Optimized MRMC technique in WMNs

Navreet Kaur[1], Jatinder Singh Saini[2]
Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab

Abstract**—** A wireless Mesh network consists of three main components: nodes, gateways, and software. The spatially distributed measurement nodes interface with sensors to monitor assets or their environment. In this research work the optimized MRMC protocol in WMNs is implemented on the basis of AACO optimization scheme. AACO is used to provide a reciprocal path for every link in case of its failure. In this method mutation operator, is used and the new mutation rate is generated by the self-adaptive approach The proposed approach helps to reduce the load and drops in the network, so using the proposed methodology the QOS parameters such as packet delivery ratio, throughput, overheads, average end-to-end delay, average energy consumption are quite improved as shown in the result section. The improvement of 16% is shown between the existing and proposed approach in above defined features.

Keywords**— WMNs, MRMC, ACO, AACO**

I. INTRODUCTION

A computer network is a digital telecommunications network which allows nodes to share resources. In computer networks, computing devices exchange data with each other using connections (data links) between nodes. These data links are established over cable media such as twisted pair or fiber-optic cables, and wireless media such as Wi-Fi. The physical layout of a network is usually less important than the topology that connects network nodes. Most diagrams that describe a physical network are therefore topological, rather than geographic. The symbols on these diagrams usually denote network links and network nodes. Network topology is the layout or organizational hierarchy of interconnected nodes of a computer network. Different network topologies can affect throughput, but reliability is often more critical. With many technologies, such as bus networks, a single failure can cause the network to fail entirely. In general the more interconnections there are, the more robust the network is; but the more expensive it is to install.

Common layouts are:

- **Bus network:** All nodes are connected to a common medium along this medium. This was the layout used in the original Ethernet, called 10BASE5 and 10BASE2. This is still a common topology on the data link layer, although modern physical layer variants use point-to-point links instead.
- **Star network:** all nodes are connected to a special central node. This is the typical layout found in a Wireless LAN, where each wireless client connects to the central Wireless access point.
- **Ring network:** each node is connected to its left and right neighbour node, such that all nodes are connected and that each node can reach each other node by traversing nodes left- or rightwards. The Fiber Distributed Data Interface (FDDI) made use of such a topology.
- **Mesh network:** each node is connected to an arbitrary number of neighbours in such a way that there is at least one traversal from any node to any other.
- **Fully connected network:** each node is connected to every other node in the network.
- **Tree network:** nodes are arranged hierarchically.

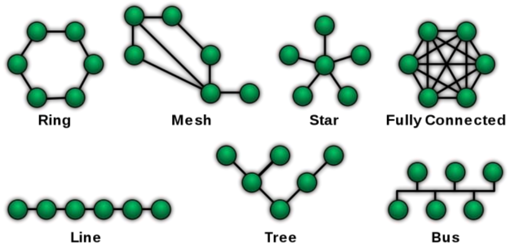

Figure 1: Network Topologies

II. MESH NETWORK

A mesh network (or simply meshnet) is a local network topology in which the infrastructure nodes (i.e. bridges, switches, and other infrastructure devices) connect directly, dynamically and non-hierarchically to as many other nodes as possible and cooperate with one another to efficiently route data from/to clients. This lack of dependency on one node allows for every node to participate in the relay of information. Mesh networks dynamically self-organize and self-configure, which can reduce installation overhead. The ability to self-configure enables dynamic distribution of workloads, particularly in the event a few nodes should fail. This in turn contributes to fault-tolerance and reduced maintenance costs.

Mesh topology may be contrasted with conventional star/tree local network topologies in which the bridges/switches are directly linked to only a small subset of other bridges/switches, and the links between these infrastructure neighbours are hierarchical. While star-and-tree topologies are very well established, highly standardized and vendor-neutral, vendors of mesh network devices have not yet all agreed on common standards, and interoperability between devices from different vendors is not yet assured.

