Load Balancing in Integrated MANET, WLAN and Cellular Network

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Abstract - ***The present work integrates mobile ad-hoc network, wireless local area network and cellular network. It balances the load among the three networks in the integrated heterogeneous environment. It uses a home agent for the selection of the optimal network depending upon the type of session of the mobile nodes. It uses route selection algorithm to select the optimal route in the selected optimal network. Two different position based ant colony routing algorithms are proposed for mobile ad-hoc network in the present work. Both the routing algorithms select an optimal route for a session before starting it. They use route maintenance algorithm to detect whether a node associated with an existing route is going out of the communication range during the ongoing session before the existing route fails completely. Such consideration helps to reduce the data packet loss for both the algorithm. Our previous route selection algorithm is used for route selection in the wireless local area network and cellular network. The performance of the proposed routing algorithms for mobile ad-hoc network are compared with the performance of the existing basic position based ant colony routing algorithm on the basis of initial path set up time, average delay and packet loss. The performance of the three networks is compared on the basis of path set up time and average packet delay in the integrated heterogeneous environment. The performance of the proposed integrated scheme is evaluated in terms of blocking probability.***

Index Terms - MANET, WLAN, Cellular Network, Basic POSANT routing algorithm

1.0 INTRODUCTION

The mobile nodes (MNs) will be equipped with multiple wireless access technology in the future wireless networks. So the future wireless networks are an integrated heterogeneous environment where each MN has multiple network interfaces corresponding to multiple wireless access technology associated with it. The seamless mobility management and load balancing are the challenging issues for such a heterogeneous wireless networks environment.

Such several integration schemes have been reported so far. Nair and Jhu introduced [1] network latency, congestion, battery power, service type as important performance criteria to evaluate seamless vertical mobility.

An end-to-end mobility management system is proposed in [2] to reduce unnecessary handoff and ping-pong effect by using measurement on the condition of different networks.

Nasser et al. proposed a vertical handoff decision method [3] to calculate the service quality for available networks and selects the network with the highest quality. The vertical handoff algorithms in [1,3] are not adequate to coordinate the QoS of many individual mobile users or adapt to newly emerging performance requirements for handoff and changing network status. The vertical handoff decision function for heterogeneous wireless network in [4] is a measurement of network quality. But the authors did not provide any performance analysis. An active application oriented handoff decision algorithm [5] was proposed for multi interface mobile terminals to reduce the power consumption caused by unnecessary handoff and other unnecessary interface activation.

The present work considers the integration of mobile ad-hoc network (MANET), wireless local area network (WLAN) and cellular network. A mobile router (MR) is associated with each MN for maintaining the session in such an integrated heterogeneous environment. Each MN in this integrated environment has three network interfaces. The cellular network has the excellence of wide coverage, seamless roaming support and better quality of service. The WLAN found its application as a low cost high speed solution to cover hot spot like Internet cafes, office buildings, apartment buildings etc. to solve the wideband data access problem and to utilize the existing infrastructure which helps to reduce the implementation cost of the network. The cellular network and WLAN provide single hop communication environment whereas MANET helps to extend this to a multi hop communication environment [6]. The MANET provides multi hop communication environment to the MNs without using any existing infrastructure. Moreover the small, low cost and low powers are suitable for frequent but short duration sessions like making a phone call, checking appointment schedule etc. So low power consumption is an important factor for such application which only can be achieved using MANET environment.

The present work maintains a home agent (HA) to select an optimal network depending upon the type of application of the MNs. When a MN wants to initiate a session it sends session request message to the HA. This message contains MN identification (MN_id) and type of session. The home agent selects MANET as optimal network for the MNs in case of short duration sessions inside the hot spot cells. It selects cellular network as optimal network for the MNs having a session with little data for transmission or reception and long idle period. Though the power consumption of the network interface card (NIC) in MN for upload in cellular network is almost two times than that of WLAN network still it is suitable because using lesser bandwidth of cellular network MNs can transmit or receive only a small amount of data. On the other

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hand the WLAN network is suitable for MNs having a session with lot of data due to its high speed, high bandwidth and low cost which helps to complete transmission or reception using the same network which in turn reduces the frequency of vertical handoff. The power consumption of the NIC in MN in case of idle mode is almost 9 times higher in WLAN network in comparison to cellular network. So it would be more advantageous to select the cellular network for mobility management [7] as energy efficient interface in case of idle MN. The HA maintains session_count counter and block_count counter. It increases session_count counter by 1 after receiving a session request message from MN. The home agent increases block_count counter by 1 if it is unable to select an optimal network in response to the session request message of MN within time out. The home agent computes the session blocking probability of the proposed scheme as the ratio of block_count and session_count.

