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Adaptive Particle Swarm Optimization based QoS Aware Scheduling Routing Protocol (APSO-QSRP) for Heterogeneous Mobile Ad hoc Networks

M.Mohanraj and Dr.M.Punithavalli

Research Scholar / Assistant Professor,
Dr.SNS Rajalakshmi College of Arts and Science (Autonomous),
Coimbatore, Tamilnadu, India.
mohanrajsns@gmail.com
Associate Professor,
Department of Computer Applications,
Bharathiar University, Coimbatore, Tamilnadu, India.

Abstract

Ensuring quality of service (QoS) is one among the plunge research topic for mobile ad hoc networks. This research work aims to propose an adaptive particle swarm optimization approach in order to provide quality of service aware scheduling routing protocol for heterogeneous mobile ad hoc networks. The proposed routing mechanism involves broadcasting. Two major parameters are estimated namely received signal strength and queuing delay. Once after estimating the parameters, adaptive particle swarm optimization algorithm is incorporated for optimized routing performance. The fitness function of the particle swarm optimization utilizes parameters received signal strength and queuing delay. Packet resizing mechanism is utilized. The proposed protocol has been tested on NS-2 using the performance metrics such as throughput, packet delivery ratio, overhead, packets drop and delay. The simulation has been carried out based on mobility speed and pausetime. Mobility speed is taken for ensuring the proposed protocol's performance on heterogeneous environment where the nodes may move at different speed that ranges from 0.5 to 2.5 meter per second. Extensive simulation results emphasizes that the proposed routing protocol (APSO-QSRP) achieves remarkable QoS in terms of throughput, packet delivery ratio, overhead, packets drop and delay based on both pausetime and mobility speed.

Keywords: QoS, Particle Swarm Optimization, Routing, MANET, Optimized Routing.

1. Introduction

Mobile ad hoc network shortly termed as MANET is an ongoing research area in wireless networks. It consists of mobile nodes which demands higher bandwidth, constrained energy utilization, and ensured quality of service (QoS) needs. The applications of MANETs are surveillance, military battlefield, and personal area networking and so on. In [1] the authors mentioned that a small transmission range is necessary to limit the interference and consequently leads to high throughput. Smaller transmission range, limited battery power, dynamic topology are some of the significant challenges for routing in the ad hoc scenario. In [2], the authors admitted a hypothesis that the delay due to the multi-hop transmission is increased when the throughput also increases. Therefore, scaling the transmission radius is capable enough to decrease the average number of hops and also results in reduce the transmission latency. On the other hand, increasing transmission radiuses of the mobile node will inexorably grounds higher interference that tends to the lower throughput. As a result, there is a trade-off between reducing the delay and improving the throughput.

There are different mechanisms for offering QoS like bandwidth reservation, channel switching, channel separation and QoS scheduling. This is the extension of previous research work called QoS aware scheduling based routing protocol (QoS – SBRP) [17] and Strategic Media Access Control and QoS Aware Scheduling Based Routing Protocol (SMAC-SBRP) for heterogeneous MANET [18]. The paper is organized as follows. The related works concerned with QoS are discussed in section 2. The proposed research work adaptive particle swarm optimization based qos aware scheduling routing protocol (APSO-QSRP) for heterogeneous mobile ad hoc networks is presented in section 3. Section 4 discusses on simulation settings and performance metrics. Results and discussion on simulation is depicted in section 5 and section 6 concludes the research work with further scope of research.

2. Related Works

The fundamental tradeoff between packet delay and transmission rate has been extensively studied for single-link communications [18], [26], [27], [28], [30], [20], ad hoc networks [29], [12], [32], [11], [31], and cellular networks [35], [33]. Despite the issue of QoS support in MANETs is a relatively novel subject it has recently received much attention from researchers worldwide. In the literature it can be seen works that focus on QoS issues related to a single protocol layer (e.g., MAC layer, routing layer) along with works that propose a QoS framework that combines more than one layer. In terms of MAC layer protocols for ad hoc networks, the IEEE 802.11 Working Group E [3] has recently completed a new MAC standard, also denoted as IEEE 802.11e, to enhance Wi-Fi networks with QoS support. In [6] Romdhani et al. propose enhancements to the IEEE 802.11e technology to offer relative priorities by adjusting the size of the contention window (CW) of each traffic class, taking into account both applications requirements and network conditions. Sobrinho and Krishnakumar propose Blackburst [7], which is a novel distributed channel access scheme that is more efficient than the IEEE 802.11e technology. Other works such as [8]–[10] also propose alternate QoS MAC schemes designed specifically for ad hoc network environments. Concerning routing layer proposals offering QoS support in MANETs, Lin and Liu [11] propose a QoS routing protocol that includes end-to-end bandwidth calculation along with bandwidth allocation schemes. Shigang and Nahrstedt [12] define a distributed QoS routing scheme that selects a network path with sufficient resources to satisfy a certain delay (or bandwidth) requirement. In [13], Xue and Ganz propose a resource reservation-based routing and signalling algorithm (AQOR) that provides end-to-end QoS support in terms of bandwidth and delay. Also, Chen and Heinzelman [14] propose a QoS-aware routing protocol that incorporates admission control and feedback schemes to meet the QoS requirements of real-time applications by offering an estimate of available bandwidth.

Cluster-based certificate revocation with vindication capability for MANETs is proposed in [4] and recently a statistical traffic pattern discovery system for MANETs is also proposed in [5]. Concerning QoS frameworks for MANETs, Lee et al. propose INSIGNIA [15], an approach to integrated services support in MANETs through a flexible signaling system. Ahn et al. propose SWAN [16], an approach to differentiated services support in MANETs using plain IEEE 802.11 plus rate-control for best effort traffic; traffic acceptance is dependent on local bandwidth estimations and admission control probes.

The opportunistic routing for flooding the packets are developed using multipath routing with multiple copies of a packet routed through the mobile ad hoc network. MORE [19] is a routing mechanism which makes use of innovative packets that inform whether a received packet brings new information or not. It also uses a transmission counter at each forwarder mobile node in order to further reduce the amount of transmissions. The mechanism GeRaF [20] is a geographical forwarding protocol which selects a forwarder set of mobile nodes and prioritizes the forwarder candidates using location information using GPS. OPRAH [21] builds a multipath set between the source and the destination via on-demand routing to support opportunistic forwarding. It allows intermediate nodes to record more subpaths back to the source and also those subpaths downstream to the destination. SOAR [22] supports multiple simultaneous flows in a wireless mesh network. A congestion aware routing mechanism has been proposed by making use of the parameters link quality, delay and overhead in the literatures [23] – [25].

In [34], the optimal energy-efficient scheduling algorithm for minimizing the total transmission energy was developed for a group of packets subject to a single transmission deadline. This optimal algorithm assumed knowledge of the total number of packets and the inter-arrival times of these packets before packet scheduling. As a result, it is an offline scheduling algorithm. An online algorithm, which assumed information of the current scheduling backlog and a maximum packet arrival rate, was also developed in [34]. Online scheduling for the single deadline model is also treated in [36]. In particular, a stochastic optimal control algorithm was developed.

