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LINK STABLE INTELLIGENT CACHING MULTIPATH AND MULTICAST ROUTING PROTOCOL FOR WSN

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***Abstract* -** Quality of Services is an important aspect in Wireless Adhoc network, where nodes are organized with reduced resources like low energy and low bandwidth due to the lack of network infrastructure. There are various QOS aware routing protocol presented to improve the link quality to enhance the WSN quality of services, but most of these protocols were limited to efficient routing and to minimizing the overhead. Moreover many of these protocols suffer from design issues which makes quality of service ,a challenging research task due to lack of efficient routing protocols . In this protocol we propose a new multipath, multicast routing protocol that addresses the issue of route congestion .In this protocol we propose a Link Stable Intelligent Caching Multipath and Multicast Routing protocol for WSN by adopting particle swarm optimization technique to identify the optimal route and employed intelligent caching to minimize route congestion and to improve the load balancing.

***Keywords* :**WSN, PSO, Load Balancing, Caching, QOS in wireless sensor network

I. INTRODUCTION

A network of spatially distributed autonomous sensors is called a Wireless Sensor Network (WSN) . Various physical and environmental conditions such as temperature, sound, pressure, or pollutant etc. can be monitored by these battery powered tiny sensors in the network and the information is sent back to a base station which can take appropriate action. These sensors can also be used for animal tracking, in disaster management, and also for battle surveillance. The tiny sensors in the network have limited battery power and hence it is a most challenging task to design an energy efficient network which can minimize the energy consumption to improve the lifetime of heterogeneous Wireless Sensor Networks.

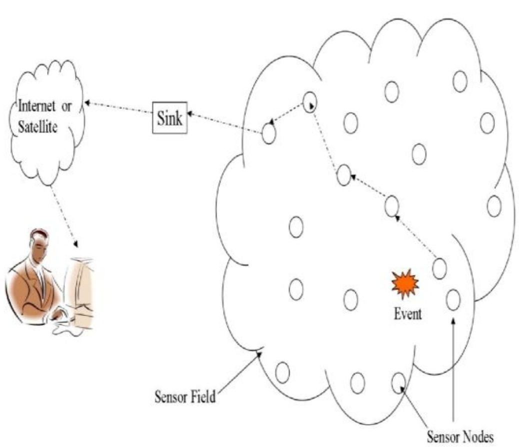


Figure1. Architecture of Wireless Sensor Network

- Routing in WSN turns out to be a more difficult job mainly due to
  - Recurrent changes in network topology
  - Link failure as Wireless links are more prone to errors
  - End-to-End QoS requirement, in terms of bandwidth or delay.
  - Maximizing the utilization of network resources.

However, researchers dealing with providing Energy efficiency with QOS guarantees for real time traffic in sensor networks have not fully addressed the following issues:

A) The node intimates the source with the congestion notice (CN) message.

B) Upon receiving CN message, the source node stops sending the data packet through the route containing the congested node.

C) Then the source verifies its route cache for other possible paths for transmitting the data packet.

D) If source node finds that the routes are available in its route cache, then it utilizes the direct random transmission technique to proceed with packet transmission through multiple paths for balancing the load.

E) If the source node does not find the routes in its route cache, then it re-establishes multiple routes.

