DEVELOPMENT OF A WIRELESS SENSOR NETWORK FOR STRUCTURAL HEALTH MONITORING

Advisor:
Prof. Paolo E. Gamba

Co-Advisor:
Dott. Emanuele Goldoni

Master Degree Thesis of:
Marco Beltrame

358880/27

Introduction: wireless sensor networks

WIRELESS NETWORKS

ADVANTAGES

- Costs
- Mobility
- Flexibility

DISADVANTAGES

- Battery Consumption
- Reliability
- Security

A WIRELESS SENSOR NETWORK:

consists of a large number of node:

- deployed in the environment
- equipped with sensors
- provisioned with short-range wireless communication capabilites
- battery-power

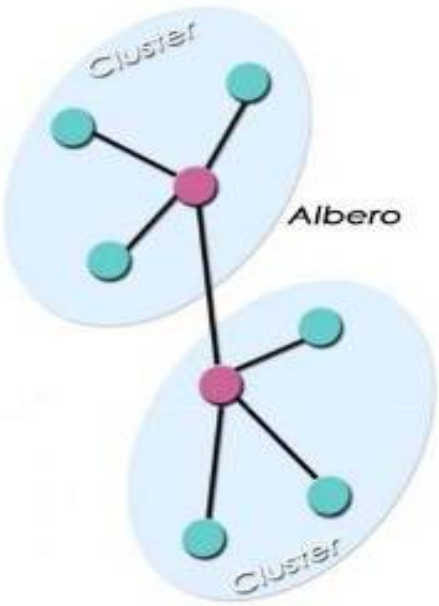
Types of motes and WSNs' topology

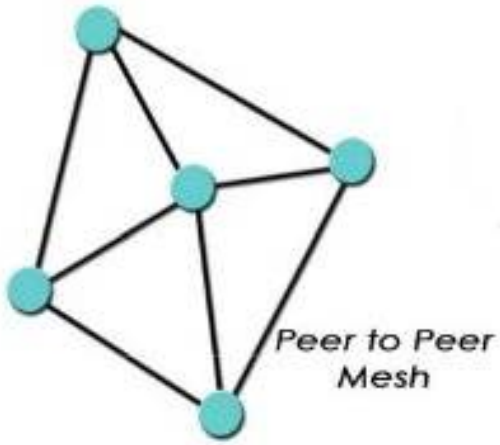
TYPES OF MOTES

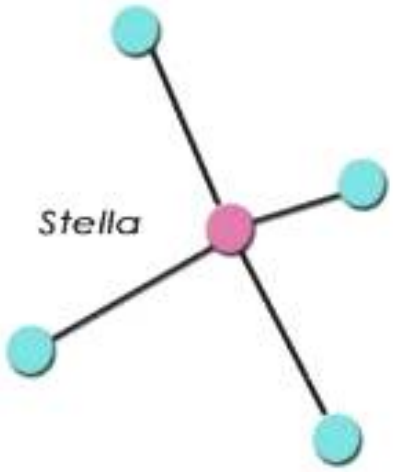
- Mote – gateway
- Mote – sensor

TOPOLOGY OF WSNs

- Star
- Mesh
- Tree







Introduction: uses of WSN

APPLICATIONS:

- Monitoring
- Supervision
- Control

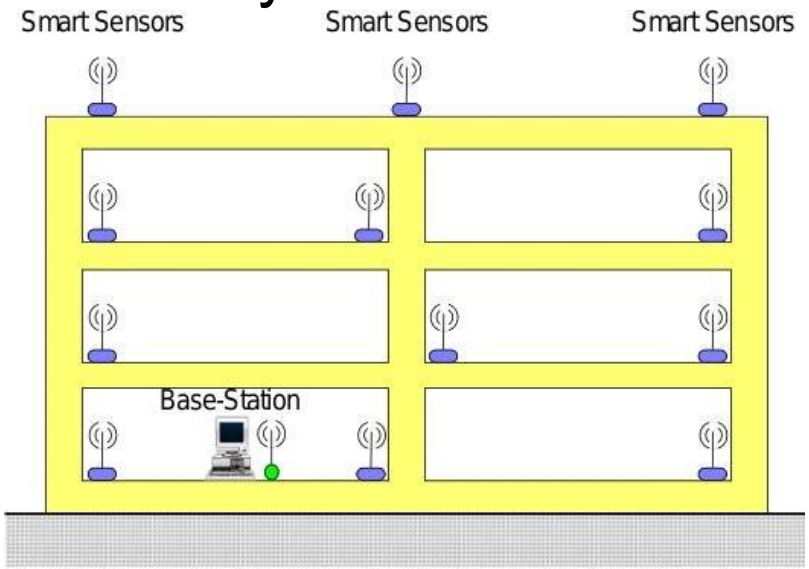
SHM
(Structural Health Monitoring)