Two different routing algorithms for MANET are proposed in the present work. These algorithms are discussed in section II. The present work uses the route selection algorithm as proposed in [8] for cellular network and WLAN. The HA of the proposed scheme works as the vertical handoff controller as considered in [8] to execute the route selection algorithm.

2.0 ROUTING ALGORITHMS FOR MANET

The routing algorithms for MANET are considered for discussion in the following sections.

2.1 HA Posant Routing Algorithm

The HA is equipped with Google Map [9] and each MN is equipped with global position system (GPS). A source MN (S_id) sends route request message (RRM as discussed in section 2.1.1) to HA for the initiation of a session with a destination MN (D_id). The HA triggers route selection algorithm (as discussed in section 2.1.2) to select an optimal route in response to RRM and sends the optimal route to S_id using route found message (RFM as discussed in section 2.1.1). The home agent assigns unique session identification (SS_id) to each session after selecting an optimal route for it. After receiving route found message S_id generates Type 0 packet (T0 as discussed in section 2.1.3). The route field (Route) of RFM and T0 contains the identification of all MNs which are associated with the optimal route. The S_id sends T0 to D_id through all MNs which are identified in Route of T0. Each MN in the MANET environment maintains a routing table (as discussed in section 2.1.4) and inserts a record in the routing table after receiving a T0. Both S_id and D_id associated with a particular session generate Type 1 packet (T1 as discussed in section 2.1.3) and send T1 to each other to maintain the bidirectional transmission of packets corresponding to a particular session among them using the optimal route which is mentioned in RFM. The HA maintains a session table (as discussed in section 2.1.5) to store the information of all the ongoing sessions among MNs in MANET. The home agent inserts a record in the session table after selecting an optimal route. As soon as an ongoing session is over S_id associated with this session sends session over message (SOM as discussed in section 2.1.1) to HA. The HA searches the session table for the record who's SS_id attribute matches with the SS_id field as mentioned in SOM and deletes that record from the session table. The HA executes route maintenance algorithm (as discussed in section 2.1.6) to detect MN(s) which is associated with an existing route(s) and is going out of the communication range from its neighboring MN associated with the same route during the ongoing session. In such a case the HA considers the existing route(s) as faulty and executes route selection algorithm for the selection of an alternative optimal route(s) to replace the faulty existing route(s). It sends the alternative optimal route to S_id(s) associated with the faulty existing route(s) using route maintenance message (RMM as discussed in section 2.1.1). After receiving route maintenance message S_id(s) generates Type 2 packet (T2 as discussed in section 2.1.3). The new route (N_Route) field of RMM and T2 contains the identification of all MNs which are associated with the alternative optimal route. The S_id sends T2 to D_id through all MNs which are identified in N_Route of T2 for necessary insertion or modification in their routing table.

2.1.1 Message Exchange among Various MNs

RRM contains S_id and D_id fields. RFM contains S_id, D_id, SS_id and Route fields. The MR associated with S_id uses the optimal route as mentioned in Route of RFM for packet transmission corresponding to a particular session which is identified by SS_id field. SOM contains SS_id and F_flag fields. The F_flag field of SOM is set to indicate the end of session which is identified by the SS_id field. RMM contains SS_id, S_id and N_Route fields. The MR associated with S_id uses the alternative optimal route as mentioned in N_Route of RFM for packet transmission corresponding to a particular session which is identified by SS_id field.

