Cooperative Network Coding Scheme over harsh scenarios

IRTF-(NWCRG)

Josu Bilbao {jbilbao@ikerlan.es}

Outline:

1. Introduction

2. Previous work

3. Network Coding Applicability

   - Research Challenges
   - NC scheme configuration

4. Useful hints when facing with Harsh environments

   - Cooperative Link Layer Control (CLLC)
   - Help Algorithm
   - Coding Methods
   - Cooperative Behavior

5. Network Coding over PLC

   - How we started (Once upon a time…)
   - Demonstrator

6. Conclusions

Introduction

○ **Embedded Systems Research Line**

- Reliability on embedded systems (SIL, Safety Integrity Level).
    - Certified by TÜVRheinland (IEC61508).
    - Mixed Criticality
    - Dependability, Availability
- High timing constraints (real-time)
    - We have developed wired and wireless interfaces to enhance QoS.
- Industrial communications
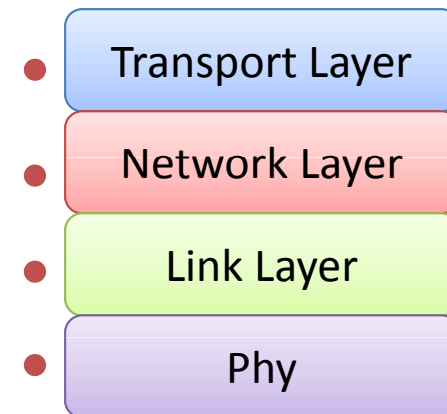   - Reliable communications

○ **Research Projects related with Network Coding**

- Open to collaboration opportunities

Introduction

Reliable communications over harsh environments

⬤ What do we consider as a **harsh environment**?

– Interference

– Mobility: Dynamic scenarios.

– Multipath, fading, etc.

– Link degradation (e.g: wireless mesh networks)

⬤ Current research fields:

– Reliable communications

  • Industrial Wireless with network coding
  • No-New-Wires

– Embedded system integration

– Tentative on Cross layer approach.

| Transport Layer |
| Network Layer |
| Link Layer |
| Phy |

Previous work…

● **Previous work:**

– Increasing communication reliability in classical solution

- Store-and-forward routing algorithms
- Forward Error Correction (FEC) methods
- …

● **Can we do anything else?**

Network Coding applicability

- Bring the features of wireless networks into line with the wired solutions
  - Noisy and lossy nature of wireless medium.
  - Provide a comparable QoS and reliability

- Lack of Reliability avoids/limits the use of wireless solutions for:
  - Mission-critical applications under harsh environments

- New research "branch" emerges from innovative information Theory field
  - Random Linear Network Coding.

[1] *R. Koetter and M. Médard, "An algebraic approach to network coding," IEEE/ACM Transactions on Networking, vol. 11, no. 5, pp. 782-795, 2003.*

Research Challenges

○ Distribution of (e.g: multimedia) streaming with High QoS requirements is a very active research topic:

– We deal with **High QoS constraints** and **packet loss sensitive** flows.

– **CooMuN**: *Cooperative Multimedia Network Coding scheme*
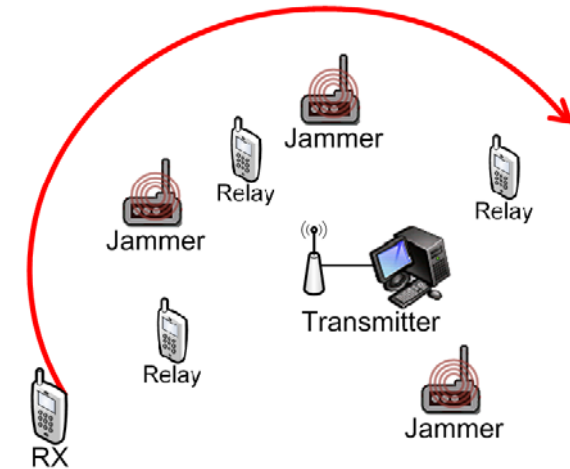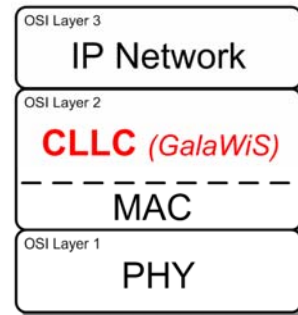
○ Realistic scenario must take into account:

– Propagation effects

– Receiver(s)/Transmitter Mobility: Dynamic scenarios

– Interfering nodes (jammer nodes)

○ Highly sensitive to communication link degradation

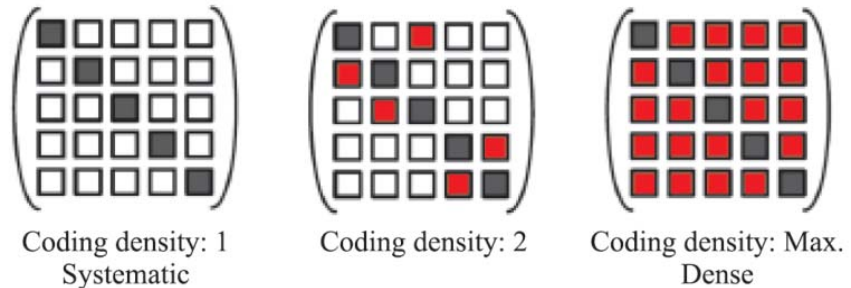– Immediate impact in the quality perceived by users.

NC scheme configuration

- Inter-node cooperative scheme with the aim of:
  - Improve achievable QoS level
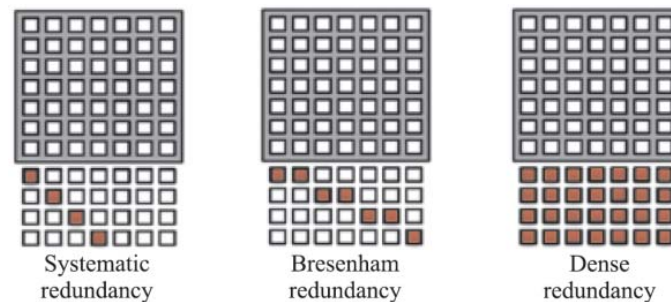 - Multicast streaming
  - OPNET Modeler implementation

- Coding structure
  - Coding Density Variation
    - Real-time comms trade-off

Coding density: 1
Systematic

Coding density: 2

Coding density: Max.
Dense

- Redundancy blocks
  - Redundancy type variation
    - Coding benefits

Systematic
redundancy

Bresenham
redundancy

Dense
redundancy

[2] *J. Bilbao, A. Calvo, I. Armendariz and P. Crespo, "Reliable and high QoS wireless communications over harsh environments," Journal of Telecommunications and Information Technology, vol. 2013, pp. 32-40.*

Useful hints when facing with Harsh env.

