Performance Analysis of Impulse-Radio UWB Networks impaired by Multiple Access Interference

Mauro Biagi, Cristian Pelizzoni, Nicola Cordeschi, Enzo Baccarelli

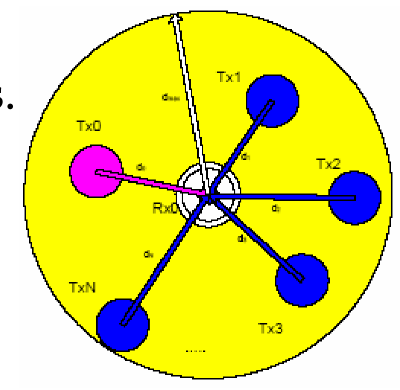
INFO-COM Department - University of Rome “La Sapienza”

{biagi, pelcris, cordeschi, enzobac}@infocom.uniroma1.it

1 – Problem Addressed

✓ The Presence of more than one pair of transmit-receive nodes induces Multi-User Interference.

✓ The system is assumed to be decentralized and asynchronous. The only synchronism is between reference transmitter and reference receiver.



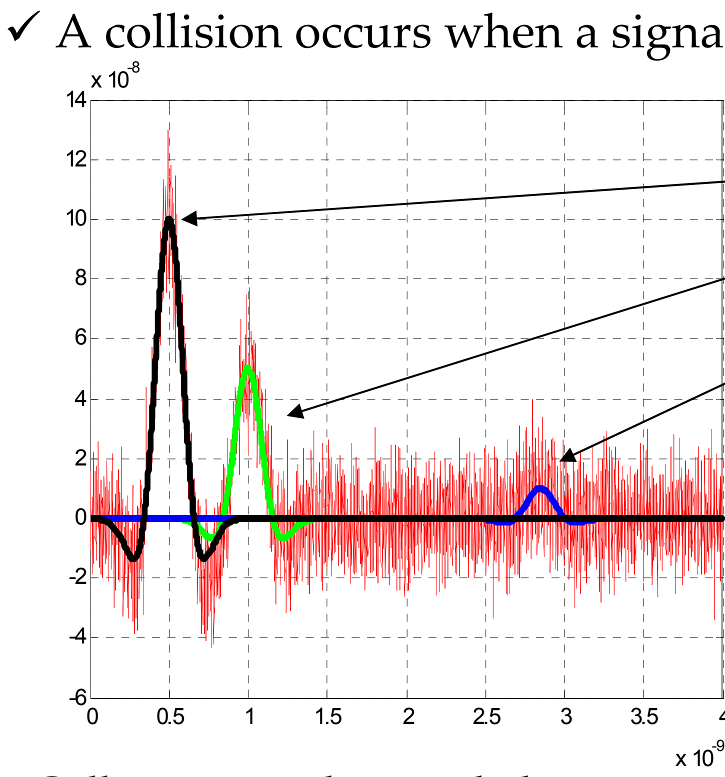
✓ From a Sensor Network point of view the nodes are assumed always on, so the performance evaluation deals with the worst case.

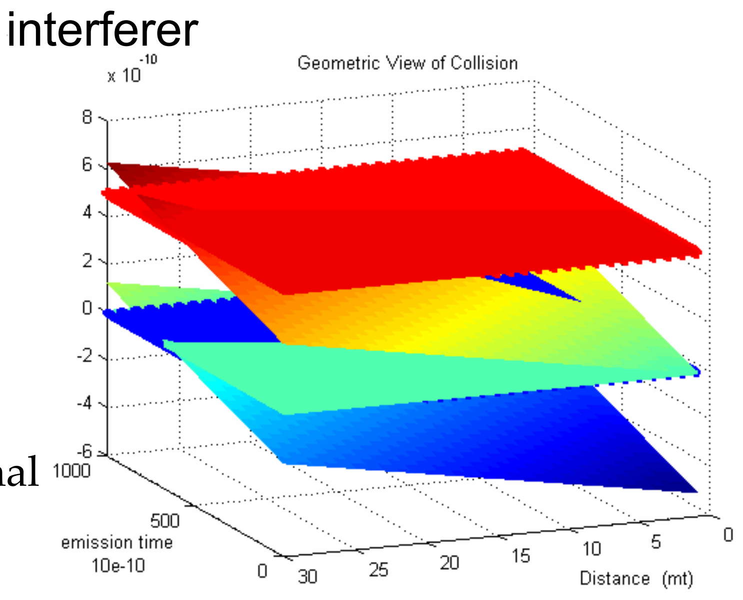
✓ The Collision Probability is evaluated and employed to evaluate the behavior of links by considering different parameters such as the number of nodes, distances, rates, etc.