2.1.2 Route Selection Algorithm

The GPS detects the current location in terms of longitude and latitude of each MN. The GPS sends this information of each MN to HA as soon as the current location of any MN changes. The home agent uses Vincenty's inverse equation [10] to calculate the distance between two neighboring mobile nodes using their current location which is obtained from GPS. The HA maintains a rectangular boundary around the MNs and the Google Map in HA shows the real time image of each MN within this rectangular boundary using the information provided by GPS. If any intruder MN crosses the rectangular boundary from outside HA sends a special security signal to the MN(s) closer to the intruder MN. The HA maintains a graph of MNs using their real time image which is provided by the Google Map continuously. After receiving RRM the HA applies depth first search to the graph and finds all possible routes from source MN which is identified by S_id to the destination MN which is identified by D_id in RRM. The HA counts the number of MNs in each possible route and selects the route having minimum number of MNs as the best route.

The HA uses basic POSANT [11] algorithm to determine the optimal route in case of multiple best routes.

2.1.3 Type of Packets

T0 contains SS_id, S_id, D_id, Type and Route fields. The Type field indicates the type of the packet as Type 0. T1 contains SS_id, Node_id, S_No, Type and PAYLOAD fields. The Node_id field of this packet is S_id in case the packet is generated by the source MN and D_id in case the packet is generated by the destination MN. The S_No field indicates the sequence number of the packet and Type field indicates the type of the packet as Type 1. The PAYLOAD field contains the data corresponding to the session which is identified by the SS_id. T2 contains SS_id, S_id, D_id, S_No, Type, N_Route and PAYLOAD. The Type field indicates the type of the packet as Type 2.

2.1.4 Routing Table

Each record in the routing table has 5 attributes as shown in TABLE-1. The attributes SN_NH and DN_NH are the source MN next hop and destination MN next hop respectively.

S_id	D_id	SS_id	SN_NH	DN_NH
S	D	s	T	E

Table 1

Let TABLE-1 is the routing table which is maintained by j^{th} MN and it shows a record for s^{th} session. The S_id and D_id which are associated with s^{th} session are identified as S and D respectively in TABLE-1. T indicates the next hop of the j^{th} MN in case of transmission from S to D and E indicates the next hop of j^{th} MN in case of transmission from D to S in TABLE-1. After receiving a T0 the j^{th} MN inserts a record in TABLE-1. After receiving a T1 the j^{th} MN searches TABLE-1 for the existing record whose SS_id attribute matches with the SS_id field as mentioned in T1. It compares the S_id attribute and the D_id attribute of the existing record with the Node_id field as mentioned in T1. If the Node_id field in T1 matches with the S_id attribute of the existing record the j^{th} MN forwards the packet to T and if the Node_id field in T1 matches with the D_id attribute of the existing record the j^{th} MN forwards the packet to E. After receiving T2 the j^{th} MN searches the routing table for the existing record whose SS_id attribute matches with the SS_id field as mentioned in T2. If found it updates the record by replacing the old route attribute by the new route attribute as mentioned in T2. Otherwise, it inserts a new record in the routing table. When a MN is not participating in packet transmission corresponding to a particular session, it deletes the corresponding record from the routing table.

2.1.5 Session Table

Each record in the session table has 3 attributes as shown in TABLE-2. The Route attribute contains the identification of all MNs which are associated with the selected optimal route starting from S_id to D_id for the packet transmission corresponding to a particular session as identified by SS_id. The number of records in the session table depends upon the number of ongoing sessions.

SS_id	S_id	Route

Table 2

2.1.6 Route Maintenance Algorithm

The HA computes the distance between the two neighboring MNs continuously using the information provided by GPS and using the Vincenty's inverse equation. The HA considers a MN as MOVE_NODE in case its distance from the neighboring MN crosses a threshold. The threshold distance is computed during simulation as discussed in section 3.1.2. As soon as HA detects such a MN, it searches the Route attribute of all the records in the session table. It selects the record(s) whose Route attribute contains the identification of the MOVE_NODE. If found it retrieves the selected record(s). It executes route selection algorithm for the selection of an alternative optimal route(s) before the existing route(s) fails completely. Such advance selection of an alternative optimal route helps to reduce packet loss of a session. The HA updates the selected record(s) by replacing the old route attribute by the new route attribute in the session table.

The installation of Google Map along with GPS increases the cost of the system. Moreover the GPS may not be able to work properly in situations such as underwater conditions e.g. within submarines. In such a situation radio detection and ranging (RADAR) works well. The RADAR POSANT routing algorithm is considered for discussion in section 2.2.