- **Cooperative Behavior**
  - HelpRequest + HelpResponse strategies.
  - Several different approaches on reception of a HelpRequest packet … depending on **AbleToResponse()** method:
    - Ignore ()
      - Ignores HelpRequests
    - ResponseIfAble ()
      - If relay node's rank > receiver's rank.
    - ResponseIfComplete ()
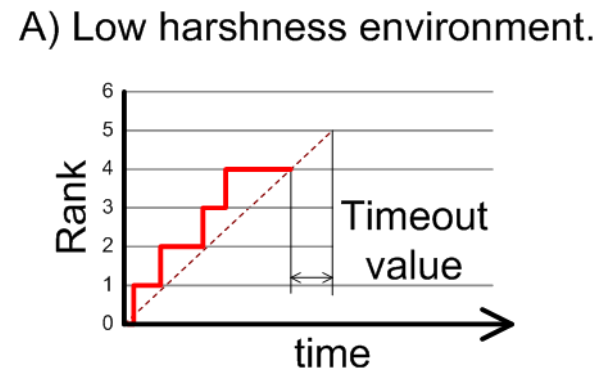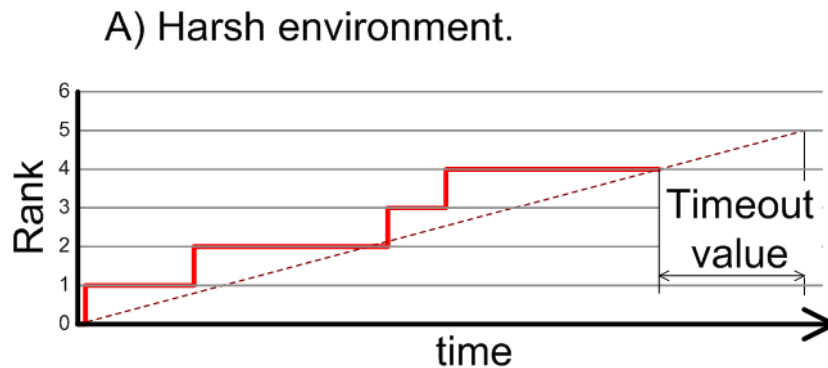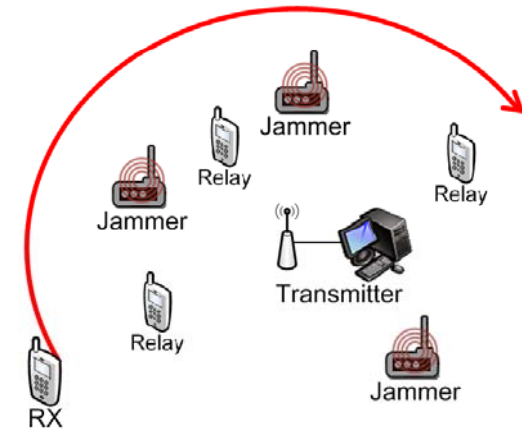   - Relay nodes have full rank
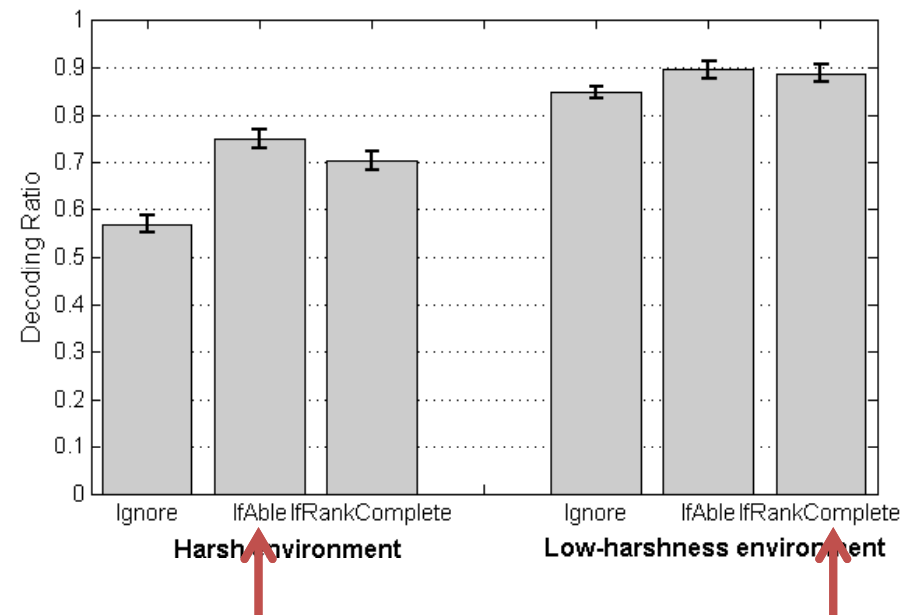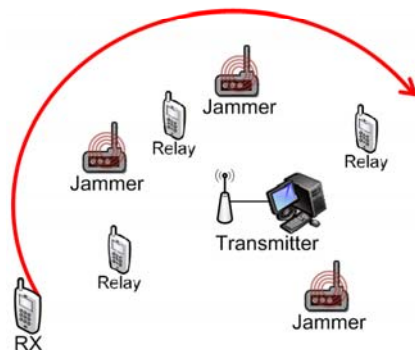
[3] *J. Bilbao, A. Calvo, I. Armendariz en P. M. Crespo "Cooperative Network Coding Scheme for Multimedia Content Distribution over Noisy Environments," IEEE BMSB 2013.*

Useful hints when facing with Harsh env.

● **HelpRequest Adaptive timeout scheduler**
  – Timer is calculated adaptively to varying conditions of the medium.
    • Control cooperative patience.
  – Based on calculation based on receiver heard degrees of freedom update.
  – Avoid medium saturation by excessive number of HelpRequest.

A) Harsh environment.

A) Low harshness environment.

[3] *J. Bilbao, A. Calvo, I. Armendariz en P. M. Crespo "Cooperative Network Coding Scheme for Multimedia Content Distribution over Noisy Environments," IEEE BMSB 2013.*

Useful hints when facing with Harsh env.

