COE 545 - Wireless Sensor Networks

Sensor Node Architecture

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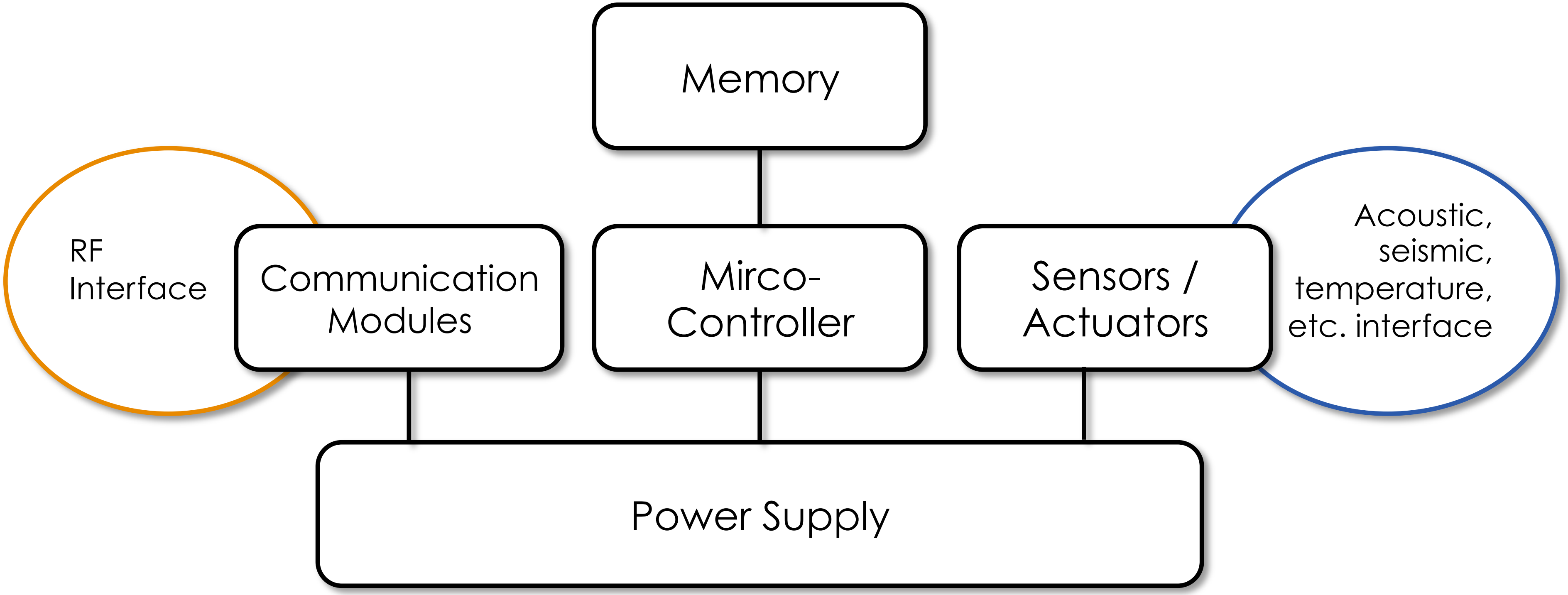
WSN Hardware Design

- Sensor nodes support wide range of application
  - Application specific requirements
    - Hardware is designed to be – Modular, flexible, programmable
- Sensor nodes have limited resources – Power / CPU / Memory
  - Hardware is designed to be – Power efficient

Sensor Node Architecture



Sensor Node Architecture

- Sensor Node Components
  - *Controller* - process relevant data, signal processing
  - *Memory* - store programs and intermediate data
  - *Sensors and actuators* - interface to the physical world, observe or control physical parameters of the environment (e.g. acoustic, temperature, imaging, etc.)
  - *Communication* - sending and receiving information over a wireless channel.
  - *Power supply* - mainly batteries, energy from the environment(e.g. solar cells)

Micro-controller

- Available architectural options:
  - CPU - highly overpowered, high energy consumption and cost, not suitable for WSN
  - DSP - optimized for signal processing tasks, not suitable for WSN
  - FPGAs – reprogrammable (flexible), time and energy tradeoffs
  - ASIC - customized design, peak performance is needed, somehow better energy efficiency, no flexibility
  - Microcontroller - optimized for embedded applications, low power consumption, flexible

