# Wireless Sensor and Actuator Networks for Protection of Critical Infrastructures

**Augusto Casaca**
**INESC-INOVAÇÃO**

## Motivation

- Critical Infrastructures (CI) are of utmost importance for our society to work properly.
- Providing monitoring capabilities for large scale infrastructures requires:
  - Low cost devices
  - Independent operation
  - Minimal additional infrastructure
  - Robust, self-* systems.
- Wireless Sensor Networks appear as ideal candidates for implementing such CI monitoring applications; **however, they must be made dependable (secure and reliable).**

# Overall WSAN4CIP objectives

- Increase the dependability of Wireless Sensor and Actuator Networks (WSANs) significantly beyond the current state of the art by
  - ➔ designing new sensor **node protection** mechanisms
  - ➔ developing innovative **dependable networking** approaches
  - ➔ creating **dependable services** to run on top of WSANs that ensure graceful degradation of quality in case of failures and attacks
  - ➔ investigating and developing **design methodologies** for WSANs according to specific CI application requirements.
- Demonstrate the feasibility of the WSAN4CIP approach using **energy-** and **water distribution** as representative Critical Infrastructures.



# Project partners and facts

Duration: 1/1/09 – 31/12/11

Total effort: 370 PM, Total costs/funding: 4.0 / 2.8 Mio EUR

# Node protection

- Strengthening the OS
  - è existing sensor platforms do not provide standard OS security mechanisms, e.g., memory management units
  - è we work on a microkernel-based architecture for sensor platforms
- Intrusion Detection Systems
  - è standard intrusion detection systems cannot be used on sensor nodes due to their constraint resources
  - è we are investigating an approach that allows designing IDS systems tailored for specific WSAN application scenarios



# Dependable networking

- Node deployment and network bootstrapping
  - è work on metrics for measuring the robustness of network topologies
  - è work on self-address collision detection and solving
  - è work on booting a microkernel-based operating system using network bootstrapping mechanisms.
- Resilient clustering and routing
  - è work on dependable routing protocols
  - è work on dependable cluster head election
  - è work on dependable MAC protocols
  - è work on dependable transport protocols.

# Dependable services

- WSAN interfaces to the Critical Infrastructure, the ICT control system and for node management
  - è we develop an architecture for the integration of WSANs in SCADA systems.
  - è includes specification of SCADA interfaces in accordance with the demonstrator requirements.



# WSAN4CIP Demonstrators

- WSAN4CIP will have demonstrators for two relevant critical infrastructures:
  - è Electricity distribution
  - è Water distribution.
- The Electricity Distribution demonstrator will be mounted at EDP substation and power lines, Setúbal, Portugal.
- The Water Distribution demonstrator will be mounted at FWA premises, Frankfurt-Oder, Germany.
- **This presentation will mainly focus into the protection of the Electricity Distribution infrastructure.**

