Labex Digicosme

ComEx Axe

Coordinators

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Outline

ComEx : Intelligent network structures

Domains

Information Theory, Coding Theory, Optimization Problems, Routing, RAN, Signal processing, Graph Theory, lattice coding, Network Coding ….

Requirements

Throughput, Time, frequency, spectral, QoS, Synchronism, Asynchronism, Security, Confidentiality…

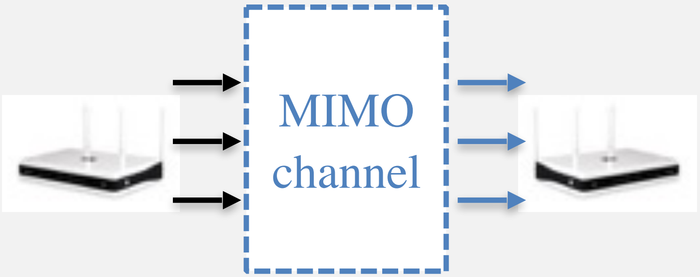
Standards

WiFi, WiMax, LTE and LTE-advanced, DVB, 5G, Heterogenous Networks…

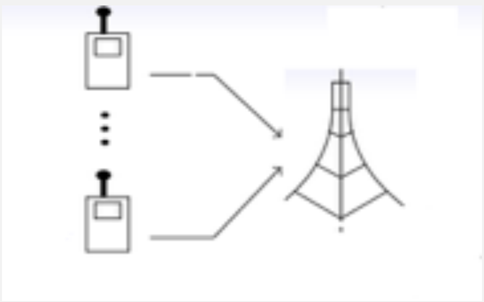
Applications

IoT, Big Data, Cloud computing, Distributed Storage, Sensor Networks…

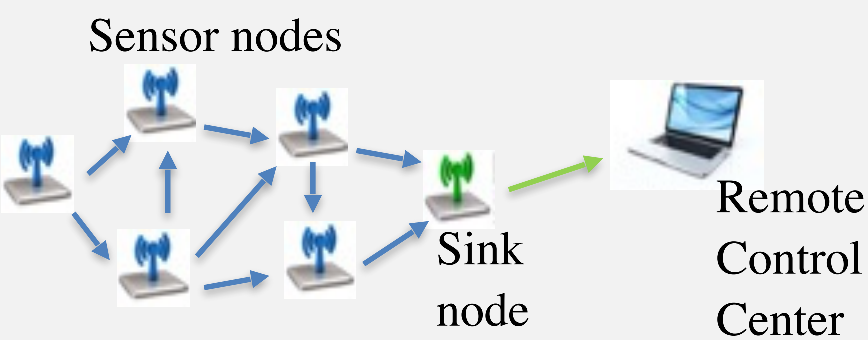
Some communication systems



Multiple antennas systems



Multi-user communications



Wireless sensor network

Optical fiber communications

Communication systems evolution

Point to point communication → Multi-nodes communication → Network

Need of Distributed Computations

Answer:
- capacity demand
- heterogenous networks
- massive connectivity
- large type of applications
- limited energy consumption

Ensure:
- Reduced latency
- Good performance
- Secure systems
- Preserve confidentiality

Challenge for futur communication systems

The long-term goal of ComEX is to create **autonomous and scalable digital systems** based on **efficient**, **agile**, **secure** and **transparent** communication means and supported by **reconfigurable** and **heterogeneous** mobile networks.

ComEx : First period

Tasks:

- **Network information theory and coding**
- **Network centric design of distributed architectures**
- **Terminal centric design of networks**

15 Laboratories :

- **DAVID** | Données et Algorithmes pour la Ville Intelligente et Durable
- **INRIA Saclay – Île-de-France**
- **INRIA Paris-Rocquencourt**
- **L2S** | Laboratoire des Signaux et Systèmes
- **Li-PaRAD** | Laboratoire d'Informatique – Parallélisme, Réseaux, Algorithmique Distribuée
- **LIMSI** | Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur
- **LMV** | Le Laboratoire de Mathématiques de Versailles - CRYPTO (Cryptologie et Sécurité de l'Information)
- **LSV** | Laboratoire Spécification et Vérification
- **CEA LIST** | Laboratoire d'Intégration des Systèmes et des Technologies
- **LIX** | Laboratoire d'Informatique de l'École Polytechnique
- **LRI** | Laboratoire de Recherche en Informatique
- **LTCI** | Laboratoire Traitement et Communication de l'Information
- **MAS |** Mathématiques Appliquées aux Systèmes
- **SAMOVAR** | Services répartis, Architectures, MOdélisation, Validation, Administration des Réseaux
- **U2IS** | Laboratoire d'Informatique et d'Ingénierie des Systèmes

ComEx : First period

5 PHDs:

- **Optimal Content Management and Dimensioning in Wireless Networks (CONTAIN)**
  Direction : Marco DI RENZO / Anastasios GIOVANIDIS
  Institutions : L2S / LTCI
  Doctorant : Jonatan KROLIKOWSKI