Micro-controller

- Examples of MCU for embedded applications
  - MSP 430
    - 16-bit RISC core, 4MHz
    - on-chip RAM (sizes are 2–10 kB)
    - 12-bit ADC converters
  - Atmel ATMega
    - 8-bit microcontroller
    - Used for embedded applications

Micro-controller

Sensor	TelosB	IRIS	MICA2	MICAz
MCU Type	TI MSP430	XM2111CA/ ATmega128L	MPR400/ ATmega128L	MPR2400/ ATmega128L
Speed	8 MHz	8 MHz	8 MHz	8 MHz
RAM	10 kB	8 KB	4-8 KB	4-8 KB
Program Flash Memory	48 KB	128 KB	128 KB	128 KB

Radio Transceiver

- Tasks and characteristics
  - Service interface to upper layers (MAC) - bit, byte, packet level
  - Power consumption and energy efficiency
  - Transmission power control
  - State change times and energy
  - Carrier frequency and multiple channels
  - Data rates
  - Modulations
  - Gain
  - Receiver sensitivity
  - Carrier sense and RSSI
  - Voltage range

Energy efficiency related (power consumption and energy efficiency; transmission power control; state change times and energy)

Radio performance related (carrier frequency and multiple channels through voltage range)

Radio Transceiver

- Transceiver operational states
  - *Transmit* – transceiver's transmit part is active
  - *Receive* - transceiver receive part is active
  - *Idle* – ready to receive (expecting), but nothing is received
    - Main parts of the receive circuitry are active, some other part should be switched off ⟶ little reduction in energy consumption
  - *Sleep* – many parts of the transceiver are switched off Not able to immediately receive something
    - *startup energy* and to leave sleep state can be significant

Examples of Radio Transceivers

- Chipcon CC1000
  - FSK
  - 868– 870 MHz (up to 4 channels) and
  - 902–928 MHz (up to 54 channels)
  - 38.4 kbps data rate
  - RF Power: -20 to +5 dBm
  - Used in MICA2/MICA2DOT

- Chipcon CC2420
  - IEEE 802.15.4 (ZigBee) compliant
  - QPSK - quadrature phase shift keying
  - DSSS modem
  - Low voltage operation
  - 250 kbps data rate
  - RF Power: -25 to 0 dBm
  - Used in MICAz, TelosB

Sensors

- Three categories
  - Passive, omnidirectional
    - No active manipulation (probing) of environment
    - No notion of direction
    - *Examples*: thermometer, light sensors, vibration, humidity
  - Passive, narrow-beam
    - No active manipulation (probing) of environment
    - Direction of measurement exists
    - *Examples*: Camera
  - Active sensors
    - Probe the environment
    - *Examples*: sonar, radar, seismic sensor

Sensing Boards

- MTS300/MTS310
  - Flexible sensor boards
- MTS420/400
  - Some basic environmental sensing parameters
    - e.g. Barometric Pressure, Ambient Light, Relative Humidity & Temperature
  - optional GPS module
- MDA100
  - Data acquisition board
  - Thermistor, a light sensor/photocell

Sensing Boards

- MEMSIC MTS300/310
  - Multi Sensor Board
    - Light, Temperature
    - Microphone, Sounder
    - Dual-Axis Accelerometer, Dual-Axis Magnetometer (MTS310)
    - Compatible with IRIS, MICA2, MICAz

MTS300CB

MTS310CB

Sensing Boards

- MEMSIC MDA300
  - Multi-Function Data acquisition board
    - Qualified with numerous external environmental probe
      - humidity, temperature, wind speed
    - 2.5, 3.3, 5V sensor excitation and low-power mode
    - 64K EEPROM for onboard sensor calibration data
    - Applications
      - Environmental Data Collection
      - Agricultural and Habitat Monitoring
      - Viticulture and Nursery Management

Sensing Boards

- Programming Boards & Gateway
  - Interface between a mote and a PC
    - Ethernet
    - USB
    - Serial
  - Base Station for Wireless Sensor Networks

Sensing Boards

- MEMSIC MIB510
  - Serial Port Programming for IRIS, MICAz and MICA2 hardware platforms
  - RS-232 Serial Gateway
  - aggregation of sensor network data on a PC
  - Onboard processor
    - programs the Mote processor/radio boards
    - monitors the MIB510 power voltage - disables programming if the voltage is not within the required limits
  - Power supply