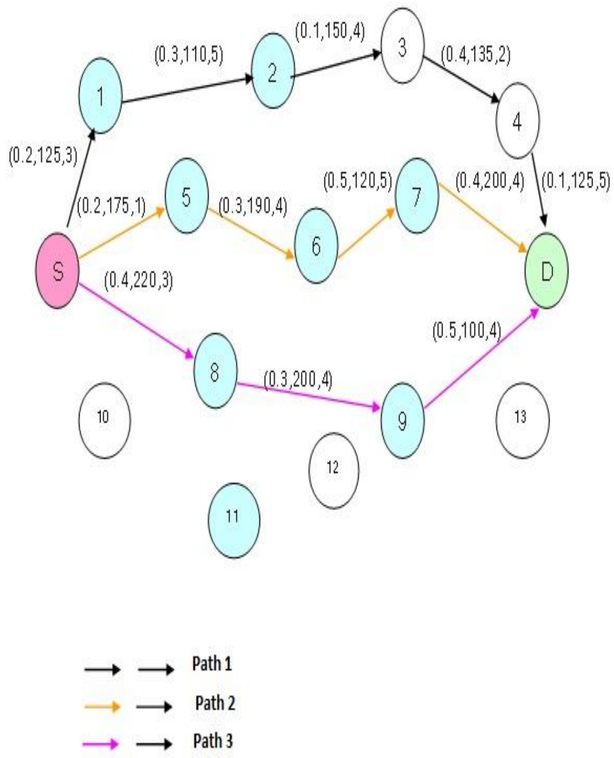


Figure 2 Sample network for Route Establishment

In this paper we proposed a Link Stable Intelligent Caching Multipath and Multicast Routing Protocol (LSICMMR) for sensor networks to minimize overhead, which in turn increases the throughput. Link Stable Intelligent Caching Multipath and Multicast Routing protocol for load balancing in wireless sensor network alleviates the network congestion by a load balancing scheme.

This proposed protocol in Wireless Sensor Network helps in storing the number of routes that are learnt without erasing the entries in the cache. It reduces the average end-to-end latency and gives quicker response to nodes, which in turn maximizes the lifetime of the network efficiently.

This paper compares the performance of the proposed protocols with existing protocols like MPOLSR, and LSICMMR through simulation and proves that the proposed approach reduces the delay, overhead ratio and energy consumption while alleviating throughput by using QOS metrics such as throughput, packet delivery ratio, end-end delay and average residual energy. The protocol also uses efficient load balancing technique and an intelligent cache technique to improve network performance.

The rest of the paper is organized as follows, Section I contains an introduction to QOS in Wireless Sensor Networks., Section II contain the related work of other n authors on efficient multicast multipath QOS routing algorithms with load balancing and caching of paths. Section III discusses formation of QOS aware route formation. Section IV explains the proposed Multicast protocol. Section V analyzes the performance of the proposed Link stable Intelligent Caching Multipath and Multicast Routing Protocol (LSICMMR) by employing a WSN model.

II. RELATED WORK

Yi, J., Adnane et al [1] have proposed MP- OLSR protocol that chooses a shortest path by using Multipath Dijkstra Algorithm to obtain multiple paths. The work does not address the issues related to QOS link quality or route metrics. P. P. Tandon et al [2] have proposed a novel congestion avoidance based load balanced routing with optimal flooding in Wireless network. The work did not take traffic load and hop count metric into consideration for selecting the route that reduces the network performance.

Dong Lee et al [3] have proposed new cache-storage mechanism named redundant cache by revising the original one. The main drawback of this method is all nodes are having the cache path resulting in wastage of cache.

Samuel Pierre et al.[4] have proposed a new approach based on a mobile routing backbone for supporting Quality of Service (QOS) in WSNs. This protocol does not consider the route maintenance and link quality as a metric. Shruti Sangwan et al [5] have proposed adaptive and efficient load balancing schemes to achieve fair routing in mobile ad hoc networks. But this scheme does not consider the congestion reduction technique in multipath routing.

Shobha.K.R et al.[6], have proposed an analysis of the effect of intelligent caching in a non-clustered network using on-demand routing protocols in wireless ad hoc networks. This technique helps in storing more number of routes that are learnt without erasing the entries in the cache, to store a new route that is learnt.

The Drawbacks of the mentioned protocols motivated the authors to develop an efficient hybrid multipath QOS routing protocol to address the problem of scalability, security and a network with good QoS provision.

III. QoS AWARE ROUTE FORMATION

Consider the values of parameters such as residual battery power, queue length and residual bandwidth that are estimated using equation (1), (2) and (3) respectively. The parameters for each link are mentioned in Figure 2 in format: (residual battery power, queue length, residual bandwidth).Based on the values given in the Figure 2, Link metric (LM) value is estimated. Assume the values of normalization factor α, β and η as 0.2, 0.5 and 0.3 respectively.

