PROSEN Project
(Proactive Condition Monitoring of Sensor Networks)

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Contributions from Teams at Kent, Stirling, Strathclyde and Essex

Prosen Intro

The major objectives are:

- to demonstrate practical methods that have the potential to increase the mean time between failure of large-scale sensor arrays
- to facilitate re-configuration of the arrays to meet unexpected new needs
- to make fundamental contributions to the emerging field of proactive system management research.

The project is addressing these issues by:

- investigating and demonstrating techniques that enable automated control and management of sensor arrays to be proactive.

The project is facilitating the use of proactive control and management software through integration with:

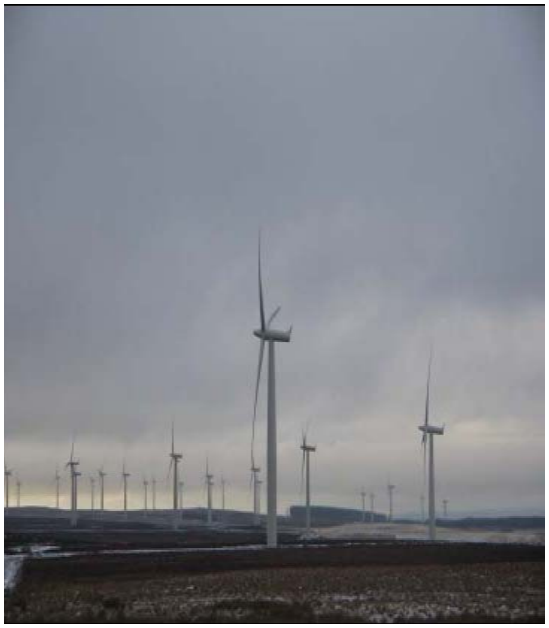
- a policy-driven management infrastructure that uses high-level user goals to constrain the instrument-level proactive behaviours
- a platform that supports appropriate observation, communication and actuation.

Research Challenges

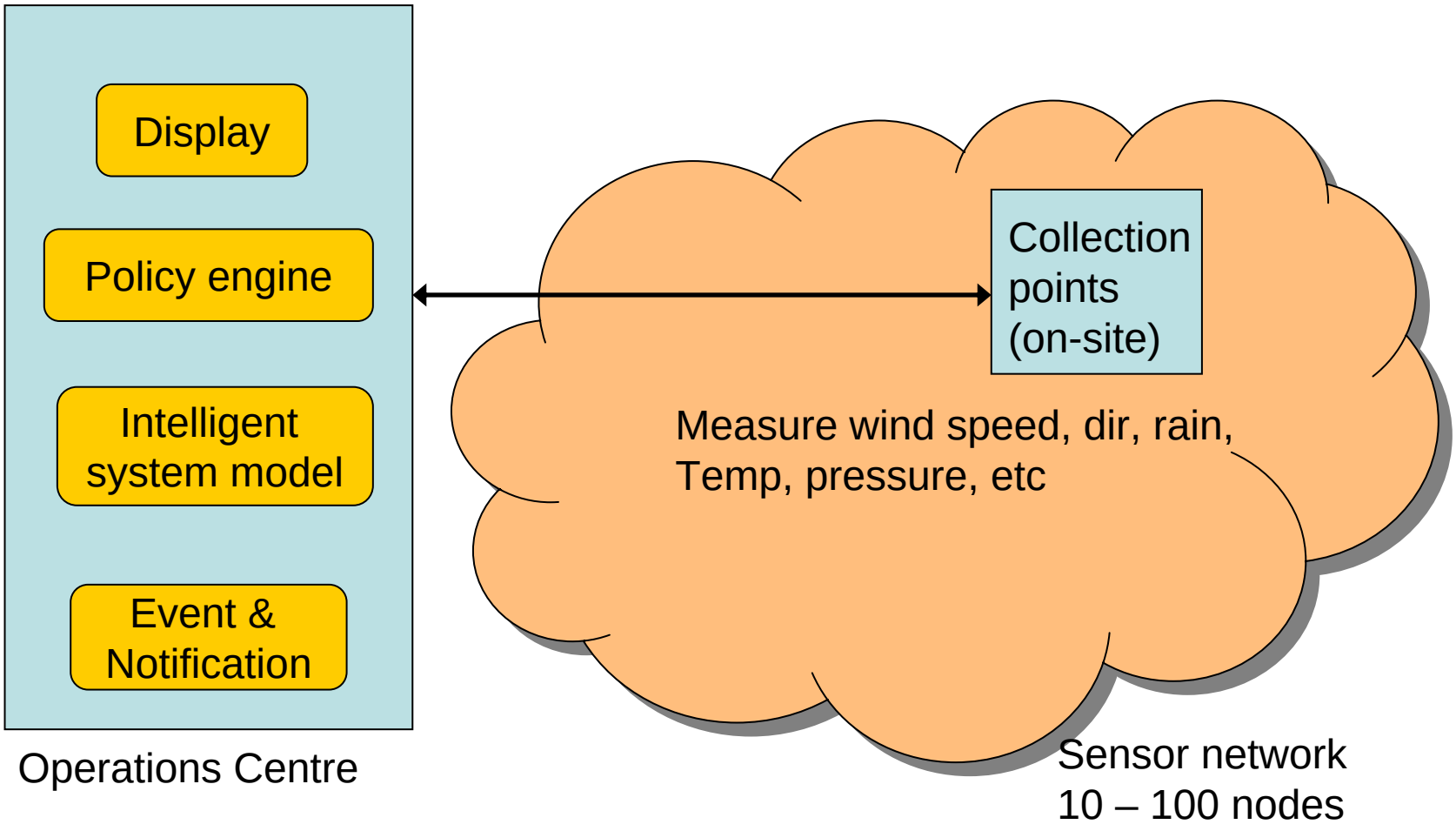
- The design of systems with a rich self-observation capability
- The construction of machines that can continuously monitor parallel streams of input
- The development of effective, efficient and appropriate proactive control techniques
- The automated configuration and maintenance of large-scale sensor networks
- The specification and implementation of effective goal-driven configuration management
- The confederation of software services in such a distributed and changing environment
- The integration of novel research into a practical large-scale demonstration that encourages exploitation.