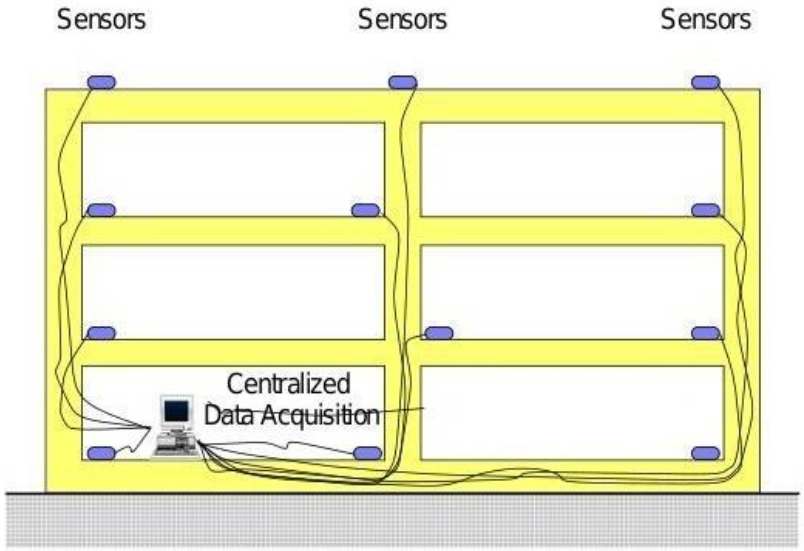
- Measurement of vibrations
- Experiments in the world

Introduction: EUCENTRE and W-TREMORS

EUCENTRE (NON-PROFIT FOUNDATION)

- Applied research in the field of seismic engineering
  - Simulations on real buildings
  - Analytical models





W-TREMORS

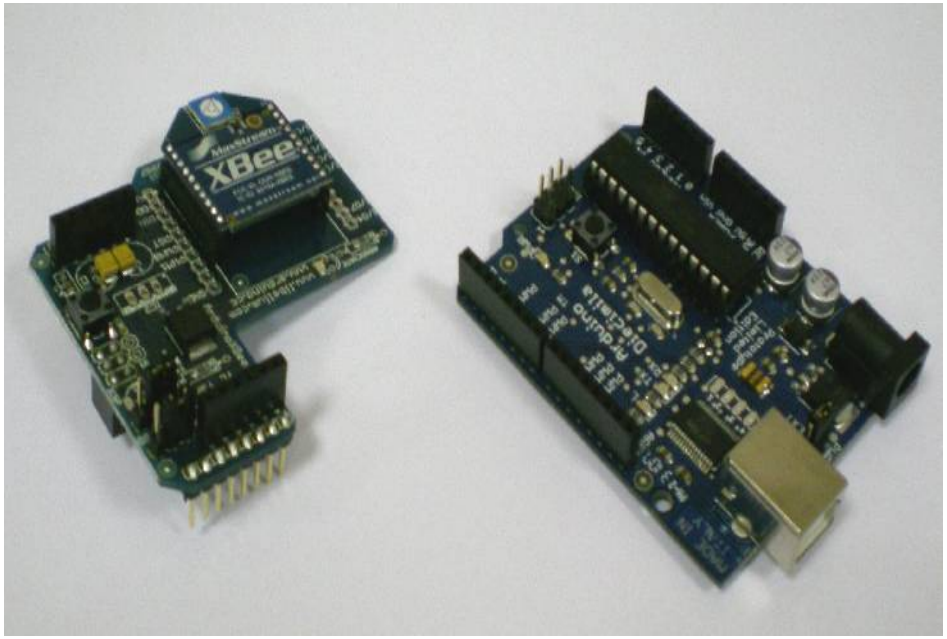
Platform was engineered and implemented:

- Ex-novo
- Alternative to existing wired system
- Wireless Tremors vibRation and Earthquakes MonitoRing

Introduction: models and standard motes

TYPES OF HW

- Motes with integrated sensors.
- Motes that use a small O.S. etc...



