Energy Efficient Multicast Algorithm for an Ad Hoc Network

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ABSTRACT

In this paper, we propose an energy efficient multicast algorithm for an Ad hoc network. The network is configured by identifying the virtual node and its neighboring nodes to form a Directed Acyclic graph. The non interference links are identified by creating realization Indicator Function. The Scheduling unequal timeshares are computed for non interference links using realization indicator functions. The Network Coding is applied based on the incoming traffic and the different number of source nodes for packet delivery. It is observed that the performance parameters PDR, throughput, energy consumption, delay, control overhead are better in the case of proposed method compared to existing methods.

Keywords

Ad Hoc Network, Multicast Algorithm, Scheduling, Network Coding, Noninterference.

1. INTRODUCTION

Over the years, the research on the wireless ad hoc network has made wireless communication ubiquitous. There are various multicast scenarios in wireless networks, which are used for multimedia sharing, software distribution, video conferencing, and much other wide range of applications. However, in such multicast multi-hop wireless networks, the general problem for establishing interference free scheduling is Non Polynomial (NP) hard complete, hence this would result in complexities in achieving the required performance from the network as well as network modeling [1]. Network Coding, used in wireless communication helps to improve network performance. The network coding was primarily developed for wired networks, with the advantage of simultaneous multi-transmissions over different interference free links and focused throughput and the same technique is adopted for the wireless networks [2].

Network coding to the wireless multicast network shows drastic improvement in parameters like total energy consumption, throughput, delay, packet overheard etc. Network coding plays an efficient role in cross-layer issue for QoS and other reliable network parameters [3]. In earlier works, it is seen that the network coding does not result in improvement in the performance measures if the Medium Access Control (MAC) and Network Coding are designed independently. It is therefore important to establish a combined optimization between MAC scheduling and network coding. A model is required to achieve optimum performance by designing a network code that supports the broadcast property of wireless network and also suitable for advanced network.

Motivation: Shared bandwidth and broadcast media are the unique characteristics of wireless network that causes collisions or interferences in case of simultaneous transmissions. An effective approach of scheduling is needed to avoid hidden station problem, also to provide an energy and throughput optimization for multi hop wireless network.

Therefore it is necessary to design and develop an efficient multi hop wireless network model suitable for advanced network with variable power control rates, signal to interference ratio, transmission power.

Contribution: In the proposed method the configuration of the network is developed by identifying virtual nodes to initiate communication. The unequal time shares for every link are measured and identifying the best non interference link using scheduling technique. The network coding is used based on the traffic flow.

Organization: The organization of the paper is as follows: The Literature survey is discussed in section 2. The proposed system is given in section 3. In the section 4 the algorithm is presented. The performance parameters are evaluated in section 5 and section 6 contains conclusions.

2. Literature Survey

In this section a review of existing techniques of scheduling and Network Coding are discussed.

Ephremides and Truong [4] described the demerits of broadcast by naive flooding which causes contention, collision, and congestion problems. The work proposed to reduce rebroadcasts and to avoid collision and latency issues. Chaporkar et al., [5] worked on the problem of identifying the maximum end-to-end throughput that a multicast connection can achieve with network coding in an unreliable Ad hoc network, by formulating for maximum throughput for a network with and without network coding in the defined network topology. Yunnan Wu et al., [6] proposed an iterative cross-layer optimization, which alternates between, jointly optimizing the timesharing in the medium access layer and the sum of max of flows assignment in the network layer and updating the operational states in the physical layer, in order to minimize aggregate congestion and minimize power consumption. Jaggi et al., [7] gives polynomial time algorithms with specified field size for centralized network code construction. X. Y. Li, J. Zhao et al., [8] proposed the study of capacity of wireless networks when the protocols for all layers are chosen, where in the node positions are given a priori, and how the capacity of wireless networks scale with the number of nodes in the networks or with the size of the deployment region for a various number of operations such as unicast and broadcast. The scaling is provided that these transmissions will not cause destructive wireless interferences to any of the transmissions. Vahid Zibakalam [9] proposed a new centralized TDMA Scheduling algorithm based on the node's congestion degree for general Ad hoc networks. J. Yuan et al., [10] presents the optimal and distributed provisioning on high throughput in mesh networks.

