Swarm and Fuzzy based Ant Colony Optimization (ACO) Routing and Cache Framework for MANET

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Abstract - **In mobile ad hoc network, when the query directory increases, the hit ratio and total delay increases including traffic overhead. To overcome this issue and also to offer a combined solution for routing, cache sharing and consistency, in this project, we propose a swarm and fuzzy based co-operative cache management framework for MANET. In this technique, reservation node selection is performed using fuzzy logic technique and the data forwarding between the reservation node and the requesting node is performed by swarm based routing ant colony optimization (ACO). This process of generation of new routes involves two ant agent namely forward ant (FANT) and backward ant (BANT). The node receives the data, the caching decision is made based on the parameters such as information presence index and content drop time. The consistency maintenance is achieved using flexible Push and pull algorithm, which satisfies user-specified consistency requirements at minimum cost by associating cache-copy with a time-out value.**

Index Terms – MANET, ACO, Fuzzy Logic, Caching Decision, Caching Maintenance.

1 INTRODUCTION

1.1 MANET

Mobile ad hoc network (MANET) is a multihop wireless network with mobile nodes that can move independently. MANET has no infrastructure in the sense that it does not require any access points or base stations for transmission [1]. Nodes can communicate with each other directly or through intermediates [2]. As the nodes move arbitrarily in the network, the network topology can change frequently. One node will communicate with the other node directly within sufficient radio propagation and indirectly through multihop routing with all other nodes. To help such kind of communication, many routing algorithms already have been developed. In MANET, the nodes are randomly present and they are supposed to develop and maintain the entire network automatically; hence, the routing algorithms are crucial. Due to active topology and limited resources, developing a dynamic routing protocol that can efficiently find arouting path with low control overhead is very important in MANETs [3-5]. Most of the devices and systems in MANET are designed in a performance-oriented manner, not considering the energy efficiency [6].

1.2 Significance of node and link lifetime prediction for route recovery process

In general, the network depends on the node assistance for providing the packet routing. Routing is the basic operation in ad-hoc networks. The routing algorithm should be robust, adaptive, and in a self-organized way. Nodes cannot forward the data packets to the receiver node when the prediction error is less than a pre-configured threshold value. Prediction is used to make the decision for transmission Re-routing in a mobile ad-hoc network is costly and would result inflooding the network due to the lack of infrastructure.

1.3 Salient feature of Ant Colony Optimization (ACO)

Swarm intelligence (SI), artificial intelligence techniques are nowadays involved in various applications. Several studies make use of genetic algorithm (GA)-based techniques to solve network problems. Ant Colony Optimization (ACO) is a paradigm for designing meta heuristic algorithms for combinatorial optimization problems. Technique for solving problems which can be expressed as finding good paths through graphs. Each ant tries to find a route between its nest and a food source. The behavior of each ant in nature is wander randomly at first, laying down a pheromone trail. If food is found, return to the nest laying down a pheromone trail. If pheromone is found, with some increased probability follow the pheromone trail. Once back at the nest, go out again in search of food However, pheromones evaporate over time, such that unless they are reinforced by more ants, the pheromones will disappear.

1.4 Cache Management

One of the key issues in mobile ad-hoc networks (MANETs) is cache management, which improves the transmission capacity of the network. Replacement - this algorithm is responsible for evicting less important or expired data, with time to live (TTL) equal to zero, when the node cache is full and a new data is to be fetched on a request from client. Consistency - this algorithm guarantees that all the copies of a data are identical to the original one on the server. Prefetching - this mechanism fetches the most important data items (that have high probability to be requested in the near future) into the caching node and stores them in the cache memory for responding to the future requests and queries.

2. RELATED WORKS

Xin Ming Zhang et al. [5] have proposed an estimated distance (EstD)-based routing protocol (EDRP) to guide a route discovery. This protocol can restrict the propagation range of route request and reduce the routing overhead.

The change regularity of the received signal strength is exploited to estimate the geometrical distance between a pair of nodes, which is called the estimated geometrical distance (EGD). An estimated topological distance (ETD) is a topology-based EstD that can mitigate the effect of inaccurate EGD.