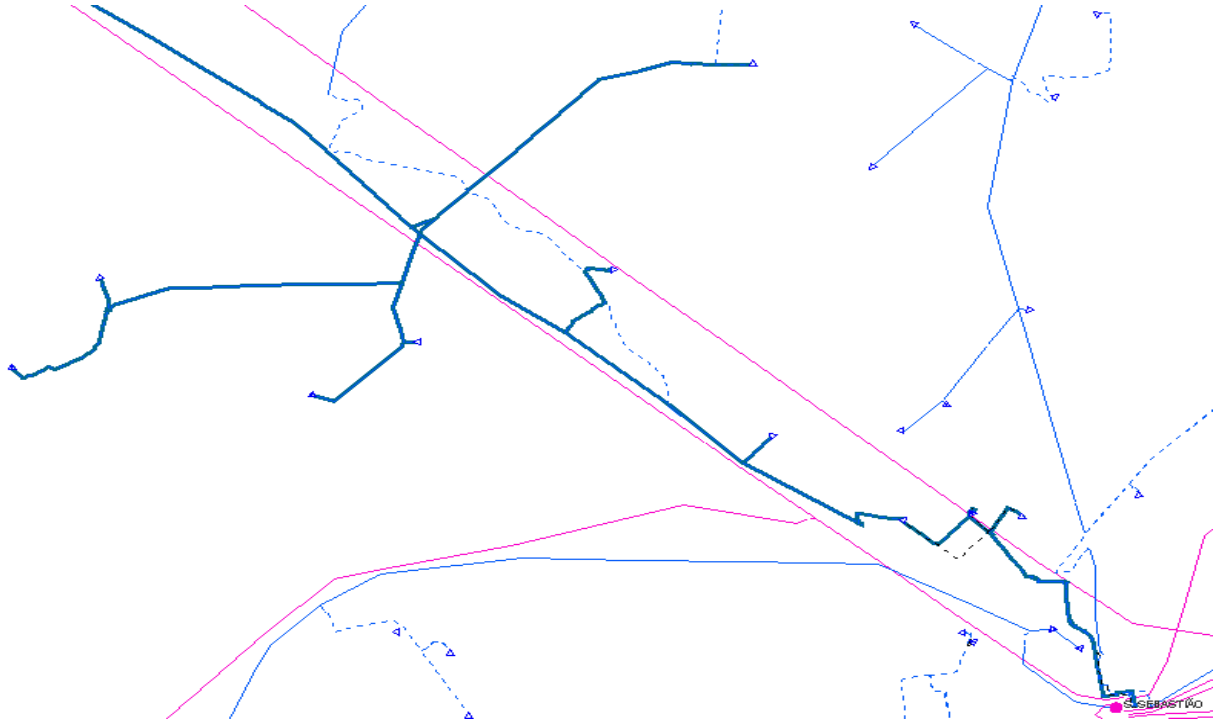
# EDP Critical Infrastructure

- The EDP CI for electricity distribution consists of:
  - è Substations
  - è MV/LV Power Lines
  - è Power Transformer Cabinets.

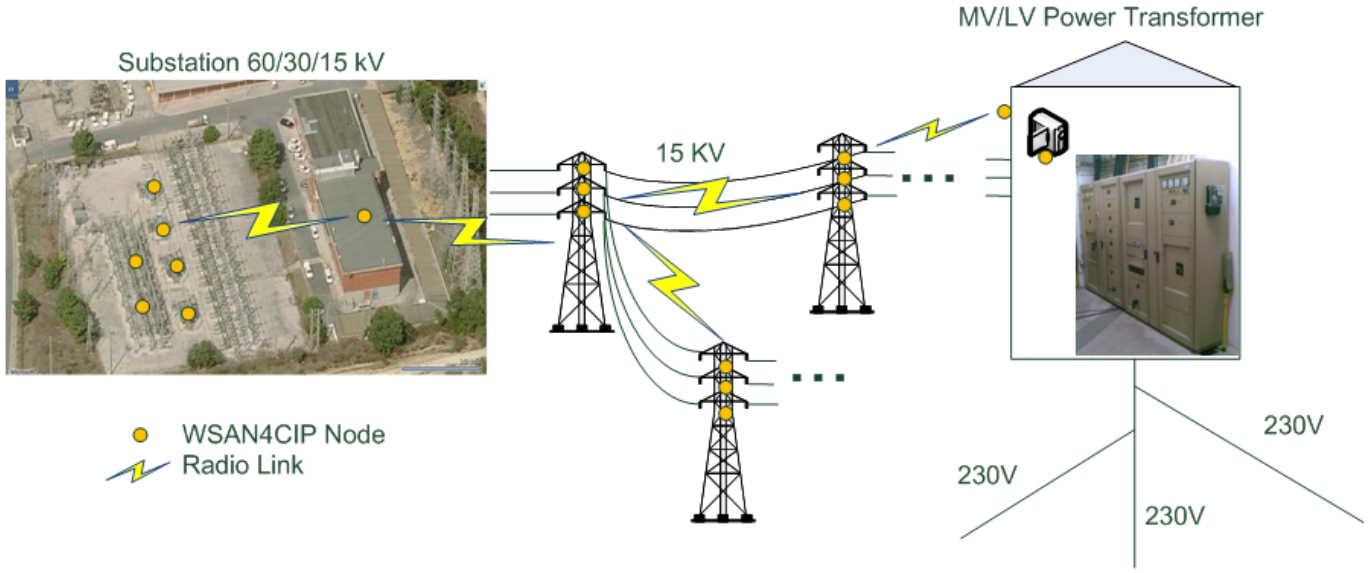
  WSAN can be used to improve the protection on safety and security aspects, taking advantage of its deployment flexibility.



