Addressing Power Requirements in Structural Monitoring

Now and in the Future

Adaptive Wireless

- Founded in 2004
- Sole UK importer of several leading US and German wireless monitoring and control products
- Application/solution orientated business
- Integrator rather than manufacturer or supplier to OEMs
- Experience of several types of wireless systems including mesh, narrowband and GSM/GPRS
- Occasional user of ‘traditional’ energy harvesting (i.e. solar PV)

Power budget:
Elements of a Sensing System

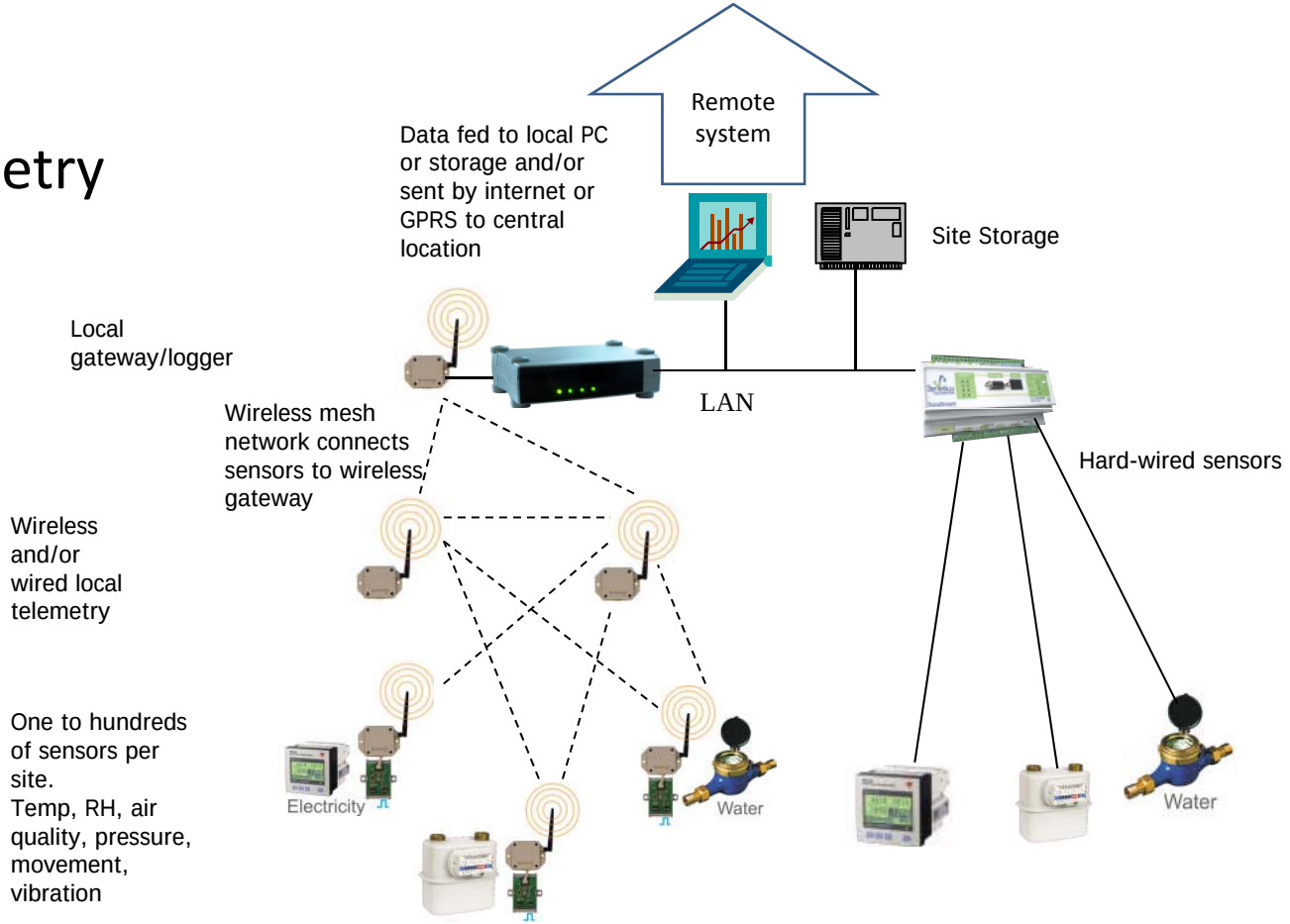
Remote system

Wide area telemetry

Local storage

Local Telemetry

Sensors



Sensors

- Very wide range of standard types typically used
  - E.g. Temperature, humidity, displacement, pressure, vibration
- Specialised types may also be used
  - E.g. ground water pore pressure, salinity, soil moisture
- All sensors require a power source
- Power required varies widely and depends on sensing technique and the type of output required.
  - Thermistors, maybe 0.9mW depending on resistance range used
  - PT100 RTD's would be 0.1 – 0.25W – inaccurate if voltage drops.
  - CMOS sensors require less power (e.g. Sensirion TRH sensors 1.5uW to 2.75mW, ave 140uW)
  - Standard 4-20mA loop-powered sensors typically need 140 – 600mW
- Warm-up/stabilisation/excitation time – may not need to be on all the time
- Environmental factors (e.g. heating elements)
- New technologies e.g. MEMS for low power accelerometers
- Commercial Off-the-shelf (COTS) or special-purpose?
- Integrated with local telemetry devices or separate?
  - Trade off flexibility with cost to develop
  - ultimate power budget usually less with integrated sensors

