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Bandwidth Allocation and Scheduling in Distributed Sensor Networks

Lokesh B. Bhajantri[1], Shiddalingesh S. Hiremath[2]

[1]Department of Information Science and Engineering, Basaveshwar Engineering College, Bagalkot, Karnataka, India

[2]Department of Computer Science and Engineering, Basaveshwar Engineering College, Bagalkot, Karnataka, India

Email address:

lokeshcse@yahoo.co.in (L. B. Bhajantri), siddalingesh.409@gmail.com (S. S. Hiremath)

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Abstract: The paper proposes bandwidth allocation and scheduling in Distributed Sensor Networks (DSNs). This approach incorporates resource (bandwidth) allocation and scheduling for transmitting of data efficiently. The objective of the proposed work is to improve the performance of network in terms of packet delivery ratio, energy consumption, efficient bandwidth allocation, and number of alive nodes. The simulation results show that the proposed approach perform better in-terms of utilization bandwidth and scheduling for communication in DSNs.

Keywords: Distributed Sensor Network, Cluster Head, Time Division Multiple Access, And Bandwidth Allocation and Scheduling

1. Introduction

DSN consists of great number of homogeneous or heterogeneous intelligent sensor nodes, these nodes are distributed randomly or static or logically or geographically in the physical environment with the high speed of network. Recent advancement in micro-electronics and telecommunication technologies have been resulted in design of tiny sensing nodes that are capable of periodically collect data from their respective environments [1].

The generated data is transmitted from the sensor nodes (cluster member node) or cluster head (CH) node to sink node through single hop or multi-hop communications in the network. The deployment of sensor nodes are varies with the applications to applications. The sensor are extremely entrenched devices that are incorporated with a physical environment and capable of acquiring signal, processing the signals, communicating, routing of data, and performing computational jobs. This innovative class of networks has the prospective to facilitate the wide range of applications and poses challenges like frequent network topology change, limited computational, and memory [2].

A logically or spatially or geographically deployment of network needs number of clusters to manage the load at the sink node in the network. And also manages the communication or routing overhead among the nodes. Apart from these, respective CHs from clusters are used provide the following advantages like to increase the network lifetime, scalability, load balancing, and optimization of energy level of sensor nodes. Nodes send data to their corresponding CH via single or multi hop communication. CH receives data from its member nodes in each cluster for transmitting of data to sink node. Clustering of nodes avoid long distance communication of sensor nodes to sink node or BS [3].

The resource allocation (bandwidth, energy, and node) is one of the main constraints in the design of DSNs. In the network, each node requires sufficient resource to transmit the data. The bandwidth is an inadequate resource in the network. The network bandwidth is distributed among the sensor nodes or clusters including cluster head. Some sensor nodes dominate the channel and some other nodes may not get the enough bandwidth for data transmission. In this context, the proper mechanisms should be required for managing the bandwidth or any other resources in the network. The proposed work is used to provide an efficient resource allocation among the sensor nodes in terms of efficient utilization of bandwidth, estimating available bandwidth, adapting the flow and rate, providing QoS guarantees etc.

The rest of the paper is organized as follows. The overview of related work discussed in section II. A proposed work for efficient bandwidth allocation and scheduling is discussed in Section III. Simulation and results analysis are presented in Section IV and finally concludes the work in section V.

2. Related Works

Some of the related works are as follows: The work given in [4] presents the management of bandwidth in wireless sensor networks based on probabilistic method. Also evaluates the protocol behaviors for energy utilization and reliability. The work given in [5] presents the resource aware task scheduling using decentralized algorithms in wireless sensor networks. Resource aware task scheduling means the execution of task takes place only when the resources are available. The bandwidth assignment for clusters in wireless sensor networks is discusses in [6]. This describes the concept of TDMA (Time Division Multiple Access) protocol used in clusters. The assignment of bandwidth is evaluated by the density of the network and super frame length in the networks.

The work given in [7] depicts the algorithm for bandwidth allocation to both real time/non real time communications in the sensor networks. It defines the distributed MAC protocol that satisfies the latency requirements and also illustrates the topological regularities. A survey on bandwidth allocation and scheduling in wireless sensor networks is presented in [8]. It comprises the solutions for bandwidth allocation and scheduling in single-hop and multi-hop wireless sensor networks. It addresses the heuristic algorithms for the problem of bandwidth allocation and scheduling. The work given in [9] describes the bandwidth allocation using priority levels of data in sensor networks. It imposes on the MAC layer modifications to meet real time requirements for various priorities of data. In this work, considers the highest priority is assigned for real time data. Deliver the data from sensor node to sink node with efficient bandwidth by the priority levels.