2.2 Radar Posant Routing Algorithm

Each MN is equipped with two antennas, one at the front end and one at the rear end of MN. Both the antenna can work as transmitter as well as receiver to achieve bidirectional transmission of packets corresponding to a particular session. One of the MNs works as a special fixed node (SFN). It maintains route information and is not taking any part in communication.

The S_id triggers route selection algorithm (as discussed in section 2.2.1) by forwarding ant packet [11] towards D_id for the initiation of a session as in basic POSANT routing algorithm. The D_id selects an optimal route and sends the optimal route to SFN using D_to_SFN message (as discussed in section 2.2.2). The SFN sends the optimal route to S_id using SFN_to_S message (as discussed in section 2.2.2). The SFN assigns a unique SS_id to each session after receiving the optimal route from D_id. After receiving SFN_to_S message S_id generates T0 (as discussed in section 2.1.3). The route field (Route) of D_to_SFN message, SFN_to_S message and T0 contain the identification of all MNs which are associated with the optimal route. The S_id sends T0 to D_id through all MNs which are identified in Route of T0. Each MN maintains a routing table (as discussed in section 2.1.4) and inserts a record in the routing table after receiving a T0. Both S_id and D_id associated with a particular session generate T1 (as discussed in section 2.1.3) and send T1 to each other to maintain the bidirectional transmission of packets corresponding to a particular session among them using the optimal route as mentioned in SFN_to_S message. The SFN maintains a session table (as discussed in section 2.1.5) to store the information of all the ongoing sessions among MNs in MANET. The SFN inserts a record in the session table after receiving D_to_SFN message. As soon as an ongoing session is over S_id associated with this session sends SOM (as discussed in section 2.2.2) to SFN. The SFN searches the session table for the record who's SS_id attribute matches with the SS_id field as mentioned in SOM and deletes that record from the session table. Each MN associated with an existing route executes route maintenance algorithm (as discussed in section 2.2.3) to detect whether its neighboring MN associated with the same route is going out of the communication range during the ongoing session and sends an alarming signal to the neighboring MN. In response the neighboring MN sends its identification to SFN. In such a case the SFN considers the existing route as faulty and sends SFN_ALT_ROUTE message (as discussed in section 2.2.2) to S_id which is associated with the faulty route for the execution of the route selection algorithm. The S_id executes route selection algorithm for the selection of an alternative optimal route to replace the faulty existing route. After selecting the alternative optimal route S_id generates T2 (as discussed in section 2.1.3). The N_Route of T2 contains the identification of all MNs which are associated with the alternative optimal route as selected by S_id. The S_id sends T2 to D_id through all MNs which are identified in N_Route of T2 for necessary insertion or modification in their routing table.

2.2.1 Route Selection Algorithm

The S_id forwards the ant packet through all the possible routes between S_id and D_id associated with a particular session as in basic POSANT routing algorithm. The ant packet deposits pheromone value to each link. The maximum pheromone value is deposited to the link having smallest length. The ant packet has 6 fields as shown in Fig.1.

S_id	D_id	A_F	T_S	Route	P_C

Figure.1: Format of ant packet

The A_F field is set to indicate the type of the packet as ant. Let i^{th} MN receives an ant packet from k^{th} MN and j^{th} MN is the successor of i^{th} MN. The i^{th} MN mentions the current time stamp in the T_S field of the ant packet and forwards it to j^{th} MN. The i^{th} MN adds its identification in the Route field of the ant packet. The i^{th} MN computes the difference in time stamp (Diff_time) between the current time stamp corresponding to the time of receiving the ant packet by it and the time stamp in the T_S field of the ant packet as mentioned by k^{th} MN. The i^{th} MN also computes its distance from k^{th} MN (D_{ik}) by multiplying Diff_time and the speed of electromagnetic signal (m/sec). The bit error rate increases rapidly when the distance between the two neighboring MNs in the WLAN environment is greater than 45 meters [12]. So in the present work the pheromone value of the link between the i^{th} MN and the k^{th} MN (P_value_{ik}) is assumed as 20 (any value >1 shows the identical performance) if D_{ik}<45 otherwise it is assumed as 1. The i^{th} MN also multiplies the value in the P_C field of the ant packet as mentioned by k^{th} MN by P_value_{ik}. At i^{th} MN the value in P_C field of the ant packet indicates the pheromone concentration of the route from S_id up to i^{th} MN.