- **Measurement Metrics**
  - Received Bytes
  - Decoding Ratio
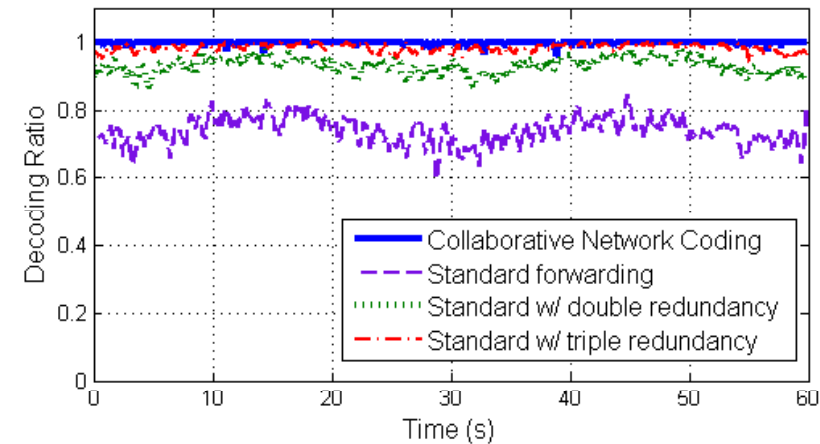 - Throughput
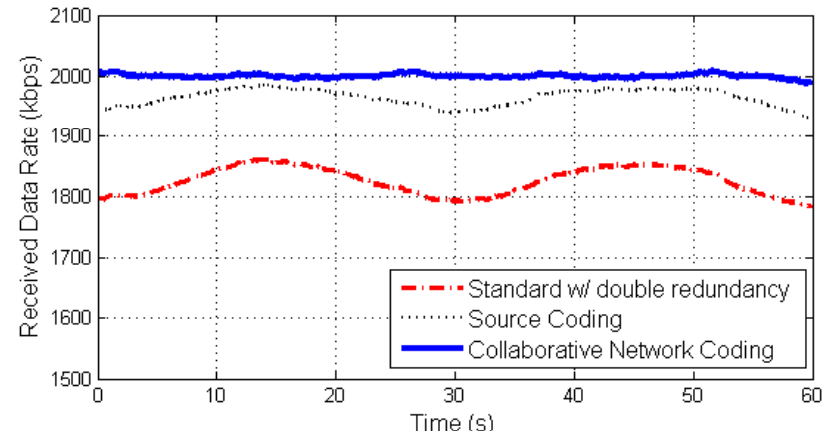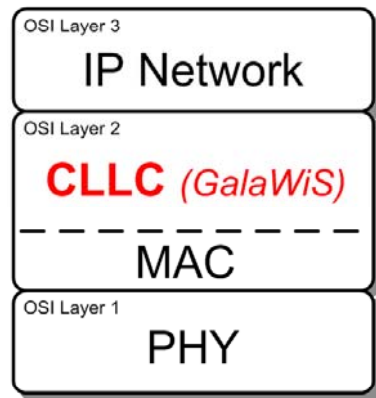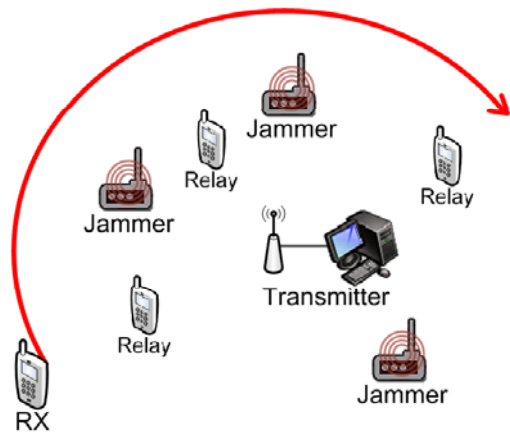 - Channel utilization
  - Link Failure
  - ...

- **We could find a consensus of which are the most suitable metrics.**
  - Challenge for IRTF-NWCRG

Useful hints when facing with Harsh env.