2 – Collision Probability (1/3)

✓ A collision occurs when a signal form interferer falls in the receive time window

$$-T_s \le -mT_f + T_{ej} + b^{(j)}\Delta \le T_h$$





• Collisions may be avoided, in principle, with Signal Processing and Centralized Controller.

• We can protect information by CODING!

3 – Collision Probability (2/3)

✓ Uniform distribution of users in the network implies uniform propagation delay

$$p(\tau_{pj}) = \begin{cases} \frac{c}{d_{\max}} & 0 \le \tau_{pj} \le \frac{d_{\max}}{c} \\ 0 & otherwise \end{cases}$$

✓ Probability of pulse emission is modeled subject the constraint that a pulse is emitted within a frame interval

$$p(T_{ej}) = \frac{\sum_{m=-M}^{0} rect_{(N+1)T_h}\left(T_{ej} - m\left((N+1)T_h\right)\right)}{(N+1)T_h(M+1)}$$

✓ Pulses are assumed to be equally distributed

$$p(\Delta) = \frac{1}{2}\sum_{\Delta=0}^{1}\delta(\Delta)$$

Collision Probability is given by

$$P_C = 1 - \prod_{j=1}^{N}\left(1 - P_C^{(j)}\right)$$

4 – Collision Probability (3/3)

$$P_C^{(j)} = \int_{-T_s}^{T_h} p(z_j)dz_j$$

$$p(z_j) = \frac{c}{2d_{\max}(N+1)T_h(M+1)}\sum_{m=-M}^{0}\left[S\left(z_j - m(N+1)T_h - \frac{2d_{\max}}{c}\right) + S\left(z_j - m(N+1)T_h - \frac{2d_{\max}}{c} - \Delta\right)\right]$$

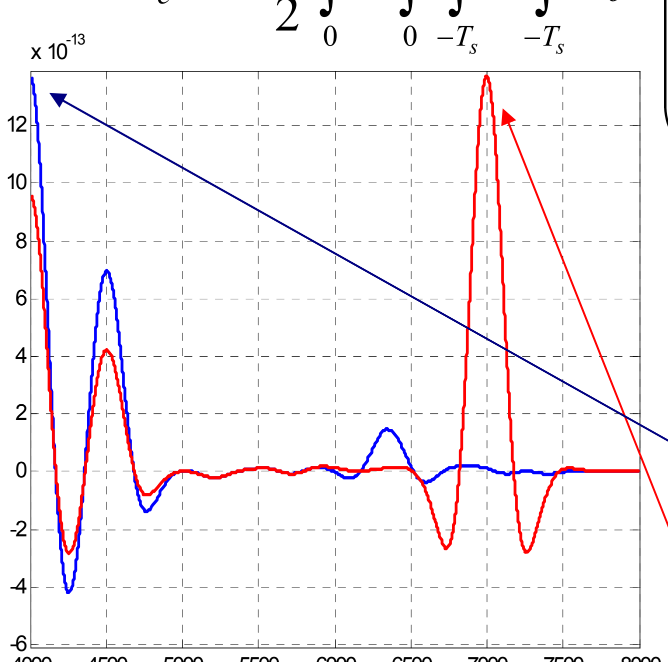
$$S(z_j) = rect_{(N+1)T_h}(z_j) * rect_{\frac{d_{\max}}{c}}(z_j)$$

$$M = \left\lceil \frac{d_{\max}}{c} \bmod (N+1)T_h \right\rceil$$

5 – Performance Evaluation

✓ The average error probability is driven by collisions. $P_E = (1-P_C)P_e + P_C P_e^{(C)}$

$$P_e^{(C)} = \frac{1}{2}\int_0^{+\infty}\cdots\int_0^{+\infty}\int_{-T_s}^{T_h}\cdots\int_{-T_s}^{T_h} erfc\left(\sqrt{\frac{2\left(\varepsilon_0 + \sum_{j=1}^{N}\varepsilon_j r_{ms}(z_j)\right)}{N_0}}\right) p(z_1)\ldots p(z_N)p(\varepsilon_1)\ldots p(\varepsilon_N)$$