Target Application

- Monitoring associated with wind turbines
  - Independent confirmation of external conditions to enable disambiguation of internal data
  - Integration with SCADA and operations centre
  - Integration of high level DSS (predictive AI) and node level optimisations
  - Long life, low intervention, large spacing
  - Uses NEL test site at Myer's Hill, and existing turbine data from VESTA. Scottish Power are providing operation centre needs



System architecture



Robustness issues

- Public interference
- Bio-interference (slime, animals etc)
- Transducer placement changes
    - Bush growth, soil movement etc
- Ageing by sunlight/acid rain/brine spray
- Etc.

All imply self-diagnosis and self-repair are essential at node level

Power

- Power demands are 1-2 orders of magnitude greater than small batteries can provide
- Microscopic electronics and megascopic batteries are common
- Tweaking routing protocol doesn’t help much
- Reduce power needs = reduce sampling or reduce comms (or both)
- **Local autonomous decision making is likely to be beneficial provided computation is fast**

Hardware

- Motes are not adequate
  - 8 bit A-D
  - Short range radio
  - Limited processor
- Later versions will improve, but what to do meanwhile
  - Programmable loggers (High power)
  - GUMSTIX (high power)
  - Custom hardware (still got to wait)

In PROSEN we will use custom multi-processor hardware, but initial steps are based on programmable loggers

