Clustering Protocols for Energy Efficiency in Wireless Sensor Networks

Comp 7251

Andrew Kefalas

Mahesh Bakshi

Overview

- Introduction to WSN’s and clustering
- Single hop Algorithms
  - LEACH
  - EECS
- Multi Hop Algorithms
  - EEUC
  - EEDUC
- Implementation Results

WSN: Energy efficiency

- One of the main challenges associated with wireless sensor networks is energy efficiency because of the inconvenience or impossibility or recharging and replacing nodes.
- Many algorithms and protocols have been proposed for energy efficiency but it has been found that cluster based algorithms have better energy utilization as compared with non-cluster algorithms [2].

Clustering

- In clustering, a group of nodes create a cluster with a cluster head. Normal nodes send their data to the CH who then performs some aggregation and sends it to the base station.
- Advantage is normal nodes just communicate directly to their cluster head, reducing the energy used. The disadvantage is that cluster heads use up more energy and will die faster.
- So we alternate the job of being cluster head around all nodes to prolong the overall system lifetime.
- The cycle of choosing a cluster head, creating a cluster and sending data to the BS is called a round.

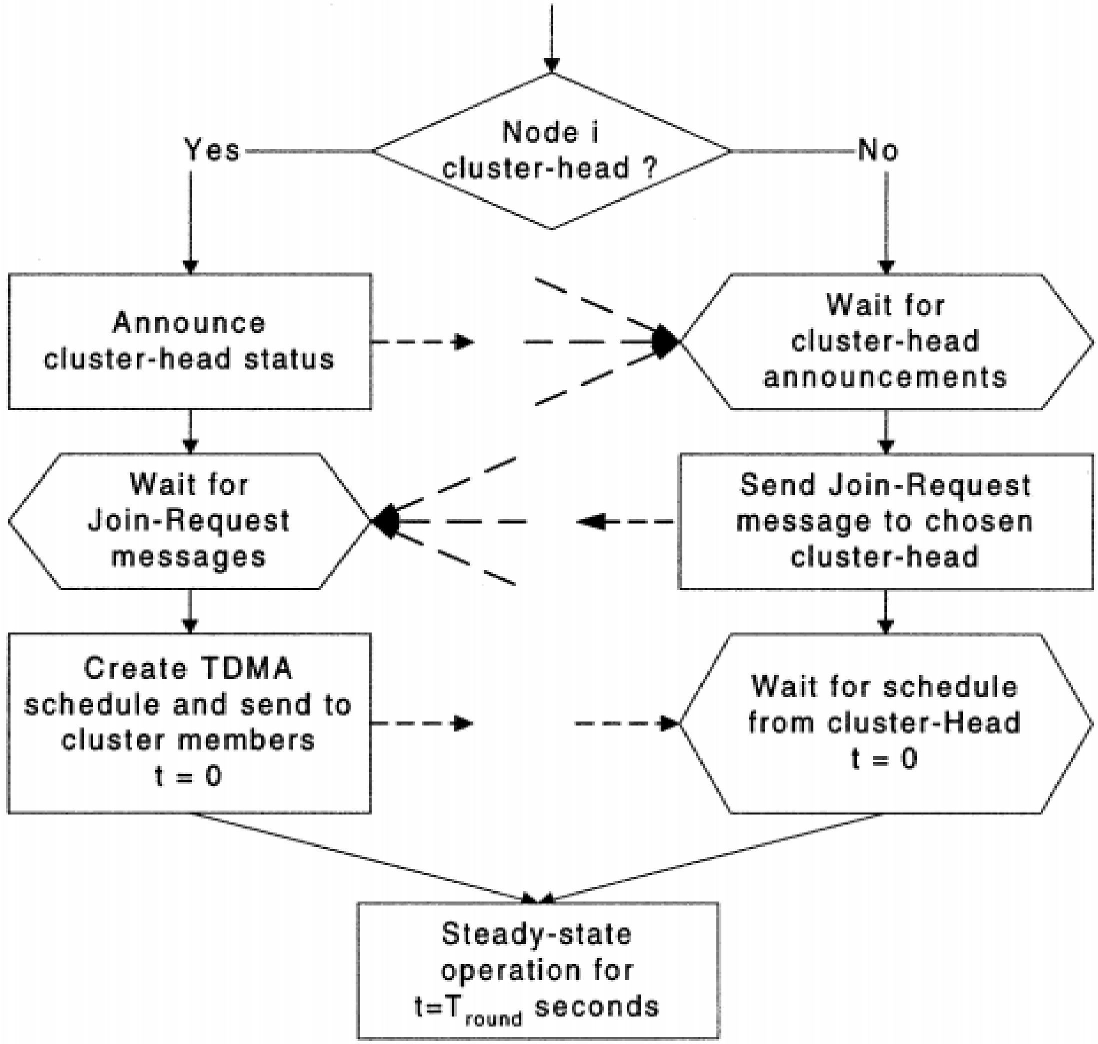
Single-Hop Algorithms

- We make a very important assumption; that all nodes can reach the Base Station.
- Also nodes are static after being placed and cannot be moved.
- Each node can calculate distance to base station based on initial hello message from Base Station.