Sensing Boards

- MEMSIC MIB600
  - Base Station/Ethernet (100 Base) Gateway for Wireless Sensor Networks
  - Mote Network Testbed
  - Remote In-System Programming for IRIS/MICAz and MICA2 Processor/Radio Boards
  - Full TCP/IP Protocol - ARP, UDP/IP, TCP/IP, Telnet, DHCP,BOOTP, TFTP, Auto IP, and HTTP
  - Power Over Ethernet (POE) Ready

Energy Supply for Sensor Nodes

- Goal: provide as much energy as possible at smallest cost/volume/weight/recharge time/longevity
  - In WSN, recharging may or may not be an option
- Options
  - Primary batteries – not rechargeable
  - Secondary batteries – rechargeable through energy harvesting (e.g. solar panels)
- Requirements include
  - Low self-discharge
  - Long shelf life
  - Capacity under load
  - Efficient recharging at low current

Battery Examples

- Energy per volume (Joule per cubic centimeter)

Primary batteries			
Chemistry	Zinc-air	Lithium	Alkaline
Energy (J/cm^3)	3780	2880	1200
Secondary batteries			
Chemistry	Lithium	NiMHd	NiCd
Energy (J/cm^3)	1080	860	650

Energy harvesting

- How to recharge a battery?
  - *Remember*: Sensors are deployed in unattended area
  - Try to ***scavenge*** energy from environment
- Ambient energy sources
  - Light
  - Temperature gradients
  - Vibrations
  - Pressure variation (piezo-electric)
  - Air/liquid flow

Examples of Energy Sources

Energy source	Energy density
Batteries (zinc-air)	$1050 - 1560\,\mathrm{mWh/cm^3}$
Batteries (rechargable lithium)	$300\,\mathrm{mWh/cm^3}$ (at $3 - 4\,\mathrm{V}$)

Energy source	Power density
Solar (outdoors)	$15\,\mathrm{mW/cm^2}$ (direct sun)
	$0.15\,\mathrm{mW/cm^2}$ (cloudy day)
Solar (indoors)	$0.006\,\mathrm{mW/cm^2}$ (standard office desk)
	$0.57\,\mathrm{mW/cm^2}$ (< 60 W desk lamp)
Vibrations	$0.01 - 0.1\,\mathrm{mW/cm^3}$
Acoustic noise	$3 \cdot 10^{-6}\mathrm{mW/cm^2}$ at $75\,\mathrm{Db}$
	$9,6 \cdot 10^{-4}\mathrm{mW/cm^2}$ at $100\,\mathrm{Db}$
Passive human-powered systems	$1.8\,\mathrm{mW}$ (shoe inserts)
Nuclear reaction	$80\,\mathrm{mW/cm^3}$, $10^6\,\mathrm{mWh/cm^3}$

Source: Holger Karl, Andreas Willig, Protocols and Architectures for Wireless Sensor Networks

Power Efficient Design

- Efficient hardware
  - Operate at low voltages and low current
  - Selectable modes of operation: *off, sleep, idle, active*
- Efficient software
  - Fine-grained control of hardware
  - In-network processing - data Aggregate, compression
- Efficient radio
  - Adaptive: transmit power, modulation, rate
  - Different radio operational states : *off, sleep, idle, active*

THIS IS THE TOPIC FOR NEXT LECTURE

Conclusion

- Many considerations must be taken while choosing/ designing the required sensor node architecture
  - Flexibility
  - Power/Energy/Energy efficiency
  - Programmability
  - Accuracy & precision
  - Physical parameters & measurements
  - Location
  - Mobility

ALL OF THE ABOVE IS ……………….

References

- Holger_Karl and Andreas Willig, **Protocols and Architectures for Wireless Sensor Networks**, *Wiley, ISBN:* 0-470-09510-5, June 2005 « Few slides are provider by the book auther »
- Baunach, M., Kolla, R., Mühlberger, C. "**SNoW^5: a modular platform for sophisticated real time wireless sensor networking**", Technical Report 399, Institut für Informatik, Universität Würzburg, 2007
- Polastre, J.; Szewczyk, R.; Culler, D., "**Telos: enabling ultra-low power wireless research**" Fourth International Symposium on Information Processing in Sensor Networks, 2005.
- www.memsic.com
- www.atmel.com