Distributed Sensor Grid for Utility Management

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Necessity

- Meter reading is a meaningful personnel cost
  - Offset, not replaced
- Fault detection
- Industrial applications for more sophisticated monitoring
- Simpler and more extensible than many more sophisticated sensors on the market with a significantly lower cost

System Overview

- Wireless, mesh-networked, distributed sensor system for power distribution observation
- Uses 802.15.4 Zigbee standard on 900 MHz band
- Uses CT for current sampling
- Uses voltage divider for voltage sampling and power
- Uses Propeller microcontroller, 8 core, 80 MHz system
- Uses a beautiful Cocoa GUI, but open source and can be configured to interoperate with any system

Zigbee – XBEE 900 Pro

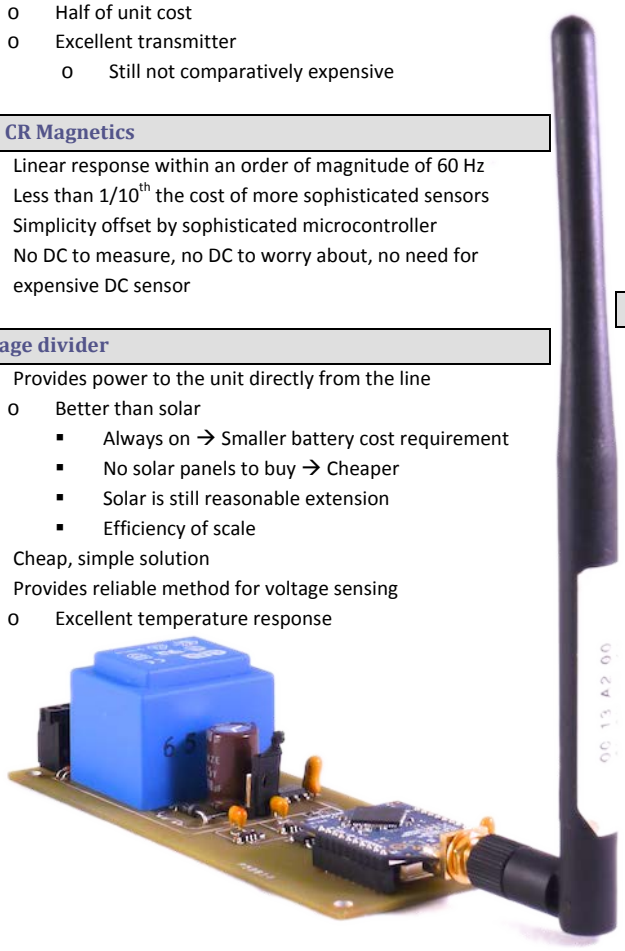
- Each unit has a unique 64 bit MAC address
- Transparent mesh networking capability
  - No networking infrastructure → Purely distributed system → Full access to network wirelessly from anywhere in range of a sensor
  - Custom designed packet structure
  - 128 bit node level encryption
  - Microcontroller architecture has limited design scope and cannot be maliciously bypassed in a Stuxnet-like attack
- 400 ft indoors, 1.5 miles LOS, 6 miles LOS (high gain)
- Most expensive part of the system
  - Half of unit cost
  - Excellent transmitter
    - Still not comparatively expensive

CT – CR Magnetics

- Linear response within an order of magnitude of 60 Hz
- Less than 1/10th the cost of more sophisticated sensors
- Simplicity offset by sophisticated microcontroller
- No DC to measure, no DC to worry about, no need for expensive DC sensor

Voltage divider

- Provides power to the unit directly from the line
  - Better than solar
    - Always on → Smaller battery cost requirement
    - No solar panels to buy → Cheaper
    - Solar is still reasonable extension
    - Efficiency of scale
- Cheap, simple solution
- Provides reliable method for voltage sensing
  - Excellent temperature response



Parallax Propeller

- Cheaper, simpler, with cleaner code than ARM
- Significantly more powerful than most other microcontrollers
- ADC sampling core
  - 100 kHz ADC
  - 2 more ADC input channels unused
- RMS Core
  - Samples at 6 kHz
  - Calculates true RMS, current and voltage
  - No samples missed
- FFT Cores
  - 1024 Hz sampling with 40 ms delay
    - Frequency domain resolution of 1 Hz
    - Can be bumped down to 128 Hz for better frequency domain resolution
  - Finds fundamental and true power factor, THD
  - Continuously recalculates DC component directly from ADC output
- Two communications cores, floating point math core

Interface

- XBEE connected device can receive data from any sensor within the mesh network
  - Great for maintenance calls
  - Can see whole grid from anywhere in locality
  - Fault tolerant
    - Power goes out, still run off batteries
    - Single unit goes out, can dynamically reroute
- Display waveforms/samples/RMS of current/voltage, power over time, kVA, fundamental power factor
- Software extensibility includes possibility of:
  - Query KVAs once per day
    - Turn off transmitters to save power
    - Units keep track of running KVAs locally
    - Only send out personnel once every few months
  - Other types of sampling on other cores
    - Continuous vibration monitoring
    - Magnetic field sensors
    - Thin film sensors

Implementation

- Low cost
  - Unit cost of ~$80 for prototypes,
  - Larger scale → Cost can go down by > 50%
  - Much lower cost than existing commercial solutions
- Open source, open hardware design
  - No licensing/patent fees whatsoever
  - Full access to the source code and design schematics
  - Possible to create cooperative developer community among power companies
    - Distribute development costs
    - Share implementation tools and solutions
    - As community grows, cost to entry for AMR and smart utility management reduces
  - Google Code project
    - http://code.google.com/p/open-energy-meter/