THE PLATFORM SQUIDBEE

- Arduino board with ATMega168 processor.
- Radio XBee of DiGi.
- SquidBee: is a platform that is not designed for SHM.
- Sensor used is a Kistler's accelerometer.

COMUNICATION PROTOCOL 802.15.4

- Physical layer
- MAC layer

W-TREMORS: restraints and requirements

REQUIREMENTS OF THE PLATFORM

- Synchronization
- Absence of collisions
- Real-Time
- Certainty on sender's ID

CONSTRAINS OF THE PLATFORM

- Mono-task
- CSMA/CA at MAC layer
- Trasmission's time
- Maximum resolution is ms

W-TREMORS: synchronization

SYNCHRONIZATION

- Managing latency errors of each motes
- Managing synchronization of the whole platform.

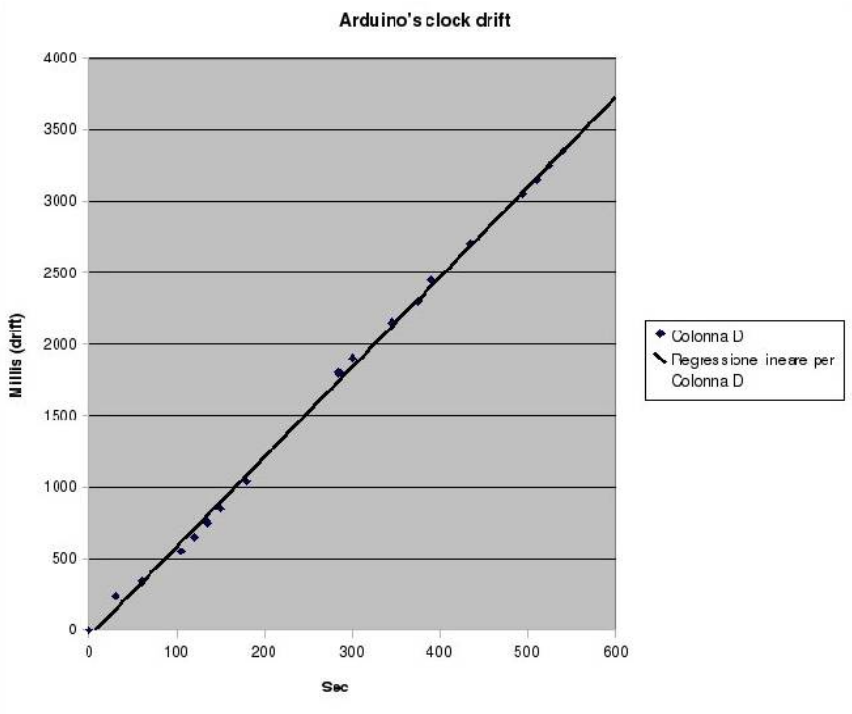
LATENCY ERROR

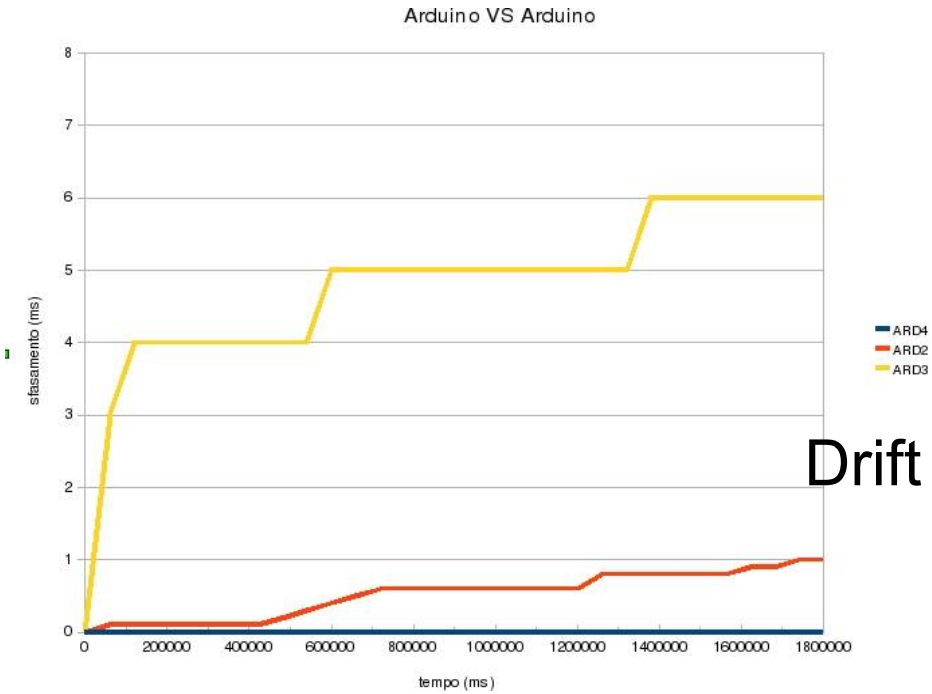
- Send-time
- Access-time
- Propagation-time
- Receive-time

W-TREMORS: drift

- Changes of physical clock.
