Institut Mines-Télécom

10 Thematic Areas @IMT

FUTURE NETWORKS & SERVICES COLLOQUIUM

14/10/2021

By the "**Networks and IoT**" key thematic area of Institut Mines Télécom

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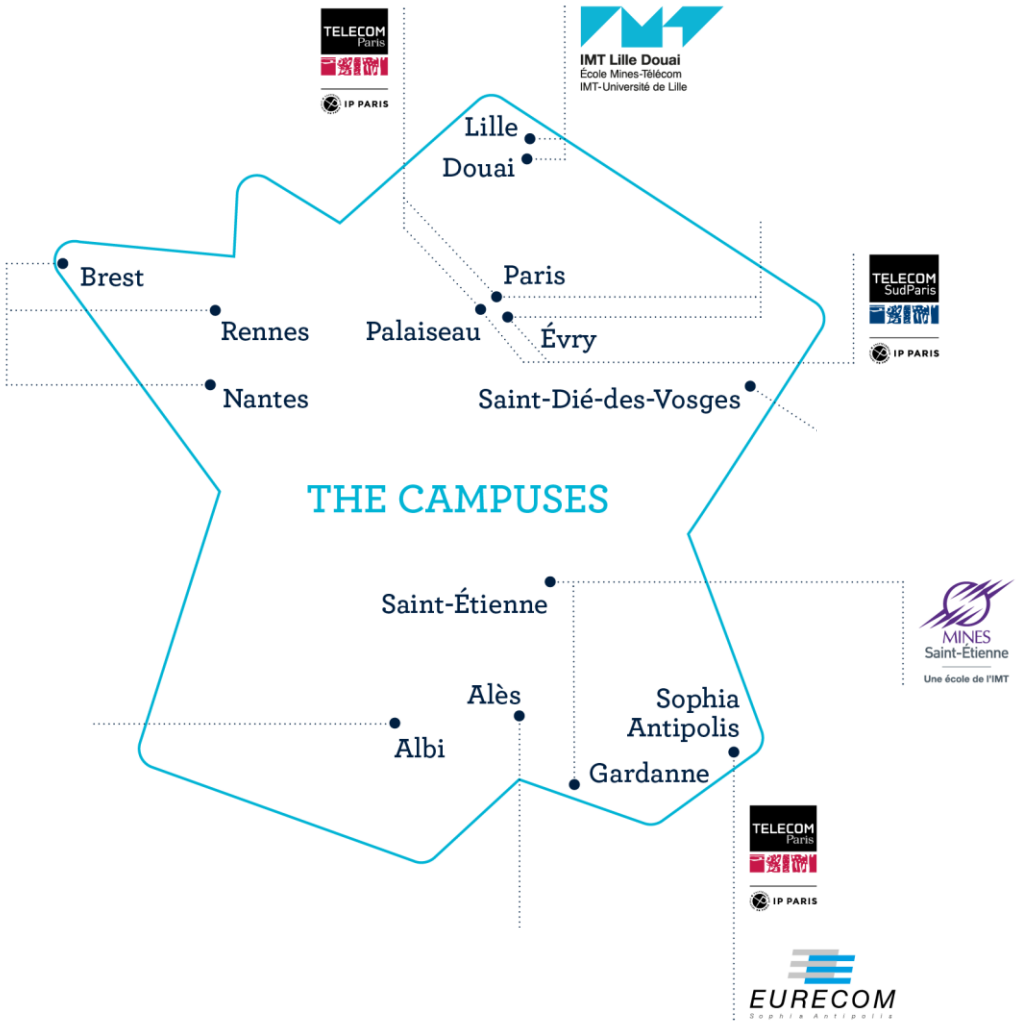
IMT Atlantique Bretagne-Pays de la Loire École Mines-Télécom · IMT Lille Douai École Mines-Télécom IMT-Université de Lille · IMT Mines Albi-Carmaux École Mines-Télécom · IMT Mines Alès École Mines-Télécom · Institut Mines-Télécom Business School · MINES Saint-Étienne Une école de l'IMT · TELECOM ParisTech Une école de l'IMT · TELECOM SudParis Une école de l'IMT · EURECOM · InSIC · MINES ParisTech · MINESnancy · ensiie Paris-Évry | Strasbourg · ARMINES · La recherche CARNOT pour l'innovation des entreprises

NETWORK SCIENCE AND ENGINEERING FOCUS

- **One of 10 IMT national themes**
  - Aiming at developing new major projects
  - Nurturing a dynamic community
  - Fostering collaboration of education and research centres and teams

- **Across IMT Centres**



Main research areas address all facets of:

- Future Networks and services (⊂ 5G and 6G), wireless communications at large and IoT
  - **Full span :** Physical layer to applications. Architecture, protocols, services, applications
    All segments: Devices, Access, Edge, Core, Cloud

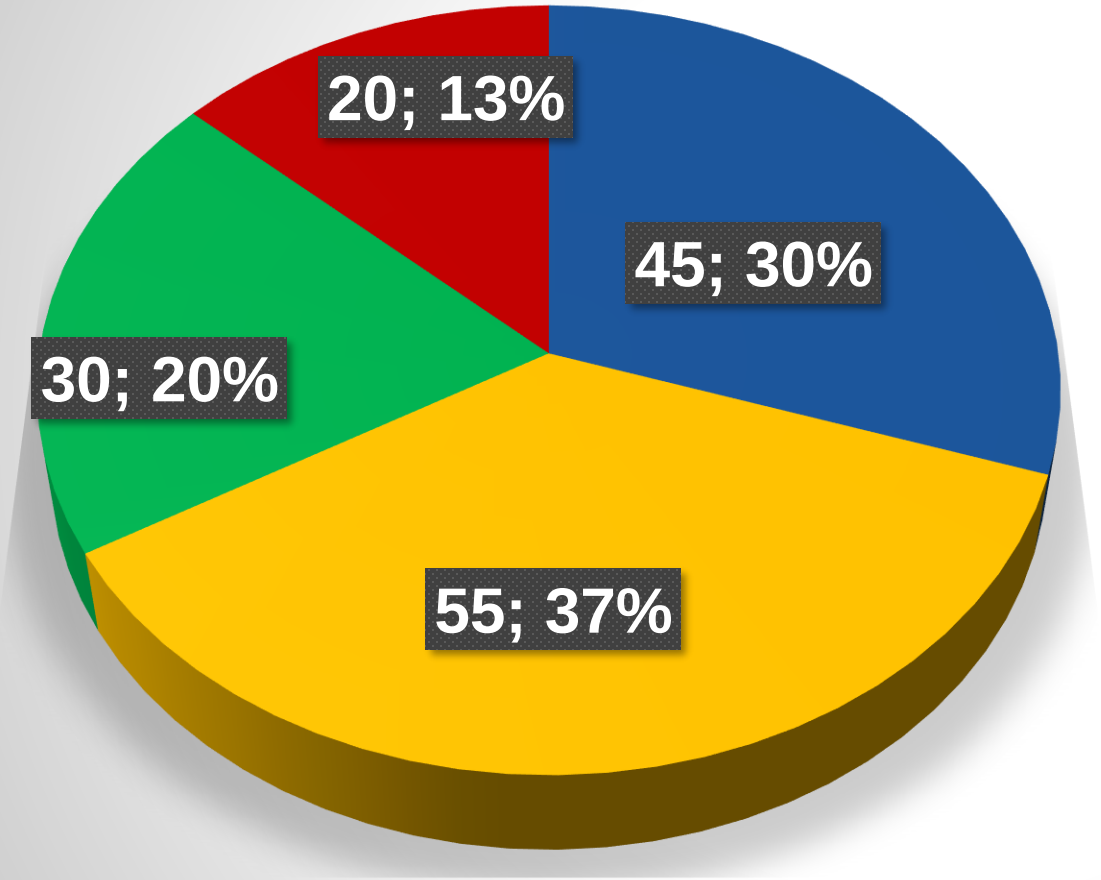
Coarse Research Clustering								
Communications and connectivity		Networks, services, distributed system and networking		IoT Embedded Systems		Physical Layer Electronics and Hardware		
Application areas and verticals								
Industry 4.0 Manufacturing	Energy	Health	Transportation	Automotive	Media	Agriculture	Smart Envts.	Public Safety
Underlying aspects								
Safety, security, protection		Rely on : AI, ML,OR, and SDN/NFV/Cloud principles						

