Enhancement of Lifetime of LEACH Network by Selecting Cluster Head Based on Residual Energy

Supervised by

Abdullahil Kafi

Assistant Professor, Dept. of C.S.E, IIUC

Presented By

Ali Haider Doha C141088

Kazi Mushfikur Rahman C141090

Mohammad Rakibul Hasan C141063

Abstract

- Wireless sensor network is one of the most widely used thinks in today’s world. Though, this kind of network is much complex and its energy consumption is high.
- In this paper we modified “LEACH“, the widely optimistic wireless sensor network's routing protocol.
- Our upgraded “LEACH" protocol used improved cluster head selection technique with the concept of assisted node that’s more energy efficient and it’s more enhanced than previous “LEACH" protocol technique.

Contribution

- Improvement of Cluster Head selection technique
- Hibernate sensor node scheme
- Minimum 5% better network lifetime than LEACH
- Maximum 20% better network lifetime than LEACH

Organization

- LEACH
- Literature Review
- Limitation and Objective
- Methodology
- Simulation
- Mathematical Analysis
- Performance Comparison
- Conclusion and Future Work
- Reference

LEACH Routing Protocol

LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol is a TDMA based MAC protocol. The main aim of this protocol is to improve the lifespan of wireless sensor networks by lowering the energy. Leach protocol consists of two phases[19]:

1. Set-up phase
2. Steady phase

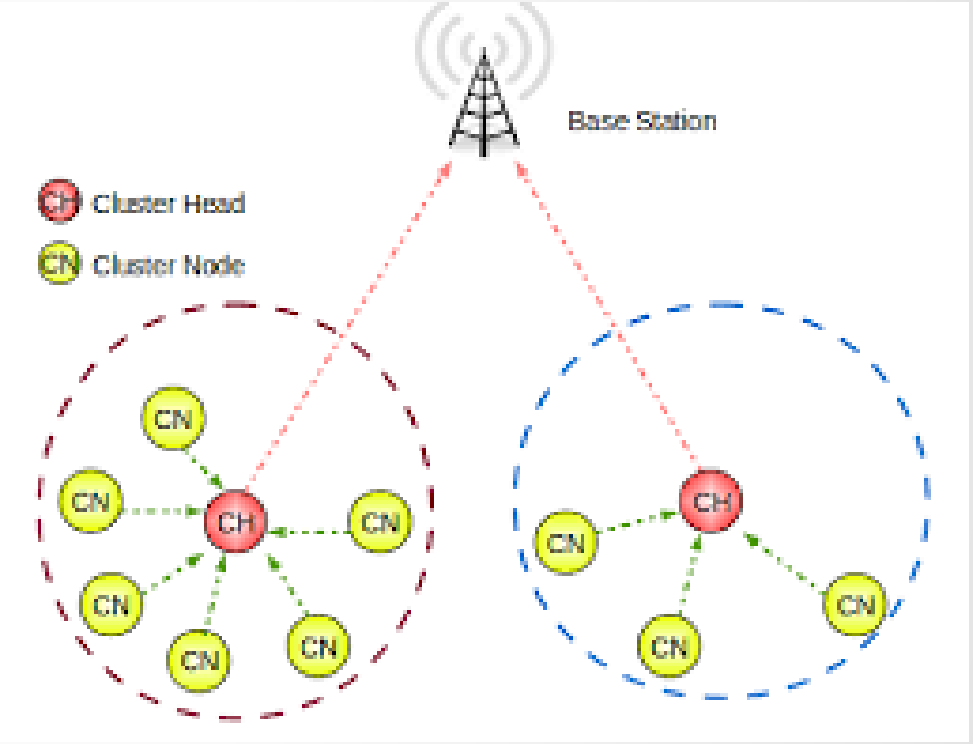


Figure 01: LEACH routing protocol

LEACH Routing Protocol (Cont.)

Set-Up Phase

- In the set-up phase, the main goal is to make cluster heads(CH) and cluster formation according to CH[3].
- Set-up phase has three fundamental steps:
  1. Cluster head advertisement
  2. Cluster set up
  3. Creation of transmission schedule

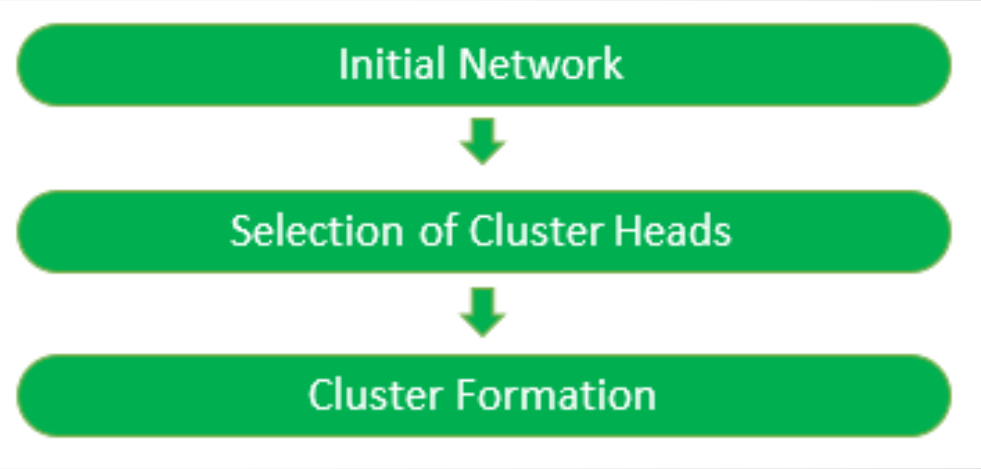


Figure 02: Setup Phase

LEACH Routing Protocol (Cont.)

Steady Phase

- Sensor nodes send their data to the cluster heads.
- Cluster head aggregates all the collected data and forwards data to the base station.