Finally, this route lifetime prediction algorithm is implemented in the new protocol environment, which is based on the dynamic source routing (DSR) protocol. This new protocol outperforms the existing protocols like the lifetime prediction routing (LPR) and DSR protocols in terms of throughput, routing failure, routing overhead, packet loss ratio, and packet delivery ratio.

.Devi Manickavelu have proposed a particle swarm optimization (PSO)-based lifetime prediction algorithm for route recovery in MANET has been proposed. This technique predicts the lifetime of link and node in the available bandwidth based on the parameters like relative mobility of nodes and energy drain rate, etc. Using predictions, the parameters are fuzzified and fuzzy rules have been formed to decide on the node status. This information is made to exchange among all the nodes. Thus, the status of the every node is verified before data transmission. Even for a weak node, the performance of a route recovery mechanism is made in such a way that corresponding routes are diverted to the strong nodes.

3. WORK DESCRIPTION

3.1 Expected Time to Stay (ET)

The expected time to stay is estimated based on the node mobility. The mobility between the two nodes can be estimated from the ratio of RSS obtained among the two consecutive packet transmissions from a neighbor node. Thus the mobility metric $Mo_j(i)$ of the node j with respect to i is computed using the following formula.

$$Mo_j(i) = 10 \log_{10} \frac{RSS^{new}_{i \to j}}{RSS^{old}_{i \to j}} \qquad (1)$$

When the estimated mobility value is more, the ET is less and vice versa.

3.1.1 Battery Life (BL)

It is defined as the ratio of power received at the node (P_{rx}) to the power transmitted (P_{tx}) by the neighbor node.

3.1.2 Bandwidth (AB)

The available bandwidth is computed using Eq (2)

$$AB = (1 - Q_d/Q_t) \; \beta \; Q_t / t_f \qquad (2)$$

Where Q_d = number of allocation slots in one frame
Q_t = total slots in the sub-frame
t_f = duration of the frame
β = number of bits transmitted in downlink slots

3.1.3 Distance from the node (D)

The distance (d_{ij}) among the sender node (N_i) and receiver node (N_j) can be estimated based on free space propagation model. It considers the wavelength utilized for transmission and reception.

$$P_{rx} = P_{tx} * \left(\frac{\eta}{4 \pi d_{ij}} \right)^2 * \alpha * \beta \qquad (3)$$

Where P_{rx} = reception power
P_{tx} = transmission power
η = wavelength
α = transmitter gain

3.2 Swarm and Fuzzy Based Co-operative Cache Management Framework

3.2.1 Fuzzy Based Reservation Node Selection

When the nodes are deployed in the network, it is examined whether it acts as caching node (CN) or reservation node (RN). The function of reservation node is to store the queries presented by the requesting nodes. Caching node stores the response message to the queries. The reservation and cache node detection is performed using fuzzy logic. The node parameters such as expected time to stay, battery life, bandwidth, and distance from the node and link quality are considered as inputs parameters.

Fuzzification

This involves fuzzification of input variables such asexpected time to stay (ET), battery life (BL), bandwidth (AB), distance from the node (D) and link quality (LQ)(Estimated in sections 3.2.1-3.2.5) and these inputs are given a degree to appropriate fuzzy sets. The crisp inputs are combination of ET, BL, AB, D, and LQ. We take two possibilities, high and low for ET, BL, AB, D, and LQ.
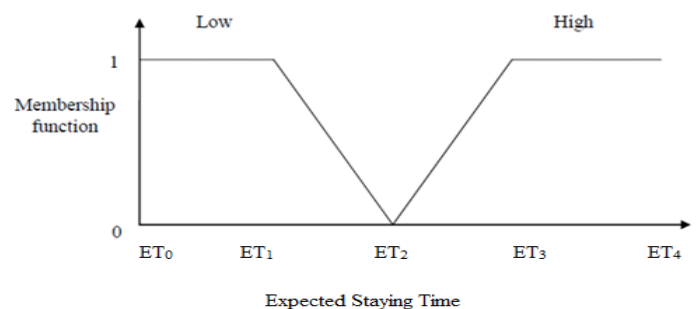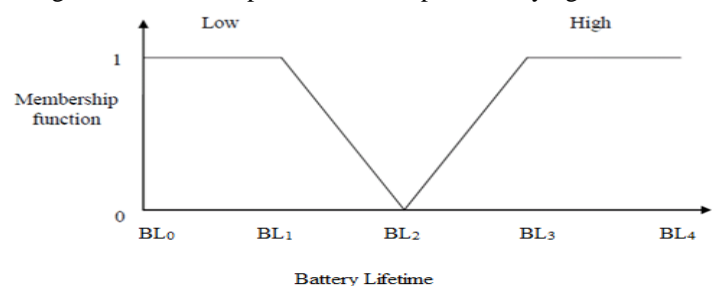