Low-Energy Adaptive Clustering Hierarchy

- Algorithm starts with random election; node computes a certain probability p and becomes a CH if p is < some threshold. Will never be CH twice in a row. Can incorporate energy into p.
- Once cluster heads are selected, they broadcast their ADV_CH message and nodes choose the CH that requires the least amount of energy to send to and send join-request message to CH.
- CH’s then organize a TDMA schedule within in the cluster to be able to sleep. Uses spreading codes and CSMA when sending to BS.

LEACH Cluster Formation



Energy Efficient Clustering Scheme

- Every node becomes a ‘candidate’ node based on some probability p. Also every node has the same competition radius Roptimal.
- Then each candidate node broadcasts a ‘compete_head_message’ to compete with other candidates in its Roptimal. If there is another node within range that has more energy, then give up being a cluster head. If there is no node, then at the end of the phase, become CH.

EECS

- Nodes choose the CH to join with the minimum cost based on a weighted function that takes into account; the energy that needs to be consumed at the CH for receiving, aggregating, and sending data to the base station and the distance of the CH from the base station.
- This function balances the workload at the CH, especially those further away from the base station because it considers how much work the cluster head will have to do based on the number of nodes in the cluster and the distance the data has to travel.
- Claims to have a 35% increase in time until first node death over LEACH.