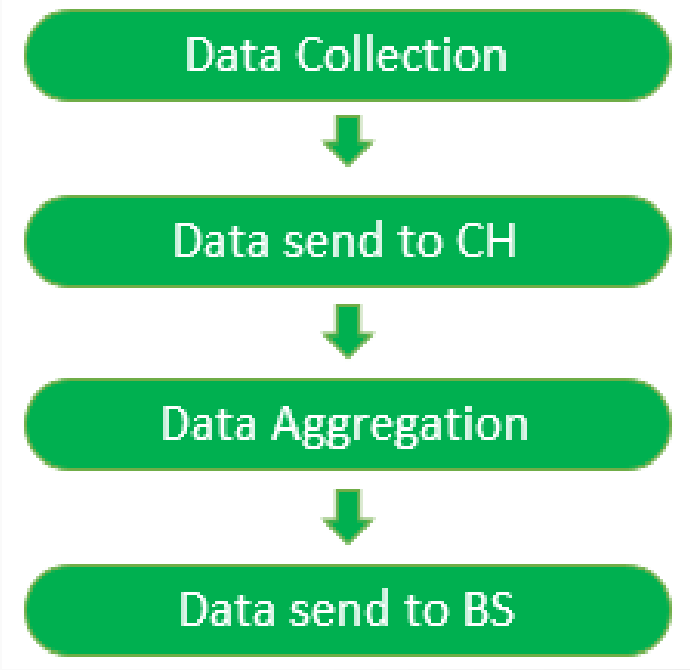


Figure 03: Steady Phase

Literature Review

- “LEACH" (Low-Energy Adaptive Clustering Hierarchy), which is
  - A clustering-based protocol
  - Randomized rotation of local clusters
  - Evenly distribute the power load among the sensors[1]

- “LEACH" protocol is able to distribute energy dissipation evenly throughout the nodes or sensors, tends to doubling the useful system lifetime for the network the simulation[2].

Literature Review (Cont.)

- An algorithm which will eliminate higher energy consumption but also it covers a wide range of area in a sensing manner[3].

- The proposed protocol with two recent clustering approach, which is distributed approach and centralized approaches also showed their performance against different “LEACH" routing protocol[4].

- Modified “LEACH" outperformed “LEACH” using metrics of cluster head formation, throughput and network life[4].

LEACH Limitations

Major Limitations of LEACH

- Limited lifespan of network
- Ignored the residual energy consideration for cluster head selection
- No real energy balancing

Objectives

- Provide energy efficient “LEACH" protocol
- Improve Cluster Head selection technique
- Enhance network lifetime
- Reduce the dead nodes per round

UP-LEACH Architecture

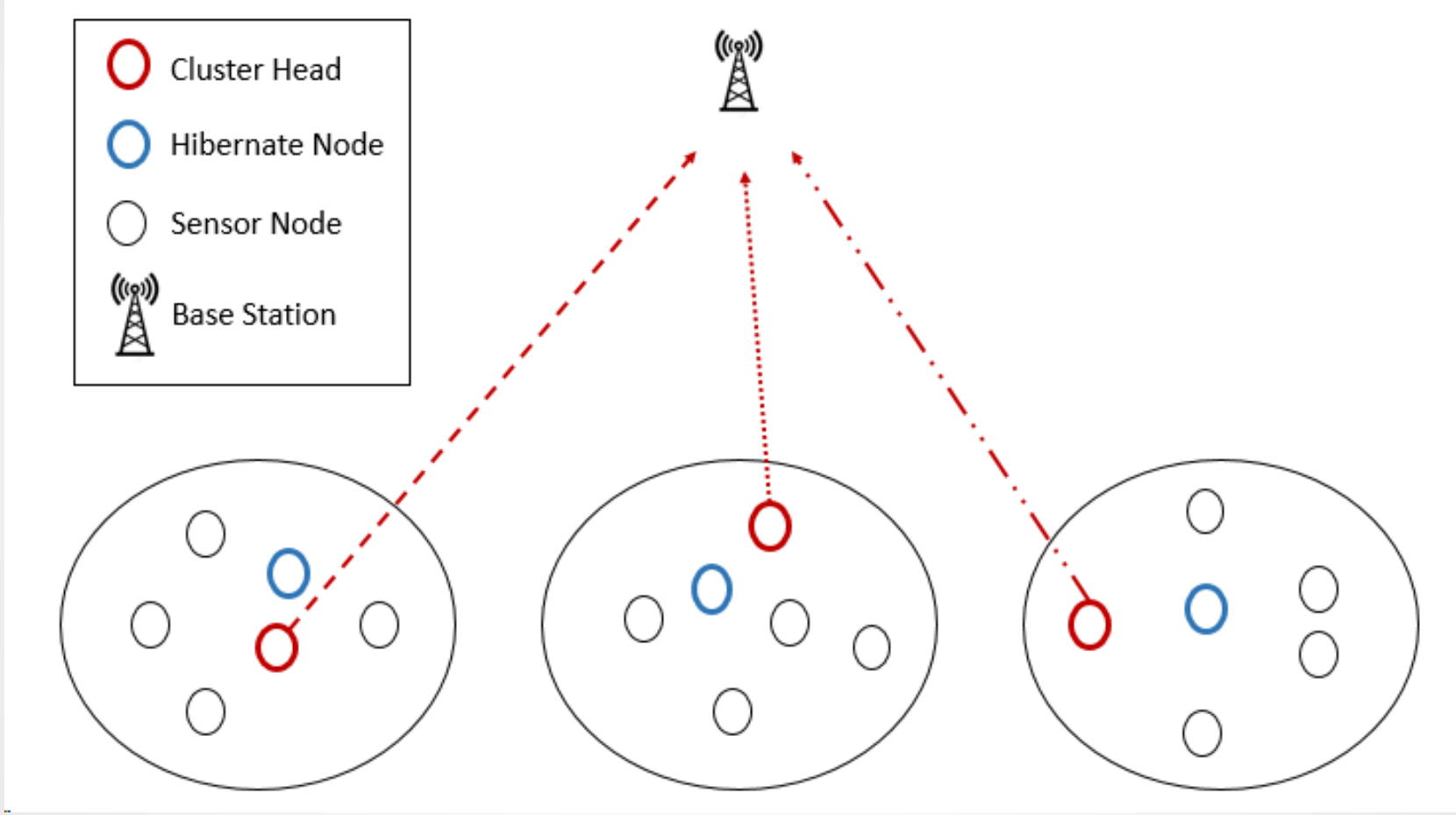


Figure 04: Architecture of UP-LEACH

Methodology

Proposed Method

- At first, The cluster head is selected based on the following formula[1]:

$$T(n) = \frac{p}{1 - p * \left\{ r mod \frac{1}{p} \right\}}$$

- After the selection of cluster heads we determine the hibernate nodes of cluster heads.