Proposed a cross layer optimization framework for throughput maximization in wireless mesh networks, in which data routing problem and the wireless medium contention problem are jointly optimized for multi hop multicast. Hongjun Zhang and Pawel Gburzynski [11] presented a TDMA Scheme intended for carrying traffic with diverse QoS requirements in mobile environments and adapted the slot size to fit the traffic, featured with dynamic and responsive bandwidth. Shuyun Luo In et al., [12] address the Minimum Data Collection Delay (MDCD) problem. Virtual Grid Network concept was introduced successfully to convert the MDCD problem into max-flow problem, uses the Ford-Fulkerson max-flow method, MDCD to find an optimal solution in polynomial time and achieves the lower bound.

D. Vir et al., [13] DSR gives better throughput, packet delivery fraction, average jitter and delay performance compared to ZRP followed by STAR by increasing the node densities and thereby increases the maximum energy consumption in STAR. Song Yean Cho et al., [14] where the multi-hop wireless networks are modeled as unit disk graphs of the plane, if their distance is lower than a fixed radio range then the two nodes are neighbors. The wireless broadcast advantage is used; each transmission is overheard by several nodes. S.C.Ergen and P.Variya [15] proposed MAC protocols for sensor networks to provide contention based access or time division multiple accesses. An efficient schedule avoids collision and minimizes the number of time slots and hence the latency. K. Pandey and A. Swaroop [16] the performance of the MANETS are evaluated by considering four performance metrics namely, throughput, average delay, number of packets dropped and routing overhead. AODV performance in terms of throughput is better than DSDV. The numbers of dropped packets in DSDV are also higher. As ZRP is a hybrid type throughput does not change even with a change in mobility or pause time. The performance of DSR is good due to route cache, with less number of routing overhead and packets dropped. Nikola Milosavljevi [17] the work emphasizes on the interference free wireless networks. The unit-disk model of radio propagation, under which a node's radio range is a disk of radius one centered at the node, wherein, the two nodes are connected if and only if their Euclidean distance is at most one. Christina and Fragouli [18] have achieved the implementation of network coding in their research work. T.Ho and D. S. Lun [19] introduced network coding and uses mathematical underpinnings, practical algorithms, code selection, security, and network management.

3. Proposed System

As the multi hop wireless network has unique properties like broadcast mechanism and collisions or interference. Therefore, it is necessary to design and develop a multi hop wireless network model suitable for advanced network. An advanced network features include variable power control rates, signal to interference noise ratio, distance between transmitter and receiver, the number of nodes, transmission power, adaptive coding and modulation. The proposed model is used to achieve optimum performance which is optimum and to design a network code that supports the broadcast property of wireless network.

The proposed energy efficient algorithm for an Ad hoc network is designed using the concepts of network coding and scheduling techniques. The corresponding block diagram is shown in Fig.1. The implementation modules of the proposed system are, Configuration of Network, Realization, Scheduling, and Network Coding are shown in fig1.

3.1 **Configuration of Network**

The Directed Acyclic Graph (DAG) is used to identify the neighbors of the virtual node. Virtual node is the root node, which initiates the communication. The virtual node is selected randomly in the network or closest to the source node. The tables called Multicast Member Table, Upstream Table, and Downstream Table are constructed that helps in identification of neighboring nodes of the virtual node. A unicast message called Multicast Group Join message is sent to upstream node by a neighboring node in order to join the group. This message creates an entry in the downstream table. The virtual node makes an entry in the Multicast Member Table as soon as it receives the unicast message. In order to find the neighbors, the beacon message is broadcasted periodically. The neighbor node receives the beacon message, it creates an entry in the Neighbor Table, based on beacon expire time. Semi Disk Graph is used, for the heterogeneous communication which is based on three probabilistic conditions viz., (i) If the transmission range lies in a strong coverage area, then the probability is equal to one and is successful. (ii) If the transmission range is an outside coverage area, then the probability is equal to zero and (iii) If the transmission range is in a week coverage area, then the probability value lies between zero and one and the communication is not possible.