The D_id receives multiple ant packets through all possible routes between source and destination. It compares the P_C value of all the received ant packets. The route field in the ant packet having maximum P_C value is selected as the optimal route.

2.2.2 Message Exchange among Various MNs

D_to_SFN message has S_id, SFN_id and Route fields. SFN_id field indicates the identification of SFN. SOM contains SS_id and F_flag. SFN_to_S message contains SS_id, S_id, SFN_id and Route fields. The SFN_ALT_ROUTE message contains S_id, SFN_id and SS_id fields.

2.2.3 Route Maintenance Algorithm

Each MN associated with an existing route computes its distance from its neighboring MN which is associated with the same route using mono-static equation [13]. The mono-static equation used by the RADAR antennas in this scheme is as follows:

$P_r = 10\log_{10}[(P_tG_tG_r\lambda^2\sigma)/((4\pi)^3R^4)]$
$= 10\log_{10}[P_tG_tG_r\{(\sigma c^2)/((4\pi)^3 f^2 R^4)\}]$

where, P_r = Received peak power
P_t = Transmitted peak power
G_t = Gain of transmitter antenna (dBi)
G_r = Gain of receiver antenna (dBi)
λ = Transmitted wavelength (m, cm, in, etc.)
σ = Radar cross-section of target - RCS (m^2, cm^2, in^2, etc.) R = Range (m, cm, in, etc.), c = speed of light

The parameter values of the mono-static equation are assumed as follows: P_t = 20 dbm, $G_t = G_r$ =16 dbi, λ = 15 cm, σ = 2.5 m^2 and c = $3*10^8$ meter/sec [14,15,16,17]. The parameter R indicates the distance between the two neighboring MNs. P_r is measured at the receiving antenna and R is computed using the mono-static equation using the known value of all the other parameters.

Each MN associated with an existing route also computes its angle with its neighboring MN which is associated with the same route using Pythagoras theorem. In ΔABC (Fig.2) the vertex B and the vertex C represent the location of the front end and rare end antenna in a MN. The vertex A represents the location of the neighboring MN. In ΔABC the side AB (=c) represents the distance between the neighboring MN and the front end antenna. P_r is measured at the front end antenna and c is computed using mono-static equation. The side AC (=b) represents the distance between the neighboring MN and the rare end antenna. P_r is measured at the rare end antenna and b is computed using mono-static equation. The side BC (=a) represents the length of MN. AP (=h) is perpendicular to BC.

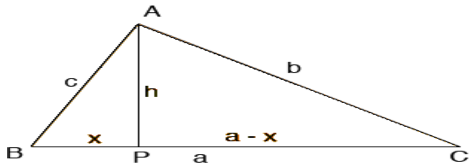

Figure.2: Triangular representation of the angle calculation process.

The angle between the two neighboring MNs (angle C) is C= $\cos^{-1}\{(a^2+b^2-c^2)/ 2ab\}$ using Pythagoras theorem. A MN sends an alarming signal to its neighboring MN (RECEIVED_NODE) in the direction of the angle as computed by the Pythagoras theorem in case its distance from the RECEIVED_NODE crosses a threshold. The threshold distance is computed during simulation as discussed in section 3.1.2. The RECEIVED_NODE sends its Node_id to SFN. The SFN searches the Route attribute of all the records in the session table. It selects the record(s) whose Route attribute contains the identification of the RECEIVED_NODE. If found it retrieves the selected record(s) and sends SFN_ALT_ROUTE message to S_id(s) associated with the selected record(s) to execute route selection algorithm for the selection of an alternative optimal route(s) before the existing route(s) fails completely. After the selection of the alternative optimal route by D_id, SFN receives D_to_SFN message and updates the selected record(s) by replacing the old route attribute by the new route attribute corresponding to the alternative optimal route in the session table.

2.3 Comparison of Routing Algorithms

In this section the basic POSANT routing algorithm [11], HA POSANT routing algorithm and RADAR POSANT routing algorithm are compared on the basis of storage requirement, routing table searching time and time complexity of the algorithm.