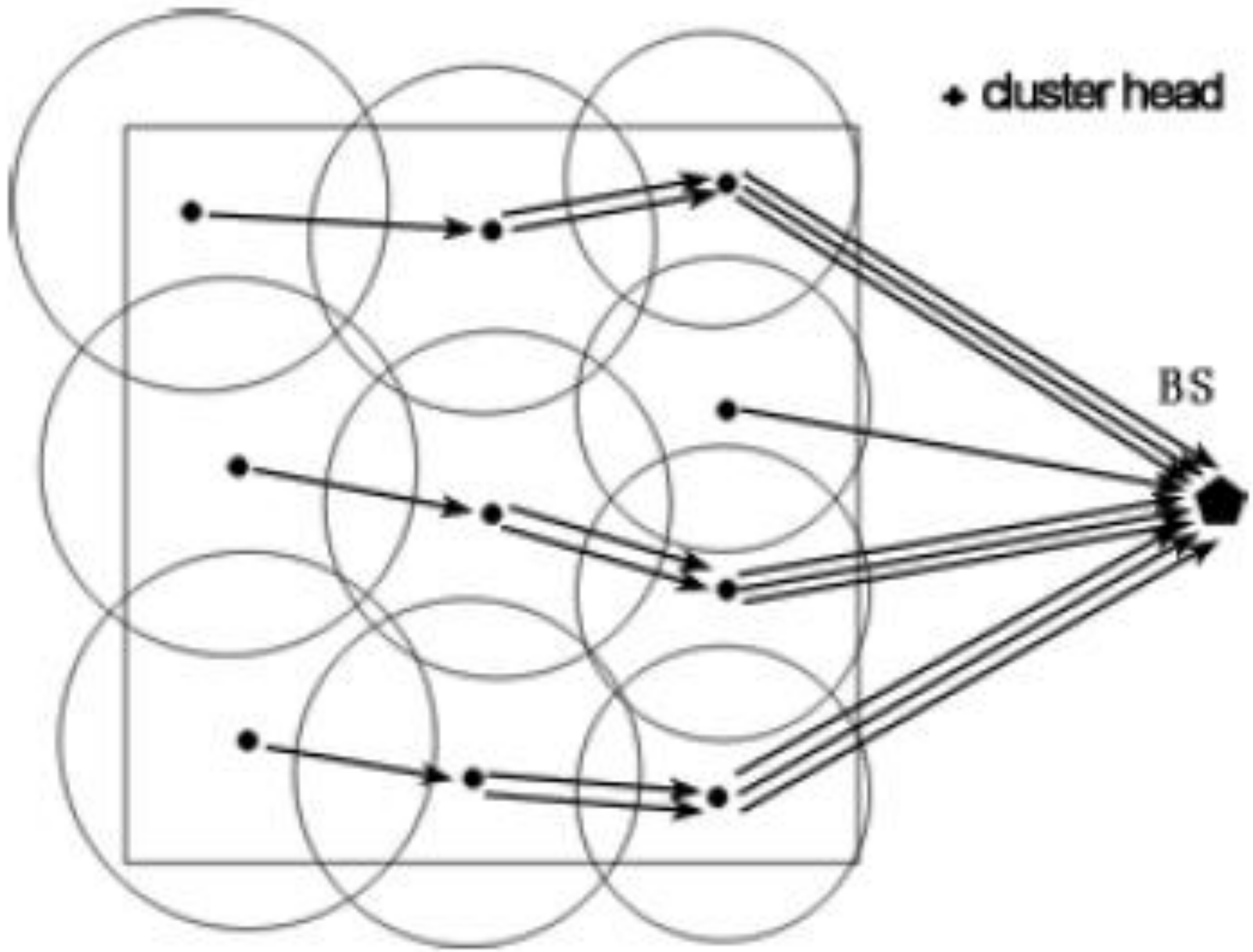
Multi-Hop Algorithms

- The previous algorithms had the assumption that each node can reach the base station. In multi-hop algorithms this is not the case and is a much more realistic scenario.
- In multi-hop algorithms cluster heads must relay their data to other cluster heads until it eventually reaches the base station.
- Multi-hop routing raises a problem that the nodes closest to the base station will be under heavy traffic and thus die early, known as the hot spot problem [6].

Energy Efficient Unequal Clustering

- Cluster Heads are electing in similar fashion to EECS. Each node becomes a ‘tentative’ cluster head based on some probability and competes in its radius.
- The main different EEUC introduces to solve the hot spot problem is that each tentative node will have a competition range based on its distance from the base station. So the closer to the base station the node is, the smaller its competition range will be.
- The advantage of this is to reduce the energy used in intra cluster data exchange in those heavy traffic heads and keep more energy for relaying the data received by other cluster heads [8].