Figure 1 Membership function of Expected Staying Time

Figure 2 Membership function of Battery Lifetime

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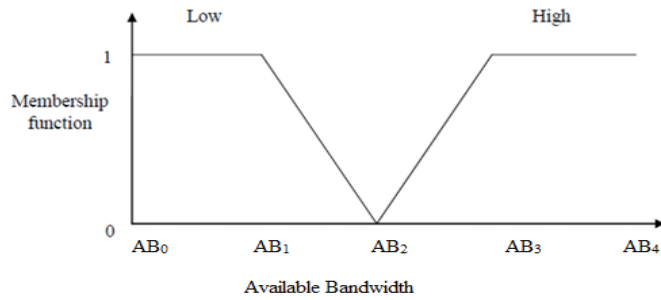**TITCON-2015 Conference Proceedings**

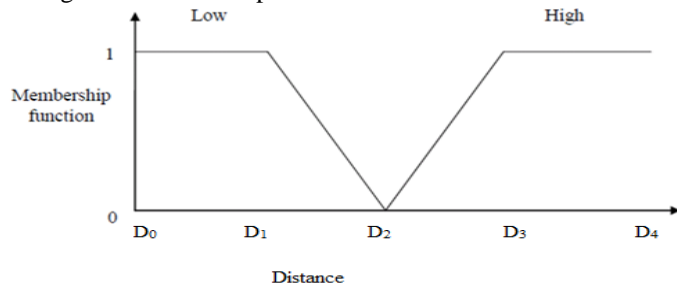Figure 3 Membership function of Available Bandwidth

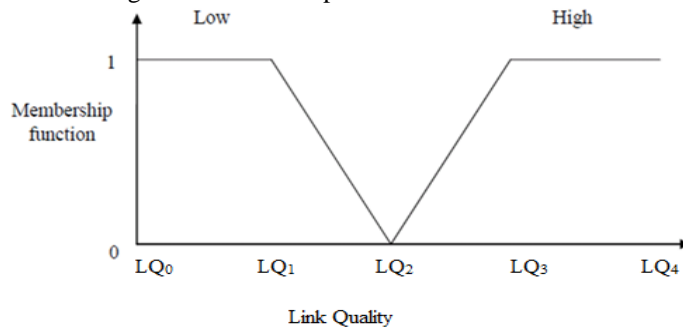Figure 4 Membership function of Distance

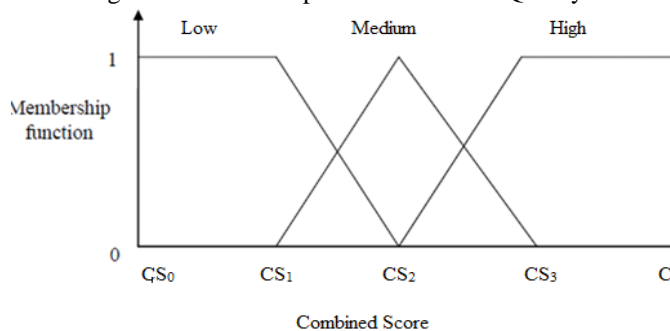Figure 5 Membership function of Link Quality

Figure 6 Membership function of Combined Score

Defuzzification

The technique by which a crisp values is extracted from a fuzzy set as a representation value is referred to as defuzzification. The centroid of area scheme is taken into consideration for defuzzification during fuzzy decision making process.

Fuzzy_cost =

$$ [\sum_{allrules} f_i * \psi \; (f_i)] / [\sum_{allrules} \psi (f_i)] \quad (6) $$

Where fuzzy_cost is used to specify the degree of decision making, f_i is the fuzzy all rules, and variable and $\psi (f_i)$ is its membership function.