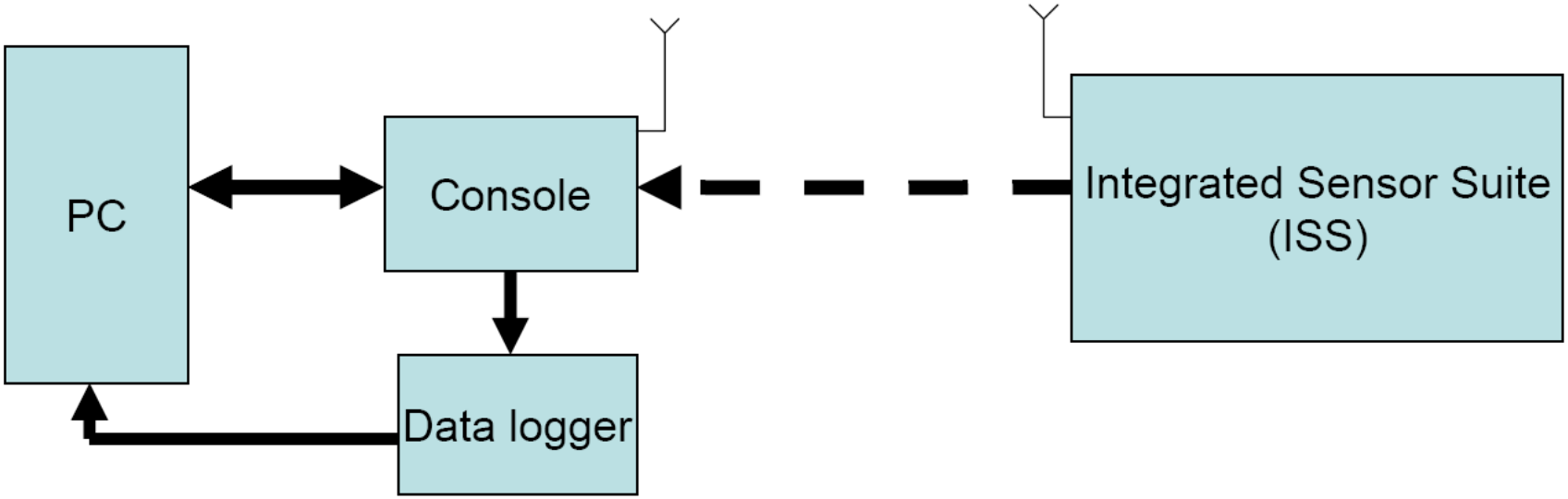
Davis Vantage Pro 2 weather station

Wireless
- 868.0 to 868.6 MHz
- up to 300 m
- Transmits every 2.5 s

Sensor set
- Anemometer
  - wind speed: 0-173 mph
  - wind direction: 0 to 360 degree
- Rain gauge (0-999.9 mm)
- Solar radiation (0-1800 W/m2)
- Temperature and humidity
  - temperature: -40°to +65°C
  - humidity: 0 to 100% RH