Faculty and Graduates

- 150 Faculty members & ~500 Ph. D. students, Post-Docs & Research Assistants combined
- ~25 M€ average external funding per year across all education & research centers

NETWORKS and IoT RESEARCH ACTVITIES CLUSTERING

Faculty Coarse Research Activities Clustering



- 150 Faculty Members
- 500 DS, Post-Docs and Ras
- ~ 600 publications/Y, ~30% journals

- Communications/connectivity/PHY
- Networks and services
- IoT and Embedded Systems
- Security and related issues

Note: All teams and Faculty addressing the evolution of networks and introducing AI

Major R&D projects

PRIVATE PUBLIC PARTNERSHIPS / COLLABORATIVE PROJECTS

Beyond 5G – French recovery Plan

- ~10 M€ involving Thales SIX GTS, Ericsson, EURECOM and Institut Mines-Télécom (IMT)
  - IMT Atlantique
  - IMT Nord Europe
  - Télécom Paris
- Sovereign and independent Beyond 5G networks and services supporting cooperation and symbiosis between R&D and Verticals
- Harnessed solutions and technologies at access and core network levels including associated and fully independent control, management and security architectures and planes.

PIIEC Electronique et connectivité (on going)

PEPR 5G et Futures technologies de telecommunication

- IMT is one of the 3 leading institutions tasked with organizing this 65 M€ national research plan

Several other joint actions in the context of the recovery plan 5 and 6G

- Health, Multi sectorial Federation, …

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PIIEC = Important Project of Common European Interest (**IPCEI**) and **PEPR** = Programmes et équipements prioritaires de recherche exploratoires

Selected non-exhaustive Research activities, projects and collaborations

Selected Joint LABs

PRIVATE PUBLIC PARTENERSHIPS / JOINT LABS AND PROJECTS

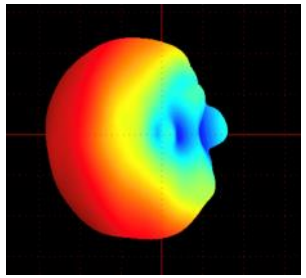
- **SEIDO LAB : Télécom Paris-EDF**
  - Involves Télécom SudParis and Mines St Etienne as well
  - Slicing and orchestration, Open RAN; Multi-RAT, Edge computing, Cybersecurity
- **AIYD-F2N : Télécom SudParis-DAVIDSON (SME) joint LAB**
  - AI and dynamic modeling for future flexibles networks
- **LINCS: Inria, UPMC, Nokia, IRT SystemX**
  - Future information and communication networks, systems and services.
- **Intelligent Network Control LAB Télécom SudParis-Airbus (ADS)**
  - Develop an ML/AI based network control plane with partial observation of heterogeneous networking segments with their own independent security perimeter
- **I4C (Interoperability for Clouds) Télécom SudParis – BYO Networks joint LAB**
  - Network services composition that leads to interoperable multi-cloud services and systems, ensures portability and prevents lock in
  - GAIA-X related activities at European level

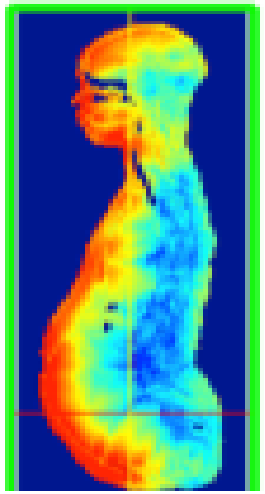
PRIVATE PUBLIC PARTENERSHIPS AND VALORISATION ACTIONS

- Industrial partners
  - SMEs (ETELM, Amarisoft, Davidson, BYO Networks,…) Large scale/corporate (Nokia, Orange, Airbus, Safran, Atos, Thalès, CISCO, EDF, etc), spanning from telecommunications sector to verticals
- Platforms
  - Lisp-lab (Internet du futur), SILECS (Future IoT), SDR 5G, NCF (Networks and Clouds Experimental Platform)
  - ***Futur Industries Pilots:*** IT'M Factory (Full Industry 4.0 environment with all associated technologies including AR, VR, MAR,…) and DIWII offering an experimental Industry 4.0 production line
- Open source
  - OpenLISP, CCNSim, VIGIE (wireless networks monitoring/metrology), ETSO (SFC/NFV Orchestrator)

Selected Platforms (sample)

- Developing mathematical and experimental methods
  - Digital methods (Finite-Difference Time-Domain, Finite Integration)
  - Statistical modeling
  - Machine Learning
- Developing Dosimetry tool
  - Stochastic dosimetry
  - Development of anatomical models
  - Impact of novel networks and usage
- Electromagnetic Exposure characterization
  - exposure induced by a network or by wireless communication systems on a population .
  - exposure induced by wireless systems near the human body.
- Contribution to standardization





Experimentation room in ISM band (802.15.4, Wifi, LORA) and
Cellular experimentation room (2G, 3G, 4G, NB-IoT, 5G)

The two facilities are part of the national platform SILECS https://www.silecs.net/.

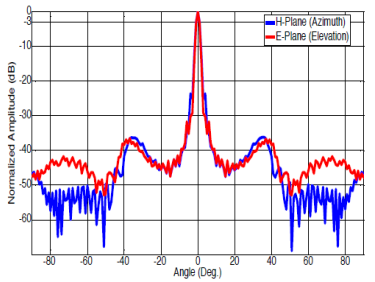
Selected
Research Activities
Teams involved in Networks and IoT

Antenna design in the mm range <100GHz

- W-band (92-95GHz) wireless system for radio distribution of high speed internet everywhere.

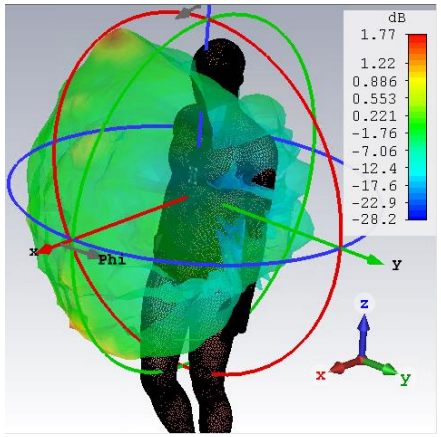
92-94 GHz
Realized gain 38 dB
Beamwidth 2°

TWEETHER



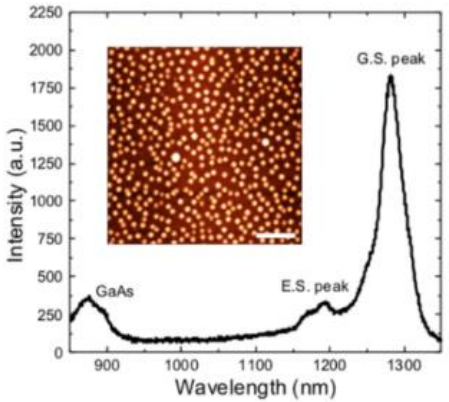
IoT context – On-body sensor network:

- Influence of the indoor environment On Body Area Network
- Statistical modeling combining measurements with full-wave Electromagnetic and Ray Tracing simulations