The bandwidth efficient multicast mechanism for heterogeneous wireless networks is presented in [10]. Their mechanism uses fewer cells to save bandwidth by clustering more mobile nodes together. The work given in [11] discusses on cluster based optimization of routing in DSNs using Bayesian networks and Tabu search. This paper proposes a cluster based optimization of routing in DSN by employing a Bayesian network (BN) with Tabu search (TS) approach. BN based approach is used to select efficient cluster heads and construction of BN for the proposed scheme. This approach incorporates energy level of each node, bandwidth and link efficiency. The work given in [12] presents an energy-aware, cluster-based routing algorithm (ECRA) for wireless sensor networks. The ECRA selects some nodes as cluster-heads to construct Voronoi diagrams and rotates the cluster-head to balance the load in each cluster. A two-tier architecture (ECRA-2T) is also proposed to enhance the performance of the ECRA. The work given in [13] presents the cluster based routing in wireless sensor networks. Simulation result shows that this work can remarkably extend the network lifetime and amount of data gathered. Some of the related works are given [14] [15] [16] [17] [18] [19].

The efficient bandwidth allocation and scheduling among distributed sensor nodes has been a hot research topic in the last years. DSNs are usually followed certain rules and policies to control the maximum allocated bandwidth for each node. The bandwidth allocation process is usually dependent on different factors including traffic type (QoS, and best effort) and the number of connected users. In the proposed work, the network is divided into number of clusters or square grids because of prolonging sensor operable lifetime. Each cluster has CH node. The election of CH node is based on highest probability of energy among the nodes in the clusters. Once CH is elected in all the clusters, the remaining nodes are associated with respective CHs. Finally the proposed bandwidth allocation and scheduling algorithm performs the processing of data efficiently in DSNs.

3. Proposed Work

The proposed work is used to solve the problem of efficient bandwidth allocation and scheduling in DSNs. In this section, the network model, communication graph, and bandwidth allocation and scheduling algorithms are presented.

3.1. Network Model

The proposed scheme associates the set of sensor nodes by connecting with high speed network is as shown in Figure 1. These sensors are randomly scattered in the real time environment. The proposed network model composed of following components: SN (Sensor Nodes), CHs, node TDMA (Time Division Multiple Access), and sink node or base station. Every node in the network is configured both initial amount of the energy and bandwidth along with GPS configuration. In the proposed network model, all sensor nodes are assumed to be static including sink node. All the sensor nodes have the same communication range between the nodes in the network. CH and cluster member (CM) nodes are communicated with single-hop, whereas CH and sink node communicated through multi-hop or single hop communication over the CHs in the network. Each node periodically sends the data to CH, CH carries the data in their TDMA time slots to sink node with efficient bandwidth. Finally sink node takes the action for computing the performance of the network.