# EDP Critical Infrastructure



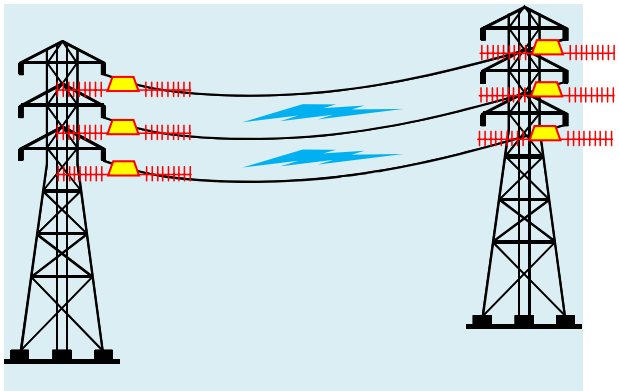
# EDP Demo Bird's Eye View






# Power line current monitoring

- 15 kV Power line monitoring
- Periodic current measurement and reporting
- Malfunction localization (e.g. short circuit)
- Energy harvesting to charge sensor node batteries through current transformers.



# Surveillance of the MV/LV Power Transformer Cabinet

- Sensors:
  - PIR sensor
  - IR camera (e.g. IRISYS Thermal Infrared Camera)
- Integrated surveillance system:
  - Movement sensors detect intruders (alarm)
  - SCADA GUI displays alarm notifications
  - Video camera automatically switches on upon intruder detection
  - Video camera can also be manually controlled
  - WSAN nodes located in the towers relay the traffic to the Substation
- 230V AC power available

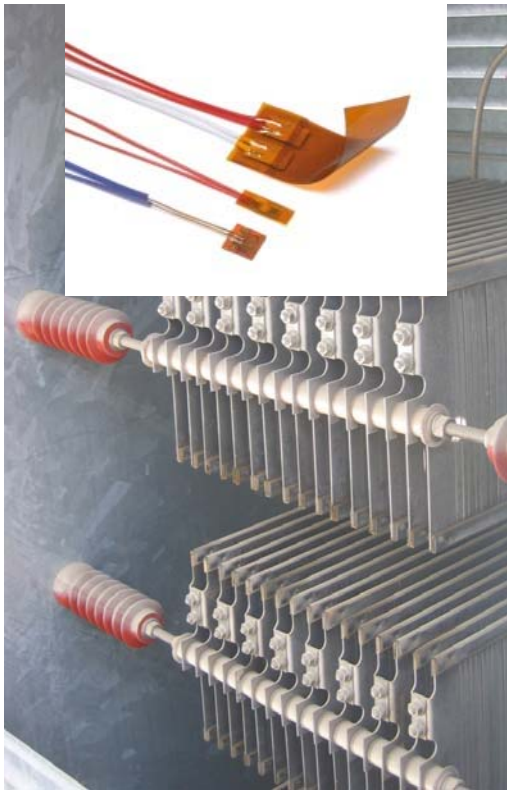


# Circuit breaker trip coil condition

- Hall effect sensor chip
  - Installed near the coil
  - Analogue voltage output (mV)
- Wireless radio SoC with A/D inputs
  - 5 V DC injector (actuator) to test the coil
- 230 V AC power grid available
  - AC/DC converter to drive the radio module