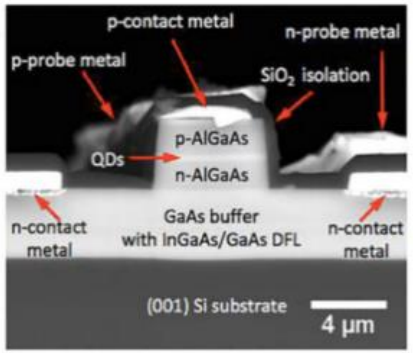


Quantum sources for optical communications

Quantum dots on silicon

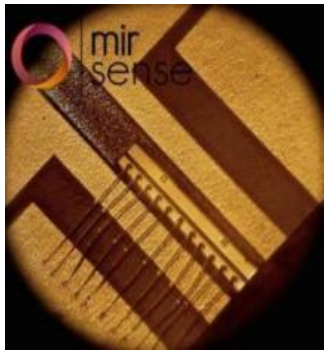


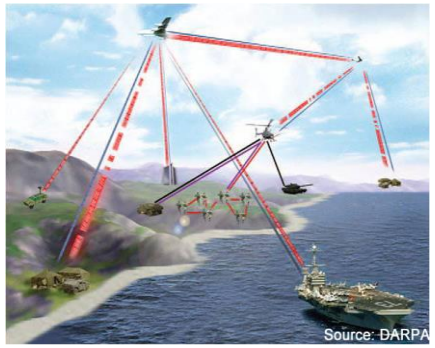
Laser structure



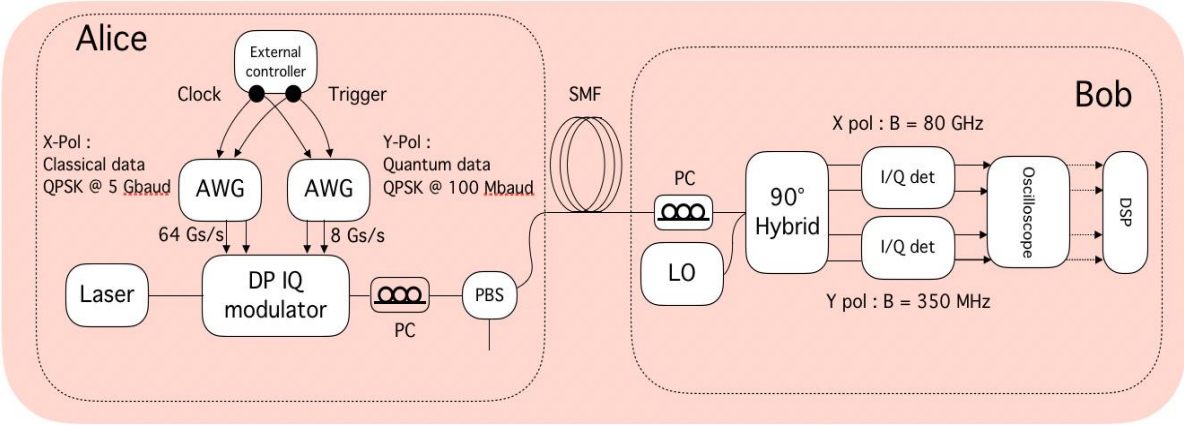
Work with UCSB

Quantum cascade laser

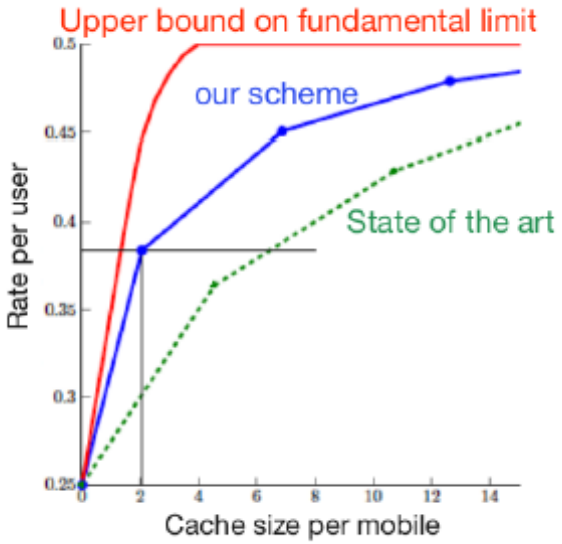




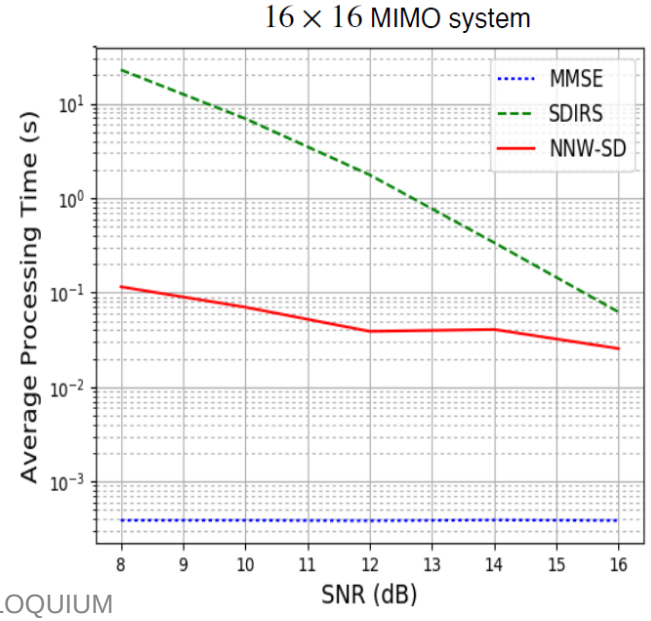
Quantum Cryptography on classical channels



- Use of caching for local storage of contents
  - Communication cost reduction
  - Contention reduction
- Our results
  - Upper bound derivation for caching
  - Best coding scheme based on Polar codes

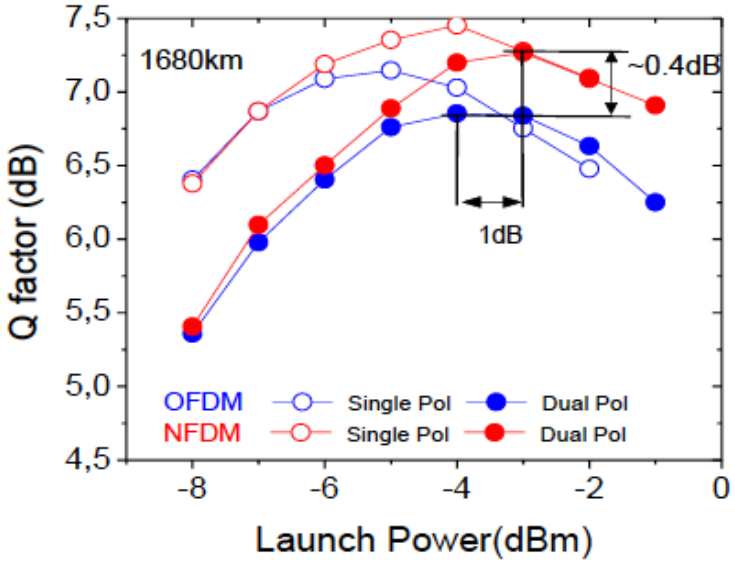


- MIMO Decoding using Sphere decoder and Neural Networks
  - MIMO decoding is an energy and time consuming task
  - A new Neural Network sphere decoder was proposed with a time reduction factor of 100 compared to conventional solution



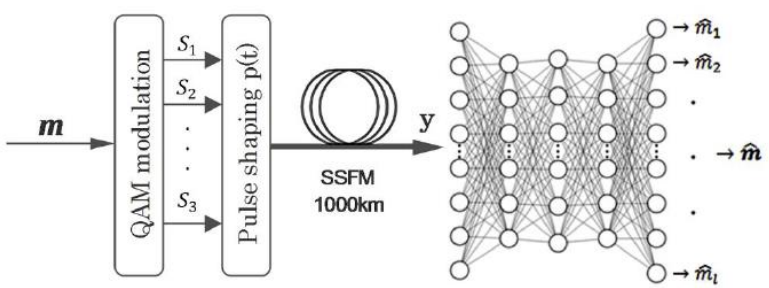
Nonlinear Fourier Transform (ERC Grant)

- First demonstration of NFT on optical communication with polarization mutiplexing