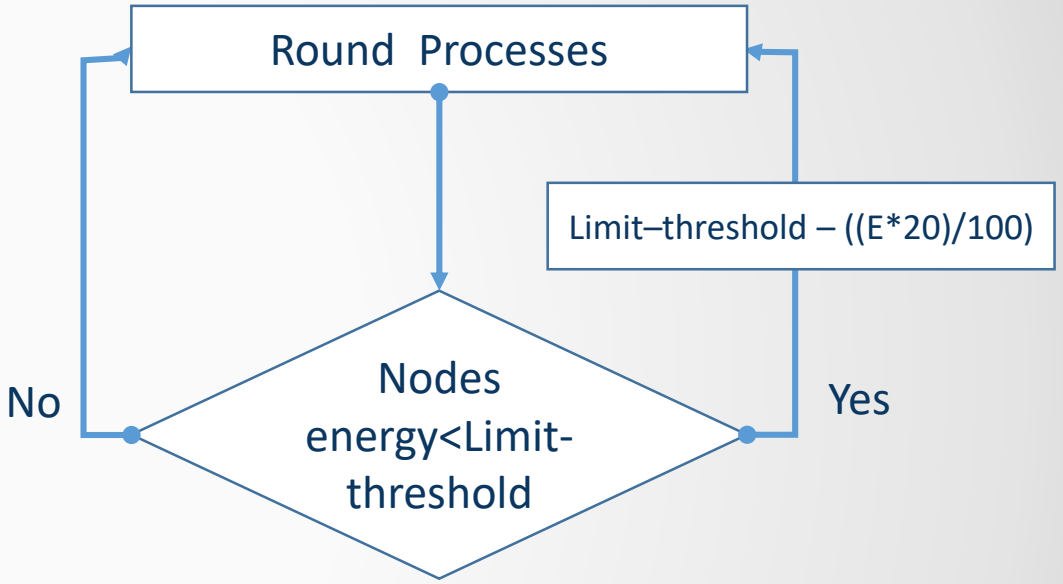


Figure 05: Round Flow Chart

Methodology (Cont.)

- When the energy of the cluster head is less than a limit value, the cluster head becomes a normal node.
- At that time the hibernate node of that cluster head will come into play the role of Cluster Head.
- Then again another hibernate node will be determined for the newly formed Cluster Head. Here we have ensured that the node which just played the role of Cluster Head will not be selected as Hibernate node immediately.
- All the selected Cluster Heads and Hibernate nodes stored in an structure array.

Add (S(i).id , C[])

Add (S(p).id , H[])

Simulation Environment and Parameter

1. Omnet++

Omnet has a model for component architecture, which are programmed in C++. It has also a high-level language (NED). In here, we can modify codes and models for our research purpose.

2. Matlab

Matlab is very unique and more user friendly for using matrix and vector manipulation. It’s comes with basic set of tools for visualizing data and for performing calculation on matrices and vectors.

Network Parameters

Network Parameters	Value
Network Size	200 X 200 m2
Bit Per Message	4000
Initial Energy of Sensor Nodes	0.5 J
Transceiver idle state energy consumption	50 nJ/bit
Data Aggregation/ Fusion Energy consumption	E_{DA} = 5 nJ/bit/signal
Amplification Energy (Cluster to BS) d <= do	E_{fs} = 10 pJ/bit/m^2
Amplification Energy (Cluster to BS) d > do	E_{amp} = 0.0013 pJ/bit/m^4

Figure 06: Network parameter

Simulation Phases

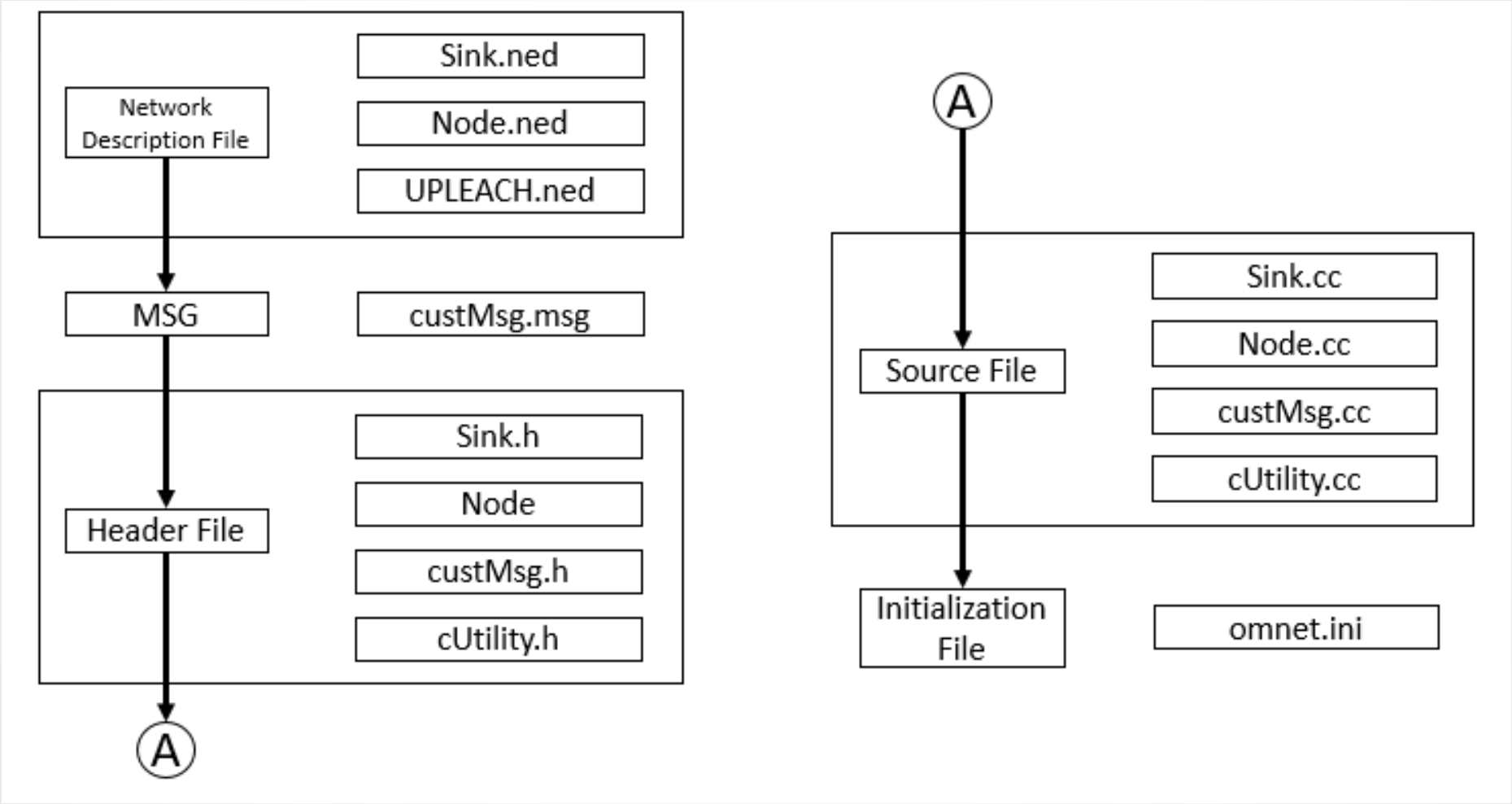


Figure 07: UPLEACH Simulation Phase

Simulation Data

First Iteration Cluster Head Matrix

xd	yd	distance	id
85.27281	89.30603	159.4223	12
234.9289	311.1384	116.4979	25
220.3239	368.359	169.5813	35
264.717	221.9252	68.3301	39
317.2354	302.1898	155.5214	49
272.9212	259.7236	94.25715	52
369.7098	39.90836	233.304	56
364.7339	369.4003	236.2916	58
361.7166	293.9417	187.0222	62
337.3407	361.9637	212.3552	63
397.3383	391.6698	275.0995	89
212.6977	397.4296	197.8375	92

Simulation Data (Cont.)