- Drift – Rate: measurement unit.

Drift – Rate: 83 * 10^-6 ~ 1 ms every 12 s





Drift – Rate: 1,67 * 10^-6 ~ 1 ms every 10 m

W-TREMORS: global synchronization

SYNCHRONIZATION ALGORITHMS FOR WSN

- RBS (Reference Broadcast Synchronization)
- TPSN (Timing-sync Protocol for Sensor Network)
- FTPS (Flooding Time Synchronization Protocol)
- ...

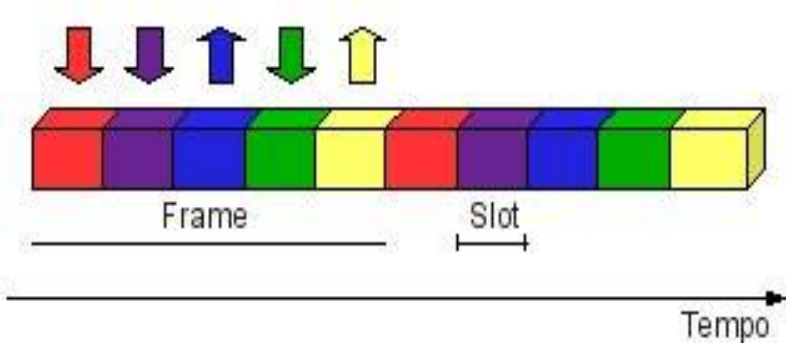
ALGORITHMS USED FOR W-TREMORS

- Star typology
- RBS
- Without reference (is single – hop!)
- Motes wait broadcasting signal

W-TREMORS: TDMA e Bursts

TDMA BUILT AT THE APPLICATION LAYER

- Define transmissions' time-slot for each motes.
- Schedule the use of the channel.
- Reduces collisions.

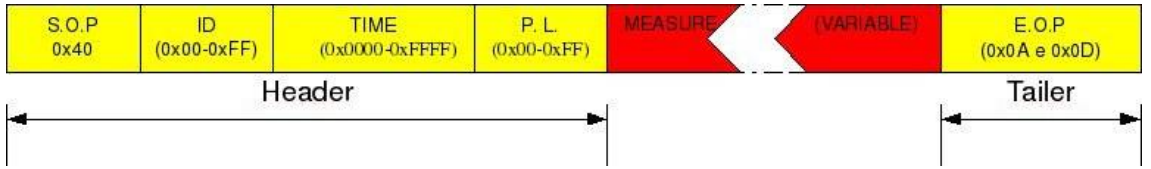


PROBLEM

- Displacement due to drifts results in:
  - Delays of trasmissions
  - Unrecognizable packages.