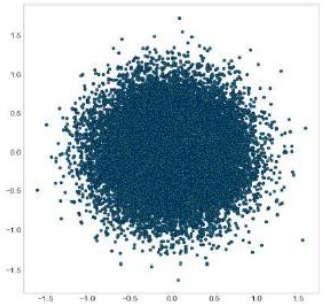


Optical communication using AI

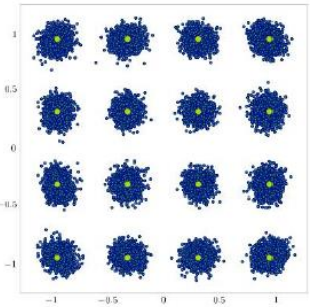
- Receiver design based on neural networks
- Nonlinear channel is learned using training data



Neural receiver

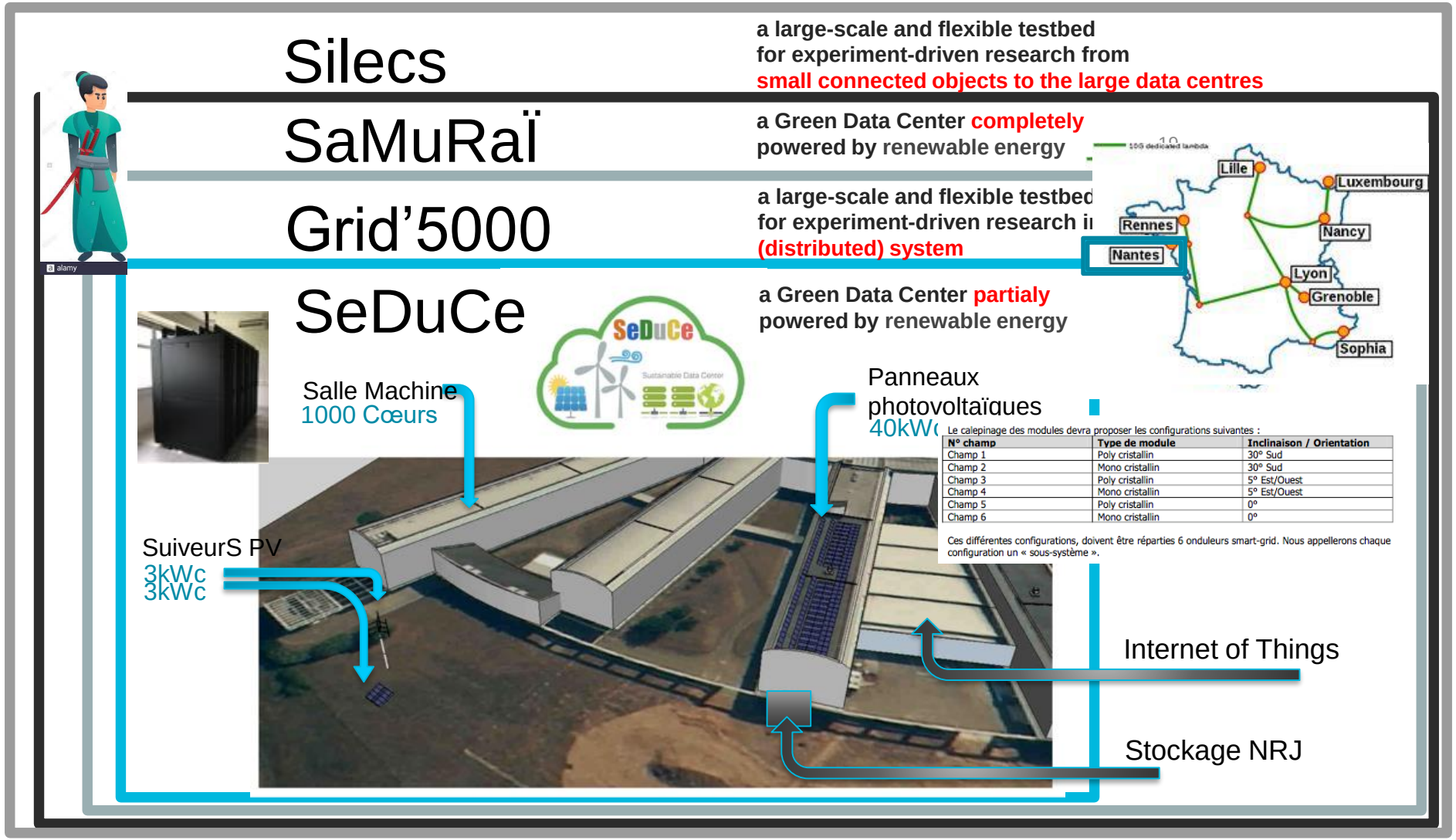


Before equal.



After equal.

RESEAUX & IOT @ IMT ATLANTIQUE



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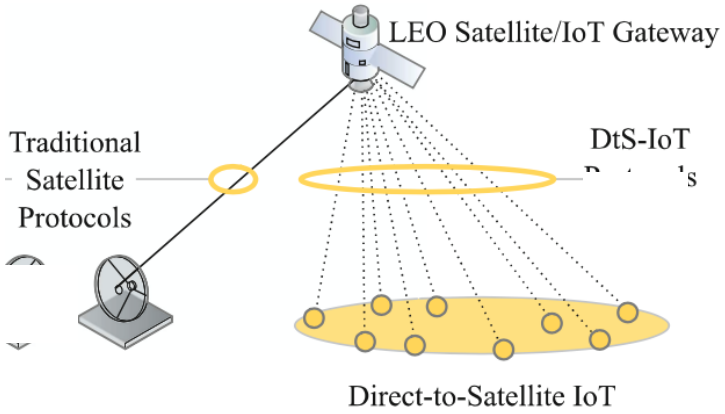
PAST AND ON-GOING WORKS



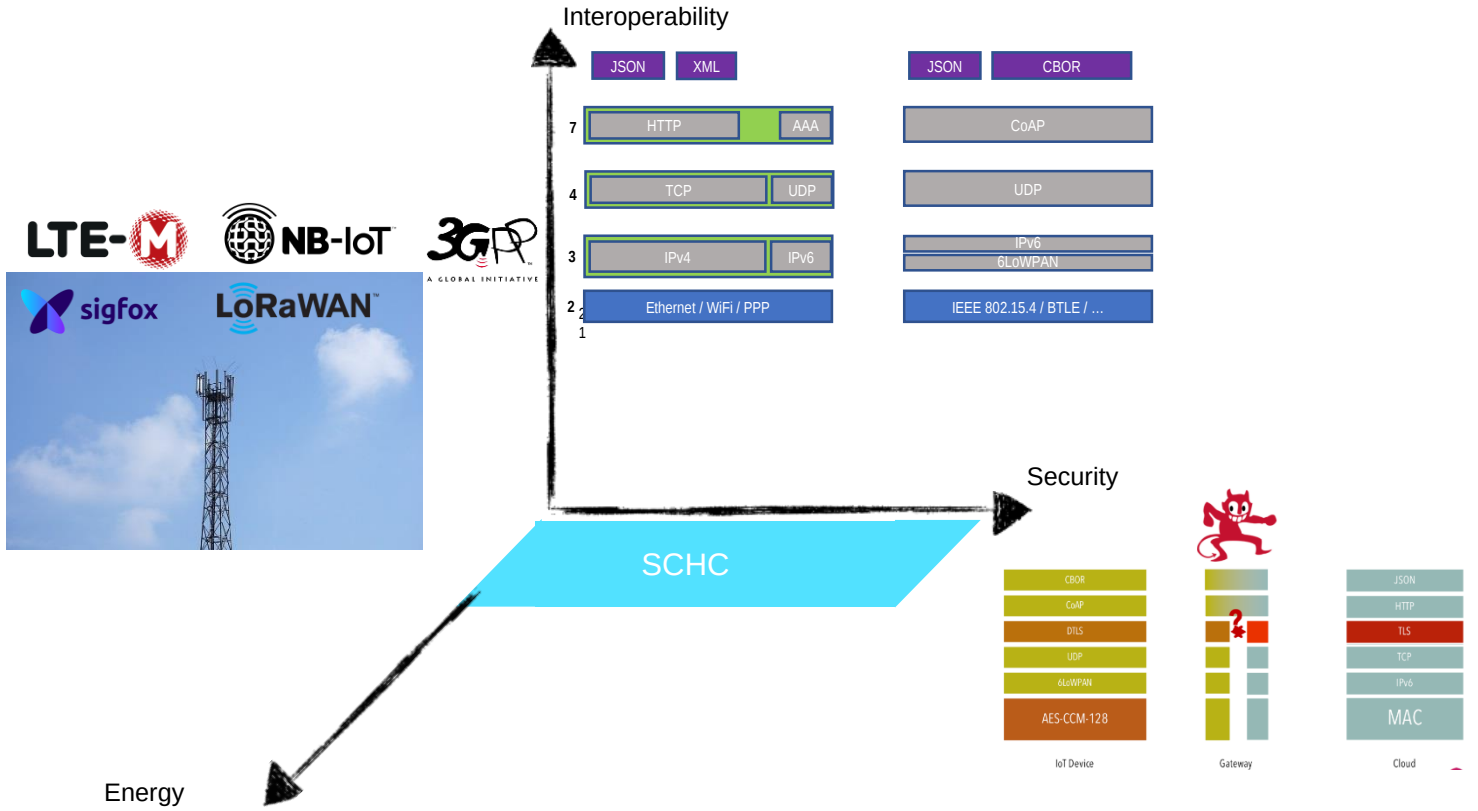
CPM (Continuous Phase Modulation)