Console

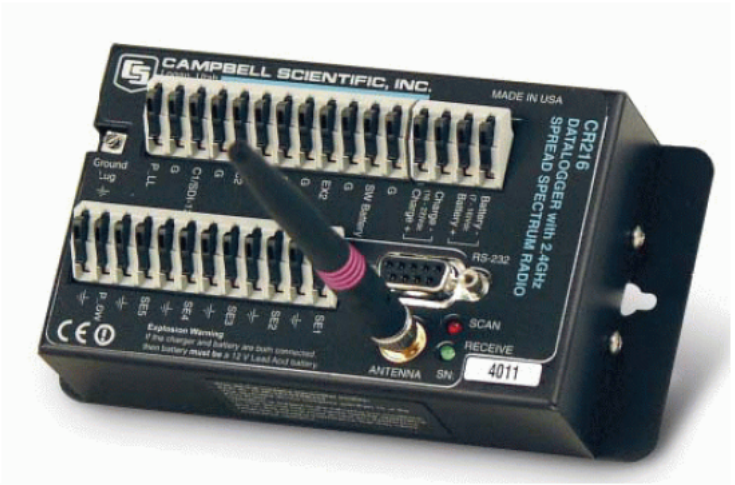
Davis Vantage Pro 2 weather station 2



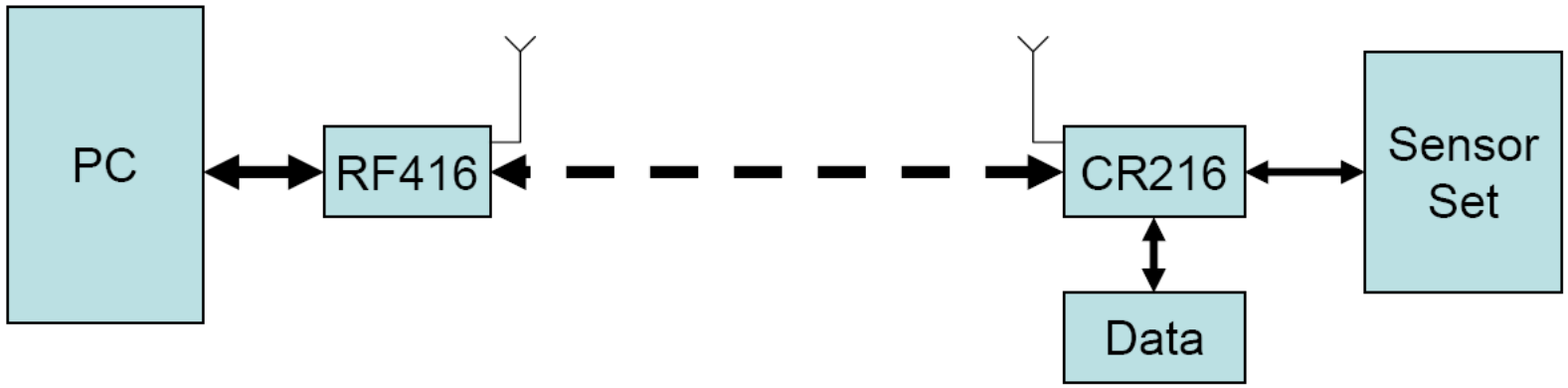
- Advantage
  - Easy to use
  - Environmentally proven
  - Low cost and effective weather station
- Disadvantage
  - One way wireless communication
  - Fixed sampling rate
  - Data logger is at base station side

Campbell CR216 data logger 1

- **Measurement Inputs**
  - 5 analog inputs (0 to +2.5v,12 bits)
  - 2 pulse inputs
  - 2 digital I/O
  - 2 switched voltage excitation
    (20mA at 2.5V, 10mA at 5V)
  - 1 switched battery (12V,300mA)
  - supply power (12V)
- **Memory**
  - 2K SRAM communication buffers
  - EEPROM 60K for code, 128K for data
- **Wireless**
  - 2.4 GHz
  - up to 400 m



Campbell CR216 data logger 2



- Advantage
  - Bidirectional wireless communication
  - Sampling rate is changeable
  - Record data on the field
  - Programmable