Path 1: (1.1, 645, 19)
Path 2: (1.4, 685, 14)
Path 3: (1.2, 520, 11)
As per the below Equation, LM value for path value is calculated as follows:

$LM = (\eta * QL) / [(\alpha * P_R) + (\beta * B_R)]$

For Path 1,
LM = (0.3 * 645) / ((0.2*1.1) + (0.5*19)) = 19.9
Similarly,
For Path 2, LM = 28.22
For Path 3, LM = 27.17
Finally, the path with minimum LM value (i.e. Path 1) is chosen for data transmission
The Mathematical analysis for Figure 2 is estimated using the equation, $LM = (\eta * QL) / [(\alpha * P_R) + (\beta * B_R)]$ both theoretically and practically. The comparison is given below:

Table 1: Link Cost Metric for Nodes at time 5 seconds

Node id	Theoretical Value	Practical Value
1	24.35	25.00
2	12.80	14.00
3	22.27	24.00
4	37.50	39.21
5	50.48	52.17
6	27.66	30.00
7	13.80	15.50
8	41.70	43.00
9	29.12	31.57

IV. PROPOSED MULTICAST PROTOCOL

In this paper we propose a Link stable Intelligent Caching Multipath and Multicast Routing Protocol (LSICMMR) which is designed based on link stability using Particle Swarm Optimization (PSO) and load balancing and load minimizing using intelligent caching. In this protocol the packet switching is scheduled based on its link load through the chosen intelligent path using particle swarm optimization. After establishing the path, data packets in the source node are scheduled to the destination based on its urgency using PSO based packet scheduling algorithm.

A. Particle Swarm Optimization for packet scheduling

In Particle Swarm Optimization (PSO), a particle is a complete single solution of problem and a Swarm is a group of particles, which searches for an optimum solution. The velocity and position of each particle is updated based on equations (1) and (2) respectively

$$V_{t+1} = W \times V_t + C_1 \times r_1 (P_{best} - x_t) + C_2 \times r_2 (g_{best} - x_t) \quad (1)$$

$$X_{t+1} = X_t + V_{t+1} \quad (2)$$

Step1: Set particles or solutions
Step2: Initialize Position x=0,Velocity=0, P_{best} =0, P_{best}= g_{best}
Step3: Update position and velocity
-Position of the particle(solution) is represented by

$$X_i = X_1, X_2 \ldots\ldots X_N$$

Where
$X_1 = U_{pkt1}(t)$
$X_2 = U_{pkt2}(t)$
.
.
.
$X_N = U_{pktN}(t)$

Where ,$U_{pkt}(t)$ is packet urgency at node along the route at time t.
S Step4: *if* $F(X_{new}) < F(P_{best})$
$P_{best} = X_{new}$
Else go to step3
if $F(X_{max}) < F(g_{best})$
g_{best} =Xnew
else go to step3

Step5: Process repeated until optimal solution is obtained.
Step6:The data packet will be scheduled from the node based on its urgency(priority)

B. Congestion Aware and Load Balancing

Intelligent cache is used to save the path discovered during route discovery and make the decisions when the route is broken. This technique helps in storing the number of routes without erasing the entries in the cache while storing a new route. In cache based Hybrid Multipath Routing Protocol, cache updating and intelligent cache are two big issues. To resolve these issues, the proposed technique is intelligent caching and redundant cache technique in Hybrid Multipath Routing protocol. In redundant cache, some information is included about the upstream path and that information helps to make a quicker response and reduce the average end-to-end latency. Issues of Caching Method are stale cache paths and low quality cache paths.

In this protocol the Topology Information Table (TIT) has to be updated frequently in order to keep the latest routing information. If the updating frequency is too low, broken routes or stale routes will be present in the table, which leads to transmission failure. If the updating frequency is too high, it will lead to high control overhead. It is necessary to design route maintenance or updating technique to remove the stale and broken routes from the topology table and reduce the control overhead.

In redundant cache, the upstream path is the path between the local hosts to the destination. Downstream path is the path between local hosts to the first node in the cached address sequence; some information about the upstream nodes is also attached. This information helps in quicker response and reduces average end-to-end delay.