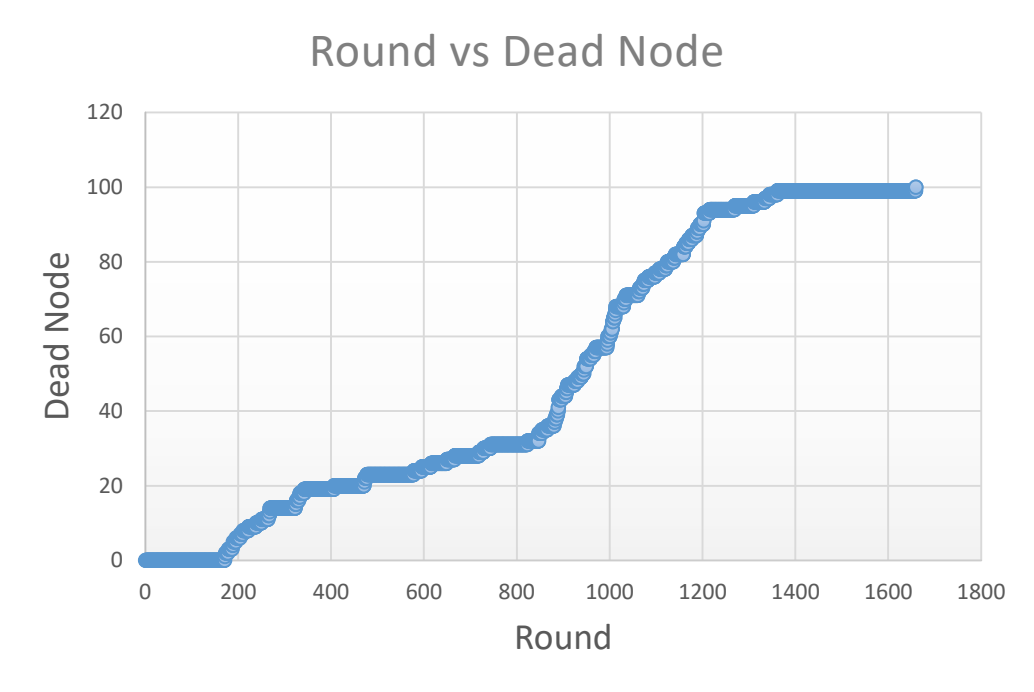


Figure 08: Dead node per round

Figure 07 shows how many nodes died per round. After all nodes are dead, the above figure formed.

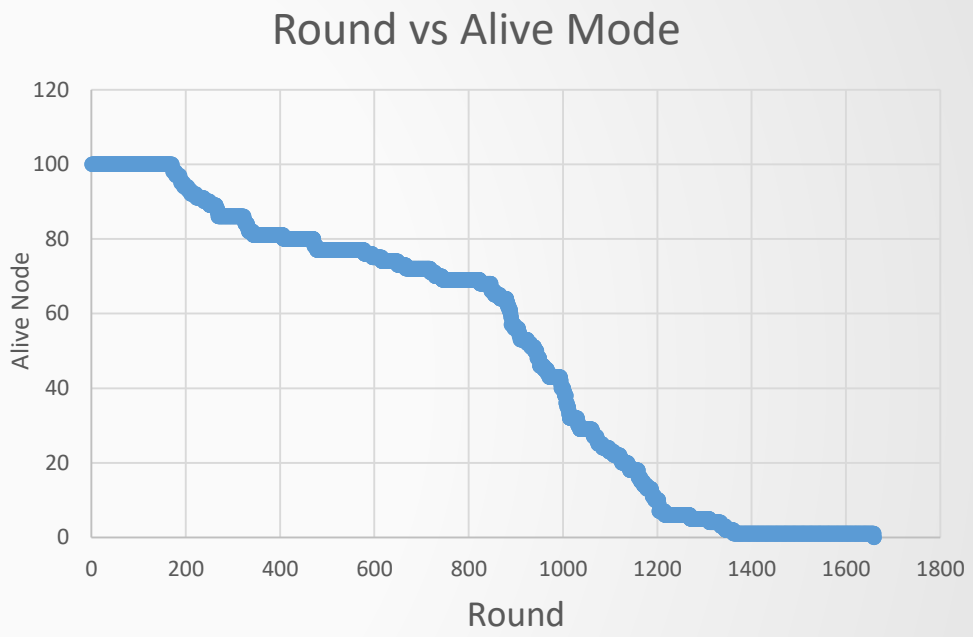


Figure 09: Alive node per round

Figure 08 shows how many nodes alive per round. After all nodes are dead, the above figure formed.

Simulation Data (Cont.)

