1. Introduction

Introduction to wireless sensor networks

Wireless sensor networks

Martin Úbl
ublm@kiv.zcu.cz

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<DCSE> DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

Subject

Basic info, requirements

- Wireless Sensor Networks
  - "Bezdrátové senzorové sítě" (BSS)
- History
  - first prepared and taught by Ing. Jiří Ledvina, CSc. in 2016
  - mostly oriented to Texas Instruments boards
  - semestral projects involving routing, sensor measurements processing, etc.
- Requirements

  credit – semestral project
  credit – activity during semester
  exam – written exam with discussion

Wireless sensor networks

First look

- computer networks are a part of modern world
- "ordinary" networks usually rely on unlimited or easily accessible power supply
  - unlimited – routers, switches, PCs, servers, ...
  - easily accessible – mobile phones, smart watches, wireless earbuds, ...
- "ordinary" networks have a requirement for higher throughputs
  - in 2020+ we usually expect to have at least 100 Mbps "Internet speed"

Wireless sensor networks

First look

- "ordinary" networks have a requirement for low latency
  - the expected web page load speed in 2020+ is less than a second
- "ordinary" networks have a requirement for high availability
  - in 2020+ we usually expect to connect everywhere whenever we need it
  - e.g., free Wi-Fi, wired connections at work, LTE-based cellular network, ...
- "ordinary" networks have a requirement for security
  - in 2020+ we usually expect an implicit use of modern cryptography

Wireless sensor networks

First look

- almost none of these requirements holds for wireless sensor networks (WSNs)
- main requirements for a WSN are:
  - maximum power-saving
  - accurate measurements
  - consistency, fault-detection, (fault-recovery if possible)
  - time synchronization
  - node localization
  - node and network security

Wireless sensor networks

First look

- main tradeoffs
  - maximum power savings
    - lower throughput
    - higher latencies
    - more complex HW/SW design
  - accurate measurements
    - expensive sensors
    - more complex HW/SW design
    - possibly less power-saving
  - node localization
    - additional hardware
    - more complex radio HW

Wireless sensor networks

First look

- typical WSN parameters:
  - 5-100 nodes
  - 1+ gateways
  - up to 1 Mbps data rate (usually a lot less)
  - 1-10 years on a single battery (and a single charge)
  - more than 99 % of the time in sleep mode
  - small transmission units (usually up to tens of bytes)
  - receives or transmits data once per a long period (an hour, a day, ...)
  - very small nodes

Wireless sensor networks

First look

- typical wired sensors
  - requires wired connection
  - usually relies on stable power supply
  - cannot be used in inaccessible areas
    - fields
    - remote places
    - difficult terrain
  - different architecture and uses
- we will focus on wireless sensor nodes

Wireless sensor networks

First look

- manufacturers
  - Texas Instruments
    - CC series (CC13xx, CC26xx, CC3xxx, ...)
    - MSP series (MSP430, ...)
  - EspressIf
    - ESP8266, ESP32
  - Telos
  - Mica
  - Atmel
  - and many more...

Wireless sensor networks

Equipment

- typical equipment of a wireless sensor node
  - microcontroller capable of low-power operation
  - memory for run-time data (RAM)
  - program memory (flash)
  - persistent memory (flash, EEPROM, memory card)
  - radio (WiFi, Bluetooth, ZigBee, ...)
  - battery
  - sensor modules and on-board communication interfaces (SPI, I2C, 1-Wire, ...)