SOLUTION

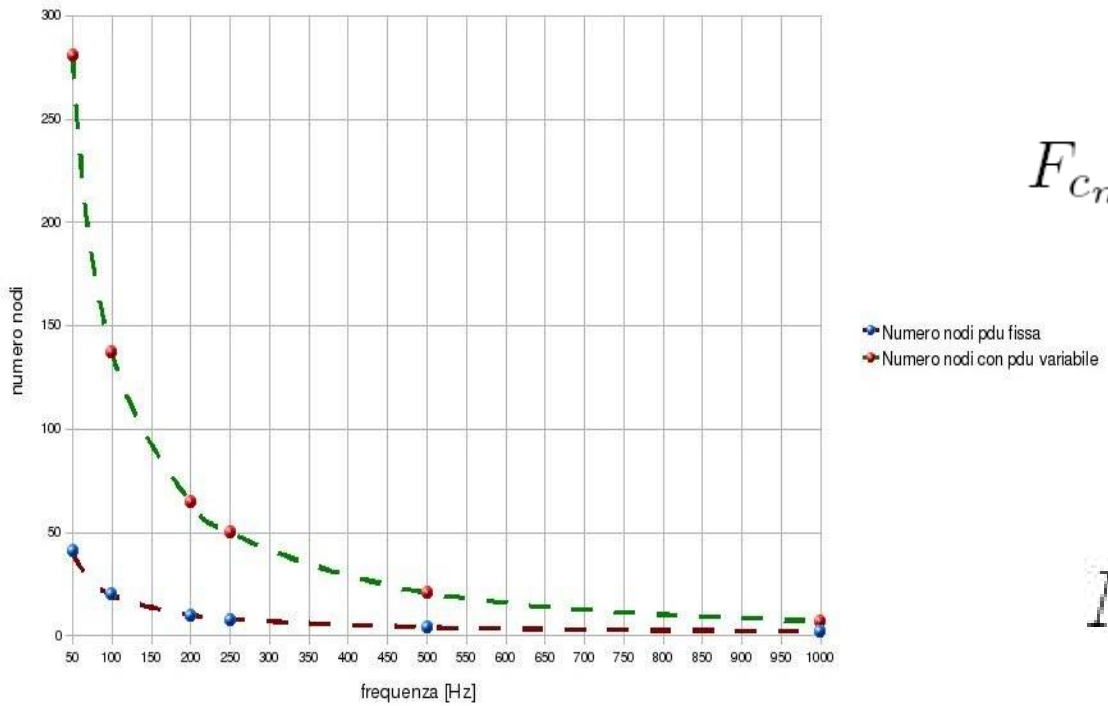
- Build an application-layer PDU including the ID of the mote
- Bursts: insert two or more measurements in a single PDU



