GENESI: Green sEnsor Networks for Structural monItoring

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GENESI overall objective

*GENESI will develop a new generation of large-scale, **heterogeneous**, **energy-efficient**, **situation-aware** wireless sensor networks for structural health monitoring and control which are able to **autonomously operate for several decades** perfoming **in situ reasoning** and evaluation of potential failures **invisible to current monitoring.***

GENESI partnership

University of Rome La Sapienza - Italy

University of Twente – Netherlands

ST Microelectronics - Italy

Alma Mater Studiorum University of Bologna - Italy

Tyndall – University College Cork - Ireland

ConsorzioTreesse - Italy

Solexperts AG - Switzerland

GENESI's vision

- Enabling a new generation of green wireless sensor networks
  - Energy harvesting
  - Replacing batteries with fuel cells
  - Reduce to the bare minimum energy consumption
    - Protocols, algorithms, in network processing
    - Radio triggering circuit
- Solving problems which prevents WSN to be brought to the market
  - Reliability/fault tolerance/resiliency to interference
  - Ease deployment and management
    - Tools
    - Integration with existing middleware and applications for the selected application scenario
- Exploit cooperative sensing/operation
  - To reduce network load and energy consumption
  - To enrich context understanding
  - Self-learning the context and adapt operation
- Design the system to meet application driven QoS

Structural Health Monitoring

Why structural health monitoring?

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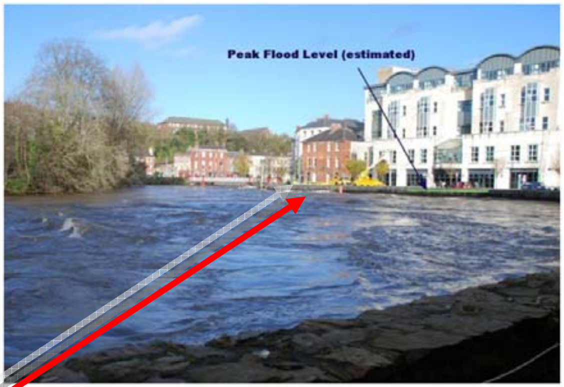


Showing Water Level Approx 10 hours after peak

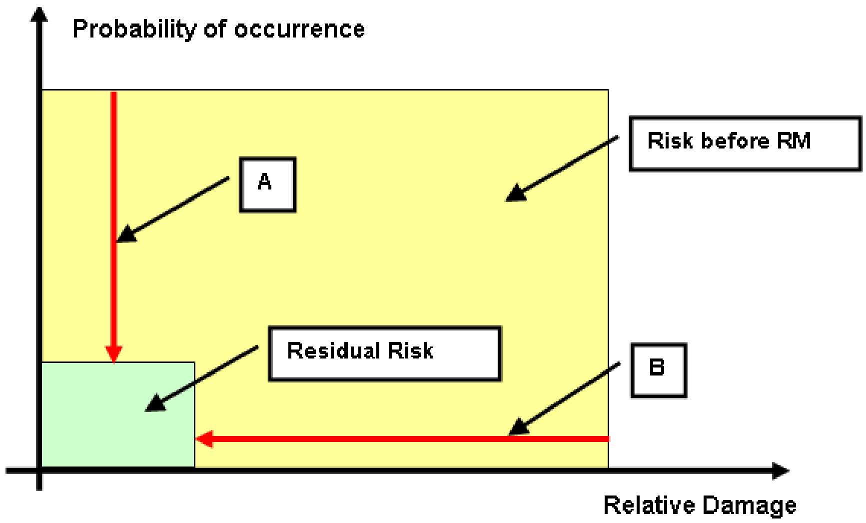
- Extensive flood damage due to collapsing containment wall
- Live depth data & video
- Structural monitoring could have saved millions

Why structural health monitoring?

- Structural health monitoring (SHM) is defined as the instrumentation of structures, including buildings, bridges, dams and highways with sensors, and accompanying equipment to assess structural integrity.
- **Risk evaluation** summarizes possible damages associated to unwanted events (loss of live, property, negative influence on schedule for construction, financial loss, damage to nature to reputation etc.)
- **Risk classification** includes estimation of the probability of occurrence of a given event combined with the expected damage associated to the event.
- **Risk handling** implies risk reduction to an acceptable level and elimination of unacceptable risks. It includes identifying in detail the monitoring strategy to be sure that possible risks are early detected and handled when no damage or little damages have occurred

