Les TICs dans le développement des réseaux électriques intelligents (Smart Grids) : au sein des postes électriques

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Interactive Information Infrastructure
for the Power Grid

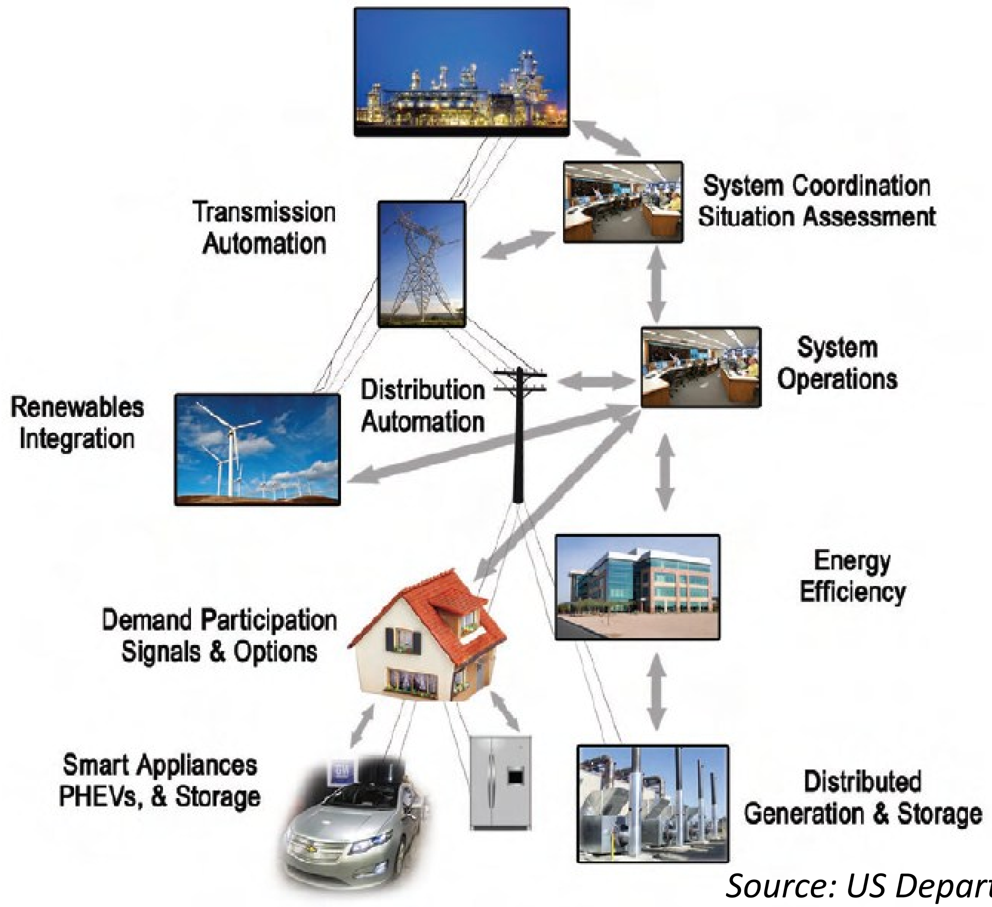
Outline

- Background and context: Smart Grids and the role of ICT
- A specific application – communications within substations
  - Noise environment and its characterization
  - Deploying Wireless Sensor Networks
- Conclusion

Background and Context

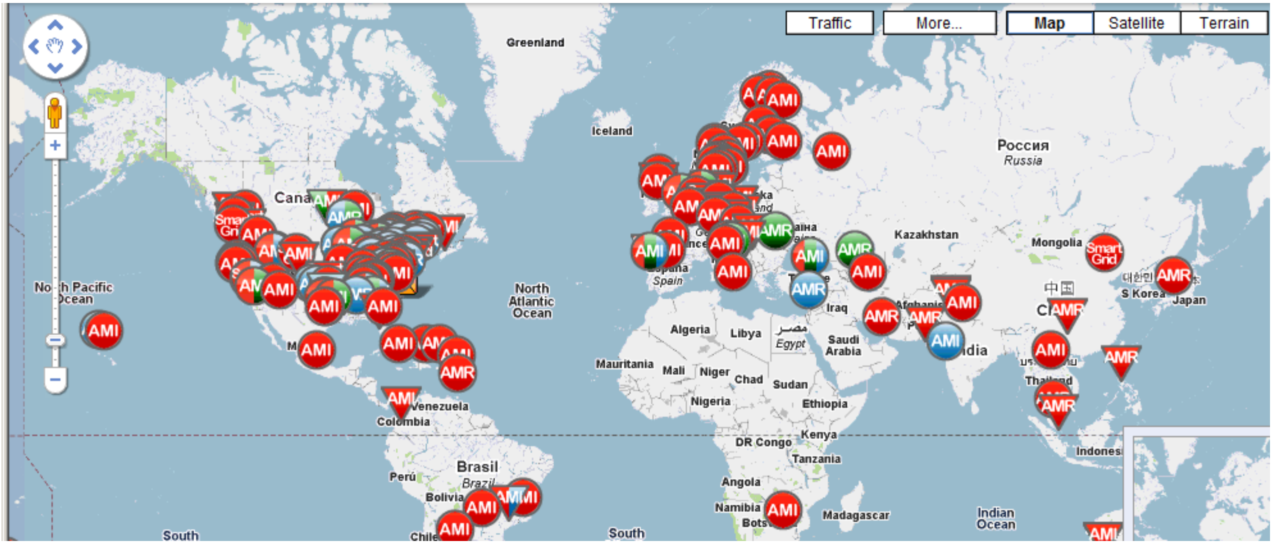
- "Smart Grid" push
- Main concerns
  - Ageing infrastructure
  - Need for enhanced reliability
  - Grid working closer to its maximum load
  - Inclusion of DER/Renewables
  - Promise of demand response/load management
- Smart Grid
  - Many definitions
  - A lot of activity worldwide