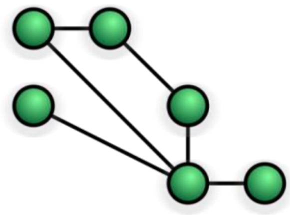

Figure 2: Mesh Network

III. Wireless Mesh Network

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. It is also a form of wireless ad hoc network.[1]

A mesh refers to rich interconnection among devices or nodes. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. Mobility of nodes is less frequent. If nodes constantly or frequently move, the mesh spends more time updating routes than delivering data. In a wireless mesh network, topology tends to be more static, so that routes computation can converge and delivery of data to their destinations can occur. Hence, this is a low-mobility centralized form of wireless ad hoc network. Also, because it sometimes relies on static nodes to act as gateways, it is not a truly all-wireless ad hoc network.

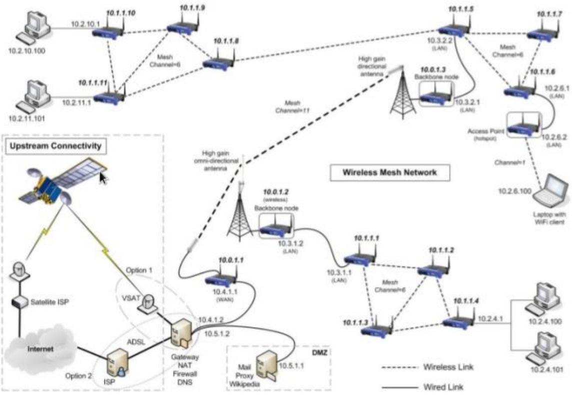

Figure 3: Wireless Mesh Network

Mesh clients are often laptops, cell phones, and other wireless devices. Mesh routers forward traffic to and from the gateways, which may, but need not, be connected to the Internet. The coverage area of all radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud depends on the radio nodes working together to create a radio network. A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes. Wireless mesh networks can self form and self heal. Wireless mesh networks work with different wireless technologies including 802.11, 802.15, 802.16, cellular technologies and need not be restricted to any one technology or protocol.

IV. Multi Radio Multi Channel Wireless Mesh Network

Multi-radio multi-channel (MRMC) wireless mesh networks (WMNs) achieve higher throughput using multiple simultaneous transmissions and receptions. However, due to limited number of non-overlapping channels, such networks suffer from co-channel interference, which degrades their performance. To mitigate co-channel interference, effective channel assignment algorithms (CAAs) are desired. In this article, we propose a novel CAA, Topology-controlled Interference-aware Channel-assignment Algorithm (TICA), for MRMC WMNs. This algorithm uses topology control based on power control to assign channels to multi-radio mesh routers such that co-channel interference is minimized, network throughput is maximized, and network connectivity is guaranteed. We further propose to use two-way interference-range edge coloring, and call the improved algorithm Enhanced TICA (e-TICA), which improves the fairness among flows in the network. However, the presence of relatively long links in some topologies leads to conflicting channel assignments due to their high interference range. To address this issue, we propose to utilize minimum spanning tree rooted at the gateway to reduce conflicting channels, and in turn, improve medium access fairness among the mesh nodes.

Channel Assignment: In radio resource management for wireless and cellular networks, channel allocation schemes allocate bandwidth and communication channels to base stations, access points and terminal equipment. The objective is to achieve maximum system spectral efficiency in bit/s/Hz/site by means of frequency reuse, but still assure a certain grade of service by avoiding co-channel interference and adjacent channel interference among nearby cells or networks that share the bandwidth.

Channel-allocation schemes follow one of two types of strategy:[1]

- Fixed: FCA, fixed channel allocation: manually assigned by the network operator
- Dynamic:
  - DCA, dynamic channel allocation
  - DFS, dynamic frequency selection
  - Spread spectrum

V. Related Work

In this section, we have a tendency to summarize and discuss connected authentication ways employed in follow or projected within the literature to boost positive identification authentication on the net and gift their limits.