3. Proposed Work

3.1. Preliminaries and Assumptions

Mobile ad hoc network that consists of nodes are randomly positioned on the terrain range. It is assumed that each mobile node knows its position built-in with GPS and is capable enough to estimate the velocity using the time difference in its positions. When a source node has packets that need to be delivered to a destination node in the ad hoc network, the source node most likely knows the location of the destination node. The source node and intermediate nodes are mobile in nature, whereas the destination node is assumed stationary with zero velocity. In general wireless communication networks, media access control MAC resolves access divergence of multiple wireless terminals in a common radio source. The IEEE 802.11 MAC uses a four-fold handshake procedure that consists of request to send (RTS), clear to send (CTS), data transmission (DATA), and acknowledgement (ACK). This procedure will get activated when the packet size is relatively large. Hence it is mandatory for the MAC protocol to be altered / modified for ad hoc network scenario. In spite of determining typical research issues in wireless networking arena, e.g. the hidden terminal problem and the exposed terminal problem, the MAC ought to be adapted to quick changes in network topology due to mobility of nodes in the ad hoc network. An enhanced version of MAC, the strategic MAC protocol is proposed in this research work along with scheduling based routing protocol in order to deliver the QoS for MANETs that obtains advantage of the mobility of the nodes present in the ad hoc network. The strategic MAC protocol employs the sender initiated carrier sense multiple access with collision avoidance (CSMA/CA), and the RTS/CTS/DATA/ACK exchange is modified and implemented in order to look into the radio channels.

3.2. Adaptive Broadcast of RTS and Prioritized CTS

While sensing and identifying that the radio channel is in idle state, a source node that wishes to send data initiates the handshake procedure by sending an RTS frame. The source node offers the RTS on a broadcast physical address. The RTS frame contains values of the positions of the source node and also the destination node. All neighboring nodes within the transmission range of the source node look into the link quality using the received RTS frame using the below equation presented in [23][24][25].

When a sender mobile node broadcasts RTS packet, it piggybacks its transmission power. On receiving the RTS packet, the desired node calculates the received signal strength using

$$P_r = P_t . \left(\frac{\lambda}{4\pi d} \right)^2 .G_t .G_r \ldots \quad (1)$$

Where λ the wavelength carrier, d denotes the distance between sender and receiver, G_t and G_r are gain of the transmitting and receiving omni directional antenna.

Each node can measure the quality of the wireless channel from the source node to itself. Then the candidate intermediate nodes assess their advantages over the source node toward the destination node based on the node position information and the velocity estimates. The evaluation results are then quantized into priority levels for responding clear to send CTS to the source node in the ad hoc network. It has been already mentioned that meticulous candidate intermediate node knows its own position of the source and destination nodes extracted from the received RTS frame. After that, the candidate intermediate node can calculate the position advance as

$$d_{ADV} = \|X_D - X_S\| - \|X_D - X_R\| \ \ldots \qquad (2)$$

The above eqn – (2) shows how much closer the candidate intermediate node is from the destination node compared with the source node. Naturally, the candidate intermediate node with larger priority index replies CTS earlier. If the destination node is among the candidate intermediate nodes, it has the highest priority and replies CTS among other nodes in the mobile ad hoc network.

3.4. Packet Scheduling Mechanism (PSM) using Particle Swarm Optimization

The previous section solves the problem of how to select intermediate mobile nodes that can guarantee the QoS of the packet transmission and how a source node assigns traffic to the intermediate nodes to ensure their scheduling feasibility. In order to further reduce the stream transmission time, a packet scheduling mechanism is proposed for packet routing. This mechanism assigns earlier generated packets to forwarders with higher queuing delays and scheduling feasibility, while assigns more recently generated packets to forwarders with lower queuing delays and scheduling feasibility, so that the transmission delay of an entire packet stream can be reduced.

Time is represented as t when the packet is generated. T_{QoS} denotes delay QoS requirement. W_S denotes the bandwidth of the source mobile node and W_I denotes the bandwidth of the intermediate mobile node. Transmission delay between source mobile node and intermediate mobile node is denoted as $T_{S\to I} = \frac{S_P}{W_S}$. Transmission delay between intermediate mobile node and destination mobile node is denoted as $T_{S\to D} = \frac{S_P}{W_I}$. T_w denote the packet queuing time of n_i. The queuing delay requirement is calculated as

$$T_w < T_{QoS} - T_{S\to I} - T_{I\to D} \ldots \qquad (3)$$

T_w can be calculated as

$$T_w^{(x)} = \sum_{j=1}^{x-1} \left(T_{I\to D}^{(j)} \cdot \left[\frac{T_w^{(x)}}{T_a^{(j)}} \right] (0 < j < x) \right) \ldots \qquad (4)$$

Where x denotes a packet with with x_{th} priority in the queue, $T^{(j)}_{I\to D}$ represents transmission delay of a packet from the intermediate mobile node to the destination mobile node and $T^{(j)}_{a}$ represents arrival interval of the packet.

3.3.1. Particle Swarm Optimization

Similar to genetic algorithm, particle swarm optimization (PSO) is one among the meta-heuristic method to perform optimization. PSO was earlier proposed and developed by Kennedy and Eberhart in the year 1995 [34, 35] which is a population based heuristic global search algorithm based on the social interaction and individual experience. PSO utilized and functioned as an optimization tool by which each member is considered as a particle and each particle is a potential solution of the chosen optimization problem. PSO has a randomized velocity associated it, that moves through the space of the problem. On the other hand, contrasting with genetic algorithm, PSO does not have crossover and mutation operators with it. In PSO, the well-known evolutionary principle "survival of the relatively fit" is not used, but the simulation of social behavior is used in it. For obtaining suitable solutions a fitness function is involved. Each particle is deemed with a position in a D-dimensional space. Also each particle position has the ability to choose the binary value (0 or1) and can also swap. The chosen binary value 0 represents "included" and 1 denotes "not included".

Let P_s denote the swarm size and 2n, the dimensionality of the search space. Each particle $i (1 \leq i \leq P_s)$ has the following attributes:

i. A current position $\tilde{x}_i = (\tilde{x}_{i1,}\tilde{x}_{i2,} \dots, \tilde{x}_{i,2n})$ in the search spaces.
ii. A current velocity $\tilde{v}_i = (\tilde{v}_{i1,}\tilde{v}_{i2,} \dots, \tilde{v}_{i,2n})$
iii. A personal best $(pbest)$ position (the position giving the best fitness value experience by the particle) $p_i = (p_{i1,}p_{i2,} \dots, p_{i,2n})$

It is to be noted that in $\tilde{x}_i$, $\tilde{v}_i$ and p_i, the first n components are integers whereas the rest one are floating points.

At each iteration, the velocity of each particle in the swarm is updated as follows:

$$\tilde{v}_{ij}^{(k+1)} = \tilde{w}\tilde{v}_{ij}^{(k)} + \tilde{c}_1\rho_{1j}^{(k)}\left(p_{ij}^{(k)} - \tilde{x}_{ij}^{(k)}\right) + \tilde{c}_2\rho_{2j}^{(k)}\left(p_{ij}^{(k)} - \tilde{x}_{ij}^{(k)}\right),$$

$$j = 1, 2, \dots, 2n;\ k = 1, 2, \dots, M_g$$

$$i.e., \tilde{v}_{i}^{(k+1)} = \tilde{w}\tilde{v}_{i}^{(k)} + \tilde{c}_1\rho_{1}^{(k)}\left(p_{i}^{(k)} - \tilde{x}_{i}^{(k)}\right) + \tilde{c}_2\rho_{2}^{(k)}\left(p_{g}^{(k)} - \tilde{x}_{i}^{(k)}\right) \qquad (5)$$

where $\tilde{v}_{ij}^{(k)}$ is the j-th component velocity of the i-th particle in k-th iteration, $\tilde{w}$ is the inertia weight, $\tilde{c}_1$ and $\tilde{c}_2$ are called acceleration coefficients, $\rho_{1j}^{(k)}$, $\rho_{2j}^{(k)}$ are two random numbers uniformly distributed in the interval [0, 1] i.e., $\rho_{1j}^{(k)} \sim U(0,1)$, $\rho_{2j}^{(k)} \sim U(0,1)$.