Wireless sensor networks

Node example (2001)

- ATMega 163 (4 MHz)
- 512 B RAM, 16 kB flash memory, 256 kB EEPROM
- ambient light, temperature, battery charge and radio strength sensors
- 5 mA current when active, few μA when asleep
- TinyOS

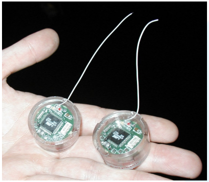


Figure: Source: `http://www.cs.uccs.edu/~cchow/pub/master/pjfong/`

Wireless sensor networks

Node example (2017)

- ATtiny85 (1 MHz)
- 2 kB RAM, 8 kB flash memory
- contact sensor, room for more over SPI / I2C
- up to 10 mA current when active, around μA when asleep
- LoRa radio

Figure: Source: `https://www.iot-partners.nl/`

Wireless sensor networks

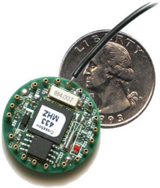
Applications

- Application examples:
  - Field monitoring (temperature, humidity)
  - Structural monitoring (building stability)
  - Motion tracking (tens to thousands of dynamic nodes)
  - Environmental monitoring (air quality, wildfire detection)
  - Military monitoring (event detection)
  - Agricultural monitoring (soil fertility, parasites)
  - Intelligent buildings and smart homes
  - Healthcare (elderly people monitoring)
  - many more...

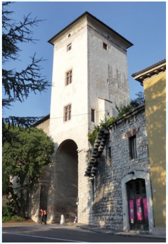
Wireless sensor networks

Structural monitoring

- `https://ercim-news.ercim.eu/en88/ri/wireless-sensor-networks-and-the-tower-that-breathes`
- WSN application to structural monitoring
- detecting structural changes of a tower
  - historical building
- inaccessible areas, wireless connection required
- detected "breathing" pattern throughout the day



(a) Sensor node



(b) Monitored tower

Wireless sensor networks

Fragile ecosystem monitoring

- Great Duck Island
- `https://doi.org/10.1145/570738.570751`
- endangered seabird species (Leach's Storm Petrel)
- presence of human causes mortality and birds leaving their habitat
- we want to monitor their lives and nesting patterns
- we must minimize human presence
  - => WSN

Figure: Great Duck Island

Wireless sensor networks

Fragile ecosystem monitoring

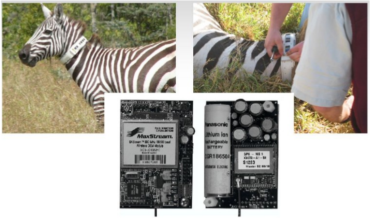
- Great Duck Island
- Sensors: light, temperature, infrared, humidity, barometric pressure
- solar-powered, where possible
- 9 months monitoring duration
- nodes distributed via drone
- hierarchical network structure

Figure: Sensor node

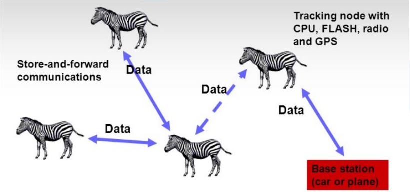
Wireless sensor networks

ZebraNet

- ZebraNet
- https://doi.org/10.1145/1031495.1031522
- migration patterns of wild zebras
- mesh network with a base station (in a car or a plane)



(a) ZebraNet node



(b) Communication of nodes

Wireless sensor networks

Radiation monitoring

- monitoring of radiation levels
- deployed in a 4 km radius around a nuclear plant
- monitors radiation using a miniature Geiger counter
- advantage of using WSN:
  - when needed, additional nodes may be dropped to inaccessible areas to spread the network coverage

Figure: Sensor node

Wireless sensor networks

Volcano activity monitoring

- monitoring of an active volcano
- `https://doi.org/10.1109/MIC.2006.26`
- microphone and a seismometer
- semi-hierarchical network
  - base station
  - linear chains of sensor nodes

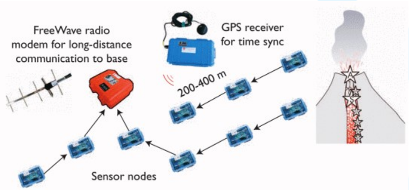


Figure: WSN architecture

Introduction

Final remarks

- wireless sensor networks are useful
- different design, than the ordinary networks
- often custom implementations
- different requirements for the function
- we will go through all the design aspects in the following lectures
- practicals will cover the programming and architecture part