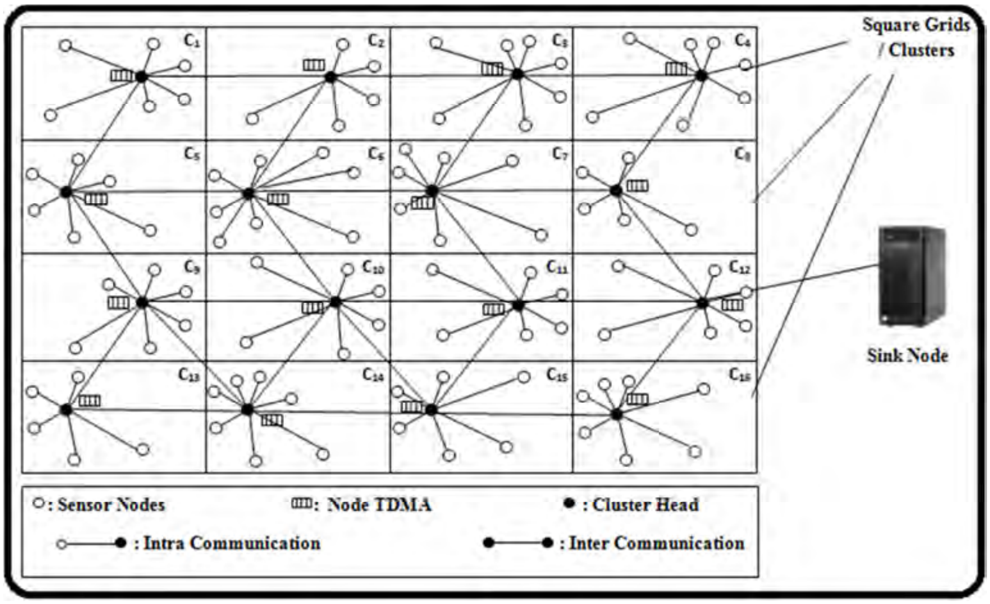

Figure 1. *Network Model.*

3.2. Communication Graph over CHs

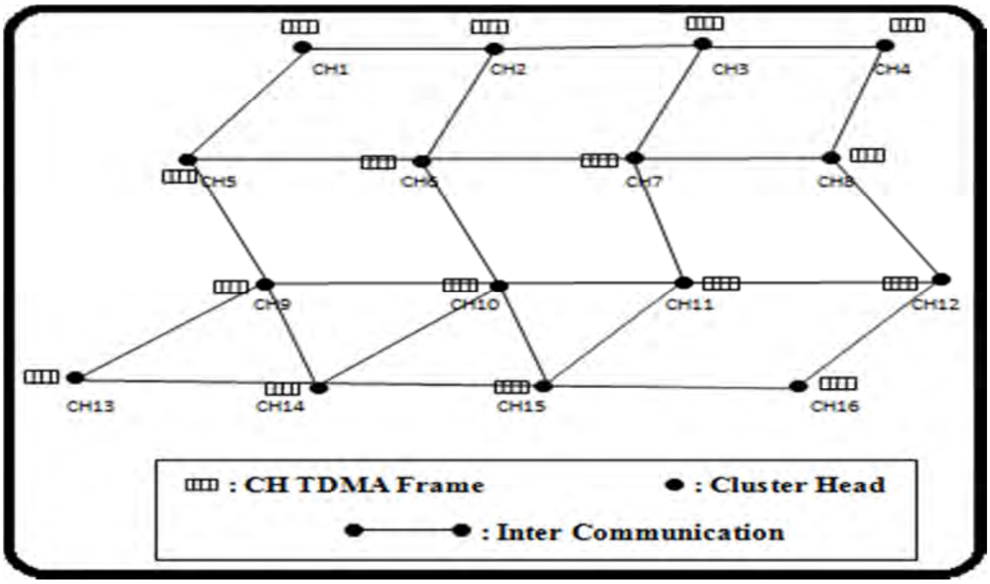

Figure 2. *Communication Graph over CHS.*

The network can be represented as a communication graph of CHs is represented as G = (V, E), where V = {v1, v2, v3 …vn}, for every CH ϵ V, i.e, represents the set of CH nodes in the network, E = {e1, e2, e3 …en} represents the edges between the nodes or link efficiency or communication links between the nodes, it could be between CM node and CH node, CH node and sink node. Each CH consists of CH TDMA, each slot is assigned with neighboring CHs for data or packet scheduling in the network is shown in Figure 2.

In the network, communications between the nodes is as follows: if{vi, vj} ϵ V, the edge or communication link e = {vi, vj} ϵ E, if and only if vj is located within the communication range of the sensor node vi. In the proposed network, CH node maintains the TDMA queue or node TDMA for data storage, scheduling, and processing. The proposed TDMA frames divided into number of time slots, each slot is assigned to CM nodes within the cluster, which is assigned by CH node based on the number of CM nodes is as shown in Figure 3. CH node transmits the data to sink node with given amount of bandwidth. The CH also maintains the CH TDMA for data processing and scheduling through its neighboring CHs in the network. Each slot carries the node data along with control section and request section. The control section consists of node ID, no. of hops between source node to sink node, and size of the data. Each node can transmit the data in their time slot with efficient bandwidth. Request section associates the scheduling time for data transmission in the CH TDMA. Each neighboring CH or CH in the network, maintain the TDMA frames, time slots are reserved for neighboring CHs data.