- Enhanced spectral efficiency through precoding [1]
- Coherent detection with reduced-complexity / robust towards parameters uncertainties [2-3]
- Detection with blind Doppler-compensation in Sat-IoT
- Synchronisation for AIS systems
- Compressed-sensing techniques for multi-user detection in CPM-based sporadic communications [4]

Coding

- Trade-off between overhead and code length for short-frame transmissions [5]

Predistortion techniques for satellite communications (DVB-S2X) [6]

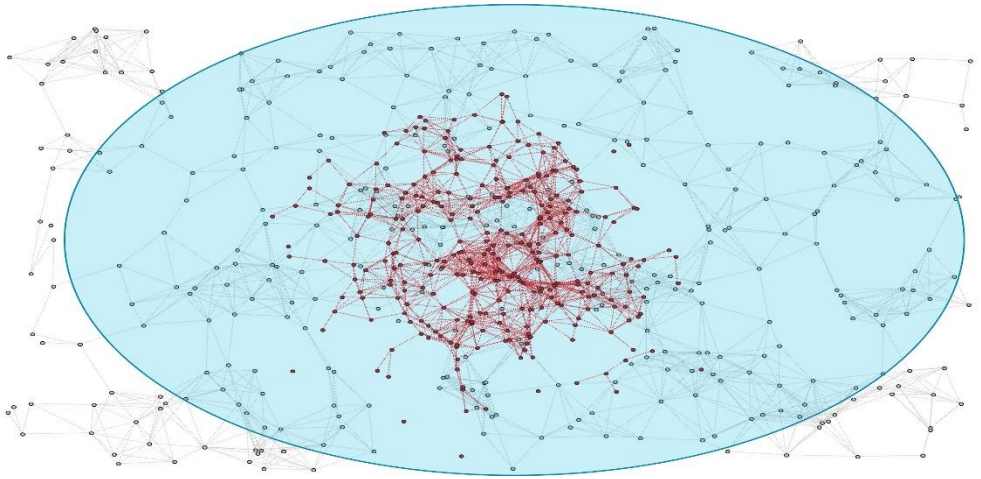


IETF RFC 8724: SCHC STATIC CONTEXT HEADER COMPRESSION

Today, IETF SCHC achieves what the entire community thought impossible before 2016: transporting IP protocols over constrained LPWAN networks.

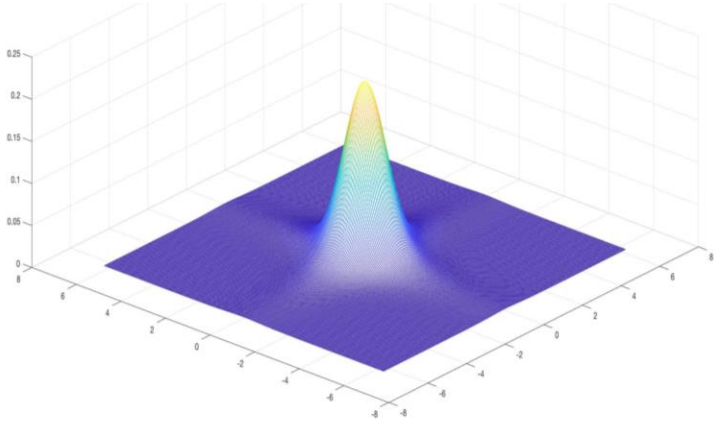
RESEAUX & IOT @ IMT NORD EUROPE

ROBUST NETWORKS



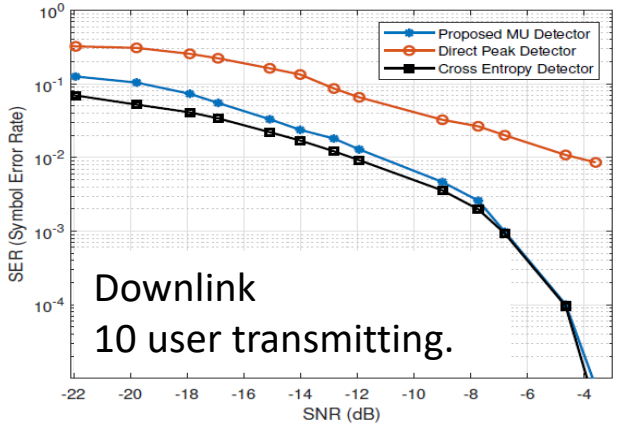
Modeling interference
Multivariate distributions

- Alpha-stable marginals for the impulsive behavior
- Copula to model the dependence structure

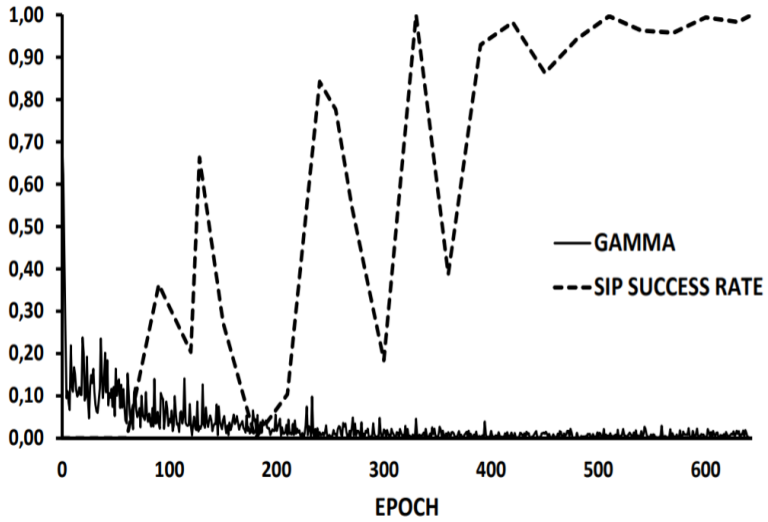


COST ACTION CA 20120 INTERACT

Increase connected devices
Power Domain NOMA and Multiuser detection in LoRa. Uplink (Serial Interference Cancellation) and Downlink



Session Initiation Protocol
Generative Adversarial Networks for detecting anomalies or attacks in the SIP.



