UWB flexible assets in radio, access, and network design

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Outline

- UWB Impulse Radio features and framework of application
- Flexible radio
- Flexible MAC
- Flexible routing

UWB Impulse Radio features

The common adoption of the term UWB comes to us from the radar community, and refers to electromagnetic waveforms with an instantaneous fractional bandwidth greater than about **0.20–0.25**

Traditionally, UWB signals have been obtained by transmitting **very short pulses** with typically no Radio Frequencies modulation

(In communication systems, "very short" refers to a duration of the pulse that is typically about a few hundred picoseconds)

This technique goes under the name of

→ **Impulse Radio (IR)**

UWB Impulse Radio features

Time duration of a pulse is smaller than original symbol duration

→ energy is spread over a large bandwidth

Contrarily to conventional Spread Spectrum, increased bandwidth is not provoked by spreading sequences, but rather by the

<u>extremely short pulse duration that induces ultra-wide bandwidth</u>

Very short pulse → **Ultra-Wide Bandwidth**

UWB Impulse Radio framework of application

IEEE 802.15.4

Standard for **low-rate** WPANs:

- ✓multi-month to multi-year battery life
- ✓data rates of 20-250 kbps
- ✓power management for low power consumption
- ✓low complexity

IEEE 802.15.4a

Same as above, plus:

- ✓**location enabled: high precision ranging/location (at least 1 meter accuracy)**
- ✓**ultra low power**

A Flexible network

Flexible routing

UWB allows accurate ranging accuracy and power management

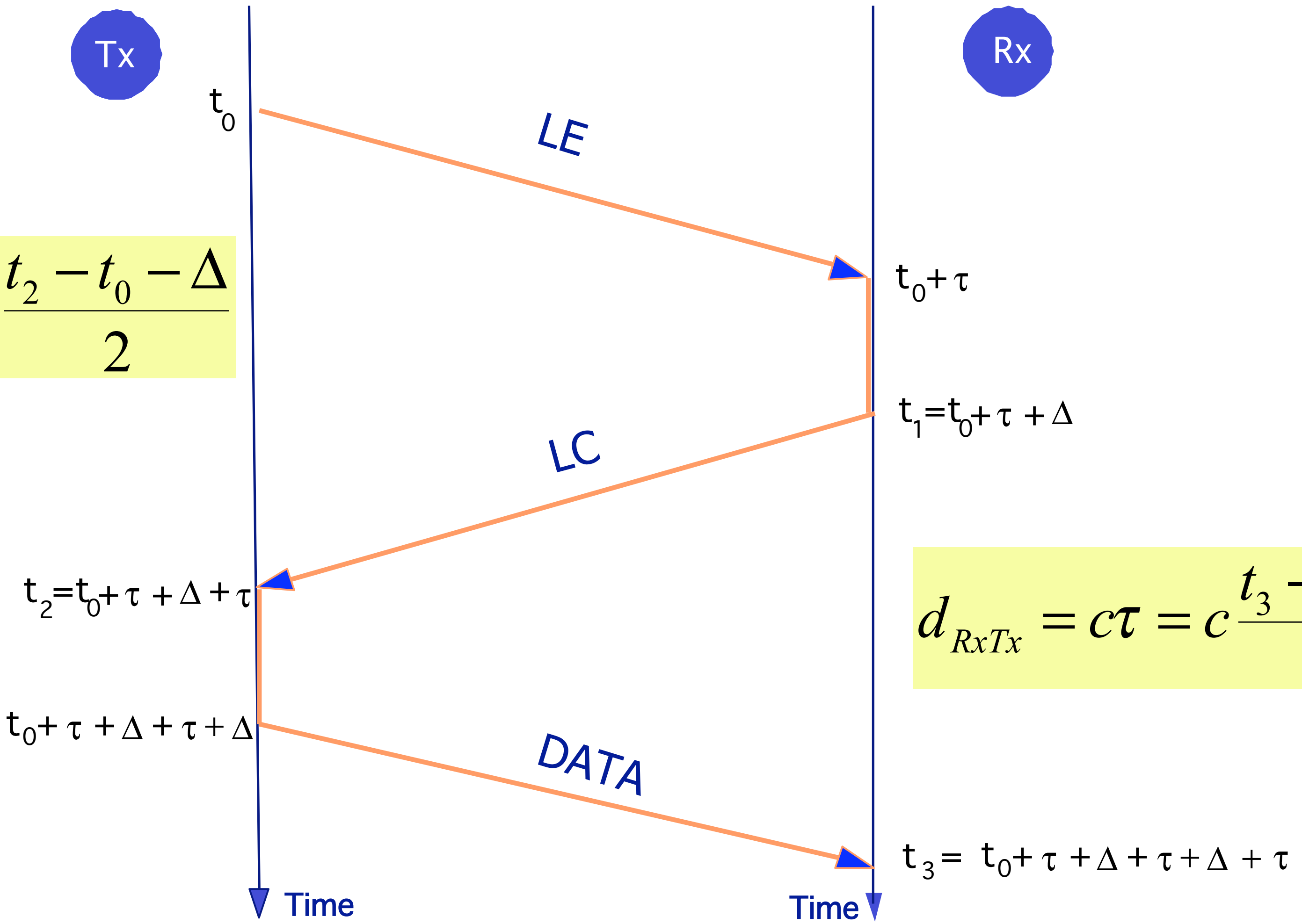
- Is it feasible to design a routing strategy that adapts its path selection criterion to internal and external network conditions?
- What is the impact of such a routing strategy in a power-constrained, interference-prone UWB network, in terms of:
  - Network performance
  - Network lifetime