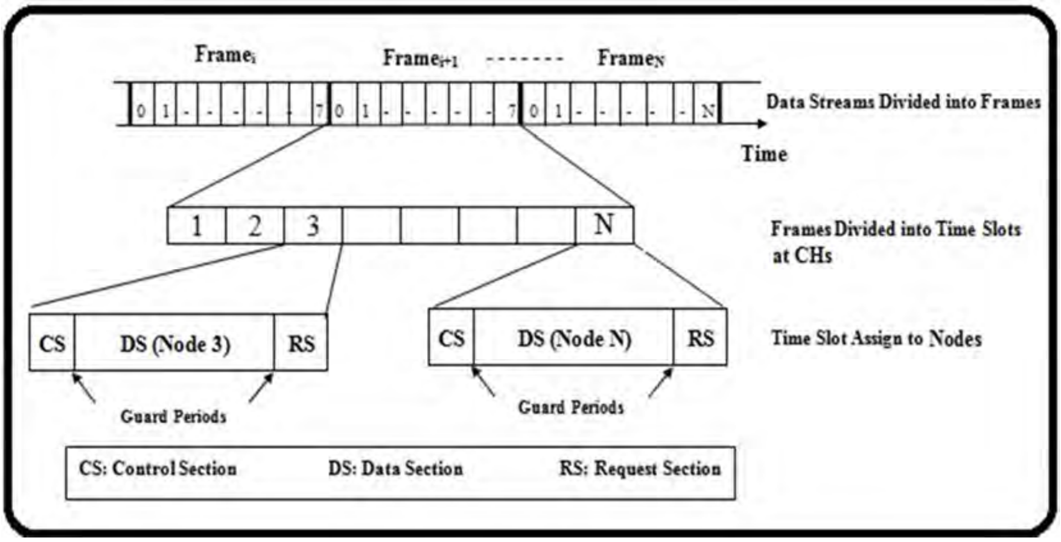

Figure 3. *Proposed TDMA Frame Structure at CHS.*

The bandwidth is the most important resource in the network for data transmission. The distribution of bandwidth among clusters in the network is as given below:

$$CB = NB / NC \tag{1}$$

Where, NB = Network Bandwidth, NC = No. of Clusters.

The distribution of bandwidth among CMi per clusters is given below:

$$CMB = CB / SN \tag{2}$$

Where, CMB = Bandwidth required for Cluster Member nodes; CB = Bandwidth required for Clusters or cluster level bandwidth; SN = No. of wireless sensor nodes.

The bandwidth requirement is varies with different size of the packets or data, the amount of bandwidth required for data transmission over the CHs to sink node is computed as follows:

Let di be the distance between nodes in the network. It can be computed by using Euclidian Distance Formula (EDF) given by Equation [20].

$$d_i = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

Link efficiency can be computed as follows. Let Ci be capacity of a discrete-time discrete-valued channel, 'B' be the bit rate (Hz) of a channel, 'ET' be the total energy consumed for transmission of a bit in link 'I', SNR be the signal-to-noise ratio [21]. Capacity of channel 'i' is:

$$Ci = B\log2\ (1+SNR) \tag{3}$$

Assume 'EN' stands for energy consumption for the transmission of the packets. 'EN' can be computed by using Eq. (4):

$$EN = SE \times Pi/bits + TE \times Pi/bits \tag{4}$$

Where,

SE – energy required for sensing data or packets,

TE– energy required for transmission of data or packets,

Pi – size of packets in terms of bits.

Let 'E' would be the energy consumed for the transmission of a bit per distance di. The energy of node E is [21]:

$$E = EN \times di \tag{5}$$

Assume 'Leff' is the link efficiency for the nodes in the network. 'Leff' can be computed by using Eq. (6) [22].

$$Leff = Ci / E \tag{6}$$

The bandwidth required for data transmission in the network (TBR) is as follows:

$$TBR = BS \times Pi/bits + (BT \times Pi/bits) \times Leff \tag{7}$$

Let 'RE' be the residual energy of each node in the DSNs as follows:

$$RE = IE - Ei \tag{8}$$

Where,

IE = initial energy of node, EN = energy consumption.

Bandwidth Allocation and Scheduling Algorithm

Input Variables:

Sn: No. of sensor nodes in DSNs;

CHi: No. of Cluster Heads;

EN: Energy of sensor node;

Leff: A link efficiency of sensor nodes;

K: cluster information;

SN: Number of Sink node.

E(SN)): Energy of Sensor Nodes;

Output:

Number of efficient CHs in the DSNs;

Efficient Bandwidth Allocation and Scheduling for Data Transmission between CH and sink node.