Smart Grid around the world



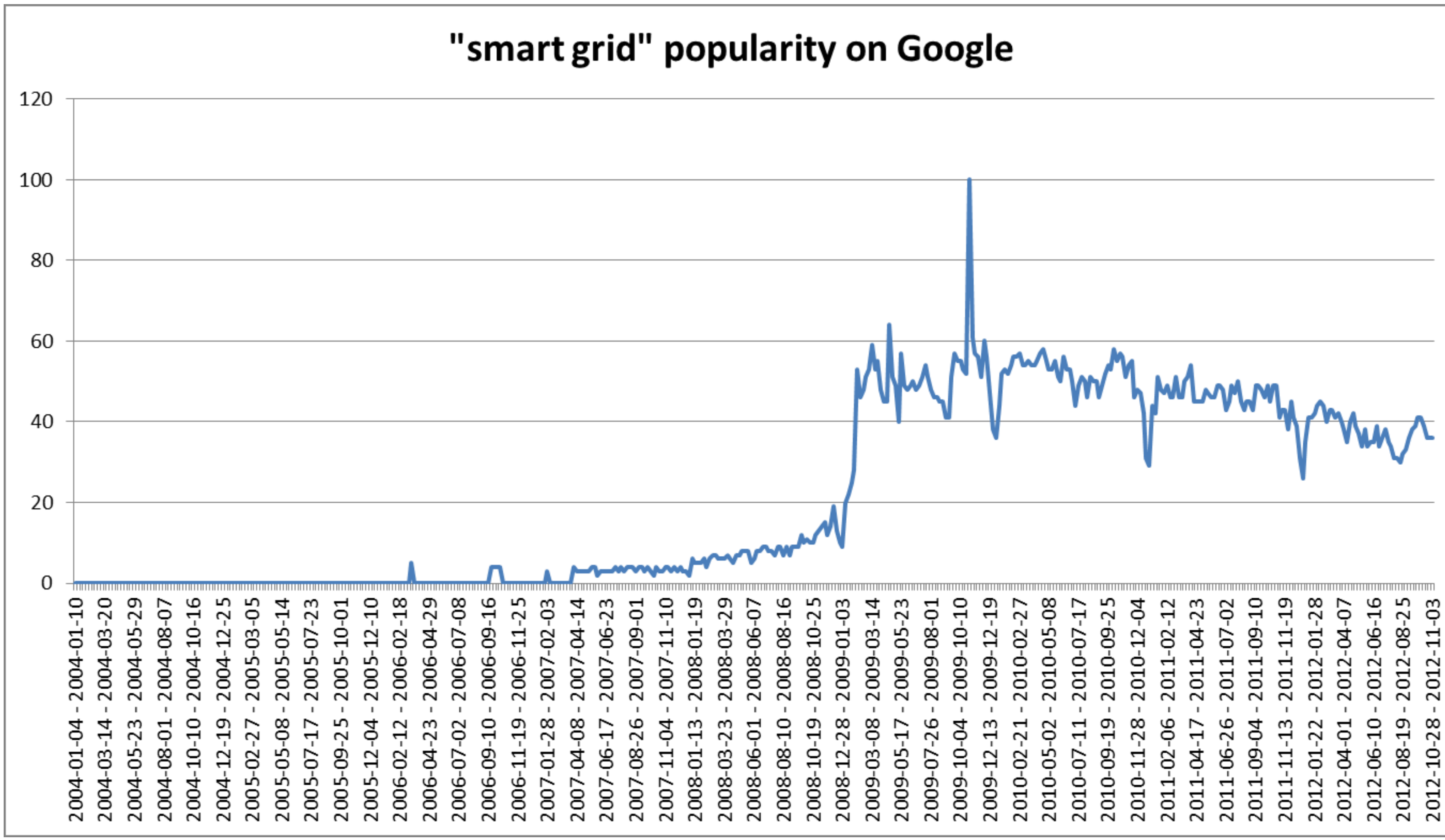
Source: US Department of Energy, Smart Grid System Report, July 2009

Smart Grid around the world



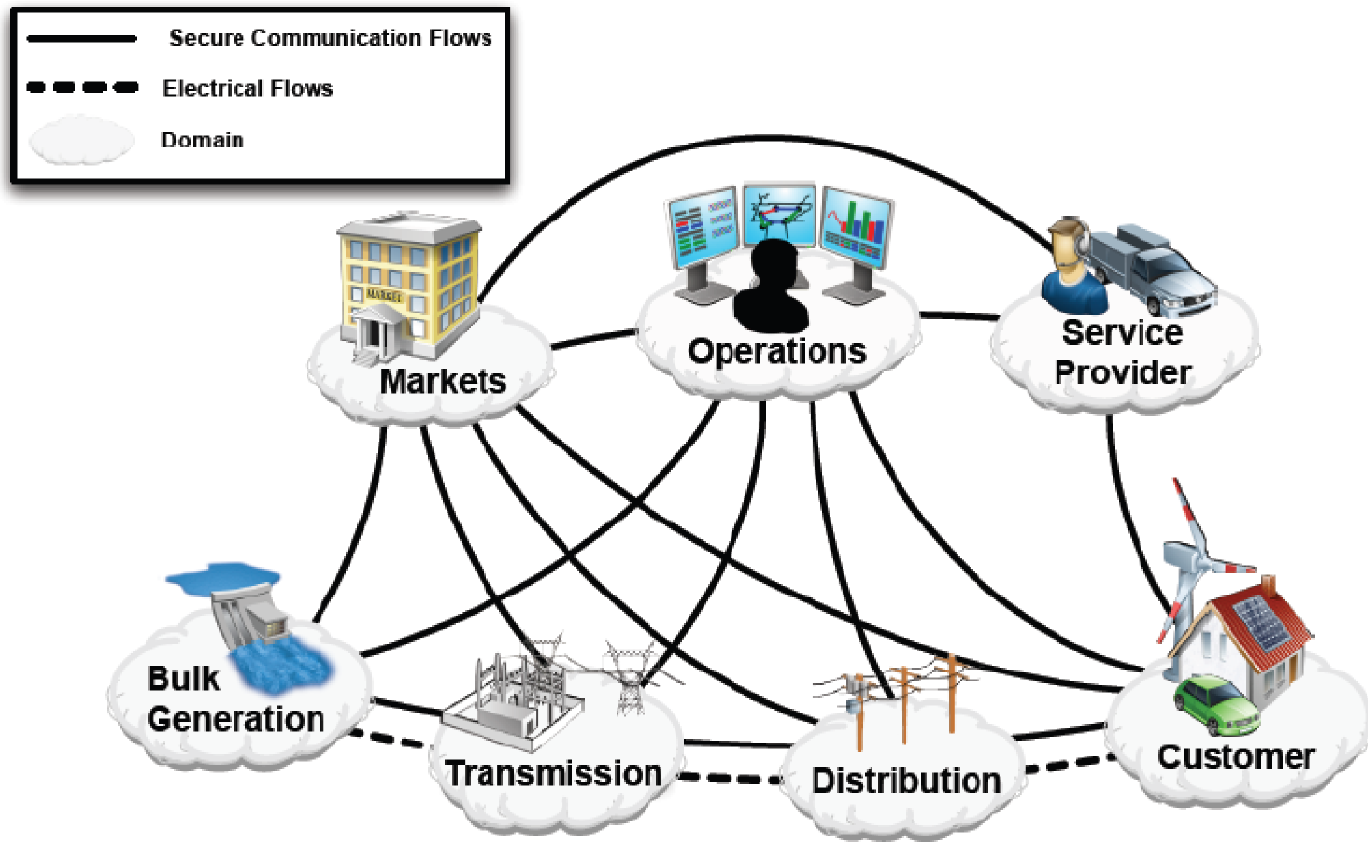
Source: SRSM smart metering project, Energy Retail Association, UK.