In the discovered route, the node is likely to be congested during any of the following cases.

Case 1.When the nodes receive excess data packets, the node queue length (QL) increases.

i.e.

If QL>QLth

Then

Congestion occurs

End if

Case 2. When the nodes residual bandwidth is below the threshold, then the node suffers from lack of bandwidth during transmission of data. i.e.

If $B_R < B_{Rth}$

Then

Congestion Detected

End if

Case 3 Congestion occurs when the nodes residual battery power is below the threshold value.

i.e $P_R < P_{Rth}$

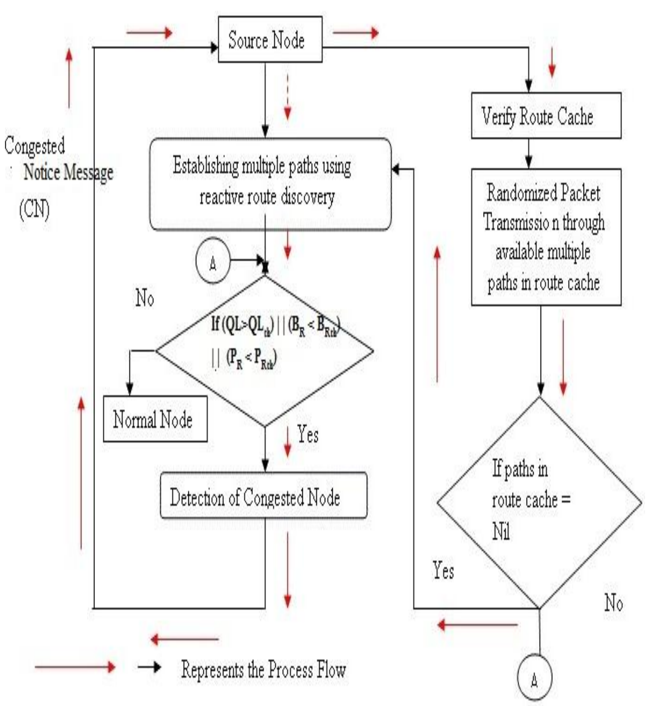
If $(QL > QL_{th}) \,||\, (B_R < B_{Rth}) \,||\, (P_R < P_{Rth})$

Then

Congestion detected

End if

The congestion may result in increased packet loss rate, channel quality degradation, and increased delays. In order to overcome these drawbacks, the following congestion mitigating technique is considered.



. Figure 3.Congestion Adaptive Multi-path Routing approach

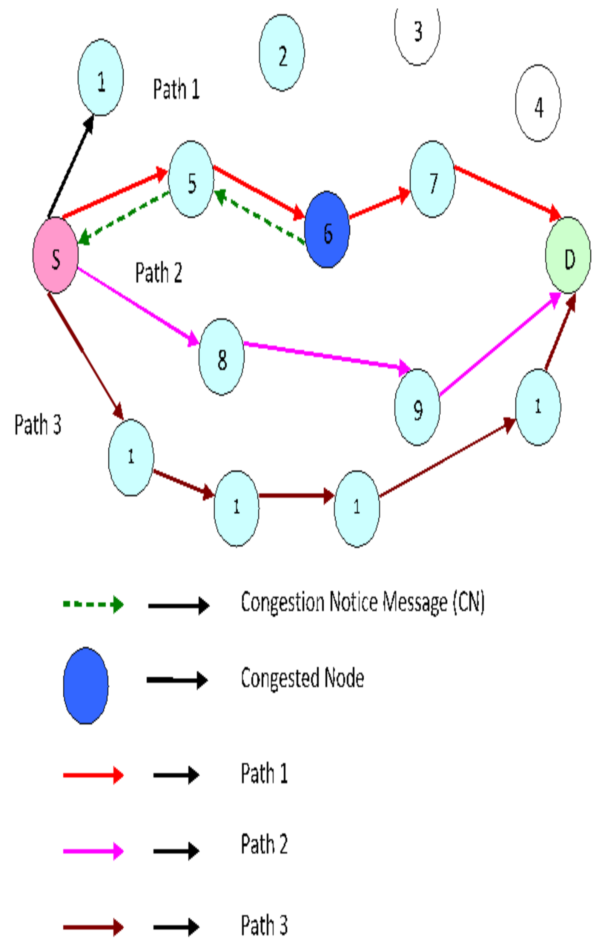


Figure 4.Congestion Detection

C. Load Balancing Technique

Each node in the network holds the topology information table (TIT) that contains the ids of the nodes within the two-hop distance .