Local telemetry (1)

- Can be wired or wireless – focus here on wireless. Important factors include:
  - Sensed data rate and frequency of readings required
  - Radio Frequency
    - Regulations and licence-free operation
    - Also related to power consumption
  - Range required
  - Scale and topology of network required
    - effect on need for repeaters/range
  - Radio protocol requirements
    - (e.g. IEEE 802.15.4 is designed to support sleep mode)

Local Telemetry (2)

- Mesh radio
  - Routers may have to be on all the time
  - Our experience is that routers should be externally powered
  - Link to latency of network
- Network latency
  - Time-stamping of readings at node?
  - More network and node overhead
- Typical battery-powered 2.4GHz mesh wireless device (e.g. for CMOS sensor) not used for routing and reading every 5 minutes would consume 120uW average including periodic excitation of sensor
- If used for routing in battery mode this figure increases to an average of 630uW due to increased on-time required
- Other types of network have mesh routers with continuous power requirements of up to 300mW depending upon I/O connected at the device.

Local Storage

- Data capture at local site (“logger”)
- Local access only or remote access required?
- Type of outputs required
  - analogue, Modbus TCP or RTU?
- Type of inputs available on standalone “loggers”
  - typically wired and analogue rather than higher-level interface from a gateway or similar
- In wireless systems often combined with wireless gateway device
- Must be on all the time
- Externally powered
- Typically would require 840mW for wireless gateway element, perhaps up to 15W if logger and higher-level functions such as web server are included in the gateway

Remote Telemetry

- Only needed if site(s) are to be connected centrally or accessed remotely
- Typically GSM/GPRS or broadband
- Local end of telemetry must be supportable at local site
- Sleep mode may be possible, with timed wake-up
- Normally externally powered, typically 15W.
- Remote command capability (e.g. to start/stop logging) can be used to conserve local power

Central System

- Could be drawing data from multiple sites
- Probably using standard IT equipment
- Most likely has a traditional power source available
- Not a key issue for this meeting

Environmental Factors

- Ambient temperature range
  - battery life can be seriously affected
  - Important to select battery type correctly
- Structure
  - If massive can affect network design and placement of devices
- Construction type
  - steel, concrete, foil-backed materials
  - can be a radio barrier
- Underground
  - Is ground penetration to above-ground required?
- Transient obstacles
  - trains in tunnels, water, vehicles

Power requirements

- We have seen values from 120uW to 15W average for different types of device
- For wireless devices the radio usually consumes the most power
- Power requirement can be very peaky
  - 20uA or less sleep current most of the time
  - 55mA transmit and receive current for 30- 60 ms depending on device type
- Some battery types do not cope well with this type of power profile
  - Reduces their effective capacity considerably
- Different battery chemistries have different voltage drop characteristics over time.
- Some sensor types become inaccurate at lower voltages
- A big driver of power required is the type of connected sensor and how it is 'managed' by the connected device in terms of on-time.

Energy Harvesting Perceptions

- Harvesting is very much application-specific and may not be possible
- Almost always intermittent therefore usually complemented by a suitable battery and/or supercapacitor system
- Battery system must therefore be rechargeable
- Solar PV
  - Becoming more efficient and affordable. Not helped by Northern latitude
- Fluid driven (Wind, water)
  - Small wind generators widely available
- Thermal
  - Fairly new
- Vibration
  - Resonant frequency tuning may be problematic in real applications
  - Can they generate enough power?
- Piezo-electric
  - Generally suitable for very 'bursty' applications with long off-times
  - Can have quite high power density
  - Must be matched with suitable wireless system – most wireless systems need their devices to be present all the time, even if using sleep mode to achieve 99%+ sleep time.

Conclusions

Main perceived challenges

Reduce System Power Requirements

- Reducing power required by sensors
  - Development of new sensing technologies
  - Continuing need to deploy/interface to vast range of COTS sensors
- Improve power efficiency of wireless chipsets
- Provide more power-efficient wireless gateway and logging devices
- Provide more power-efficient remote telemetry devices (GSM/GPRS)

Effective System Engineering

- Match wireless system to application from relatively small pool of useful COTS systems
  - Assuming solution engineering from first principles for every project is not economically viable!
- Engineer application-specific integrated solutions where commercially viable

Improved Energy Harvesting

- Improve effectiveness of energy harvesting equipment
- Match energy harvesting devices to duty cycle and physical environment of application
- Improve performance of rechargeable battery systems

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