EEUC Diagram



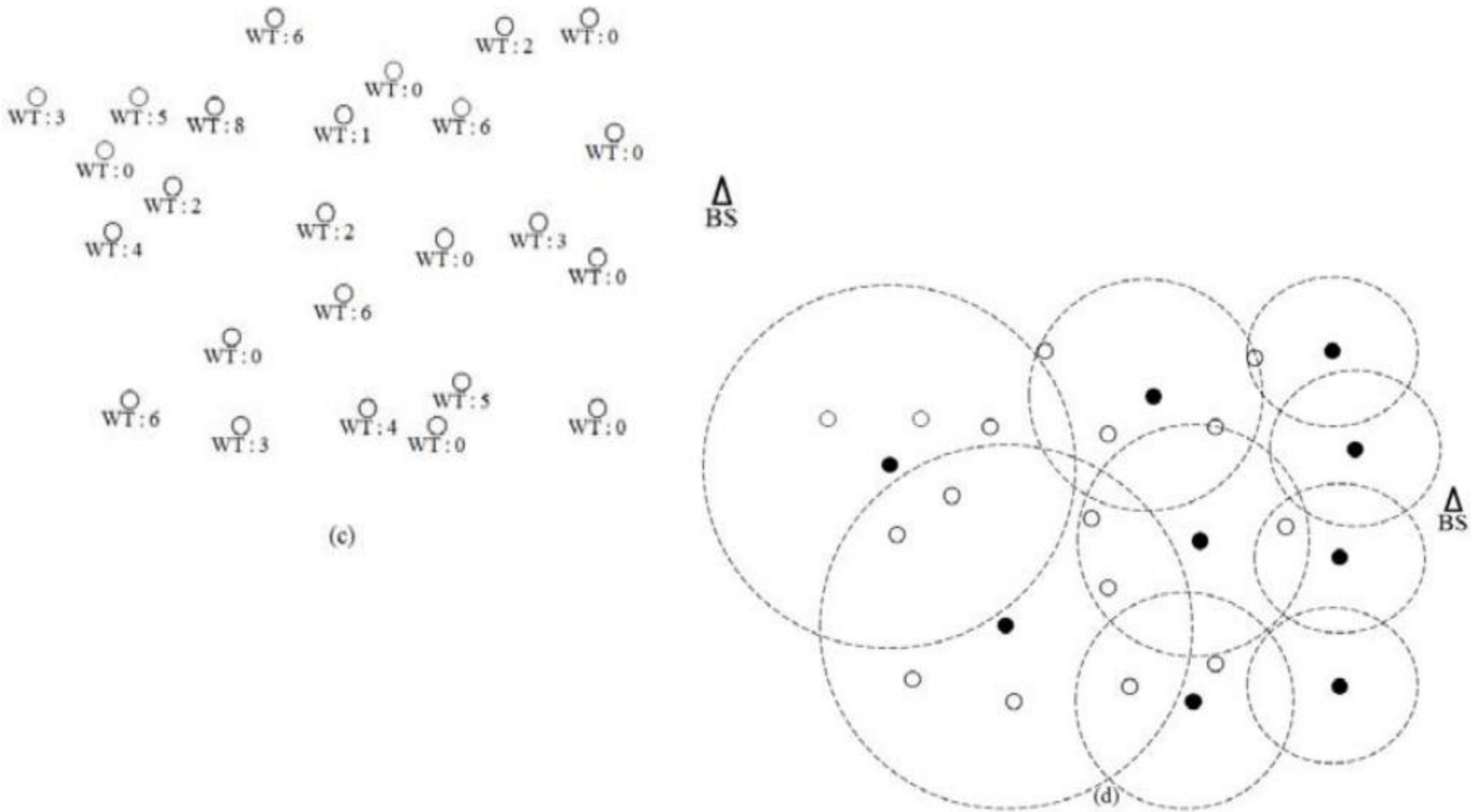
EEUC Multi Hop

- The last part of the algorithm is to decide when and which node to relay data to in the case that you need multiple hops to reach the BS.
- So if the CH is within a certain distance to the BS, it cant send directly to the BS as in single hop.
- If the node is further than this distance, it must choose another CH to relay its data to.
- Each CH takes into consideration its adjacent CH nodes and chooses the one to relay based on the adjacent CH's residual energy and distance cost to the base station. It chooses the node which minimizes distance cost and maximizes residual energy.
- Improves time of first node dead and overall time.

Energy Efficient Distributed Unequal Cluster Protocol

- EEDUC is another multihop protocol that uses unequal size clusters to solve the hot spot problem but presents a different way to select cluster heads.
- EEDUC adds steps to the initialization phase; each node counts the number of nodes within 1 hop range, the base station sends out a time unit and max amount of sensors in the network. Nodes then calculate a ‘waiting time’ based on these three values.
- Then every node decrements its waiting time based on a synchronized node timer. When a node’s waiting time becomes 0, it sends out a message within a competition range and the node with the most energy within its range will become a CH.