A. Meddahi *et al.*, ISNCC-2021

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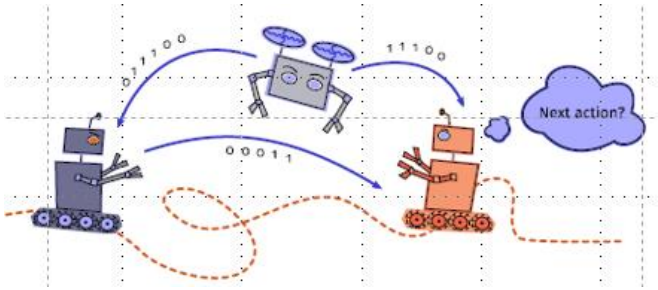
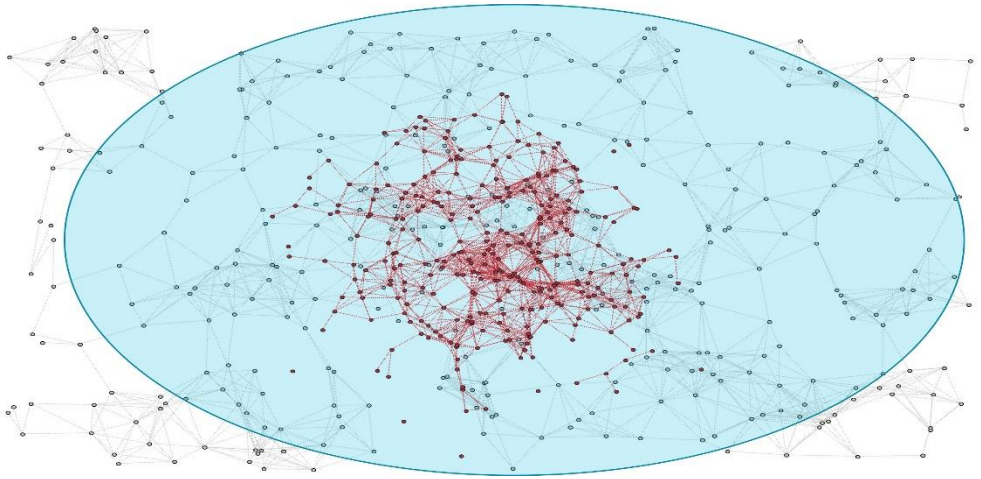
RÉSEAUX & IOT @ IMT NORD EUROPE
RESILIENT NETWORKS

Efficient code design for finite-blocklength coordination

- New finite blocklength theoretical bounds
- Practical codes for coordination

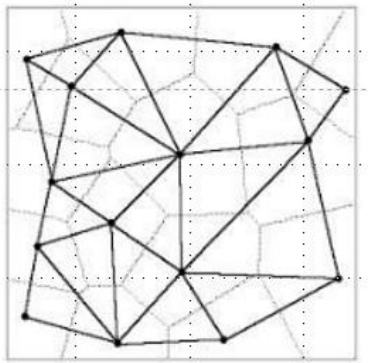


G Cervia *et al.*, IEEE Trans. on IT, 2020



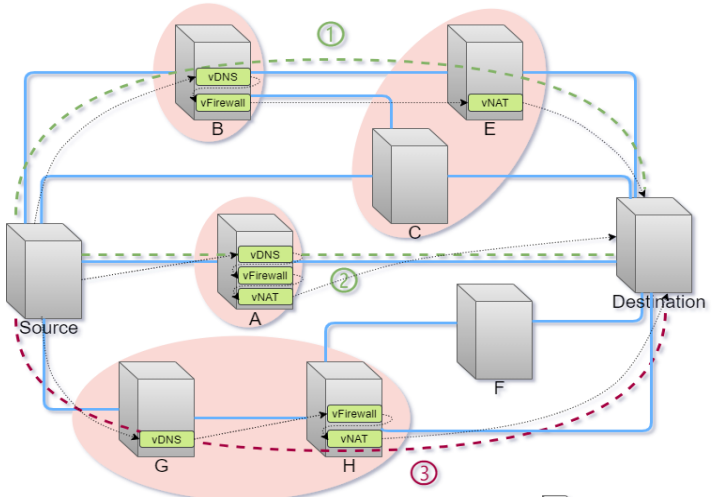
D2D connectivity

- Optimal resource allocation
- Percolation on Delaunay Triangulation



Disaster-Resilient Service Function Chaining (SFC)

- Resilient placement of network functions
- Multiple disjoint working-paths for SFC
- Optimisation : ILP and heuristique



Sixu Cai *et al.*, IEEE **Infocom'21**

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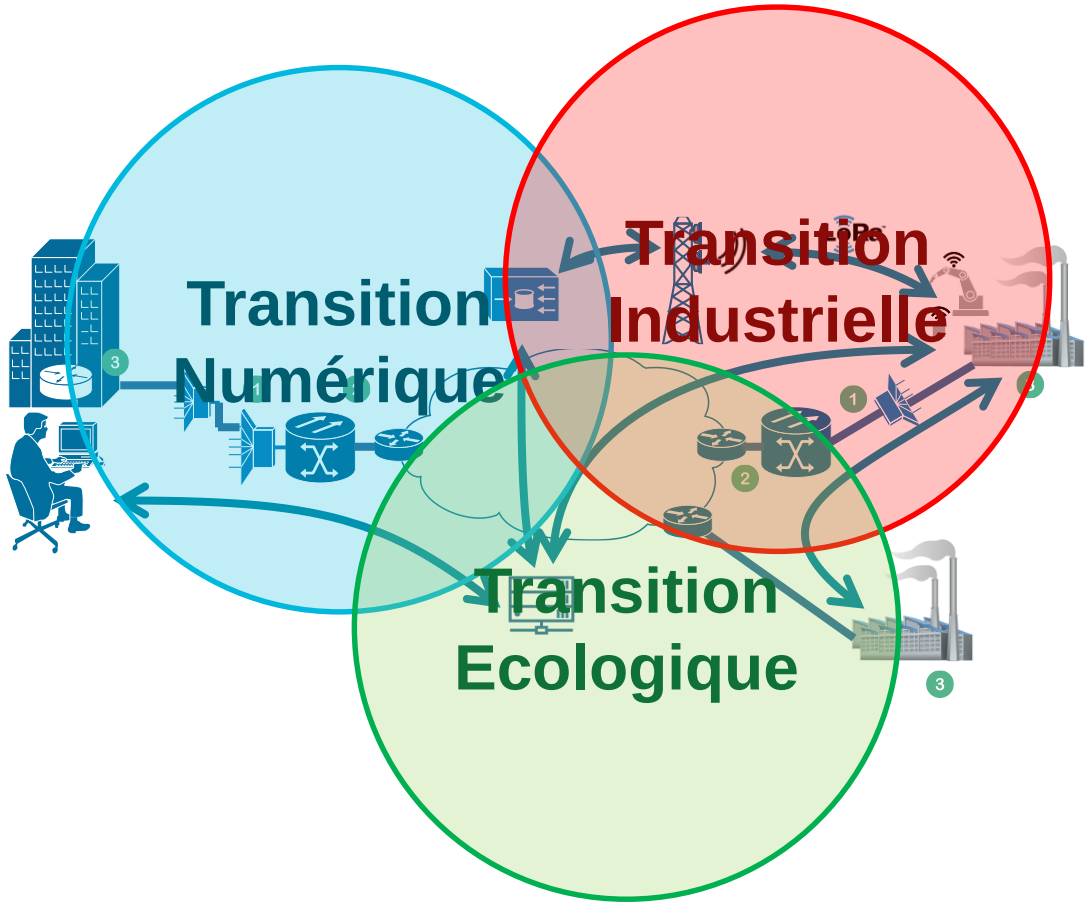
- Institut Henri Fayol : 4 teams
  - Computer science and intelligent systems
  - Mathematical and industrial engineering
  - Environmental and organizational engineering
  - Responsible management and innovation