The probability p is given in an equation (1)

P = (Outside coverage area – distance) / (Outside coverage area – inside coverage area)……………. (1)

The probability is based on distance given in equation (2)

$$P\alpha \frac{1}{d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The graph is constructed by using NP complete in order to find the optimal solution.

3.2 Realization: The path from the virtual node to the destination node is established in the realization phase, to find all the optimal paths of the network to solve the constraints. The Realization Link Function *L* determines the member of a link in a set of realizations. The optimization is obtained by the link capacity, which is given by $\sum L$, for the links. The timeshares are allotted to each realization in the set to identify whether the node link is active or inactive. It represents the duration of time in a particular working cycle, where the realization link is active. If the value of link function is equal to one, it indicates that, it has an entry in the neighbor table. A node sends a Multicast Group Initiation message, which must have the capability to identify the available realization. After the reception of the Multicast Group Join message, a source node identifies the path to the destination, and computes the timeshares of realization. If the timeshares are maximum the solutions are optimized. The Timeshare T is inversely proportional to the number of links connected in the realization N_R is given in equations (3) and (4)

$$T\alpha \frac{1}{N_R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$T = \frac{K}{N_R} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where K is the slot time.

The two ways to identify the time shares are (i) equal timeshare in which all the links where all the links have equal length of time to connect with other links, and (ii) unequal timeshare is based on incoming and outgoing traffic flow. In case of multicast scenario, it is necessary to maximize the network throughput and to reduce the transmission energy, which is achieved by knowing all the link capacities having different constraints over it. The link with more traffic is given highest priority. The conservation constraints are used in order to convert the semi disk graph to unidisk graph using equation (5).

$$\sum_{n=1}^{N} \left\{ \sum f_{a,b}^{(n)}(d) - \sum f_{b,a}^{(n)}(d) \right\} = r \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where N is the set of available realizations,

n is the nth realization link,

a is the source node,

b is destination node,

r represents the throughput.

f functions over the n^{th} realization represents a portion of the flow of the link.

The availability of the link depends on the value of L, if L=1 the link is available, else link is not available, because of non interference free links.

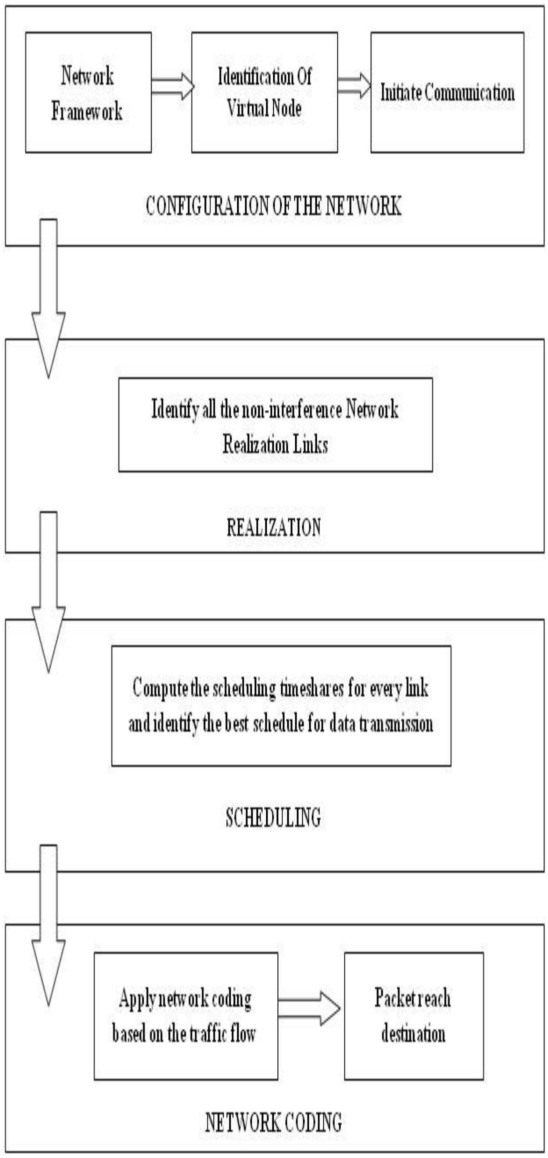

Fig.1 Proposed Block Diagram

Since the network is using a virtual node, it is seen that there is a change in the entire network. Scenario, where in virtual node is acting source node. Hence now the network can be considered as the expanded network and assured to obtain the expanded realizations from it. The flow constraints and optimal values of virtual node and realization of corresponding edge links are same.