3.2.2 Swarm Based Routing Technique

In our approach, the data forwarding between the source node and the reservation node (RN) is performed by swarm based routing based on ant colony optimization (ACO) This process of generation of new routes involves two ant agent namely forward ant (FANT) and backward ant (BANT).

Let S be the requesting node (Source)

Let N_i be the intermediate node

The steps involved in this algorithm are as follows.

1. Each node N_i investigates its routing table to determine whether the valid routing information exists for RN.

   If valid data exists

   Then

   Node chooses the RN with the minimum number of hops to transmit the data.

   Else

   Performs swarm based routing.

   End if

2. Initially S launches FANT. FANT visits each N_i whose mobility is based on probabilistic decision rule (shown in Eq.7).

$$ P_r(N_i, S) = \begin{cases} \dfrac{[a(N_i,S)^\zeta .[b(N_i,S)]^\sigma}{\sum_{N_i \in N_R}[a(N_i,S)]^\zeta .[b(N_i,S)]^\sigma} & , \text{if } r \notin RT(N_i) \\ 0, otherwise \end{cases} $$

(7)

Where $a(N_i, S)$ represent pheromone value

b (N_i, S_o) represent the heuristic value related to bandwidth.

N_R represents the receiver node.

RT (N_i) represents the routing table for N_i.

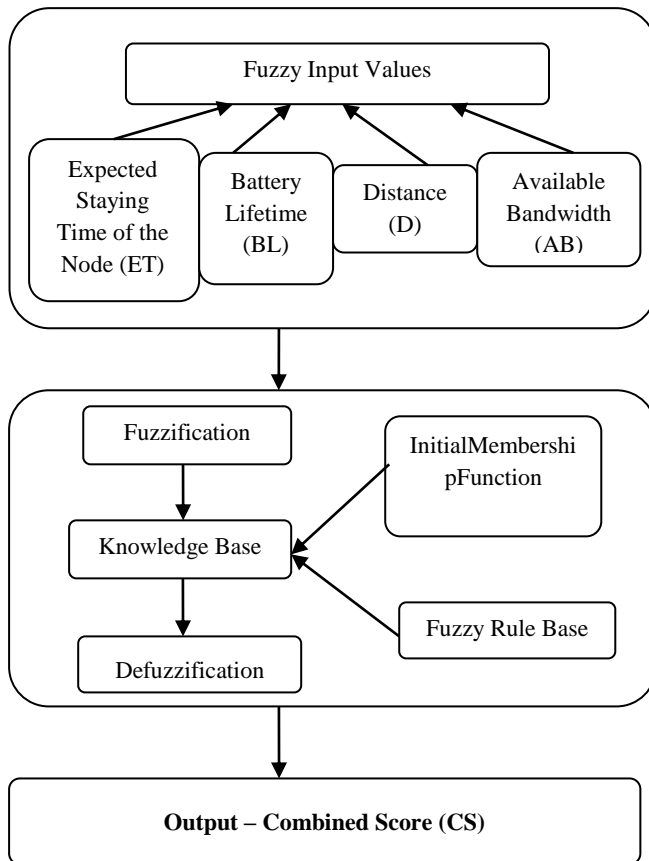ζ and σ are the parameters that control the relative weight of the pheromone and heuristic value respectively.

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Figure 7 Fuzzy Interference System

S. No	ET (High)	BL (High)	BW (High)	D (Min)	LQ (High)	Combined Score
1	Low	Low	Low	Low	Low	Low
2	Low	Low	Low	Low	High	Low
3	Low	High	Low	High	High	Medium
4	High	High	High	High	High	High
5	Low	High	High	High	High	Medium
6	High	High	High	High	High	High
7	Low	Low	High	High	Low	Low
8	High	High	Low	High	High	Medium

Table 1 Fuzzy Rule for the Determining Output

3. Each FANT deposits a quantity of pheromone ($\Delta\tau^u(r)$) in the visiting N_i as per the following equation

$$\Delta\tau^u(r) = 1/X_s^u(r) \qquad (8)$$

Where $X_s^u(r)$ represents the total number of N_i visited by FANT during its tour at iteration r and u = 1, 2….n

4. Using rule described in step 2, FANT moves through N_i and verifies the existence of RN ID in its routing table. If RN ID exists,
    Then
        BANT is generated in respective N_i and the information collected by FANT is transferred to BANT.