Smart Grid around the world



Source: Google Insights

Smart Grid around the world -- ICT



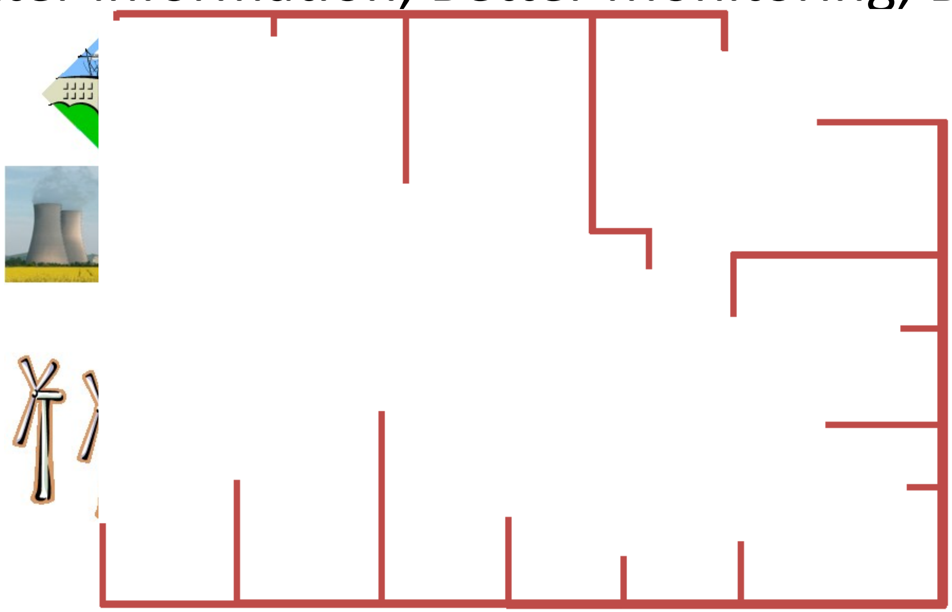
Source: NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 , Jan 2010.

NIST Smart Grid Framework 1.0 January 2010

Background and Context

What is actually needed

- Better information, Better Monitoring, Better Control



- an Interactive Information Infrastructure

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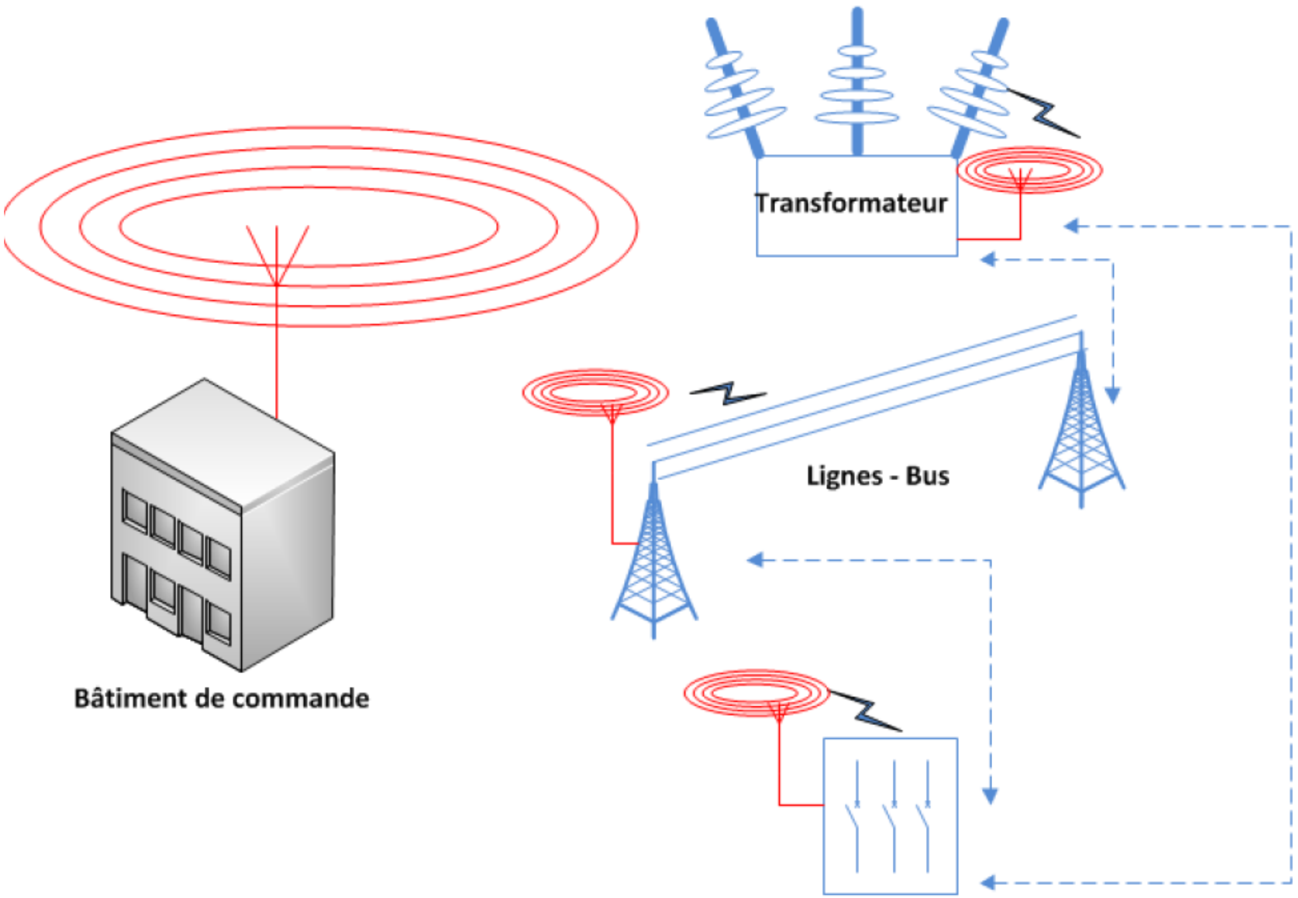
A less known issue: Communications in substations