2.3.1 Storage Requirement

In basic POSANT routing algorithm each MN maintains a forward routing table to send packets from source MN to destination MN and a backward routing table to send packets from destination MN to source MN. Each record in the routing table has 3 attributes as shown in TABLE-3. Let TABLE-3 is the forward routing table at j^{th} MN. The Node_Address attribute is the address of the destination MN in case of forward routing table. The Next_Hop attribute is the address of the next hop MN from j^{th} MN towards destination which is identified by the Node_Address attribute. The Pheromone_Value attribute indicates the pheromone value corresponding to the next hop MN which is indicated by the Next_Hop attribute. The Node_Address attribute and the Next_Hop attribute are 128 bit IPv6 address. The maximum pheromone value which is deposited to a link is 20 as discussed in the section 2.2.1 and the number of bits require to represent the maximum pheromone value is 5. So the length of each record in the forward routing table at any MN is 261 bits. The number of records in the forward routing table at j^{th} MN for a single session depends upon the number of possible next hop MNs from j^{th} MN towards destination. So the storage requirement per forward routing table is (261*number of possible next hop towards destination MN) bits.

Node_Address (128 bits)	Next_Hop (128 bits)	Pheromone_Value (5 bits)

Table 3

Let TABLE-3 is the backward routing table at j^{th} MN. The Node_Address attribute is the address of source MN in case of backward routing table. The Next_Hop attribute is the address of the next hop MN from j^{th} MN towards source which is identified by the Node_Address attribute. The number of records in the backward routing table at j^{th} MN for a single session depends upon the number of possible next hop MNs from j^{th} MN towards source. The storage requirement per backward routing table is (261*number of possible next hop towards source MN) bits. So the storage requirement for each bidirectional session is 261*(number of possible next hop towards destination + number of possible next hop towards source) bits.

In HA POSANT routing algorithm and RADAR POSANT routing algorithm each MN maintains a single routing table as shown in TABLE-1. The S_id, D_id, SN_NH and DN_NH are 128 bits IPv6 addresses. Now for 1000 number of different bidirectional sessions the number of bits requires to represent SS_id is 10. So the length of each record in the routing table is 522 bits. There is a single record for each bidirectional session in the routing table and so the storage requirement for each bidirectional session is 522 bits. The storage requirement for each bidirectional session in basic POSANT routing algorithm is greater than that in HA POSANT routing algorithm and RADAR POSANT routing algorithm if the number of next hop MNs from j^{th} MN towards source or destination is greater than unity in TABLE-3.

2.3.2 Routing Table Searching Time

Let in case of basic POSANT routing algorithm the number of forward ongoing session through j^{th} MN as an intermediate MN is m and the number of next hop from j^{th} MN towards destination is n. So at j^{th} MN the forward routing table contains m*n number of records and the time complexity to select the desired record from the forward routing table is $O(\log_2 m*n)$. The j^{th} MN compares the pheromone value of all the n number of next hops and selects the optimal next hop having the maximum pheromone value. The link between j^{th} MN and the selected optimal next hop is considered as the optimal outgoing link towards destination. The time complexity to select the optimal outgoing link from the forward routing table at j^{th} MN is $O(n^2)$. So the total time complexity at j^{th} MN for the selection of an optimal outgoing link is $O(\log_2 m*n+n^2)$.

In case of HA POSANT routing algorithm and RADAR POSANT routing algorithm the routing table at j^{th} MN contains m number of records and the time complexity to select the desired record from the routing table is $O(\log_2 m)$.

So the time complexity of searching the routing table is higher in basic POSANT routing algorithm than in HA POSANT routing algorithm and RADAR POSANT routing algorithm.

2.3.3 Time Complexity of the Algorithm

In case of basic POSANT routing algorithm the routing table at each MN contains the possible next hop and their pheromone value. During the ongoing session the routing table at each MN is searched for the selection of an optimal outgoing link. In case of HA POSANT routing algorithm and RADAR POSANT routing algorithm the routing table at each MN contains the optimal route. During the ongoing session the routing table at each MN is searched for the optimal route. So the optimal route is selected during the ongoing session in basic POSANT routing algorithm which increases its time complexity than the HA POSANT routing algorithm and RADAR POSANT routing algorithm. The time complexity of the HA POSANT routing algorithm is higher due to the time complexity of the depth first search than the time complexity of the RADAR POSANT routing algorithm

3.0. SIMULATION

The simulation experiment is performed in two different phases. The performance of the basic POSANT [11] routing algorithm, HA POSANT routing algorithm and RADAR POSANT routing algorithm are compared in Phase 1. The performance of the integrated heterogeneous environment has been studied in Phase 2. The simulation experiment is conduced for 1280 number of packets and 6 numbers of MNs in both the phases.