● **Cooperative Link Layer Control (CLLC)**
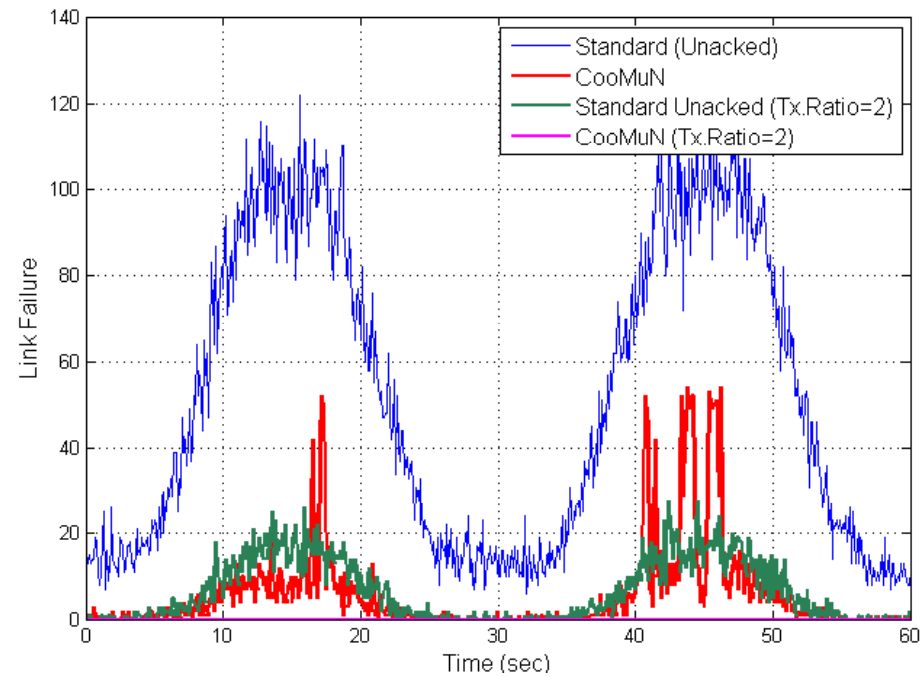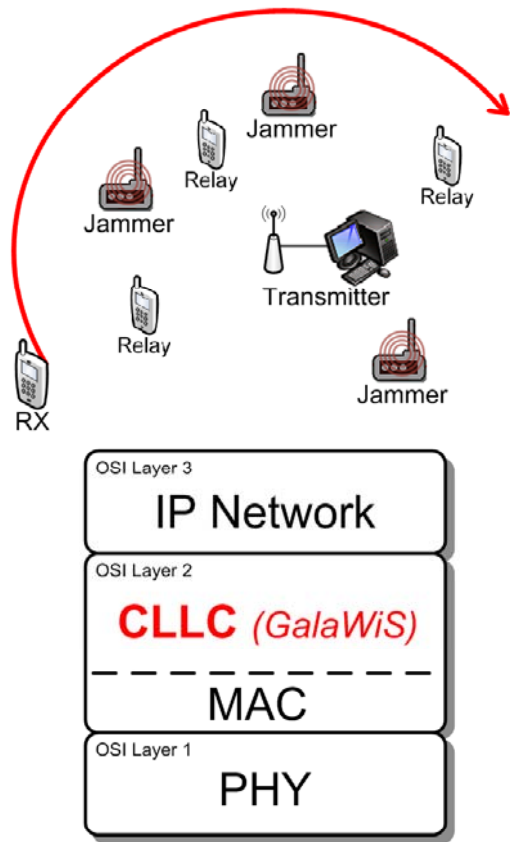
– Based on nodes cooperation to improve reliability

[3]   J. Bilbao, A. Calvo, I. Armendariz en P. M. Crespo "Cooperative Network Coding Scheme for Multimedia Content Distribution over Noisy Environments," IEEE BMSB 2013.

Useful hints when facing with Harsh env.

- **Cooperative Link Layer Control (CLLC)**
  - Based on nodes cooperation to improve reliability