- Technologies
  - PLC
  - Wireless communications (Wi-Fi, ZigBee, Wimax, LTE, Bluetooth…)
- Peculiar environment: impulsive noise

Possible architecture



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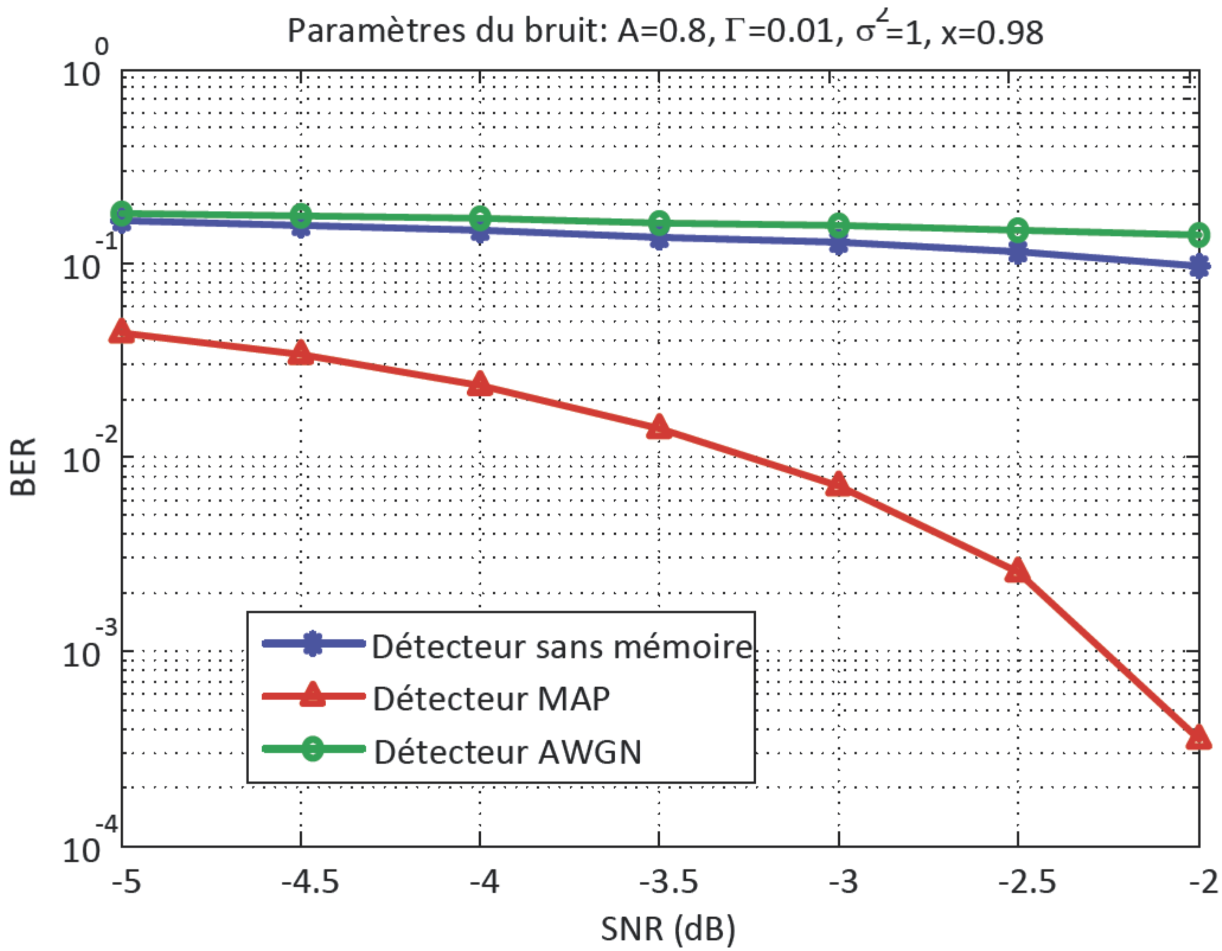
Noise in a Substation

- Noise Sources
  - Voltage lines
  - Bushings
  - Transformers
  - Circuit Breakers
  - Disconnect Switches
  - Power Electronic Equipments (FACTS, HVDC, VSC)
- Emitted Signals:
  - Current transients
  - Radiated electromagnetic fields