- Disadvantage
  - Power hungry

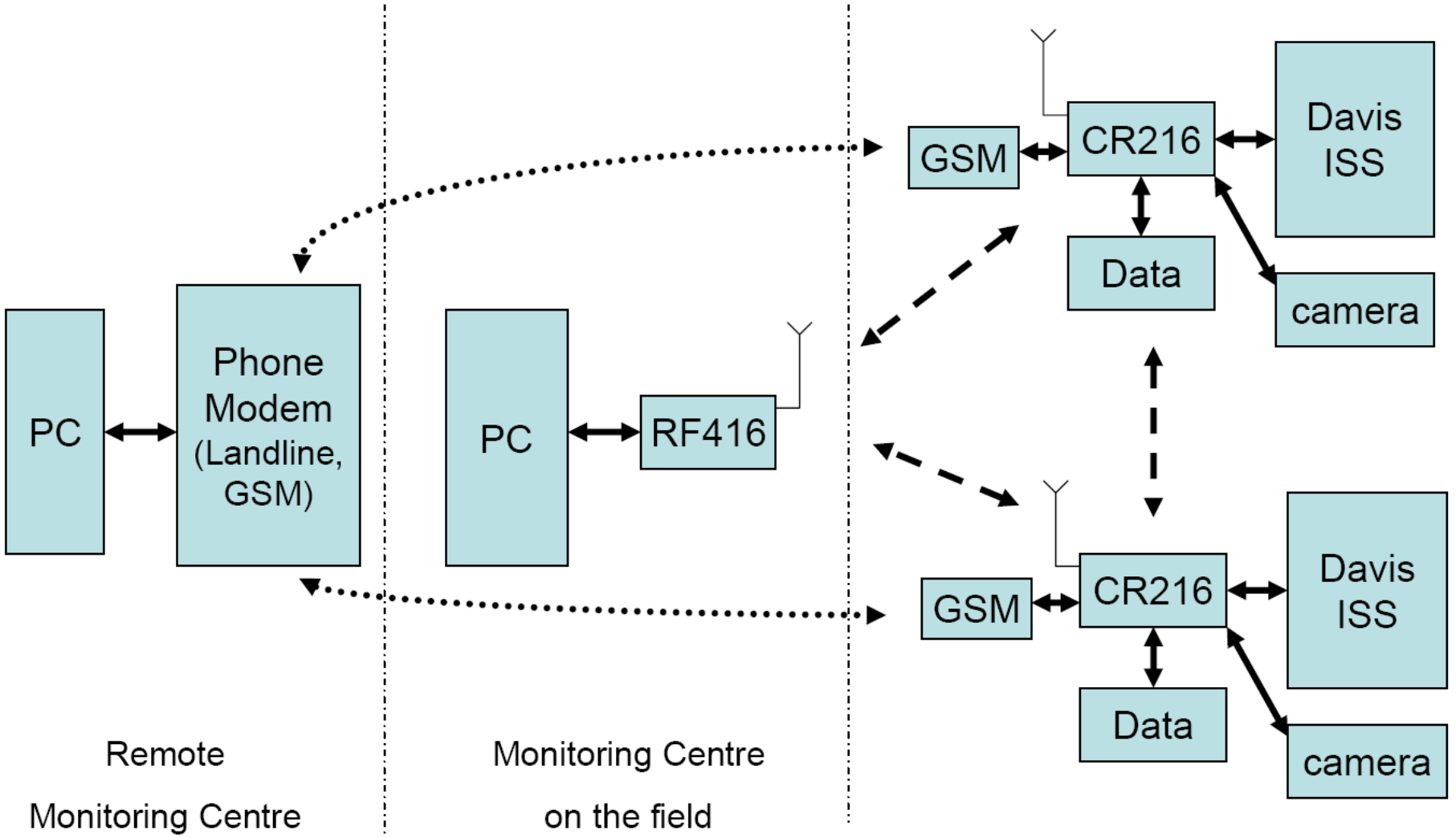
    Active (re: 36mA, tr: 75mA)

    Stand by:

    Radio always on: 36mA

    Radio in 1s cycle: 4mA
  - Expensive

Evaluation Platform



Embedded AI

- Step 1 – Rule based self-diagnosis and self-adaptation
    - Send alarms when thresholds exceeded
    - Enable update from operations centre
- Step 2 – Bayesian learning
    - Change thresholds and behaviours as data accumulate
- Step 3 – Neural novelty filter
    - Dynamic predictive coding
    - Inspired by Retina
- Step 4 – Collective learning
    - Prioritise actions that succeeded elsewhere

Sensor Network Options

- Low power radio
  - Small distance
  - Limited bands (interference)
- TDMA or CSMA
- To IP or not to IP
- Standard/proprietary
- High gain antennae
  - High visibility
  - No mobility
- Dynamic routing?
- Star or multi-hop
- More power (e.g. GSM)
  - Minimise usage
  - Process in situ
  - Real time alarms only
- Wireless local access (mobile reader)
  - Bluetooth
  - Enhanced Rfid
  - Full data retrieval
- Reader on person, in car or on autonomous vehicle

Middleware

- Event based (non-blocking)
- Message queues at collection points
- SMP for local comms (on chip/board)
- Process oriented on nodes
- Agent based at collection points and ops centre (model nodes as agents)
- Policy distribution by controlled flooding

Upper layers

- Developing Ontologies (OWL) for user level policies and events
- Visualise modelled impacts/risks using spatial database and interface
- Integration with existing data sources on spatial basis first
- High level models build on previous implementations by power management group at Strathclyde

Summary

- Prosen is building a self-diagnosing, self-adapting sensor network and associated management platform
- This will be evaluated in the context of wind farm management
- The project is making good progress
    - Basic system architecture agreed
    - Initial evaluation platform installed
    - Hardware development initiated
    - Comparative evaluation of existing technologies completed
    - Development of new technologies started
    - Evaluation results to follow
    - Full system demo in 2 years