Procedure:

1. The number of sensor nodes are scattered randomly;
2. Divide the DSN into no. of Square Grids (N_SGi) are as follows:
   N_SGi = length × breadth / 2 Є for every Grids(Gi)
3. Selection of CHi in each Gi is as follows:

```
for each cluster (CN) do
    for each sensor node(SN) do
        if ( random(CHi ) > E(SN)) Є Vi
            CN (CH) = = CHi;
        else
            CN (CMi ) = = CHi;
        endif
    endfor
endfor
```

4. The bandwidth allocation for data transmission is as follows:
   for each CN do /*in each cluster CH receives the data from its CM nodes */
   4.1 Each CH assigns the TimeSlot to CM node;
   4.2 Each CH reserves the bandwidth and scheduling of data in their time slot for transmission of data;
   End for
5. for each CHi do
   5.1 To maintain the CH TDMA for scheduling;
   5.2 CH node schedules the data from TDMA frame for transmission to sink node through its neighbor CH nodes in the network;
   5.3 If sufficient bandwidth is available for requesting nodes, CH to allocate the bandwidth for data transmission, otherwise requesting CH node will wait for sufficient bandwidth. Or any one of the slot bandwidth is free, to allocate the bandwidth to requesting CH.
   end for

4. Simulation

The proposed work is simulated to various network scenarios using MATLAB programming language. Simulations are carried out extensively with random number for 100 iterations. This section presents the simulation model, simulation procedure, performance parameters, and results.

4.1. Simulation Model

The simulation model comprises of set of sensor nodes (SN) deployed randomly in an environment. The network is divided into number of square grids to form the clusters. The performance parameters of the proposed are simulated effectively for achieving better network performance.

4.2. Simulation Procedure

Simulation inputs for the proposed scheme are as follows: Number of Nodes (SN) = 500, Energy of each nodes (EN) = 2Joules, Number of sink nodes (Ns) = 1, Size of the network = 5000*5000 meters, Transmission range (TR) = 100 meters, Energy required for sensing of each node (ES) = 50nJ/Bit, Energy required for transmission of data (ET) = 50nJ/Bit, Size of packets (P) = 64Bits, 128Bits, 512Bits, 1024Bits and so on, and Threshold Level Energy (THE) = 0.05 Joules, Transmission of data = bits/sec and bandwidth of the network (BN) = 4mbps.

Begin

1) Deploy the number of nodes randomly in DSN environment;
2) Divide the network into number of Clusters or Square Grids;
3) Select the number of Cluster Heads based using proposed algorithm;
4) Apply the proposed scheme;
5) Compute the performance parameters;
6) Generate the graphs.

End

4.3. Performance Parameters

The following performance parameters were used in proposed scheme:

1) Bandwidth Allocation: As the size of the packet increases, the percentage of bandwidth allocation increases with given number of nodes in the network.
2) Packet Delivery Ratio (PDR): It is defined as the number of nodes increases, the increase in the packet delivery ratio. The PDR is measured in terms of percentage (%).
3) Energy Consumption: The number of rounds increases, the decreases energy consumption of each sensor nodes in the network.
4) Number of Alive Nodes: As the number of iterations increases, the decrease in the number of alive nodes.

4.4. Results and Discussions

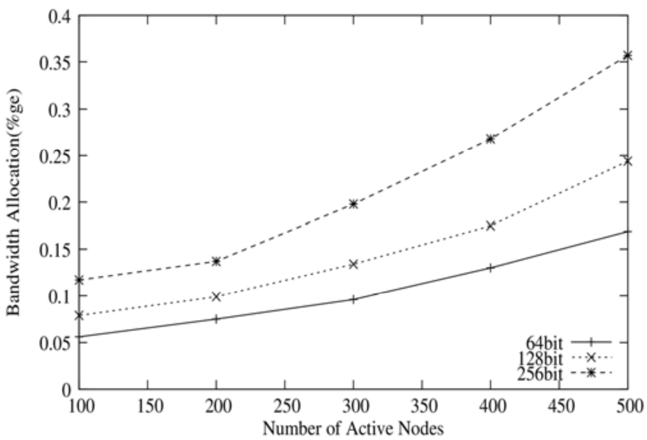

Figure 4. *Number of Active Nodes vs. Bandwidth Allocation.*

The Figure 4 shows the bandwidth allocation to the variable size of packets with given number of active nodes in DSN. In this approach, as the size of the packet increases, the gradually increases the bandwidth allocation with given number of nodes. The graph illustrates allocation of bandwidth to different types of packets (64bit, 128bit, 256 bit). The proposed TDMA based protocol is energy efficient and better network lifetime.