- **Energy-aware resource allocation for Cloud Virtual Services (E-CloViS)**
  Direction : Joana TOMASIK
  Institutions : E3S - Supélec
  Doctorant : Alexandre DAMBREVILLE

- **Persistence topologique pour l'analyse des réseaux sans fil (PERSANFIL)**
  Direction : Laurent DECREUSEFOND
  Institutions : LTCI , Institut Mines-Télécoms
  Doctorant : Aurélien VASSEUR

- **Optimal Design of Secure and Scalable Content Centric Networks (ODESSA-CCN)**
  Direction : Fabio MARTIGNON / Dario ROSSI
  Institutions : LRI / LTCI
  Doctorant : Andrea Giuseppe ARALDO

- **Réseaux sans fil collaboratifs**
  Direction : Hikmet SARI / Romain COUILLET / Jamal NAJIM
  Institutions : E3S / LIGM
  Doctorant : Adrien PELLETIER

1 Working Group:

- **Performances, QoS et gestion de ressources des réseaux sans fil dynamiques:**

Contact : Michel MAROT

ComEx Tasks

Task 1 Network Information Theory

Task 2 Future Access Networks

Task 3 Distributed Networks

Task 4 Optical Communication

High Links, Interactions and Complementarities between tasks

Task 1 Network Information Theory - Contact : Sheng Yang

- Information Theory → Theoretical Limits
- Coding Theory → Tools to achieve the limits

Efficient tools : code everything anywhere

Coding in networks ≠ Orthogonalization

Task 1 Network Information Theory

- **Network Coding:**
  - MAC and Physical Layers
  - Relays decode linear invertible functions and forward them.
  - Wireless channel faces Interferences due to Broadcasting and Superposition.
  - Advantages: Rate maximization, Latency and Power consumption minimization.
  - Important open issues : synchronism, decoding problems, complexity analysis, Physical-Layer Network Coding for distributed storage and Physical-Layer Network Coding for optical communications.
- **Caching :**
  - Variable flow traffic on the time (example multimedia)
  - Need of creation of caches
  - Advantage: avoid network congestion
  - Important open issues: How many caches ? how much information to storage on caches ? and where to put caches on the network ? Optimal coding strategy ?
  - Complex optimisation problem

Task 1 Network Information Theory

- **Deep learning and big data :**
  - Huge quantity of data on networks
  - Advantage: Learning high dimension structures from multiple points of view.
  - Important open issues: Learning using Information theory tools, Compressed sensing, Sublinear sampling

- **Low-Power Wide-Area Network (LPWAN)**
  - Advantage: Long range Network, Low energy Consumption, Low cost and Licence free frequencies.
  - Focus on battery operated devices
  - Example of Standards : LORA, Dash 7 …
  - Industrial IoT : implementation of Sigfox and LoRA networks in France
  - Important open issues: Increase coverage distances on LOS, Security, Coding, Complexity, Manage interference.

Task 2 Future Access Networks - Contact : Kinda Khawam

- **To cope with the restless demand for high capacity:**
  - Design efficient Future Radio Access Networks that intelligently invest in network infrastructure by using existing Radio Access Networks
  - Diverse RANs (3GPP and IEEE families) are being integrated and jointly managed
  - Deployment of low power small cell nodes overlaid with macro cell BSs
  - Aggressive reuse of existing spectrum and adapted interference management
  - Inclusion of heterogeneous infrastructures and distributed cloud networking
  - With the combination of C-RAN and multiple RANs, small cells have chance to exploit the resource holes in each BBU

- **Cloud RAN:**
  - C-RAN decouples the baseband processing unit (BBU) from the remote radio head (RRH)
  - Centralized operation of BBUs and scalable deployment of lightweight RRHs
  - When radio signals of multiple BSs are processed centrally, computational diversity can be exploited (its benefit grows with UE density)

Task 2 Future Access Networks

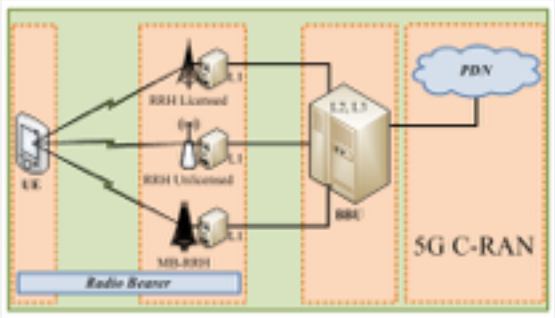
- **Issues for Future Access Networks:**

  - High heterogeneity:
  1. Heterogeneity in size: the wireless access is a mix of macro cells and small cells.
  2. Technology heterogeneity: coexistence between recent LTE and LTE-Advanced with legacy 2G, 3G, with WiFi and unlicensed spectrum.
  3. Heterogeneity in RRM elements: transmitted power, modulation, coding schemes, spectrum bands (mmWave, unlicensed bands, etc.) etc.
  4. Heterogeneity in resource allocation: **distributed** for SONs and **centralized** for CoMP, C-RAN, etc.
  5. Heterogeneity in the cloud: HCRAN

  - All Radio Ressource Management (RRM) schemes must be inevitably green and energy efficient.