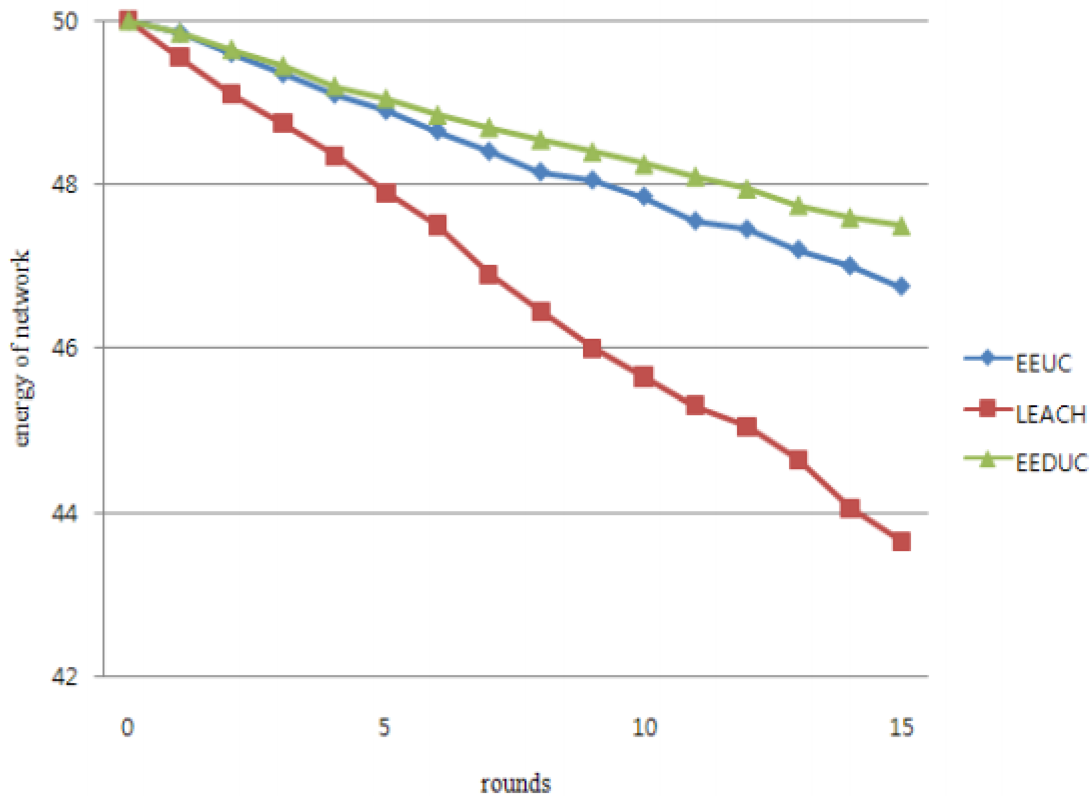
EEDUC Waiting time



EEDUC

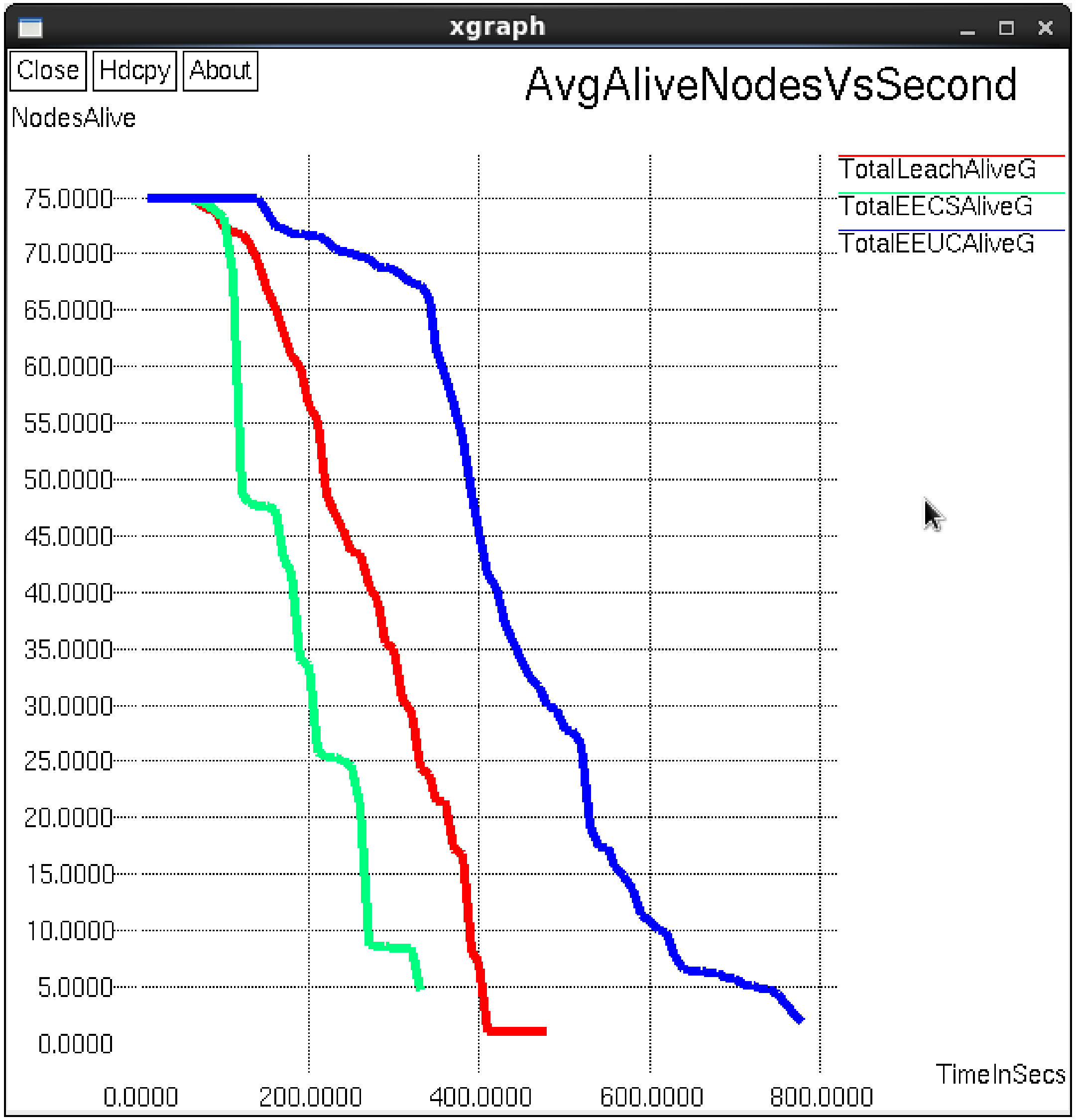
- EEDUC implements the same algorithm to have a smaller competition range close to the BS.
- It also chooses the relay nodes in similar fashion as EEUC except it chooses from its 1 hop neighbours, which was calculated in initialization phase.
- The waiting time function is how EEDUC allows the election of cluster heads to be distributed across the system. Since the waiting time is based on residual energy and neighbouring nodes, a node that has low energy and many neighbours will have a high waiting time and thus is not likely to become the cluster head in that round.
- In EEDUC, the performance of energy consumption is improved 24.2% compared to EEUC[8].