[3] J. Bilbao, A. Calvo, I. Armendariz en P. M. Crespo "Cooperative Network Coding Scheme for Multimedia Content
     Distribution over Noisy Environments," IEEE BMSB 2013.
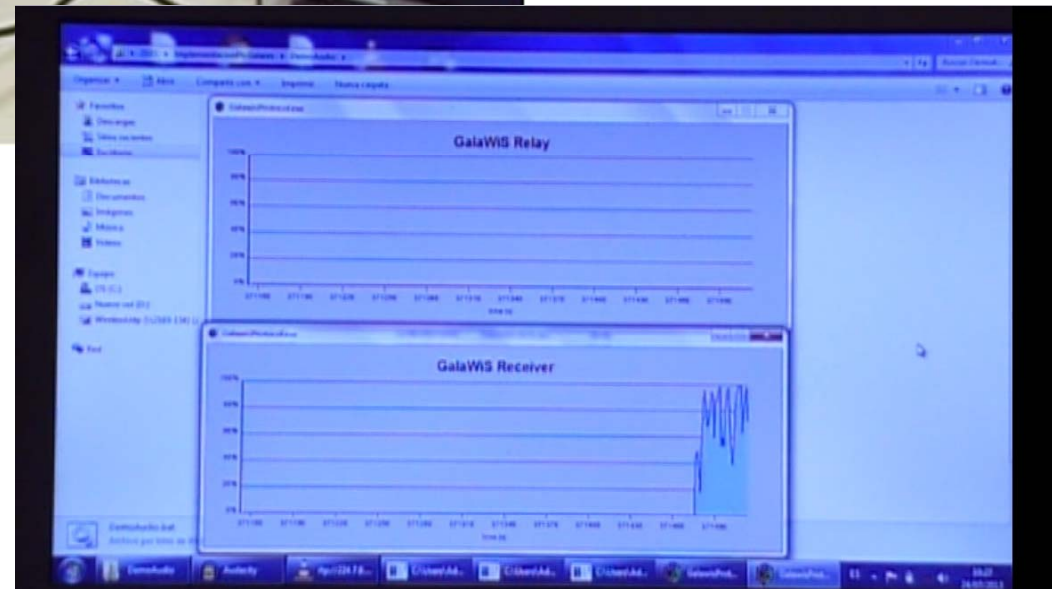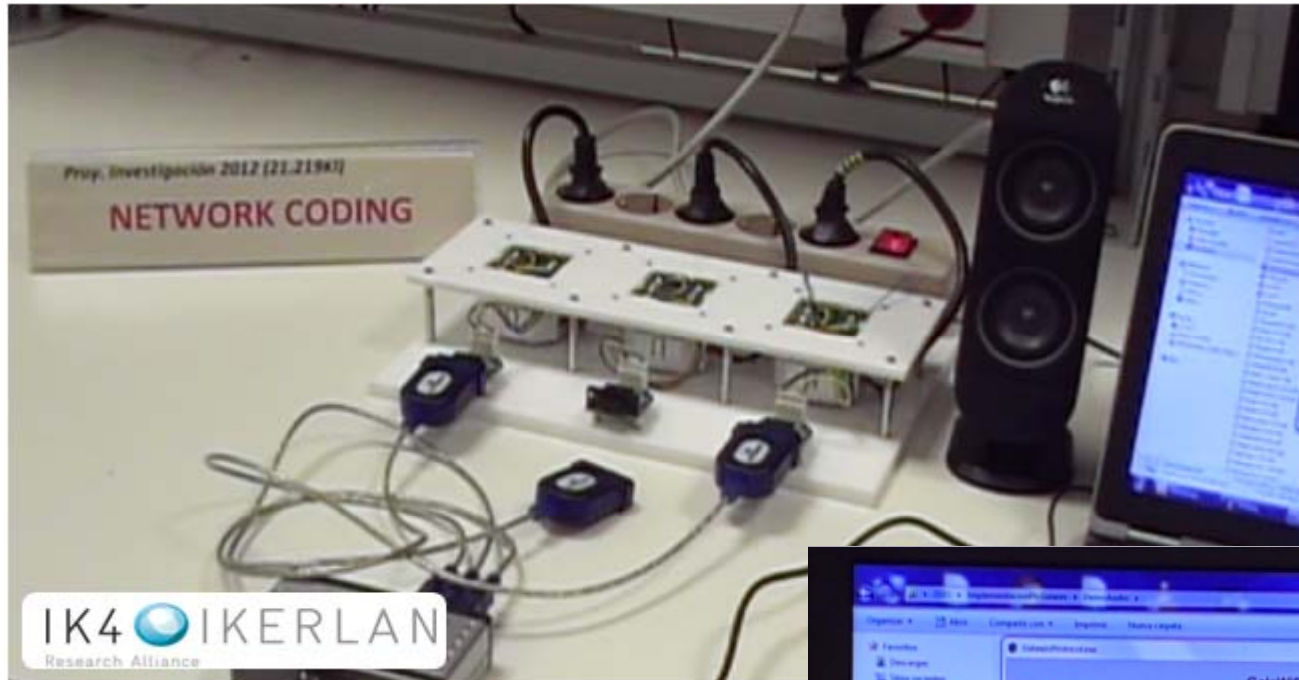
NC over PLC (example of harsh environment)