The steps involved in the direct random transmission technique are as follows

Step 1:

When a source wants to transmit the data packets to the destination, it adds a time-to-live (TTL) field to each data packet. The initial value of TTL field is set by the source node for controlling the total number of randomized transmission.

Step 2:

The source node also adds the lists of last hop neighbor nodes (H_{neigh}) to the packet header. The format of the data packet is shown in Table 2.

Table 2: Data packer format

Source Node ID	*Time To Live (TTL)*	*Last Hop Neighbor Node*

Step 3:
After updating both TTL and H_{neigh} , the source node starts transmitting the data packet.

Step 4
When any intermediate node receives the data packet, it compares the $\mathbf{H_{neigh}}$ field against its own neighbor list and randomly selects one node from its neighbors that are not included in the $\mathbf{H_{neigh}}$.

Step 5
The intermediate node then decrements the TTL value, updates the $\mathbf{H_{neigh}}$ field, and transmits the data packet to the next hop node, and this process continues till the overlapping of the Hneigh field occurs.

Step 6
If $\mathbf{H_{neigh}}$ field completely overlaps or it possess the transmitting node's neighbor list, then a random neighbor is drawn from the neighbor list and transmits the packet to it.This technique proves to be very efficient load balancing technique and improves the performance efficiency.

Algorithm 1: Intelligent Cache

1 Start
2. Paths are selected and Cached at Cache node
3. If (Source node found)
4. {
5. Go to step 11
6. }
7. Else
8. {
9. Intermediate node forwards the packet to the next node based on cache.
Go to 3
10. }
11. Find the threshold value
12. If (Threshold = small)
13. {
14. Delay will increase and lot of memory will be wasted
15. }
16. If (Threshold = large)
17. {
18. Memory will be saved
19. }
20. If (Threshold = Too large)
21. {
22. Overhead and delay will be increased
23. }
24. End

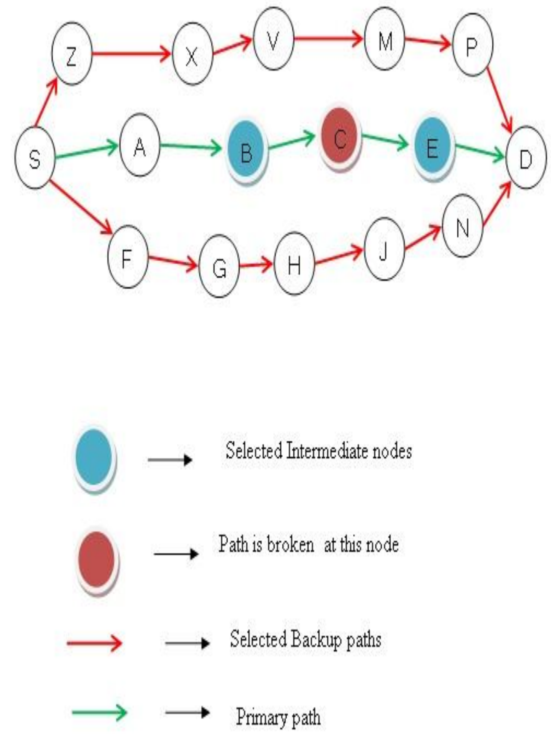


Figure5. Intelligent Cache path selection

V. EXPERIMENTAL STUDY

In this section, we analyze the performance of the proposed Link stable Intelligent Caching Multipath and Multicast Routing Protocol (LSICMMR) by employing a WSN model. We simulated WSN with set of sensor nodes and each node represented as a sensor device which captures data and transfers data towards destination. We compared the performance of AFDP on these parameters: packet delivery ration (PDR), Average throughput, Average delay, energy consumption and network overhead. We compared the performance of LSICMMR with MP-OLSR [5]. The proposed system is simulated with the network simulator-2 (NS-2)[12] with the simulation parameters of Table 3.

