Distributed Diversity in Sensor Networks

Simon Yiu, Robert Schober, and Lutz Lampe
Email: \{simony, rschober, lampe\}@ece.ubc.ca

Communication Theory Group
Department of Electrical and Computer Engineering
University of British Columbia
Vancouver, Canada
Agenda

• Sensor Networks
  ◦ Applications
  ◦ Characteristics and Challenges

• Distributed Diversity
  ◦ Multihop Transmission
  ◦ Straightforward Approach
  ◦ Our Approach: Distributed STBCs (DSTBCs)

• Conclusions
Sensor Networks: Applications

- Environment monitoring
  - Air, Sea, and ground

- Machinery monitoring and vehicle tracking

- Battlefield, surveillance and security

- Chemical, biological, and nuclear weapon detection

- Human and animal bio monitoring
Sensor Networks: Characteristics and Challenges

- **Characteristics**
  - Tiny, low-cost, and low-power
  - Densely deployed
  - Self maintenance

- **Challenges**
  - Long distance transmission is not possible due to energy constraint
  - Multiple antennas cannot be employed due to size constraint → traditional MIMO techniques cannot be employed to improve the BER performance
  - No coordination among the nodes due to *ad hoc* nature
Solution: Multihop Transmission
Solution: Multihop Transmission

- The other nodes in the network help forwarding the source information to the destination
Solution: Multihop Transmission

• The other nodes in the network help forwarding the source information to the destination
Solution: Multihop Transmission

Phase 2
$N = 15$
$N_S = 4$

- The other nodes in the network help forwarding the source information to the destination
- The cooperating nodes form a virtual antenna array
Space–Time Block Code for Co–located Antennas

- Co–located antenna array with four co–located antennas
- Each antenna transmits a column of the STBC matrix $B$

\[ b_n = n^{th} \text{ column of the STBC matrix } B \]
Space–Time Block Code: Diversity Gain

\[ \text{BER} = 10 \log_{10}(E_b/N_0) \quad [\text{dB}] \]

- Green line: 1 x 1
- Blue line: 4 x 1
Sensor Networks: Distributed Diversity

- Straightforward Approach

Phase 1

\[ N = 4 \]

\[ b_n = n^{th} \text{ column of the STBC matrix } B \]
Sensor Networks: Distributed Diversity

- Straightforward Approach

Phase 2

\[ N = 4 \]
\[ N_S = 2 \]

\[ b_n = n^{th} \text{ column of the STBC matrix } B \]

Distributed Diversity in Sensor Networks – p.8/13
• BER performance of a network with 4 relay nodes and different numbers of cooperating nodes $N_S$. 
Sensor Networks: Distributed Diversity

• Limitations of straightforward approach:
  ◦ Full-rate orthogonal STBCs are only available for relatively small dimension
  ◦ It does not work for networks with a large number of nodes

• Our Approach: Distributed STBCs (DSTBCs)
  ◦ Assign a pre-designed signature vector $g_n$, $1 \leq n \leq N$, to each relay node in the network
  ◦ Each active node transmits a linear combination of the STBC matrix: $B g_n$
  ◦ There is no limitation to the total number of relays in the network
Sensor Networks: Distributed Diversity

- Our Approach

Phase 1
\[ N = 15 \]

\[ B: \text{STBC matrix} \]
\[ g_n: \text{signature vector of node } n \]
Sensor Networks: Distributed Diversity

- Our Approach

Phase 2
\[ N = 15 \]
\[ N_S = 6 \]

\[ B \]: STBC matrix
\[ g_n \]: signature vector of node \( n \)
Our Approach (DSTBCs): Results

- BER performance of a network with 50 relay nodes and different numbers of cooperating nodes $N_S$. 
Conclusions

- New distributed space–time block codes (DSTBCs) achieve a large performance gain over the $1 \times 1$ system
- Work for large network and enable uncoordinated and long distance transmission
- Future works
  - Synchronization
  - Frequency–selective channels
- Publications

*http://www.ece.ubc.ca/~simony/publications.htm*