EEDUC Simulation Results



Simulation Results

- Ideal scenario according to papers is on the right.
- LEACH first node should die first and overall should die second.
- EECS first node should die second and overall should die first.
- EEUC should be better in both cases.
- We can achieve this by manipulating threshold.



Comparison of Results

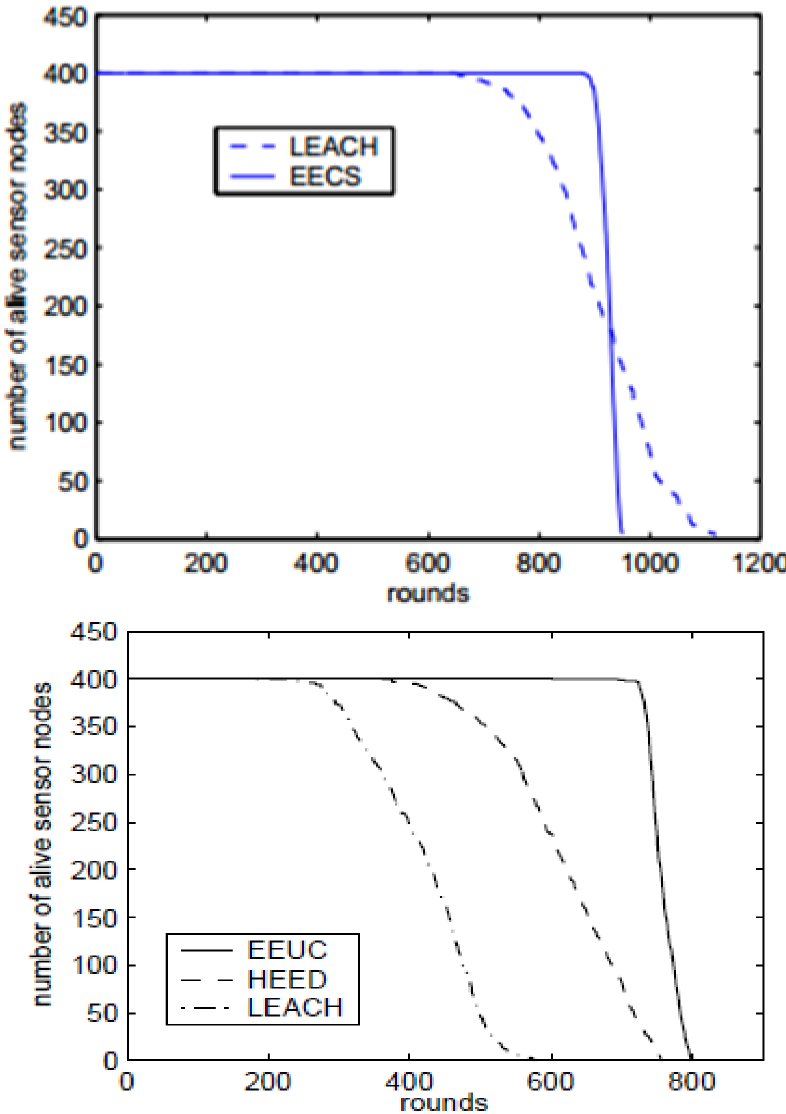
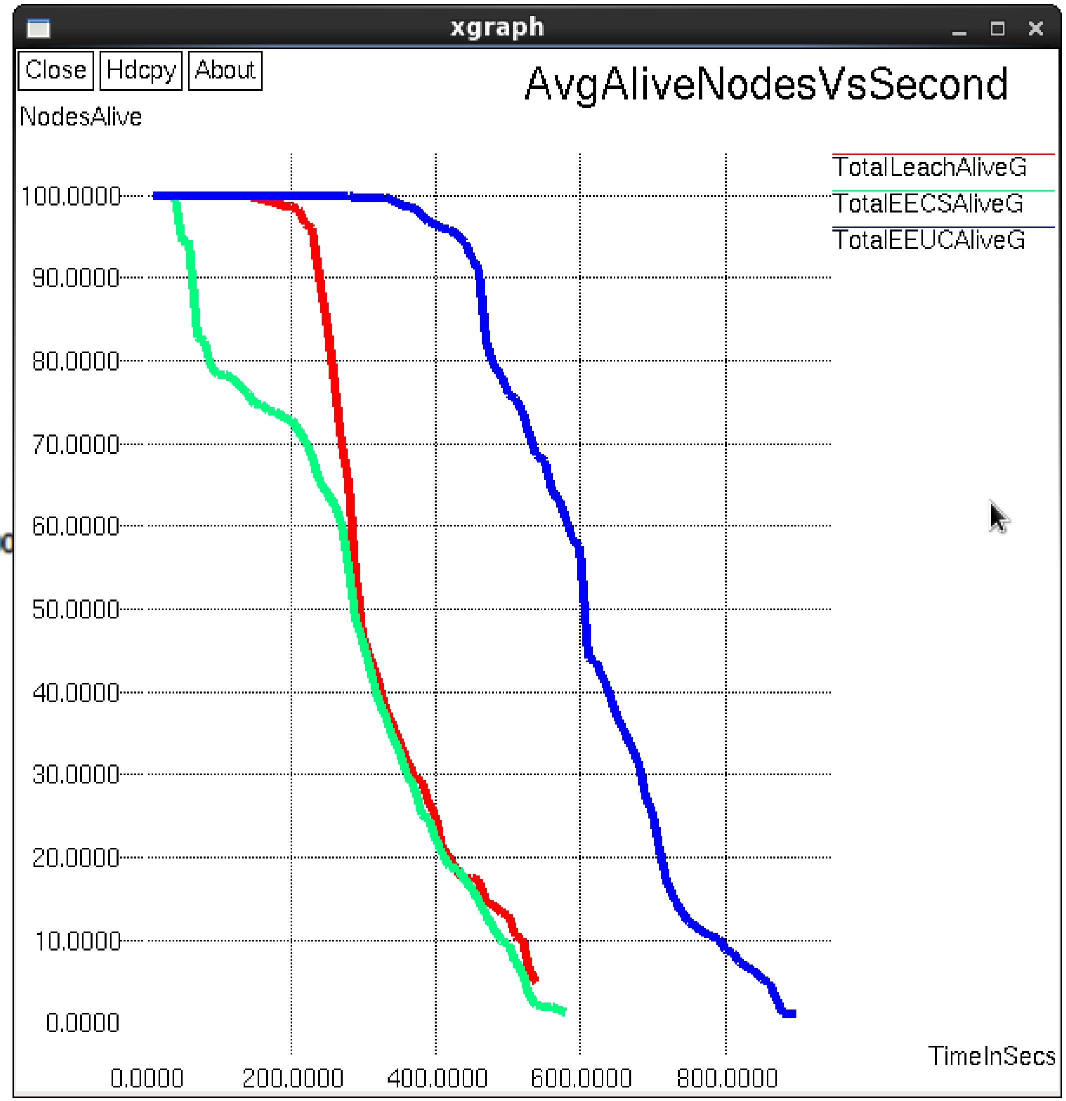
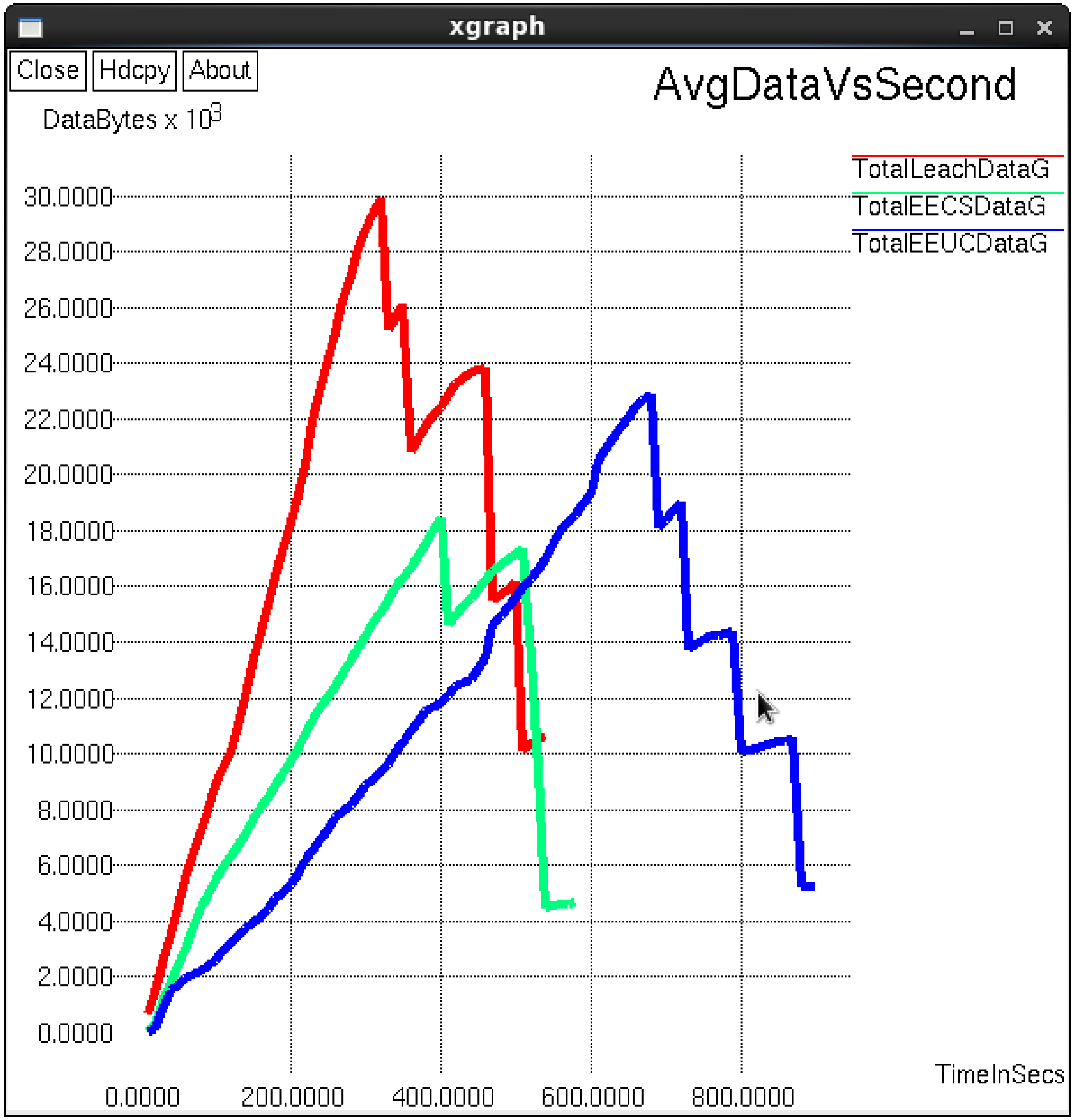