Chaudhry, A.U.; et al. [1] proposed a novel CAA, Topology-controlled Interference-aware Channel-assignment Algorithm (TICA), for MRMC WMNs. This algorithm uses topology control based on power control to assign channels to multi-radio mesh routers such that co-channel interference is minimized, network throughput is maximized, and network connectivity is guaranteed. We further propose to use two-way interference-range edge coloring, and call the improved algorithm Enhanced TICA (e-TICA), which improves the fairness among flows in the network. However, the presence of relatively long links in some topologies leads to conflicting channel assignments due to their high interference range. To address this issue, we propose to utilize minimum spanning tree rooted at the gateway to reduce conflicting channels, and in turn, improve medium access fairness among the mesh nodes.

Mert Akdere et al (2006) [2]showed the applicability of epidemic algorithms in the context of wireless sensor environments, and provide a comparative performance analysis of the three variants of epidemic algorithms in terms of message delivery rate, average message latency, and messaging overhead on the network.

Nicolaos B. Karayiannisand S.M. NagabhushanKaliyur (2006) [3] introduced an entropy-constrained algorithm for routing of communication networks.

Ahmed Abbasiand Mohamed Younis (2007) [4]surveyed different clustering algorithms for wireless sensor networks (WSNs); highlighting their objectives, features, complexity, etc and also compared of these clustering algorithms based on metrics such as convergence rate, cluster stability, cluster overlapping, location-awareness and support for node mobility.

Sofiene Jelassi and Habib Youssef(2008) [5] described the design of a playout algorithm tailored for real-time, packet-based voice conversations delivered over multi-hop wireless ad-hoc networks.

Lei Guoet al (2008) [6] addressed the problem of shared sub-path protection with considering the constraint of traffic recovery time and proposed a new heuristic algorithm called Traffic recovery time Constrained Shared Sub-Path Protection (TC_SSPP) to compute the working path and the Shared-Risk-Link-Group (SRLG)- disjoint backup sub-paths. The main target of this work was to improve the resource utilization ratio and reduce the blocking probability for dynamic network environment. By properly setting the delay parameter for each link and running the Delay Constrained Shortest Path Algorithm (DCSPA) to compute the backup sub-paths, TC_SSPP can effectively guarantee the traffic recovery time. Simulation results showed that the proposed TC_SSPP can outperform the traditional algorithms.

An energy-efficient multi-level clustering algorithm called EEMC, which was designed to achieve minimum energy consumption in sensor networks was proposed by Yan Jin et al (2008) [7].

Several multi-sender algorithms are proposed to reliably deliver a media stream to the receiver through the intrinsically unreliable peer-to-peer(P2P) networks by Mohammad Hamed Firooz et al (2009) [8]. A routing algorithm termed Energy-efficient Routing Algorithm to Prolong Lifetime (ERAPL) was proposed by Yi-hua Zhu et al (2010) [9], which is able to dramatically prolong network lifetime while efficiently expends energy. ently expends energy.

LannySitanayah et al (2010) [10] proposed a heuristic algorithm to find the boundary nodes which are connected in a boundary cycle of a location-free, low density (average degree 5–6), randomly deployed WSN and developed the key ideas of our boundary detection algorithm in the centralized scenario and extend these ideas to the distributed scenario.

PatrikMoravek et al (2011) [11] was focused on the sophisticated Vivaldi algorithm and its variations. A special simulation tool was developed in order to simulate the influence of configuration parameters and setting to algorithm performance. Several tests were performed to examine how both convergence and accuracy of localization process are affected by different settings of algorithm constants and by the number of reference points.

P. Mérindol, P. Francois, O. Bonaventure, S. Cateloin, J.-J. Pansiot et al (2012) [12] was presented an efficient algorithm that allows routers to enable more path diversity andthey achieves a good tradeoff between path diversity and overhead.

EimanAlotaibi, Biswanath Mukherjee et al(2012) [13] presenteda survey of the routing algorithms proposed for wireless networks. A number of routing algorithms have been proposed as extensions to these basic routing algorithms to enhance their performance in wireless networks.