3.1 Experimental Results for Phase 1

The simulation experiment is conducted to compare the performance of the three routing algorithms for MANET.

3.1.1 Initial Path Set Up Time

It is the time to set up an optimal route for the initiation of a session. Fig.3 shows the plot of initial path set up time for all the three routing algorithms. The basic POSANT routing algorithm needs the transmission of forward ant packets and backward ant packets for route selection. The optimal outgoing link corresponding to the optimal route is decided from the pheromone value in the ant packets. The HA POSANT routing algorithm needs the transmission of RRM and RFM among MNs for route selection instead of the transmission of forward ant packets and backward ant packets. The transmission of RRM and RFM select the optimal route instead of the optimal outgoing link which reduces the initial path set up time of HA POSANT routing algorithm than basic POSANT routing algorithm. The RADAR POSANT routing algorithm needs the transmission of forward ant packets for initial route selection which increases the initial path set up time of RADAR POSANT routing algorithm than HA POSANT routing algorithm. But the transmission of backward ant packets is not required in RADAR POSANT routing algorithm which reduces the initial path set up time of RADAR POSANT routing algorithm than basic POSANT routing algorithm.

3.1.2 Average Packet Delay

Fig.4 shows the plot of average packet delay vs. simulation time for all the three routing algorithms. It can be observed from Fig.4 that the average packet delay is higher in basic POSANT routing algorithm as it selects the optimal route during the ongoing session than the other two routing algorithms.

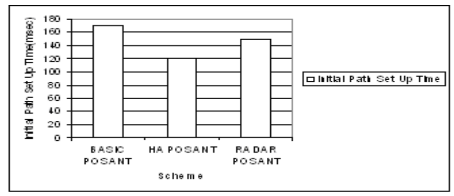

Figure 3: Initial path set up times

Fig.5 shows the plot of average packet delay vs. the number of packets received for all the three routing algorithms. The speed of MN is assumed as 6 km/hr [18,19,20]. If a MN associated with the optimal route of a particular session starts to move in the opposite direction of another MN associated with the same route, their relative velocity becomes 12 km/hr. The communication range of WLAN is assumed as 100 m [21]. So the failure occurs in the existing route when the two neighbouring MNs associated with the same route go out of the communication range with relative velocity 12 km/hr after 30 sec. It can be observed from Fig.3 that the initial path set up time for HA POSANT routing algorithm is 120 msec and for RADAR POSANT routing algorithm is 150 msec. The two neighbouring MNs having relative velocity 12 km/hr covers a distance of 0.4 m (≈ 1 m) in 120 msec for HA POSANT routing algorithm and .5 m (≈1 m) in 150 msec for RADAR POSANT routing algorithm. So the packet loss and average packet delay of an ongoing session can be minimized by triggering the route maintenance algorithm in advance when the two neighbouring MNs associated with the same optimal route are at a threshold distance of 99 m (100 m-1 m) from each other. During simulation it has been observed that the time requires to transmit a single packet using basic POSANT routing algorithm is 40 msec whereas the time requires for transmitting a single packet using HA POSANT routing algorithm and RADAR POSANT routing algorithm is 30 msec. So the number of packets that can be transmitted using basic POSANT routing algorithm in 30 sec is 700 whereas the number of packets that can be transmitted using HA POSANT routing algorithm and RADAR POSANT routing algorithm in 30 sec is 950 before the failure occurs in the existing route.

It can be observed from Fig.5 that the initial average packet delay is higher in basic POSANT routing algorithm due to its higher initial path set up time as discussed in section 3.1.1 than the other two routing algorithms. The new route is selected in basic POSANT routing algorithm after the transmission of 700 packets. The new route is selected in HA POSANT routing algorithm and RADAR POSANT routing algorithm after the transmission of 950 packets. The average packet delay in the new route for basic POSANT routing algorithm is also higher due to its higher initial path set up time than the other two routing algorithms.

