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Battery Power Issues for WSN's

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Outline of talk

- Designing low powered electronic circuitry
- WSN's: Main features for our purpose
- Microcontrollers
- Radios
- Interface circuitry
- Batteries: Alkaline batteries
- Batteries: Rechargeable

Designing Low Powered Electronic Circuitry

- The usual design approach for ultra-low-powered devices is to minimize average current by spending as much time as possible in a low-power consumption mode sometimes called "sleep".
- When response is needed, the device "wakes" into a state where it can carry out actions. During this time the device is active and draws current.
- After the device has carried out its work, it returns to sleep.
- We talk about the "duty cycle" of the device in the system.
- For WSN's we might aim for a duty cycle from 0.1% to 1%.

Wireless Sensor Networks

- For our purpose of discussing power consumption, we distinguish the following aspects of WSN's
- The microcontroller
- The radio
- The interface circuitry
- The software running on the microcontroller

Microcontrollers – Power Consumption

- Microcontrollers (uC) comprise a CPU + timers + UARTs + I/O + other features to reduce system component count.
- Microcontrollers usually have at least two low-power modes called "idle" and "sleep".
- Idle mode: current ~ 40% of active current. Timers keep running and can wake uC.
- Sleep mode: current ~uA. Timers do not run. Need external source to wake uC.
- Active current proportional to clock freq, may be 0.5 - 1mA/MHz.
- Design software to minimize time spent active.

Radios – Power Consumption

- WSN's tend to use transceivers (Trx), which cannot receive and transmit simultaneously.
- Eg Chipcon CC2420 is a 2.4GHz Trx;
  - 19.7mA receiving;
  - 17.4mA transmitting 0dBm (1mW) RF;
  - 20uA in low power mode.

Interface Circuitry – Power Consumption

- Application dependent; may include
  - indicator lights,
  - external analog or digital inputs,
  - external analog or digital outputs, relays.
- These can draw considerable current.

- Note that the microcontroller needs to be awake to change the state of an output, but can go to sleep, leaving an output device powered up.

Batteries: Alkaline cells

- Nominal voltage 1.5V.
- Battery capacity specified as no of mA Hrs (charge) to discharge to 60% of nominal voltage at one hour rate.
- Amount of charge that can be taken from a battery increases as the discharge rate is reduced.
- Not much data available for very slow discharge regimes.

Cell size	Typical mA Hr capacity
AAA	700
AA	1500-2000
C	5000
D	9000-12000
9V	550

Batteries: Rechargeable

- Consider using rechargeable batteries powered by a solar cell. Different types of rechargeable batteries are available:
  - NiCADs: 1.2V: suffer from "memory effect"
  - NiMH: 1.2V: less memory effect
  - Lithium Ion: Used in Notebooks and phones; more stringent charging requirements;
- Capacities same order of magnitude as alkaline cells of same size

Design Example Using Alkaline cells

- # Hours in one year = 8760
- -> a series battery of alkaline D cells should last for a year supplying an average current of 1mA.
- -> Requires WSN sleep current < 1mA !!!!!
- Suppose uC + radio draws 35mA when active.
- Suppose Duty Cycle = 1%.
- -> Avge ct = 0.99 X sleep current + 0.01 X 35mA < 1mA
- -> sleep current < 0.66 mA.

- With Duty Cycle = 0.1%, av ct = .999 X .66 + .001 X 35 = 0.69mA

QoS in wireless sensor networks

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Outline

- A very brief word on QoS
- QoS metrics in wireless sensor networks
- Open QoS problems in a "real" wireless sensor network

A very brief word on QoS

- QoS – A measure of the service quality a network offers its users and/or applications.
- Level of QoS indicated by a set of measurable attributes.
  - Delay, jitter, available bandwidth, packet loss.
- Conventional networks employ end-to-end metrics.
- Examples of current QoS indicators:
  - Best effort (no Qos)
  - Guaranteed services (hard Qos)
  - Differentiated services (soft Qos)
- End-to-end does not necessary apply in WSNs.

QoS metrics in WSNs

- Difficult to generalize QoS from an end-to-end perspective.
- Ideally provide mapping from network QoS metrics to application requirements.
- QoS in WSN depends on data delivery model.
  - Event driven
    - Multiple sensor linked to a single sink.
    - Highly correlated data flows.
    - Low rate bursty transmission.
    - Low latency for control applications.

QoS metrics in WSNs continued

- Query driven
  - Data pulled by the sink.
- Continuous
  - Real-time voice, video or data.
  - Periodic sensor measurement reporting.
- Hybrid
  - Most often WSN systems fall in this category.

- QoS metrics for WSNs must not focus on individual node links.
  - Collective latency
  - Collective packet loss
  - Collective throughput

Open QoS problems in a practical WSN

- **W**ater **I**nformation **N**etworks large project (**WIN**)
  - Monitor and control water flows throughout a canal irrigation network.
  - Control on-farm crop irrigation.
- Guarantee a maximum network transmission delay.
  - Water flow levels must be communicated over several "hops" to trigger gate control.
  - Measurements are made at multiple nodes (sources).
  - The destination is a single node (sink).
  - Potentially large correlation in measurements.
  - Delay sensitivity on the order of seconds.
  - Preferably, minimize the maximum delay!

Open QoS problems in a practical WSN continued

- How many nodes can fail before a network fails to operate?
  - Need a measure of satisfactory network operation.
  - Provides insight into network deployment.
    - How many nodes?
    - Relative node placement?
    - **Constrained by application!**
  - Aim is a graceful degradation in network performance.
  - Avoid weak points in the network, such as routers.

- **WIN** WSN parameters
  - Tree topology.
  - CSMA-CA medium access protocol.
  - Sleep schedule overlay.
  - Variable node density.
  - Random node placement.
  - Variable node count.
  - Event driven data model.

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