The new position of the i-th particle is computed as follows:

$$\tilde{x}_{ij}^{(k+1)} = \tilde{x}_{ij}^{(k)} + \tilde{v}_{i}^{(k+1)} \text{ i.e., } \tilde{x}_{i}^{(k+1)} = \tilde{x}_{i}^{(k)} + \tilde{v}_{i}^{(k+1)}$$

The personal best ($pbest$) position of each particle is updated as follows:

$$p_i^{(0)} = \tilde{x}_i^{(0)}$$

$$p_i^{(k+1)} = \begin{cases} p_i^{(k)} \; if \; f\left(\tilde{x}_i^{(k+1)}\right) \leq f(\, p_i^{(k)}) \\ \tilde{x}_i^{(k)} \; if \; f\left(\tilde{x}_i^{(k+1)}\right) > f(\, p_i^{(k)}) \end{cases}$$

where the function f is to be maximized.

The global best ($gbest$) position found by any particle during all previous iterations pg is defined as

$$p_g^{(k+1)} = argmaxf\left(p_i^{(k+1)}\right), 1 \leq i \leq p_s$$

From equation (4), it is seen that the velocity of the i-th particle is computed by considering the following three components:

i. Previous velocity of the particle

ii. The distance between the particle's best previous position and current position.

iii. The distance between swarm's best experience (the position of the best particle in the swarm) and the current position of the particle.

3.3.2. Scheduling using PSO

Particles are designed as sequence of jobs in available mobile ad hoc network environment. The solutions are encoded in m X n matrix shortly coined as position matrix where m denotes number of available mobile nodes and n denotes number of jobs. The position of every particle consists of the two properties mentioned below:

1. Every elements of the matrices have either the value of 0 or 1 which is mathematically denoted as

$$X_k(i,j) \in \{0,1\} \tag{6}$$

2. In every column of the above said matrices comprises of only one element and it will be 1 and the rest of the elements are 0.

It is to be noted that the each column in the position matrix denotes job allocation and the row denotes allocated jobs. Also in each column it is resolved that which job needs to be performed by which node.

Velocity of each particle is considered as m X n matrix whose elements are in range [-V_{max}, V_{max}] which is mathematically implied as

$$V_k(i,j) \in [-V_{max}, V_{max}] \quad (7)$$

Also Pbest and nbest are m X n matrices and their elements are 0 or 1 as position matrices. $Pbest_k$ denotes the best position that kth particle has visited since the first time step and $nbest_k$ denotes the best position that k^{th} particle and its neighbours visited from the beginning. The start topology is chosen which is commonly applied for nbest. In every time step Pbest and nbest will be updated by estimating the fitness of the particle. When the fitness value is greater than the fitness value of $pbest_k$ is replaced with X_k. In order to update bnest, Pbest are used.

The velocity matrix will be updated using the equation (7) and the position matrix will be updated using the equation (8)

$$V\frac{(t+1)}{k}(i,j) = w.V\frac{t}{k}(i,j) + c_1 r_1 (pbest\frac{t}{k}(i,j) - X\frac{t}{k}(i,j)) + nbest\frac{t}{k}(i,j) - X\frac{t}{k}(i,j)) \quad (8)$$

$$X\frac{(t+1)}{k}(i,j) = \left\{ \begin{array}{l} 1 \dfrac{if\,(V\frac{(t+1)}{k}(i,j) = \max\left\{V\frac{(t+1)}{k}(i,j)\right\}}{otherwise} \\ 0 \end{array} \right\} \quad (9)$$

In (8) $V\frac{t}{k}(i,j)$ is the element in the i^{th} row and j^{th} column of the k^{th} velocity matrix in the t^{th} time step and $X\frac{t}{k}(i,j)$ represents the element in the i^{th} row and j^{th} column of the k^{th} position matrix. Equation (9) means that in each column of the position matrix value 1 is assigned to the element whose corresponding element on velocity matrix has the maximum value in its corresponding column.

3.3.3. Fitness Evaluation

The parameters received signal strength (P_r) and queuing delay (T_w) are taken to evaluate the performance of the scheduler simultaneously. The fitness value of each solution is estimated using (10)

$$fitness = \left(\lambda.\frac{1}{P_r} + (1 - \lambda.T_w)\right) \quad (10)$$

λ is used to regulate the effectiveness of the parameters. The greater λ, more attention will be given by the scheduler in minimizing queuing delay (T_w). The smaller queuing delay and better received signal strength will result in greater fitness value and hence better solution it is regarded.

3.4. Packet Resizing Mechanism (PRM)

Reducing packet size can increase the scheduling feasibility of an intermediate node and reduces packet dropping probability. However, the size of the packet could not be made too small since it generates more packets to be transmitted, producing higher packet overhead. Based on this underlying principle and taking advantage of the benefits of node mobility, packet resizing algorithm is deployed.

The basic idea is that the larger size packets are assigned to lower mobility intermediate nodes and smaller size packets are assigned to higher mobility intermediate nodes, which increases the QoS-guaranteed packet transmissions. Also, when the mobility of the node increases, the size of the packet decreases.

$$S_p(new) = \frac{\gamma}{v_i} S_p(unit)$$

Where γ represents scaling parameter and v_i is the relative mobility speed of the node.

4. Simulation Settings and Performance Metrics

200 mobile nodes starting from IP address 192.168.1.1 to 192.168.1.200 move in a 1500 x 1500 meter rectangular region for 100 seconds (simulation time). The channel capacity of mobile nodes is set to 2 Mbps. Distributed Coordination Function (DCF) of IEEE 802.11 is used for wireless LANs. It has the functionality to notify the network layer about link breakage. It is assumed that each node moves independently with the variant mobility speed between 0.5 to 1.5 m/s. The transmission range has been varied from 150 to 200 meters. The simulated traffic is Constant Bit Rate (CBR). The simulation settings are also represented in tabular format as shown in Table 1.

Table 1. Simulation Settings

No. of Nodes	200
Terrain Size	1500 X 1500 m
MAC	802.11b
Radio Transmission Range	150 - 200 meters
Simulation Time	100 seconds
Traffic Source	CBR (Constant Bit Rate)
Packet Size	256 Kbits
Mobility Model	Random Waypoint Model
Speed	0.5 – 1.5 m/s

The following metrics are taken into account for evaluating the proposed routing mechanism with RAB, QoS-SBRP.

