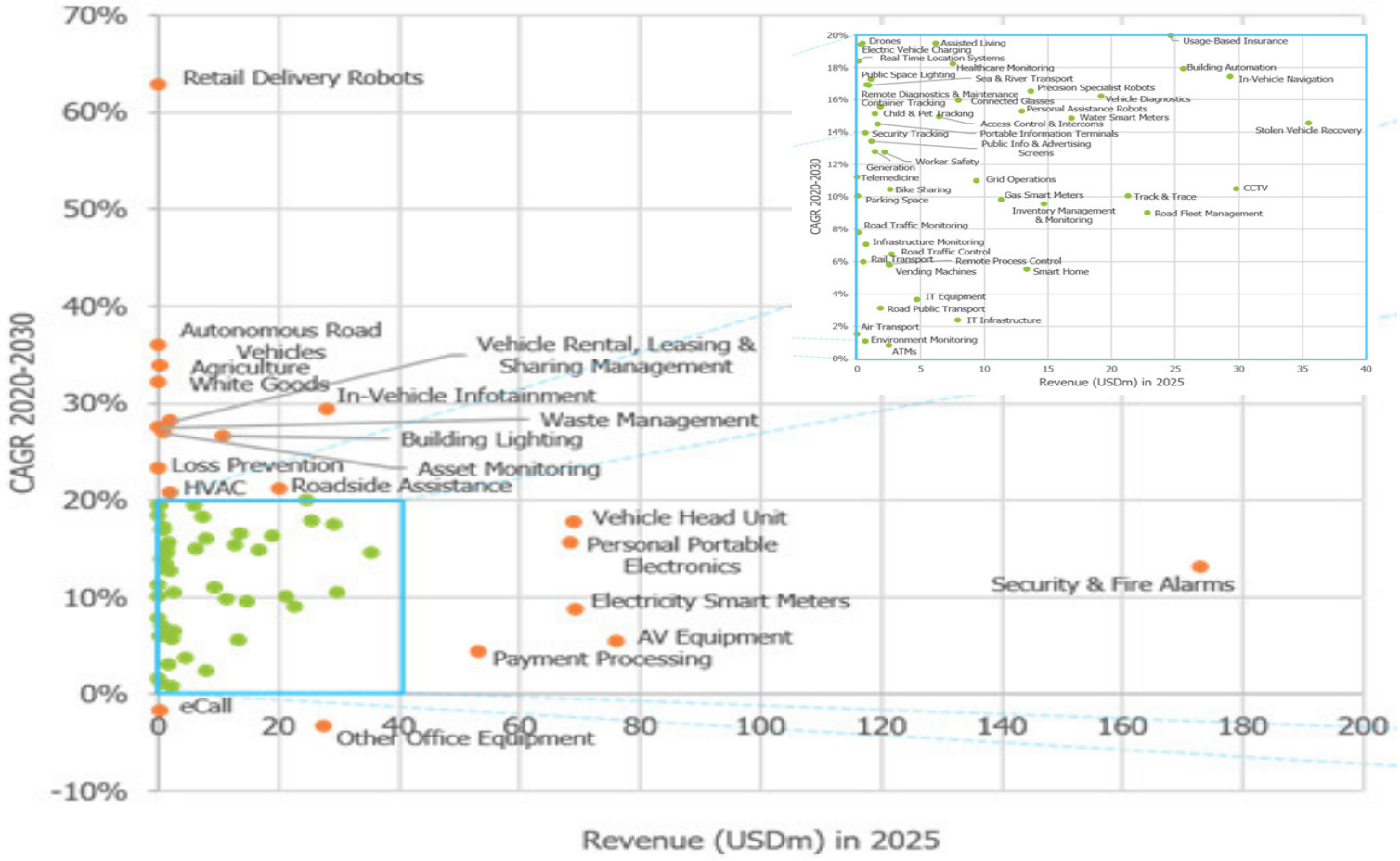
Communications: IoT Context

- Why is it interesting to consider IoT?

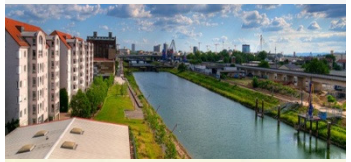


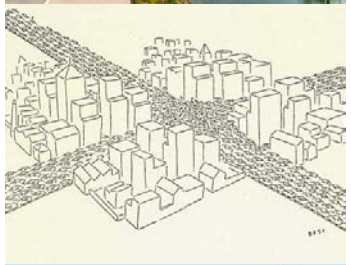


IoT revenue CAGR 2020-2030 and total 2025, by application group
[Source: Transforma Insights TAM Forecasts, 2020]



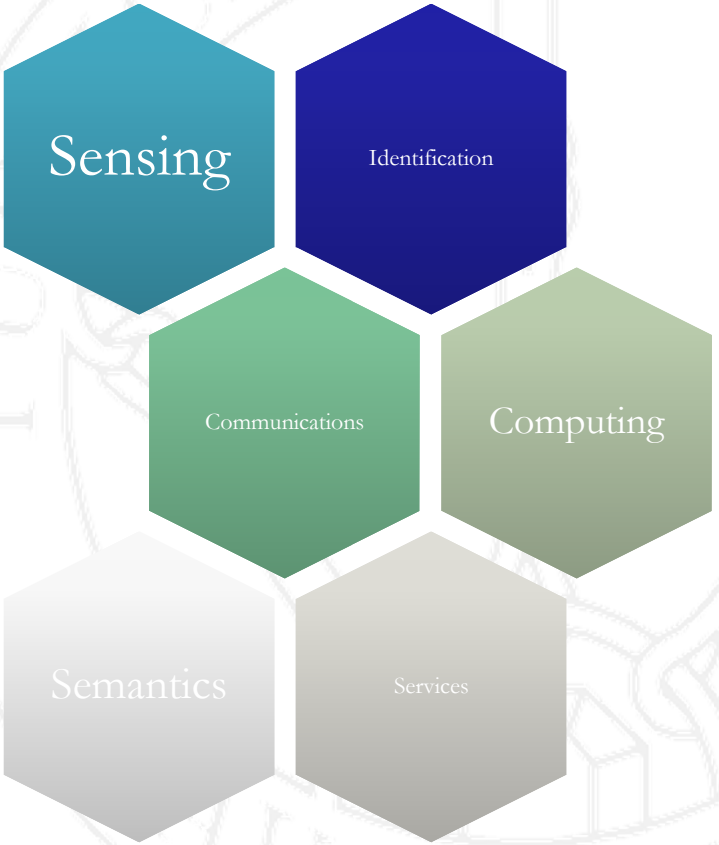
IoT Elements





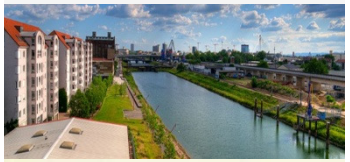
Physical

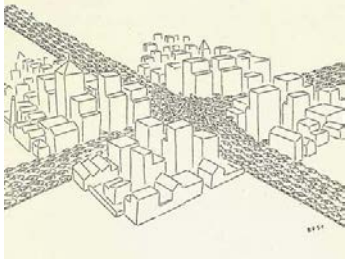
Virtual

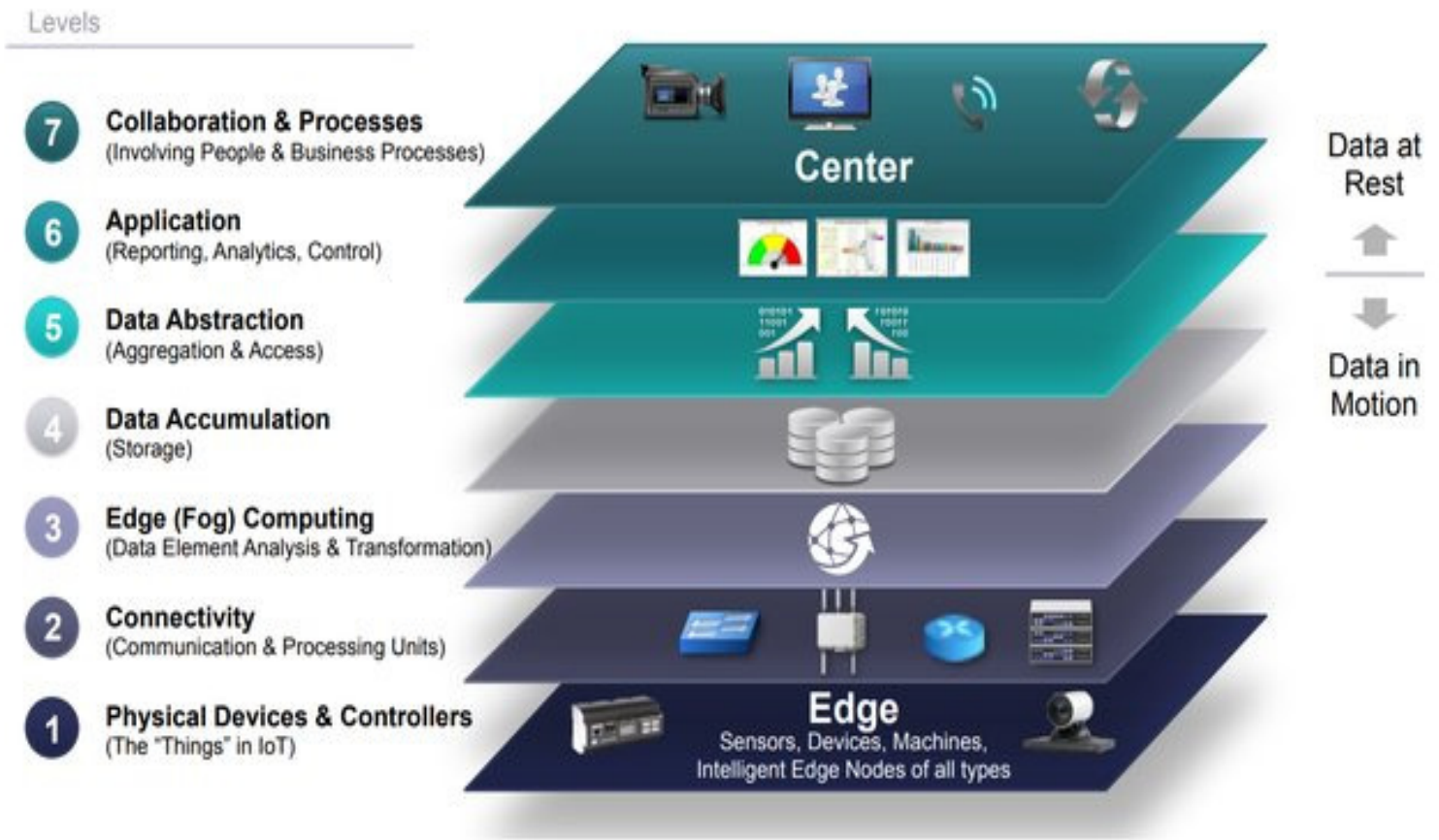


- Massive Data Gathering
- Limited Energy
- Limited Computation
- Diverse Connectivity
- Variable QoS/QoE
- Low Cost
- Hostile Environment

IoT Reference Architecture



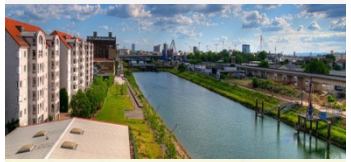


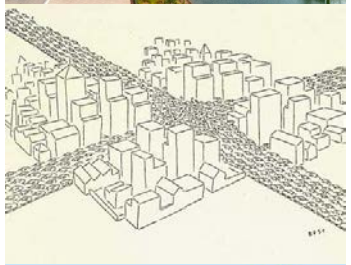


HW+SW

https://blogs.cisco.com/news/the-internet-of-things-moving-beyond-the-hype

Smart Cities/Regions





- Interoperation of multiple systems
- Set of multiple information gathering elements (sensors) and the need to perform actions (actuators)
- Potential to generate and analyze massive amounts of data
- Requirements in terms of information processing and actions to be taken in real time or quasi-real time
- **Communication Networks: Enable information transport, processing and further actions, playing a key role in context aware environment implementation**

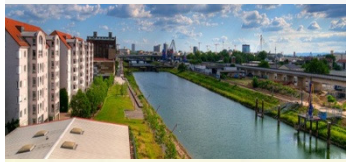
PLMN
Public Land Mobile Networks

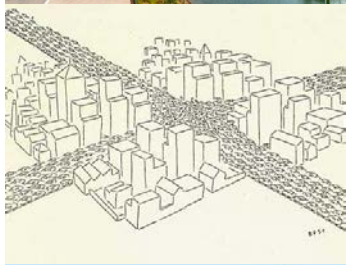
LPWAN
Low Power Wide Area Networks

WLAN
Wireless Local Area Networks

Communication Systems-PLMN

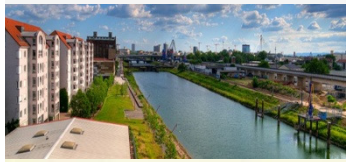
- In order to provide mobility and scalability: focus on Wireless communications
- As a function of coverage/capacity: PLMN, WLAN-WSN, LPWAN
- PLMN (Public Land Mobile Network)





- First Generation Systems, analog, born in the 80s (NMT, TACS;). 450MHz/900MHz freq. band
- Second Generation Systems (GSM/IS-95) digital end to end, embedded SS7/ signaling. Frequency Band 900MHz/1800MHz. Data supported by GPRS.
- 3G Systems: UMTS/CDMA 2000, digital multiservice; operates in 2.1GHz band. HSPA for data services
- **4G Systems: LTE (Long Term Evolution); full IP end to end connectivity. Provision up to approximately 1 Gbps (quasi-static/100Mbps high mobility). NB-IoT/Cat M.**
- **5G Systems: FR1/FR2 (below 6GHz/above 6GHz)**
- **B5G/6G**

PLMN: Socio-Economic Context



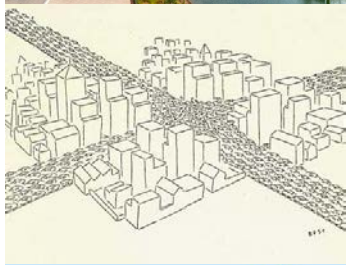
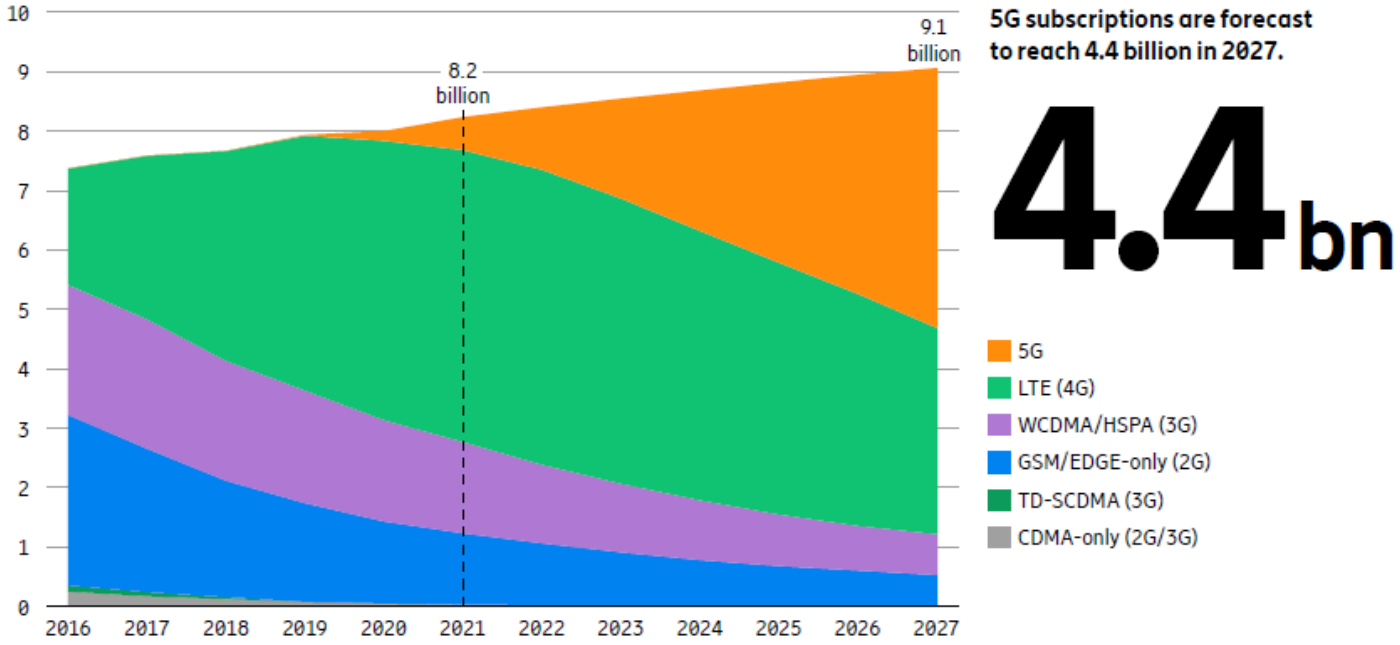
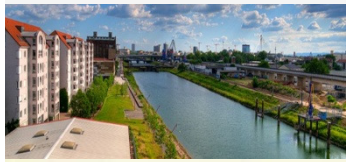


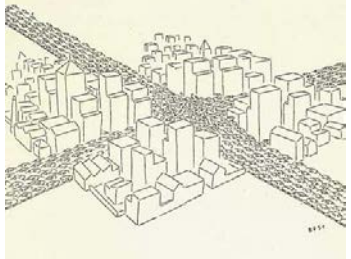
Figure 1: Mobile subscriptions by technology (billion)

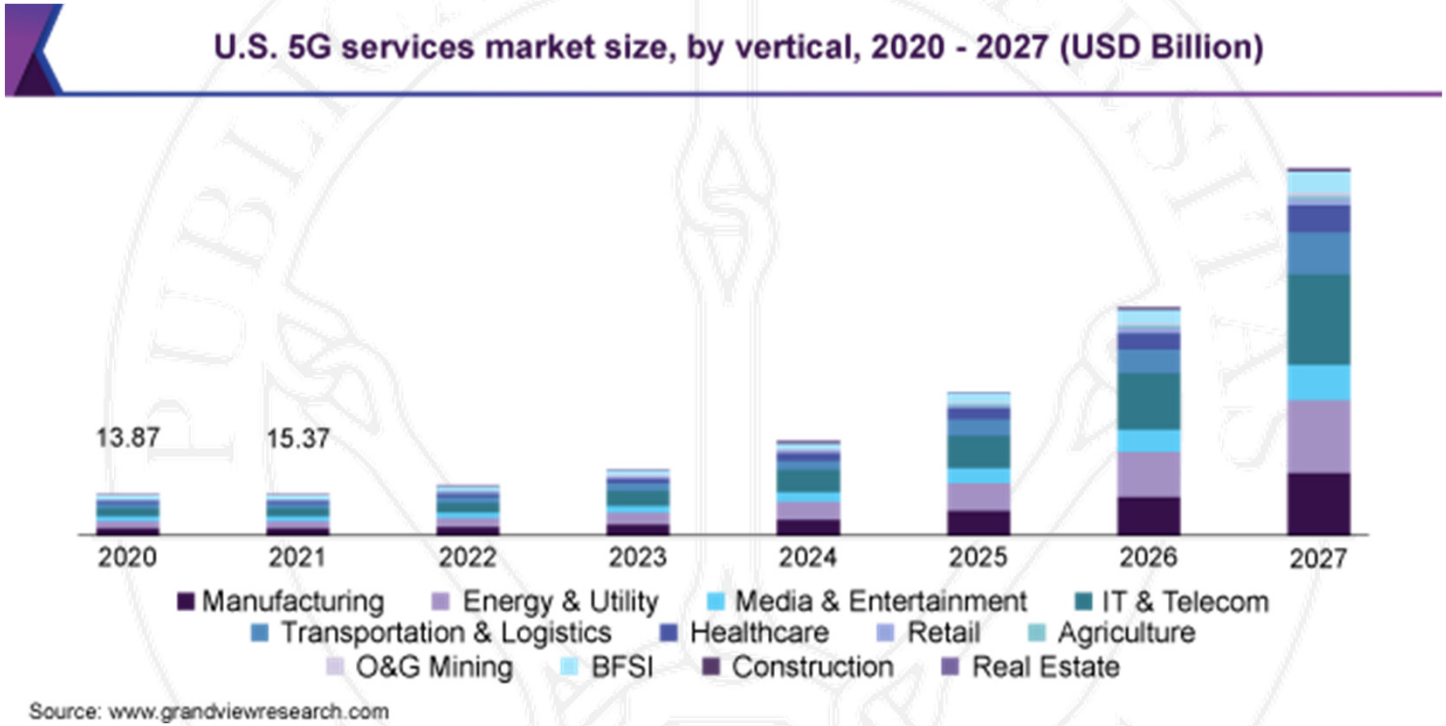


Source: Ericsson Mobility Report, June 2022
https://www.ericsson.com/en/mobility-report/dataforecasts

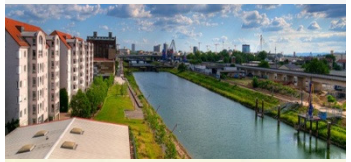
5G: Socio-Economic Context

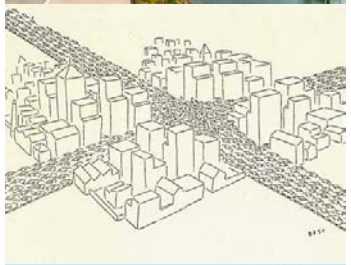




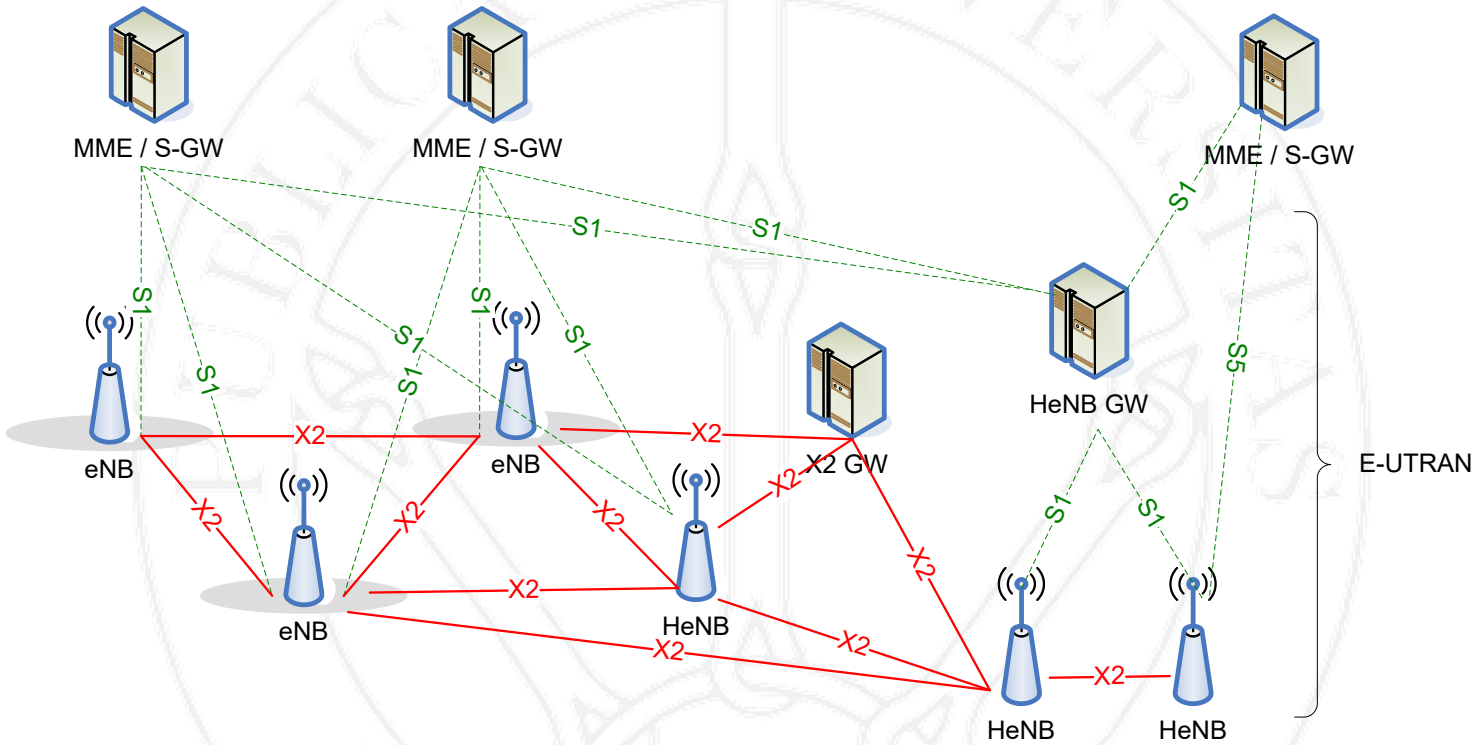


https://www.grandviewresearch.com/industry-analysis/5g-services-market



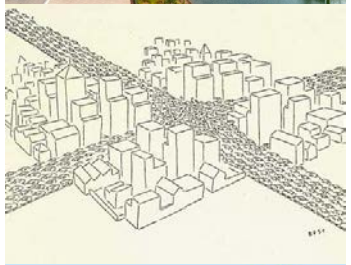


LTE



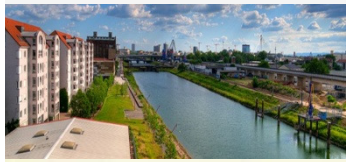
Source: 3GPP-TR 36.300

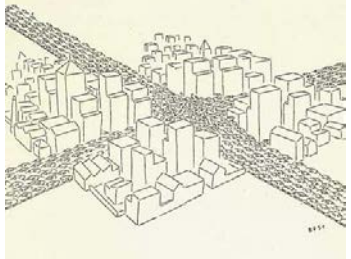
- Full IP Connectivity
- Inter-Node communication capabilities
- Greater Network Intelligence at eNodeB level



- NB-IoT(Narrow Band IoT)
  - Long battery duration (up to 10 años)
  - Latency: between 1.6 and 10 seconds
  - Transfer rate of 250kbit/s
  - Allows high node density
  - Narrow BW (200kHz)
- LTE-M (Cat. M1)
  - Higher bit rate (up to 1Mbps, 4Mbps in the case of Cat. M2)
  - lower latency: 10-15 msec
  - Allows full duplex mode
  - Larger BW (1.4MHz, 5MHz Cat. M2)
  - Higher cost per node as compared with NB-IoT

NB-IoT™ LTE-M





WLAN

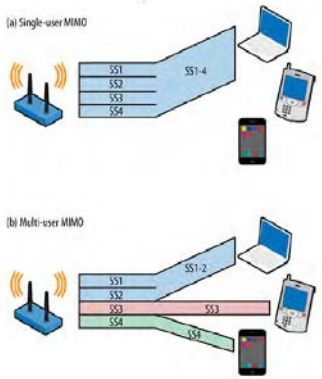
802.11 (2 Mbps) → 802.11b (11 Mbps) → 802.11a/g (24-54 Mbps)

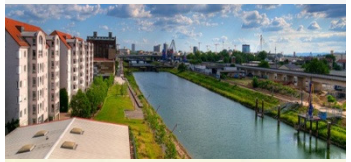
802.11n (65-600 Mbps) → 802.11ac w1 (290-6900 Mbps) → 802.11ac w2 (290-6900 Mbps)

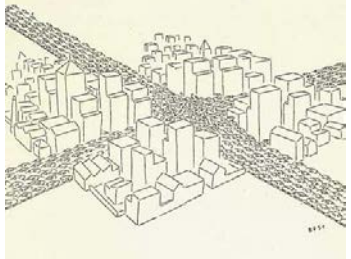
802.11ax (10 Gbps) → 802.11be (40 Gbps)

IoT: 802.11 ah (Wi-Fi Ha Low) Sub 1 GHz

- Steady increase in capacity (Mbps towards Gbps range)
- Introduction of features such as:
  - Different Spectrum Allocation (2.4GHz-5.8GHz-6GHz (ax/be)-60GHz (ad/ay))
  - AMC (high complexity modulation schemes)
  - OFDM (increased spectral efficiency)
  - MIMO (increased channel capacity if radio channel matrix is adequate; use of multiple spatial streams)

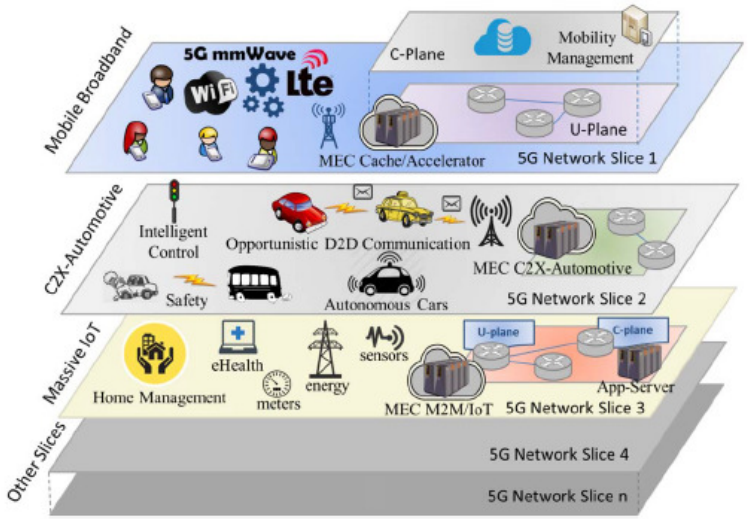


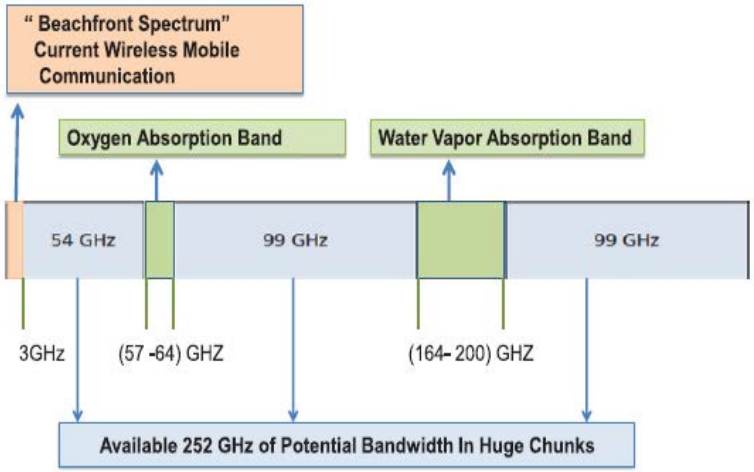




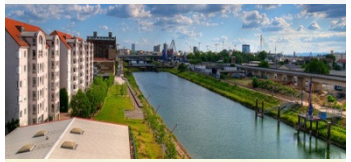
5G Systems

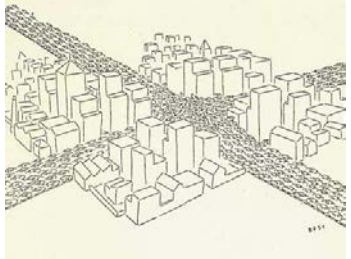
- EMB: Enhanced Mobile Broadband
- MEC Mobile Edge Computing
- uRLLC: Ultra Reliable Low Latency Communications:
- NW slicing:



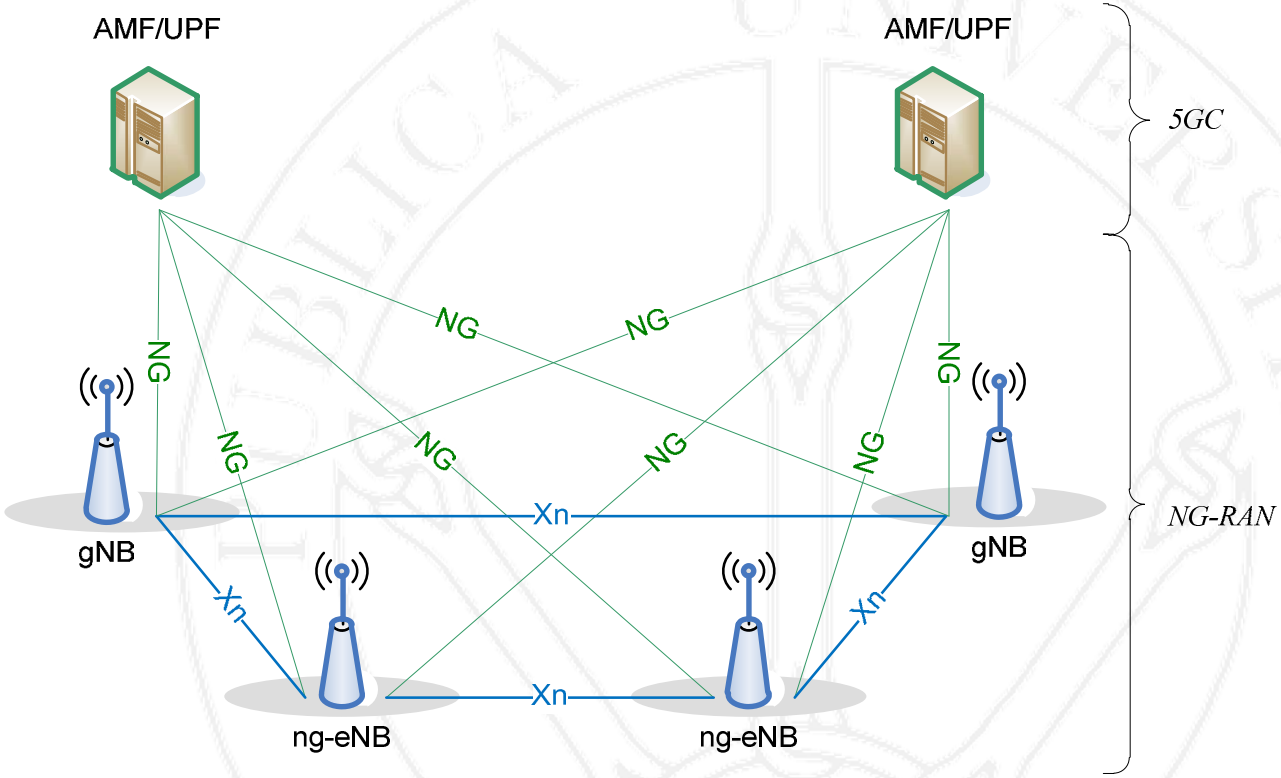


Syed Adeel Ali Shah, Ejaz Ahmed, Muhammad Imran, and Sherali Zeadally, "5G for Vehicular Communications", IEEE Communications Magazine • January 2018





