A Comparison Between UWB and DSSS for use in a Multiple Access Secure Wireless Sensor Network*

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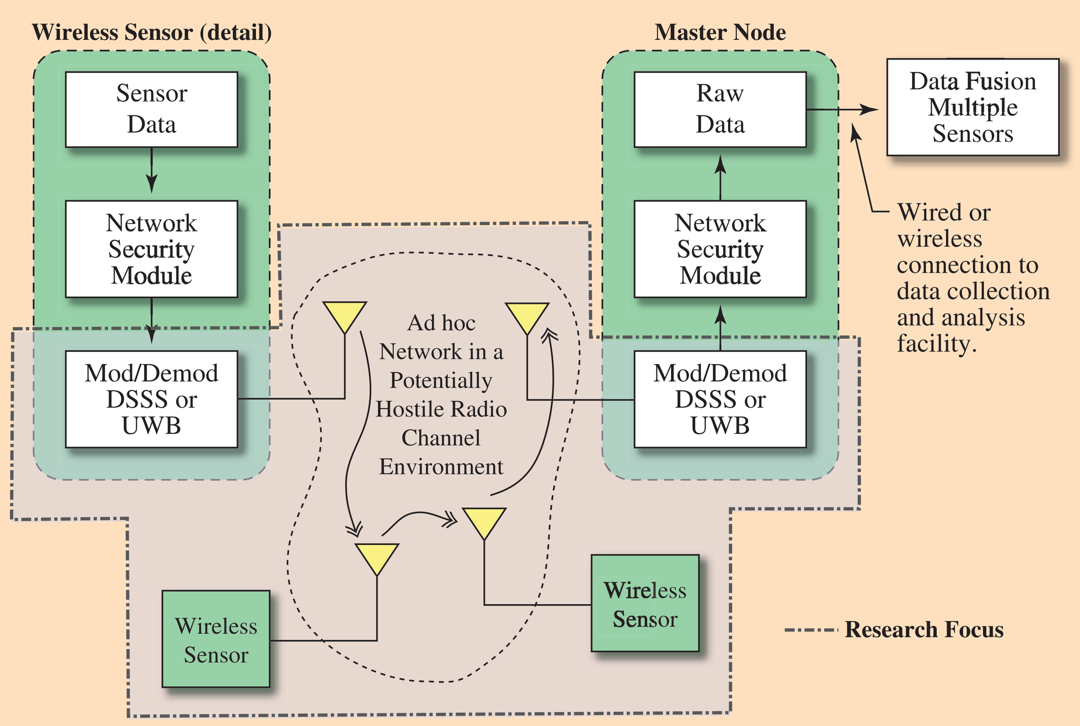
Problem Statement

- Interconnection of an array of sensors used for monitoring purposes for reporting disturbances and intrusions requires several attributes among which are:
  - ① Ease of setup;
  - ② Low energy consumption;
  - ③ Low probability of intercept (LPI);
  - ④ Resistance to jamming, either unintentional or intentional;
  - ⑤ The ability to reconfigure in a timely fashion if one or more nodes become inoperable;
  - ⑥ The accommodation of multiple users;
  - ⑦ Some measure of security.

System Block Diagram



System Performance Model

- Each sensor node broadcasts in an omnidirectional fashion, with an assumed power attenuation law of

$$A(i, j) = \alpha d_{i,j}^{n}$$

  where the indices refer to emitter i and receiver j which are distance apart, with $n = 3.5$ and $\alpha = 10^3$
- The emitted power is 100 mW and AWGN is the only other interference source beyond that due to other emitters
- Each node can act as a bit repeater (demod/remod)
- Bits composing a packet of bits are assumed independent, so the probability of error for a packet, $P_p^{(l)}$, on the lth link is

$$P_p^{(l)} = 1 - (1 - P_b^{(l)})^{n_p}$$

  where n_p is the number of bits in a packet and $P_b^{(l)}$ is the bit error probability of the lth link
- For a chain of L links in a path from source sensor to central node, the probability of error for a packet is given by