Jiong Jina, Marimuthu Palaniswamia, Bhaskar Krishnamachariet al (2012) [14] addresses the rate control and resource allocation problem for heterogeneous wireless sensor networks, which consist of diverse node types or modalities such as sensors and actuators, and different tasks or applicationsand they also developeda utility framework of rate control for heterogeneous wireless sensor networks with single- and multiple-path routing, and propose utility fair rate control algorithms, that are able to allocate the resources efficiently and guarantee the application performance in a utility proportional or max–min fair manner. Furthermore, the optimization and convergence of the algorithm is investigated rigorously as well.

VI. EXISTING STUDY

Multi-Radio Multi-Channel Wireless Mesh Networks achieve higher throughput using multiple simultaneous transmissions and receptions. However, due to limited number of non-overlapping channels, such networks suffer from co-channel interference, which degrades their performance. To reduce co-channel interference, effective channel assignment algorithms (CAAs) are desired. So, Co-Channel interference and energy consumption are the key issues which are still to be solved. Topology control is another critical design issues in multi-hop wireless networks. It has been investigated extensively in the literature. Many techniques have been proposed to solve these problems such as a novel CAA, Topology-controlled Interference-aware Channel-assignment Algorithm (TICA), for MRMC WMNs has been developed. Furthermore, an improved algorithm i.e., Enhanced TICA (e-TICA), which improves the fairness among flows in the network has been developed. Also, an algorithm e-TICA version 2 (e-TICA2) has been developed to improve the network performance. Still the problem of Co-channel interference exists in network.

Previous study also shows that a simple topology control scheme has been introduced that maximizes the overall throughput in a network with random unicast traffic demands. For this topology control scheme, it is also shown that other advanced technologies, including network coding and Physical Layer Network Coding (PLNC), can be applied to significantly improve the throughput capacity of the network. The connectivity of WMN should be ensured in the process of assigning channels to the radios. Any change in the CA is likely to render certain links to be non-existent. Consequently, flows that are utilizing these links are disrupted and need to be re-routed, which in turn impacts the network throughput. Proposed work aims to delete the extra links without which the data can be transferred. With this, the interference can be minimized and data loss is reduced.

VII. AACO

ACO is characterized as a policy search strategy aimed at learning the distributed parameters (called pheromone variables in accordance with the biological metaphor) of the stochastic decision policy which is used by so-called ant agents to generate solutions. A population-based method that can be used to find approximate solutions to difficult optimization problems. ACO algorithm was called the Ant system and it was aimed to solve the travelling salesman problem, in which the goal is to find the shortest round-trip to link a series of cities. The general algorithm is relatively simple and based on a set of ants, each making one of the possible round-trips along the cities.

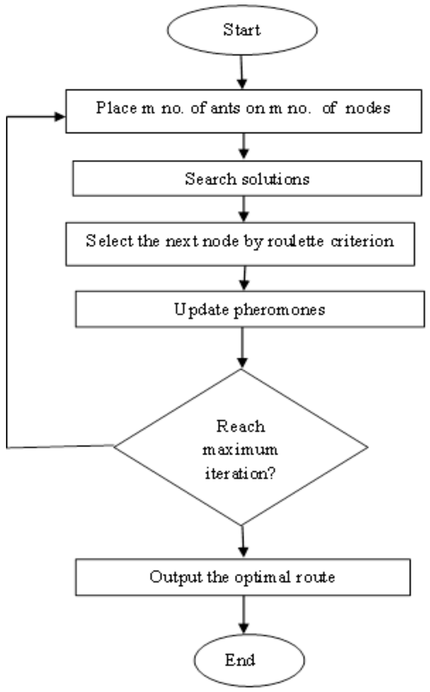

Fig 4: Flow Chart of ACO

At each stage, the ant chooses to move from one city to another according to following rules:

1. It must visit each city exactly once.
2. A distant city has less chance of being chosen.
3. The more intense the pheromone trail laid out on an edge between two cities, the greater the probability that that edge will be chosen.
4. Having completed its journey, the ant deposits more pheromones on all edges it traversed, if the journey is short
5. After each iteration trails of pheromones evaporate.