○ **Network Coding over PLC**

– We started a couple of years ago

• MIT (Muriel Médard) + IKERLAN (Josu Bilbao, Aitor Calvo, Igor Armendariz and IK4-CEIT/Tecnun Pedro Crespo)

– Where we are now (experimental real implementation)

– Based on physical layer characterization

– Demo on streaming

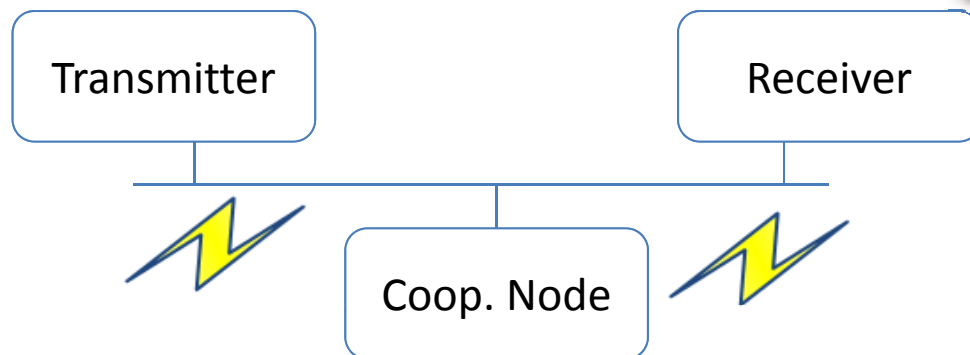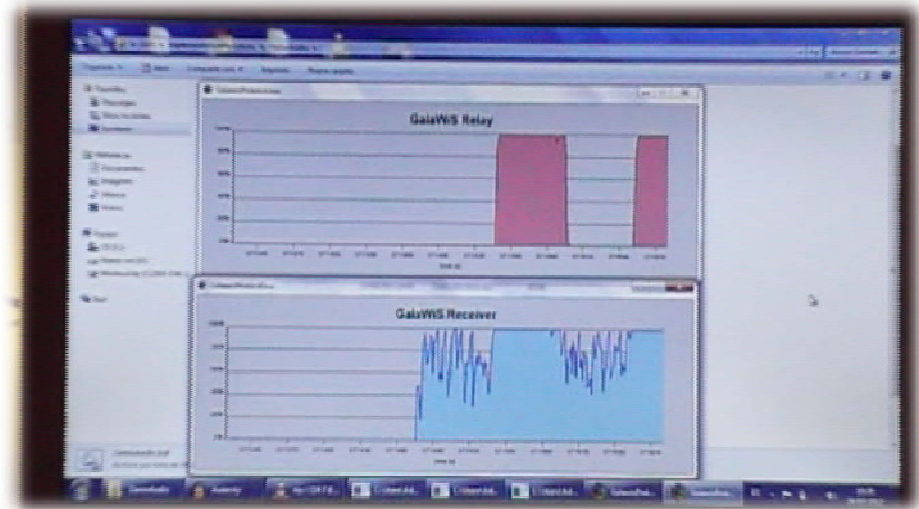[4] J. Bilbao, A. Calvo , I. Armendariz *et al. Ask for references at*: jbilbao@ikerlan.es

NC over PLC (example of harsh environment)

[4] J. Bilbao, A. Calvo , I. Armendariz *et al. Ask for references at*: jbilbao@ikerlan.es

NC over PLC (example of harsh environment)

Transmitter

Receiver

Coop. Node

[4]   J. Bilbao, A. Calvo , I. Armendariz *et al. Ask for references at*: jbilbao@ikerlan.es

Conclusions

- ### Network Coding helps to improve link reliability

  - Harsh environments are main issue for Mission-Critical applications

  - Interesting research topic

- ### Measurement metrics definition

  - I am volunteer to describe it with an IRTF draft.

- ### Research Projects related with Network Coding

  - Open to collaboration opportunities

  - Concept ideas and implementations

IK4 IKERLAN

Research Alliance

Presenter:

Josu Bilbao {jbilbao@ikerlan.es}

Cooperative Network Coding Scheme over harsh scenarios

IKERLAN

Eskerrik asko

Muchas gracias

Thank you

Merci beaucoup

Contact: jbilbao@ikerlan.es

P.º J.M. Arizmendiarrieta, 2

20500 Arrasate-Mondragón (Gipuzkoa)

Tel.: 943 71 24 00

Fax: 943 79 69 44

www.ikerlan.es

19