M.-G. Di Benedetto and L. De Nardis, " Cognitive routing in UWB networks," invited paper, IEEE International Conference on UWB 2006 ICUWB 2006, Boston, Massachusetts, USA, September 24-27, 2006.

UWB ranging: Transmission and Ranging procedure

The LE -> LC -> DATA packet exchange allows both Tx and Rx terminals to determine their distance

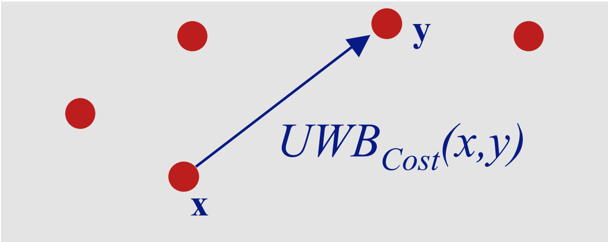
$$d_{TxRx} = c\tau = c\frac{t_2 - t_0 - \Delta}{2}$$



$$d_{RxTx} = c\tau = c\frac{t_3 - t_1 - \Delta}{2}$$

Flexible routing

1. Define a routing metric that determines the cost of a link based on internal and external conditions
2. Select the minimum cost route



The following metric was defined

$$\begin{aligned} UWB_{Cost}(x,y) = {} & c_{Sync}(t)\cdot Sync(x,y) + c_{Power}(t)\cdot Power(x,y) + \\ & + c_{MUI}(t)\cdot MUI(x,y) + c_{Reliability}(t)\cdot Reliability(x,y) + \\ & + c_{Traffic}(t)\cdot Traffic(y) + c_{Delay}(t)\cdot Delay(x,y) + \\ & + c_{Autonomy}(t)\cdot Autonomy(y) + c_{Coexistence}(t)\cdot Coexistence(y) \end{aligned}$$

Flexible routing

Delay term

$$Delay(x,y) = 1$$

Autonomy term

$$Autonomy(y) = 1 - \frac{Residual\ Energy(y)}{Full\ Energy(y)}$$

Coexistence term

$$Coexistence(y) = \frac{Measured\ External\ Interference(y)}{Maximum\ Interference(y)}$$