- Throughput
- Packet Delivery Ratio
- Drop
- Overhead
- Delay

5. Simulation Results and Discussions

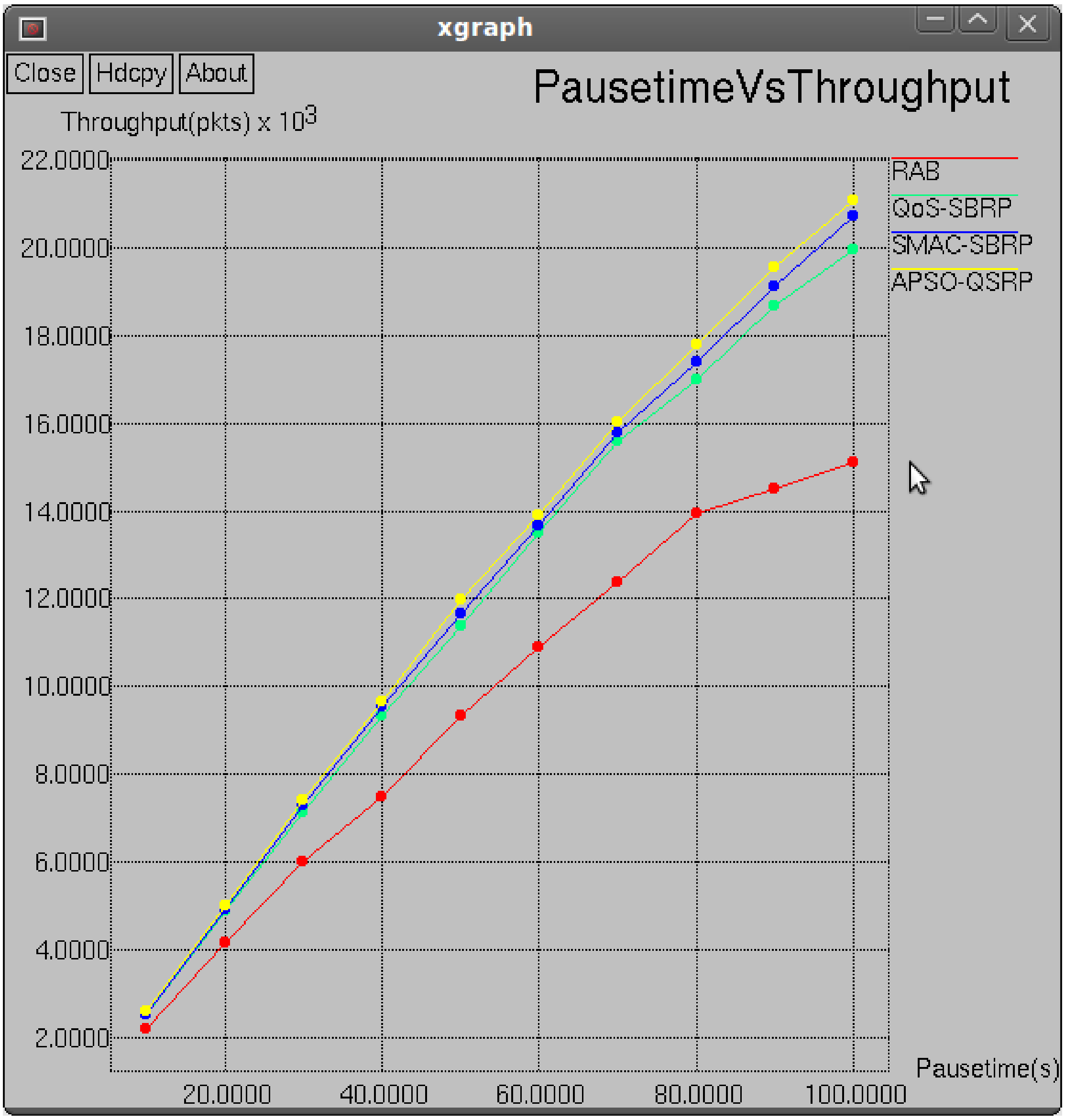

Figure 1. Pausetime Vs Throughput

Table 1. Pausetime Vs Throughput

Pausetime	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
10	2176	2509	2509	2612
20	4147	4864	4915	5016
30	5990	7142	7296	7387
40	7475	9318	9523	9667
50	9344	11392	11648	11973
60	10906	13517	13670	13901
70	12365	15590	15770	16034
80	13926	16998	17408	17811
90	14515	18662	19123	19572
100	15104	19968	20736	21098

The Figure 1 shows the performance evaluation against pausetime of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP outperforms the rest of the protocols in terms of throughput. The numerical results are also shown in Table 1.

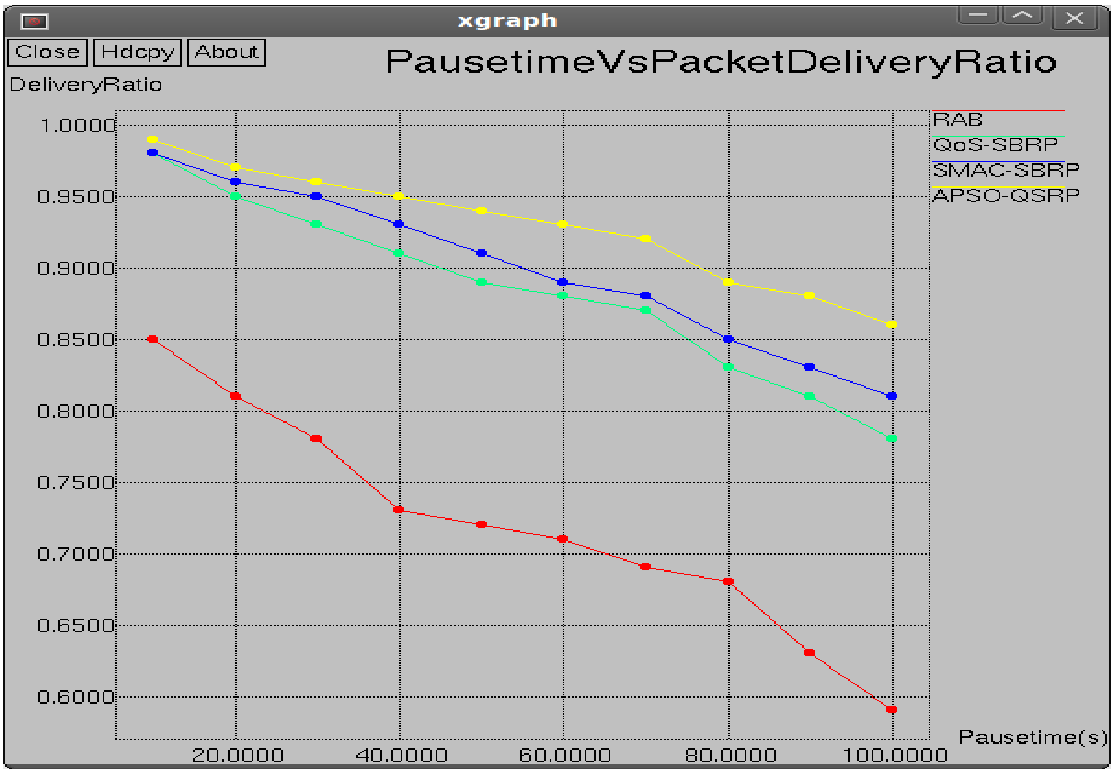

Figure 2. Pausetime Vs Packet Delivery Ratio

Table 2. Pausetime Vs Packet Delivery Ratio

Pausetime	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
10	0.85	0.98	0.98	0.99
20	0.81	0.95	0.96	0.97
30	0.78	0.93	0.95	0.96
40	0.73	0.91	0.93	0.95
50	0.72	0.89	0.91	0.94
60	0.71	0.88	0.89	0.93
70	0.69	0.87	0.88	0.92
80	0.68	0.83	0.85	0.89
90	0.63	0.81	0.83	0.88
100	0.59	0.78	0.81	0.86

The Figure 2 projects the performance evaluation against pausetime of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP outperforms the rest of the protocols in terms of packet delivery ratio. The numerical results are also presented in Table 2.