$$P_L = 1 - \prod_{l=1}^{L}(1 - P_p^{(l)})$$

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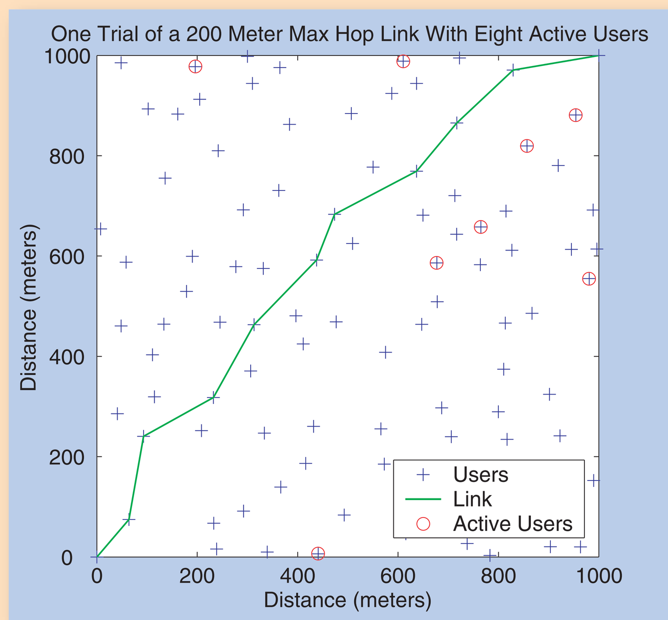
Multiple Access and Signal Modeling

- For DSSS, each information bit is spread by an N-chip spreading code
  - Code multiplication provides a degree of the attributes 3, 4, 6, and 7
  - Bit error probability performance, with multiple access interference (MAI) and WGN, is obtained using a Gaussian approximation
- For UWB-PPM, multiple pulses are used to represent each M-ary symbol
  - Short pulse duration along with time hopping provide a certain degree of attributes 3, 4, 6, and 7
  - Bit error probability performance, with MAI and WGN, is obtained using a Gaussian approximation and the union bound for M-ary symbols
- For certain results, the spectral bandwidths of the two systems are equated
  - For DSSS the null-to-null bandwidth is used making $B_{DSSS} = 2$(Chip Rate)
  - For UWB-PPM, a Gaussian monocycle pulse is assumed, with pulse width constained by the PPM signal design; the corresponding 3 dB bandwidth of the baseband spectrum defines $B_{UWB\text{-}PPM}$

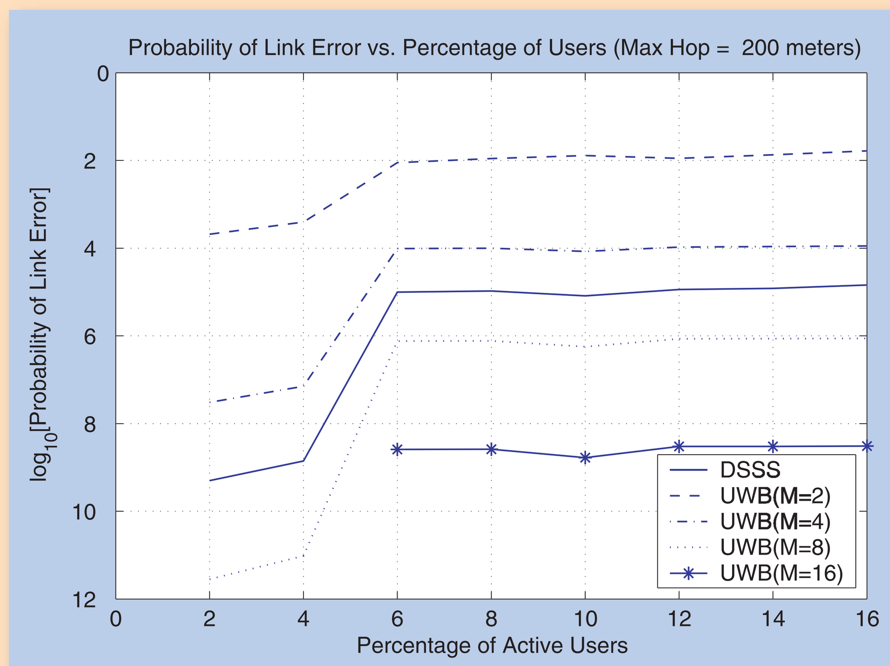
Geometrical Configuration of Sensors

- Randomly scatter 100 sensors over a 1000 m^2 field
- The paths are constrained with a maximum hop distance of either 200, 250, 300, 350, or 400 m
- Interfering sensors are randomly selected from the entire field of nodes
- For a given maximum hop distance and number of active interferers, 50 trials are run with the sensor locations and link path fixed but the interferers randomly reselected
- Below is a typical scenario for 8 active users and a 200 m maximum hop