In ACO, a set of software agents called artificial ants search for good solutions to a given optimization problem. To apply ACO, the optimization problem is transformed into the problem of finding the best path on a weighted graph. The artificial ants incrementally build solutions by moving on the graph. The solution construction process is stochastic and is biased by a pheromone model, that is, a set of parameters associated with graph components (either nodes or edges) whose values are modified at runtime by the ants. All the ants cover all the nodes once and come back to the source that is from where they started their journey.

VIII. SIMULATION ENVIRONMENT

During preliminary study it has been studied that, there are a number of parameters that are to be assumed before the simulation like Frame Duration, frequency Bandwidth, Mode of transmission, network size etc. The area taken into consideration is 100*100m. For the implementation of coverage techniques in WSN, simulation parameters used are shown in Table 1.

Table 1 Simulation Parameters for MRMC Protocol

Simulation parameters	**Value**
Frame duration	1ms
Frequency bandwidth	25MHZ
Mode of transmission	TDD
Packet size	5kb
Simulation grid size	100m*100m
Rounds	3000
Initial Energy	0.5J
Energy for transmission	50*0.000000001J
Energy for reception	50*0.000000001J
Energy for Amplification	0.0013*0.000000000001J
Energy for Data Aggregation	5*0.000000001J

Performance Metrics

Performance metrics are the parameters on the basis of which we analyze the performance of the network. The performance metrics that are to be used are packet delivery ratio, average end-to-end delay, overheads, throughput, average energy consumption which are discussed below.

1. Packet Delivery Ratio: The first metric is PDR, which is defined as the number of packets successfully received Prx, to the number of packets transmitted Ptx. As shown in equation 1.

$$PDR = Prx/Ptx \quad (1)$$

Where Prx is packets received and Ptx is packets transmitted

2. Average End-to-end Delay: It is the average time between a packet being created and being delivered to the sink. The average delay in a TDMA multi-hop based protocol depends greatly on the order of the allocated time slots of the forwarding nodes.

3. Overhead: Overhead is a major factor in designing routing protocols for mobile sensor networks since more no. of packets can cause congestion, which will limit the throughput of data. There are generally two types of overhead; packet overhead and control overhead. Packet overhead is the ratio of non-data bits to data bits in a data packet. Control overhead is the ratio of bits in control packets to bits in data packets. Control packets are often used to negotiate channel access, discover routes or share topology information.

4. Throughput: Throughput is defined as the number of data bits successfully delivered to the sink in predefined time.

5. Average Energy Consumption: It is the energy consumed in transmitting and receiving the message packets in a mobile wireless sensor network.

IX. RESULTS

In this research various performance metrics are improved by using the optimization schemes that is ant colony optimization and adaptive ant colony optimization. The effect on various QoS parameters such as Packet Delivery Ratio, Overheads, Average End-to-End Delay, Throughput, Average Energy Consumption have been observed by varying the no. of nodes i.e. 20, 40, 60, 80 and 100 nodes by taking same number of rounds. Firstly by taking the 20 number of nodes the values are plotted against packet delivery ratio. Then the average mean of ten values are taken and we get one value. The whole process is repeated for 40,60,80,100 no. of nodes. Similarly the values are plotted against throughput, overhead, average energy consumption and average end-to-end delay. The values are plotted by using both ACO and AACO optimization techniques.

Packet delivery ratio:

Figure 5 shows the PDR in existing MRMC, ACO and AACO the values are plotted against no. of nodes and packet delivery ratio. AACO-MRMC shows better results as compared to the ACO-MRMC and MRMC. . From the graph shown below it may be defined that the average value of Packet Delivery Rate in MRMC is least i.e. 0.68 whereas in case of ACO-MRMC it is slightly greater than that of MRMC i.e. 0.7 and in case of AACO-MRMC it is quite better and it is 0.8. According to this figure the proposed results shows 12.5% improvement in packet delivery ratio. If there is link breakage or there is a dead node in a network due to more energy dissipation; then we use the reciprocal path generated by AACO, as a result of which losses are reduced thus the packet drop is reduced so packet delivery ratio is improved in AACO-MRMC.