Task 2 Future Access Networks

- **Issues for C-RAN:**
  - Design of a logical mapping between each RRH and one or multiple managing BBUs.
  - **Dynamic** design to optimize the resource consumption on the backhaul, taking into account: user profile, load factor of the served cell, its size, etc.
  - Joint optimization of the usage of radio resources and backhaul resources
  - Challenging modeling:
    - Modeling the BBU resources for multiple RANs
    - Modeling spectrum utilization, etc.
    - Optimization of the number of BBU (if the number of UEs is low) and RRH
    - Multi-Cloud...



Task 3 Distributed Networks - Contact : Ghaya Rekaya

- **Distributed Networks**
  - Distributed Coding, Storage, Computation, Security, Routing, Clustering, Optimisation...
  - For wired and wireless networks
  - For heterogenous networks
  - Challenge : Efficient solutions locally and globally good for the network.
  - Reliability, Flexibility, Scalability, Speed and Good complexity/gain tradeoff

- **Distributed storage**
  - Very important for future networks due to huge quantity of data to conserve.
  - Need of more efficient codes for repair and reliability, Reduce Energy consumption.

Task 3 Distributed Networks

- **Distributed Security / Privacy**
  - Very important issue for all applications
  - Layering of security mechanism
  - Physical layer security
  - Link with classical cryptographie
  - Link with distributed storage...
- **Distributed Routing / Clustering**
  - Ressource allocation in ad hoc networks using Coalition Formation Game.
- **Distributed Optimization:**
  - Ressource allocation in big networks with no connection between small cells.

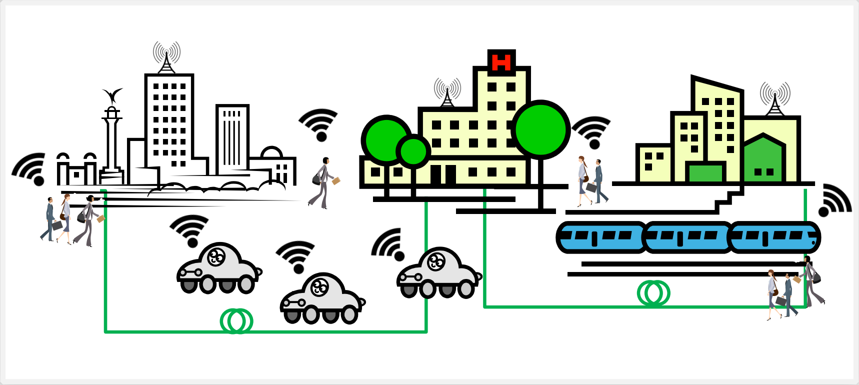
Task 3 Distributed Networks

- Link with Task 1 : Information theory limits like secrecy capacity, caching
- Link with Task 2 : Distributed optimisation for C-RAN
- Link with DataSense Axe : Could computing
- Link with SciLex Axe: Cryptography

Task 4 Optical Communication - Contact : Philippe Ciblat

Optical Communication

- Many degrees of freedom : polarization, space (modes or cores) and wavelengths.
- Fiber non linearity as a new degree of freedom.
- Advantages: Very high throughputs, very good performances
- Important open issues: Channel modeling (deterministic or random numerical models), Need of advanced signal proceeding and advanced coding tools, Definition of new decoders adapted to new waveforms based on NLFT..
- Applications : link between base station, link between data center Servers...



Task 4 Optical Communication

- **Wireless optical communications**
  - Free space optical communications (FSO) using infrared laser light, LEDs
  - Advantages: Ease of deployment, Licence-free, Long or short distances, high bit rates or low bit rates, Electromagnetic interference free, Secure.
  - Important open issues: Signal processing solution to overcome limiting Factors as fog, rain, snow, Interference from background light sources and beam dispersion, MIMO FSO and cooperative networks (using relays)
  - Application: Vehicular and vehicular-to-infrastructure communications
  - High potential solution for LPWAN.

Task 4 Optical Communication

- Link with Task 1 : optical communication capacity limits
- Link with Task 2 : study and optimization of the network in FSO communications
- Link with Task 3 : distributed network with optical fiber communication for the last 100 meters .

Conclusion

- Future communication systems **NEED** a GLOBAL design and optimisation of the network.

Network & Digital communication
High Levels & lower levels

- Enhance Links and interaction between ComEx Tasks.

- Avril 2017 : Organisation of a Spring School «Internet of Things ».

Conclusion

Enhance and Encourage Interactions and collaborations between Digicosme Axes