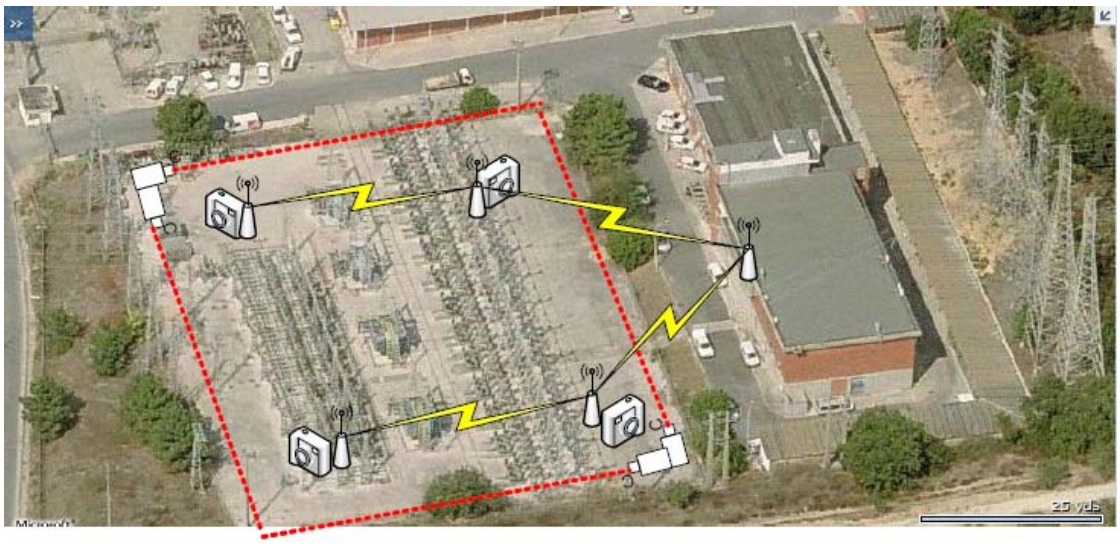
# Temperature monitoring

- Temperature monitoring: power transformer oil, neutral reactance oil, neutral resistor box
- Temperature sensor
  - Easily attachable to the various surfaces of the 3 scenarios
  - Stable and reliable
  - Low current (<1mA)
- Analogue electronic circuit is relatively simple
- 230 V AC power grid available