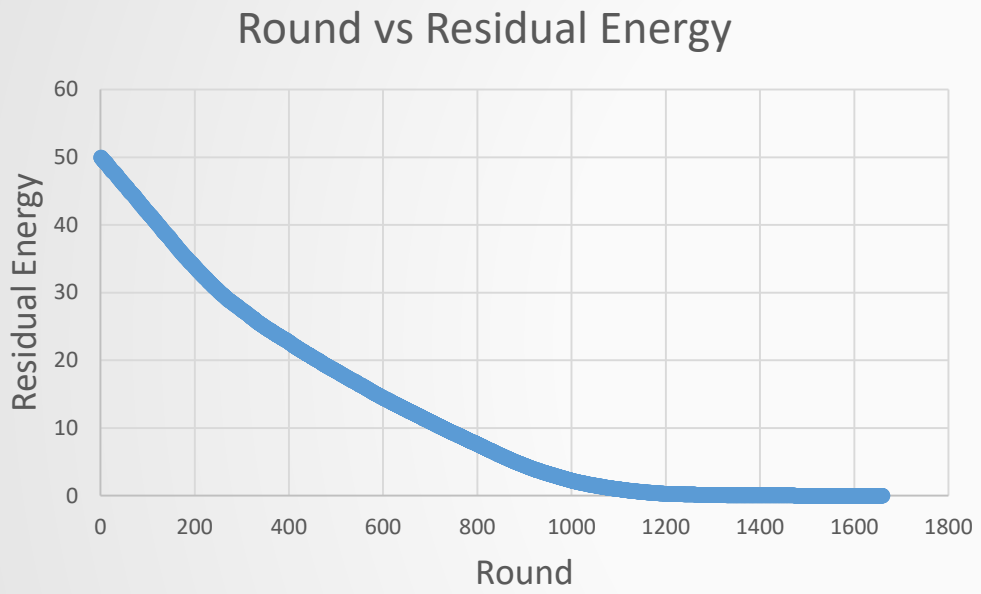


Figure 10: Residual Energy per round

Figure 09 shows that residual energy per round consist in the simulation

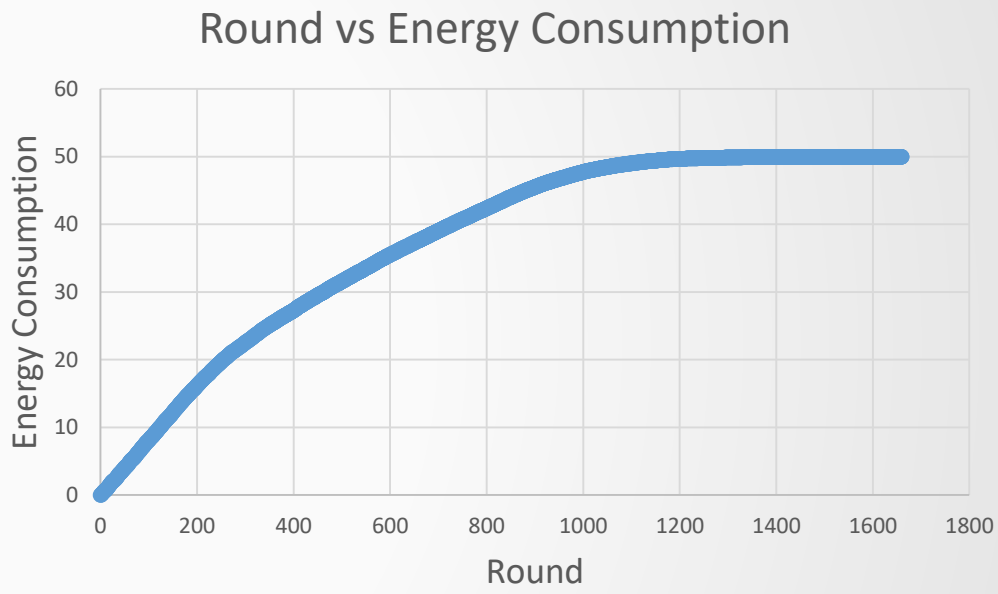
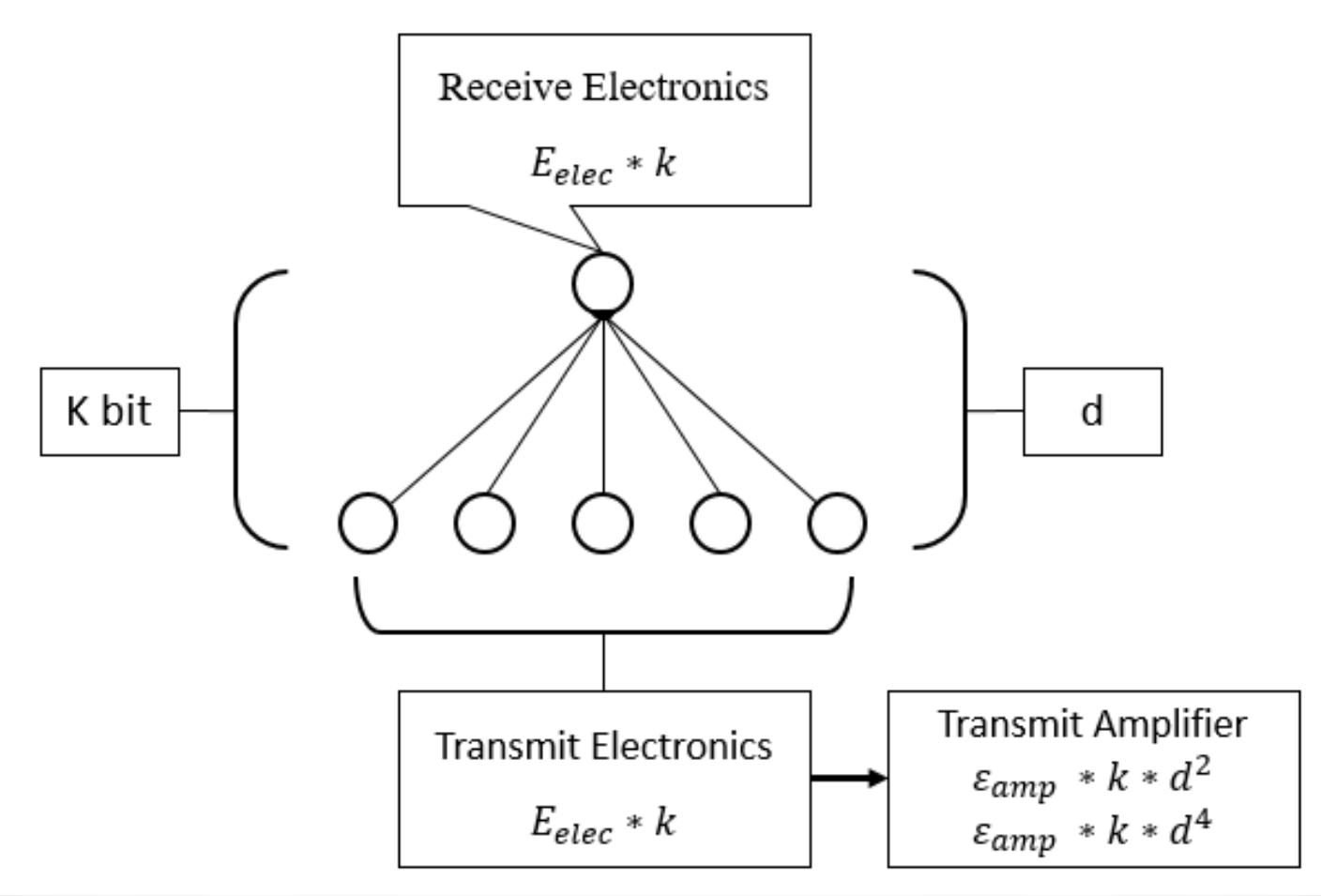


Figure 11: Alive node per round

Figure 10 shows that the energy consumption rate per round. This figure formed for energy consumption rate.

Energy Calculation ???

First Order Radio Model (FORM)



First Order Radio Model (Cont.)