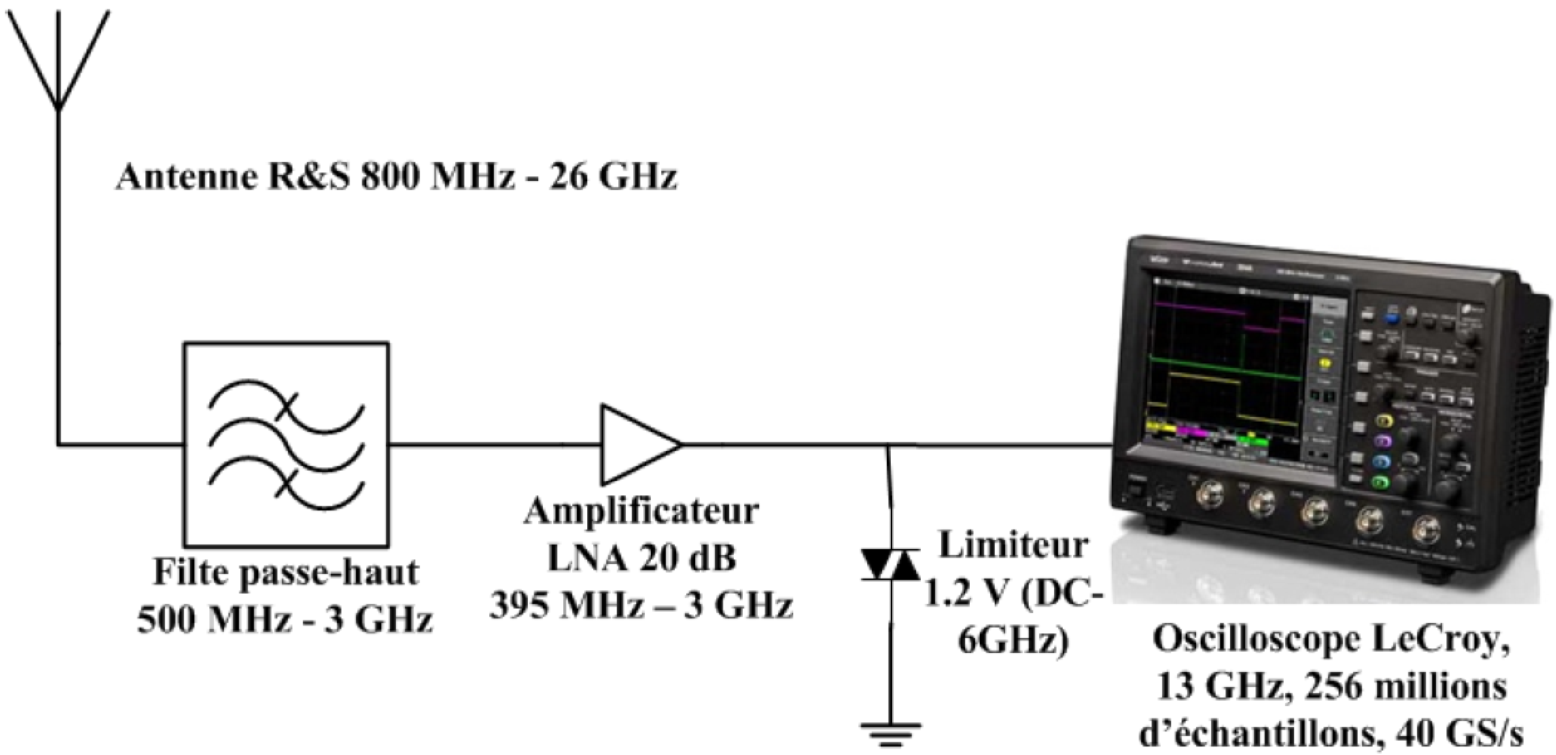
The impulsive noise

- Impulsive noise is a repetition of damped oscillations with short durations and spaced with inter-arrival times
- The oscillation can be found on a DC-10 GHz band
- The amplitudes grow with the voltage applied
- Weather conditions change the noise level