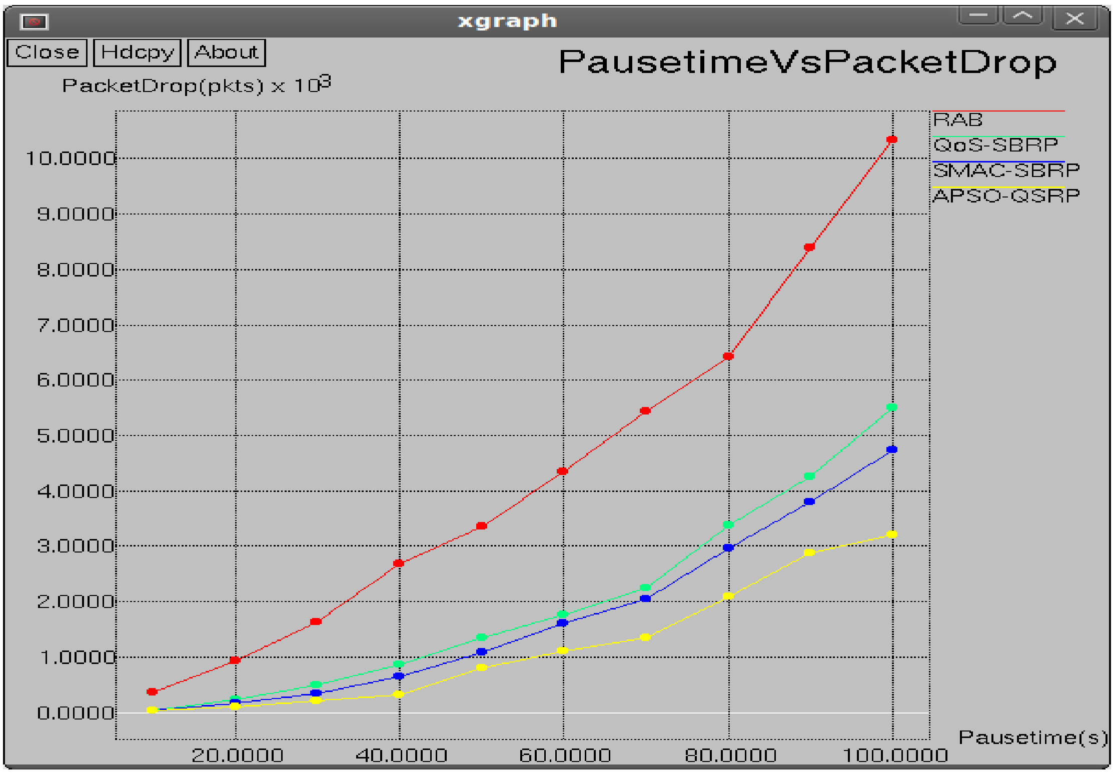

Figure 3. Pausetime Vs Packet Drop

Table 3. Pausetime Vs Packet Drop

Pausetime	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
10	362	36	36	28
20	931	227	175	104
30	1630	495	340	219
40	2690	866	660	329
50	3363	1340	1082	799
60	4345	1762	1608	1118
70	5432	2236	2056	1356
80	6414	3380	2968	2101
90	8380	4266	3802	2890
100	10345	5512	4740	3201

The Figure 3 emphasizes the performance evaluation against pausetime of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP drops less number of packets that rest of the protocols. The numerical results are also presented in Table 3.

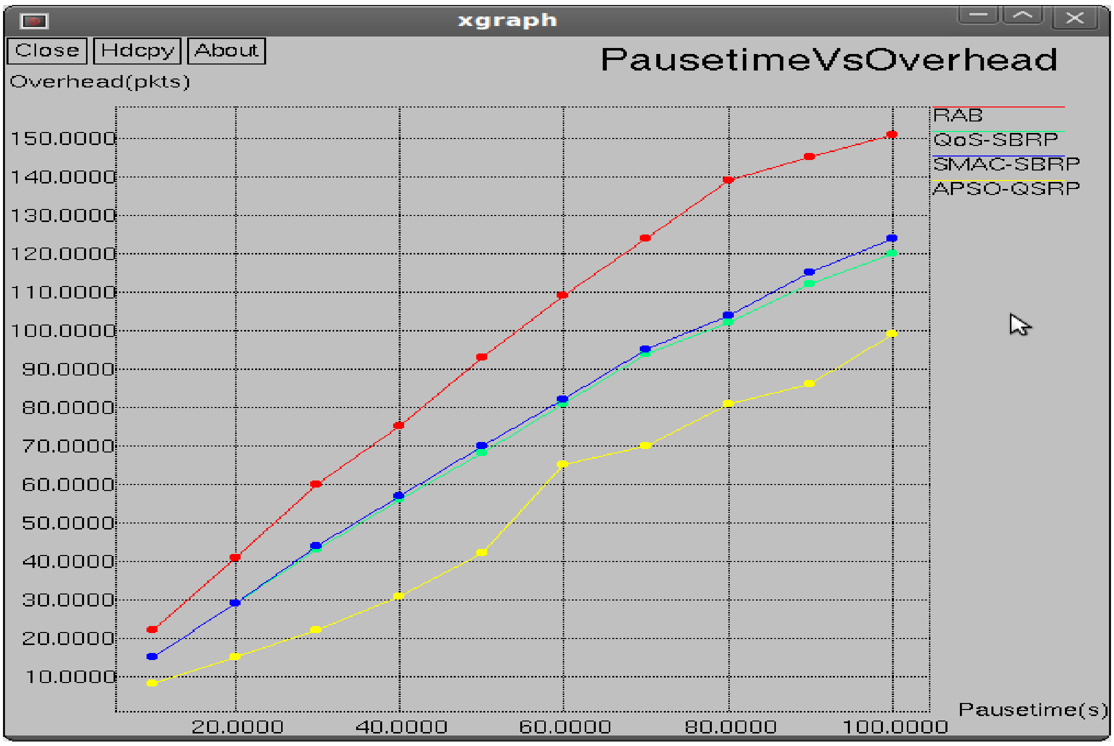

Figure 4. Pausetime Vs Overhead

Table 4. Pausetime Vs Overhead

Pausetime	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
10	22	15	15	8
20	41	29	29	15
30	60	43	44	22
40	75	56	57	31
50	93	68	70	42
60	109	81	82	65
70	124	94	95	70
80	139	102	104	81
90	145	112	115	86
100	151	120	124	99

The Figure 4 shows the performance evaluation against pausetime of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP produces less number of overhead packets. The numerical results are also shown in Table 4.