W-TREMORS: Bursts

ADVANTAGES

- Less PDU sent by each node
- More motes are allowed inside the sensor network

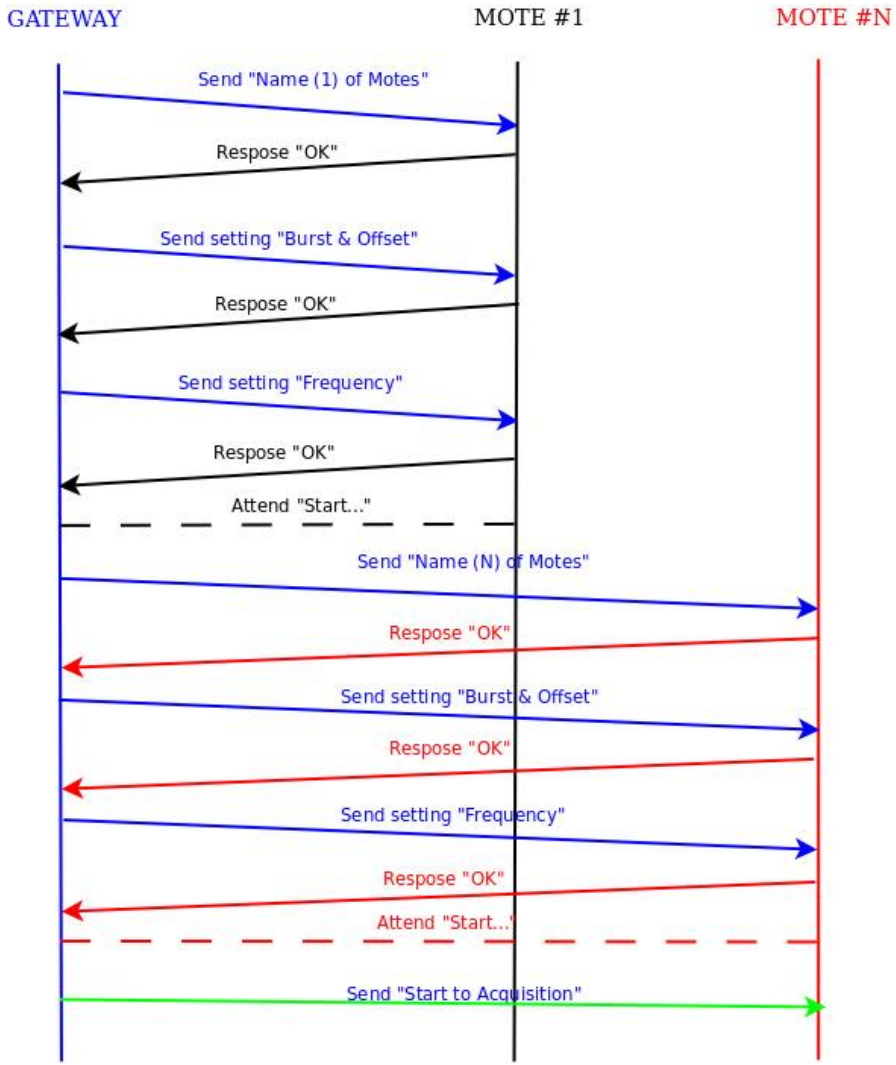


$$F_{c_{max}} = \frac{C_{canale}}{(P_{header} + N + P_{tailer})}$$

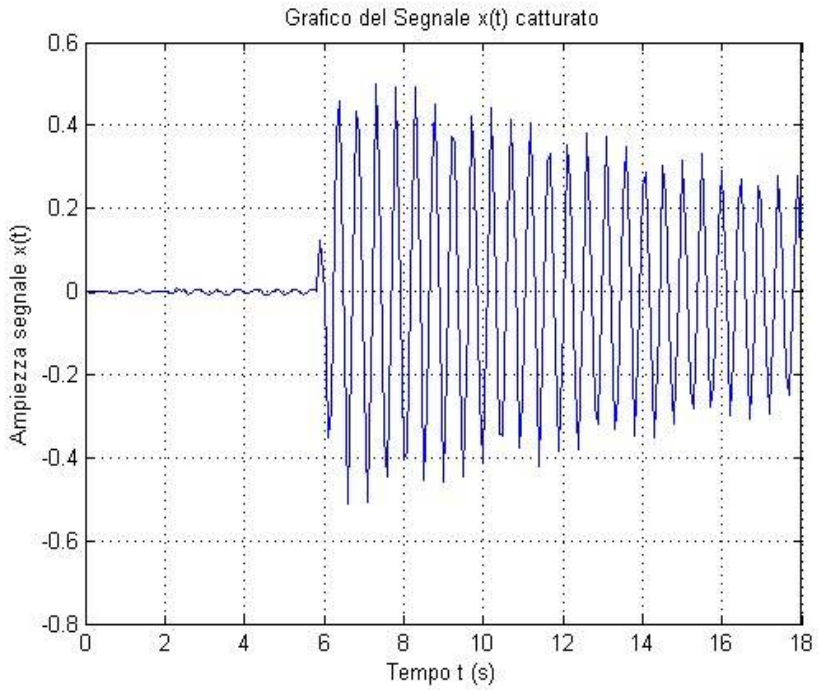
$$N_{max} = \left\lfloor \frac{C_{canale}}{F_c} - 7 \right\rfloor$$