5G Systems

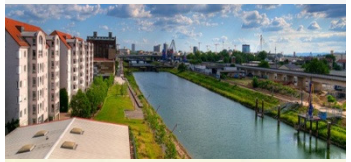


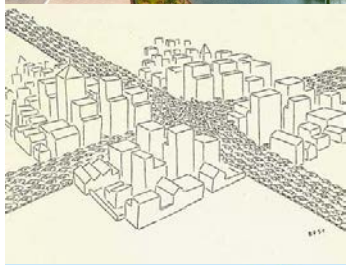
- **gNB:** node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC
- **ng-eNB:** node providing E-UTRA user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC

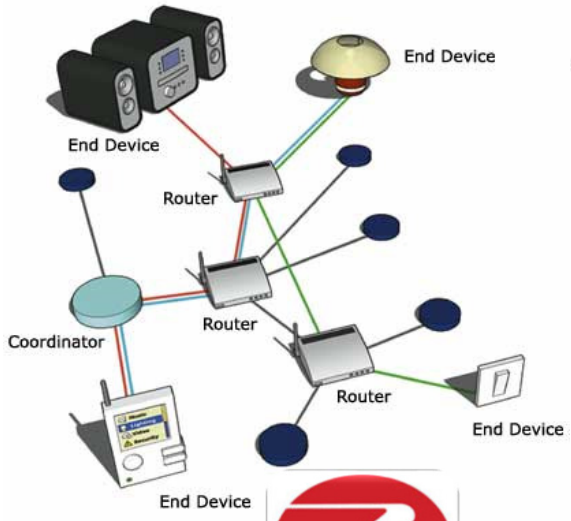
AMF: Access and Mobility Management Function
UPF: User Plane Function

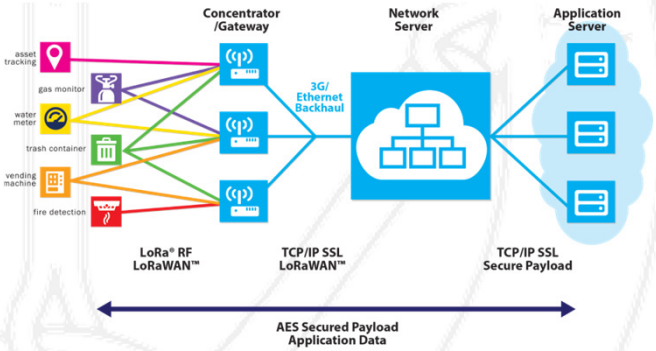
3GPP TS 38.300 V15.6.0 (2019-06)

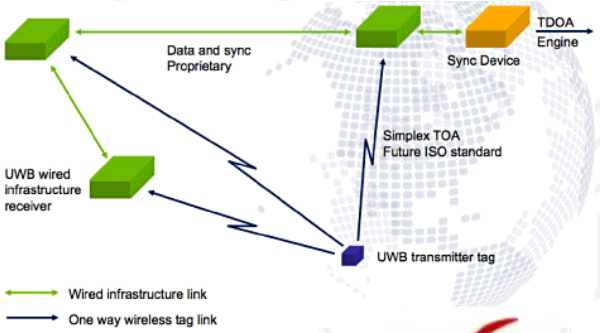
Wireless Sensor Networks





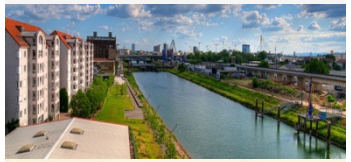


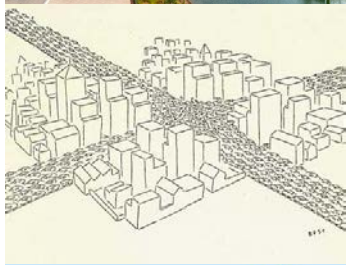




uwb embedded technology

Wireless Sensor Networks: WBAN

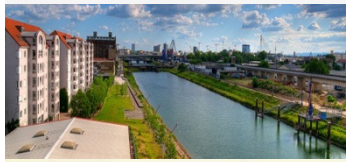


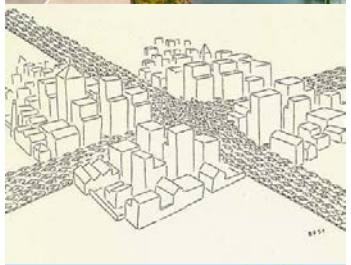


- WBAN / WPAN allow the connection and integration of multiple types of elements that communicate with the user
- Wearable: element transported by the user, seeking to increase the degree of interaction with the environment, seeking ergonomic and aesthetic criteria
- Multiple applications:
  - Sports
  - Location and control
  - Sanitary/Health assistance
  - Leisure
  - Smart Watches
- Precursor the first watches with calculator, popular in the 80s:

- Classification:
  - Mobile phones
  - Bracelets
  - e-Textiles/Smart Textiles
  - Helmets
  - Glasses
  - keyrings
  - Intrabody Communications (IEEE 802.15.6)

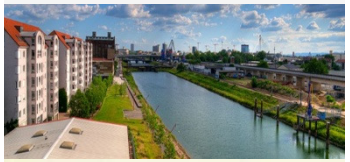
Wireless Sensor Networks

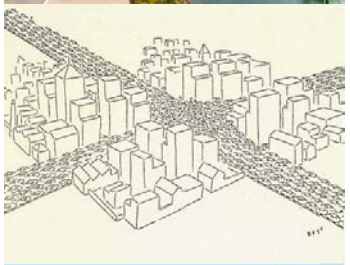


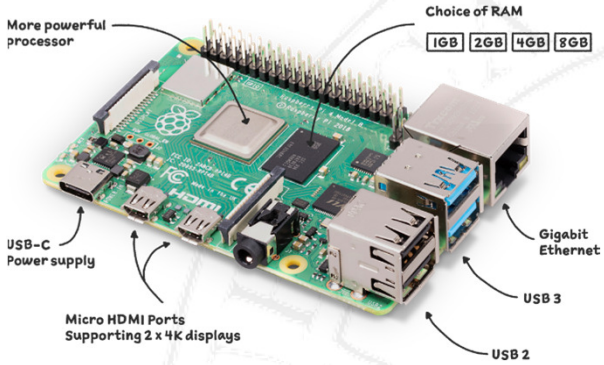


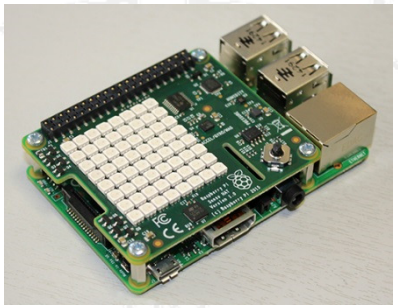
- One of the fundamental limitations is device power feed..
- Energy consumption must be optimized, due to limitations in the capabilities to provide power to these devices
- To this end, the following is considered:
  - Ultra low power consumption circuits
  - Energy efficient routing protocols (data centric routing, proactive routing, on demand routing, hierarchical routing, location based routing)
  - Optimized device states (Sleep mode, hibernated nodes)
- The use of alternative eneregy sources is sought for, known as *Energy Harvesting*:
  - Mechanical
  - Thermal
  - Light
  - Electromagnetic (Rectenna)
  - Other potential sources (wind, human body, chemical sources…)

Wireless Sensor Networks





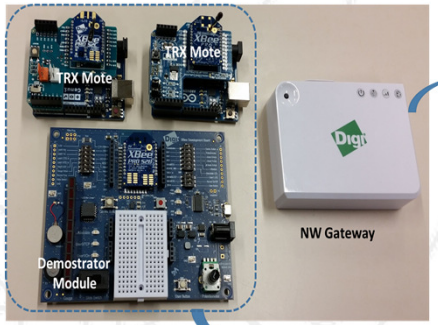


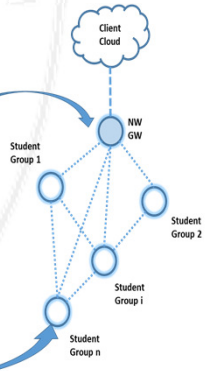


Raspberry Pi 4 Model B **Raspberry Sense HAT** **Raspberry Pi Zero 2 W**

https://www.raspberrypi.org

Xbee/Arduino





Arduino Pro

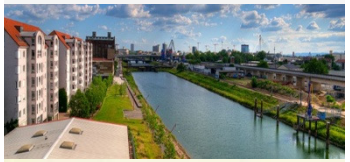
https://www.arduino.cc/

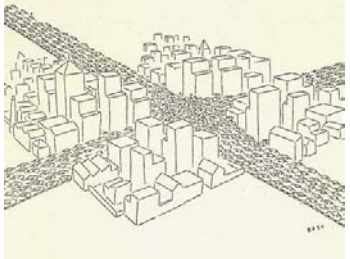
NVIDIA Jetson Nano

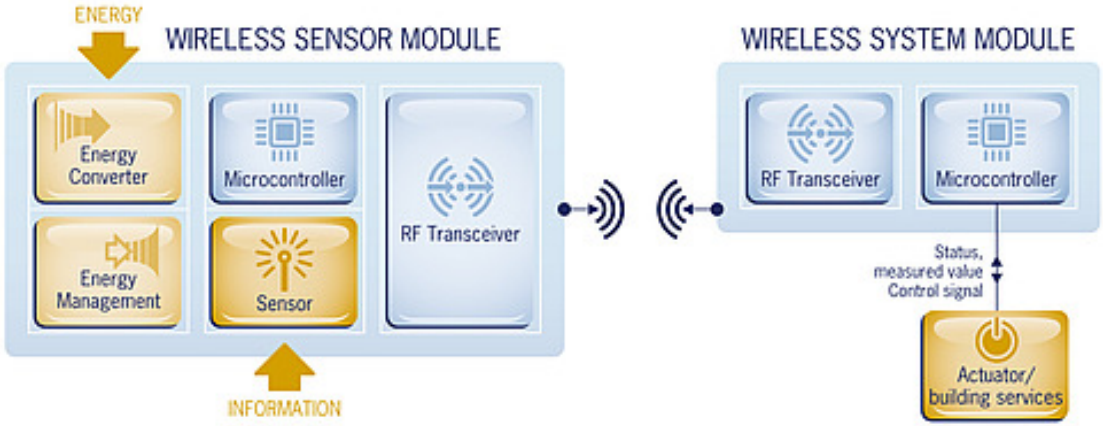
https://www.nvidia.com/es-es/autonomous-machines/embedded-systems/jetson-nano/

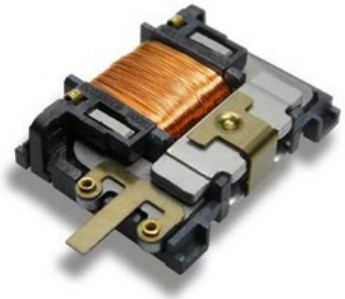
- ❑ Cloud capable communications
- ❑ Integration with web services

Wireless Sensor Networks

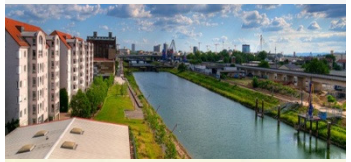


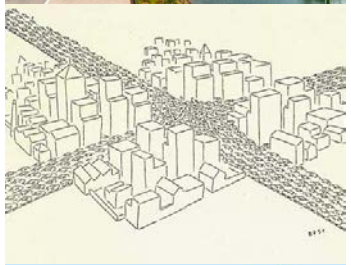






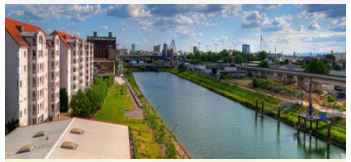
https://www.enocean.com/

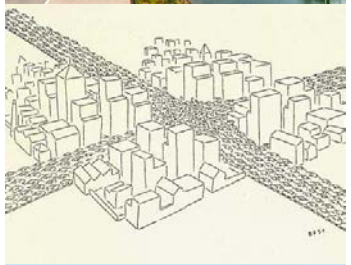


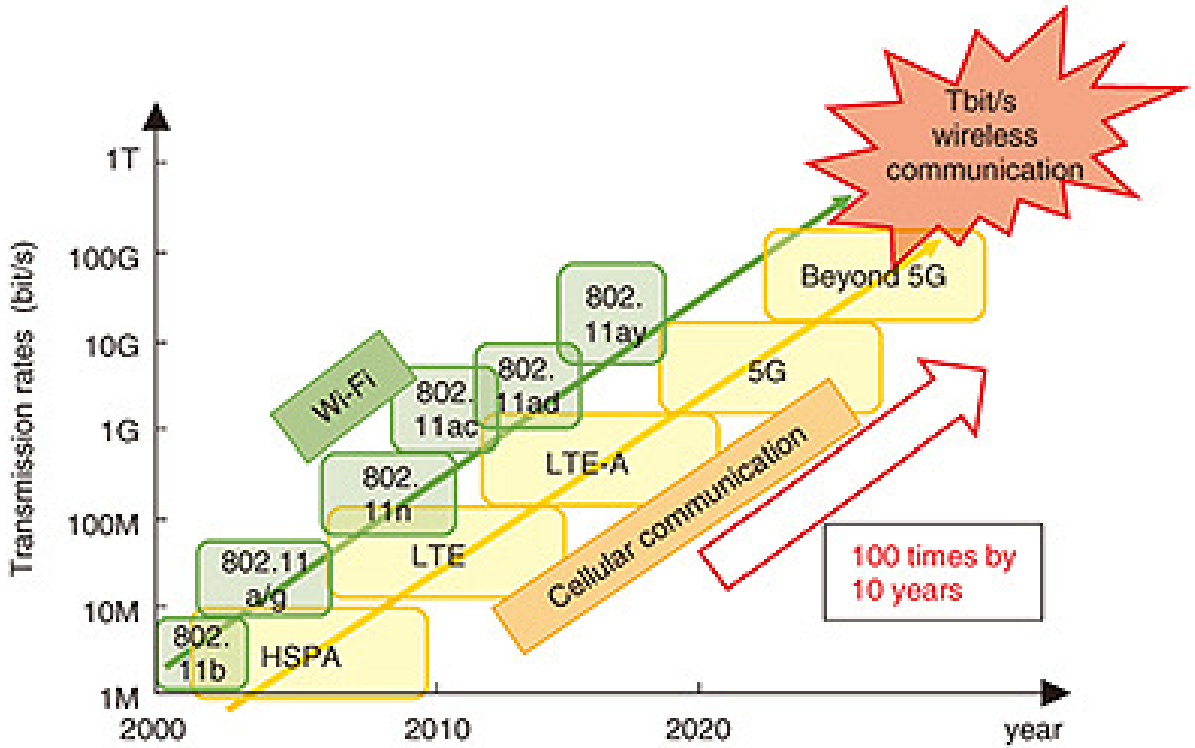


PLMN	WSN/WLAN	WBAN
• 2G/3G: GSM/GPRS/UMTS • 4G: LTE • 5G • 6G?	• ZigBee • eNocean • LoRa • Sigfox • WiFi	• Bluetooth/BLE • NFC • RFID • Intrabody • UWB

Evolution

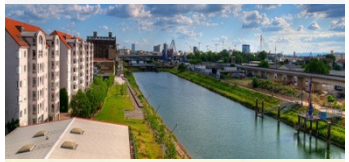


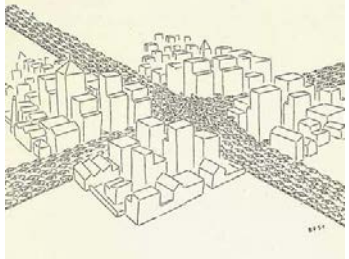




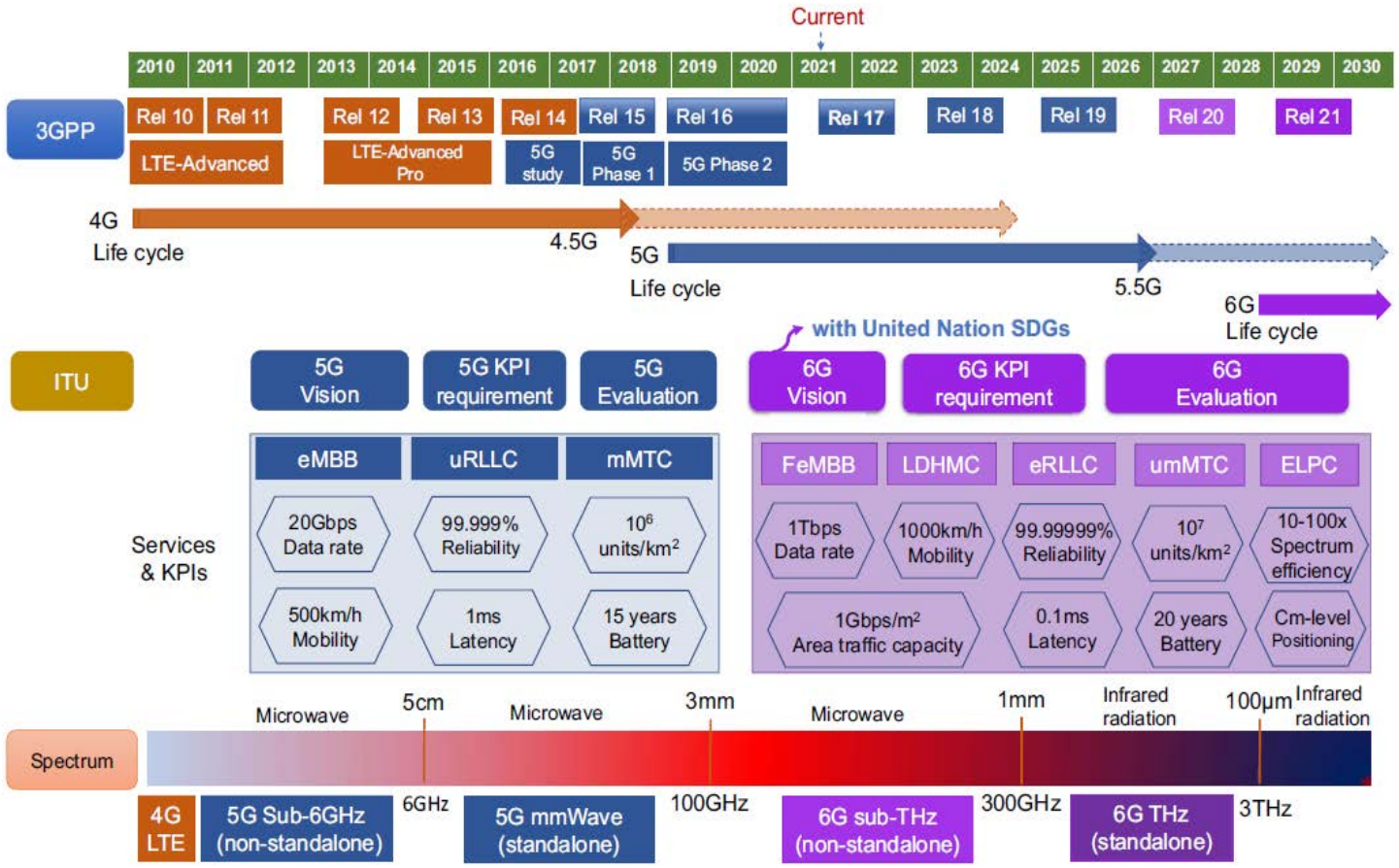
5G: fifth-generation mobile communications network
HSPA: high-speed packet access
LTE: Long-Term Evolution
LTE-A: LTE-Advanced

Source: NTT Technical Reviews
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201709ra1.html

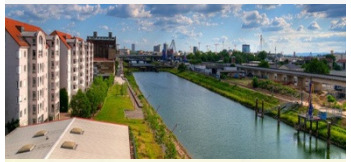


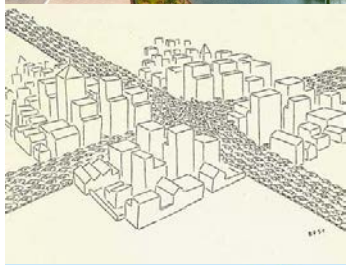


Towards 6G

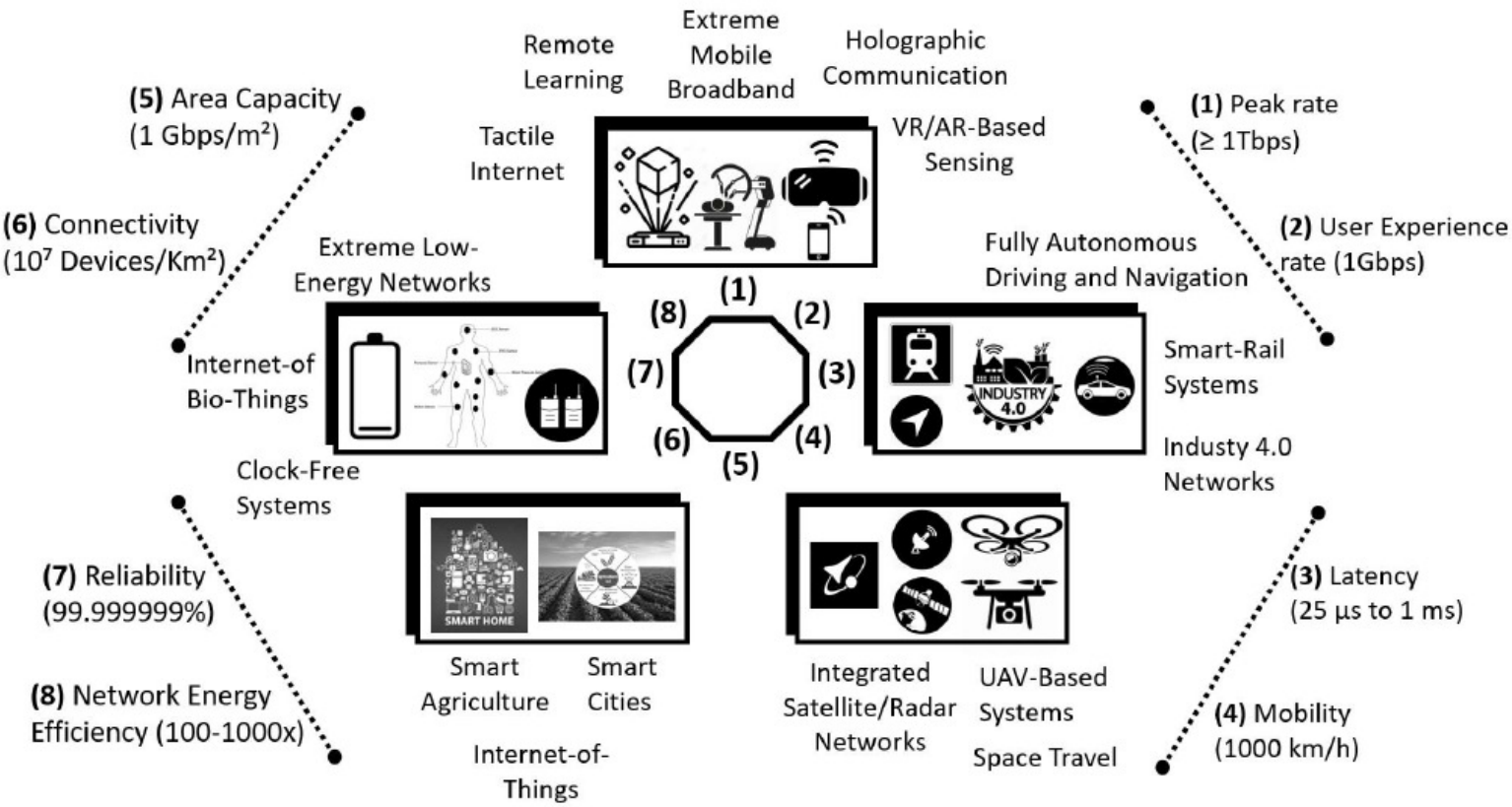


V. -L. Nguyen, P. -C. Lin, B. -C. Cheng, R. -H. Hwang and Y. -D. Lin, "Security and Privacy for 6G: A Survey on Prospective Technologies and Challenges," in IEEE Communications Surveys & Tutorials, vol. 23, no. 4, pp. 2384-2428, Fourthquarter 2021, doi: 10.1109/COMST.2021.3108618.



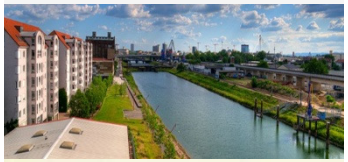


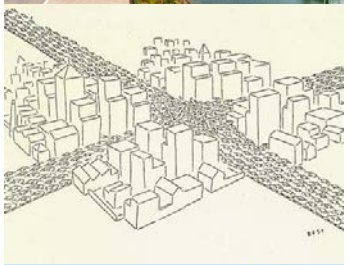
Towards 6G-Goals

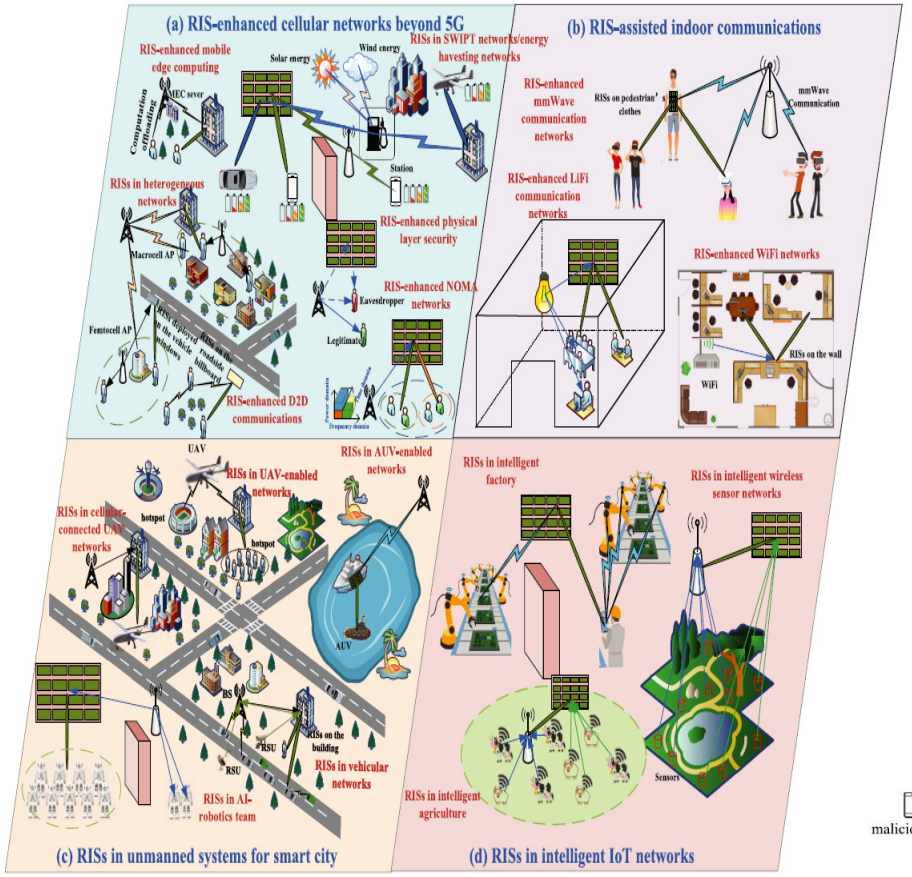


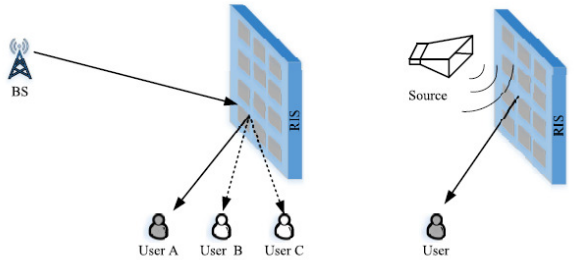
H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjöland and F. Tufvesson, "6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities," in Proceedings of the IEEE, vol. 109, no. 7, pp. 1166-1199, July 2021, doi: 10.1109/JPROC.2021.3061701.

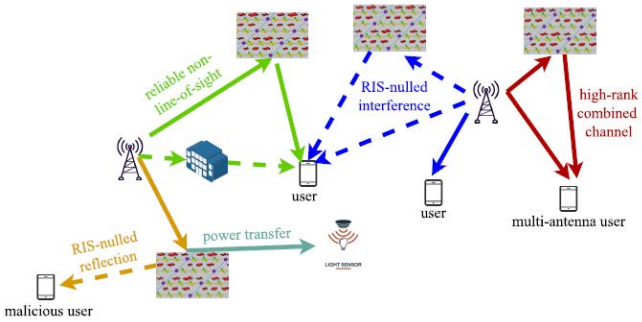
Towards 6G-RIS





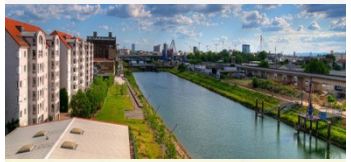


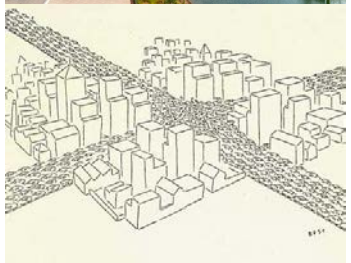


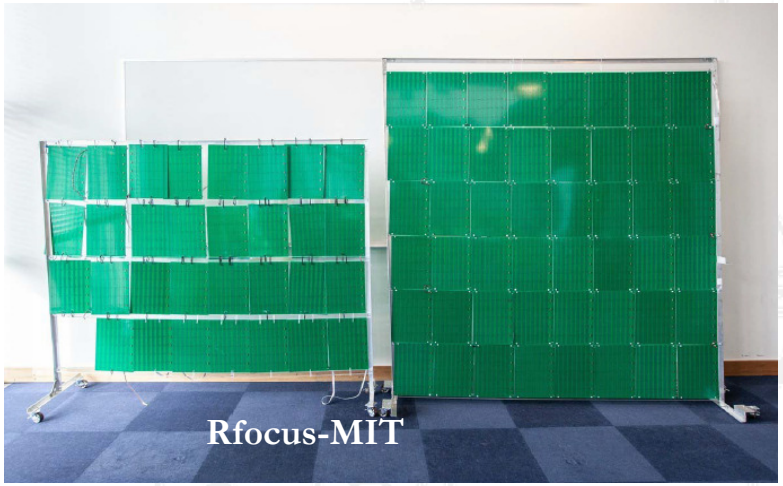


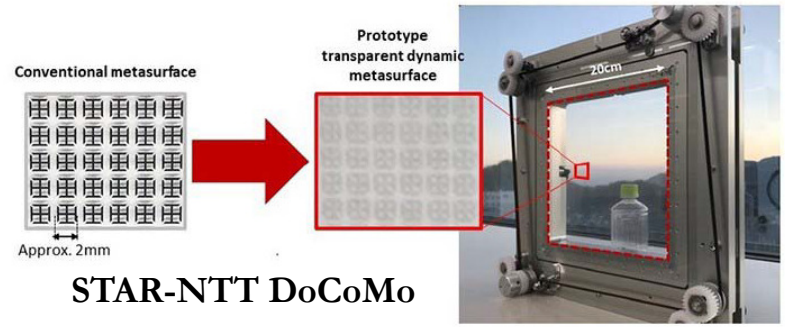
Y. Liu et al., "Reconfigurable Intelligent Surfaces: Principles and Opportunities," in IEEE Communications Surveys & Tutorials, vol. 23, no. 3, pp. 1546-1577, thirdquarter 2021, doi: 10.1109/COMST.2021.3077737.
M. Di Renzo et al., "Smart Radio Environments Empowered by Reconfigurable Intelligent Surfaces: How It Works, State of Research, and The Road Ahead," in IEEE Journal on Selected Areas in Communications, vol. 38, no. 11, pp. 2450-2525, Nov. 2020, doi: 10.1109/JSAC.2020.3007211.