Table 3.. Simulation Parameters

No. of Nodes	**30, 50, 70, 90 & 110**
Area	**1250 X 1250 sq m**
MAC	**802.11**
Radio Range	**250 m**
Simulation Time	**50 sec**
Traffic Source	**CBR**

Rate	**2.5 Mbps**
Packet Size	**512 Bytes**
No. of connections	**7**
Mobility Model	**Random Way Point**
Speed	**10, 20, 30 & 40 m/s**
Pause time	**5 seconds**
RxPower	**0.395W**
TxPower	**0.660W**
Idle Power	**0.035W**
Initial Energy	**10.3Joules**

D. Performance Evaluation

- <u>*Average Packet Delivery Ratio*</u>:It is the ratio of the number of packets received successfully and the total number of packets transmitted.
- <u>*Throughput*</u>**:** It is the number of packets successfully transmitted per unit time.
- <u>*Control overhead*</u>: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.
- <u>*Average end-to-end delay*</u>**:**

End-to-end delay is the time taken for a packet to be transmitted across a network from source to destination and the average end to end delay is calculated in the following formula, where $T_{r_{ij}}$ is the packet received time of jth packet of node i and $T_{s_{ij}}$ is the packet sending time of packet j for node i and n is the total number of packets sent or received at node i.

$$E2E = \sum_{\forall i} \sum_{\forall j} \left(\frac{T_{r_{ij}} - T_{s_{ij}}}{n} \right)$$

- <u>*Energy consumed:*</u>
  It is the total amount of energy consumed by the nodes during the data transmission.

$$E = \sum_{\forall j} E_{C_j}$$

A. Performance Results

1) Effect of varying number of nodes

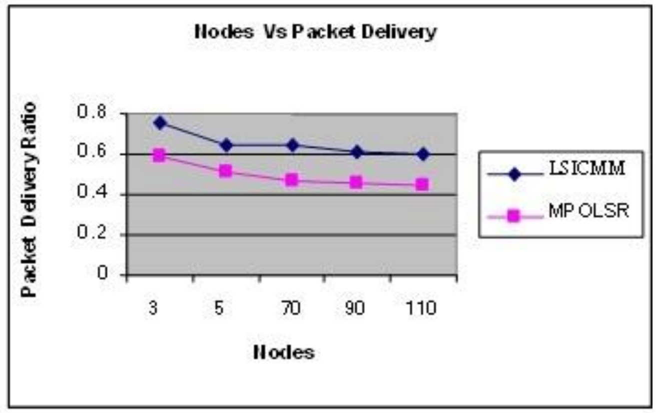


Figure 6. Nodes VS Packet Delivery Ratio

Figures 6 and 9 show that the proposed LSICMMR protocol achieves 23% better packet delivery ratio and 17% throughput than the MPOLSR.

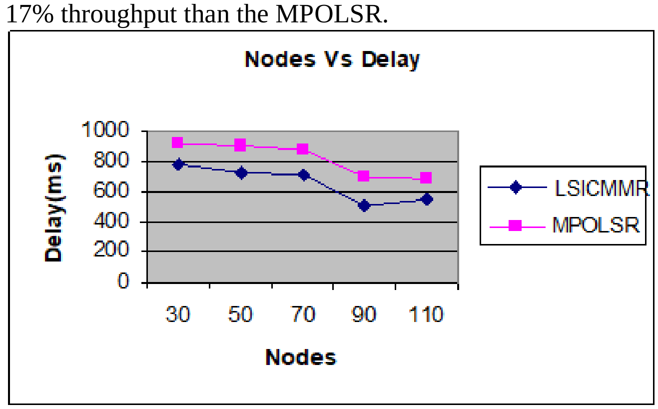


Fig 7. Nodes VS Delay

Figure 7 shows that LSICMMR protocol has 20% lower delay than the MPOLSR protocol.