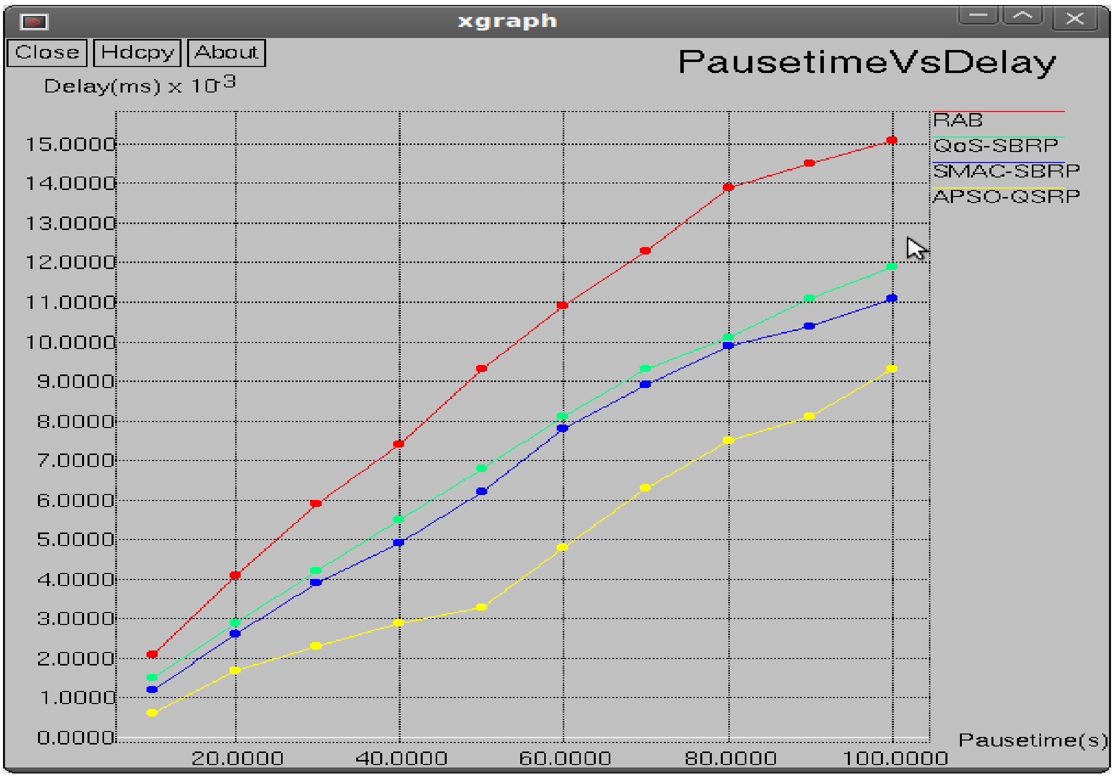

Figure 5. Pausetime Vs Delay

Pausetime	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
10	0.0021	0.0015	0.0012	0.0006
20	0.0041	0.0029	0.0026	0.0017
30	0.0059	0.0042	0.0039	0.0023
40	0.0074	0.0055	0.0049	0.0029
50	0.0093	0.0068	0.0062	0.0033
60	0.0109	0.0081	0.0078	0.0048
70	0.0123	0.0093	0.0089	0.0063
80	0.0139	0.0101	0.0099	0.0075
90	0.0145	0.0111	0.0104	0.0081
100	0.0151	0.0119	0.0111	0.0093

The Figure 5 shows the performance evaluation against pausetime of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP consumes less delay than that of rest of the protocols. The numerical results are also presented in Table 5.

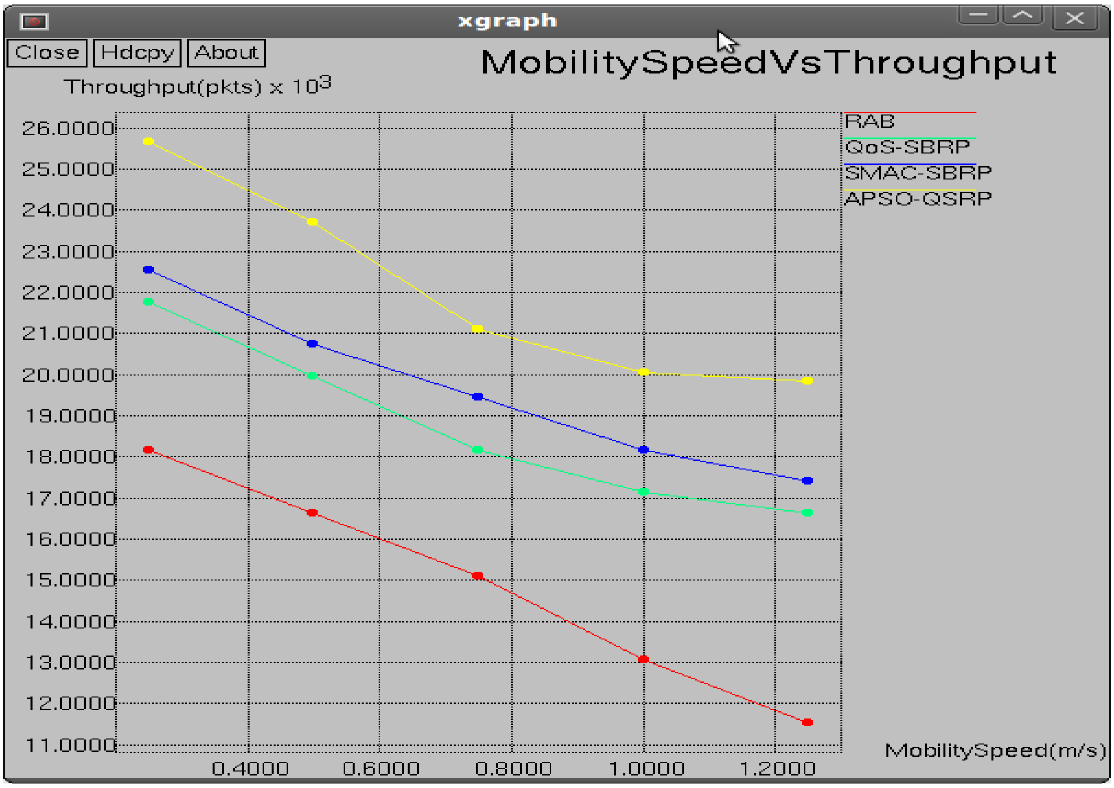

Figure 6. Mobility Speed Vs Throughput

Table 6. Mobility Speed Vs Throughput

Mobility Speed	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
0.25	18176	21760	22528	25671
0.50	16640	19968	20736	23712
0.75	15104	18176	19456	21094
1.00	13056	17152	18176	20065
1.25	11520	16640	17408	19848

The Figure 6 depicts the performance evaluation against mobility speed of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP outperforms the rest of the protocols in terms of throughput. The numerical results are also shown in Table 6.