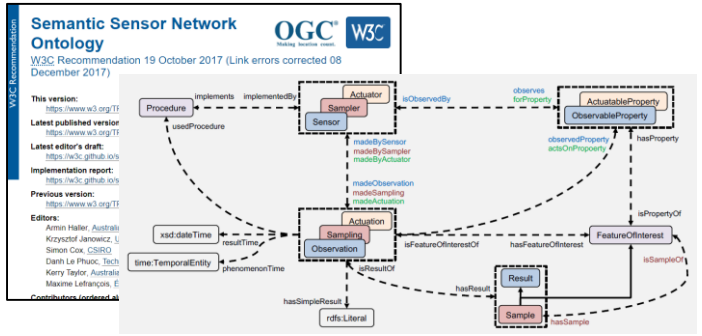


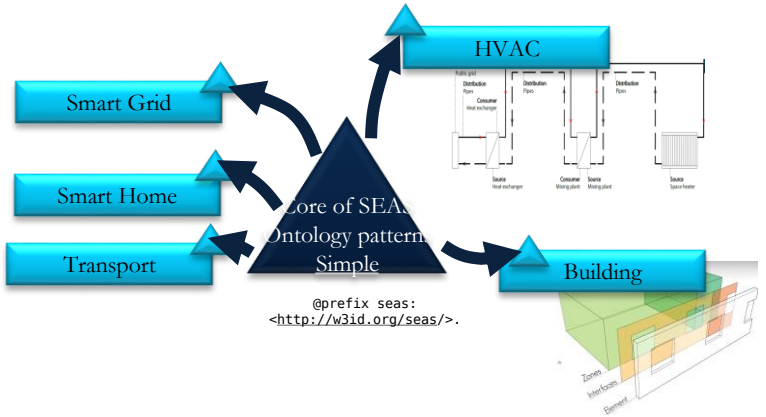
Network is the heart
of the transformation of the society

Territory and Industry 4.0 plateform

Efficiency, Resilience and Sustainability of the Industry and Territories of the Future

- Semantic interoperabilty in future industry context
- Standardization Actvities
  - **OGC & W3C Semantic Sensor Networks**
  - **ETSI : Smart Applications REFerence (SAREF) + ETSI Smart BAN**





- **Projects**

SIRAM

Systèmes d'information pour robot assistant mobile

coswot

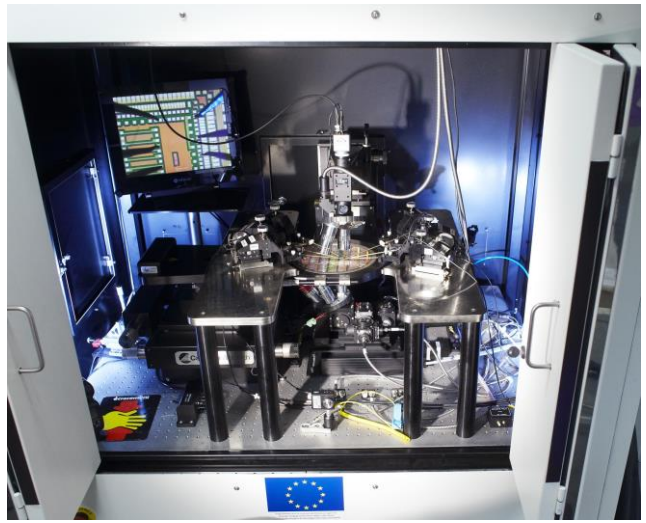
aonstrained Semantic Web of Things

HyperAgents

bypermedia aommunities of People and nutonomous ngents

CENTRE DE MICRO-ÉLECTRONIQUE DE PROVENCE – GEORGES CHARPAC, DÉPARTEMENT SAS

- MSE / CEA Collaboration : joint Team
- Hardware security of Integrated systems, objects, and embedded systems.
  - Caracterization, modeling and protection
- State of art experimental facilities
  - Attacks through fault injection and observation
  - Machine learning, embedded neural networks attacks
  - Cryptography and applied cryptography: vulenaribilities, : efficient, safe and trusted integration
  - New system/hardware architectures: RISC V (ASICs, FPGA)

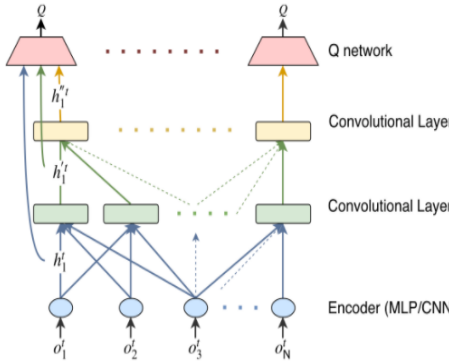


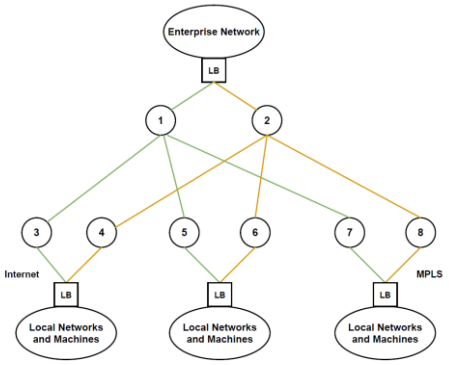
R3S AND METHODES RESEARCH TEAMS @ TÉLÉCOM SUDPARIS

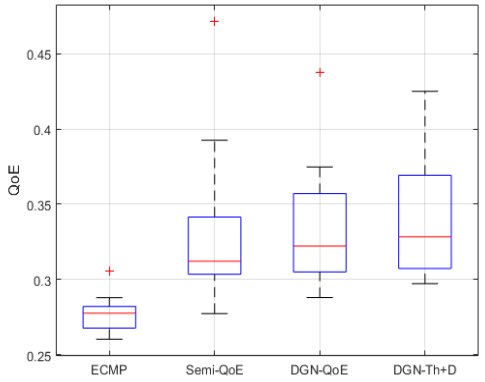
R3S: Networks, services, systems and security

- Networks and Services Science and Engineering
- Networks and services design, modeling, representation, description, performance evaluation and optimization
- Sharing, configuration, control and management (of the lifecycle) of networks, services and resources

- Evolution towards programmable and dynamic infrastructures
- E2E Distributed intelligence and multi-agent based cooperation
- Data & model driven science & engineering of networks & services







MARL and GCRL based Smart Load Balancing

R3S: On going research

- Resource allocation and network optimization
- Slicing, services/networks virtualisation
- Data driven services & networks optimization
- ML and AI techniques and modeling frameworks (e.g.: MDP, MPC, ML, DL, RL)
- Test and monitoring and validation
- Behavior analysis, anomaly detection, prediction
- Energy efficiency in networks and systems
- Large scope in terms of addressed networks and infrastructures, includes verticals

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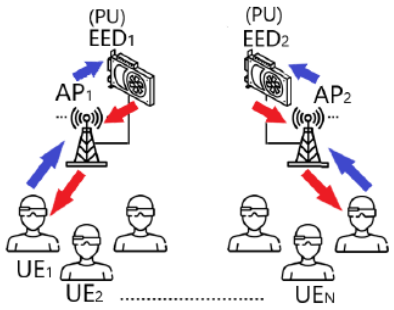
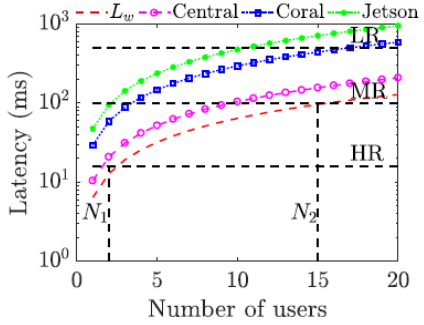
R3S AND METHODES RESEARCH TEAMS @ TÉLÉCOM SUDPARIS

METHODES: Methods and models for networks and services

- **Combining networks, computer science and applied mathematics**
  - Optimization, test and validation and performance evaluation.
  - Fundamental and Applied Science based on methods including:
    - graph theory, stochastic bounds, stochastic modeling, formal methods, robust optimization, queuing theory, game theory, Markov decision processes, aggregation, etc…

Cloud at the Edge study





On going research

- Resource allocation in networks (4/5/6G)
- ML and AI techniques
- Robust Optimization
- Quadratic programming
- Graphs and combinatorial optimization
- Distributed Optimization
- Diffusion and dynamics of information and opinions
- Data analysis
- Verification and proof, formal models, test and validation