Towards 6G-RIS





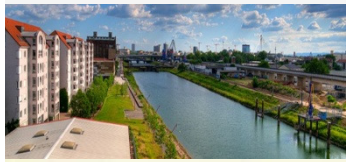


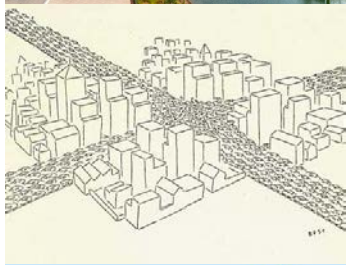


STAR-NTT DoCoMo

Y. Liu et al., "STAR: Simultaneous Transmission and Reflection for 360° Coverage by Intelligent Surfaces," in IEEE Wireless Communications, vol. 28, no. 6, pp. 102-109, December 2021, doi: 10.1109/MWC.001.2100191.
M. Di Renzo et al., "Smart Radio Environments Empowered by Reconfigurable Intelligent Surfaces: How It Works, State of Research, and The Road Ahead," in IEEE Journal on Selected Areas in Communications, vol. 38, no. 11, pp. 2450-2525, Nov. 2020, doi: 10.1109/JSAC.2020.3007211.

Standards: Overview





TECHNICAL COMMITTEES
ISO/TC 268
Sustainable cities and communities

ETSI

IETF

ISO JTC1 IEC
INFORMATION TECHNOLOGY STANDARDS

ITU

IEEE SA STANDARDS ASSOCIATION

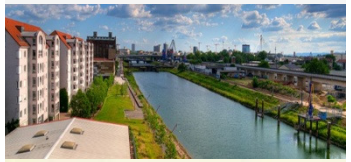
AENOR
CTN 178

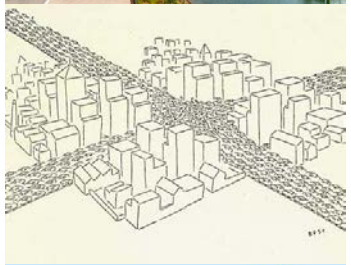
bsi.
BSI's PAS 181:2014 Description: British Smart City Framework

DIN DKE
German Standardisation Roadmap Smart City

- Adapt4EE/Ready4SmartCities: eeSmantics
- H2020 SCC-03-2015 Espresso: Development of system standards for smart cities and communities solutions
- DIN SPEC 91357: Industry Memorandum of Understanding on Urban Platforms
- Fed4IoT: goal is to federate IoT and Cloud infrastructures to provide scalable and interoperable Smart Cities Applications by introducing novel IoT virtualization technologies

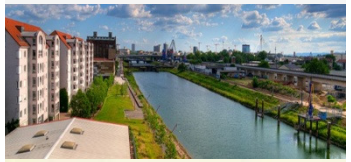
Wirelss Links-Challenges and Limitations

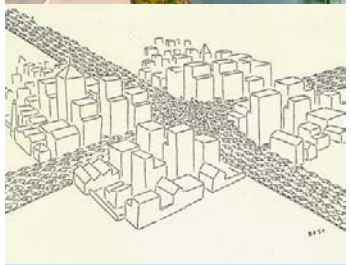




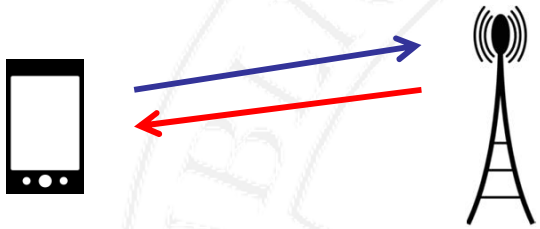
- Physical Media: Radio waves
- Fundamental Characteristics: Amplitude and Frequency (Coding, Modulation, Access Method…)
- EM waves interact with the sorrounding environment:
  - Distance effect
  - Medium in which propagation occurs (atmospheric absorption losses, effect of hydrometeors)
  - Reflection, refraction, difraction, diffuse scattering (building facades, vegetation)
  - In the case of vehicles: metallic environment; antenna integration is complex!!
- Easy to deploy channel, but….
- It is variable and hostile!
- Moreover: it is detectable…**security**???

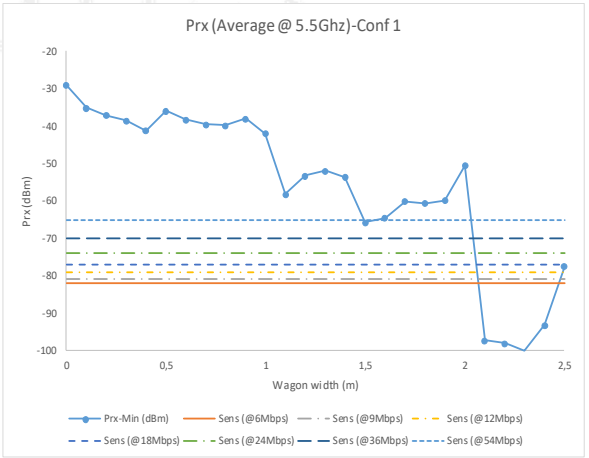
Wireless Channel





QOS: Link Balance Analysis:





$$P_{RX} = P_{TX} - L_{cable,\ feed} + G_{TX\ ant} - L_{radioprop} + G_{RX\ ant} - L_{cable,\ feed}$$

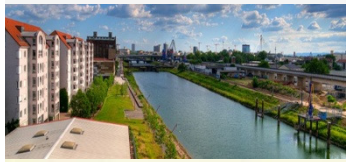
Several considerations must be taken:

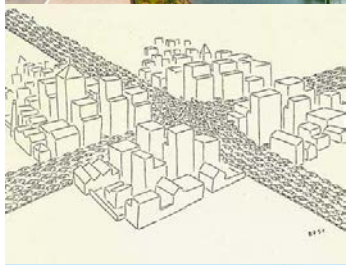
- $P_{RX} \geq SENS_{RX}$
- $SENS_{RX} \leftrightarrow f(\text{modulation scheme, coding, binary rate, hw})$

Compuslory to compute coverage/capacity requirements!

Wireless Channel

$$P_{RX} = P_{TX} - L_{cable,\ feed} + G_{TX\ ant} - L_{radioprop} + G_{RX\ ant} - L_{cable,\ feed}$$



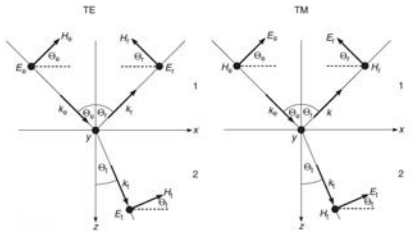


FSL

$$P_{RX}(d) = P_{TX} G_{TX} G_{RX} \left(\frac{\lambda}{4\pi d}\right)^2$$

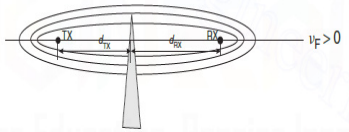
Distance/Freq dependence

Reflection/Transmission



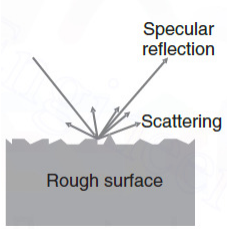
Angle/Material/Polarization/Freq

Diffraction

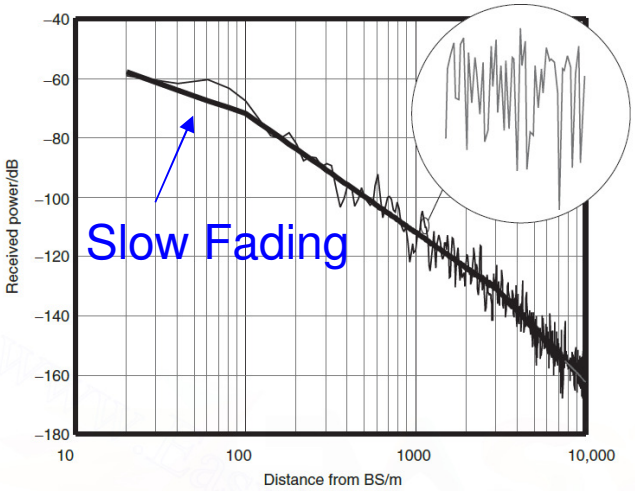


Object Geometry
Single/Multiple Diffraction
PEC/Dielectric

Scattering



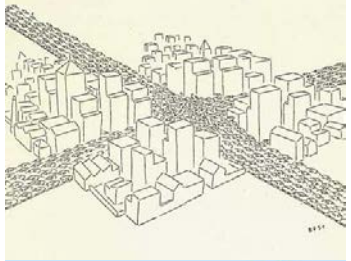
Rough Surfaces/Diffuse Scattering
Lambert/Spatial Correlation



Fast Fading (MPC)

Indoor
Wearable/body
Vegetation
Vehicular
Industrial
……

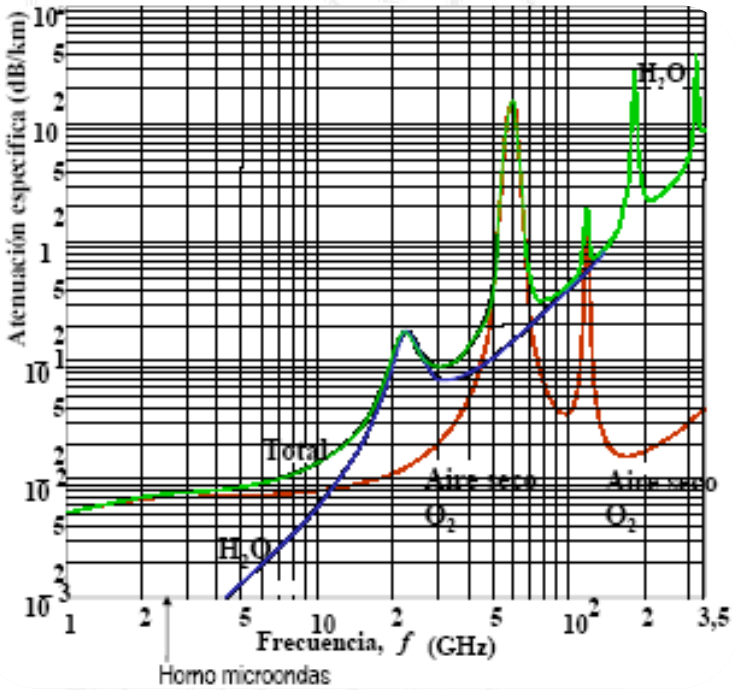
Wireless Channel



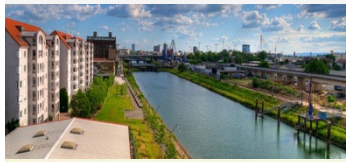
Tropospheric propagation is affected by the dispersive nature of constituents of atmposphere:

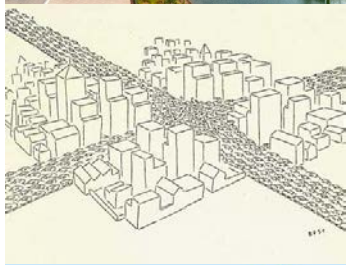
TABLE 9.1 Composition of Dry Atmosphere from Sea Level to about 90 km (Livingston, 1970)

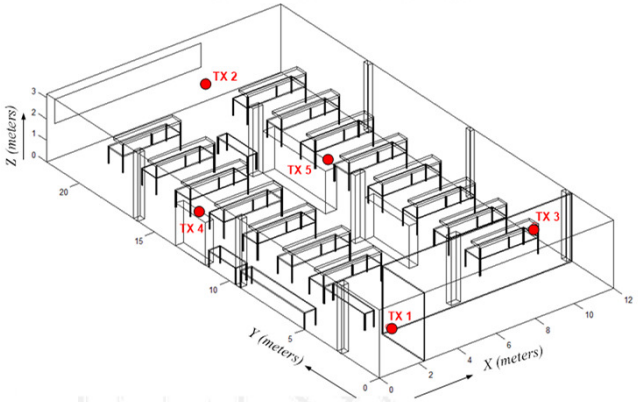
Constituent	Percent by Volume	Percent by Weight
Nitrogen	78.088	75.527
Oxygen	20.949	23.143
Argon	0.93	1.282
Carbon dioxide	0.03	0.0456
Neon	1.8×10^{-3}	1.25×10^{-3}
Helium	5.24×10^{-4}	7.24×10^{-5}
Methane	1.4×10^{-4}	7.75×10^{-5}
Krypton	1.14×10^{-4}	3.30×10^{-4}
Nitrous oxide	5×10^{-5}	7.6×10^{-5}
Xenon	8.6×10^{-6}	3.90×10^{-5}
Hydrogen	5×10^{-5}	3.48×10^{-6}

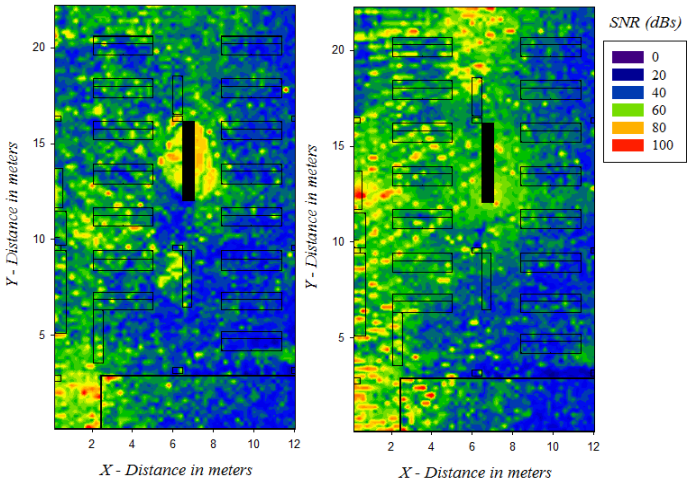


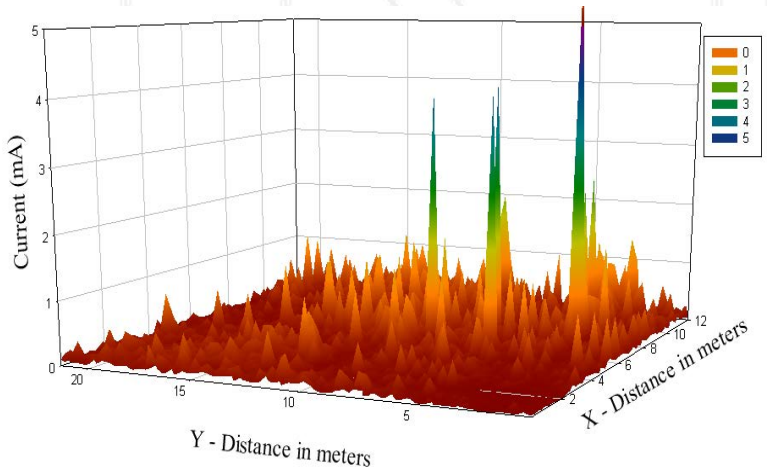
Wireless System Performance Analysis

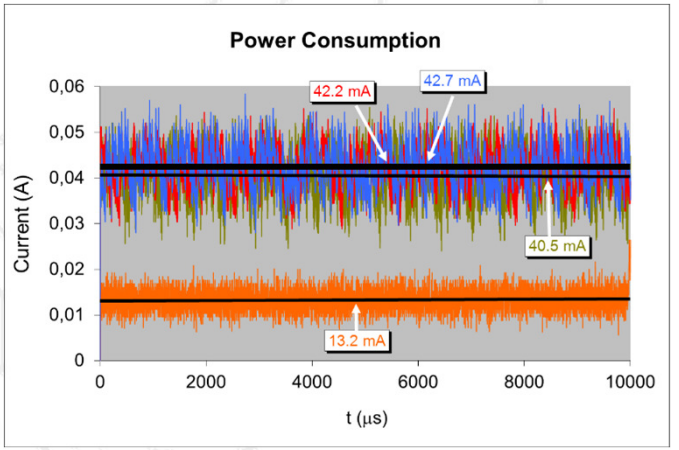




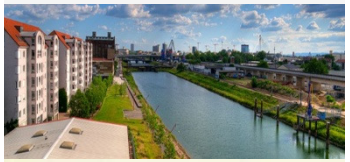


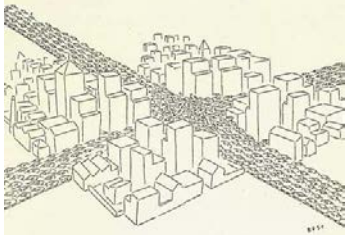






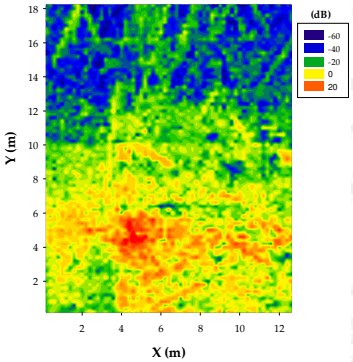
P. Lopez et al, "Analysis of Energy Consumption Performance towards Optimal Radioplanning of Wireless Sensor Networks in Heterogeneous Indoor Environments", Radioengineering 2014



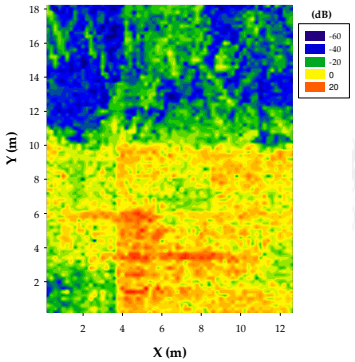


Interference

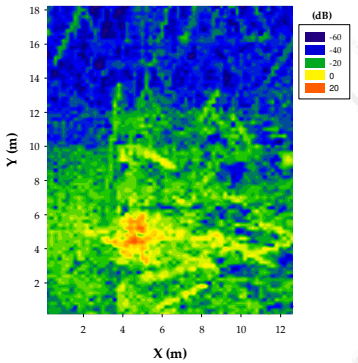
SNR: TX1, 2.4 GHz, 7 antennas, h=0.5m



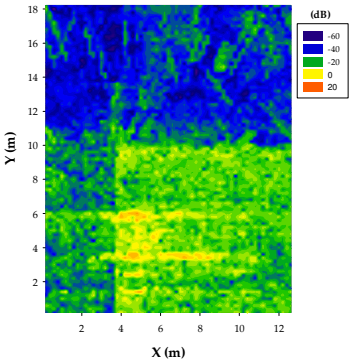
SNR: TX1, 2.4 GHz, 7 antennas, h=2m



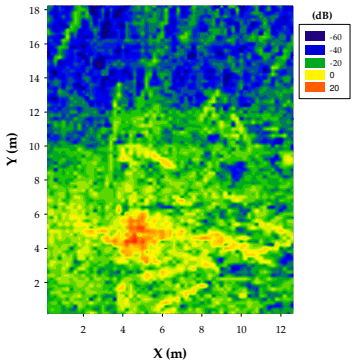
SNR: TX1, 2.4 GHz, 54 antennas, h=0.5m



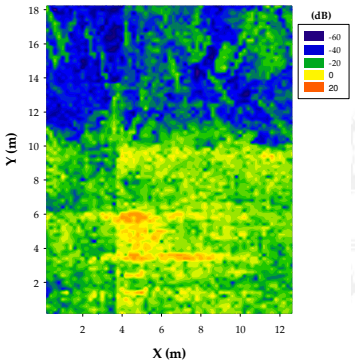
SNR: TX1, 2.4 GHz, 54 antennas, h=2m



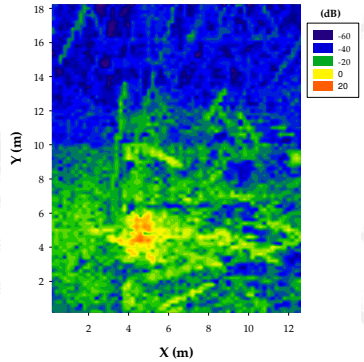
SNR: TX1, 2.4 GHz, 27 antennas, h=0.5m



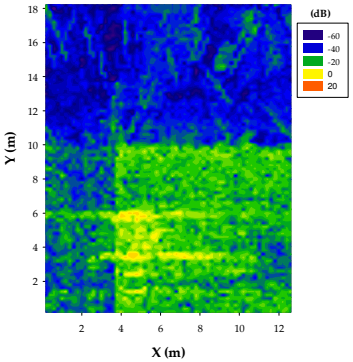
SNR: TX1, 2.4 GHz, 27 antennas, h=2m



SNR: TX1, 2.4 GHz, 108 antennas, h=0.5m

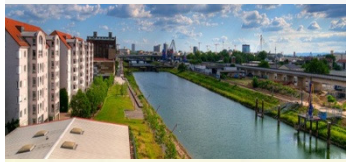


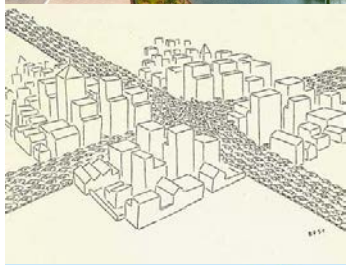
SNR: TX1, 2.4 GHz, 108 antennas, h=2m



P. Lopez, L. Azpilicueta. E. Aguirre, F. Falcone , "Wireless Performance in Dense-Transceiver Scenarios to Enable Context-Aware Scenarios", Radio Channel Characterization", The World of Applied Electromagnetics, Chapter 13, Elsevier, 2018

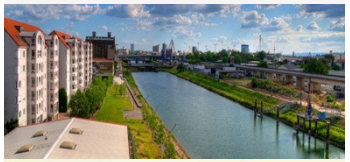
Coverage/Capacity Considerations

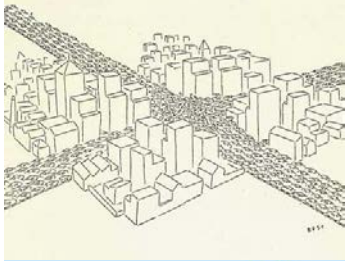


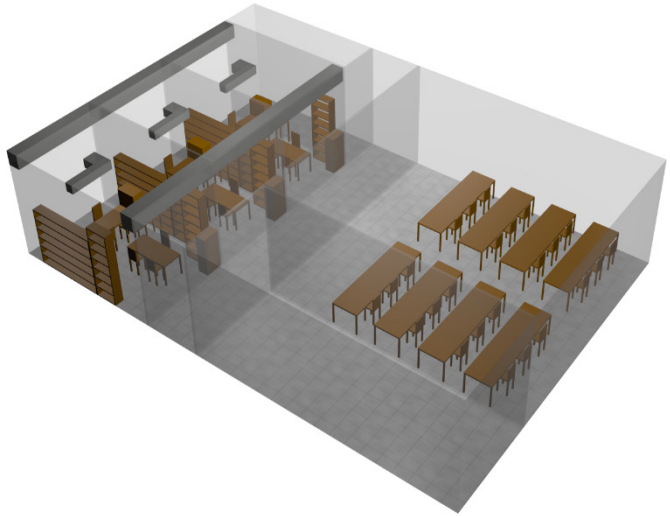


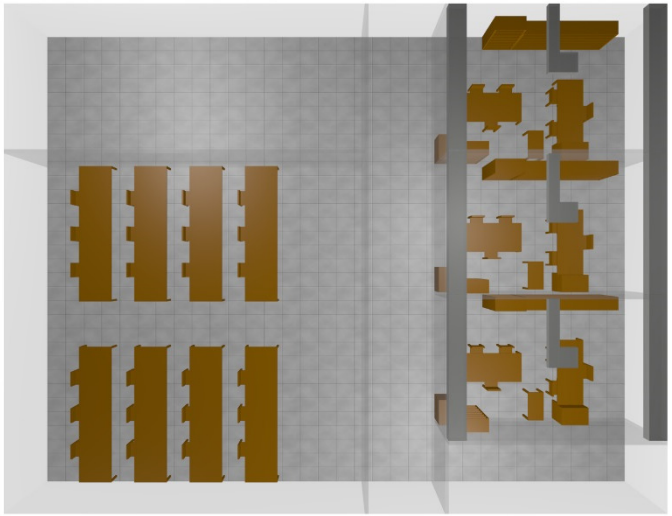
- Receiver sensitivity varies dynamically, as a function of:
  - Bit rate: an increase in bit rate modifies the values of energy per bit
  - Coding scheme: as a function of detection capabilities and required redundancy
  - Modulation scheme: compromise between sensitivity and spectral efficiency
  - HW factors: Noise Factor levels
  - Use of diversity mechanisms:
    - Conventional: frequency, space, time, polarization
    - Advanced/Hybrid: different implementations of MIMO techniques
- **Interference-Node distribution play a key role in QoS/QoE determination**

Node Density Analysis





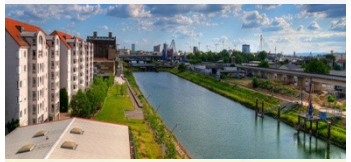


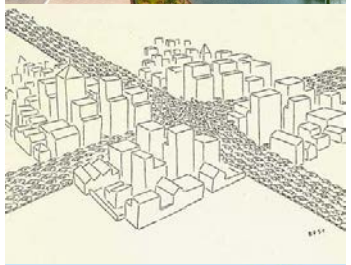


Material	2.4 GHz	5.8 GHz
Concrete	8.1	5.5
Brick Wall	4.44	3.56
Glass	6.06	5.98
Wood	2.88	2.05
Plasterboard	2.02	2.02

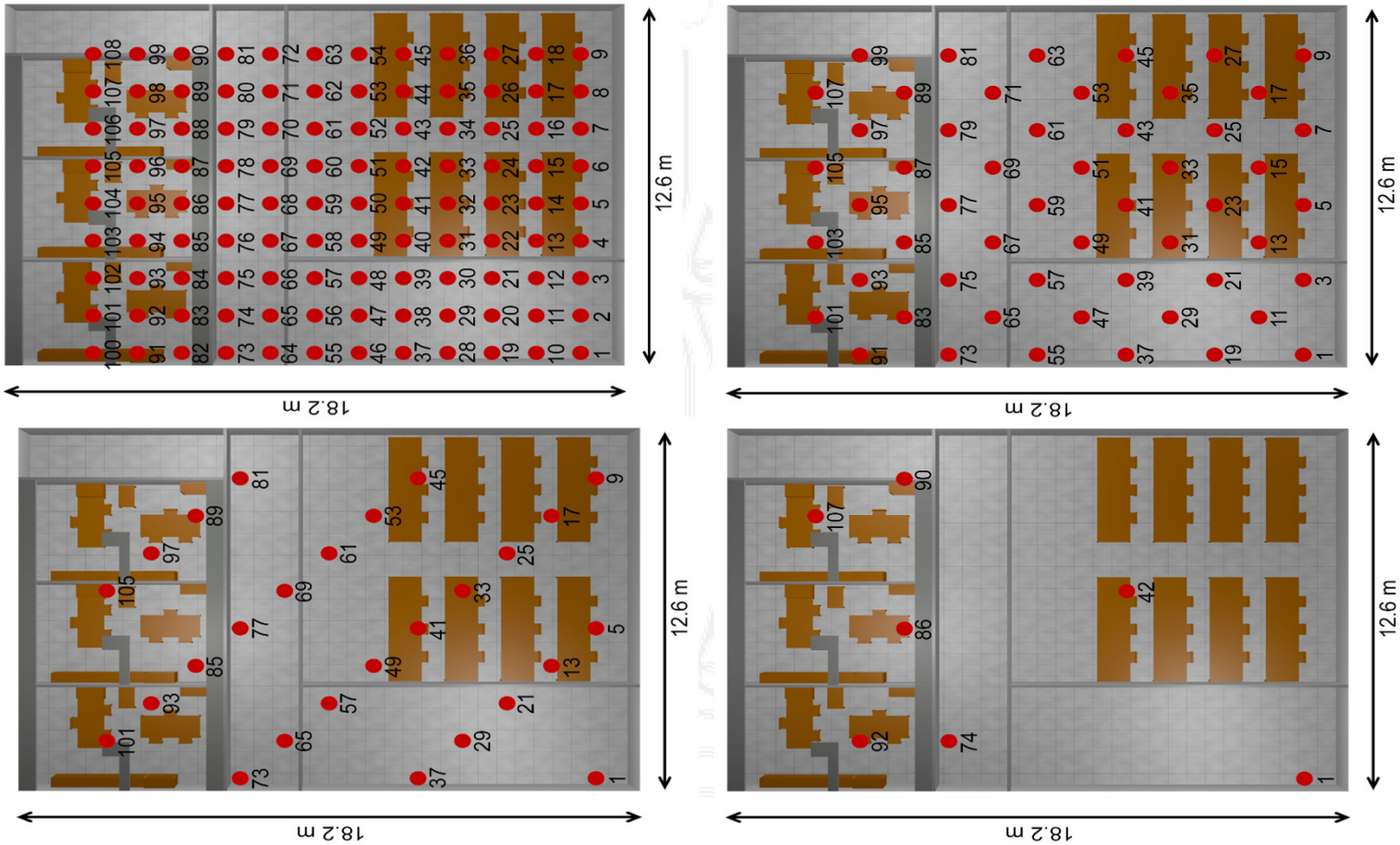
Material	2.4 GHz	5.8 GHz
Concrete	0.02	5.01×10^{-2}
Brick Wall	0.11	9.46×10^{-2}
Glass	0.11	2.99×10^{-1}
Wood	0.21	8.23×10^{-2}
Plasterboard	0	1.48×10^{-2}

Parameter	2.4 GHz	5.8 GHz
Transmitted power	10 dBm	10 dBm
Transmission data rate	250 Kbps	1 Mbps
Antenna type	Monopole	Monopole
Antenna gain	0 dB	0 dB
Launched rays angle resolution	1°	1°
Maximum permitted reflections	6	6
Cuboids resolution	20 cm	20 cm

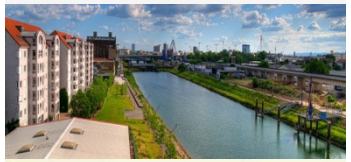


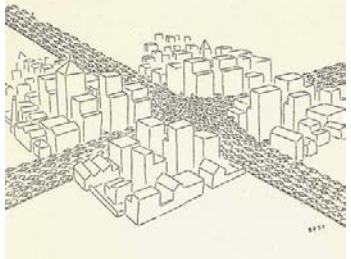


Node Density Analysis



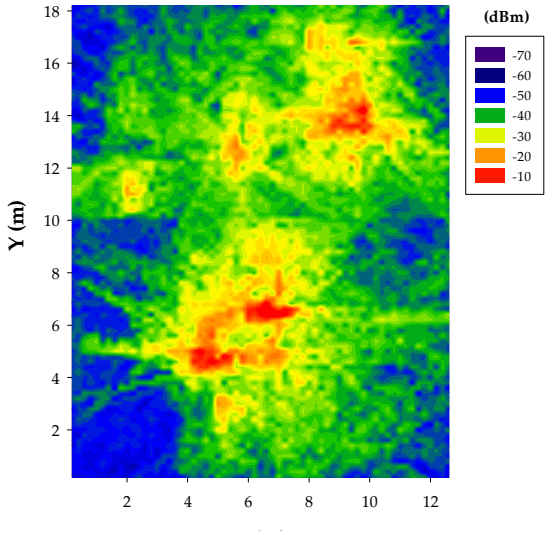
- 108 Sources
- Variable density (108 to 7 sources in the scenario)
- Uniform & Random distributions