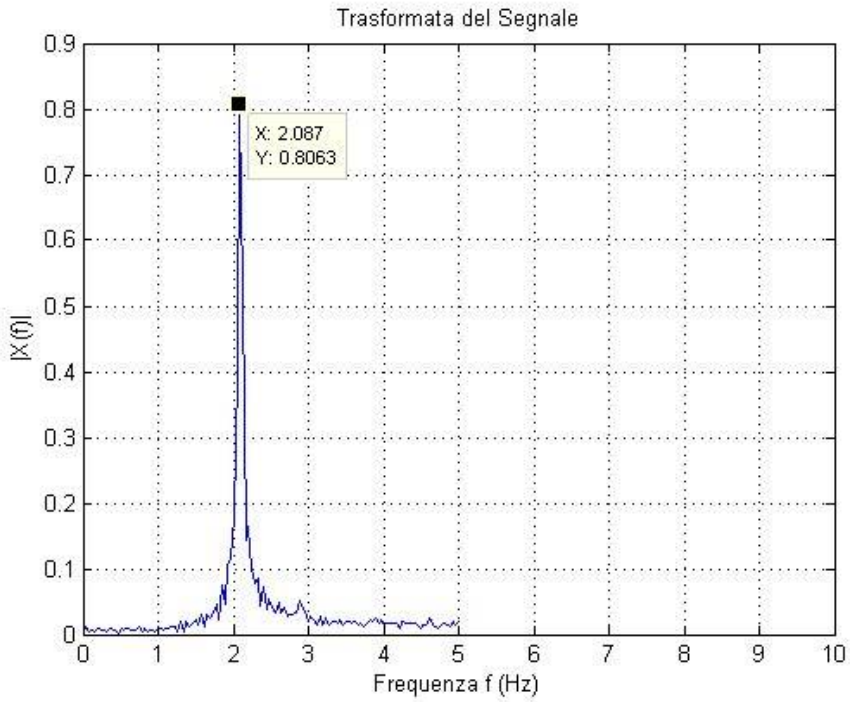
W-TREMORS: network setup

Setup phase: sample Gateway – Sensor communication

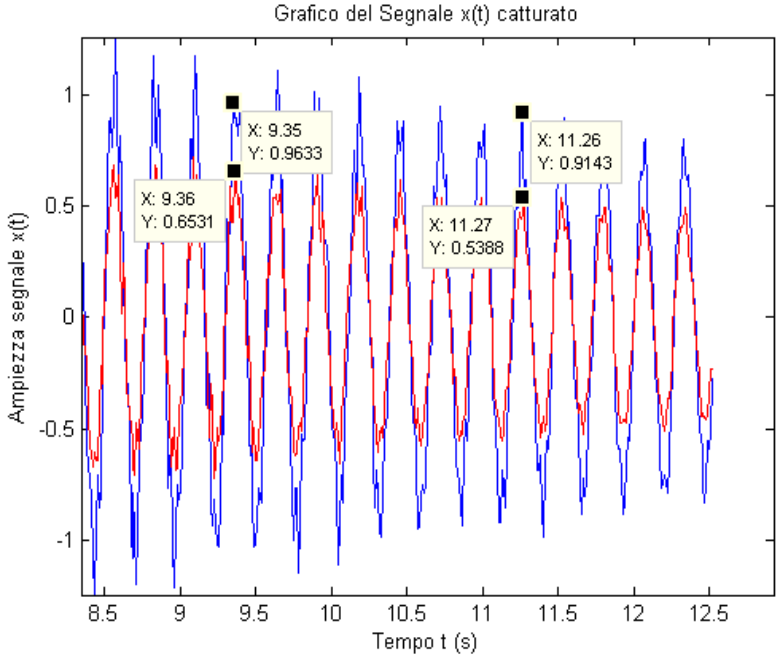


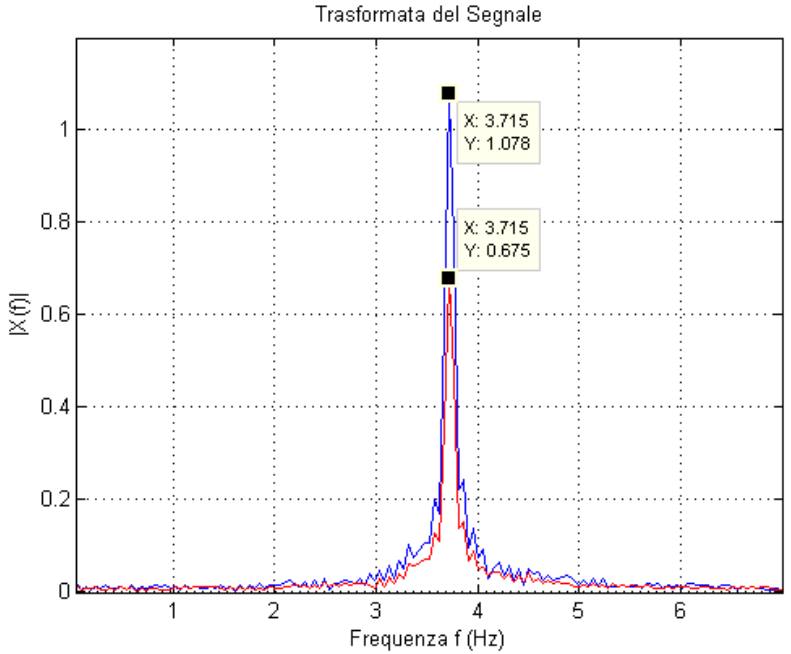
W-TREMORS: test at EUCENTRE





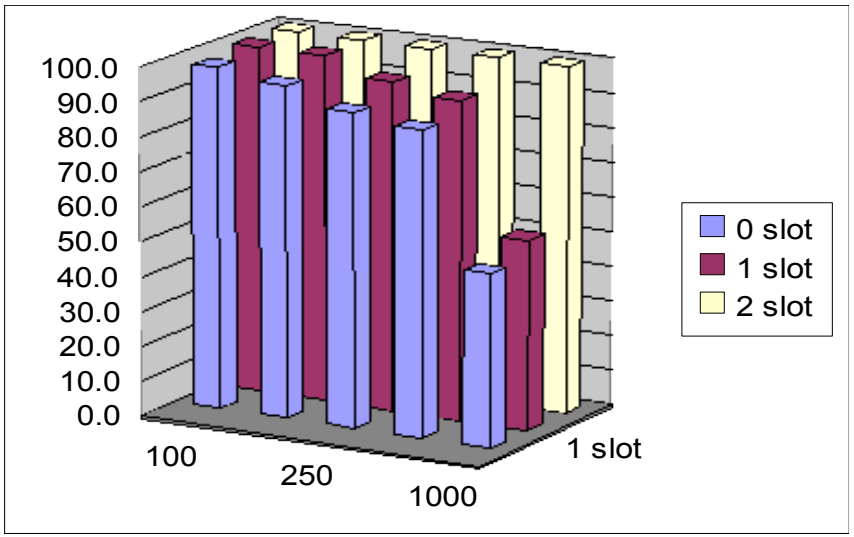
W-TREMORS: test at TLC lab (Mantova)





Conclusion: considerations