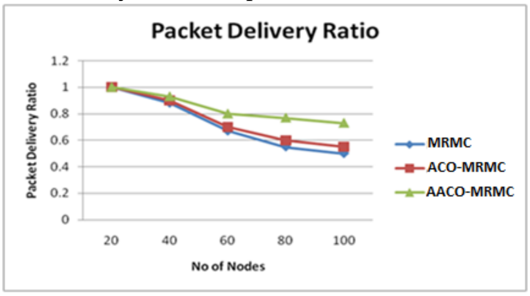

Figure 5: Comparison of PDR in MRMC, ACO-MRMC, AACO-MRMC

Average End-To-End Delay:

Figure 6 shows the graphical results of the existing MRMC protocol and ACO and ACCO based protocols. The values are plotted against the varying nodes. From the graph it may be seen that the average value of Average End-to-End Delay in MRMC is most i.e. 0.25 sec whereas in case of ACO-MRMC it is slightly less than that of MRMC i.e. 0.2 sec and in case of AACO-MRMC it is quite better and it is 0.135 sec. According to this figure the proposed results shows 4.5% improvement in average end to end delay. If there is a link down in the network; that energy of any node goes below the desired level then message will not reach to the destination in time. Due to which the messages are delayed in order to reduce this delay the message packets are forwarded to the new path that is generated by the ACO and AACO optimization technique. Hence AACO- MRMC will show better results than other two.

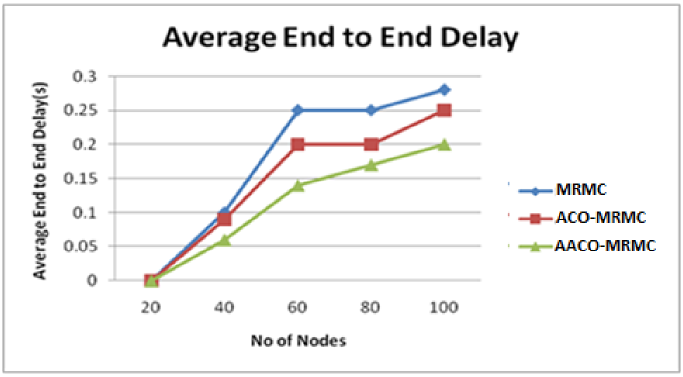

Figure 6: Comparison of Average End-to-end delay in MRMC, ACO-MRMC, AACO-MRMC

OVERHEAD:

Figure 7 compares the overhead in MRMC, ACO-MRMC, AACO-MRMC. The result is plotted against the overhead bitts and number of varying nodes. From the graph it may be defined that the average value of overheads in MRMC is most i.e. 1.1 whereas in case of ACO-MRMC it is slightly less than that of MRMC i.e. 0.9 and in case of AACO-MRMC it is quite better and it is 0.8. According to this figure the proposed results shows 27% improvement in overheads. As the packet drop is reduced due to new path generation the packet delivery ratio is improved; all the packets are delivered in time as the result of which overhead is reduced in AACO-MRMC.

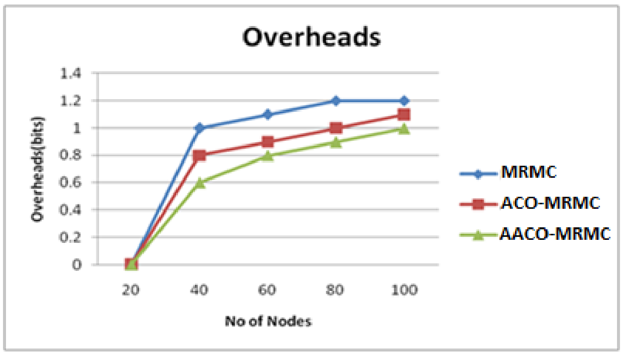

Figure 8: Comparison of Overhead in MRMC, ACO-MRMC, AACO-MRMC

Throughput:

Figure 9 represented the relation between MRMC, ACO-MRMC, AACO-MRMC. AACO-MRMC shows better results as compared to the existing protocol and the other one. From the graph it may be defined that the average value of throughput in MRMC is least i.e. 1000 bits whereas in case of ACO-MRMC it is slightly more than that of MRMC i.e. 1100 bits and in case of AACO-MRMC it is quite better and it is 1200 bits. According to this figure the proposed results shows 20% improvement in throughput. As the packets will take the reciprocal path more no. of packets will reach to the destination without any loss; which means maximum number of data bits will reach successfully to the sink hence throughput of AACO-MRMC is improved than the other two.