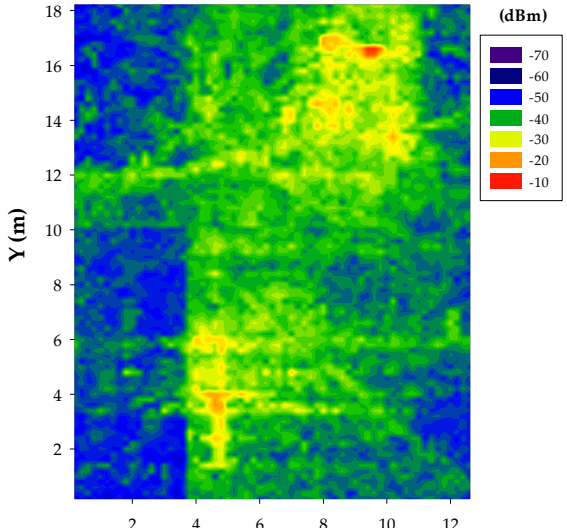


Node Density Analysis

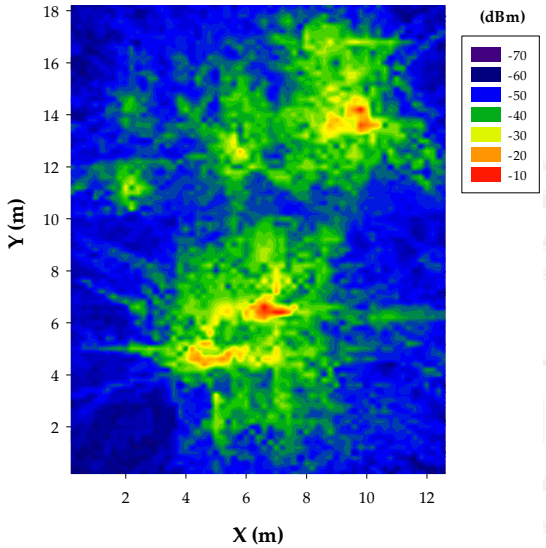
2.4 GHz, Wearables, h=0.5m



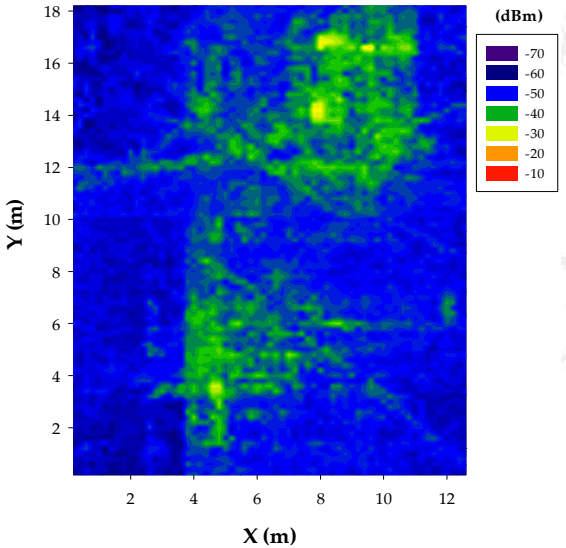
2.4 GHz, Wearables, h=2m



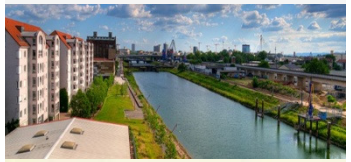
5.8 GHz, Wearables, h=0.5m

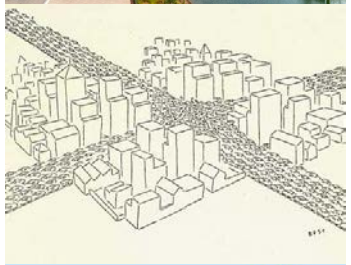


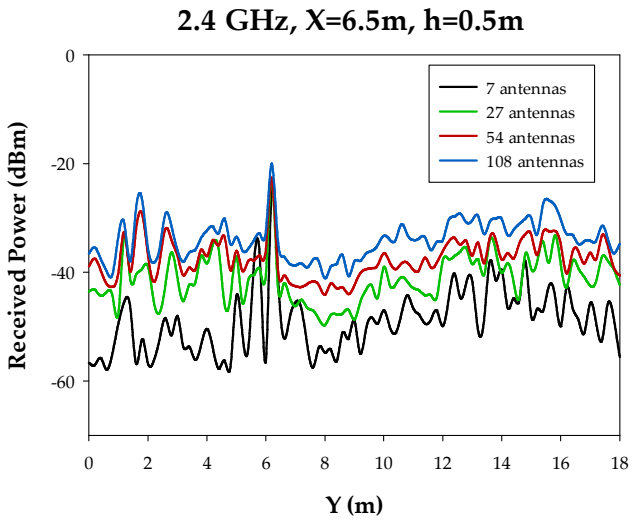
5.8 GHz, Wearables, h=2m

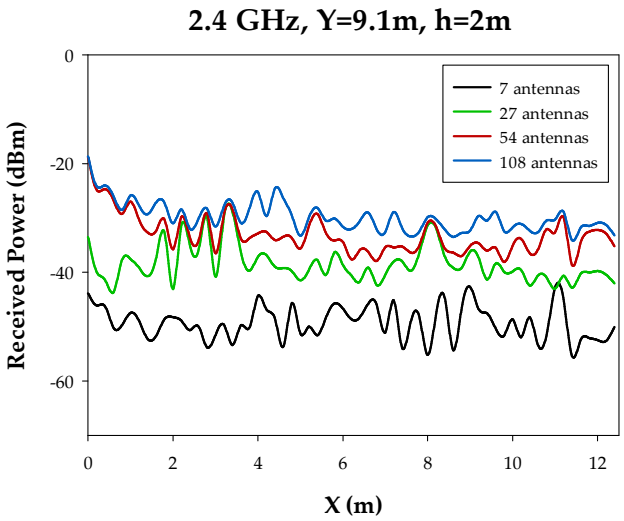


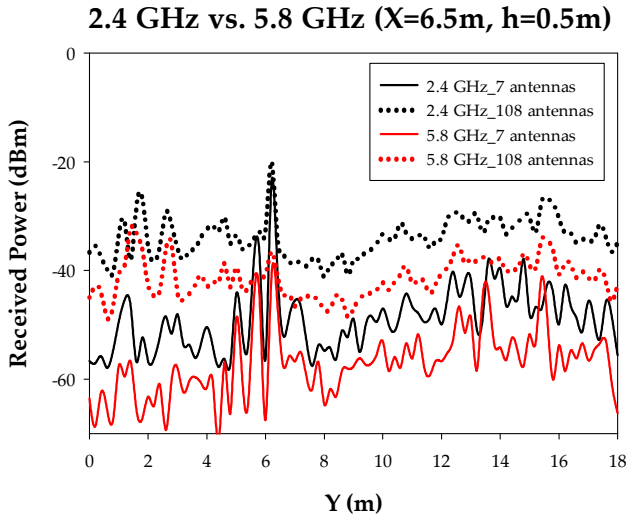
Node Density Analysis



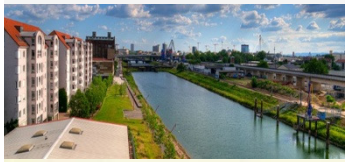


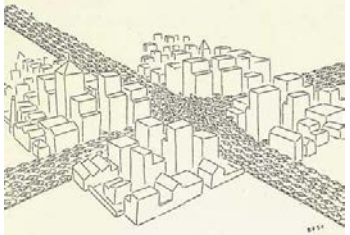


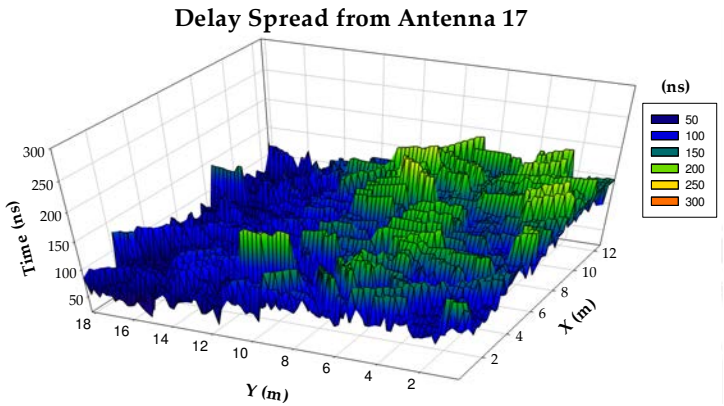


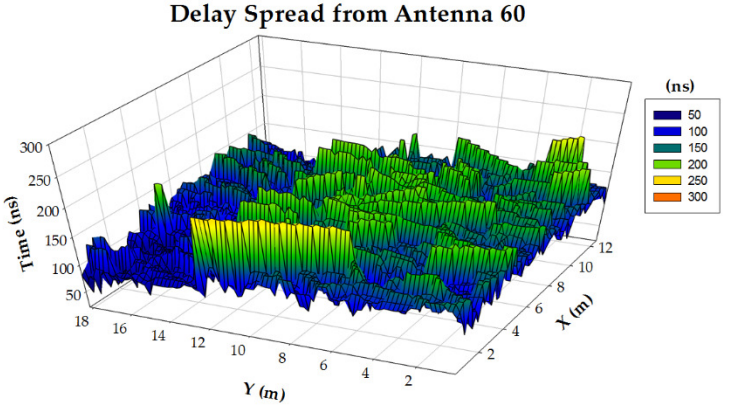


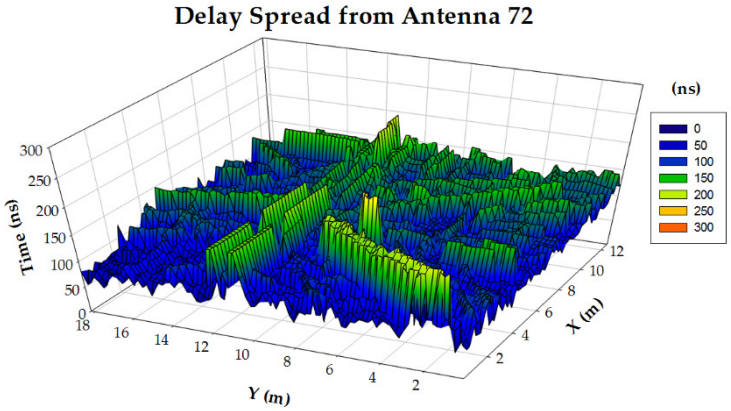
Node Density Analysis-Delay Spread

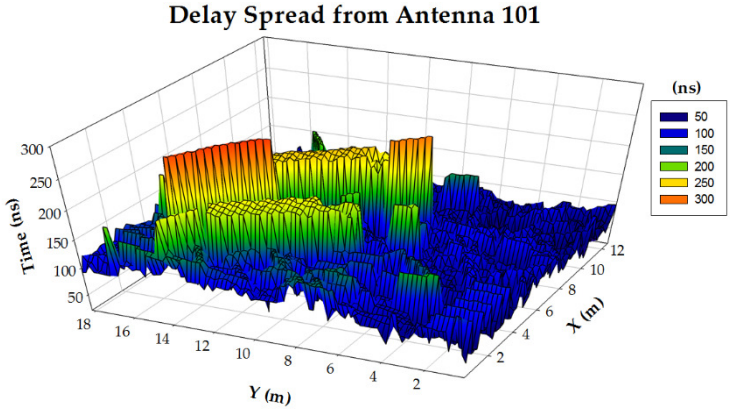






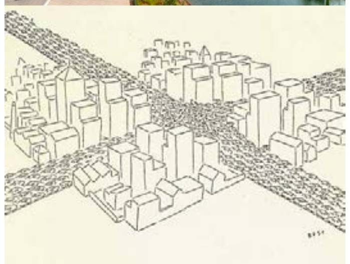




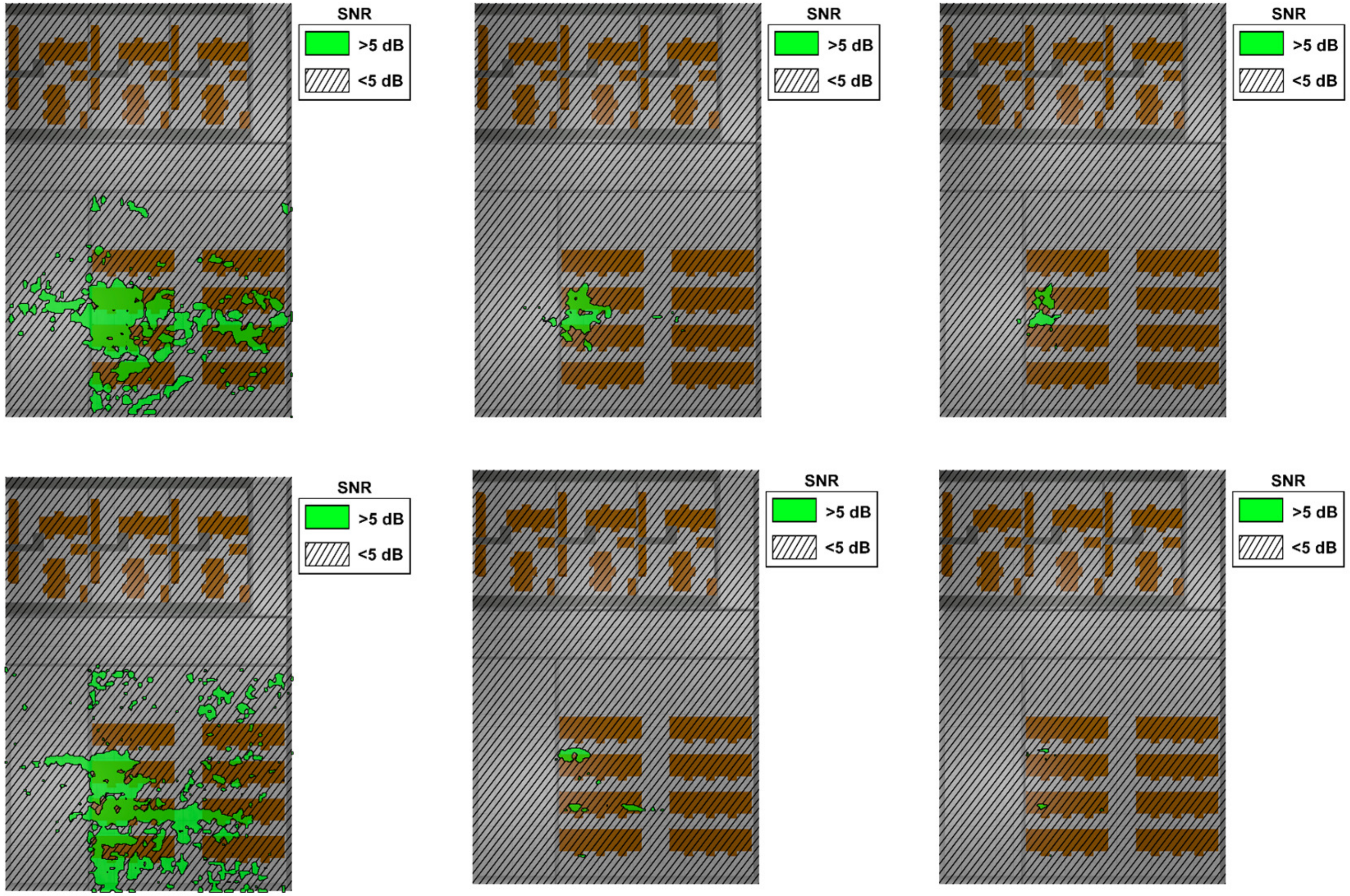


Antenna #	Mean value (ns)	Standard Dev (ns)
17	110	31
23	117	31
60	123	26
65	120	35
72	111	24
101	105	39

López-Iturri, P.; Aguirre, E.; Azpilicueta, L.; Astrain, J.J.; Villandangos, J.; Falcone, F. Challenges in Wireless System Integration as Enablers for Indoor Context Aware Environments. Sensors 2017, 17, 1616.


Node Density Analysis-QoS



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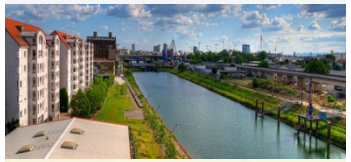
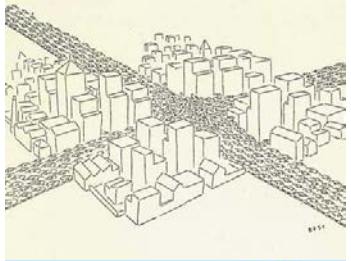
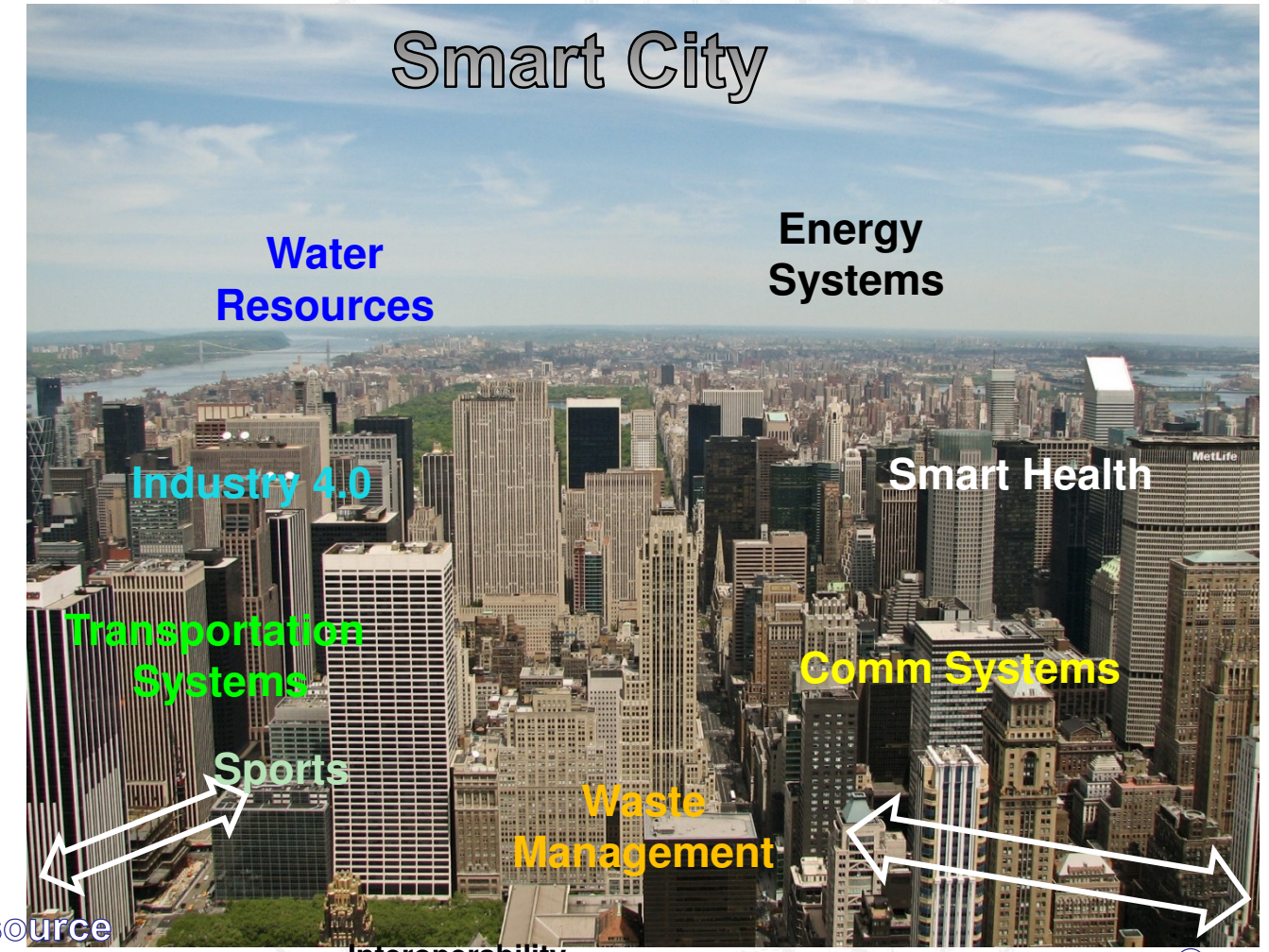
López-Iturri, P.; Aguirre, E.; Azpilicueta, L.; Astrain, J.J.; Villandangos, J.; Falcone, F. Challenges in Wireless System Integration as Enablers for Indoor Context Aware Environments. Sensors 2017, 17, 1616.

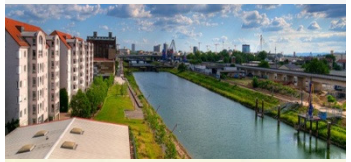
Smart City Connectivity and Applications

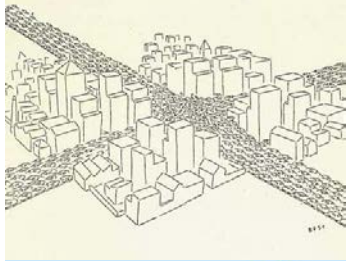


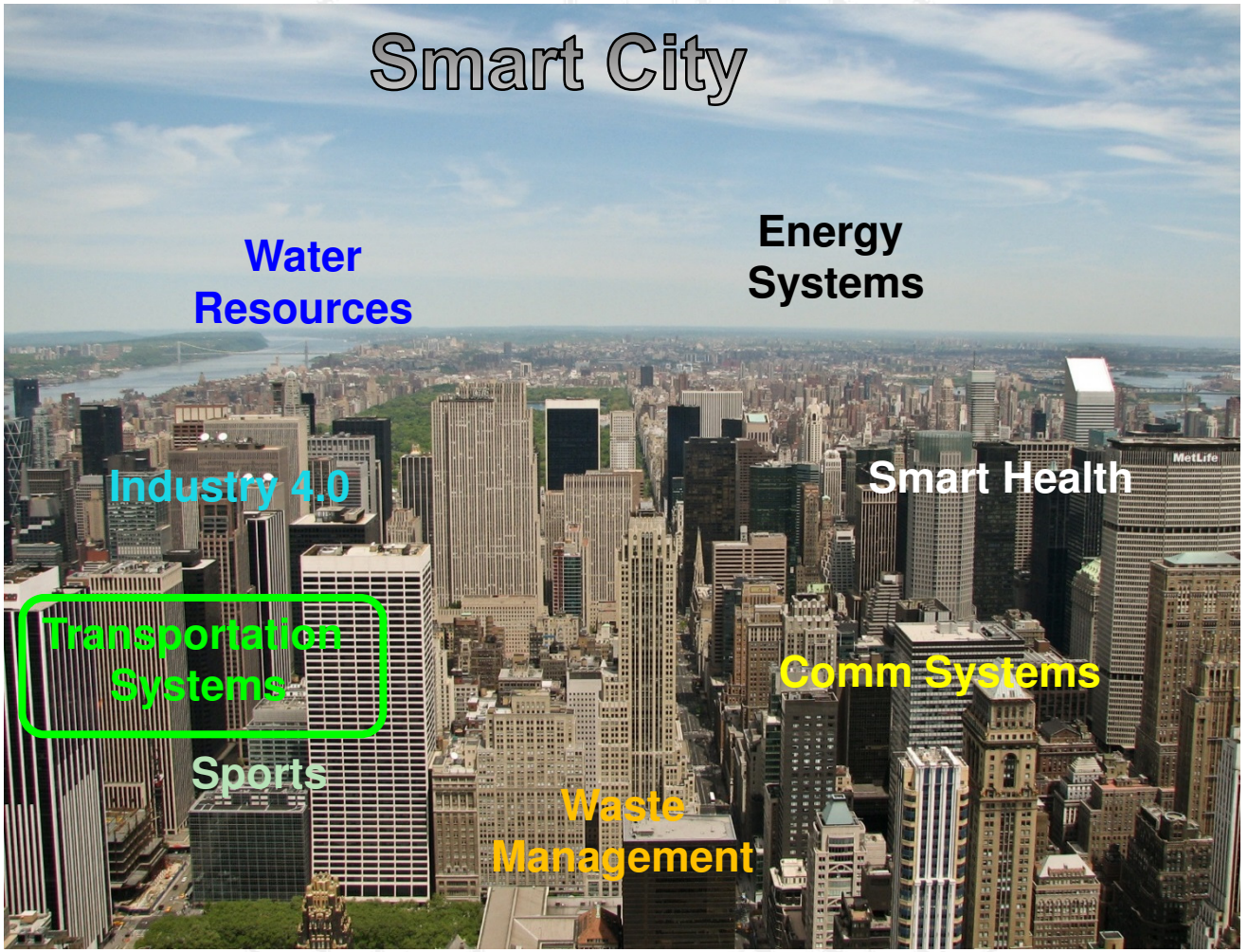




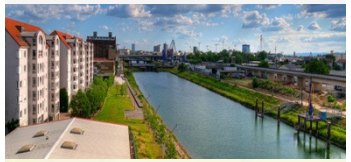
- Interoperability
- Big Data Management
- Seamless Interaction
- User Centric: Usabilty and Adoption

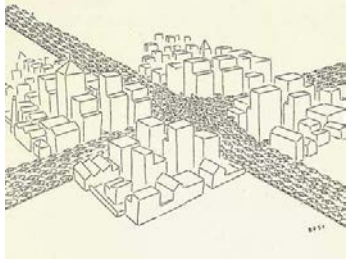





Smart City
Water Resources
Energy Systems
Industry 4.0
Smart Health
Transportation Systems
Comm Systems
Sports
Waste Management

ITS-Introduction





Advanced Notification of Road Hazards	Optimal Vehicle Distance Setting and Route Planning
Multiple Communication Scheme Operation	Location Specific Application of Traffic Regulation
Journey Planning and Handling of Multimodal Public Transportation Systems	Logistic and Custom Operation Handling


Briefing
September 2017

EU strategy on cooperative intelligent transport systems

SUMMARY

Digital technologies, and systems based on them, are being rapidly introduced in transport all over the world. Cooperative intelligent transport systems (C-ITS) in road transport are part of this development, and one element in a wider drive towards vehicle automation. These systems use technologies allowing road vehicles to communicate with other vehicles or road users and roadside infrastructure. By increasing the quality and reliability of information, C-ITS can improve road safety and traffic efficiency as well as reduce energy consumption and emissions from transport, provided that cyber security and data protection are ensured.

The European Commission has put forward a strategy outlining the path towards commercial deployment of C-ITS in the EU by 2019, seeking to avoid market fragmentation and maintain EU competitiveness. The main steps proposed are to adopt a legal framework for providing investors with legal certainty, to make EU funding available for projects, and to continue cooperation with EU stakeholders and international partners. The strategy addresses key issues such as data protection and cyber-security, systems interoperability and technical specifications. In the meantime, several ongoing pilot projects are consolidating the experience to be shared.

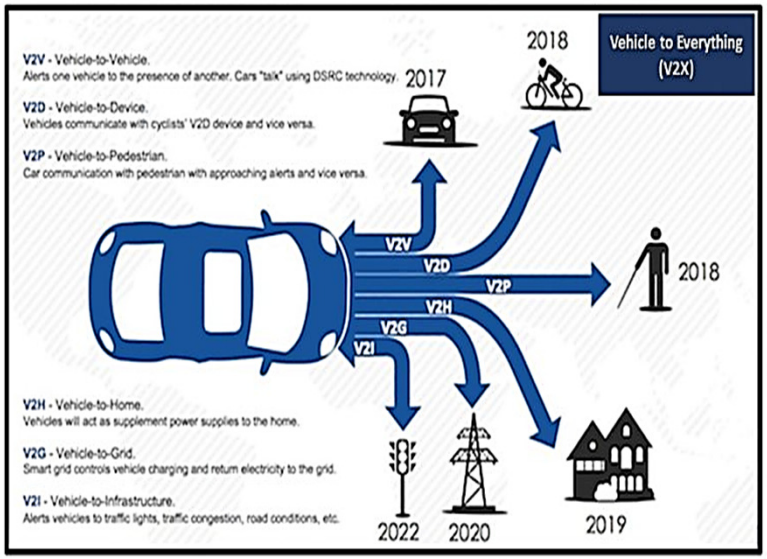
The European Parliament, a long-time supporter of C-ITS and defender of personal data protection, is preparing a report on the strategy.


ITU-R

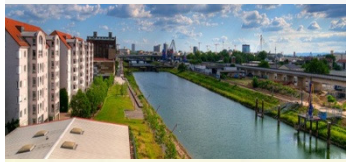
Report ITU-R M.2228-1

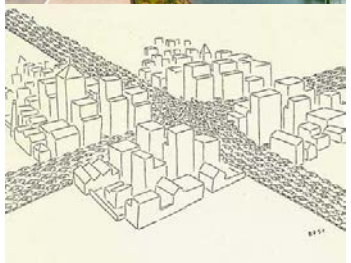
Advanced intelligent transport systems radiocommunications

M Series
Mobile, radiodetermination, amateur and related satellite services



ITS-What should they do?

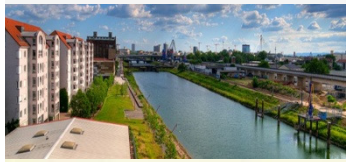


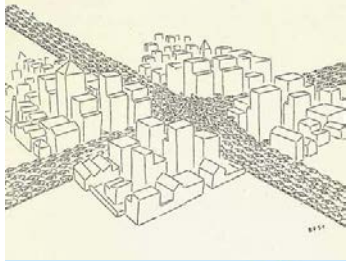


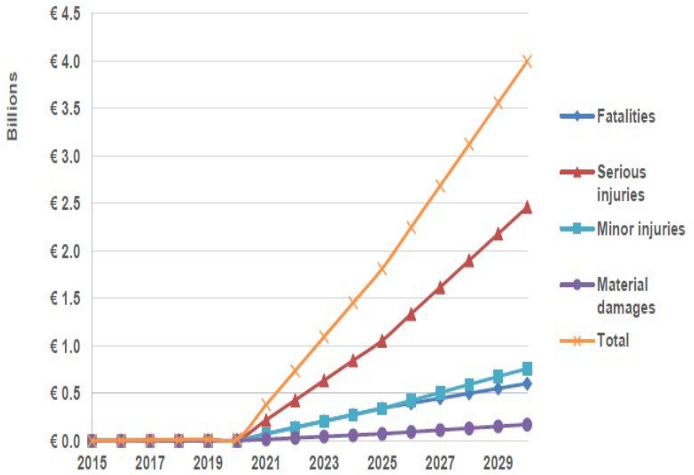
- Can notify drivers in advance of **hazards on the road** ahead before they are visible.
- Can improve **driver safety**, e.g., by keeping vehicles at a safe distance from one another by suggesting optimum speed based on various parameters related to traffic conditions.
- Makes use of **machine-to-machine (M2M)** communications, which include vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications as special cases.
- Keeps the **drivers informed** of the local speed limit. In addition, they can also provide area specific information (parking lots, service stations)
- Provides users with **real-time information** on public transport services, real-time travel and traffic information (RTTI), as well as smart and seamless ticketing solutions. With this kind of service information, ITS can enable users to plan their journey in a multimodal way.
- Enforces a **specific traffic regulation policy**, e.g., buses and trams can be given priority by integrating public transport into traffic-management systems.
- Serves the needs of **freight operators and customs authorities**. This is accomplished by tracking the position and status of shipments, as well as by directing their vehicles along the most efficient, economical, and secure route.
- By choosing the optimal route and speed to the destination, ITS can **maximize the efficiency of vehicles**. As a result, the CO2 emissions can be reduced.

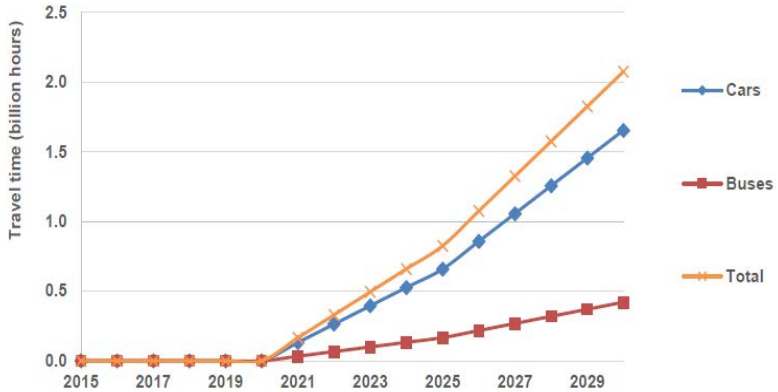
G. Rafiq et al., "What's New in Intelligent Transportation Systems?", IEEE Vehicular Technology Magazine, Dec, 201310

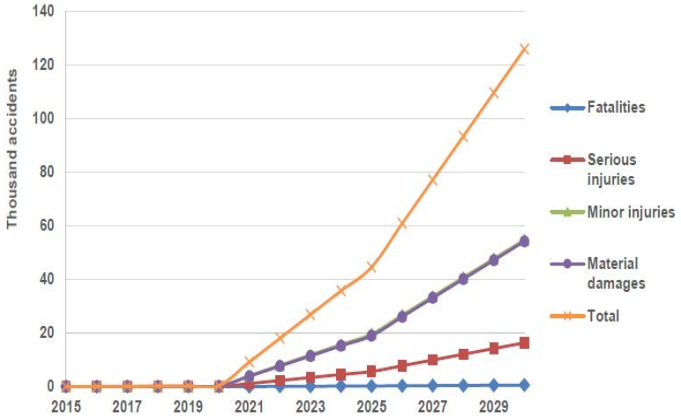
ITS-Impact







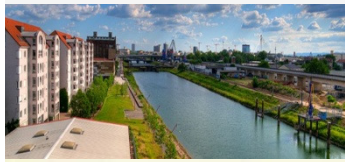


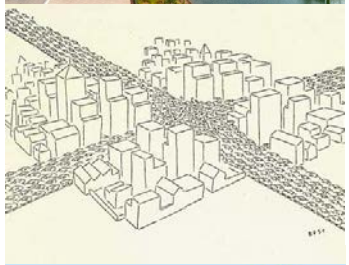


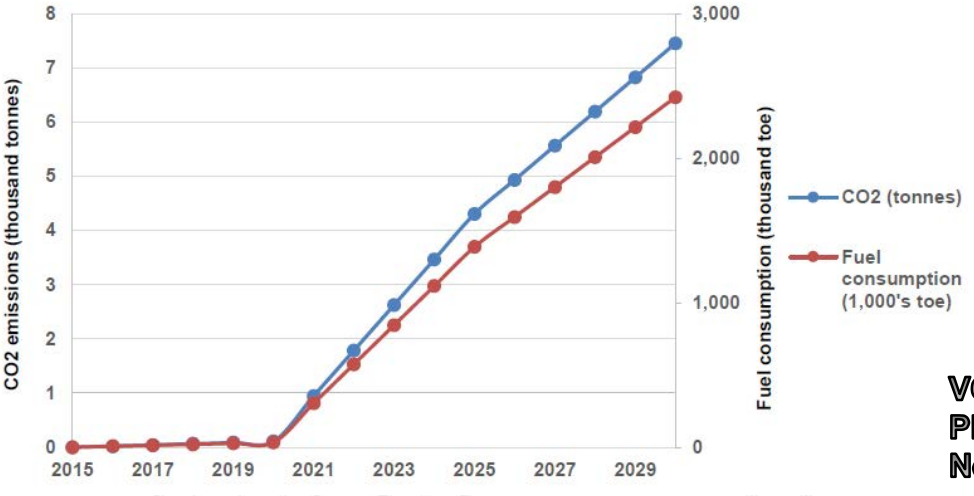
- Fatalities: reduced by c. 600/year by 2030, representing a c. 7% reduction in estimated fatalities.
- Serious injuries: reduced by c. 16,000/year by 2030, representing a c. 7% reduction in estimated serious injuries.
- Minor injuries: reduced by c. 54,500/year by 2030, representing a c. 7% reduction in estimated minor injuries.
- Material damages: reduced by c. 54,000/year by 2030, representing a c. 7% reduction in estimated material damages.