3.3 Scheduling: is a process of making a node active and inactive during the transmission, it solves hidden station problem, channel accessing and to obtain optimized scheduling. Multicast group is established by forming tree from a source to many destinations. The link function helps in achieving linear optimization with schedule specific flows. Initially, before scheduling it is necessary to identify interference free links, and then create an initial schedule to form the number of schedules. The best schedule without interference is identified finally the data are transmitted Calculate the time share for both interference and non interference sets from the scheduling. The divisions of time slots for links are calculated. The time slot allocation is done in simulation for a link, if time share is 0.1sym/slot.

The different time slots can be defined as:

Start a time= ID mod T

End time= ID+1*mod* T

Where *ID* is the node ID.

The slot size of the node depends on their node densities, which indicates, that the node with more hop neighbors has more interference. Therefore the wireless nodes should be scheduled in different timeshares to avoid the collisions or interferences.

3.4 Network Coding: It is a process of combining two or more packets into one packet and sending to the destination. It is seen that the optimization problem can be resolved by scheduling technique. Therefore, network coding is employed in order to achieve optimization in wireless network which is based on scheduling constraints. The codes designed must therefore preserve the broadcast property of the network in the realization. The network coding also carries the coding coefficients that relate the coded packet to the source packets, and obtain a centralized code design for the wireless networks. The nodes are aware of the incoming packets from different sources. If the incoming packet is single packet, the network coding is not applied instead the packet is forwarded as it is.

The steps for network coding are similar to realizations. The coding coefficient of a link is determined only when coefficients for its entire upstream links are assigned.

The following steps are followed in case of more number of incoming traffic from different nodes:

a) If the node has incoming traffic in continuous time slots i,e., the time gap between incoming traffic is a minimum, then apply network coding (Critical Node).

b) If the time gap is not a minimum, then there is no need to use network coding.

The four modules of proposed implementation in which the data is transmitted with interference-free links are necessary to maximize the throughput and minimize the energy consumption.

4. Algorithm

Problem Definition: Shared bandwidth and broadcast media are the unique characteristics of wireless network that causes collisions or interferences in case of simultaneous transmissions. An approach of scheduling is needed to avoid hidden station problems, and to provide an energy and throughput optimization for multi hop wireless network. Therefore unique combined optimized structure is required for MAC scheduling and network coding. The proposed algorithm is given in Table 1.

Objectives: The following are the objectives of the proposed algorithm.

(i) Increase Throughput

(ii) Decrease energy consumption

(iii) Optimum path identification with non interference link.

Table 1: Proposed Algorithm

- Identify the Virtual Node.
- The virtual node broadcasts the beacon messages and identifies the neighbors in the network.
- The Directed Acyclic Graph (DAG) is constructed.
- Identify the realizations in the graph.
- Compute the timeshares for all the Realization and the Realization that has the maximum value is the most optimized solution. Timeshares (T) is inversely proportional to the number of links connected in the realization (N_R).
- T α $1/N_R$
- Identify all the Realizations.
- Identify both the interference and non-interference set.
- Compute the timeshare for both the interference and non-interference set.
- Calculate the division of time slots for links.
- The source node sends the packet.
- Based on the traffic level, determine whether to apply network coding or not.
- The packet reaches the destination.
- Compute the throughput and energy consumed by the nodes in the network.

5. Performance Analysis

In this section network simulation parameters, definitions of performance parameter, performance parameter evaluation and performance comparison of proposed method with existing methods are discussed.