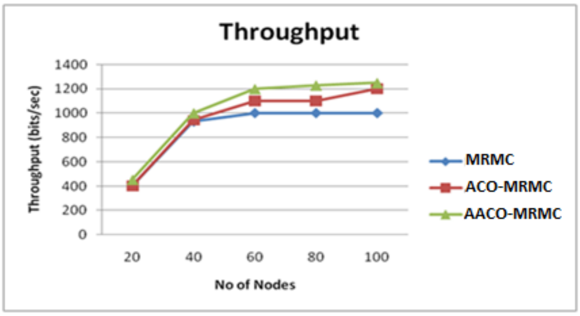

Figure 9: Comparison of Throughput in MRMC, ACO-MRMC, AACO-MRMC

Average Energy Consumption:

Figure 10 shows that there is less energy consumption in AACO-MRMC. From the graph it may be defined that the average value of Average Energy consumption in MRMC is most i.e. 0.0015 joule whereas in case of ACO-MRMC it is slightly less than that of MRMC i.e. 0.0013 joule and in case of AACO-MRMC it is quite better and it is 0.001 joule. According to this figure the proposed results shows 12.5% improvement in average energy consumption.As the packet drop is less; the re-transmission attempts for sending the message to receiver are less. So as a result of which there is less energy dissipation and hence there is less energy consumption in optimized scheme as compared to the existing protocol.

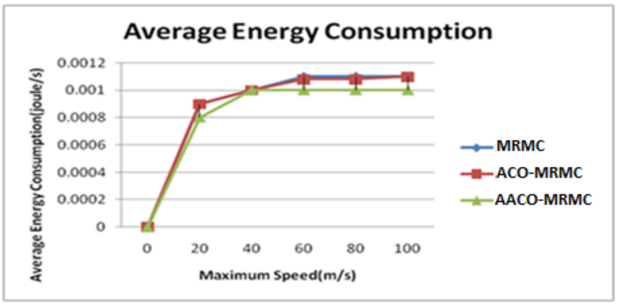

Figure 10: Average Energy Consumption in MRMC, ACO-MRMC, AACO-MRMC

Tabular comparison of existing protocol parameters and protocol with optimization scheme is shown in Table 2. the values of all the performance metrics packet deliver ratio, overhead, throughput, average end-to-end delay, average energy consumption is shown in the following table against the number varying nodes that is 20, 40, 60, 80, 100 nodes.

Table 2: Comparative study for AACO-MRMC, ACO-MRMC and MRMC

Technique / Parameters	Existing	ACO-MRMC	AACO-MRMC
Packet delivery ratio	.76	0.8	0.9
Average end-to-end delay(sec)	.14	.20	.25
Overheads	1.1	0.8	0.6
Throughput(bits/sec)	1000	1100	1200
Average energy consumption(joule)	.0011	.0011	.0013

X. Conclusion

A wireless Mesh network consists of three main components: nodes, gateways, and software. The spatially distributed measurement nodes interface with sensors to monitor assets or their environment. In this research work the optimized MRMC protocol in WMNs is implemented on the basis of AACO optimization scheme. AACO is used to provide a reciprocal path for every link in case of its failure. In this method mutation operator, is used and the new mutation rate is generated by the self-adaptive approach The proposed approach helps to reduce the load and drops in the network, so using the proposed methodology the QOS parameters such as packet delivery ratio, throughput, overheads, average end-to-end delay, average energy consumption are quite improved as shown in the result section. The improvement of 16% is shown between the existing and proposed approach in above defined features.

In the future scope the scalability of the approach can be improved so that quality parameters cannot be reduced. Any other algorithm can also be used in order to improve the QoS parameters if it shows better results than this proposed work.

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