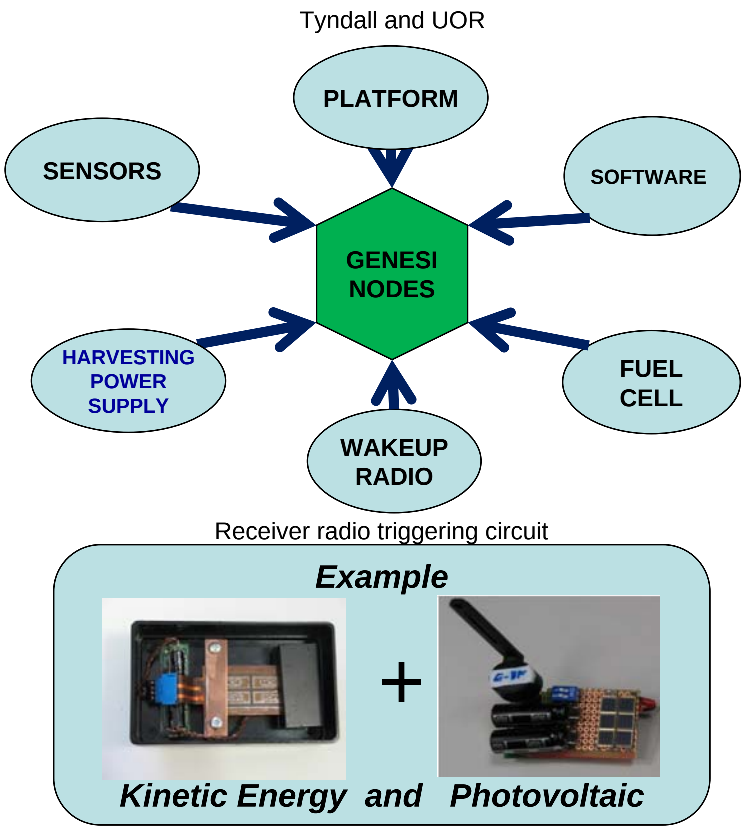
End users

Structural health monitoring: a methodology to reduce risks



- A: Monitoring as early warning system can alert to improve structure stability and thus prevents structure collapse.
- B: Monitoring can alert to evacuate building on time before collapse

GENESI nodes: Harvesting

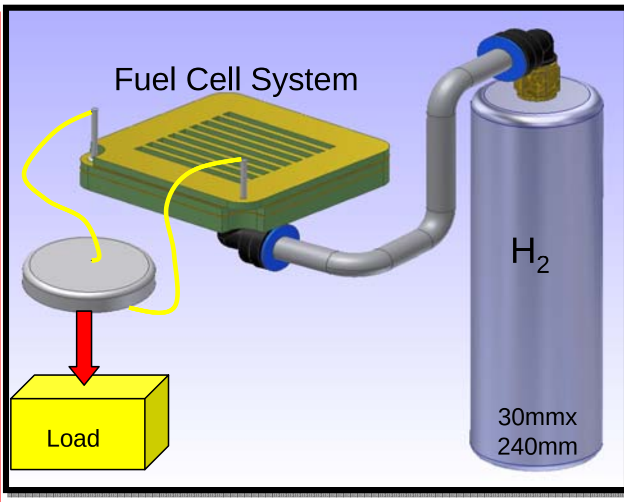


- Multi-source scavenging
  - Light
  - Wind (air flow)
  - Kinetic (vibrations)
  - Thermal
- Distributed energy management
  - Environmental and Human Energy is **different** from battery energy
  - Availability varies in time sometimes is scarce and sometime over-abundant
  - Availability varies in space different nodes get different energy
  - Somehow repetitive & predictable Opportunity for predictive and adaptive management techniques

Low cost small factor fuel cells

	Wh/Kg	Wh/L	Self Discharge (room temperature)
Primary Batteries	From 200 up to 400	From 400 up to 1000	From 8% up to 20% per year
Secondary Batteries	From 40 to 150	From 75 to 400	From 5% up to 30% per month
H2 Tank	230	900	**0 (Hydride alloy is stable for > 10 years).**

Ideal conditions



- They are green
- Can store more energy per cube centimeter
- High theoretical yield (80%)

Endurance of batteries under intermittent usage more challenging.