End if
5. The BANT then takes the same path as that of its corresponding forward ant, but in the opposite direction. It updates the pheromone table with the routing information of the respective N_i.
6. Once S receives the BANT, it collects the routing information about all N_i along each path from its updated pheromone table.
7. From the collected information, S chooses the route with minimum hop as primary path for data transmission to RN. The next level of minimum hop values from the collected information helps in deciding the backup path.

3.2.3 Caching Decisions
        After the node receives the data, the caching decision is made using the two observations such as overhear queries and information such as nodes distance on the wireless channel. Based on the observed information, the node estimates the information presence index (λ_i) (Case – 1).

Case - 1
        N_i estimates λ_i using the following equation.
        $\lambda_i (N_i, k) = \min \{1, C_{i1}(N_i, k) + C_{i2}(N_i, k)\}$
                (9)
                Where   k = time step
                        $C_{i1}(N_i, k)$ = Source counter
        $C_{i1}(N_i, k)$ reveals the existence of new copies of information (ε) deposited by the node to RN within the transmission range at k. This counter value is updated each time the node acts as S.

$$C_{i1}(N_i, k) = C_{i1}(N_i, k) + \frac{1}{H_1} \qquad (10)$$

        Where H_1 = number of hops covered by the new copies of data
                $C_{i2}(N_i, k)$ = movement counter
        C_{i2} reveals the existence of ε transmitted between two nodes within transmission range and overheard by N_i at k.

$$C_{i2}(N_i, k) = C_{i2}(N_i, k) + \frac{1}{H_1} + \frac{1}{H_2} \qquad (11)$$

        H_2 be the number of hops covered by the existing copies of data
        $\lambda_i(N_i, k)$ is in the range (0, 1).
0 $\rightarrow$ the presence of ε was not sensed by N_i during k
1 $\rightarrow$ If ε is cached one hop away from N_i

Case – 2
        When N_i contains large sized cache, it computes cache drop time ($T_{di}(N_i, k)$) at k for the data i.

$$T_{di}(N_i, k) = (1- \lambda_i(N_i, k)) \, T_{dmax} \quad (12)$$

        Where T_{dmax} = maximum cache drop time
The above estimated drop time can be used for all ε of data i received during (k+1).

Case – 3
        When N_i contains a small sized cache, it performs cache content replacement technique. This allows balanced

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distribution of data over the network such that the content remains close to requesting node. This technique allows removing chunks from the memory upon arrival of new content.

$$\hat{T}_{di}(N_i,k)=(1-\frac{(\hat{\lambda}_i(N_i,k)}{\max_i\{\hat{\lambda}_i(N_i,k\}})T_{p\max}$$
(13)

Where T_{pmax} = maximum cache stability time

After T_{pmax}, the chunk is discarded to prevent stored information from becoming out-dated and node movement resulting to discrepancies with respect to previous information λ_i ratings.

3.2.4 Consistency Maintenance

A flexible Push and pull algorithm is used to achieve the consistency maintenance which satisfies user-specified consistency requirements at minimum cost by associating cache-copy with a time-out value (u).

This technique involves two actions:
Push: S informs caching nodes about cache information.
Pull: Caching node fetches cache information from S.

The combined push pull action on the caching and source node is described as.

1. When a query is received, the following condition is verified
    If u > 0
        Then
        The received query is offered with the cached copy.
    Else
        u is decreased to zero.