Advantage of proper noise modeling

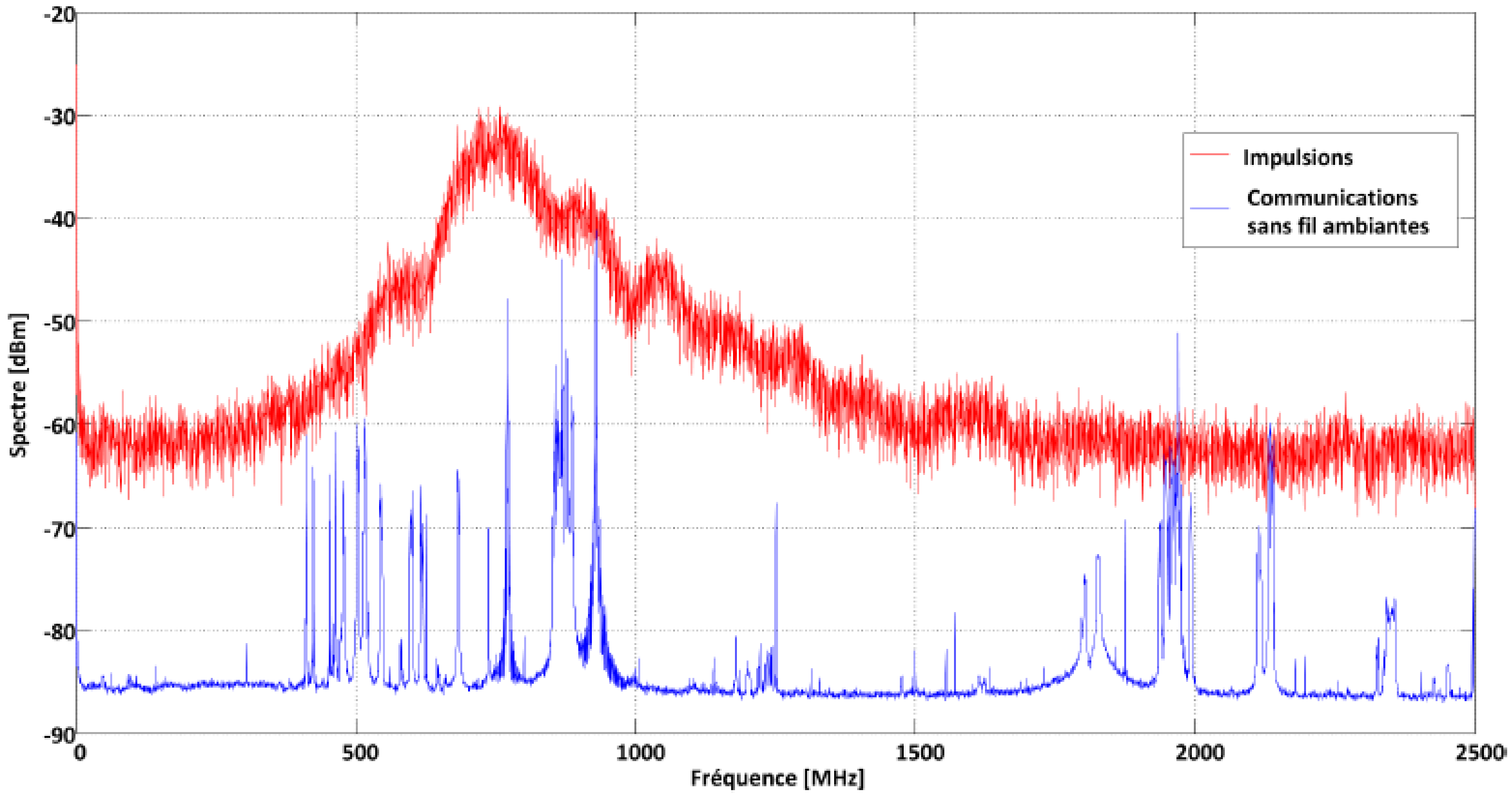


Measurement Setup

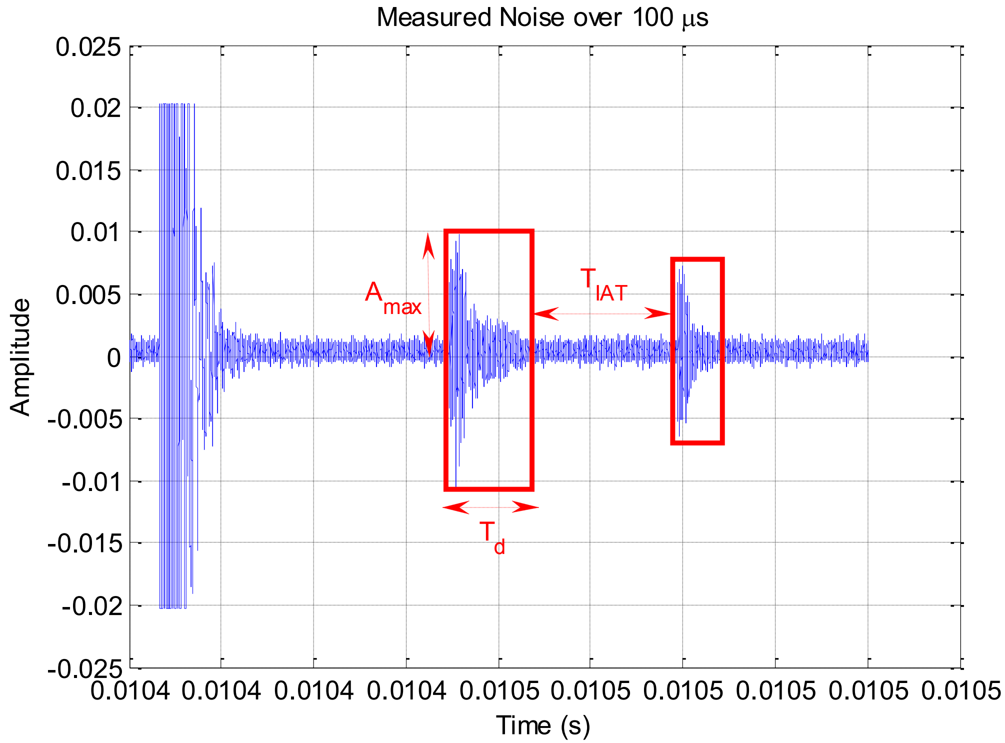


Measurement Campaign

Measurements



A closer look



- Amax: maximum amplitude
- IAT: Inter-arrival time
- Td: Impulse duration

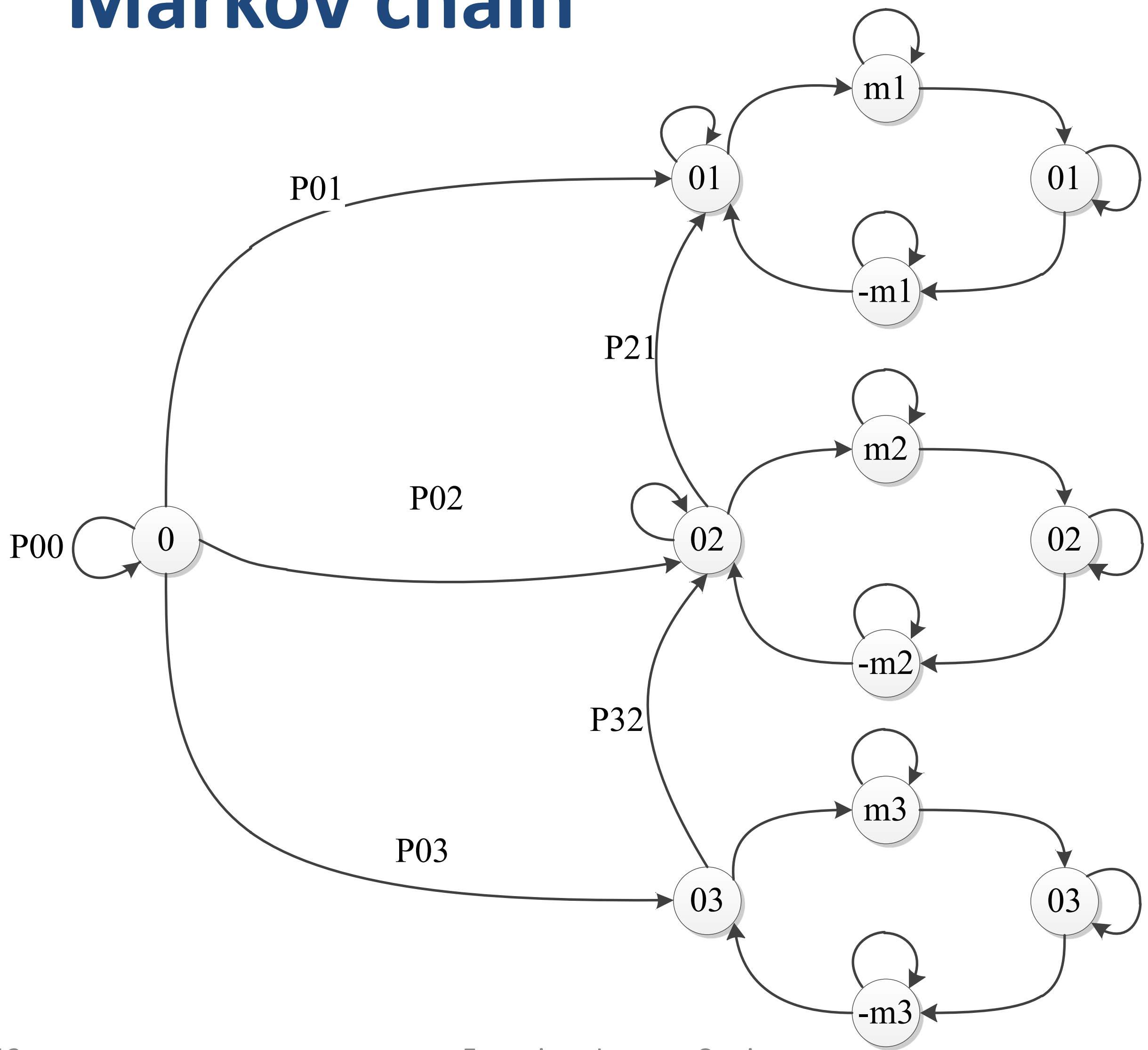
- Sampling frequency: 1 GHz
- Frequency band: 200-400 MHz