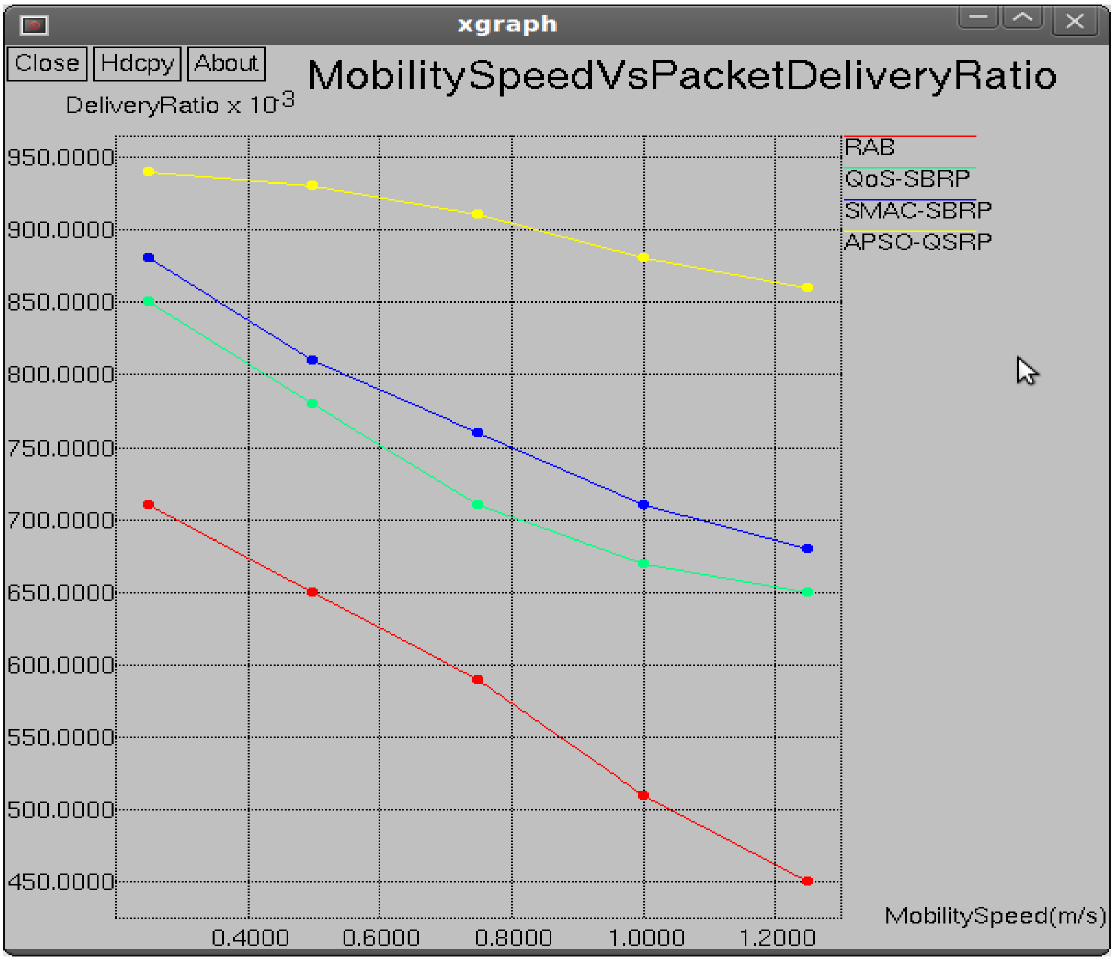

Figure 7. Mobility Speed Vs Packet Delivery Ratio

Table 7. Mobility Speed Vs Packet Delivery Ratio

Mobility Speed	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
0.25	0.71	0.85	0.88	0.94
0.50	0.65	0.78	0.81	0.93
0.75	0.59	0.71	0.76	0.91
1.00	0.51	0.67	0.71	0.88
1.25	0.45	0.65	0.68	0.86

The Figure 7 projects the performance evaluation against mobility speed of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP outperforms the rest of the protocols in terms of packet delivery ratio. The numerical results are also presented in Table 7.

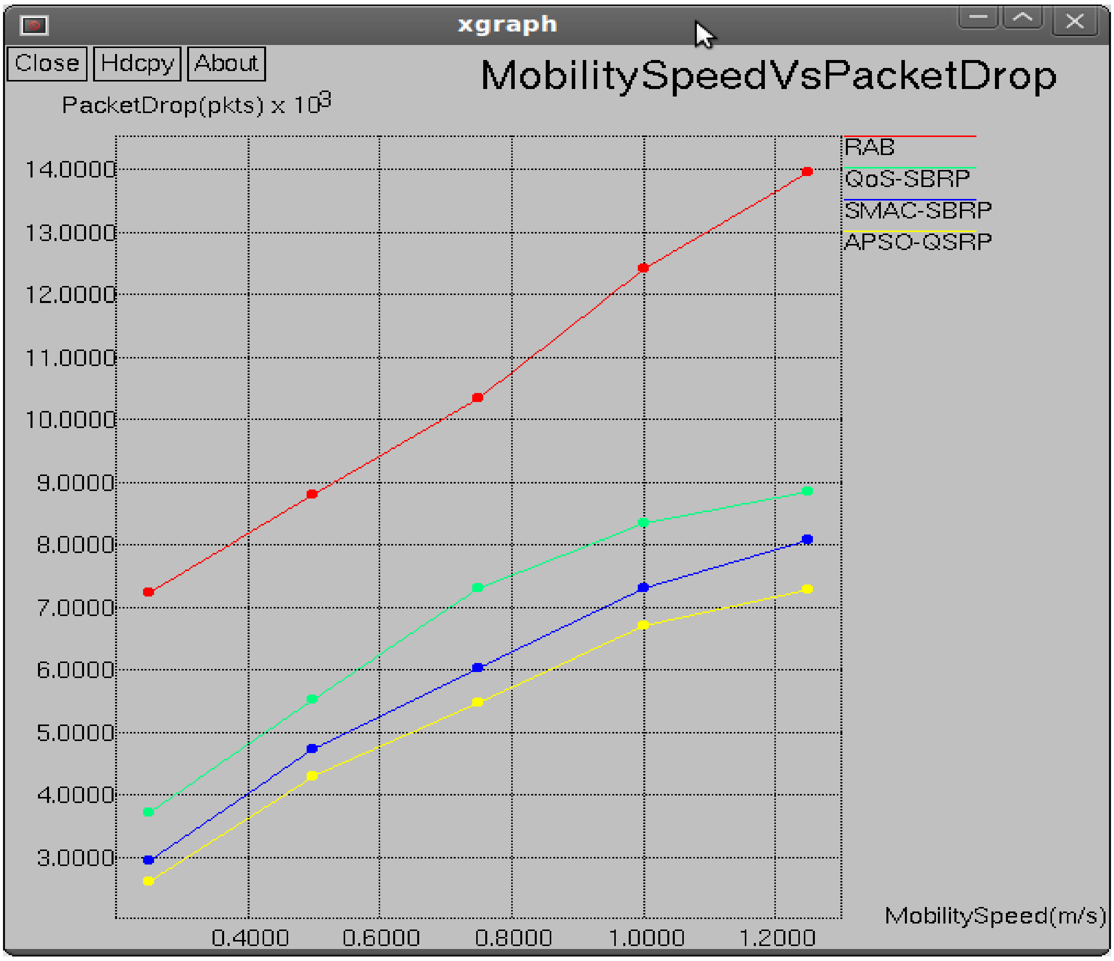

Figure 8. Mobility Speed Vs Packet Drop

Table 8. Mobility Speed Vs Packet Drop

Mobility Speed	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
0.25	7242	3709	2937	2599
0.50	8794	5512	4740	4298
0.75	10345	7315	6027	5486
1.00	12413	8345	7315	6693
1.25	13965	8860	8088	7294

The Figure 8 shows the performance evaluation against mobility speed of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP drops less number of packets than rest of the protocols. The numerical results are also shown in Table 8.