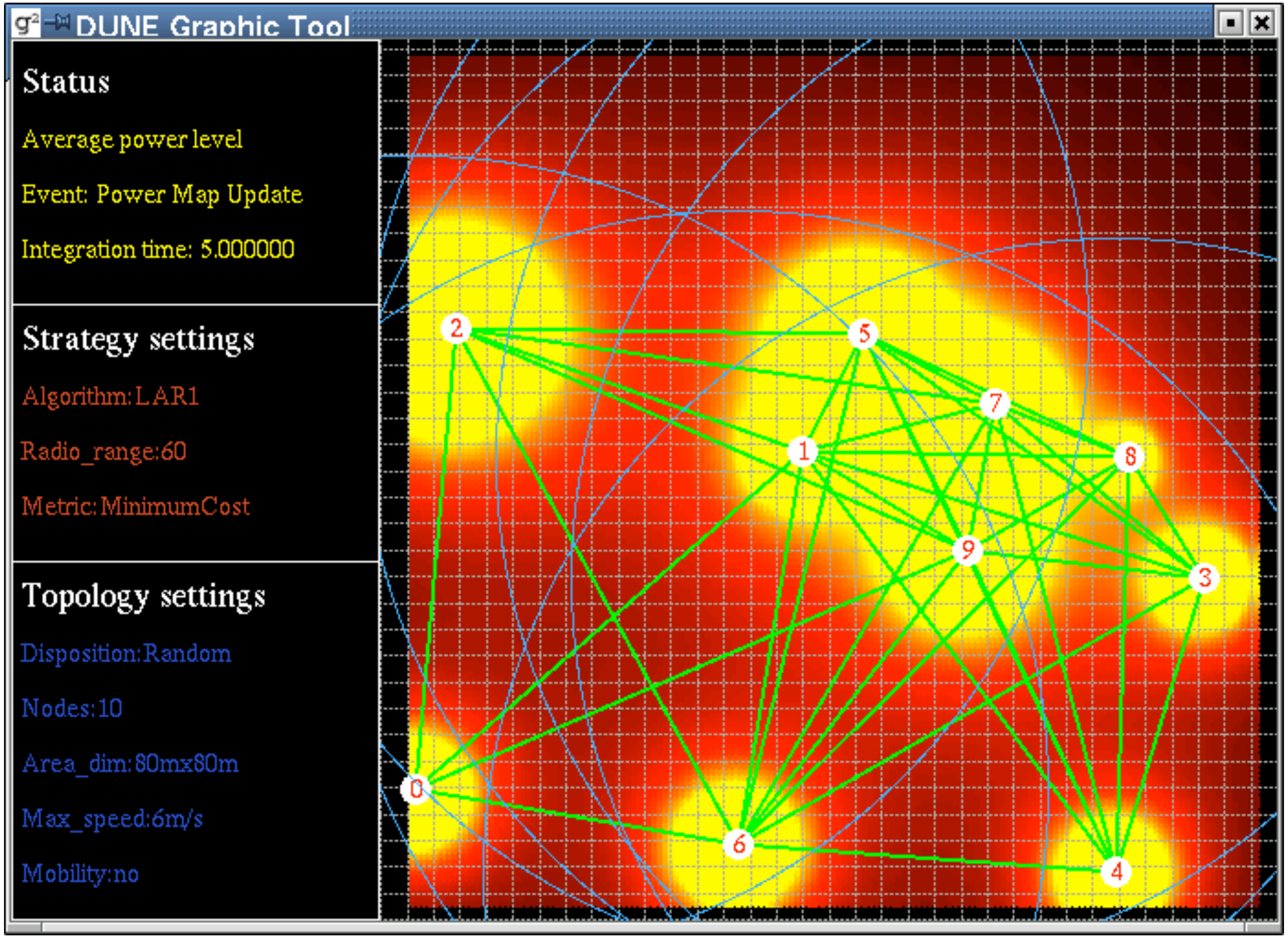
Analysis by simulation

- Three different coefficient sets

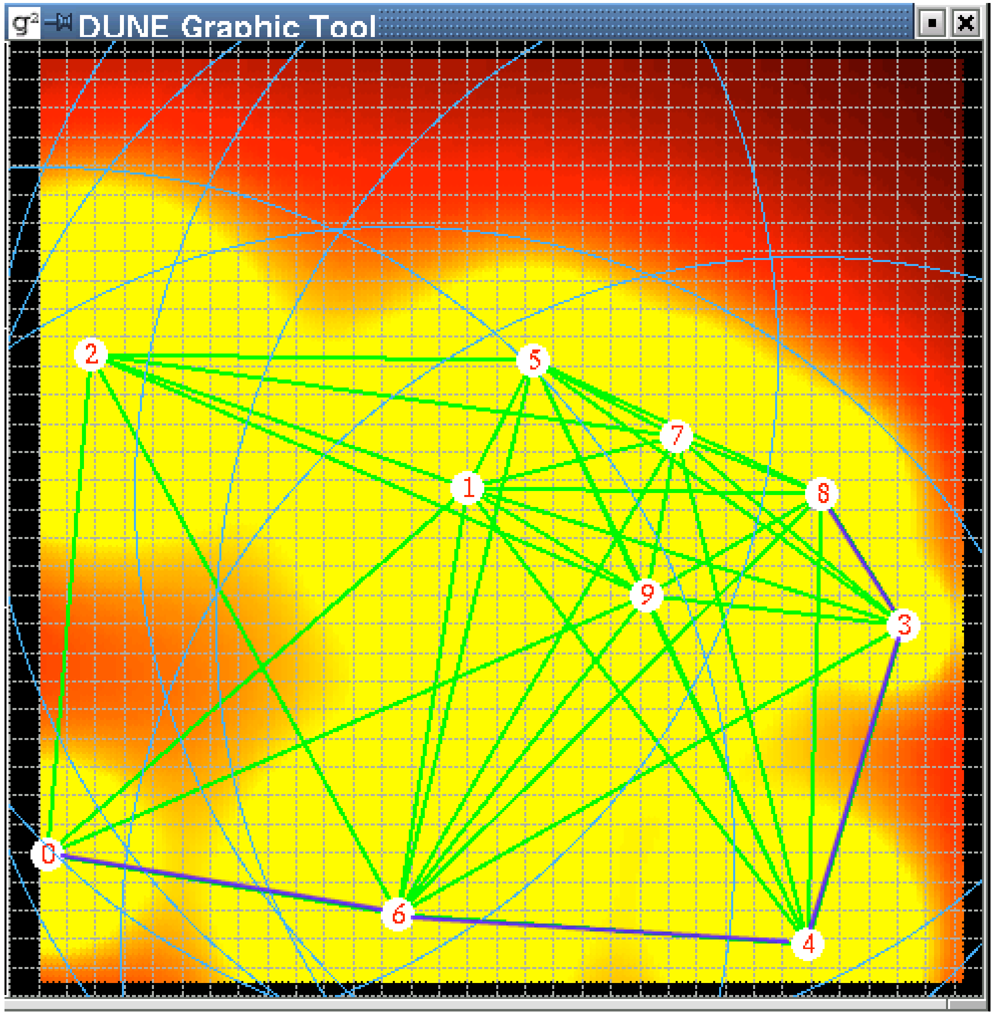
Coefficient	Set 1	Set 2	Set 3
C_{Delay}	1	0.0001	0.0001
$C_{Autonomy}$	0	1	0
$C_{coexistence}$	0	0	1