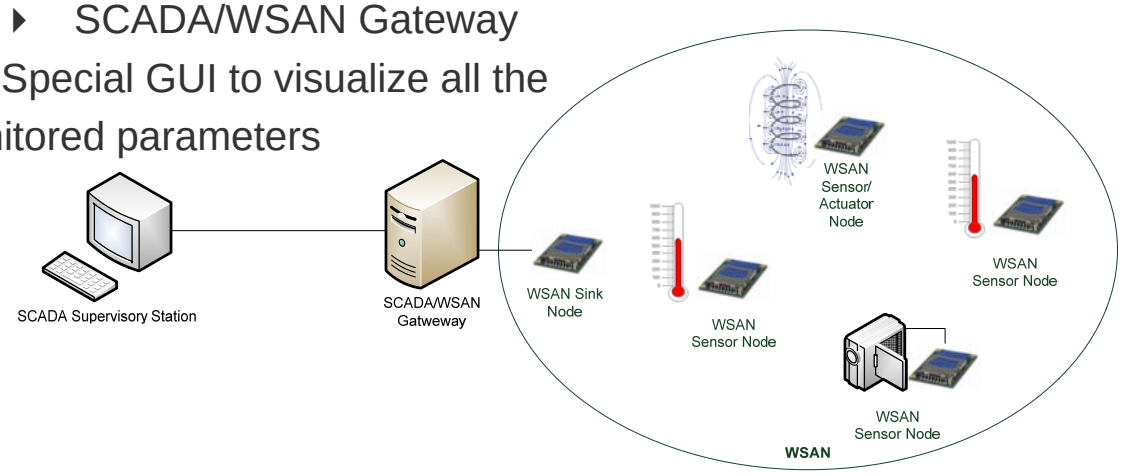


# Substation Perimeter Surveillance



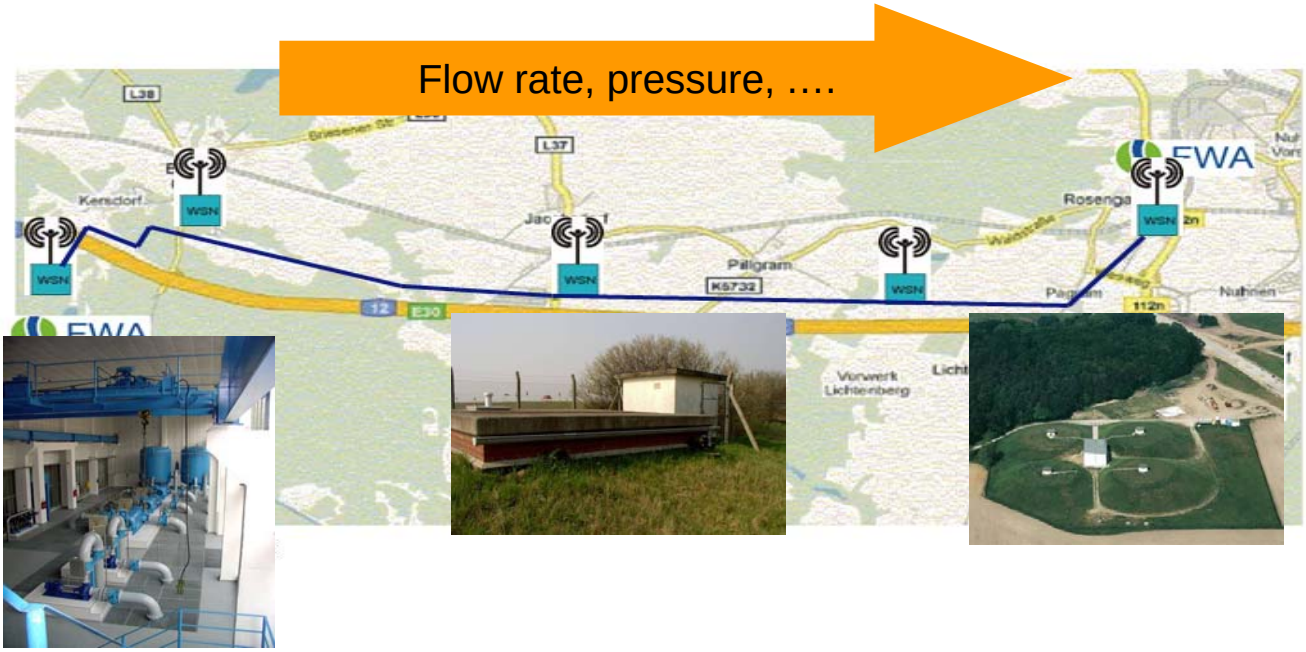
# Demonstrator Architecture

- Video transmission requires high bit-rate
  - IEEE 802.11 WSAN
  - Silex SX-560 module running Linux
- Integration with the SCADA system
  - SCADA/WSAN Gateway
- Special GUI to visualize all the monitored parameters



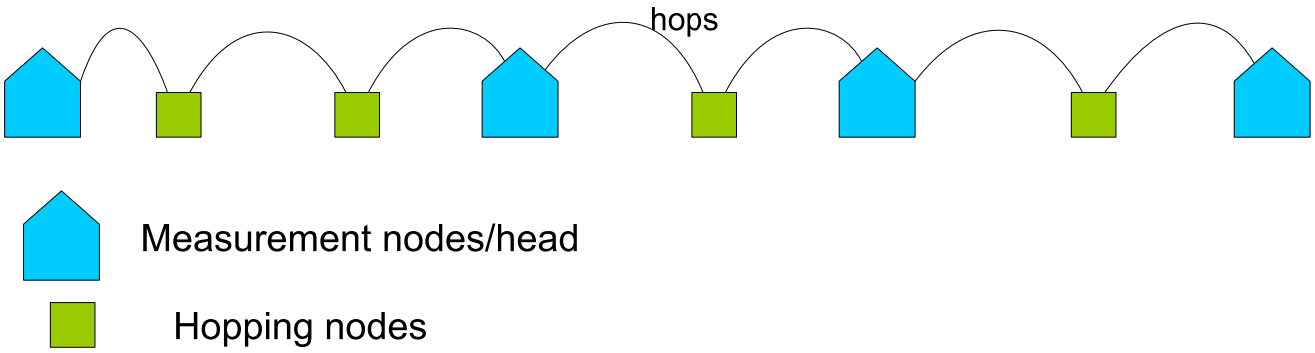



# FWA Demonstrator



# FWA Implementation Approach

Monitoring operation of water mains.
Two parallel water pipes over a total length of 17.5 km.






# Conclusions

- Wireless sensor networks appear as ideal tools for monitoring large scale critical infrastructures
- However, in order to be useful, they must be dependable
- The main objective of the WSAN4CIP project is to design mechanisms by which WSAN dependability can be significantly increased
- We address dependability at all layers: OS and execution environment on the nodes, wireless networking, middleware services
- Two demos to serve as proof-of-concept
- More information: **www.wsan4cip.eu**