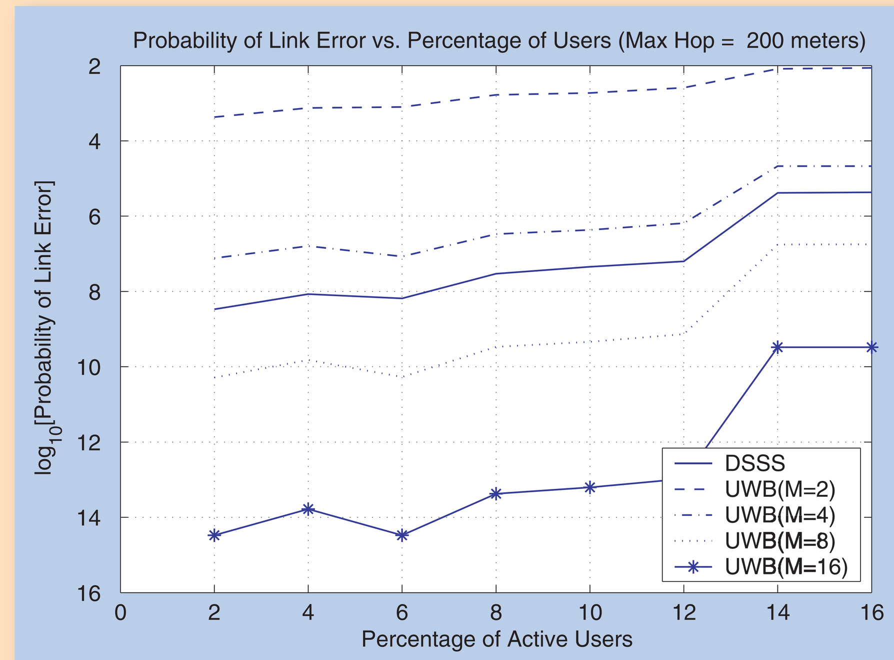
Performance – Equal Bandwidth High Data Rate

- Equal bandwidths and high data rate: Bandwidth = 1 GHz, Bit rate = 1 Mbps, Code length UWB = 127, Code length DSSS = 511, $\tau_n = 0.64$ ns (UWB), T_{Frame} ranged from 900 to 996 ns (UWB)



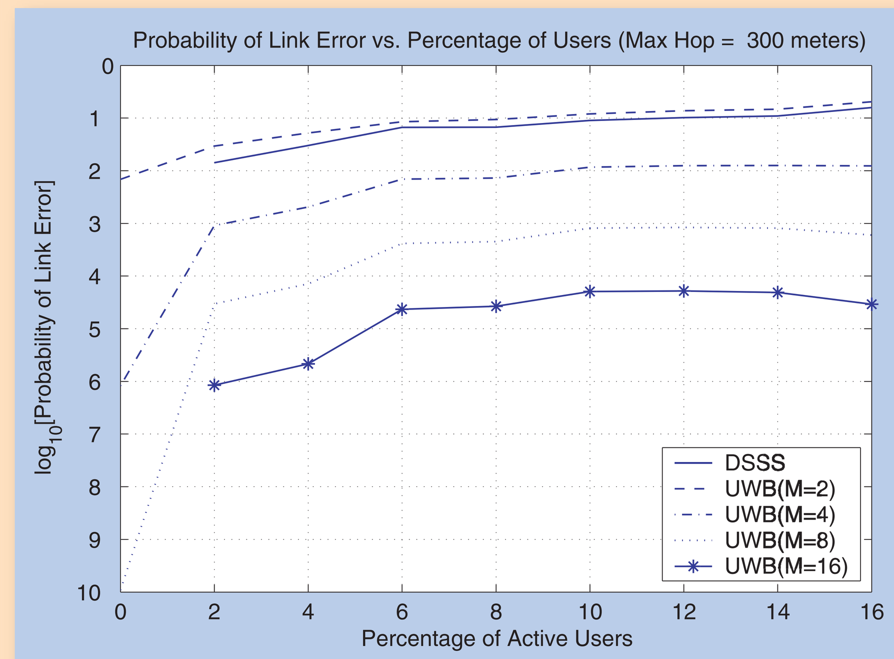
Performance – Equal Bandwidth Low Data Rate

- Bandwidth = 100 MHz, Bit rate = 100 kbps, Code length UWB = 127, Code length DSSS = 511, $\tau_n = 6.43$ ns (UWB), T_{Frame} ranged from 9.03 to 10.0 µs (UWB)



Performance – Equal code length and data rate, unequal bandwidths

- Bandwidth UWB = 3.7 GHz, Bandwidth DSSS = 1 GHz, Code Length = 511, $\tau_n = 0.175$ ns (UWB), T_{Frame} ranged from 972 to 998 ns (UWB)



Conclusions

- For UWB to give a performance competitive with DSSS on an equal bandwidth basis, it is necessary to go to higher modulation orders than binary
- Thus, one must give up part of the competitive advantage of UWB, namely simplicity, to obtain performance comparable to DSSS
- On the basis of performance in Gaussian noise and the presence of other users, then, it appears that DSSS is the better choice
- How implementation factors, such as ease of synchronization or design of final power amplifiers, influence the choice of DSSS over UWB remains to be investigated
- Another consideration is that of bandwidth occupancy
  - The type of UWB considered in this study basically uses a spectral occupancy from zero to some large frequency, whereas the FCC regulation for UWB requires bandpass occupancy
  - This is a further factor influencing the choice between DSSS and UWB

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