A renewal message is transmitted to perform renewal of u from S and cache copy is updated. The received query is offered with the cached copy.
        End if

2. When S is ready to be updated, an invalid message is transmitted to each caching node with positive u value.

$$S \xrightarrow{\{u\}\{invalid\_mes\}} CN$$

3. If S receives an acknowledgement message (ACK_mes) for each invalid message, the source data is updated.

$$S \xleftarrow{ACK\_mes} CN$$

4. Following the reception of renewal message from CN
    If source data has been updated
        Then
        An update message has been transmitted to CN
    End if
5. If there is no pending update
    Then
        Timeout u is allowed and data is updated to CN
    End if

4. SIMULATION RESULTS

4.1 Simulation Model and Parameters

The Network Simulator (NS2) [21], is used to simulate the proposed architecture. In the simulation, 40 mobile nodes move in a 1000 meter x 1000 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).
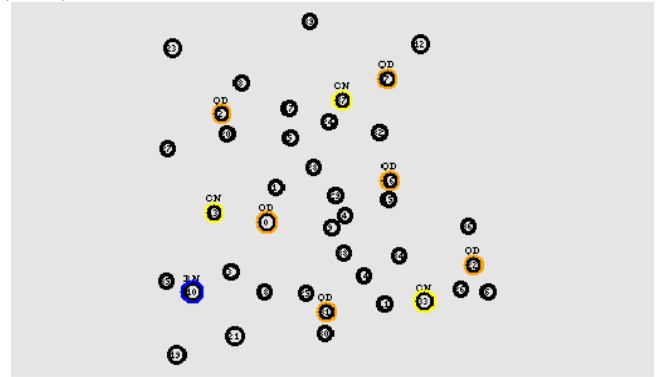
4.2 Results
1) Based on Speed

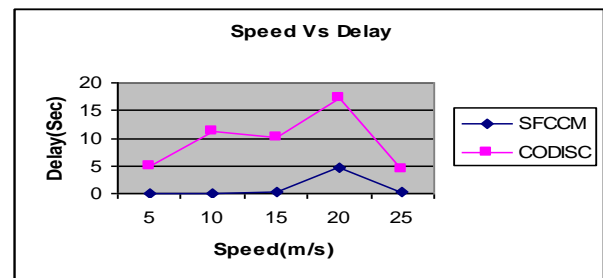In our first experiment we vary the mobile speed as 5,10,15,20 and 25m/s.
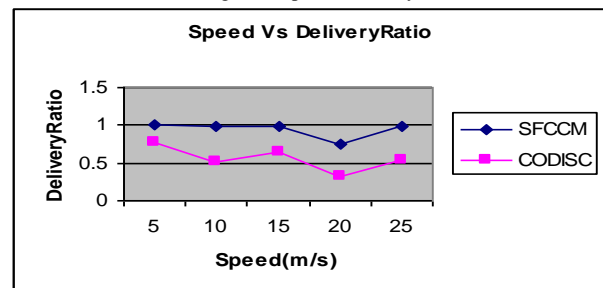

Figure 8 Speed Vs Delay
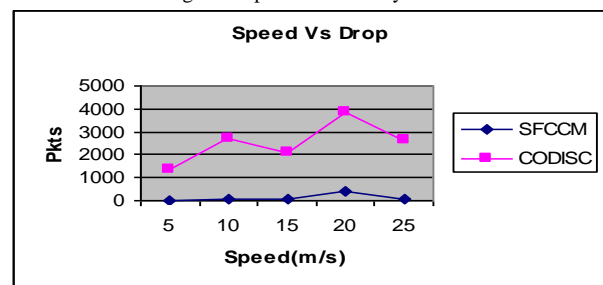

Figure 9 Speed Vs Delivery Ratio
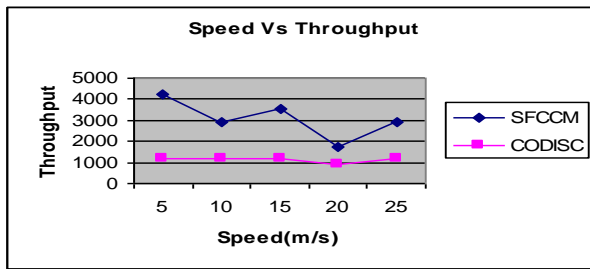

Figure 10 Speed Vs Drop

Figure 11 Speed Vs Throughput

Figure 8 shows the delay of SFCCM and CODISC techniques for different speed scenario. We can conclude that the delay of our proposed SFCCM approach has 92% of less than CODISC approach.

Figure 9 shows the delivery ratio of SFCCM and CODISC techniques for different speed scenario. We can conclude that the delivery ratio of our proposed SFCCM approach has 42% of higher than CODISC approach.

