Problem Statement

- Technology advances enable pervasive use of sensor networks in a variety of defense and commercial applications
- Sensor nodes are battery powered and recharging is usually unavailable, so energy is an extremely expensive resource
- Design of algorithms for processing information in sensor networks is an emerging research area
- 1-d distributed FFT can be realized with sensor networks through butterfly communication structure
- Redundant calculations in 1-d distributed FFT can be eliminated via data shuffling in a balanced way

Unbalanced Redundancy-Free Power-Aware FFT

- \((N \log_2 N)/2\) complex multiplications
- \(N \log_2 N\) additions/subtractions
- \(N \log_2 N\) transmissions
- Some sensors will drain their energy much faster than others
  \(\Rightarrow\) decreased sensor network lifetime

Conventional Distributed FFT

- \(N\) point-FFT
- 1 input point per sensor
- 1 output point per sensor
- \(N \log_2 N\) complex multiplications (twice the number of multiplications in a serial algorithm)
- \(N \log_2 N\) additions/subtractions
- \(N \log_2 N\) transmissions
- Colored nodes represent the nodes computing complex multiplications

Balanced Power-Time Efficient FFT

- Has 2-Unbalanced Main Stages
- Sensor Data values are shuffled at the end of stage \((\log_2 N)/2\)
- \((N \log_2 N)/2\) complex multiplications
- \(N+N \log_2 N\) transmissions
- \(N \log_2 N\) additions/subtractions
- Shuffle Formula:
  - Every Sensor \((b_3b_2b_1b_0)\) sends its data to Sensor \((b'_0b'_1b'_2b'_3)\)
  - Correctness:
    - \((b'_0b'_1b'_2b'_3)\) sends its data to \(((b'_3)'(b'_2)'(b'_1)'(b'_0)') = (b_3b_2b_1b_0)\)
    - If they are not same, \((b_3b_2b_1b_0)\) and \((b'_0b'_1b'_2b'_3)\) exchanges their data.

Figure 1

- Figure 2

Figure 3

Regarding the diagrams:
- Computations Time vs Total Delay
- Total energy vs Number of Sensors
- Network Lifetime vs Number of FFTs