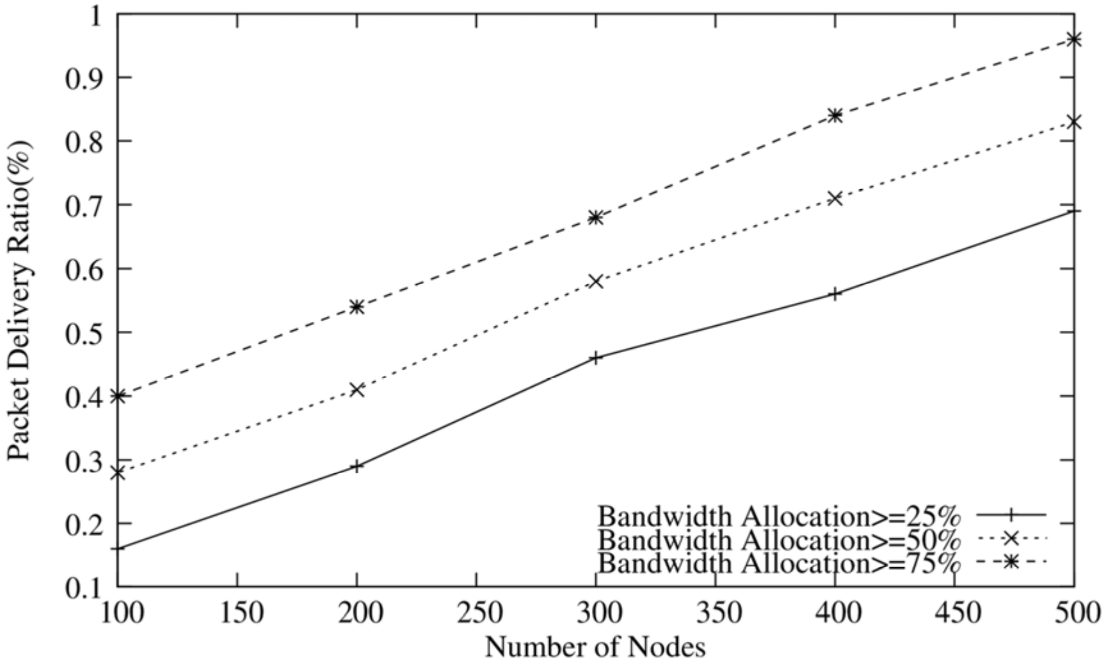

Figure 5. *Number of Nodes vs. Packet Delivery Ratio.*

The Figure 5 illustrates the packet delivery ratio with given number of nodes. As the number of node increases, the increase in the packet delivery ratio. Because of this, more bandwidth is required for transmitting of data over CHs in the network. The proposed protocol performs the better packet delivery ratio with respect to percentage of bandwidth allocation like >=25%, >=50%, and >=75% i.e., percentage of bandwidth allocation increases, the increase in the packet delivery ratio in the network.