5.1 Network Simulation Parameters

The simulations of energy model were performed using NS 2.32. The traffic sources are CBR. The source destination pairs are randomly chosen over the network. Setting the x and y parameters as 1000mX1000m, transmission range is set to 250m, creating a scenario for different node densities, with proposed routing protocol. The topography created is as follows,

Area: 1000m X 1000m
Interval: 0.1Symbols/slot
Node configuration: AdhocRouting
MacType: Mac/802_11
AntType : Antenna/OmniAntenna
PropType: Propagation/TwoRayGround
PhyType : Phy/WirelessPhy
ChannelType: Channel/WirelessChannel
Initial Energy: 100 Joules
Transmission Power: 0.02w
Receiving Power: 0.01W
Simulation Time: 200 Sec

5.2 Definitions of Performance Parameters

1. Throughput: It is a measure of the amount of data transmitted from the source to the destination in a unit period of time (second). The throughput of a node is measured by counting the total number of data packets successfully received at the node, and computing the number of bits received, which is finally divided by the total simulation runtime.
2. Normalized Overhead: Normalized Routing Overhead is defined as the total number of routing packet transmitted per data packet. It is calculated by dividing the total number of routing packets sent (includes forwarded routing packets as well) by the total number of data packets received.
3. Packet Delivery Ratio: Indicates the percentage of the transmitted data packets that are successfully received. The PDR is the ratio of the number of packets generated at the source to the number of packets received by the destination.
4. Average Energy Consumption: The average energy is the measure of percentage energy consumed by a node with respect to its initial energy. It is computed as,

$$\textit{Average energy consumption} = \frac{\textit{sum of percentage of energy consumed}}{\textit{number of nodes}}$$

5. Delay: The delay is the time taken for a data packet to reach the destination node.
6. Total Energy: The total energy is formulated as, Energy= (number of packets received × energy to receive a single packet) + (number of packets sent× energy to transmit a single packet) + (number of packet overheads × energy for overhead packet).

5.3 Performance Parameters Analysis

The performance parameters of the proposed method are evaluated by simulating the network parameters using Network Simulator NS2 (v2.32). The values of Throughput, Normalized Overload, Packet Delivery Ratio, Average Energy, Total Energy and Delay parameters are computed by varying node densities. The performance parameter values are calculated by varying number of destination nodes and total number of nodes in the given network scenario.

The variation of throughput versus total number of nodes in the network with destination nodes of 2, 3, 4, and 5, are given in the Fig.2. The values of throughput depend on the number of destination nodes, and the density of nodes in the network. As the number of destination nodes increases throughput also increases. The maximum throughput values (in kbps) are 313, 483, 528 and 643 for number of destination nodes 2, 3, 4 and 5 respectively.

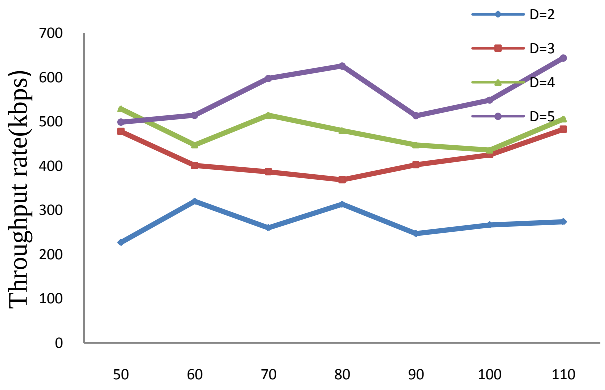

Figure2: Throughput Vs number of nodes

It is a measure of the amount of data transmitted from the source to the destination in a unit period of time (second). The throughput of the network is finally defined as the average of the throughput of all nodes involved in data transmission, for better performance the throughput must be high. Based on proposed algorithm, it is intended to solve the throughput optimization problem with different number of nodes and different destination nodes. Assuming the neighbor node density to be constant for all the network models, it is achieved that optimal throughput improvement using unequal timeshare whose performance parameters depend on the flow conservation constraints and link capacities. With the increase in the network size the number of variables and constraints also varies, thereby making the optimization problem more complex. The simulation results are self-explanatory, where it can be observed that the throughput rate is increased with the number of nodes in the network model, thereby achieving the required throughput maximization.