- The energy consumption of transmitting a k-bit packet at a distance d can be expressed by[1]:

$$E_{Tx}(k,d) = E_{elec} * k + E_{fs} * k * d^2 \qquad if (d \leq d_0)$$

$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^4 \qquad if (d > d_0)$$

- And receiving a k-bit packet can be calculated by:

$$E_{Rx}(k,d) = E_{elec} * k$$

where

$E_{elec} = E_{TX} + E_{DA}$ *or* $E_{RX} + E_{DA}$

ε_{amp} = transmit amplifier to ensure the smooth operation

k = size of the transmitting or receiving packet

d = the distance between the transmission node and receiver node and

d_0 = a predefined value, which depends on the performance of the sensor node

Individual Round Energy Consumption

- Transceiver idle state energy consumption
- Same energy cost for these following steps:

<table>
<tr><td>CH forming</td><td rowspan="3">Sent data to sink(BS)</td></tr>
<tr><td>CH remains as CH</td></tr>
<tr><td>H → CH conversion</td></tr>
<tr><td colspan="2">Here energy consumption is same as transmitting energy which is stated below.</td></tr>
</table>

- When CH receives data, energy consumption is same as receiving energy which is stated below.

Mathematical Analysis

- In idle state:

  per round energy consumption = 0.000000005J

  1000 round energy consumption = 1000 * 0.000000005 = 0.000005J

- Suppose, Message size = 4000bit.

  d_0 = 50m

  d_1= 20m

  d_2= 60m

- Required energy to receive:

  receiving energy $= (E_{RX} + E_{DA}) * 4000$

  = {(0.000000005 + 0.000000005) * 4000 }

  = 0.00004J

Mathematical Analysis (Cont.)

Required energy to transmit:

- for d1,if(d<=d0) then

  transmit energy = $(E_{TX} + E_{DA}) * 4000 + E_{fs} * 4000 * d^2$

  transmit energy = {(0.000000005 + 0.000000005) * 4000 } + ($0.000000000001 * 4000 * 20^2$)

  = 0.0000416J [Lowest energy consumption for single transmission]

- for d2,if(d>d0) then

  transmit energy = $(E_{TX} + E_{DA}) * 4000 + \varepsilon_{amp} * 4000 * d^4$

  transmit energy = {(0.000000005 + 0.000000005) * 4000 } + ($0.0000000000000013*4000* 60^4$)

  = 0.00071392J [Highest energy consumption for single transmission]

Mathematical Analysis (Cont.)

- Hibernate node’s energy remain same till they turned into CH.
- Suppose, a CH remains as CH for 10 round. For this 10 rounds, linked hibernate node have no energy dissipation. So its energy remains same for 10 round i.e. till convert to CH.

H.E = 0.0000416 (Lowest energy dissipation per round)
10 round will cost = 10 * 0.0000416 = 0.000416 J

H.E = 0.00071392 (Highest energy dissipation per round)
10 round will cost = 10 * 0.00071392 = 0.0071392 J

Mathematical Analysis (Cont.)

- If total round is 1000, then Hibernate node's energy remains same for 100times.

  So, for 1000 round,

  H.E = 0.000416 * 100 = 0.0416 (Lowest energy dissipation)

  H.E = 0.0071392 * 100 = 0.71392 (Highest energy dissipation)

  This energy is saved in 1000 rounds for single CH.

- If there are 10 CH, then

  Total lowest energy dissipation = 0.0416 * 10 = 0.416 J [0.83% of total network energy]

  Total highest energy dissipation = 0.71392 * 10 = 7.1392 J [14% of total network energy]

  By this energy, the network can run another 100+ rounds.

  But in simulation around 8%-10% energy saved that enhance the network lifetime.

Performance Comparison

This figure differentiates occurrence of dead node placed in round for three LEACH variations.