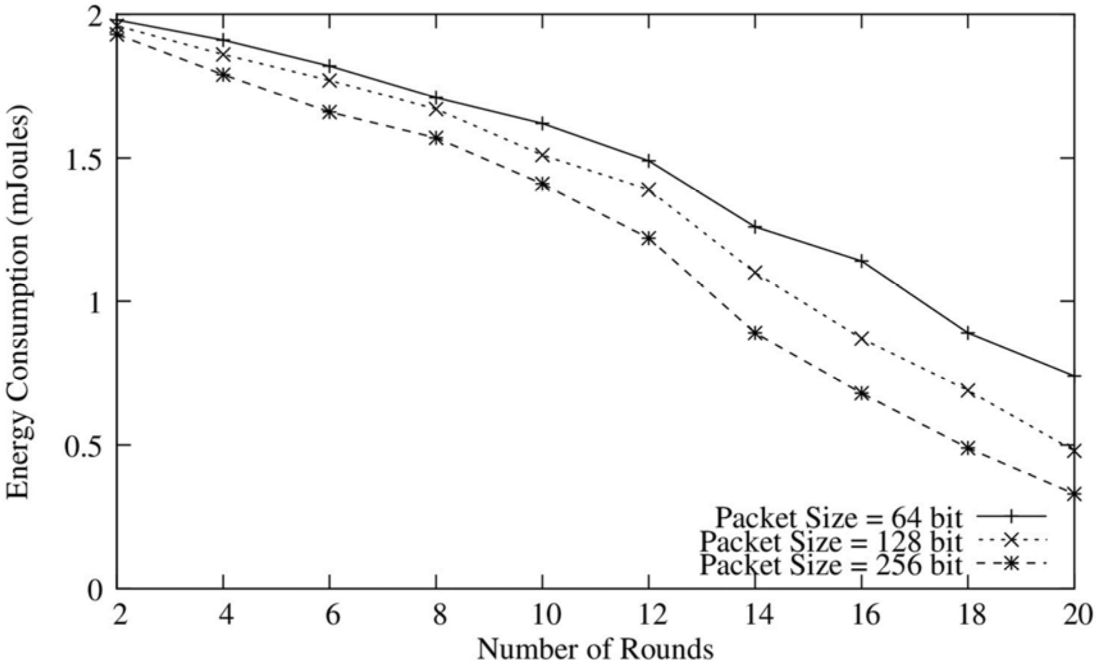

Figure 6. *Number of Rounds vs. Energy Consumption.*

The Figure 6 depicts the energy utilization or consumption with respect to the number of rounds. As the number of rounds increases, decrease in the energy consumption of sensor nodes. The energy consumption of sensor nodes depends on the variable size of packets (64 bit, 128 bit, 256 bit, and so on) in the network. The proposed TDMA based protocol is energy efficient for transmission of packets from source node to sink node. The energy consumption of each sensor node is measured in terms of 'mJoules' in the network.

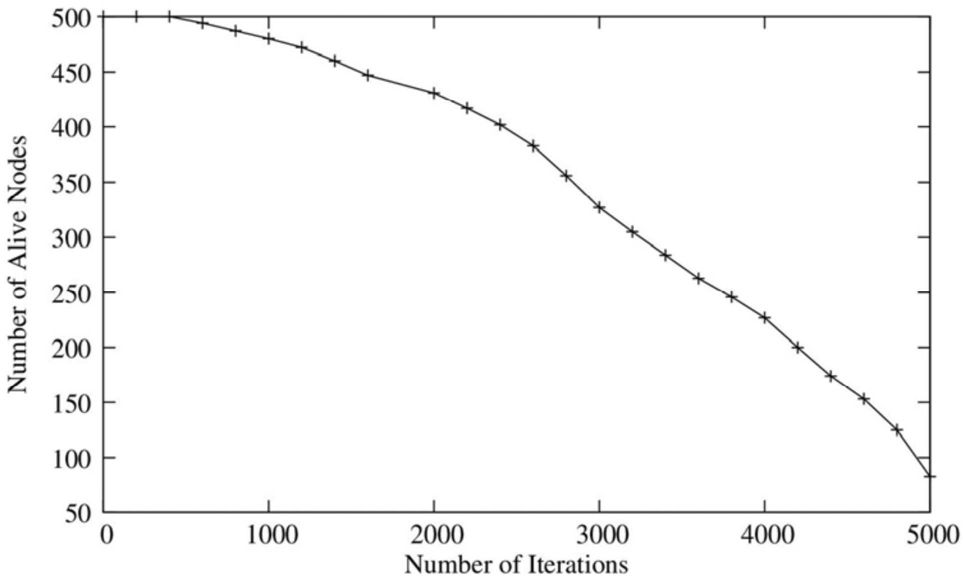

Figure 7. *Number of Iterations vs. Number of Alive Nodes.*

The number of iterations with respect to number of alive nodes is shown in Figure 7. The number of iterations increases in the network, the decrease in the number of alive nodes. In this work, there is no dropping of alive nodes up to 500 iterations, after that gradually decrease in the number of alive nodes.

5. Conclusion

The proposed method is energy efficient and responsive to network. It includes CH selection, bandwidth allocation and scheduling, and data processing using proposed TDMA protocol. The proposed approach is more reliable for scheduling, managing resources, better network lifetime, and energy consumption. The proposed scheme is simulated in terms of performance parameters like energy consumption, packet delivery ratio, bandwidth allocation, and number of alive nodes in the network.

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