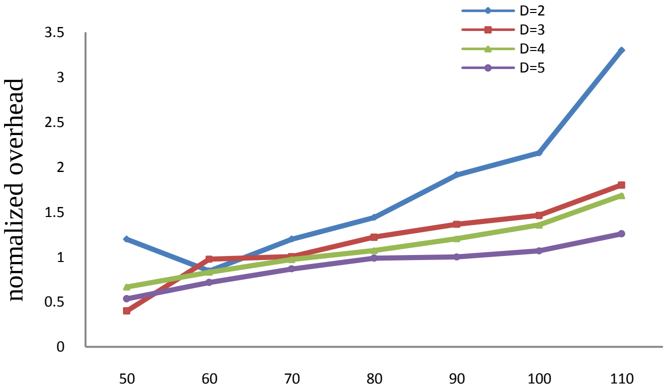

Figure3: Normalized overhead vs number of nodes.

Packet Delivery Ratio (PDR) indicates the percentage of the transmitted data packets that are successfully received. The PDR is the ratio of the number of packets generated at the source of the number of packets received by the destination.

From the above simulation results it is observed that the Packet Delivery Ratio is affected with the increase in node density and is more for model with less number of destination nodes. Hence, as the numbers of destinations are increased, the PDR is decreased. This performance can be reasoned due to the congestion in the network having high node density; it drops a large number of data packets due to increased collision between the nodes. Normalized Routing Overhead is defined as the total number of routing packets transmitted per data packet. It is calculated by dividing the total number of routing packets sent (includes forwarded routing packets as well) by the total number of data packets received. It can be observed that the normalized routing overhead is increased with the increase in the number of nodes, which is an advantage of the system having large node densities.

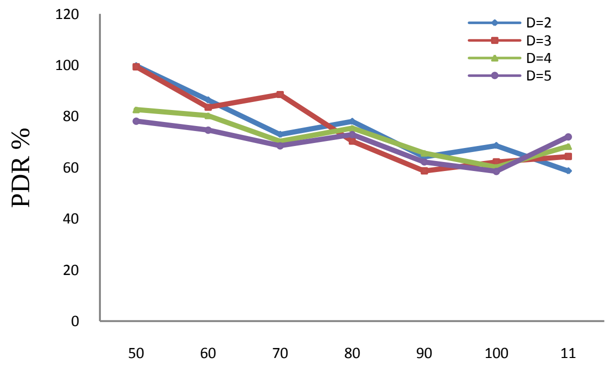

Figure4: PDR vs Number of Nodes

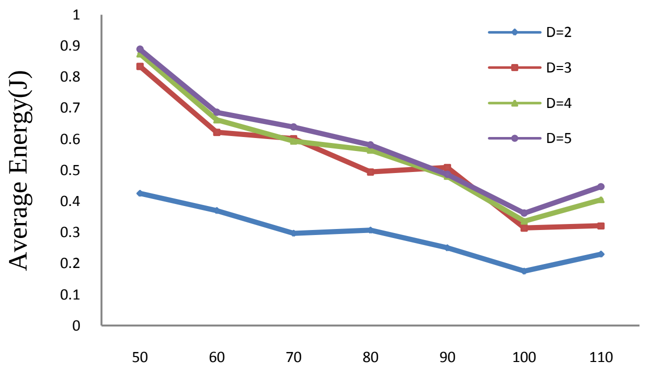

Figure5: Average energy vs. Number of Nodes

The average energy is the measure of percentage energy consumed by a node with respect to its initial energy. Hence, it is concluded that as the number of nodes increases the energy consumed by each individual nodes decrease, and thereby saving the energy.