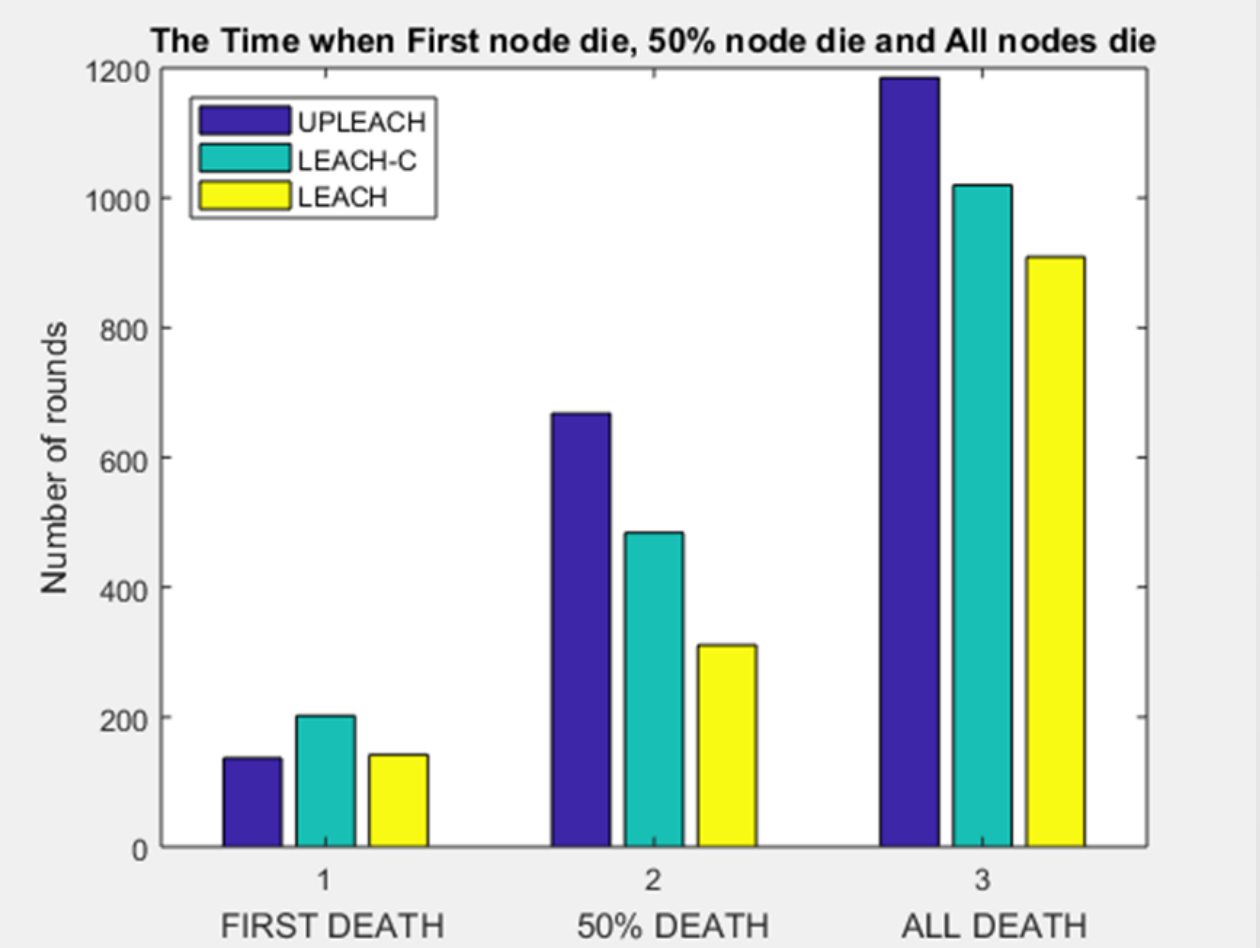


Figure 12: Dead Node Count Per Round

Performance Comparison (Cont.)

This figure shows the flow of residual energy placed in round for three LEACH variations.

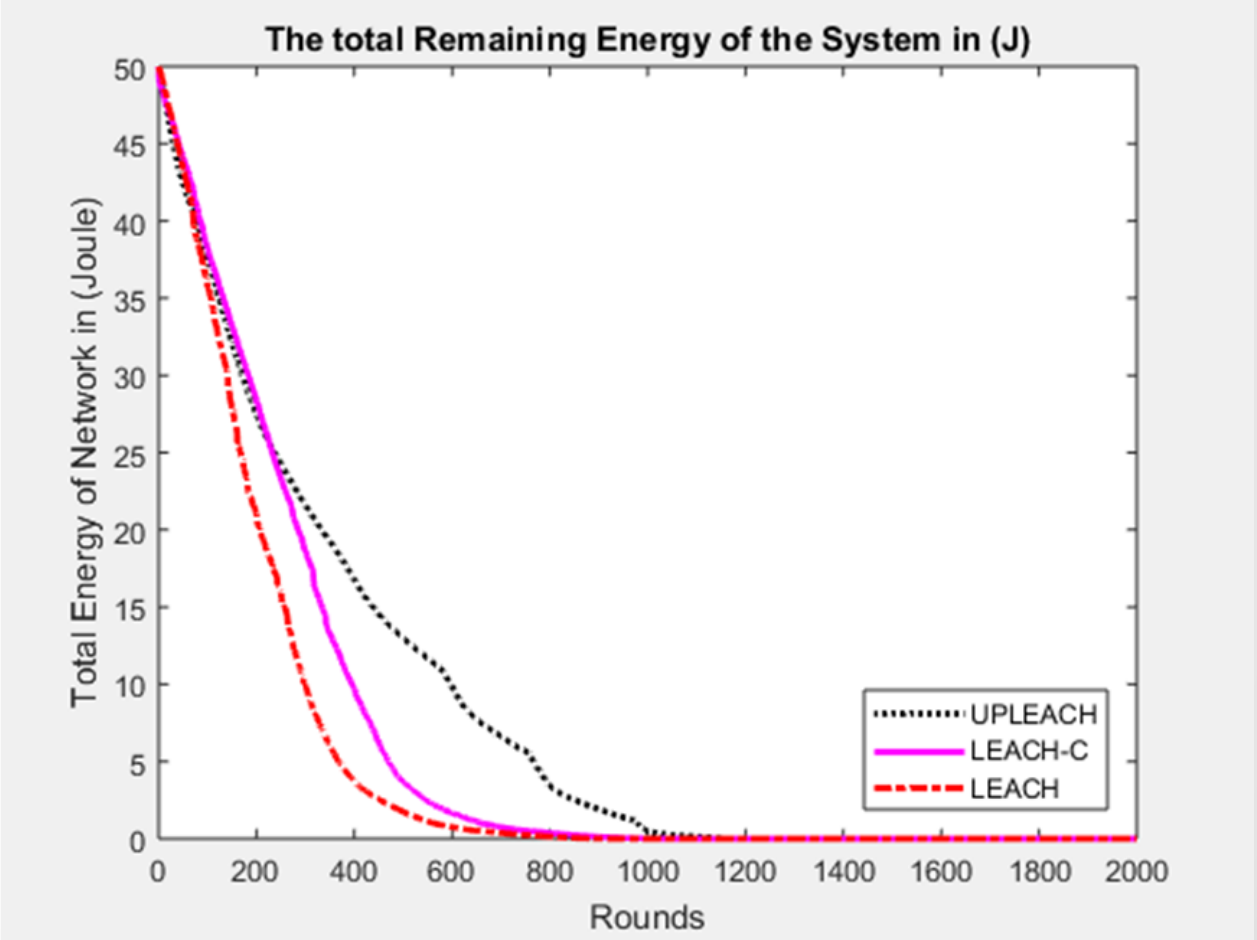


Figure 13: Total remaining energy of the system per round

Performance Comparison (Cont.)

This figure shows alive nodes ending into dead nodes placed in rounds for three LEACH variations.