- Generation of external interferers
  - f_c=3.5 GHz, B=20 MHz, P_t=10 mW
  - Random activity factor *a* in the interval (0,1]
  - Random position
  - Death/birth of interferers every 100 sec

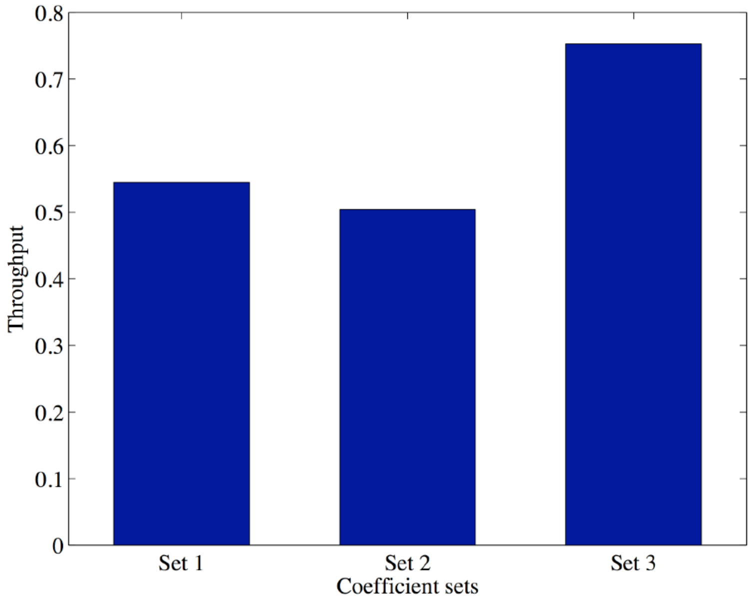
Effect on Power



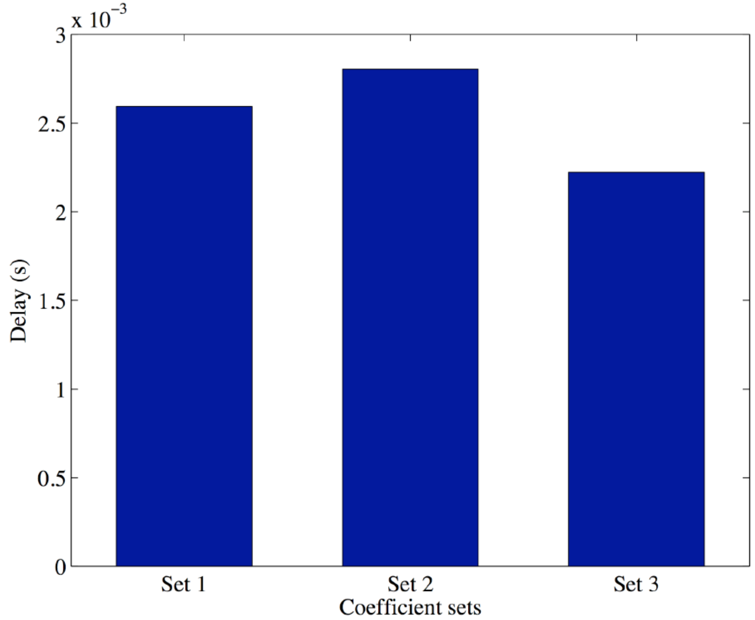
Effect on Multi User Interference



Results



Throughput



End-to-end delay