Once supposed to transmit 0, we have

(BLU CASE) correct decision,

(RED CASE) wrong decision

We can increase these (and make it positive!) by centralized controller

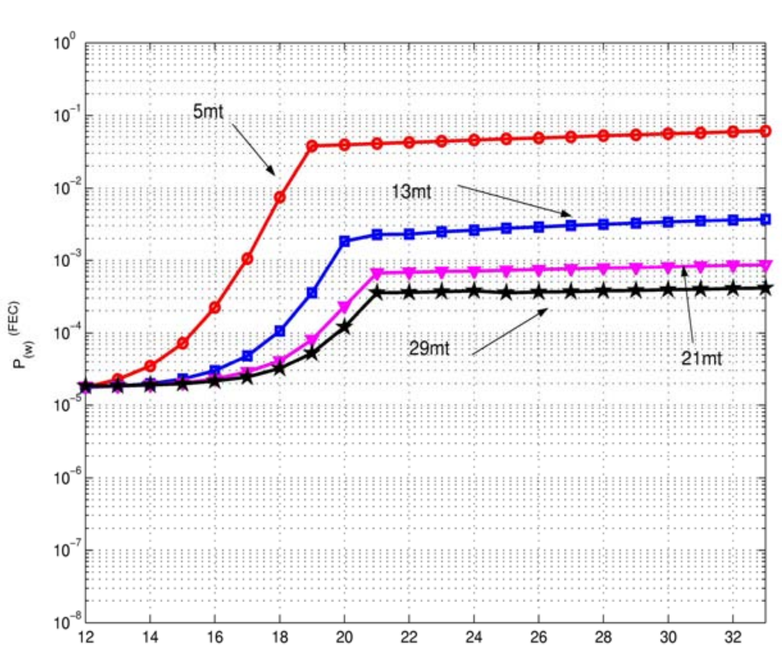
We can increase this by Coding

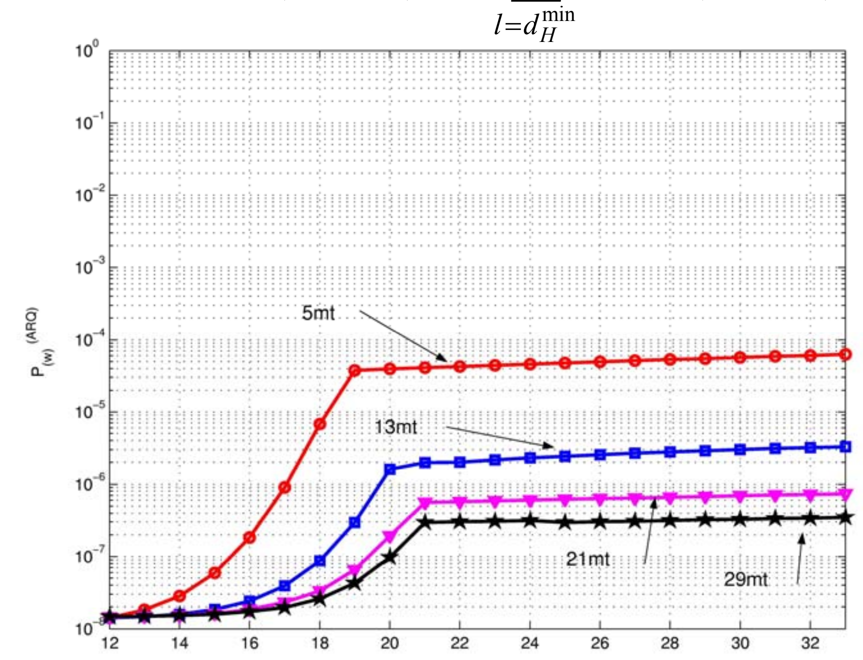
6 – Performance (Error Protection)