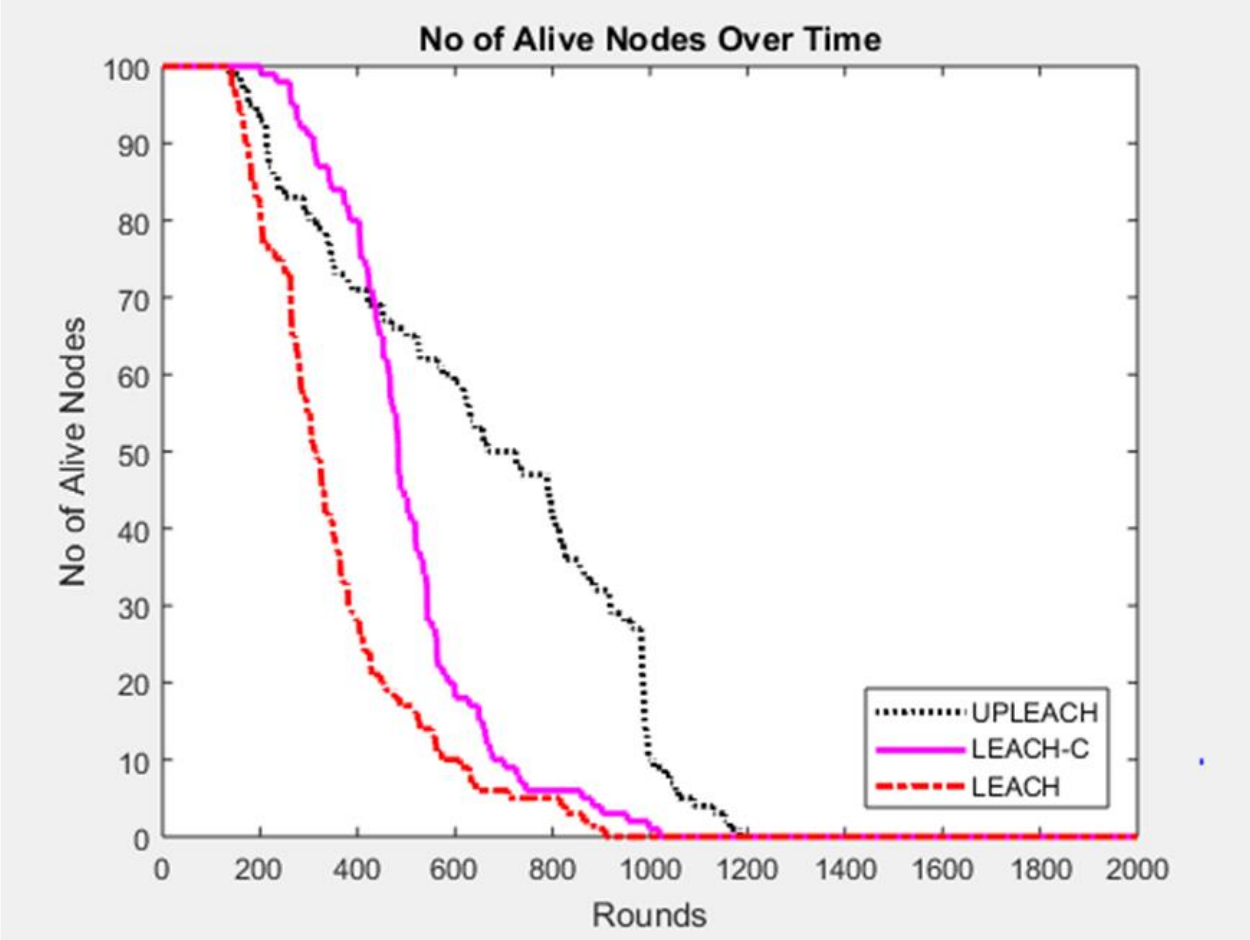


Figure 14: Number of alive nodes per round

Performance Comparison (Cont.)

This figure shows dead nodes increment in respected rounds for three LEACH variations.

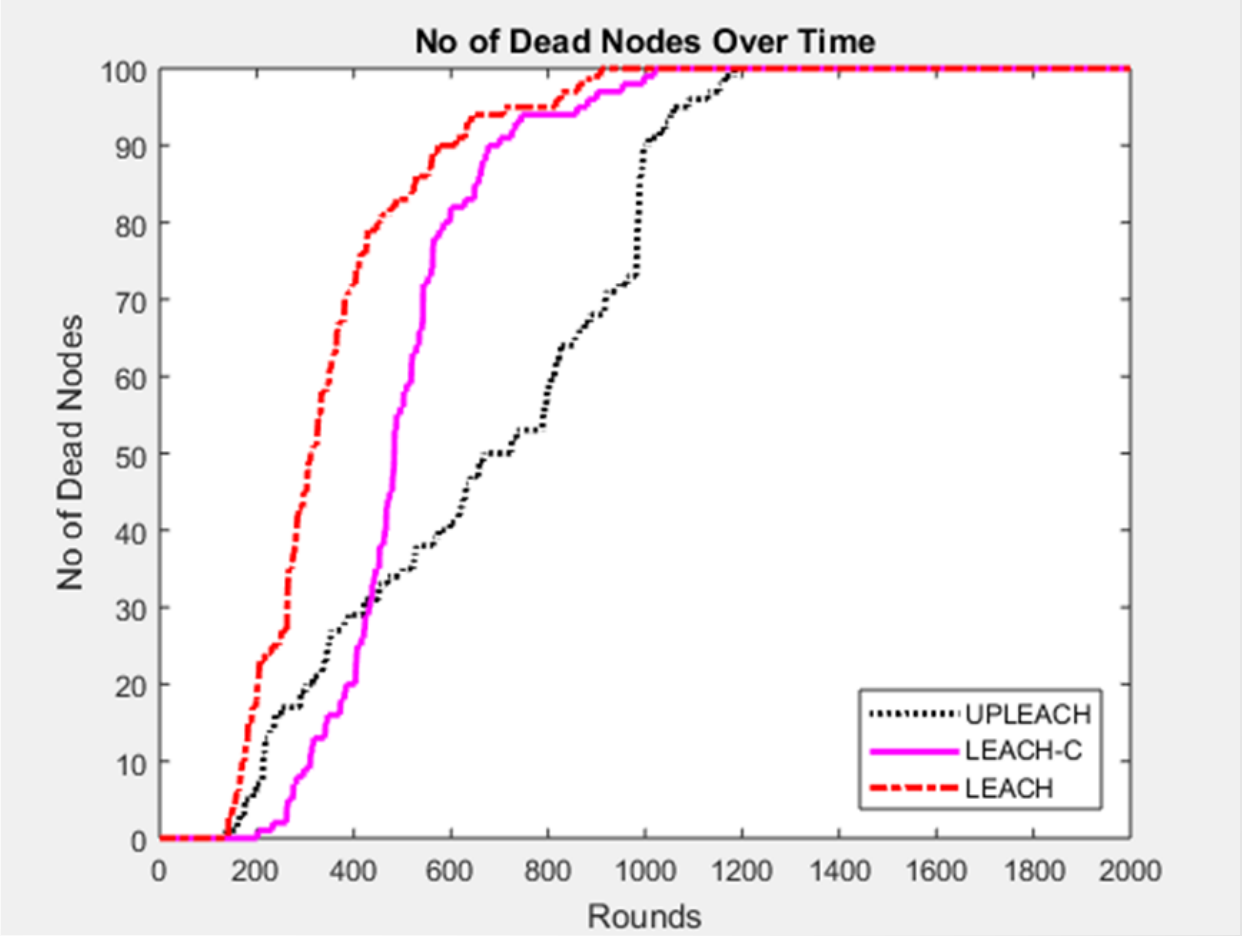


Figure 15: Number of dead nodes per round

Conclusion

- We work on LEACH by implement different cluster head formation technique.
- By upgrading the leach protocol, we found the efficiency in the result.
- In here our “LEACH” protocol performs higher in terms of energy efficiency and nodes survival ratio.

Future Work

- We will try to develop an efficient wireless node charging module to enhance the life time of sensor node.
- Moreover, we will develop an energy station which recharges the energy nodes that lead to an immortal WSN.
- Multihop and Intra-Cluster communication development.

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