Modeling the sequences

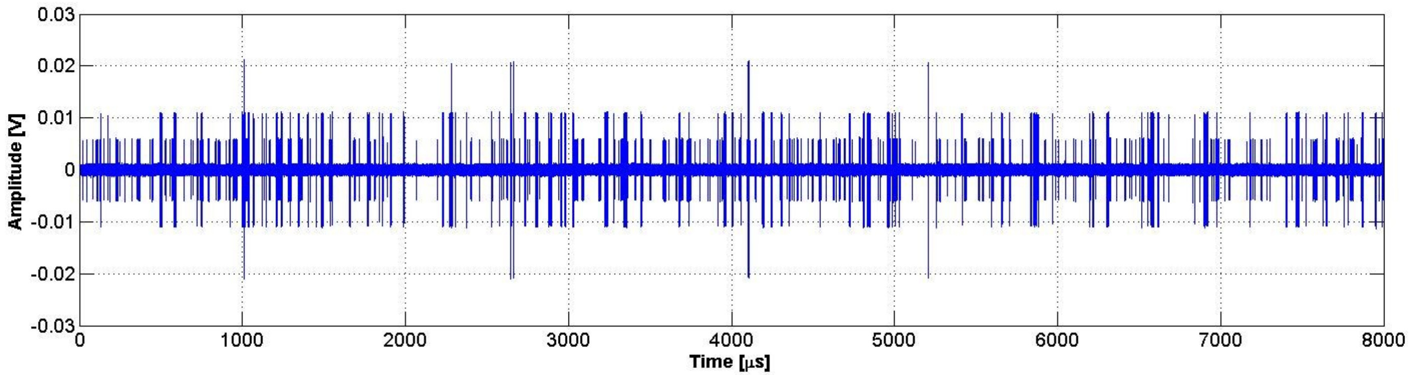
- The amplitude repartition can be modeled by
  - Bernoulli-Gaussian mixture (Problems : Gaussian groups and pulses durations)
  - Middleton model (Problem : Pulse durations)

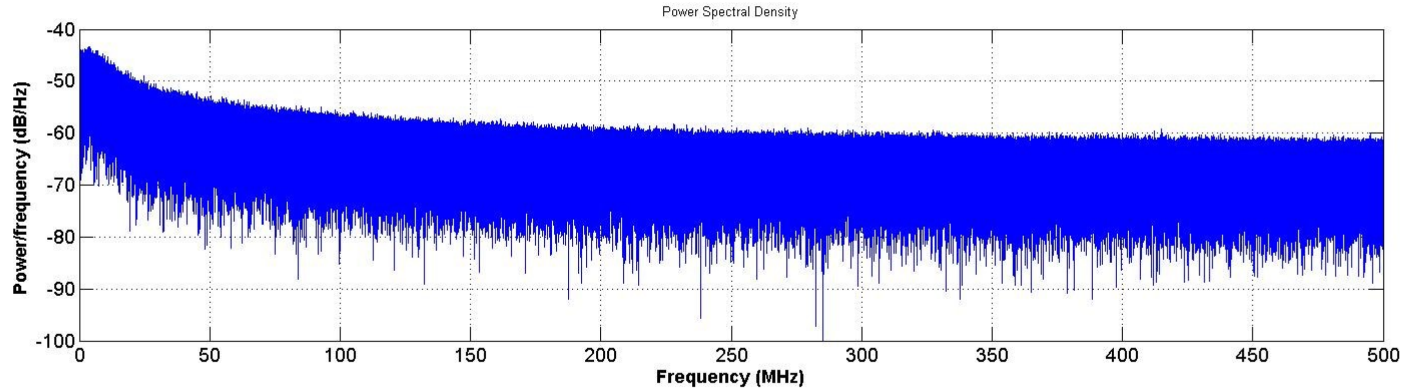
- The damped oscillation problem can be matched using :
  - Markov chain model

Markov chain



Markov chain





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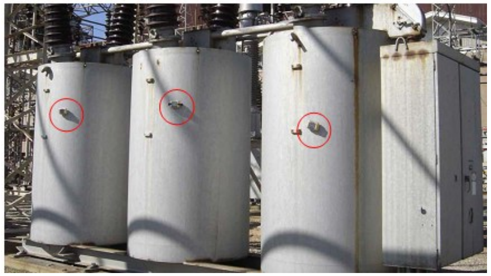
Sensors and Data Processing

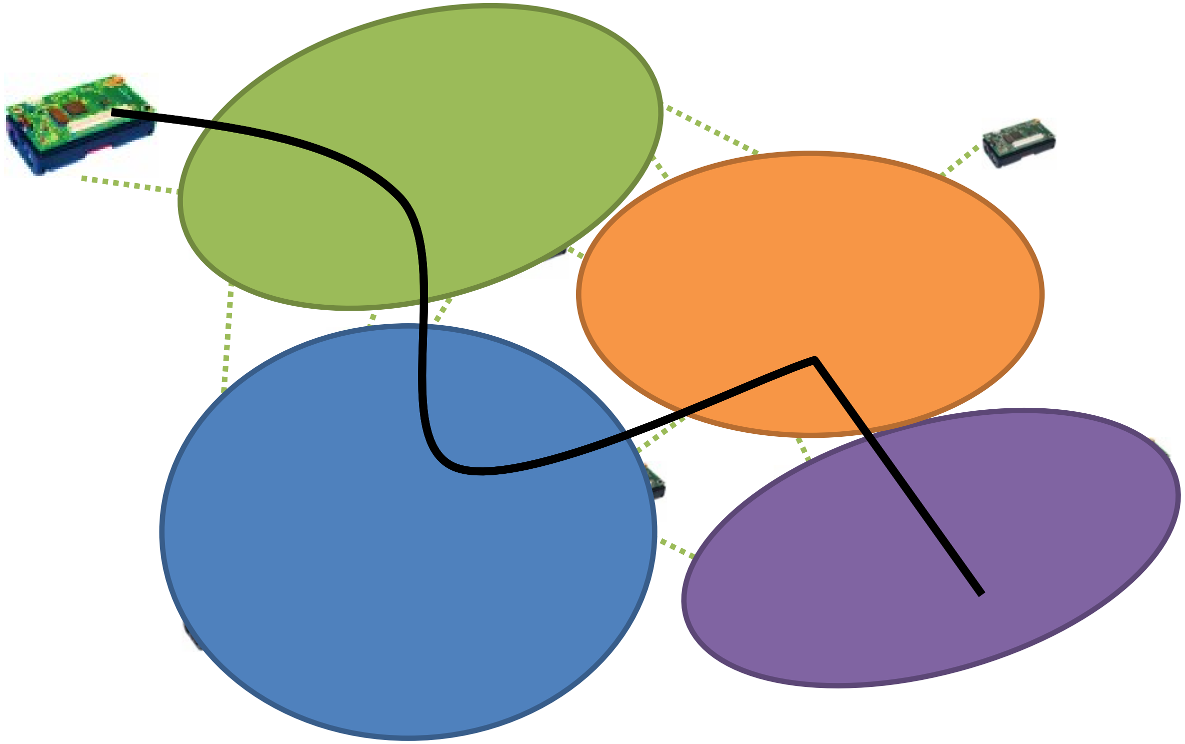
- Distributed sensing in Wireless Sensor Networks