Ricardo/ED60721/Issue Number 1

ITS-Impact

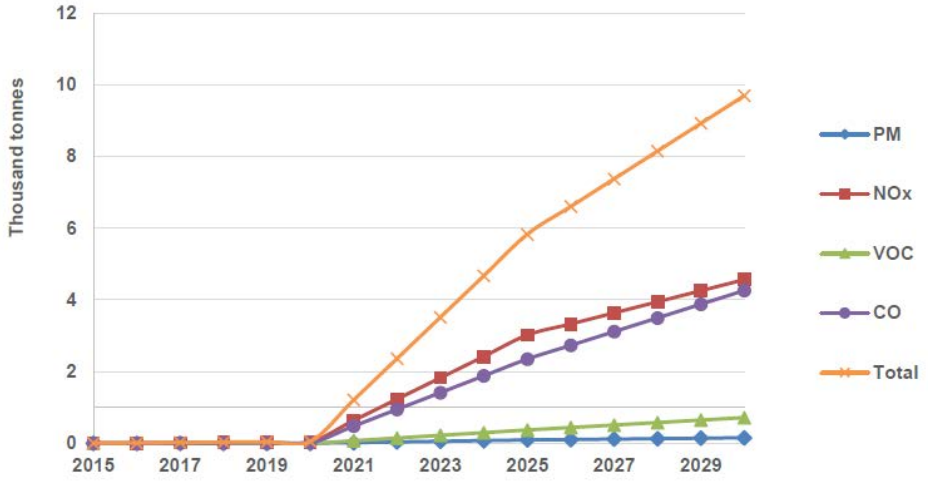






- Fuel consumption is reduced by c. 2.4 million toe/year by 2030, or c. 1.2% of baseline fuel consumption.
- CO2 emissions are reduced by c. 7,500t/year by 2030, or c. 1.2% of baseline emissions.

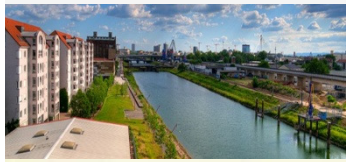
VOC: Volatile Organic Compounds
PM: Particulate Matter
Nox: Nitrogen Oxides

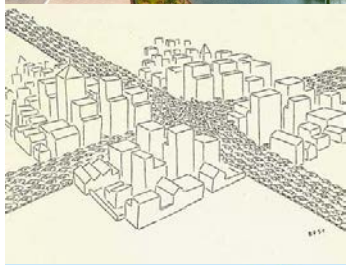


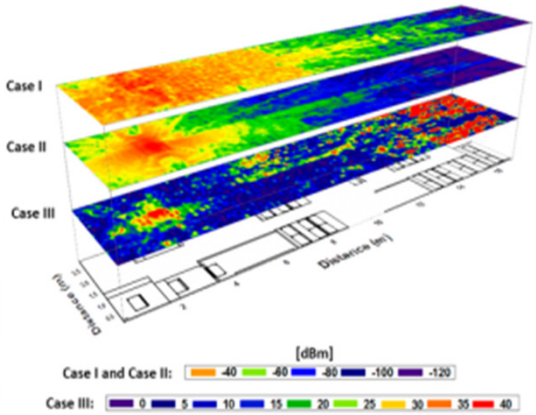
- NOx emissions are reduced by c. 4,500t/year by 2030, or c. 0.7% of baseline emissions in that year.
- CO emissions are reduced by c. 4,300t/year by 2030, or c. 0.4% of baseline emissions.
- VOC emissions are reduced by c. 700t/year by 2030, or c. 0.4% of baseline emissions.
- PM emissions are reduced by c. 150t/year by 2030, or c. 0.5% of baseline emissions.

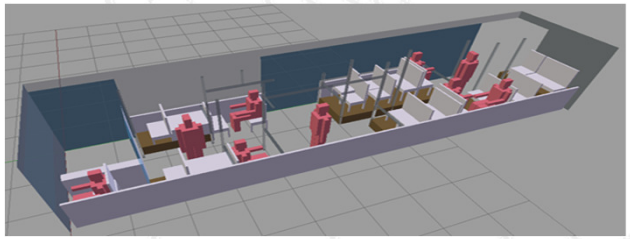
Ricardo/ED60721/Issue Number 1

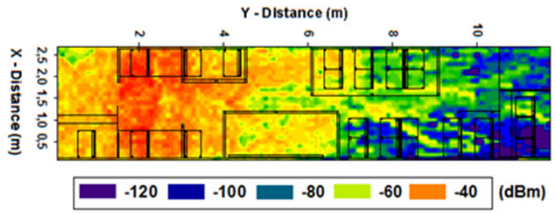
Urban Buses

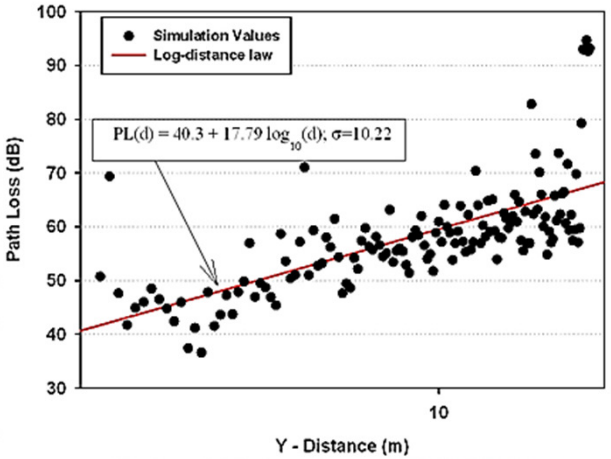








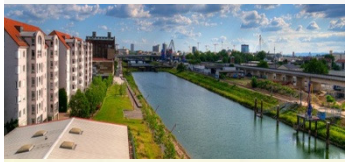


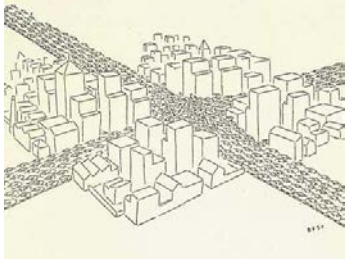


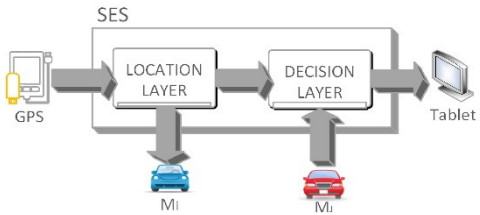
L. Azpilicueta, P. Lopez-Iturri, E. Aguirre, J.J. Astrain, J. Villadangos, C. Zubiri and F. Falcone, "Characterization of Wireless Channel Impact on Wireless Sensor Network Performance in Public Transportation Buses", IEEE Transactions on Intelligent Transportation Systems, In press.

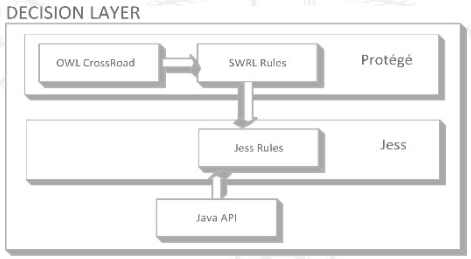
Mancomunidad Comarca de Pamplona Iruñerriko Mankomunitatea

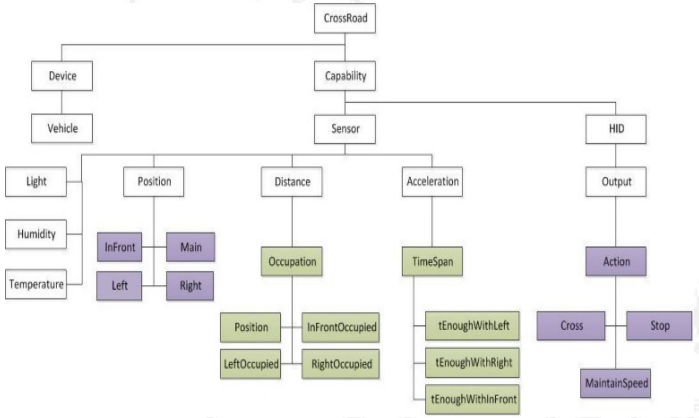
SesToCross

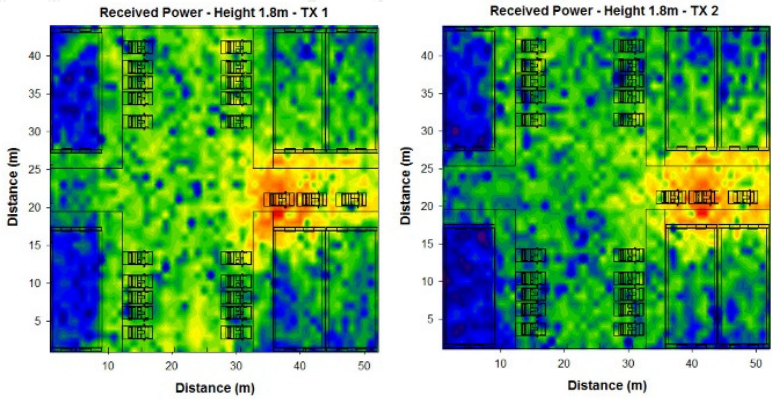






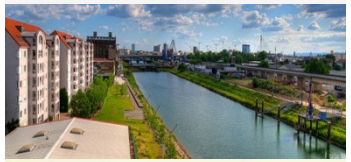


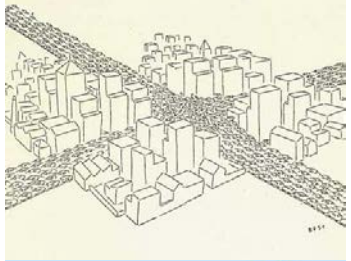


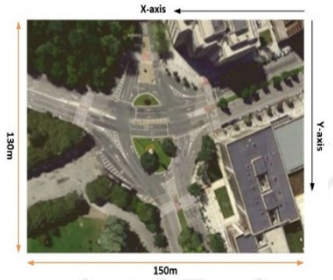


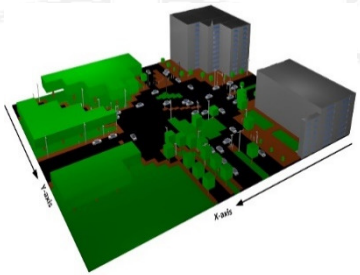
Alberto Córdoba, José Javier Astrain, Jesús Villadangos, Leire Azpilicueta, Peio López-Iturri, Erik Aguirre, Francisco Falcone, " SesToCross: Semantic Expert System to Manage Single-Lane Road Crossing", IEEE Transactions on Intelligent Transportation Systems, May 2017

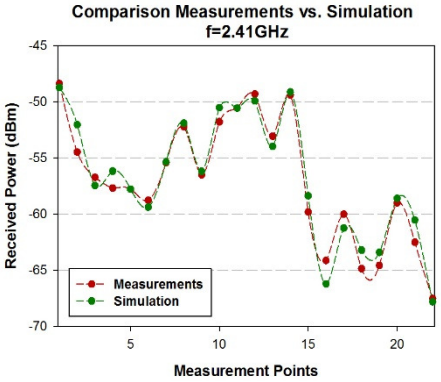
Traffic Lights-V2P

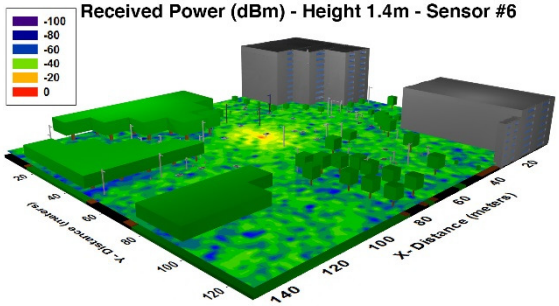


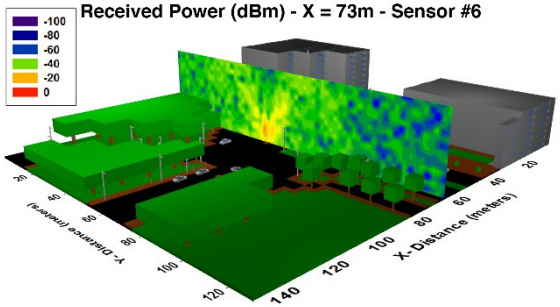


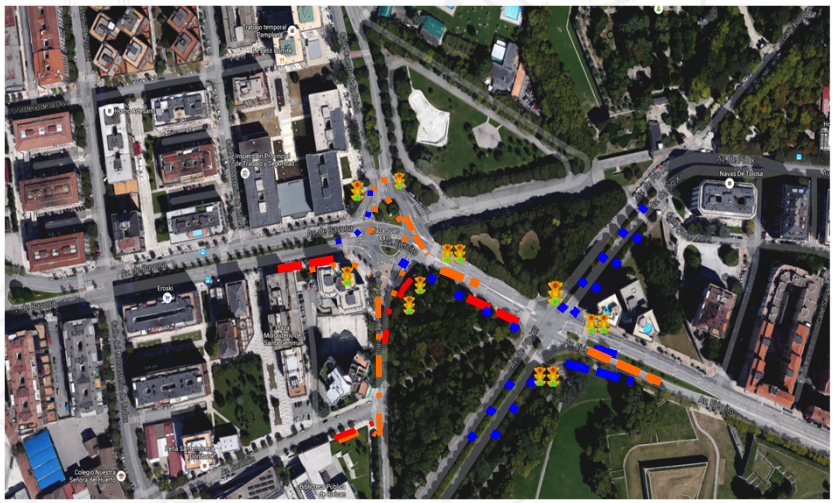






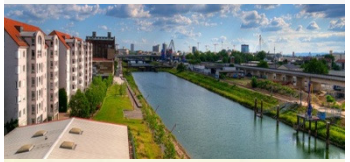


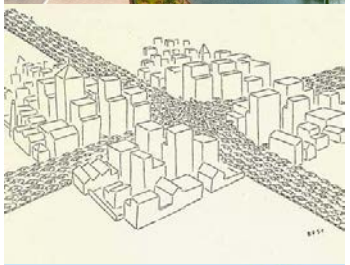


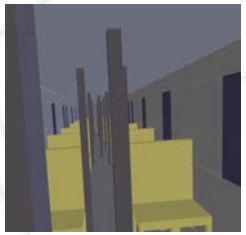


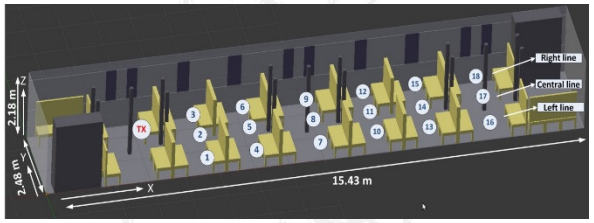
L. Azpilicueta et al, "Evaluation of Deployment Challenges of Wireless Sensor Networks at Signalized Intersections", Sensors, August 2016

WSN in Trains

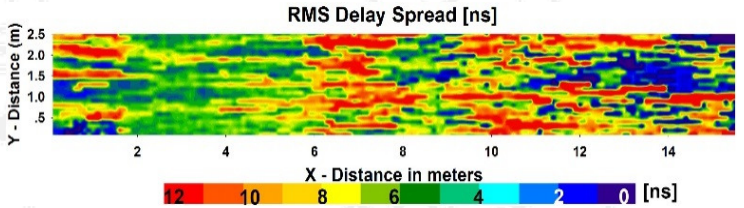


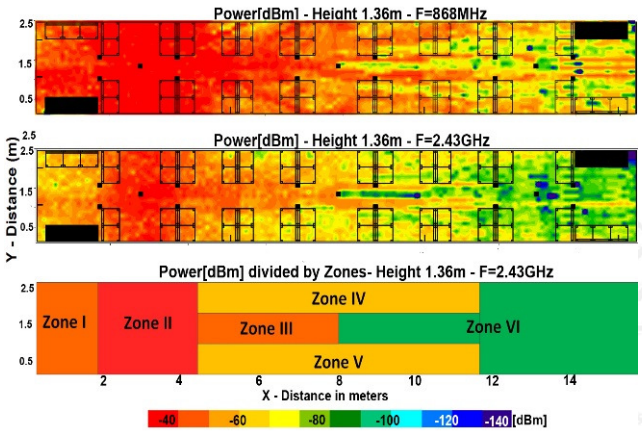


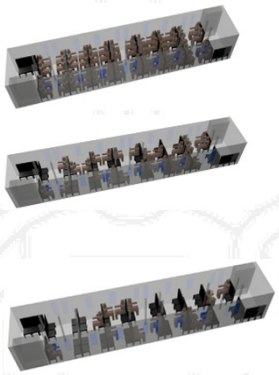


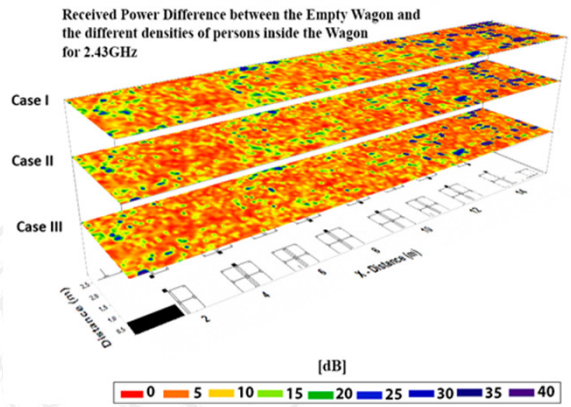


- Implementation Added Value Service based on WLAN/WBAN inside trains
- Monitoring support
- Route/Service information

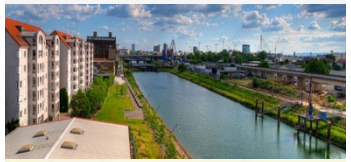


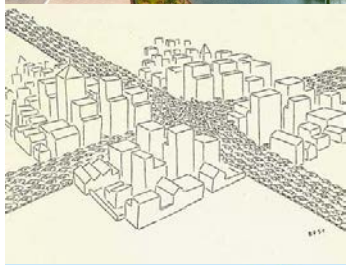




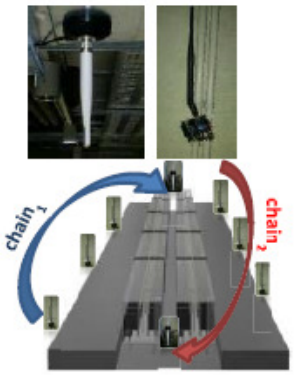


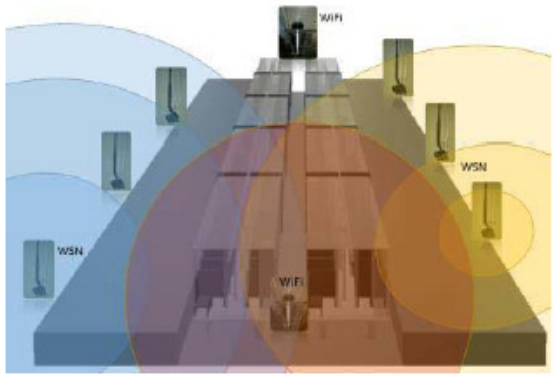
Leyre Azpilicueta, Jose Javier Astrain, Peio Lopez-Iturri, Fausto Granda-Gutierrez, Cesar Vargas-Rosales, Jesus Villadangos, Asier Perallos, Alfonso Bahillo, Francisco Falcone, "Optimization and Design of Wireless Systems for the Implementation of Context Aware Scenarios in Railway Passenger Vehicles", IEEE Transactions on Intelligent Transportation Systems, 2017

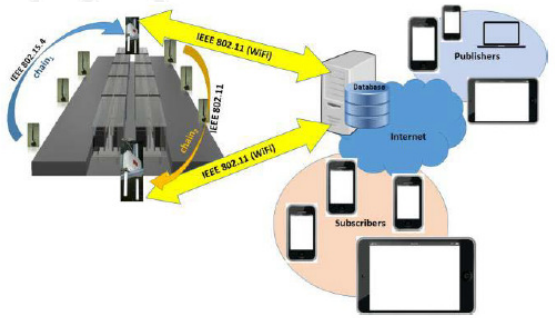


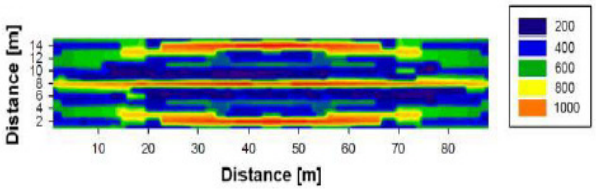


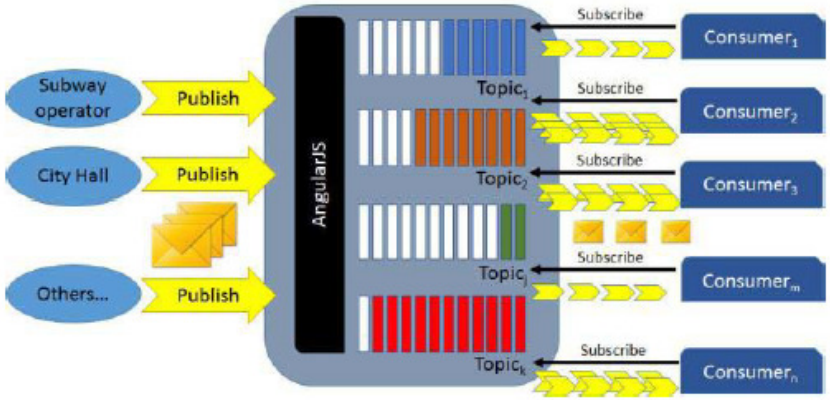
Intra-Station Communications

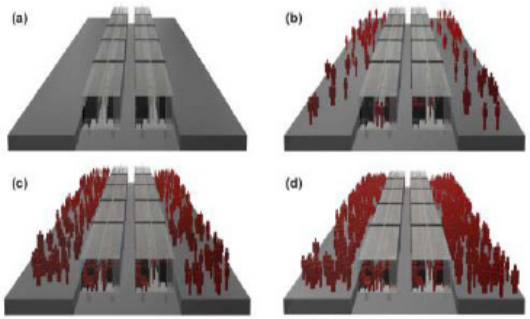






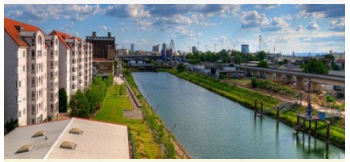






Erik Aguirre, Peio Lopez-Iturri, Leyre Azpilicueta, Aitor Redondo, José Javier Astrain, Jesús Villadangos, Alfonso Bahillo, Asier Perallos, and Francisco Falcone, "Design and Implementation of Context Aware Applications With Wireless Sensor Network Support in Urban Train Transportation Environments", IEEE SENSORS JOURNAL, VOL. 17, NO. 1, JANUARY 1, 2017

Urban Bus Monitoring



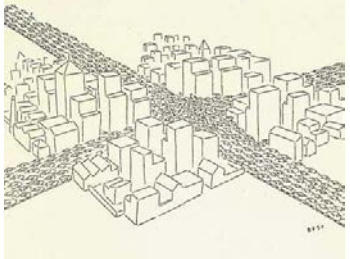
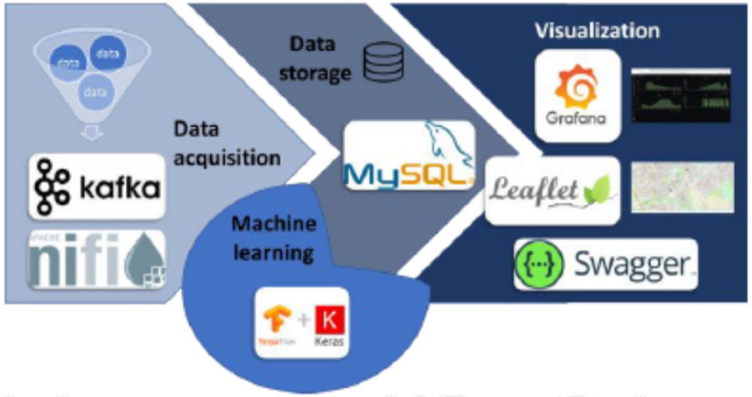
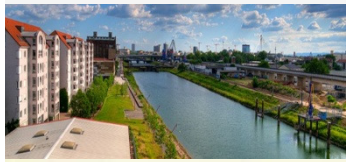
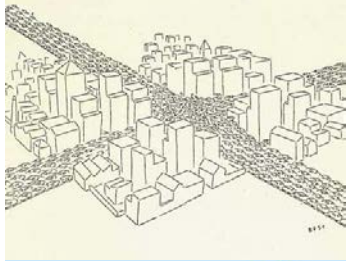


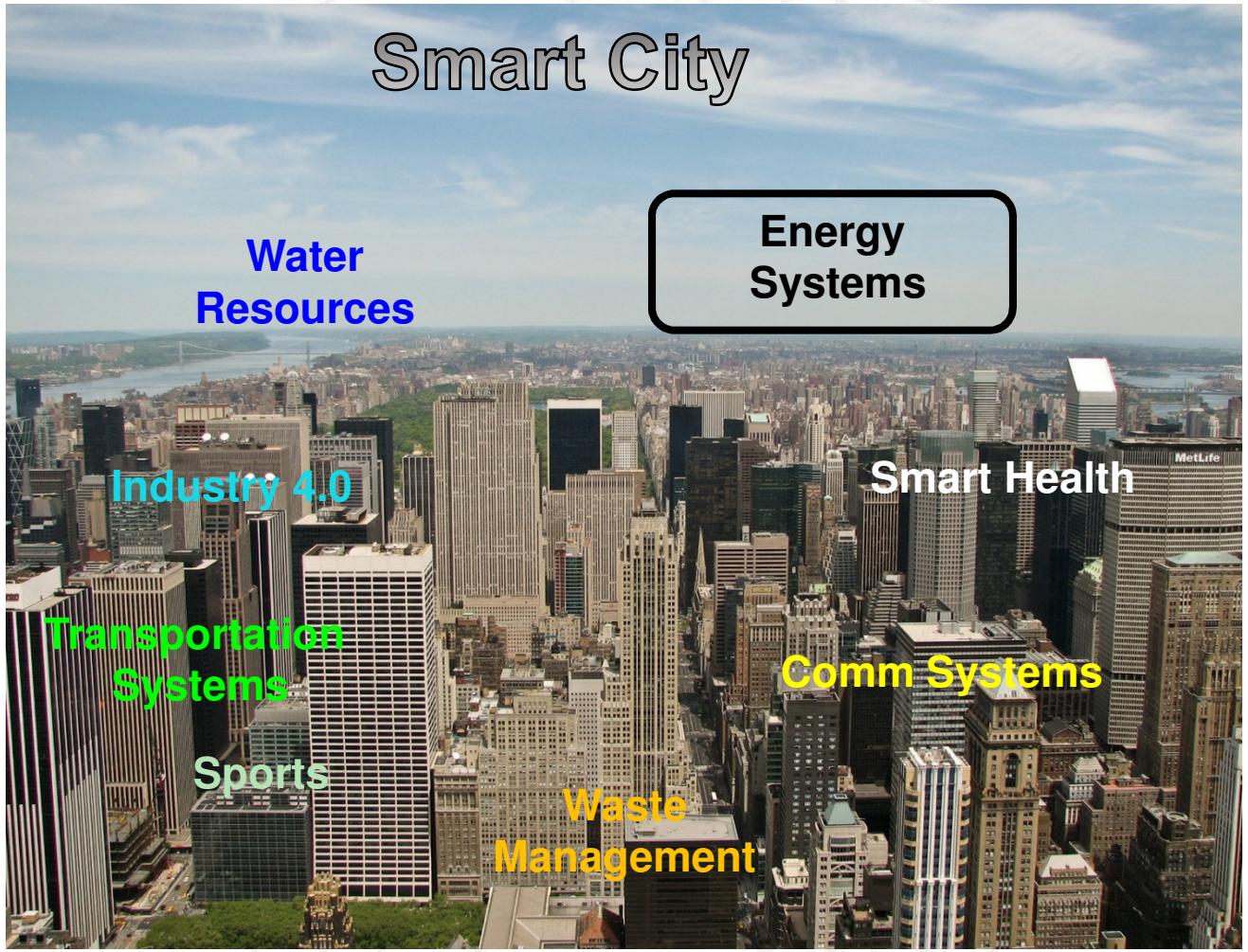
Fig. 1. Common challenges identified by STARDUST project (left) and the associated cities (right).



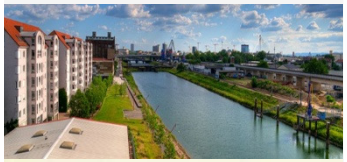
J. J. Astrain, F. Falcone, A. J. Lopez-Martin, P. Sanchis, J. Villadangos and I. R. Matias, "Monitoring of Electric Buses within an Urban Smart City Environment," in IEEE Sensors Journal, doi: 10.1109/JSEN.2021.3077846.