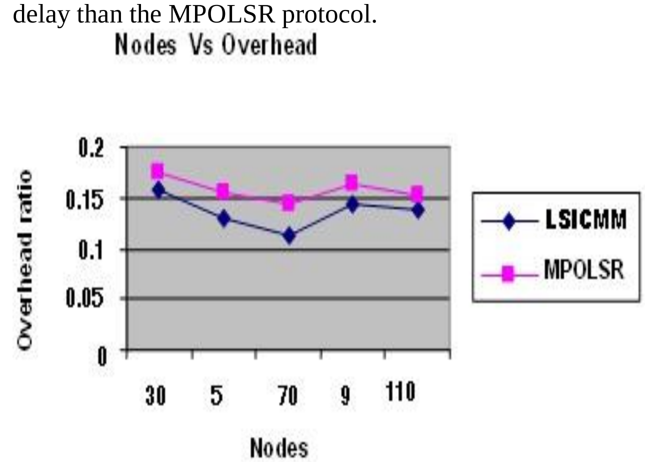


Figure 8.Nodes VS Overhead ratio

Figure 8 shows the results of routing overhead versus number of nodes. LSICMMR protocol has 13% less overhead than MPOLSR protocol.

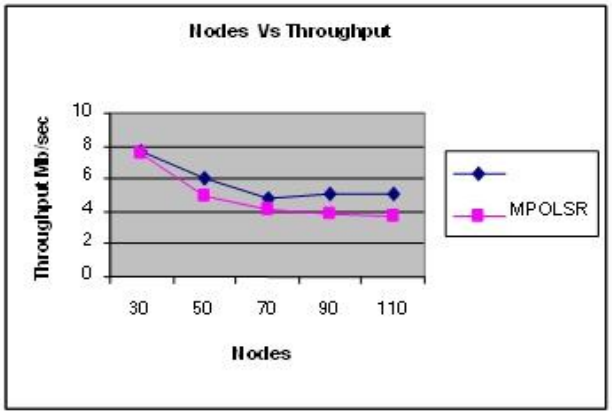


Figure 9. Nodes VS Throughput

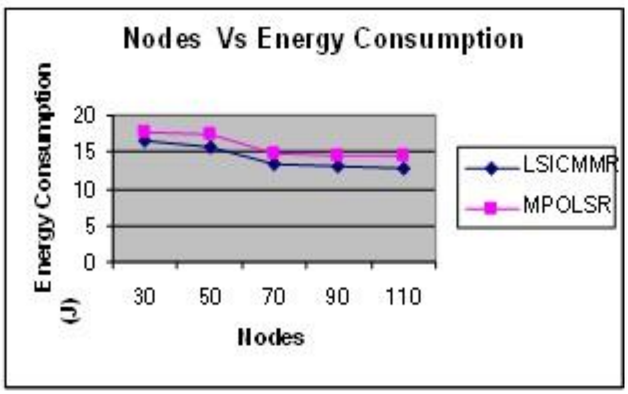


Figure 10. Nodes VS Energy Consumption

Figure 10 shows that the energy consumption for LSICMMR protocol is 13% less than MPOLSR.

2) Effect of Varying Transmission Rate

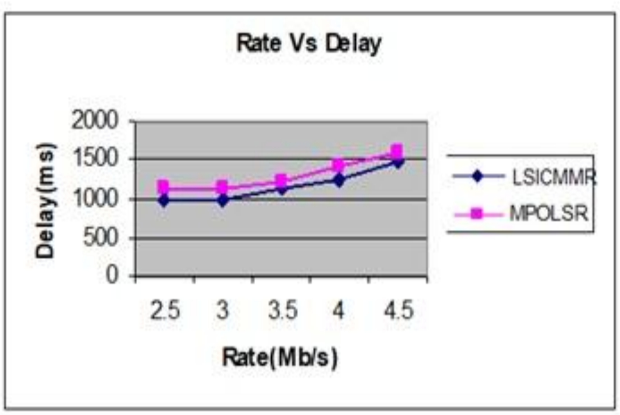


Figure 11. Rate VS Delay

It can be seen that the average end to end delay of the proposed LSICMMR is 10% less than the existing MP-OLSR protocol.