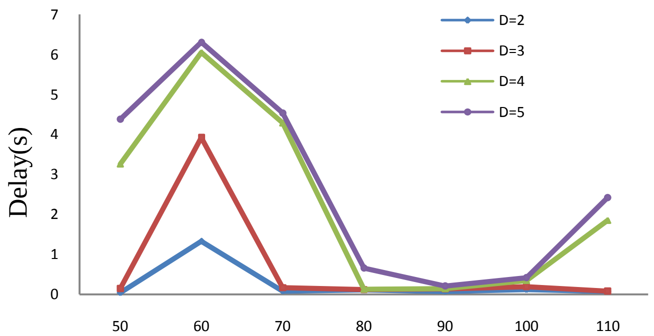

Figure6: Delay vs Number of Nodes

The delay is the time taken for a data packet to reach the destination node.This delay is built up by all the delays in the network that adds together, which might be due to the time spent in packet queues, forwarding delays, propagation delay and the time needed to make retransmission if a packet get lost etc. Due to the adopted caching route technique (network realization), since the number of computations to form routes increase with the node size, It is observed that the average delay increases with the increase in the node density. However, once the routes are created, on demand on a large network, the delay becomes less as observed in the graph. The graph depicts the total energy of the network model with respect to the varying node densities. The total energy is formulated as,

Energy= (number of packets received × energy to receive a single packet) + (number of packets sent× energy to transmit single packet) + (number of packet overheads × energy for overhead packet)

It can be observed that the total energy is a variant of overhead packet. And the total energy increases with the increase in node densities.

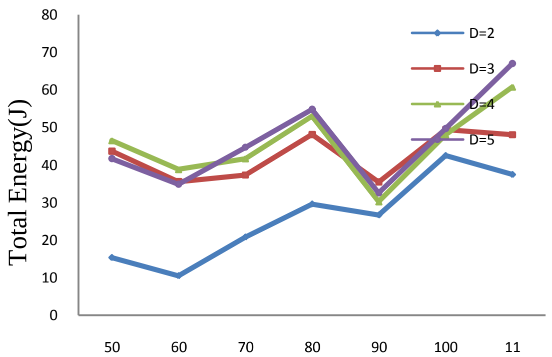

Figure7: Total Energy vs Number of Nodes

5.4 Performance Comparison

The performance parameters such as PDR, number of nodes, energy and delay of proposed method is compared with existing methods and is presented by Meenakshi and Ramanaiah [20], Priya and Solai Manohar [21], Chiraz Chaabane et al.,[22] is tabulated in Table 2. It is observed that the number of nodes used in the proposed method is high with moderately high PDR compared to existing methods. The delay is less with moderate energy values in the case of proposed method compared to existing methods. The proposed method has better performance compared in existing methods since

(i) the virtual node concept is used in configuring the network.

(ii) The realization link function is used to find the availability of the optimum link in the realization phase.

(iii) The time shares are computed for both non interference and interference links and considered only non interference links from scheduling.

(iv) The network coding is used to support scalability for high throughput.

Sl No	Authors	Technique		Results			
				PDR%	Number of Nodes	Energy (J)	Delay(ms)
1.	Meenakshi and Ramanaiah [20]	Performance Evaluation and Analysis of MAC protocols.	S-MAC	90	10	18	2
			IEEE 802.11	99.9	10	1	0
2.	Priya and Solai Manohar [21]	EE- MAC: Energy Efficient Hybrid MAC.	HyMAC	35	60	3.3 (μ)	12.2
			EE-MAC	69	60	3 (μ)	4.2
3.	Chiraz Chaabane et al.,[22]	A Joint Mobility Management Approach and Data Rate Adaptation Algorithm for IEEE 802.15.4 nodes.	MM	15	30	0.4 (m)	-
			STD	9	30	0.2 (m)	-
4.	Proposed Method	Energy Efficient Multicast Algorithm based on combined optimization and network coding algorithm to provide access to the shared media in wireless networks.		70	100	0.4	0.2

Table 2 Performance Comparison of proposed method with existing methods

6. Conclusion

A network plan that is an efficient routing algorithm to multicast the information for wireless network is implemented using combined scheduling and Network coding. Proposed model is the design to provide an energy and throughput optimization for multi hop wireless network. Hence proposed model achieves optimum performance, and includes a network code that supports the broadcast property of wireless network. Shows better performance in comparison with the networks with this proposed approach. The future work includes solving the interference problem for a scaled network based on more efficient interference models and adaptive network coding theories for more complex network scenarios.

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