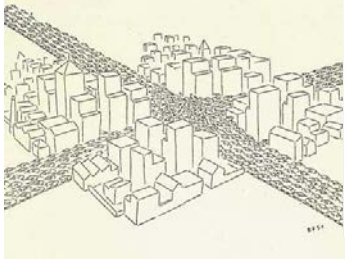


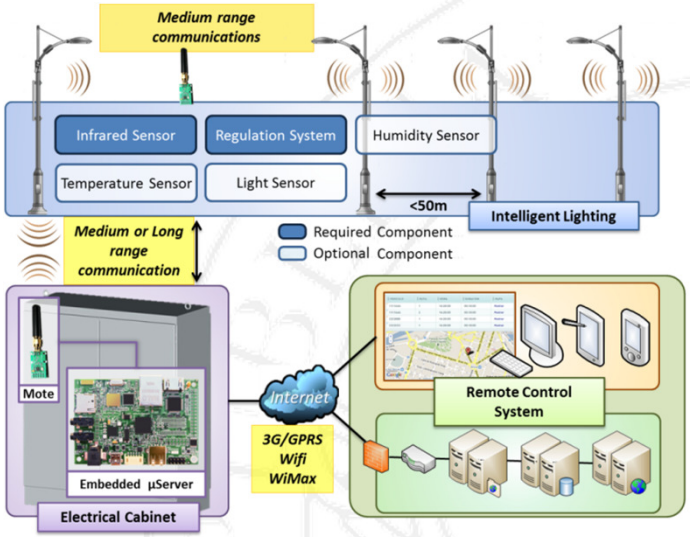


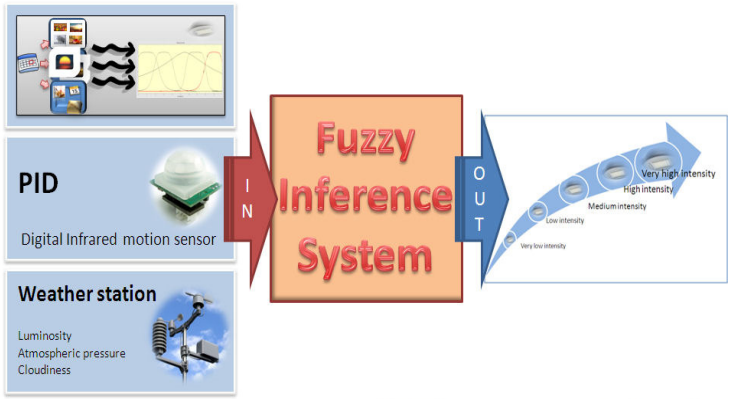

Smart City
Water Resources
Energy Systems
Industry 4.0
Smart Health
Transportation Systems
Comm Systems
Sports
Waste Management

Smart City: Street Lights

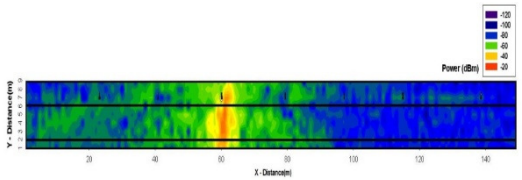


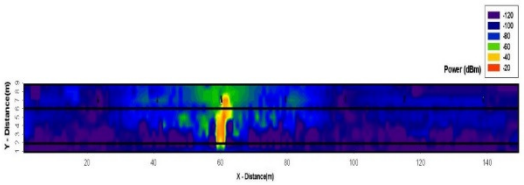


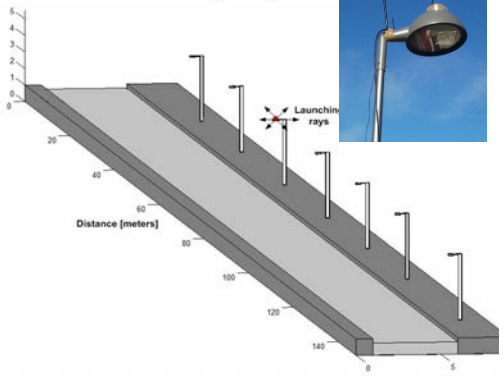


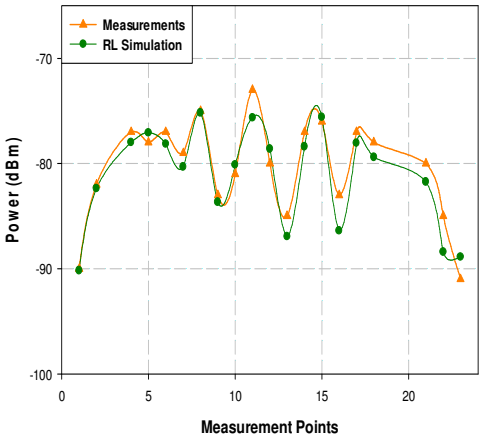


DeustoTech









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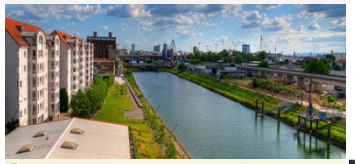
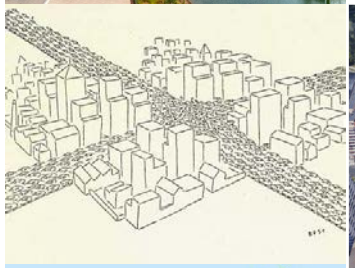
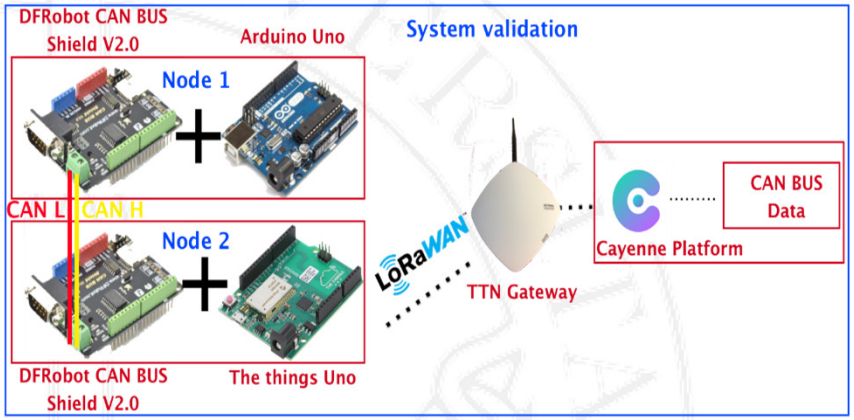
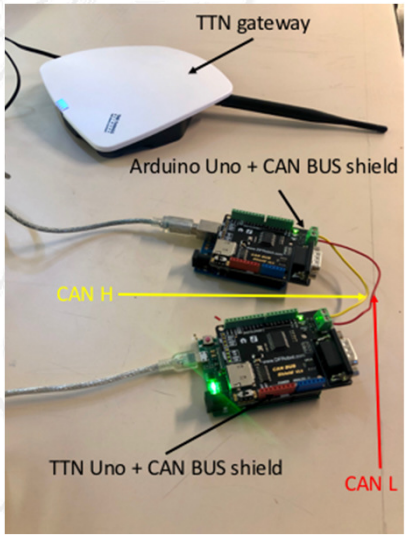
Smart City: V2V/V2G



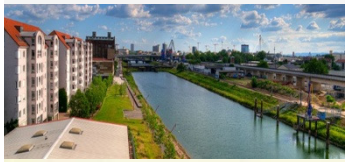


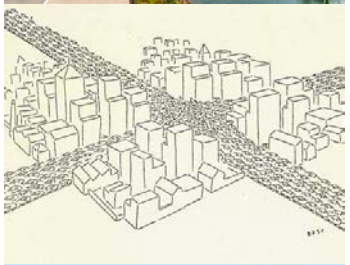


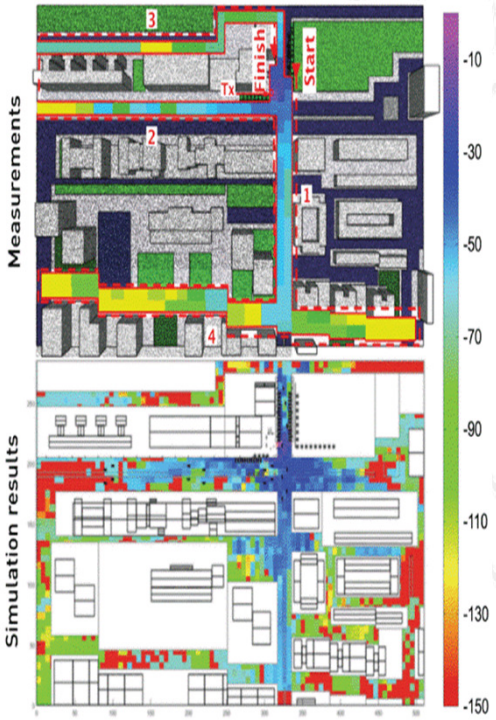


H. Klaina *et al.*, "Aggregator to Electric Vehicle LoRaWAN Based Communication Analysis in Vehicle-to-Grid Systems in Smart Cities," in *IEEE Access*, vol. 8, pp. 124688-124701, 2020, doi: 10.1109/ACCESS.2020.3007597

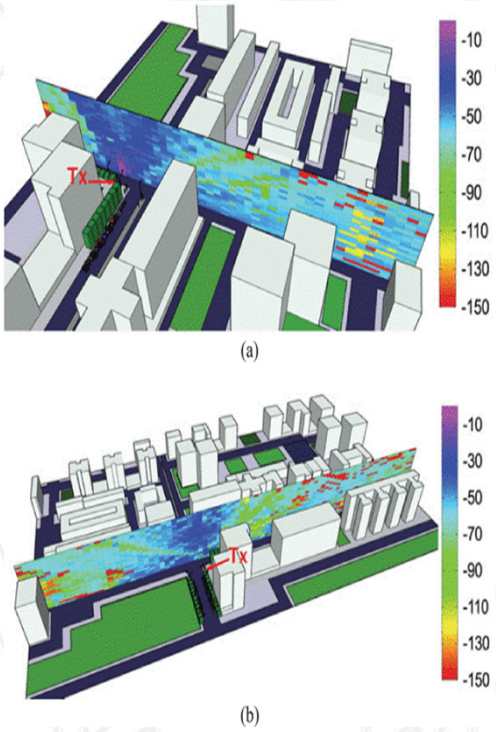
Smart City: V2V/V2G



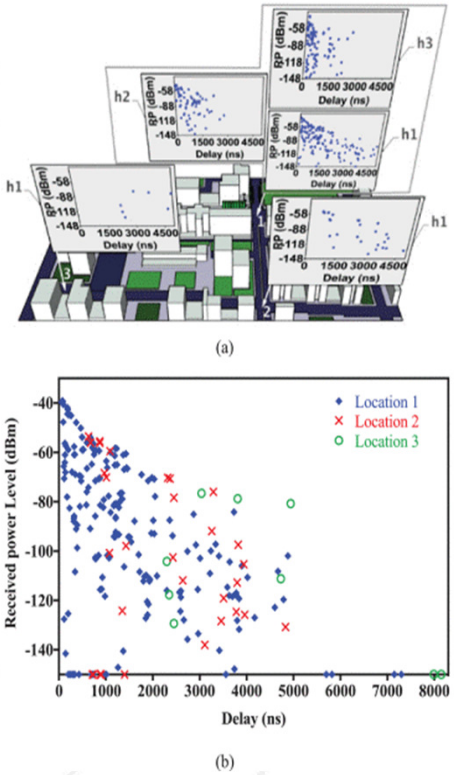




Comparison between measurement and simulation results, for the urban scenario under analysis and an operating frequency of 868 MHz (in dBm)

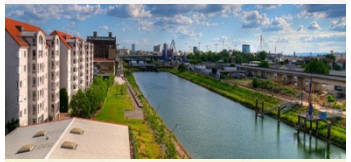


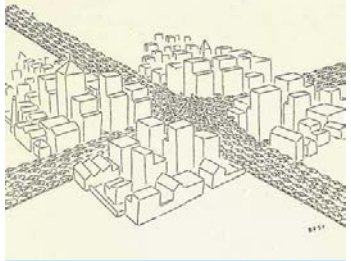
Estimated received power (in dBm) in vertical planes corresponding to paths (1) and (2) respectively

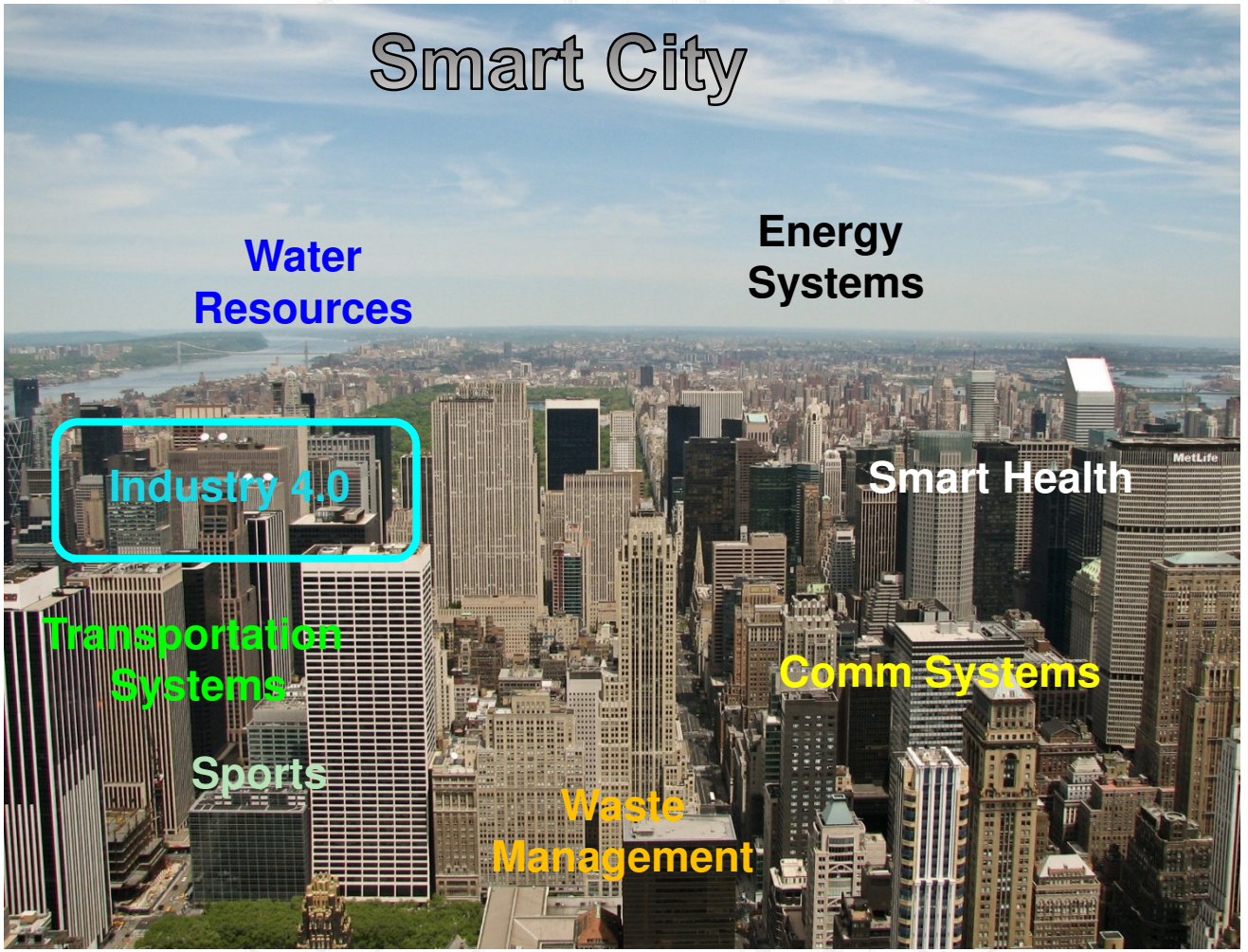


(a) Estimated power delay profile for locations 1, 2 and 3 and at different heights; (b) Comparison between the results at h1 for the three locations.

H. Klaina *et al.*, "Aggregator to Electric Vehicle LoRaWAN Based Communication Analysis in Vehicle-to-Grid Systems in Smart Cities," in *IEEE Access*, vol. 8, pp. 124688-124701, 2020, doi: 10.1109/ACCESS.2020.3007597






Smart City
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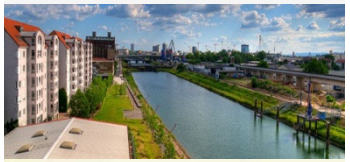
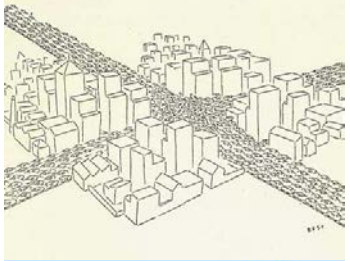
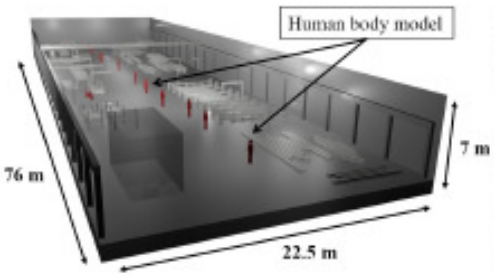
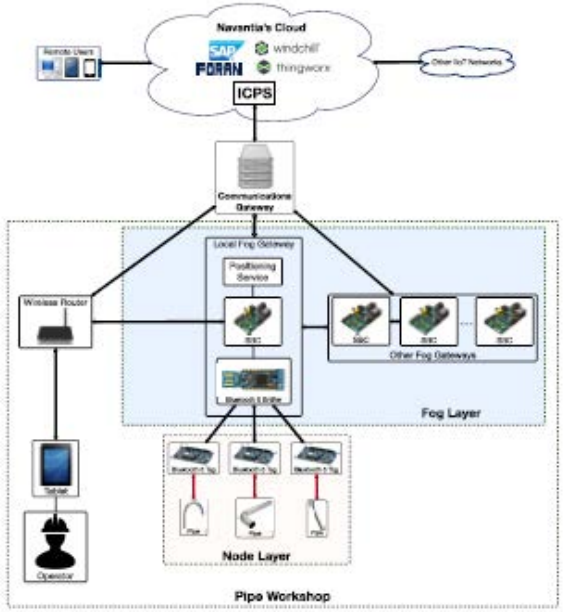
Smart Health
Transportation Systems
Comm Systems
Sports
Waste Management

Industry: Shipyard



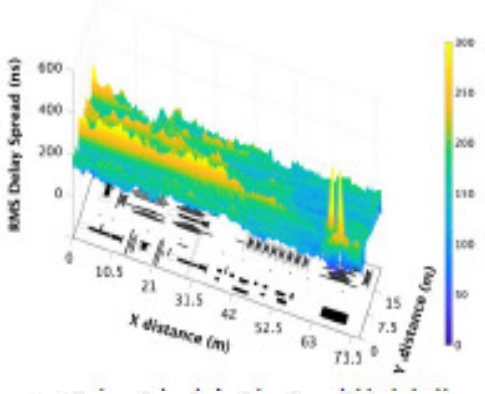


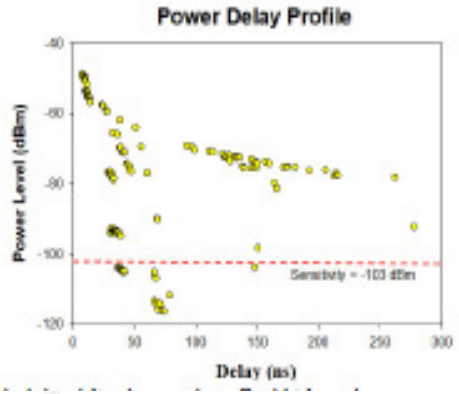




UNIVERSIDADE DA CORUÑA

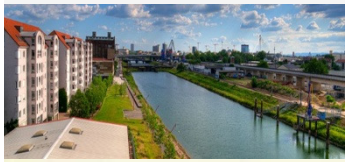
Tecnológico de Monterrey

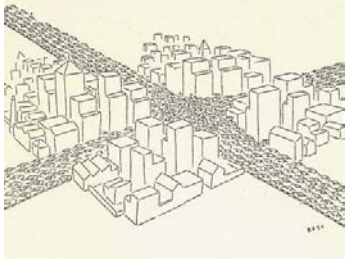


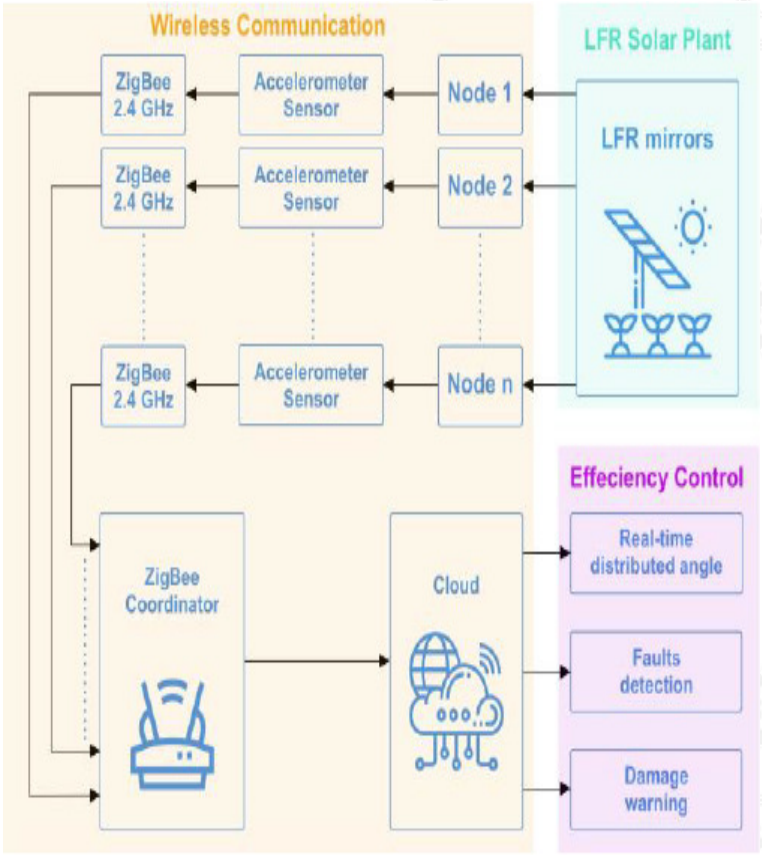


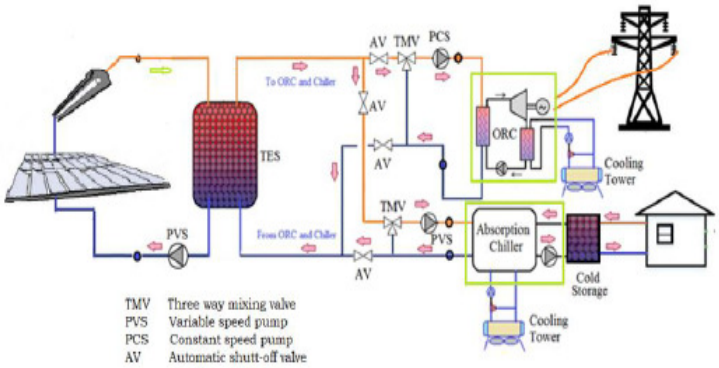
P. Fraga-Lamas et al., "Design and Empirical Validation of a Bluetooth 5 Fog Computing Based Industrial CPS Architecture for Intelligent Industry 4.0 Shipyard Workshops", IEEE Access, Vol. 8, 2020

Industry: LFR Plant Modeling



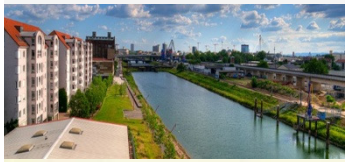


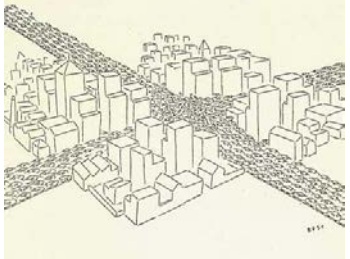


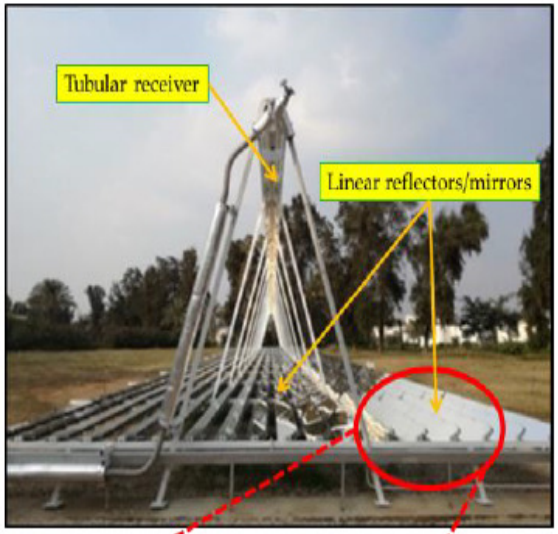


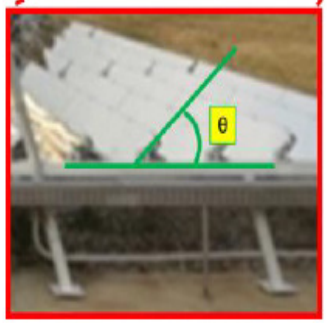
R. Meligy *et al.*, "IoT Enabled Low Cost Distributed Angle Measurement Fault Detection System for LFR Plants," in *IEEE Sensors Journal*, vol. 21, no. 21, pp. 24855-24868, 1 Nov.1, 2021, doi: 10.1109/JSEN.2021.3116025

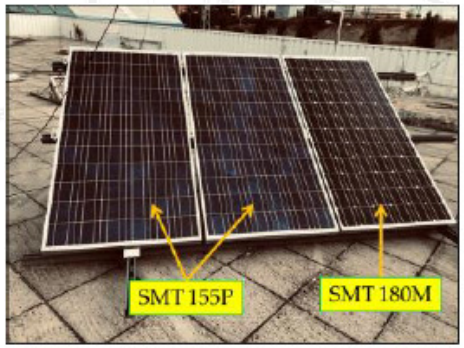
Industry: LFR Plant Modeling

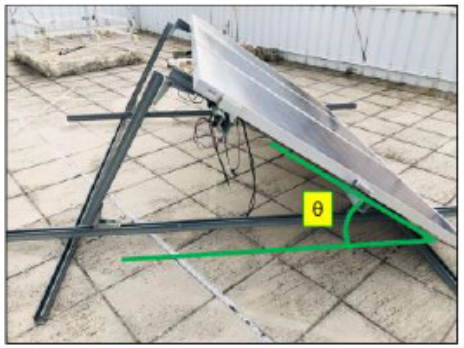


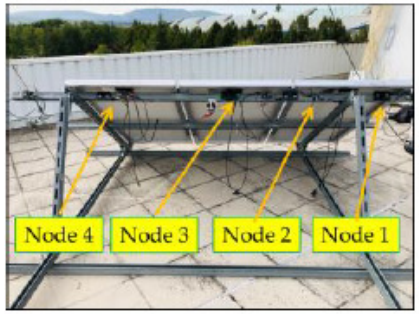


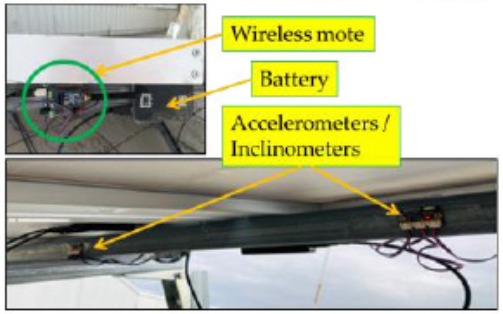


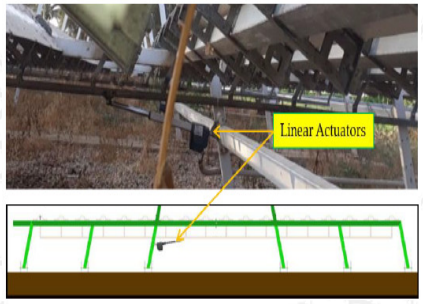


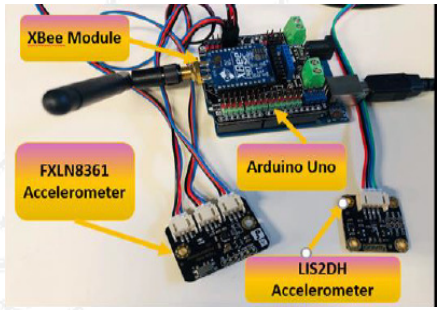






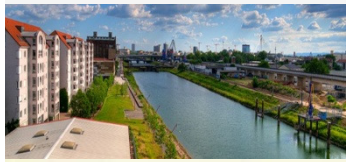


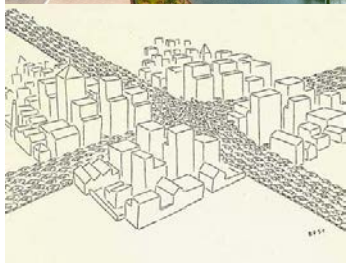


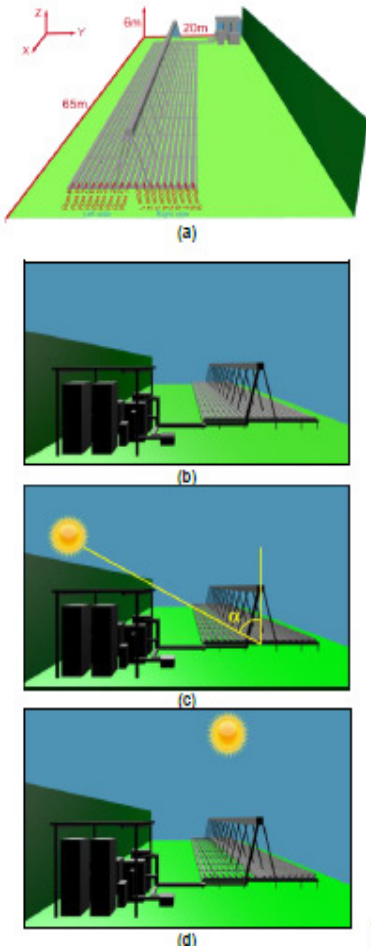


R. Meligy *et al.*, "IoT Enabled Low Cost Distributed Angle Measurement Fault Detection System for LFR Plants," in *IEEE Sensors Journal*, vol. 21, no. 21, pp. 24855-24868, 1 Nov.1, 2021, doi: 10.1109/JSEN.2021.3116025

Industry: LFR Plant Modeling







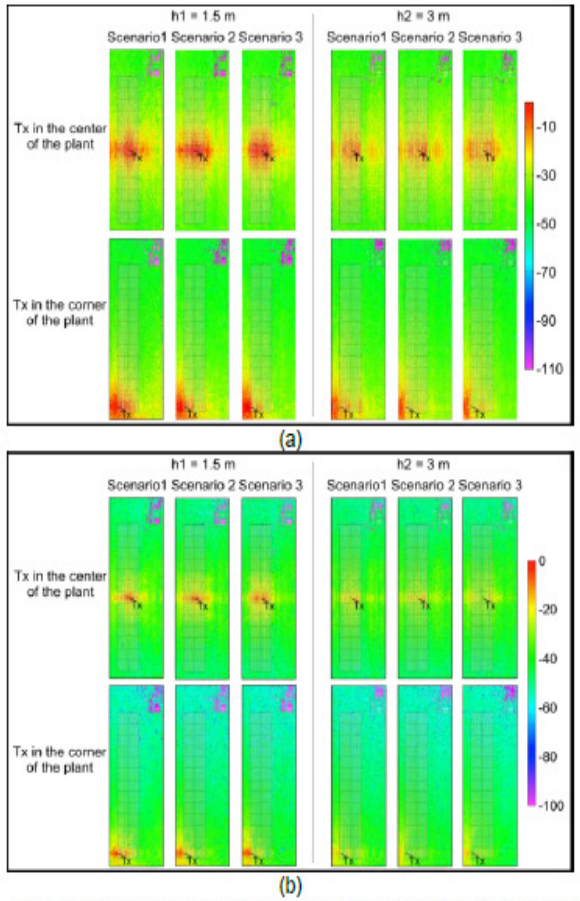


Fig. 15. Estimated RF power distribution planes obtained by 3D-RL for all scenarios for Tx=10 dBm (a) for 868 MHz; (b) for 2.4 GHz.

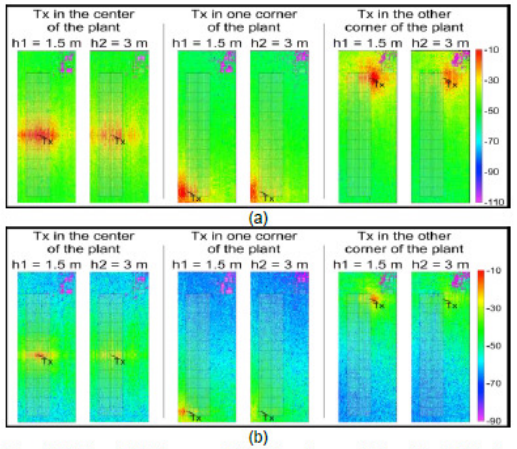


Fig. 16. Estimated RF power distribution planes obtained by 3D-RL for scenario 2 with Tx= 0 dBm (a) for 868 MHz; (b) for 2.4 GHz.

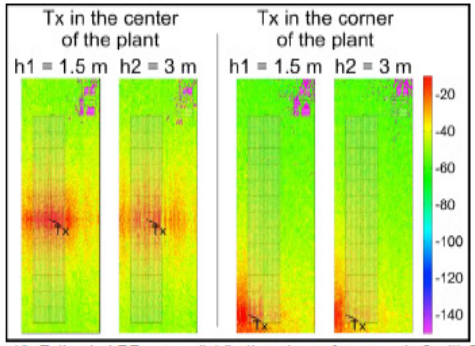


Fig. 18. Estimated RF power distribution planes for scenario 2 with Tx= 0 dBm for LoRaWAN 868 MHz.