Cooperative and reliable networking

- **Spottier availability of energy resources**
  - has an impact on the overall system design (task allocation/sensor activation/MAC and routing protocols)
    - to ensure all energy available is effectively used (due to leakages and different task priority)
    - heterogeneity (due to e.g., harvesting, storage capabilities, energy available over time)
- Learning the ‘mode of operation’ and an **application driven model of QoS** is key to adapt system behavior to optimize trade-offs
- Fault tolerance, robustness to failures, communication unreliability, and resiliency to interference will be addressed

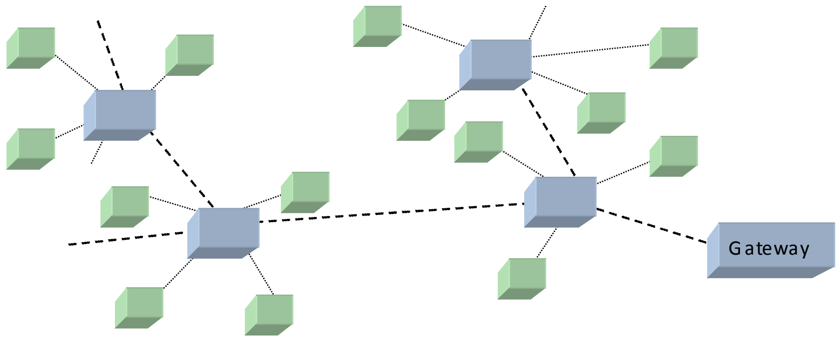
Nodes cooperation and in network sensor fusion

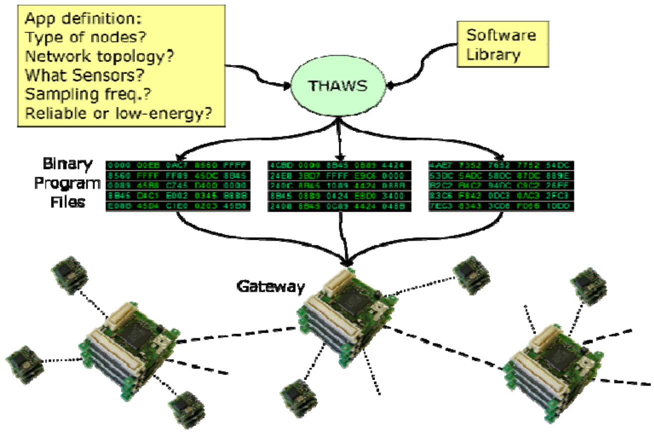
- **Quality-aware distributed mechanisms for online situation awareness**
  - Problem of periodic monitoring:
    - High energy consumption
    - High data traffic: high packet loss, hidden terminal, high latency
    - Each sensing device has only a limited perception of the situation at hand
  - Contribution:
    - Development of sampling and data filtering/fusion strategies that maintain a reasonable trade-off between: data resolution, energy efficiency, and application's required quality of services (QoS) and ensure the quality of services requested by the end user.
    - Sensor fusion, collaborative online distributed classification and reasoning to: 1) Increase situational awareness, 2) Increase accuracy and decrease false alarms, 3) Enable real-time event detection at the point of action.

Nodes cooperation and in network sensor fusion

- **Adaptive learning and control**
  - Problem of current structure health monitoring systems:
    - No consideration for dynamic nature of the network
    - Lack of proper knowledge about all factors influencing health of structures necessitate
    - Lack of real-time feedback and warning
  - Contribution
    - Develop self-learning and self-adapting mechanisms
      - Based on AI and machine learning to predicted behavior of the environment
      - To maintain quality of real-time feedback and control as well as early warning for potential failure and damage of the structures
      - Avoid generating false alarms or missing important occurrences.

Tools for Rapid Deployment





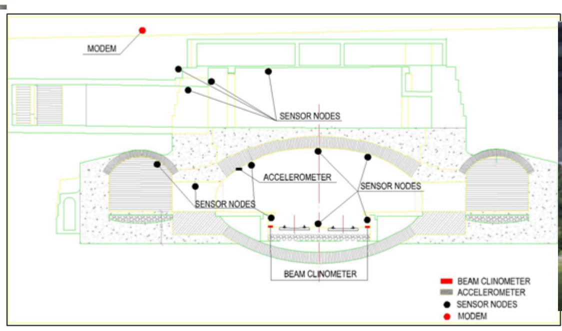
- ➢A tool for automated software synthesis of WSN applications
- ➢Programming entire network from single application definition / user constraints
- ➢Application built from software modules
- ➢Considerably reduced time to develop applications for large networks
- ➢Fast , low power re-programming and re-configuration after deployment → cost reduction

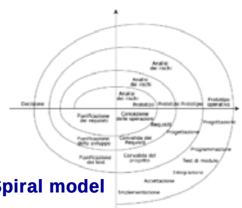
An experimental methodology to design

- Monitoring of a tunnel under construction
- Each monitoring section is constituted by 2 or 3 concrete segments equipped with 6 strain gauges with vibrating string.