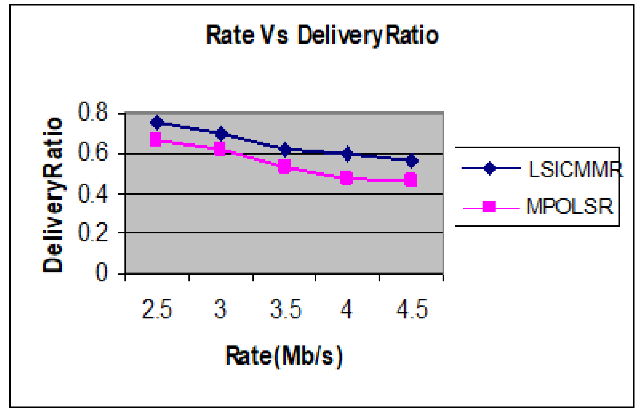


Figure12. Rate VS Delivery Ratio

Figure 12 shows that the delivery ratio of the proposed LSICMMR is 17% higher than the existing MP-OLSR protocol.

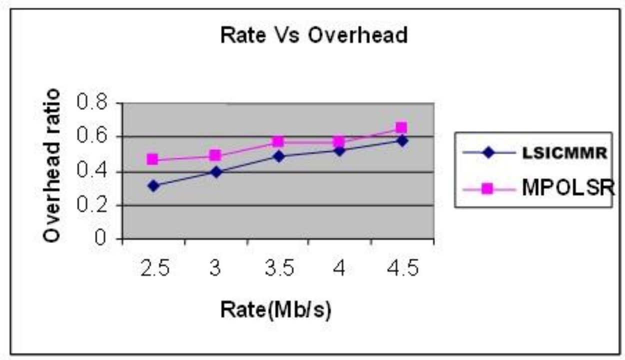


Figure 13. Rate VS Overhead Ratio

Figure13 explains that the overhead of the proposed LSICMMR is 23% less than existing MP-OLSR protocol

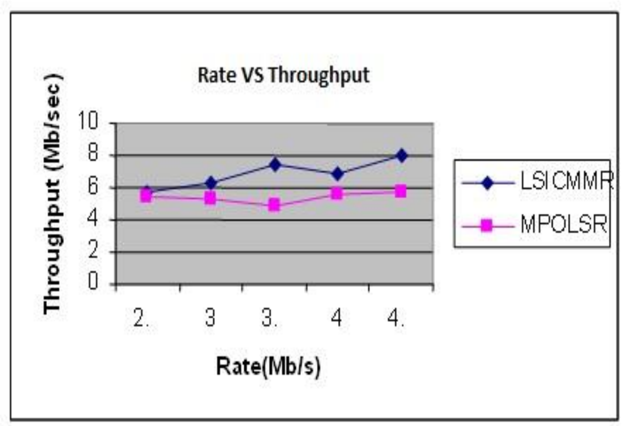


Figure 14. Rate VS Throughput

Figure 14 shows that throughput of the proposed LSICMMR is 19% higher than the existing MP-OLSR protocol.

VI. CONCLUSION

A Link stable Intelligent Caching Multipath and Multicast Routing Protocol (LSICMMR) (LSICMMR) protocol using Intelligent Caching in sensor networks is proposed along with Congestion Adaptive Multipath Routing for load balancing. This approach is a very efficient load balancing technique that improves network performance and alleviates the network congestion. The performance of the protocols is evaluated using application oriented metrics such as throughput, packet delivery ratio, end-end delay and average residual energy. These metrics are compared with existing protocols like MPOLSR, and LSICMMR using NS2. By simulation results, it is shown that the proposed approach reduces the delay, overhead ratio and energy consumption while alleviating throughput by using QOS metrics, efficient load balancing technique and intelligent cache technique to improve network performance.

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