Fig. 11. The number of alive sensor nodes over time



Data Sent

- Only LEACH talks about how much data is sent however, the other algorithms do not.
- According to our results, the amount of data sent at any one point is less in non-LEACH algorithms.



References

- [1] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “An Application-Specific Protocol Architecture for Wireless Microsensor Networks,” *IEEE Transactions on Wireless Communications*, vol. 1, no. 4, pp. 660–670, October 2002.
- [2] Y. Li, N. Yu, W. Zhang, W. Zhao, X. You, M. Daneshmand, “Enhancing the Performance of LEACH Protocol in Wireless Sensor Networks”, *In Proceeding of “M2MCN-2011”,* pp. 223-228, 2011.
- [5] M. Ye, C. F. Li, G. H. Chen, and J. Wu, “EECS: An Energy Efficient Clustering Scheme in Wireless Sensor Networks”, in *Proceedings of IEEE Int’l Performance Computing and Communications Conference (IPCCC)*, pp. 535-540, 2005.
- [6] C. F. Li, M. Ye, G. Chen and J. Wu, “An energy-efficient unequal clustering mechanism for wireless sensor networks,” *in Proc. of the 2nd IEEE International Conference on Mobile Adhoc and Sensor Systems (MASS), Washington, DC*, Nov. 2005.
- [8] S. Lee, J. Lee, H. Sin, S. Yoo, S. Lee, J. Lee, Y. Lee, and S. Kim, “An energy-efficient distributed unequal clustering protocol for wireless sensor networks,” *in PWASET*, pp. 1274–1278, December 2008.