- Monitoring of the metro station Colosseo
- Existing station
- Contineous monitoring, during excavations under the metro station, real time data communication

- Monitoring during construction of the Poya Bridge in Switzerland





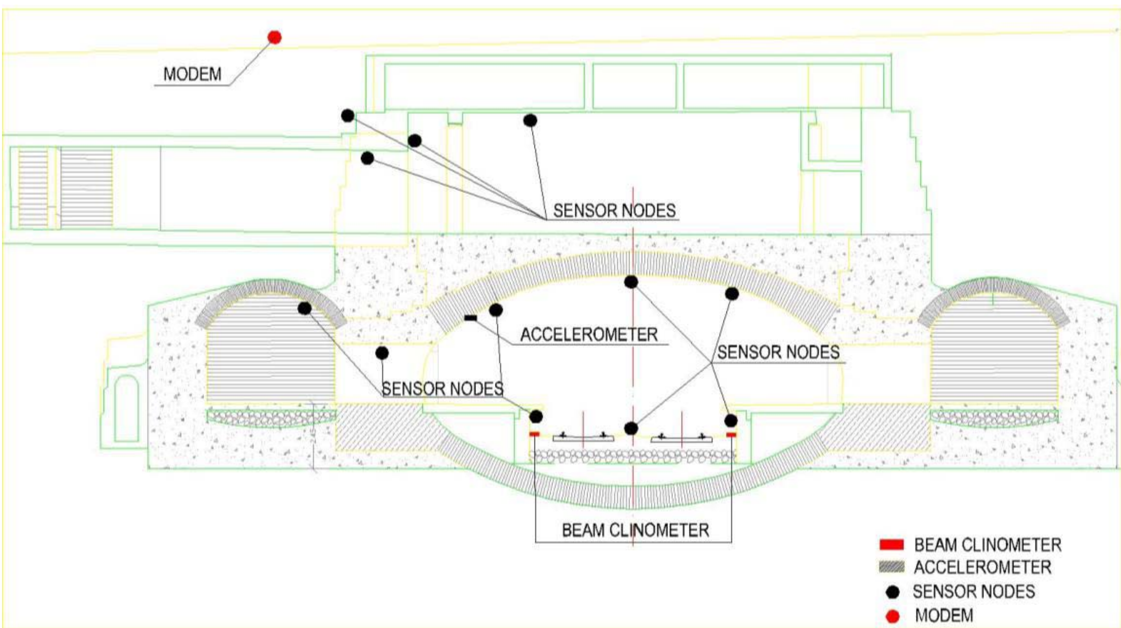
Spiral model

Metodology

Mixed test-bed and in lab experiments

Testbed 1: Rome Metro B1

Testbed 2: Colosseo Metro Station,

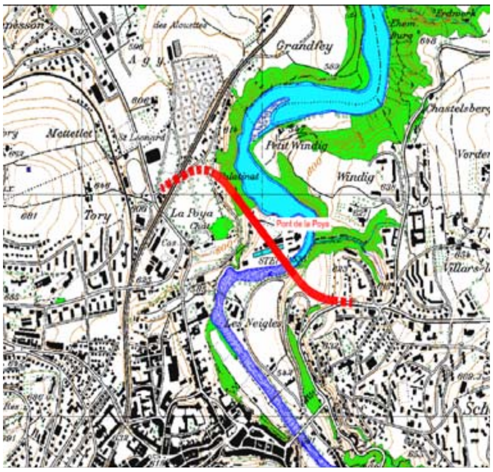


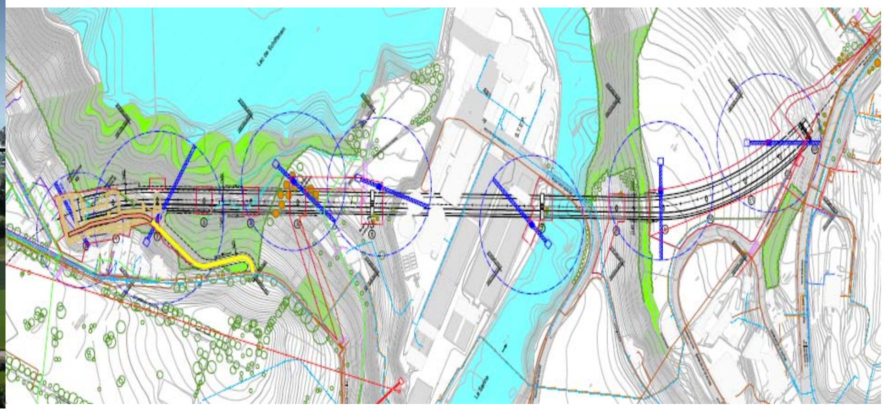
Monitor the infrastructure during the excavation works for the construction of a new underground line