PRIORITIES @ TSP

- “Network Engineering and Science”
  - Distribution and cooperation via multi-agent cooperative systems
- Softwarization, SDN/NFV/Slicing, Radio slicing
  - Service architecture Evolution (B5G and 6G), Internet of Things, Digital Twins
- Applied AI, Edge Continuum, Intelligent control and management systems
  - Network operating models for verticals, energy efficiency and green challenges

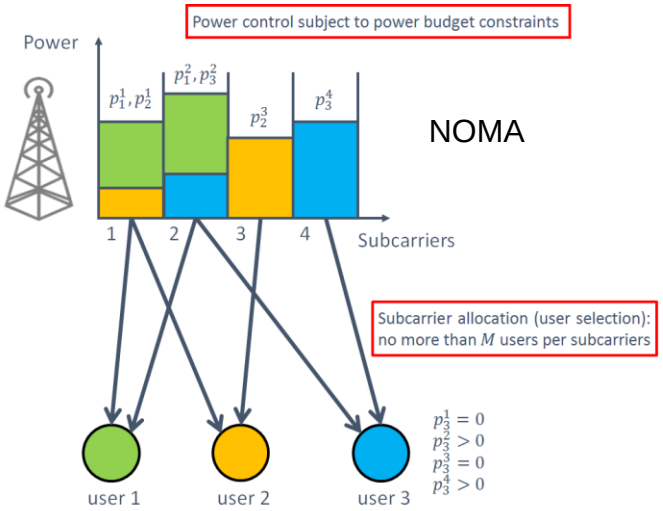
PRIORITIES @ TSP

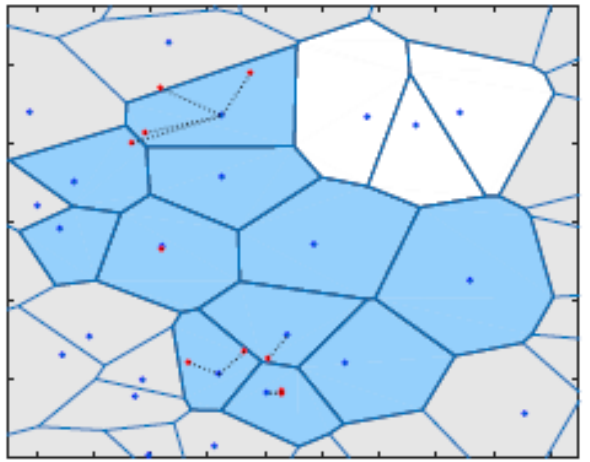
- Math programing and optimization
  - Partitioning and cover in graphs
  - Multi-source maximal concurrent flow in graphs
  - Dominance in k-independent clusters
  - Multipolar approach to robust optimization
- Complex networks and systems verification
  - Verifications, Proofs,
  - Monitoring, Test
- Performance evaluation models for dynamic networks
  - MDP, MCP, Learning, prediction
  - Resource allocation in all types of networks and multi domain and technologies context

- Focus on Large scale networks and operated/managed systems
  - Wireless communications and networks
  - Future Internet and IoT
  - Cloud and Virtualization
- Methods and Methodology: From theory to practice and vice versa
  - Experiments and metrology
  - Architectures and Protocols
  - Algorithms design and mathematical modeling

SAMPLE ACTIVITIES AT TÉLÉCOM PARIS - RMS TEAM

- NOMA resource allocation, joint power and sub-carrier allocation problem
- Network MIMO for mission critical communications
  - Cell clustering algorithms, MIMO transceivers, PHY layer security schemes
- Telemetry & Automation
  - Network Telemetry & Analysis
    - ML Analysis of measures, extracting service statistics from simple measure (ML)
  - Network Automation
    - Traffic Engineering methods (re-optimization of the network)
- OpenRAN in 5/6G
  - Free5GRAN, Telemetry Probe for 5G
    - Scheduling (end-to-end isolation of slices), allocation and placement of resources of virtualized functions for NB-IoT, IoT 5G
    - Resource allocation in RAN (Interference reduction, robustness, …)

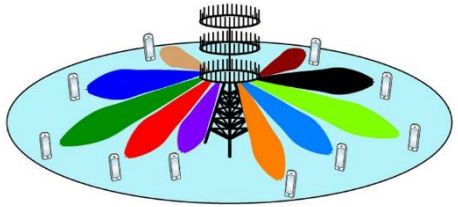




Network MIMO for MCC

EURECOM FUTURE NETWORK RESEARCH : FOUNDATIONS AND ALGORITHMS

- Goal: Predict fundamental limits and design limit-approaching methods and algorithms using
  1. Communication theory
  2. Machine learning & decentralized learning
  3. Network science
- Key topics (2021)
  1. Massive MIMO (mMIMO)
  2. Robot-augmented IoT
  3. RF sensing & Localization
  4. Caching
  5. AI-driven resource allocation



H2020: 2 ERC Projects, 3 ITN Marie Curie Projects,

EURECOM FUTURE NETWORK RESEARCH : NETWORKED SYSTEMS & EXPERIMENTS

5G radio access and network virtualization

- Cloud radio access network and virtualization of radio access network (SDN, NFV)
- Service-based architecture to support Slicing
- Network store
- 5G/6G standardization

Edge Computing

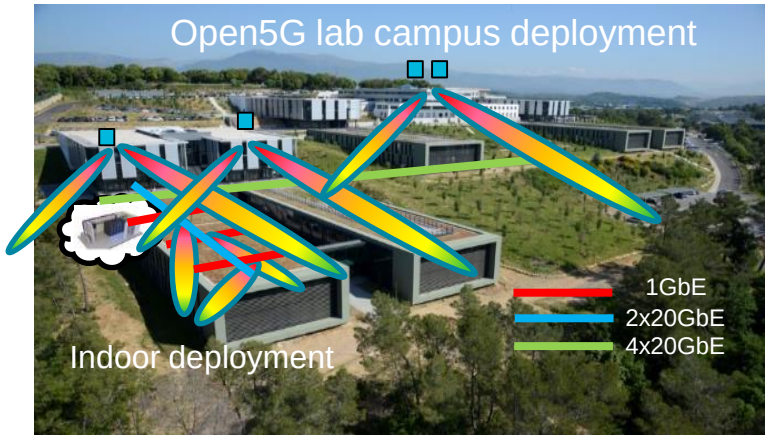
- Cloud-edge continuum
- Compute first networking (identify computing opportunities)

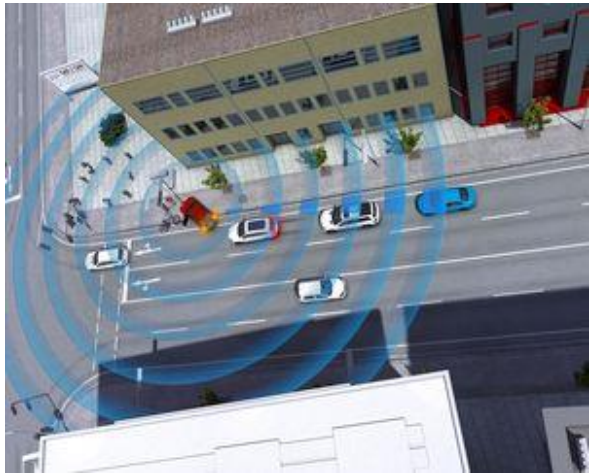
ITS

- V2X communication (ITS-G5, C-V2X)
- 5G-assisted Connected Cooperative Automated Mobility (CCAM)
- ML/AI - assisted mobility and transportation optimization

5G outdoor test site deployment

- Used in several H2020 – collaboration with INRIA – integration with Orange 5G equipment in Paris
- Mmwave radio (outdoor tests – 26GHz)





H2020: 12 EU Projects ongoing in 2021

Institut Mines-Télécom

Future Networks & Services
Colloquium 14/10/2021

THANKS FOR YOUR ATTENTION

COMMENTS /QUESTIONS ?

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