Impulse-Radio Ultra-Wide Band Networks

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1  Impulse-Radio UWB Networks

- A short intro on UWB
- UWB for ad hoc networking with very low power
- Interference in IR-UWB networks
What are UWB signals?

- **Narrowband (GSM: 200 kHz)**
- **Spread spectrum (802.11b: 20 MHz)**
- **UWB: > 500 MHz to several GHz (802.15.4a: 500 MHz)**
Impulse-radio UWB

- Time-hopping sequence: here [..., 2, 8, 4, ...]
- One time-hopping sequence/user: multi-channel physical layer
UWB from a wireless networking point of view

Very wide bandwidth

1. Trade power for bandwidth: very low emitted power
2. Lots of multipath: this is good
   - Random signature for concurrent transmitters
   - Excellent robustness against fading
3. Fewer interference from concurrent transmitters than in narrowband communications
   - Parallel/concurrent transmissions are possible
   - Much simpler MAC design

Our interest: understand how to organize a UWB network that can get the maximum performance out of a very small radiated power budget
What is the optimal MAC design for UWB ad hoc network?

MAC design options:
- Power control
- Rate control
- Scheduling

What is the “optimal”?

[Radunovic, 2004] rate efficiency
[El Fawal and al., 2005] power efficiency
- No power control
- Send whenever you want
- Don’t control interference, adapt to it ⇒ rate control
A MAC protocol for UWB ad hoc networks

[Merz and al., 2005] an uncoordinated MAC with adaptive rate and no power control.

- What is the MAC doing then?
  - Rate adaptation (AIMD)
  - Contention at a destination
  - Helps for multihop communication

- Some features:
  - Assumes no carrier sensing
  - No control channel
  - Receiver-based THS

- Applications:
  - Sensors network with very low emitted power
  - Wireless body area networks
DCC-MAC: a simple example

Data 1, THS(D)

ACK, THS(D)

Idle, THS(S1)

idle

Data 2, THS(S1)

Interference but no "collision"

Data 1 to D via S1

Data 2 to D via S1

Send Timer

Wait for Idle

Backoff Timer

Send Timer

Max. Backoff Timer

Idle, THS(S1)

ACK, THS(D) idle
Interference still matters in real IR-UWB networks

1. Real systems have a finite bandwidth
   - Quasi-orthogonal multi-channel physical layer and rich multipath environment
   - Operation with no power control
   \[ \Rightarrow \] near-far effect

2. The interference distribution is impulsive and non-Gaussian

3. Multi-user interference occurs and matters
   - Interference must be mitigated
   - A proper receiver can help
   [Flury and al., 2006]
Whether concurrent transmissions are possible depends on the receiver

- Performance of a “real” IR-UWB radio: IEEE 802.15.4a standard
  - 500 MHz bandwidth
  - Very simple energy detection receiver
- In this case, concurrent transmissions are not possible
- See presentation tomorrow [Flury and al., 2007]...
Summary

Understand how to organize a UWB network that can get the maximum performance out of a very small radiated power budget

- How to build realistic receiver that manage interference
- Power saving protocols
- Efficient ranging and location positioning

- It can work! We are building an UWB interference radio platform.
  - Demonstrated packet detection and timing acquisition with interference at MICS SC 06

http://icawww1.epfl.ch/uwb
For Further Reading (1)

B. Radunovic and J.-Y. Le Boudec
Optimal Power Control, Scheduling and Routing in UWB Networks
IEEE JSAC, December 2004

R. Merz, J. Widmer, J.-Y. Le Boudec, and B. Radunovic
A Joint PHY/MAC Architecture for Low-Radiated Power TH-UWB Wireless Ad-Hoc Networks
WCMC Journal, Special Issue on UWB Communications, July 2005.

A. El Fawal, J.-Y. Le Boudec, R. Merz, B. Radunovic, J. Widmer, and G. M. Maggio
Tradeoff Analysis of PHY-aware MAC in Low-Rate, Low-Power UWB Networks
For Further Reading (2)

M. Flury, J.-Y. Le Boudec
Interference Mitigation by Statistical Interference Modeling in an Impulse Radio UWB Receiver
IEEE International Conference on Ultra-Wideband (ICUWB 2006), 2006

M. Flury, R. Merz, J.-Y. Le Boudec, and J. Zory
Performance Evaluation of an IEEE 802.15.4a Physical Layer with Energy Detection and Multi-User Interference
IEEE International Conference on Ultra-Wideband (ICUWB 2007), 2007