Testbed 3: Bridge Monitoring

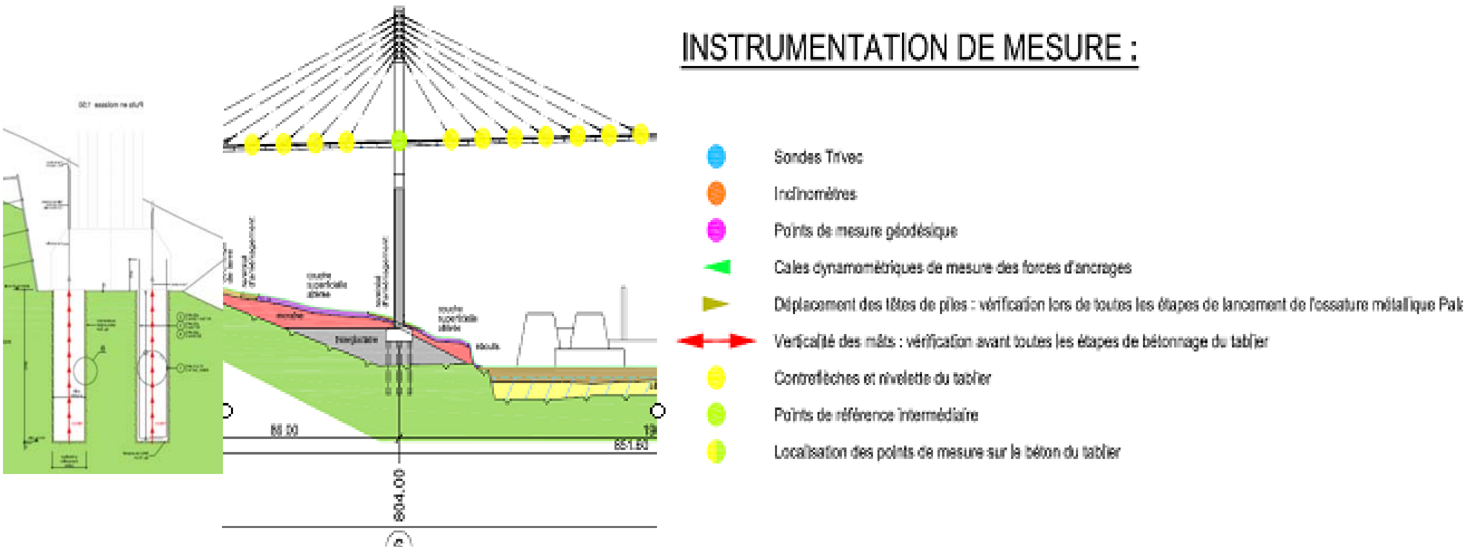
Pont de la Poya: Fribourg

Barrier Lake Saane, near Fribourg

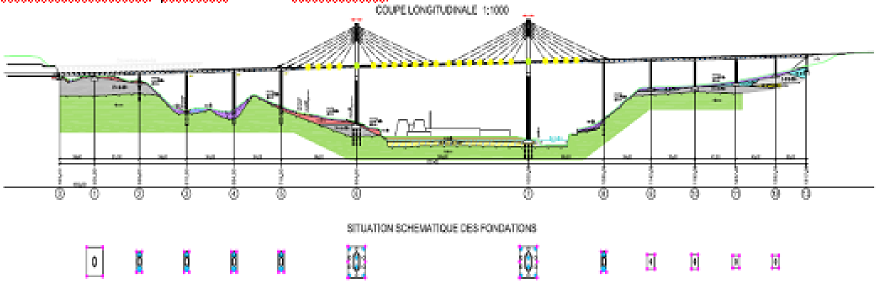




Pont de la Poya Structural Monitoring



Measurement points and methods



Sensors for Pont de la Poya

Concrete and /or steel Strain gages in foundation (piles) and pylons

Strain and structural temperature

Tilt meters (capacitive) installed in the pylons

Meteo:

Wind velocity direction, air temperature, barometric pressure

Displacement meters (linear potentiometer) bridge bearing displacements

Task distribution – workpackage leaders

WP 1 Project coordination:

University of Rome La Sapienza

WP 2 System architecture and requirements:

leader Tyndall

WP 3 Green Sensor Platforms:

leader University of Bologna

WP 4 Collaborative and reliable networking:

leader University of Rome

WP 5 Collaborative in-network data processing and reasoning:

leader University of Twente

WP 6 Integration, deployment and validation:

leader Solexperts

WP 7: Dissemiantion and Expoitation:

leader ST Microelectronics

End-user: Treesse

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Thanks for your attention.