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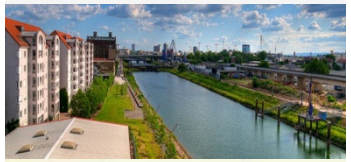
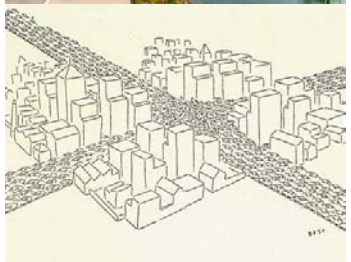
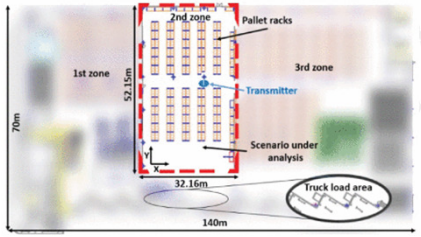
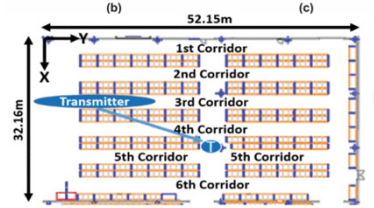
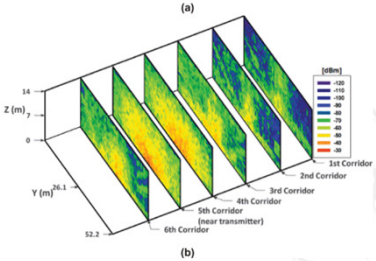


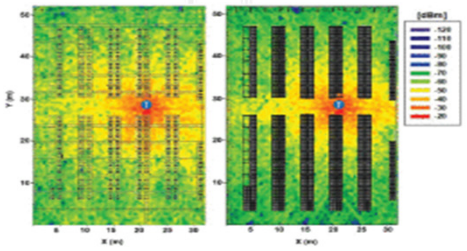


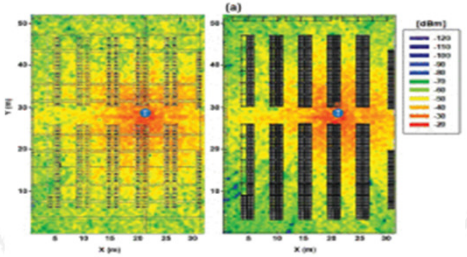
UWB Assisted Indoor Tracking

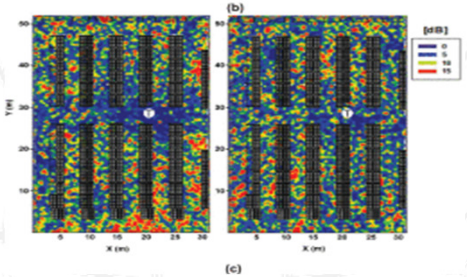


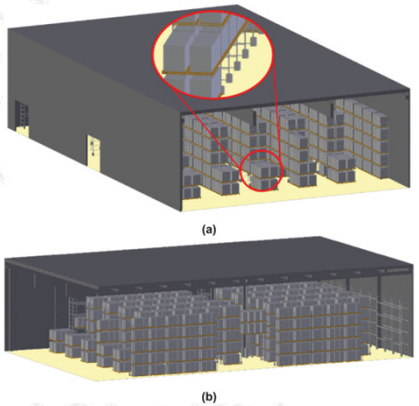


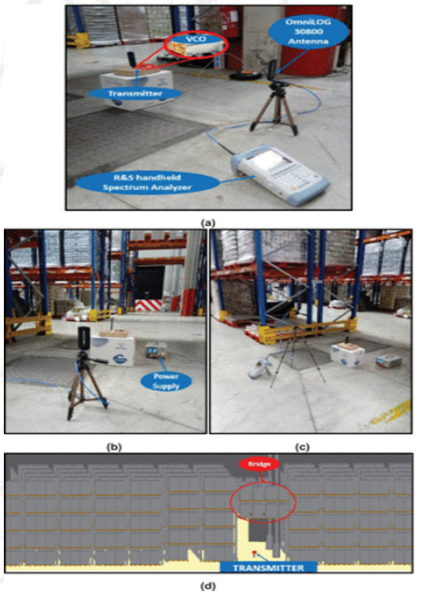




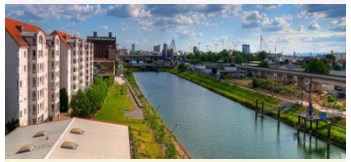


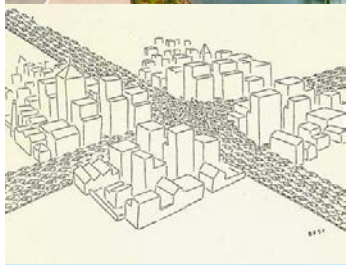




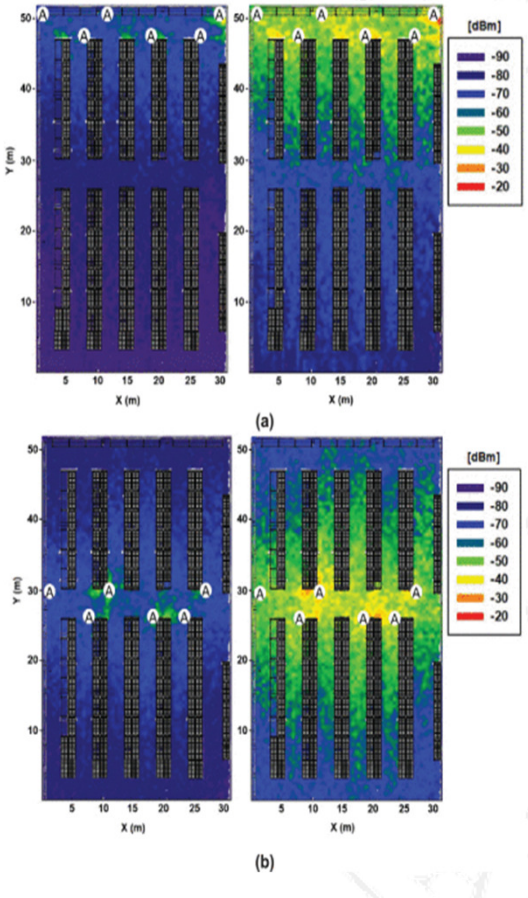


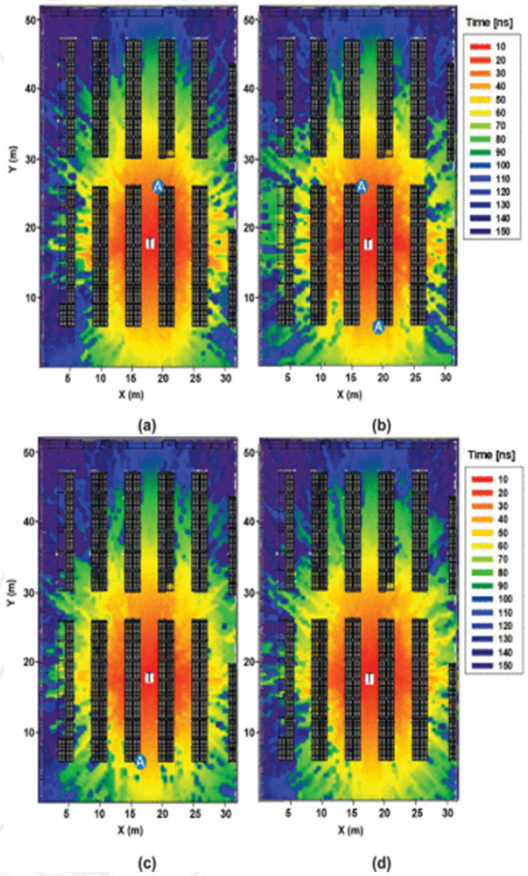
I. P. Guembe *et al.*, "Wireless Characterization and Assessment of an UWB-Based System in Industrial Environments," in *IEEE Access*, vol. 9, pp. 107824-107841, 2021, doi: 10.1109/ACCESS.2021.3101690.





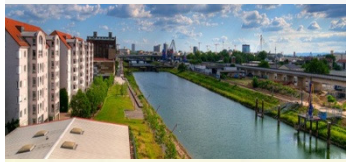
UWB Assisted Indoor Tracking

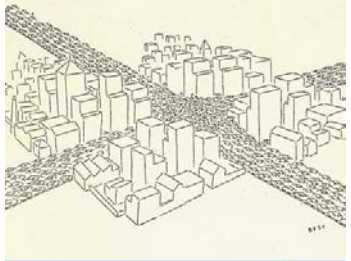


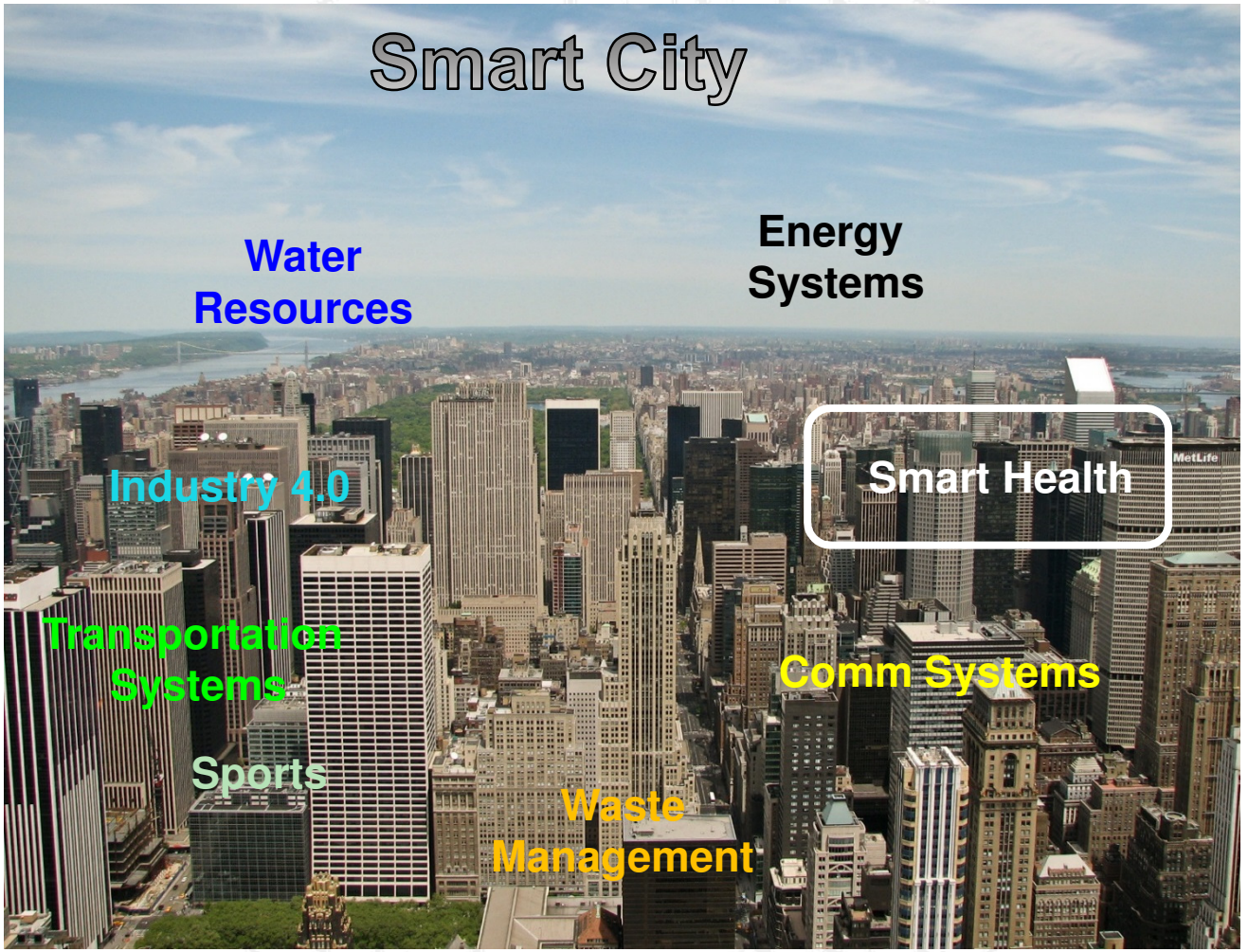


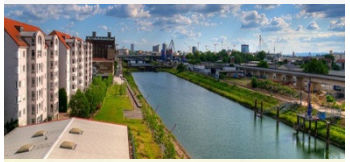
UWB-Coverage **Anchor Deployment** **TOF Estim.**

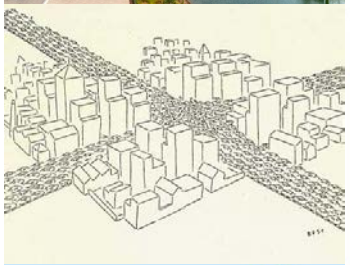
I. P. Guembe *et al.*, "Wireless Characterization and Assessment of an UWB-Based System in Industrial Environments," in *IEEE Access*, vol. 9, pp. 107824-107841, 2021, doi: 10.1109/ACCESS.2021.3101690.



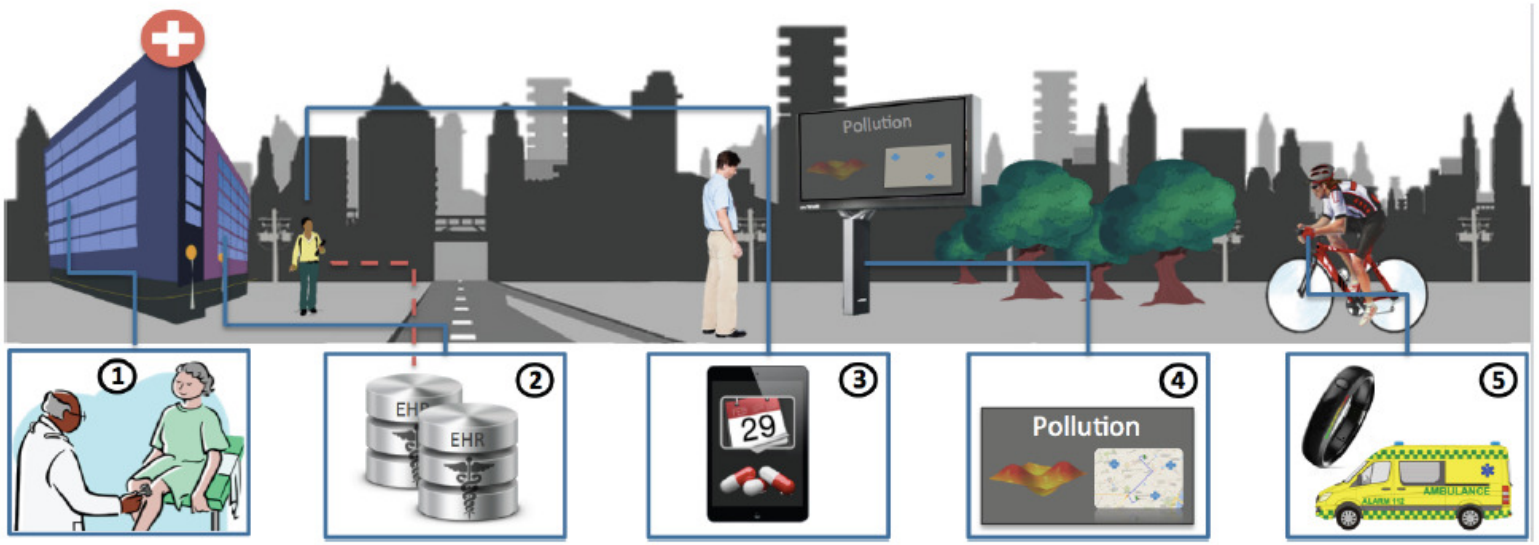


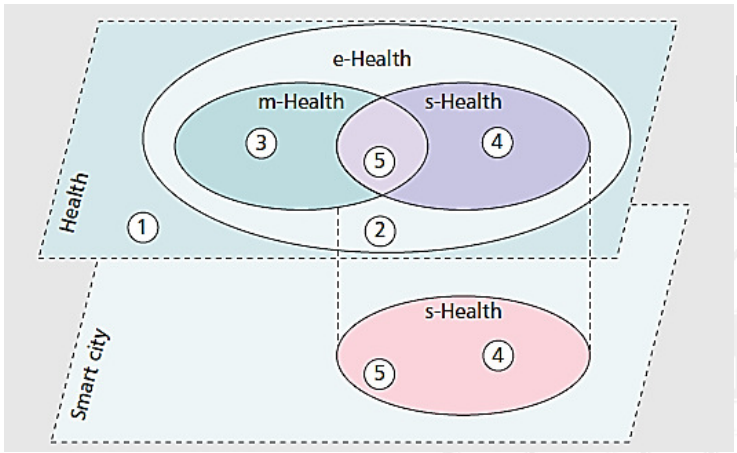

Smart City
Water Resources
Energy Systems
Industry 4.0
Smart Health
Transportation Systems
Comm Systems
Sports
Waste Management





Smart Health (s-Health)

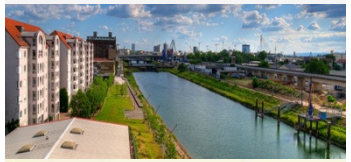


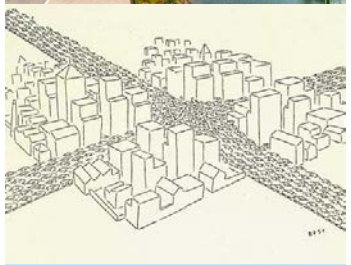


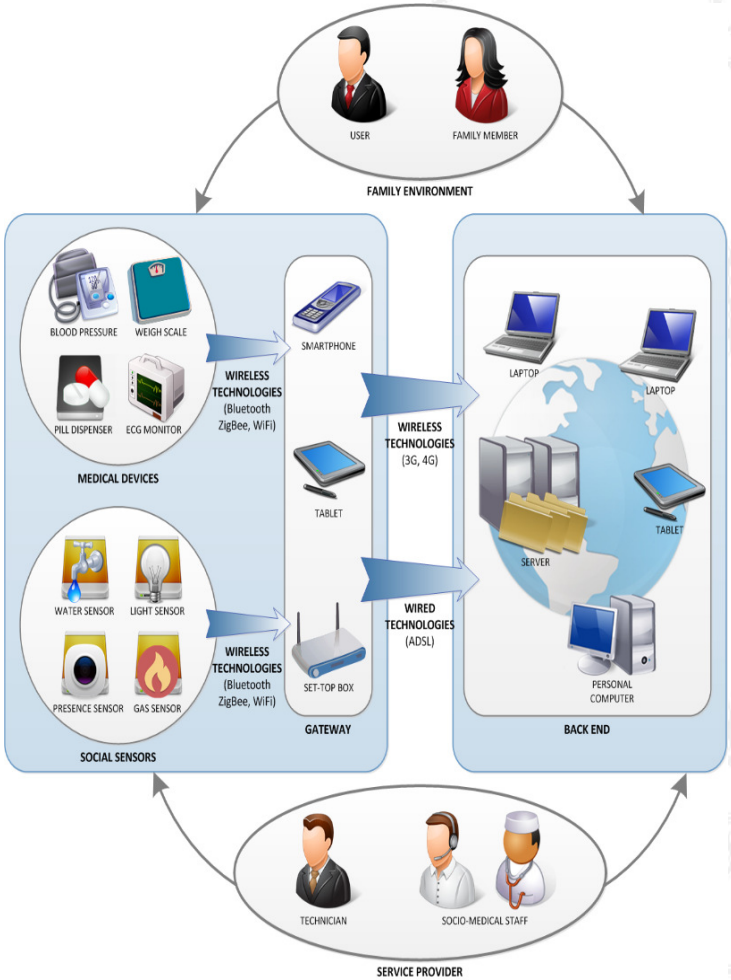
- Paradigm of Context Aware Scenario
- In terms of network implementation:
  - PON/GPON backbone
  - WBAN/WPAN initial sensor access
  - 3G/4G gateways
  - 4G/5G dense WSN gateways

Agusti Solanas, Constantinos Patsakis, Mauro Conti, Ioannis S. Vlachos,Victoria Ramos, Francisco Falcone, Octavian Postolache, Pablo A. Perez-Martınez, Roberto Di Pietro, , Despina N. Perrea, Antoni Martınez-Balleste, "Smart Health: A Context-Aware Health Paradigm within Smart Cities", IEEE Communication Magazine, Volume 52, Issue 8, pp. 74-81, August 2014

eHealth: Social Sensors

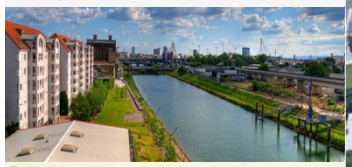


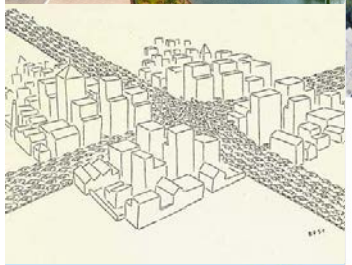




E. Aguirre et al., "Implementation of Context Aware e-Health Environments based on Social Sensor Networks", Sensors, March 2016

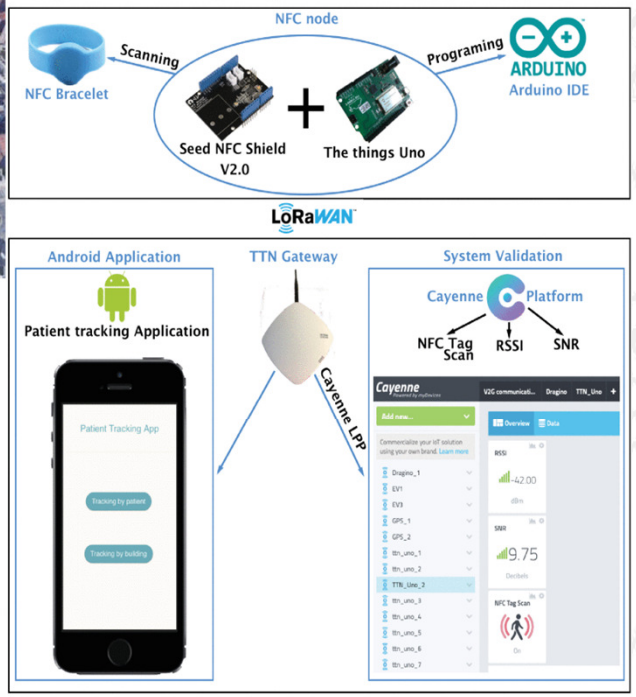
eHealth: CHN

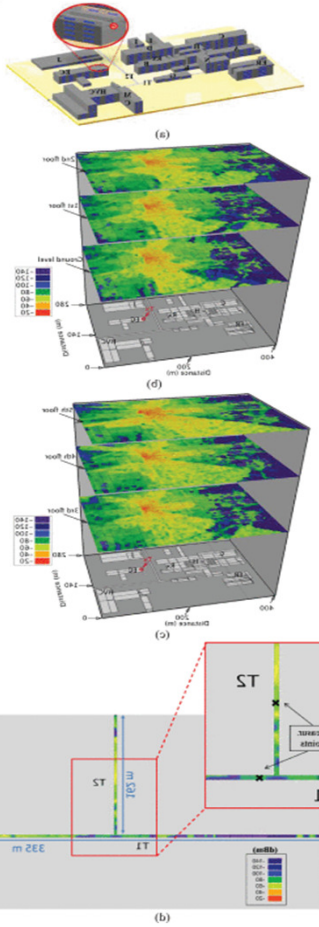




(a)

(b)

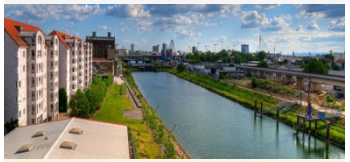


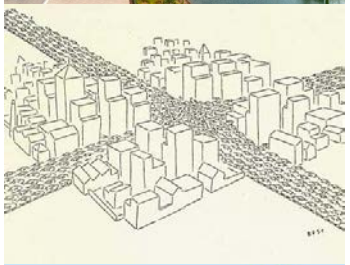


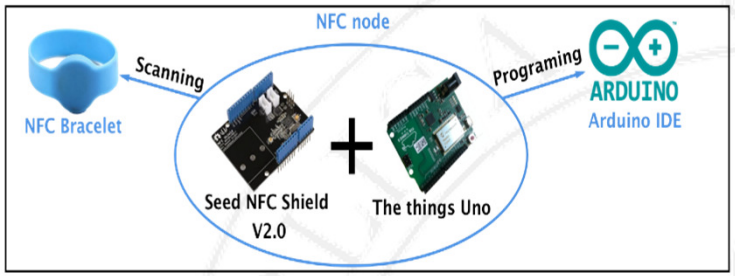
(b)

J. D. Trigo *et al.*, "Patient Tracking in a Multi-Building, Tunnel-Connected Hospital Complex," in *IEEE Sensors Journal*, vol. 20, no. 23, pp. 14453-14464, 1 Dec.1, 2020, doi: 10.1109/JSEN.2020.3007593.

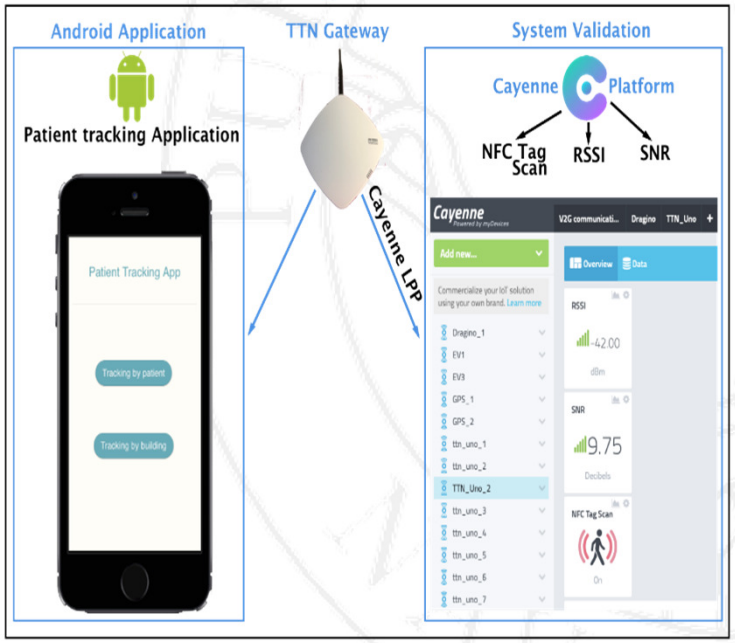
eHealth: CHN

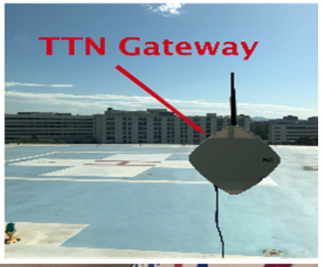


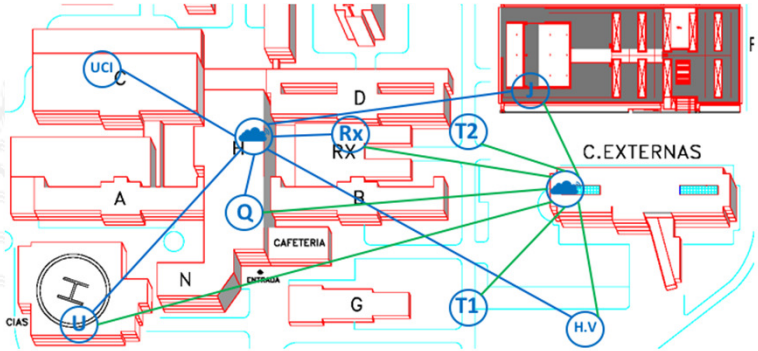




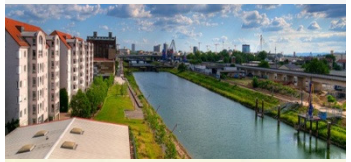
LoRaWAN

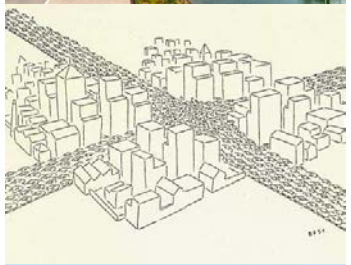


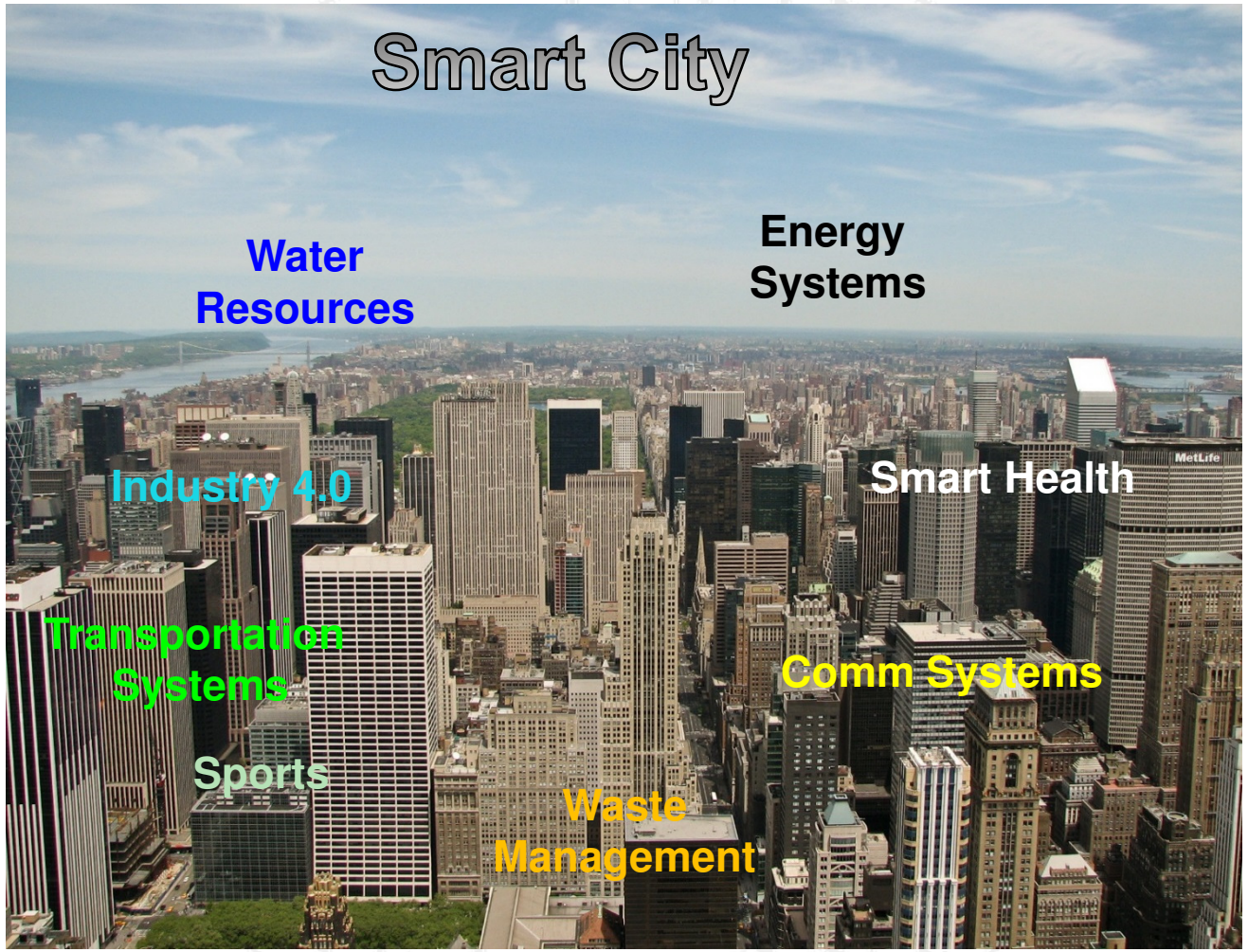




J. D. Trigo *et al.*, "Patient Tracking in a Multi-Building, Tunnel-Connected Hospital Complex," in *IEEE Sensors Journal*, vol. 20, no. 23, pp. 14453-14464, 1 Dec.1, 2020, doi: 10.1109/JSEN.2020.3007593