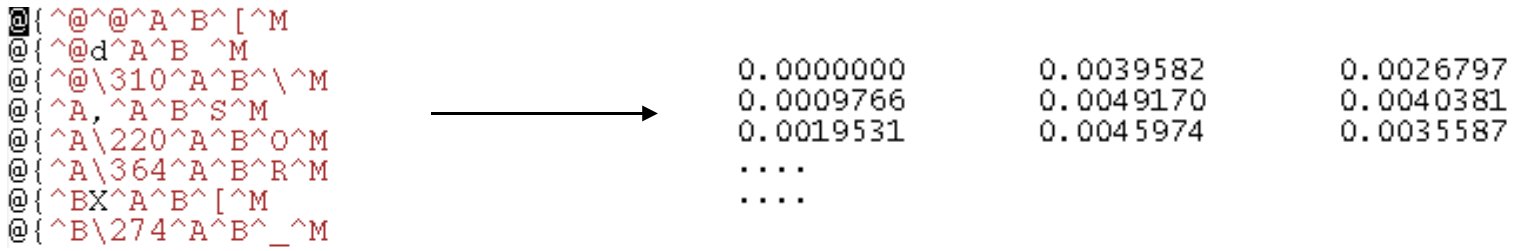
- Need to add a guard band at high frequencies.



- Developed code is modular and open source

Conclusions: future developments

- DataBase: improve and speed-up data extraction.



- Remote reset of node (now this is a missing feature)

- Engineering an external case for sensor nodes.

The End