Requirements

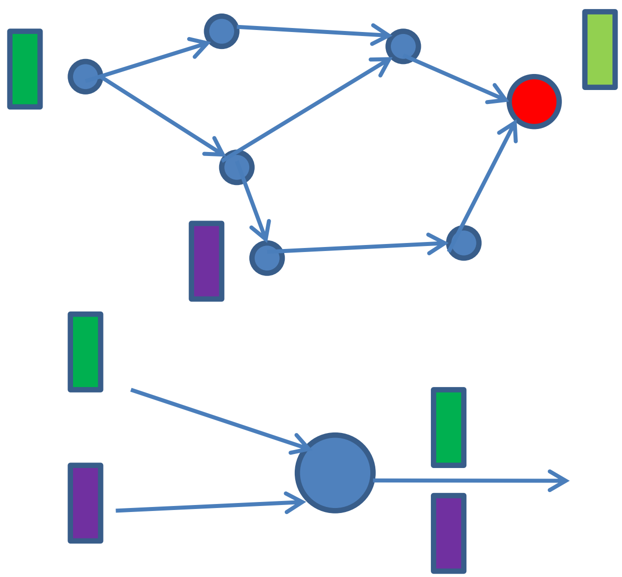
- Long sensor lifetime
  - Minimize maintenance
- Robust transmission
  - Noisy environment
- Efficient data gathering
  - Low delay requirements

Energy Efficient routing



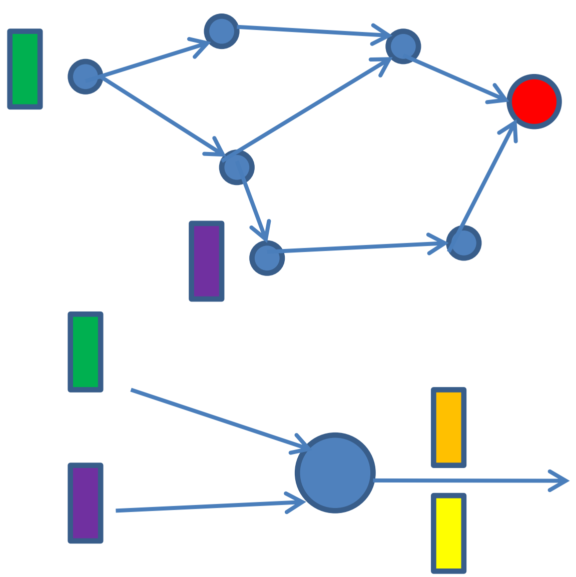
- Formation of clusters
- 2-round transmission
  - Nodes → cluster head
  - Path through cluster heads

Packet Forwarding via Routing



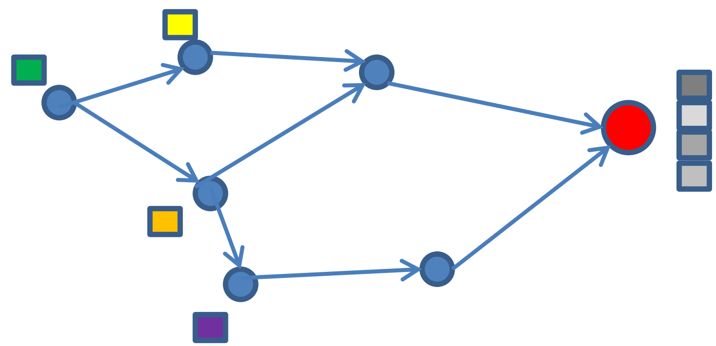
- Nodes forward according to Forwarding Table
- Forwarding Table is adaptively set by using Routing algorithms.

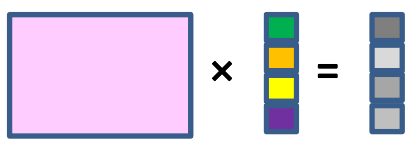
Network Coding



- Nodes forward a *function* of incoming packets
- In practice a *random linear* combination is used as the NC function.

Random Linear Network Coding

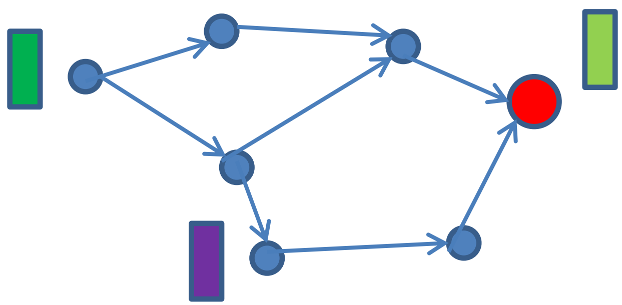




$$\Psi \times \underline{x} = \underline{z}$$

- Sufficient number of received packets,
- Appropriate linear mapping (full column rank).

Network Coding vs Packet Forwarding



- Increase in the Infinite Block Length Rate of Transmission,
- Diversity in the Information Flow,
- Decrease in the Probability of Error,
- Robustness to Changes in Network Deployment,
- Distributed Compression (!).

Proposed solution

- Low delay method allows to recover good approximations of packets with a limited number of received network coded packets at sink

In conclusion

- ICT can be used to make power transmission and distribution "greener" and more intelligent
- Lesser known area where ICT is needed in the *Smart Grid*: substations
- We propose solutions to allow communications within this difficult environment