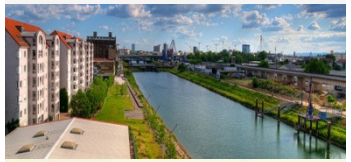


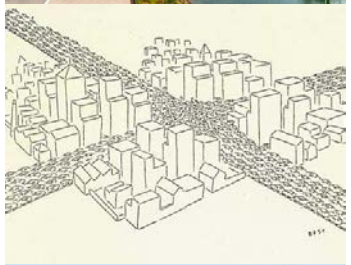


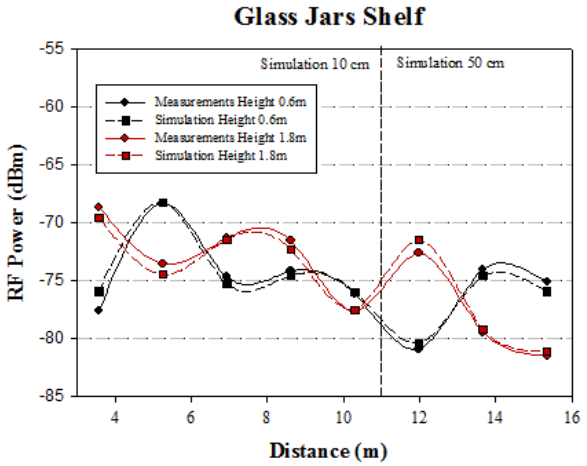


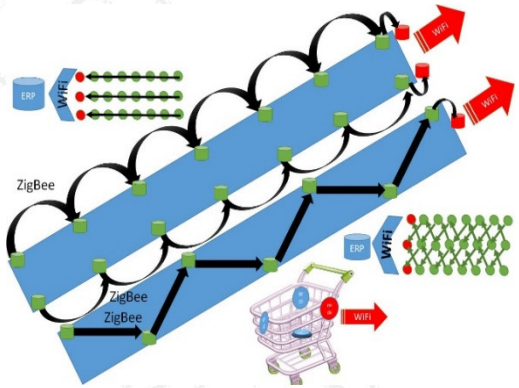
IoT-Context Aware

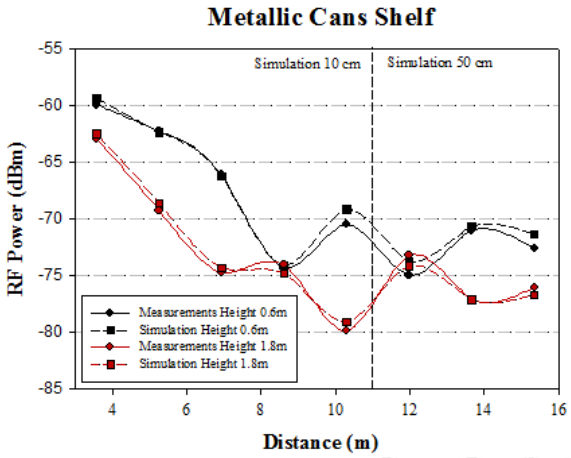
Interactive Shopping Carts

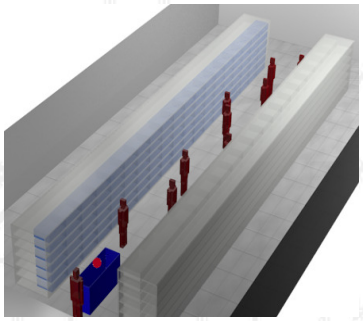


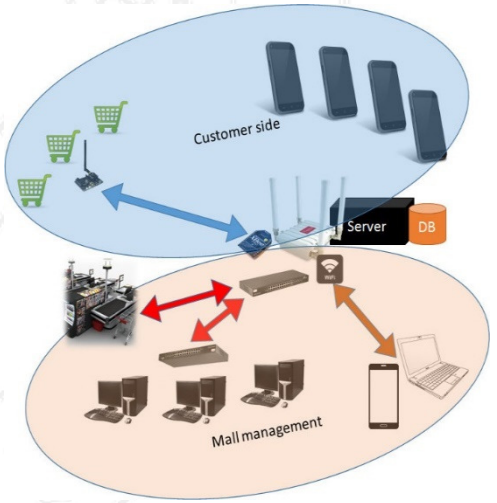






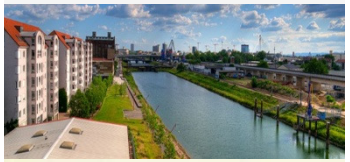


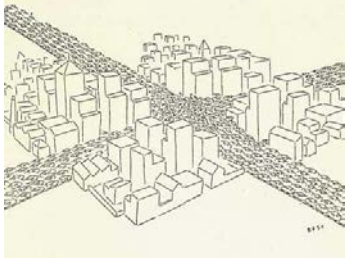


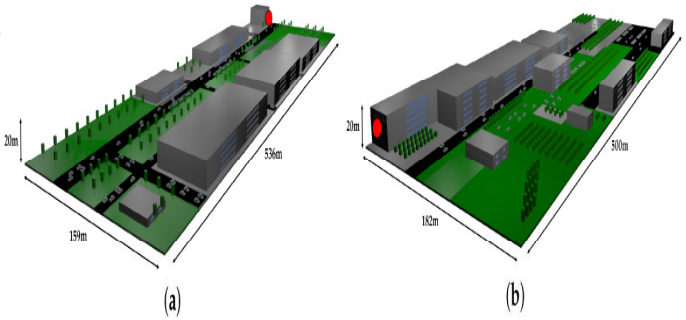


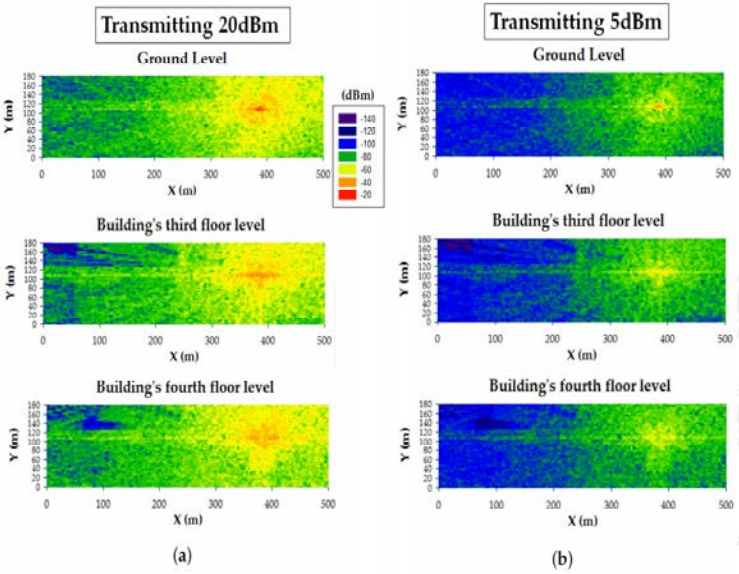
Peio Lopez-Iturri, Leyre Azpilicueta, José Javier Astrain, Erik Aguirre, Eduardo Salinero, Jesús Villadangos and Francisco Falcone., "Implementation of Wireless Sensor Network Architecture for Interactive Shopping Carts to Enable Context Aware Commercial Areas", IEEE Sensors Journal, July 2016

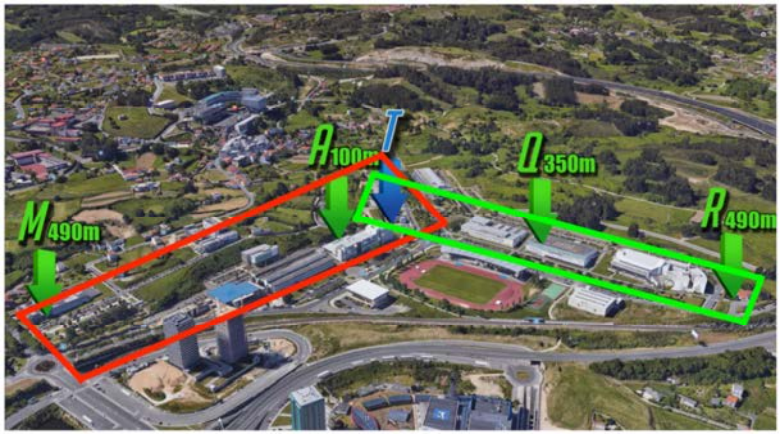
Smart City: Campus Monitoring











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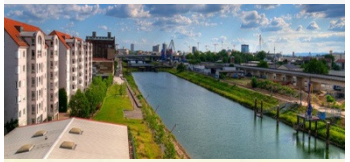
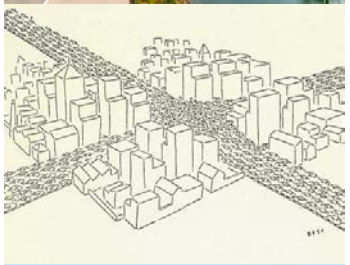
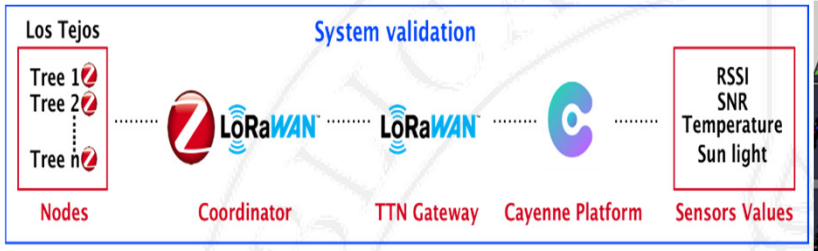
UNIVERSIDADE DA CORUÑA

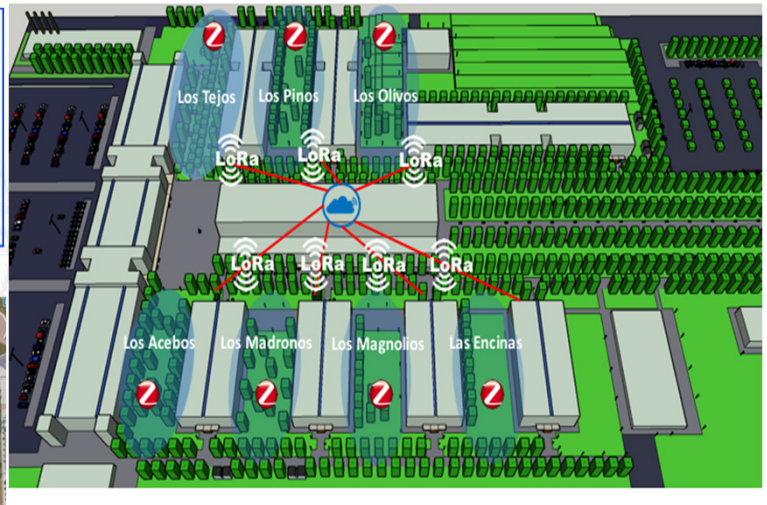
P. Fraga-Lamas et al., "Design and Experimental Validation of a LoRaWAN Fog Computing Based Architecture for IoT Enabled Smart Campus Applications", Sensors, 2019

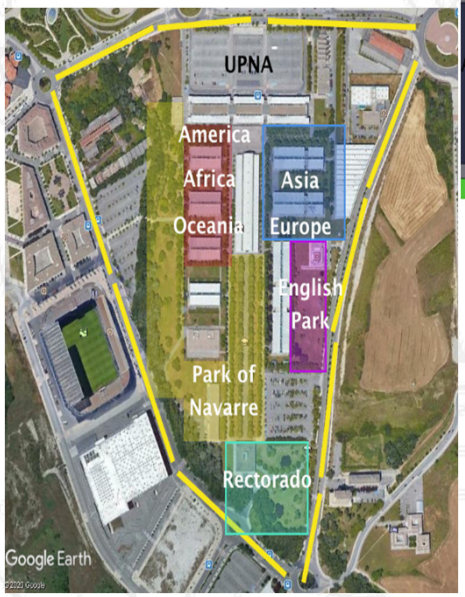
Smart City: Smart Campus

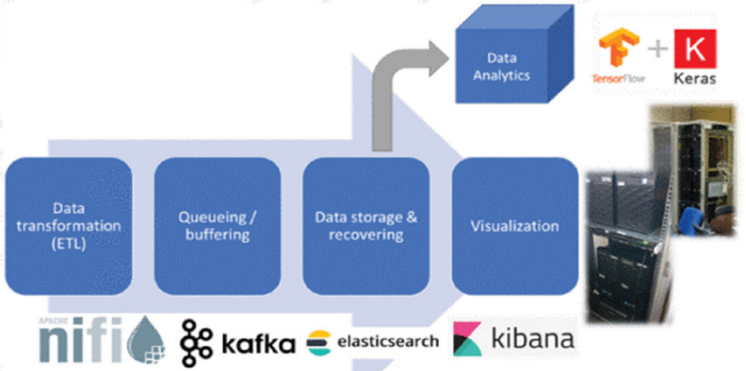






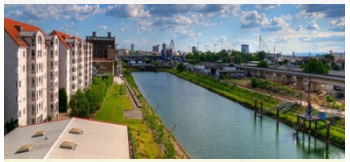


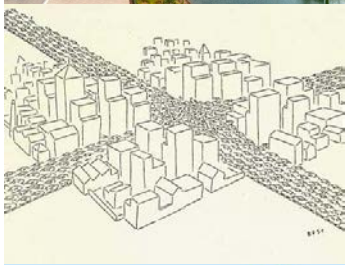


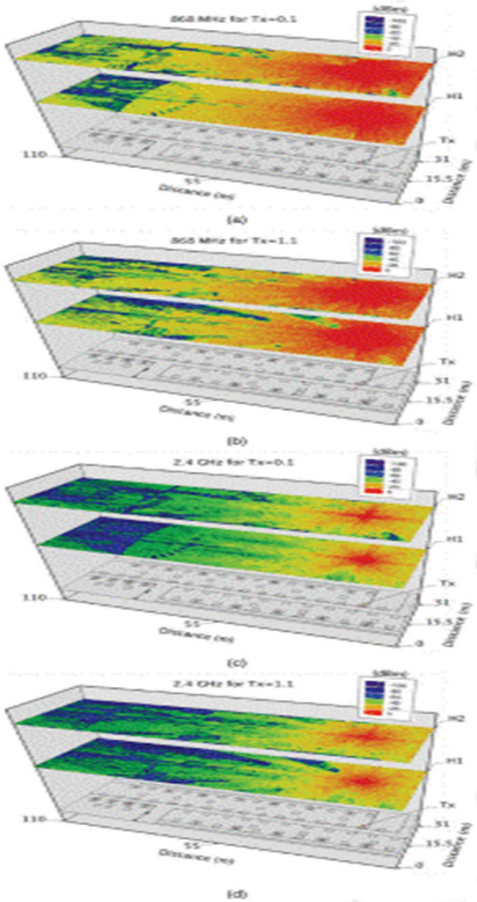


H. Klaina *et al.*, "Implementation of an Interactive Environment With Multilevel Wireless Links for Distributed Botanical Garden in University Campus," in *IEEE Access*, vol. 8, pp. 132382-132396, 2020, doi: 10.1109/ACCESS.2020.3010032.

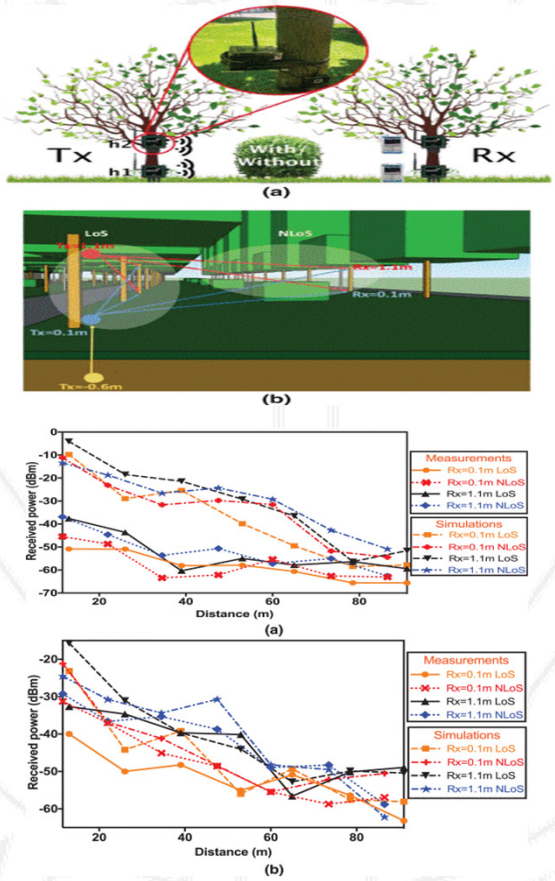
Smart City: Smart Campus



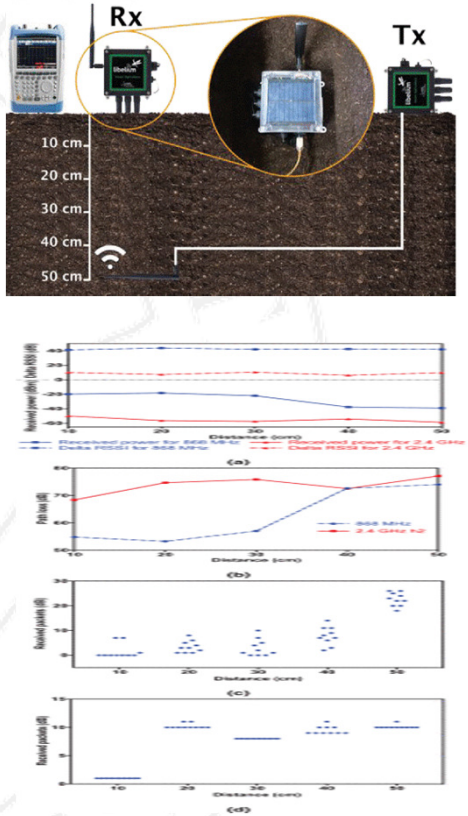




Estimated RF power level distributions for 868 MHz for (a) Tx = 0.1m; (b) Tx = 1.1m; and for 2.4 GHz for (c) Tx = 0.1m; (d) Tx = 1.1m

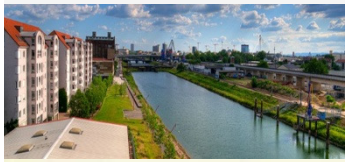


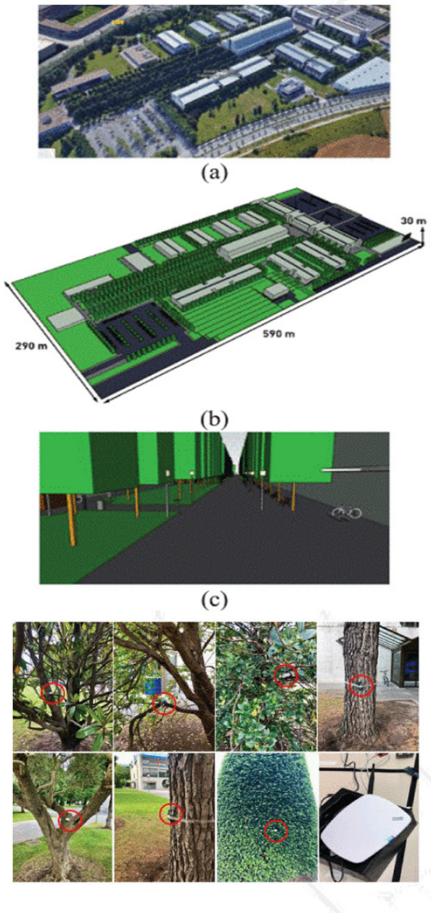
Comparison between the measured and the simulated results for 868 MHz radio frequency; (a) for Tx = 0.1m, and (b) Tx = 1.1m.

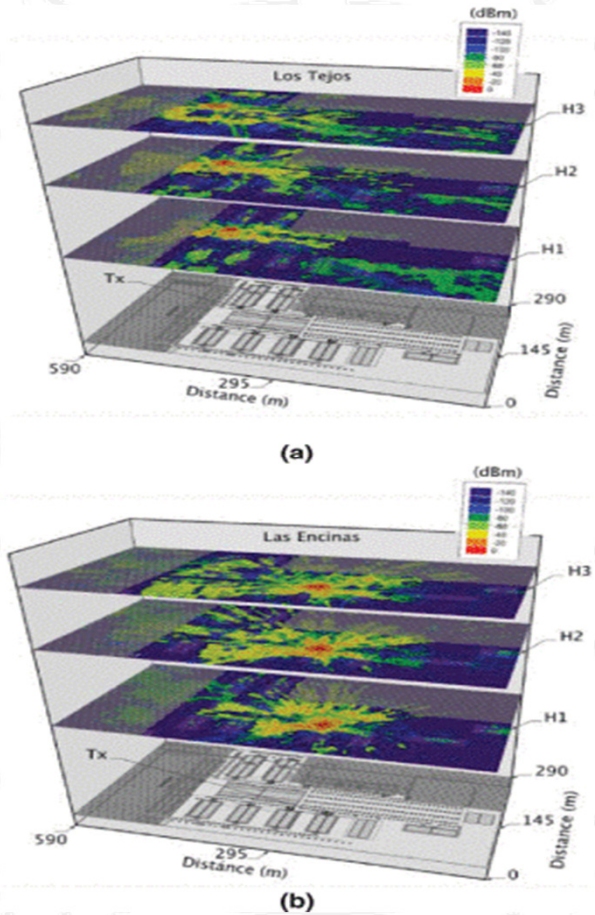


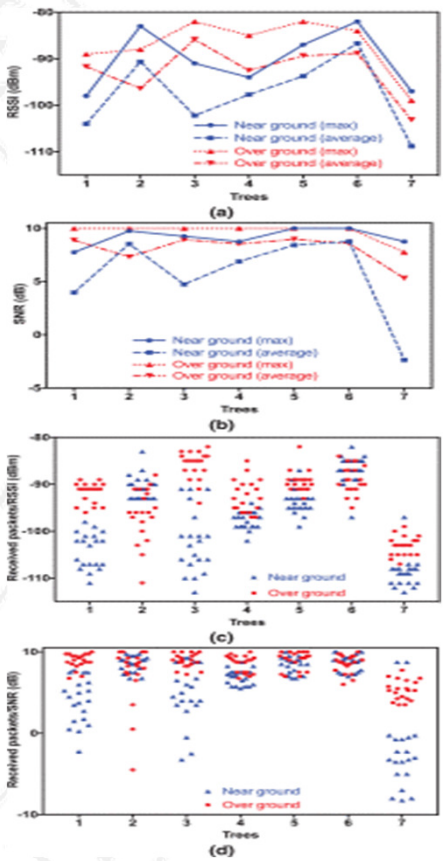
(a) Received power and Delta RSSI at 868 MHz and 2.4 GHz, (b) path loss at the same frequencies, (c) difference between the received packets RSSI for propagation in both soil and air at 868 MHz and (d) 2.4 GHz.

Smart City: Smart Campus









Estimated RF power distribution planes obtained by 3D RL at different heights for a transmitter placed at (a) *Los Tejos* building, and (b) *Las Encinas* building.

Near ground and over ground TTN nodes to gateway results: (a) RSSI, (b) SNR, (c) received packets/RSSI and (d) received packets/SNR.

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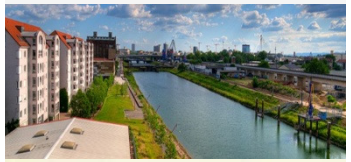
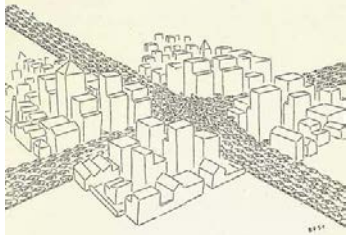
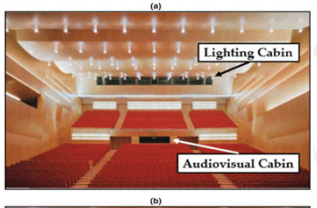
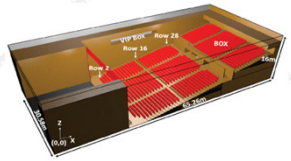
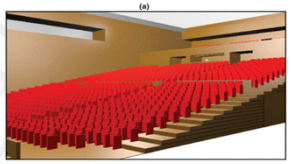
Smart City: Auditorium

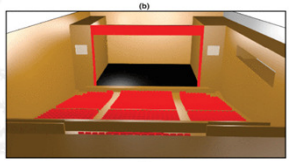


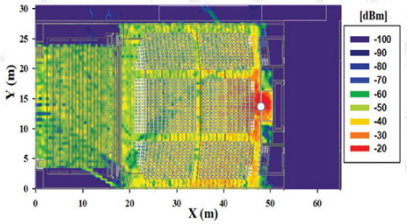


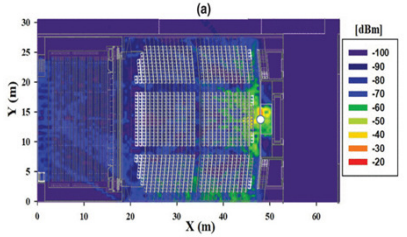


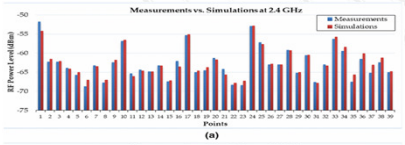


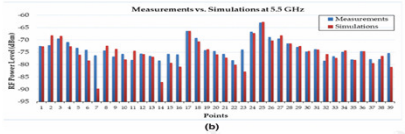


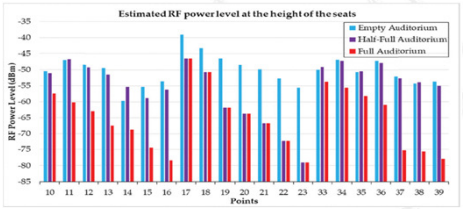


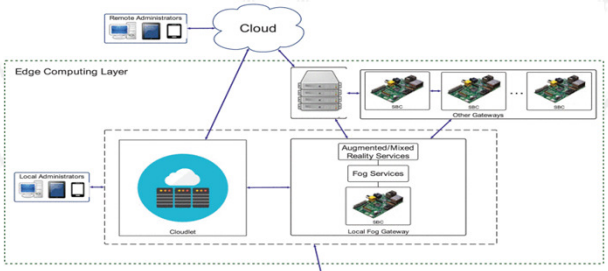


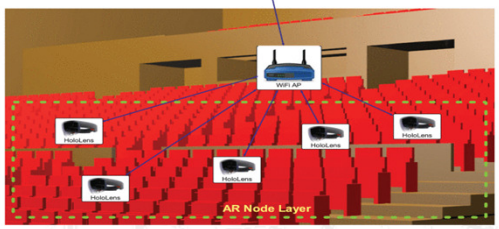


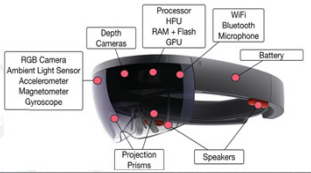


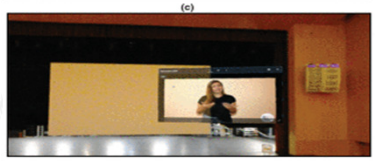






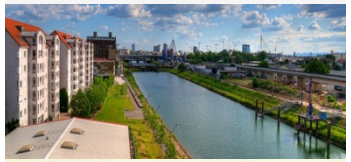






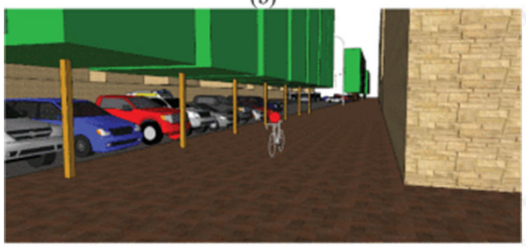
I. Picallo *et al.*, "Design and Experimental Validation of an Augmented Reality System With Wireless Integration for Context Aware Enhanced Show Experience in Auditoriums," in *IEEE Access*, vol. 9, pp. 5466-5484, 2021, doi: 10.1109/ACCESS.2020.3048203.

Smart City: Bike-2-Bike



(a)


(b)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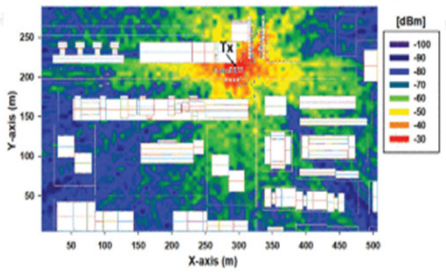
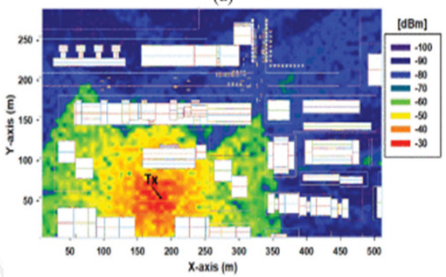


(a)



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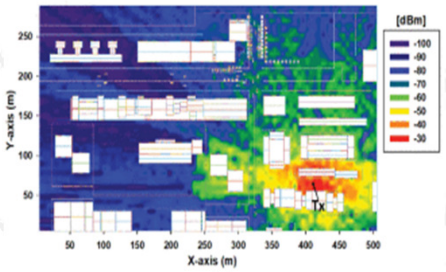
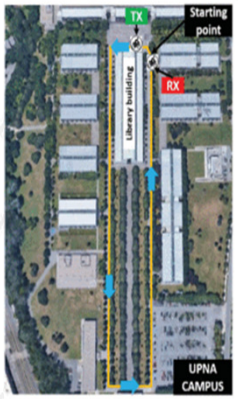


(c)

(a)

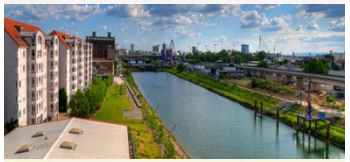


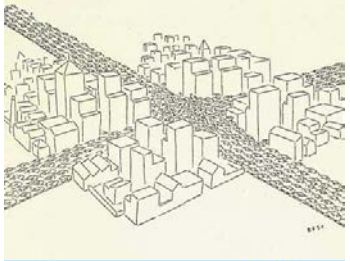
(b)

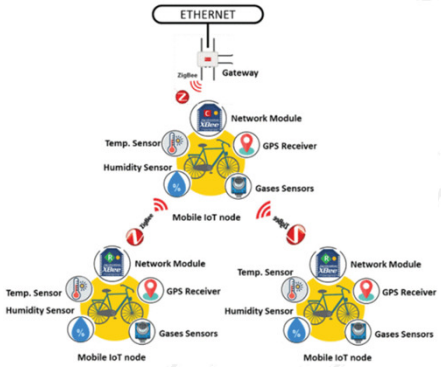
(c)

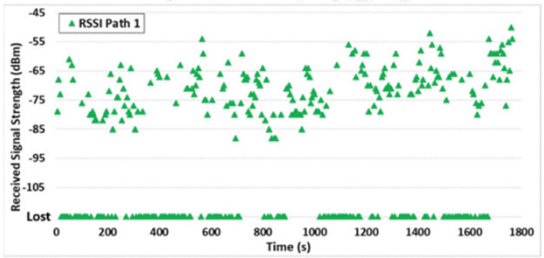
A. Al-Rahamneh *et al.*, "Bi2Bi Communication: Toward Encouragement of Sustainable Smart Mobility," in *IEEE Access*, vol. 10, pp. 9380-9394, 2022, doi: 10.1109/ACCESS.2022.3144643.

Smart City: Bike-2-Bike

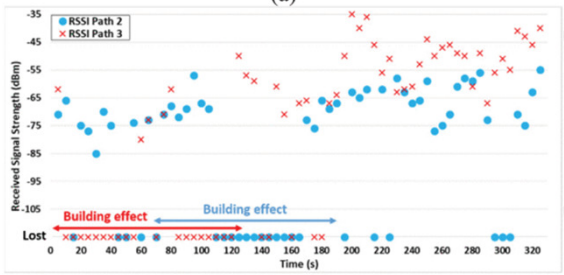






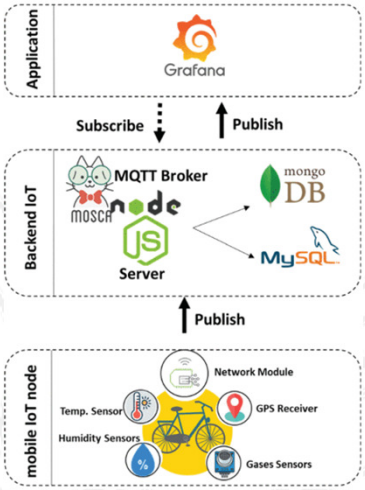


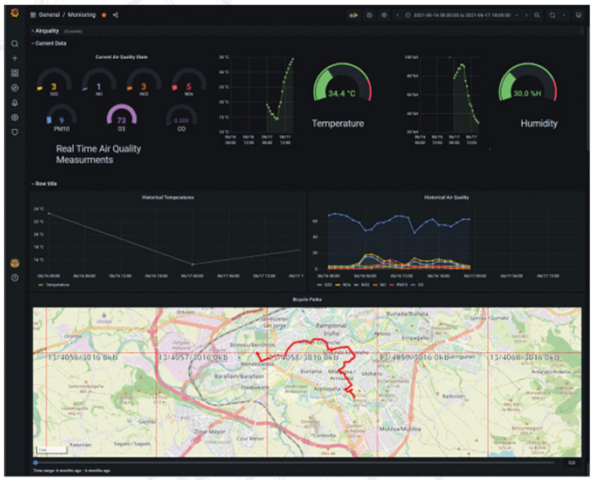
(a)

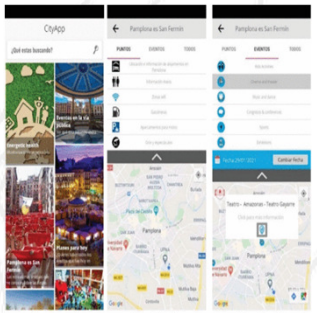


(b)

(a) (b) (c)







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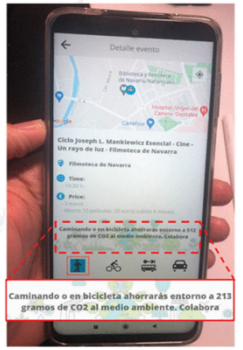
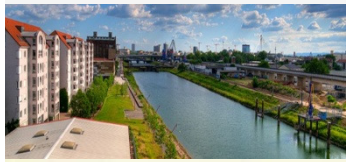
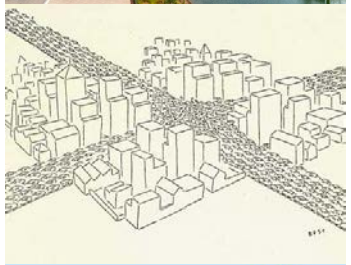


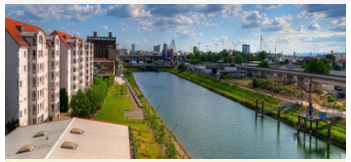
A. Al-Rahamneh *et al.*, "Bi2Bi Communication: Toward Encouragement of Sustainable Smart Mobility," in *IEEE Access*, vol. 10, pp. 9380-9394, 2022, doi: 10.1109/ACCESS.2022.3144643.

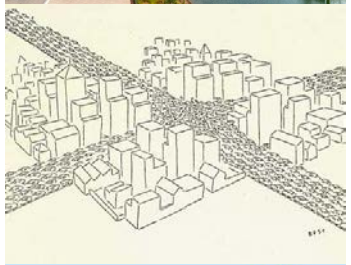




Bottom Line:

- IoT requires optimized SW/HW components
- Interoperability/Standard IoT Architecture model to be still found
- IoT devices: must be small, low cost, low energy, communication resilient
- Communication NWs are key elements that provides Context Aware Capabilities in Smart City/Smart Region frameworks, with Massive IoT deployments foreseen. Multiple Wireless NW can provide different acces capabilities as a function of QoS/QoE, cost and device requirements. Challenges:
  - Interference management
  - Scalability-Node density variabitiy
  - Energy management
- Solutions:
  - Wider spectrum usage
  - Purpose specific Wireless systems
  - True Het-Net Operation
- *An exciting journey opens ahead!!*





Smart City Connectivity and Applications

Thank You!

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