Figure 10 shows the drop of SFCCM and CODISC techniques for different speed scenario. We can conclude that the drop of our proposed SFCCM approach has 96% of less than CODISC approach.

Figure 11 shows the throughput of SFCCM and CODISC techniques for different speed scenario. We can conclude that the throughput of our proposed SFCCM approach has 61% of higher than CODISC approach.

2) Based on Cache Size

In our second experiment we vary the cache size as 500, 750, 1000, 1250 and 1500.
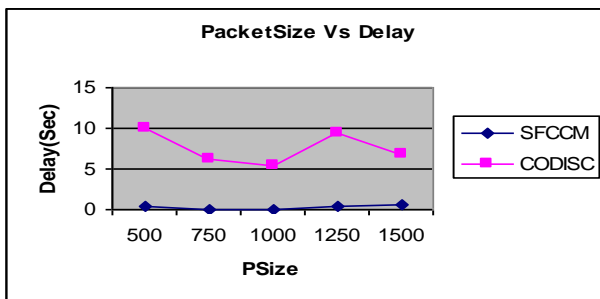

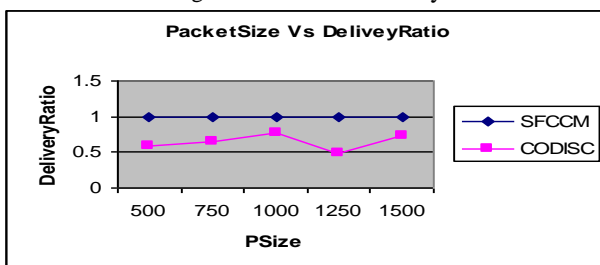
Figure 12 Psize Vs Delay

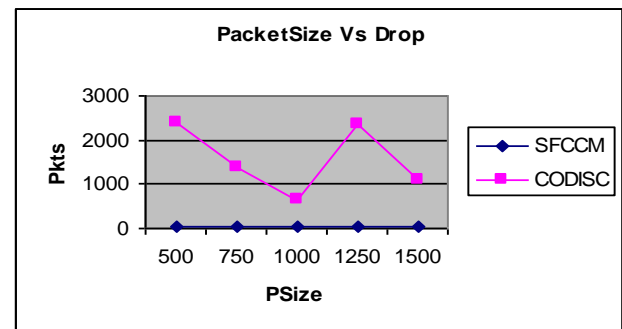Figure 13 Psize Vs Delivery Ratio
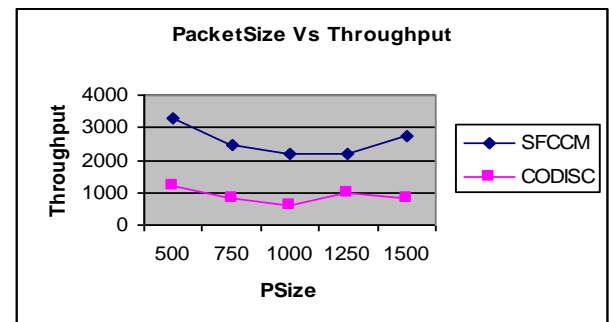

Figure 14 Psize Vs Drop

Figure 15 Psize Vs Throughput

Figure 12 shows the delay of SFCCM and CODISC techniques for different packet size scenario. We can conclude that the delay of our proposed SFCCM approach has 95% of less than CODISC approach.

Figure 13 shows the delivery ratio of SFCCM and CODISC techniques for different packet size scenario. We can conclude that the delivery ratio of our proposed SFCCM approach has 37% of higher than CODISC approach.

Figure 14 shows the drop of SFCCM and CODISC techniques for different packet size scenario. We can conclude that the drop of our proposed SFCCM approach has 97% of less than CODISC approach.

Figure 15 shows the throughput of SFCCM and CODISC techniques for different packet size scenario. We can conclude that the throughput of our proposed SFCCM approach has 66% of higher than CODISC approach.

CONCLUSIONS

In this paper we have presented a reservation node selection is performed using fuzzy logic technique and the data forwarding between the reservation node and the requesting node is performed by swarm based routing. The consistency maintenance is achieved using flexible Push and pull algorithm which satisfies user-specified consistency requirements at minimum cost by associating cache-copy with a time-out value.

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