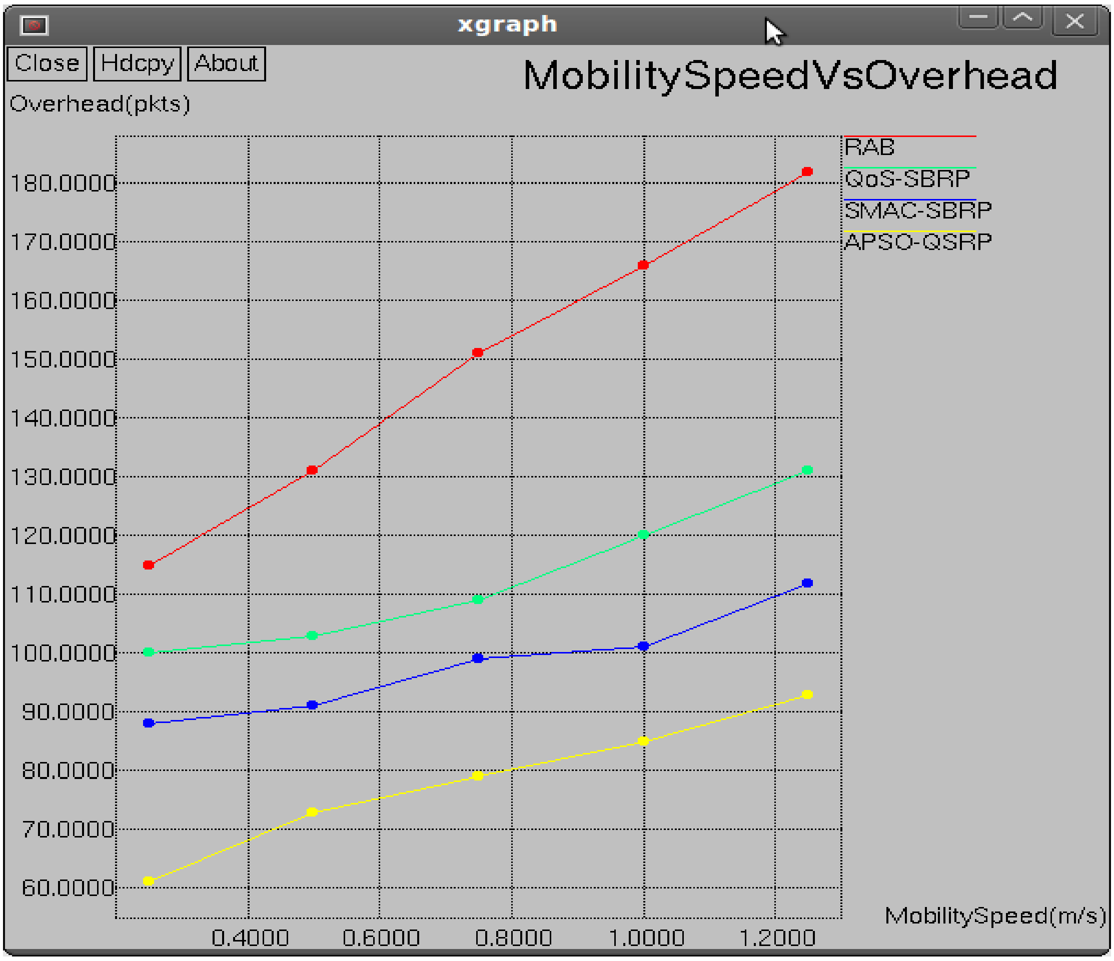

Figure 9. Mobility Speed Vs Overhead

Table 9. Mobility Speed Vs Overhead

Mobility Speed	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
0.25	115	100	88	61
0.50	131	103	91	73
0.75	151	109	99	79
1.00	166	120	101	85
1.25	182	131	112	93

The Figure 9 shows the performance evaluation against mobility speed of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP. Simulations are carried out using NS2 and the results shows that the proposed protocol APSO-QSRP consumes less number of overhead packets than rest of the protocols. The numerical results are also presented in Table 9.

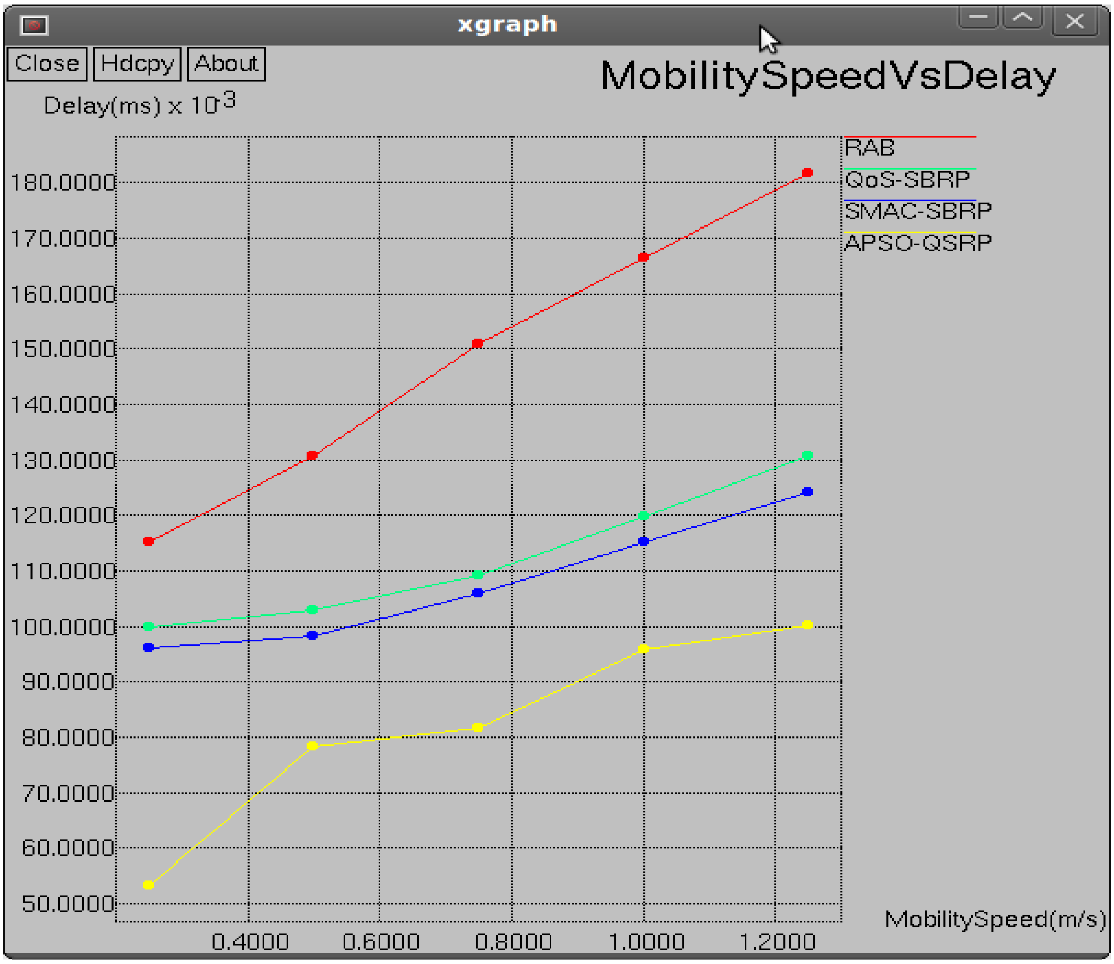

Figure 10. Mobility Speed Vs Delay

Table 10. Mobility Speed Vs Delay

Mobility Speed	Protocols			
	RAB	QoS-SBRP	SMAC-SBRP	APSO-QSRP
0.25	0.1152	0.0998	0.0960	0.0532
0.50	0.1306	0.1029	0.0983	0.0785
0.75	0.1510	0.1091	0.1059	0.0816
1.00	0.1664	0.1198	0.1153	0.0959
1.25	0.1818	0.1306	0.1241	0.1001

The Figure 10 presents the performance evaluation against mobility speed of the protocols namely RAB, QoS-SBRP, SMAC-SBRP and APSO-QSRP in heterogeneous scenario. Simulations are carried out using NS2 and the results emphasizes that the proposed protocol APSO-QSRP consumes less delay than rest of the protocols. The numerical results are also shown in Table 10.

6. Conclusion

This research manuscript presents an adaptive particle swarm optimization approach to ensure quality of service aware scheduling routing protocol for heterogeneous mobile ad hoc networks shortly termed as APSO-QSRP which makes use of parameters namely received signal strength and queuing delay. Once after estimating the parameters, adaptive particle swarm optimization algorithm is utilized optimized routing performance. The proposed protocol has been tested on NS-2 using the performance metrics such as throughput, packet delivery ratio, overhead, packets drop and delay. The simulation has been carried out based on mobility speed and pausetime. Mobility speed is taken for ensuring the proposed protocol's performance on heterogeneous environment. Simulation results projected that the proposed routing protocol (APSO-QSRP) achieves significant QoS performance in terms of throughput, packet delivery ratio, overhead, packets drop and delay based on both pausetime and mobility speed.

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