✓ The ARQ scheme outperforms the performance of FEC

$$P_w^{(FEC)} = \sum_{l=t+1}^{L}\binom{L}{l}P_E^l(1-P_E)^{L-l}$$

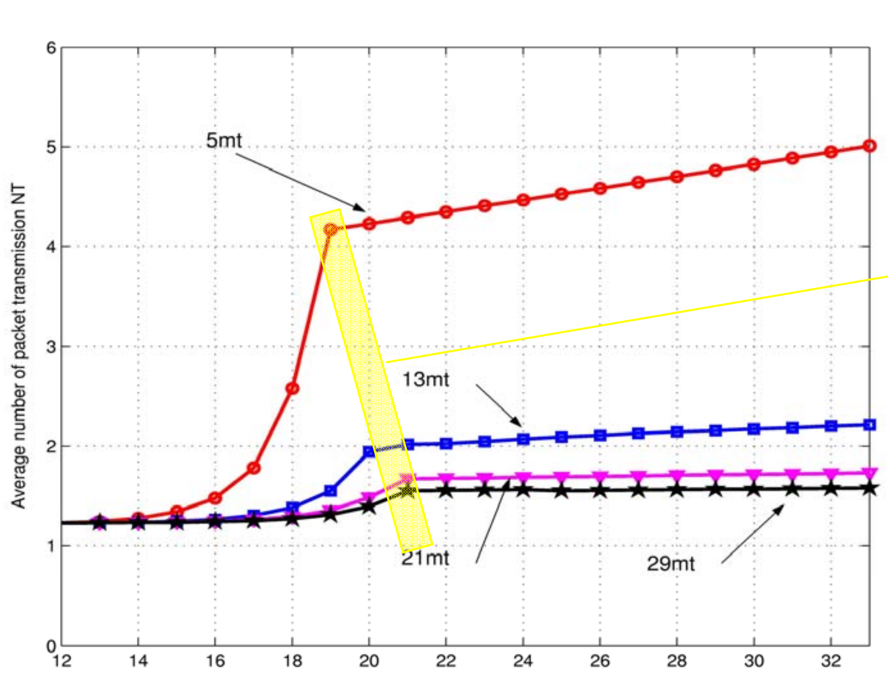
$$P_w^{(ARQ)} = \frac{\sum_{l=d_H^{\min}}^{L} A_l P_E^l (1-P_E)^{L-l}}{(1-P_E)^L + \sum_{l=d_H^{\min}}^{L} A_l P_E^l (1-P_E)^{L-l}}$$





7 – Performance (error protection)

✓ The number of packet retransmission could be very high and this counterbalances the gain achieved by ARQ with respect to FEC



The knee can be justified by considering that the level of interference greater than noise

$$\overline{NT} = \frac{1}{(1-P_E)^L + \sum_{l=d_H^{\min}}^{L} A_l P_E^l (1-P_E)^{L-l}}$$

8 –Performance in sensor nets

Users in the network

Activity percentage

	N=15	N=20	N=25	N=30
10%	1E-8	6E-6	8E-6	9E-6
20%	1.2E-8	8.2E-6	1.1E-5	1.4E-5
30%	1.3E-8	1E-5	2E-5	2.2E-5
40%	1.4E-8	1.42E-5	2.62E-5	2.7E-5
50%	1.5E-8	1.6E-5	2.81E-5	3.1E-5
60%	1.6E-8	1.75E-5	3.27E-5	3.4E-5
70%	1.7E-8	1.9E-5	3.8E-5	4.2E-5
80%	1.8E-8	2.15E-5	4.1E-5	4.7E-5
90%	1.9E-8	2.3E-5	4.3E-5	5.2E-5
100%	2E-8	2.5E-5	4.5E-5	6E-5

5mt

ARQ Scheme

BER

This work was partially supported by the Project PRIMA ALBA