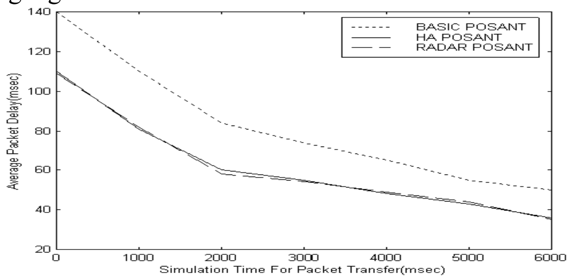

Figure 4: Average packet delay vs. Simulation time

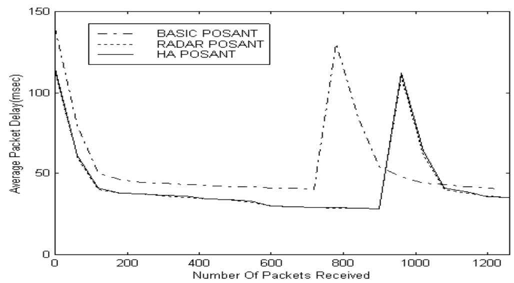

Figure.5: Average packet delay vs. Number of packets received

3.1.3 Percentage Of Successfully Delivered Packets

TABLE-4 shows the percentage of successfully delivered packets for the 3 routing algorithms. The new route discovery process starts after the failure occurs in the existing route in basic POSANT routing algorithm. So the data packets that are generated during the time interval between the occurrence of route failure and finding out a new route are lost. The route maintenance algorithm selects an alternative optimal route in advance before the failure occurs in the existing route in HA POSANT routing algorithm and RADAR POSANT routing algorithm. So the percentage of successfully delivered packets is lesser in basic POSANT routing algorithm than the other two routing algorithms.

Scheme	Packet generated	Packet delivered	% of successfully deliver packets
11	1280	1203	94%
HA	1280	1280	100%
RADAR	1280	1280	100%

Table 4

3.2 EXPERIMENTAL RESULTS FOR PHASE 2

The simulation experiment is conducted to evaluate the performance of the proposed integrated scheme.

3.2.1 Path Set Up Time

Fig.6 shows the path set up time for all the networks in the integrated heterogeneous environment. The path set up time in the cellular network and in WLAN is higher due to the infrastructure access overhead than the path set up time in MANET. The path set up time in cellular network and WLAN are identical as they are using the same route selection algorithm [8].

3.2.2 Average Packet Delay

Fig.7 shows the plot of average packet delay vs. simulation time for all the three networks in the integrated network environment. The average packet delay is lesser in MANET due to its lesser path set up time. The average packet delay of WLAN and cellular network is slightly higher due to higher path set up time and the overhead of executing the route selection algorithm [8] than MANET. But the average packet delay of WLAN is lesser due to its high speed than cellular network.

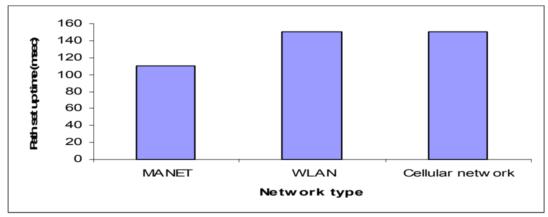

Figure.6: Path set up time for three networks

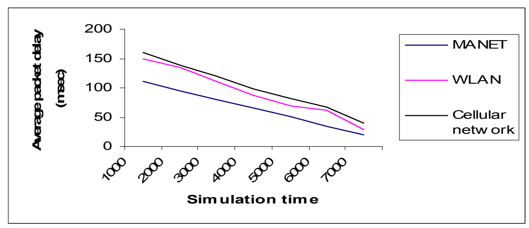

Figure.7: Average packet delay vs. simulation time

3.2.3 Session Blocking Probability

Fig.8 shows the plot of session blocking probability vs. the number of sessions of the proposed scheme. It increases with the number of sessions. The blocking probability in [22] is 90. The maximum session blocking probability of the proposed scheme is 60%.

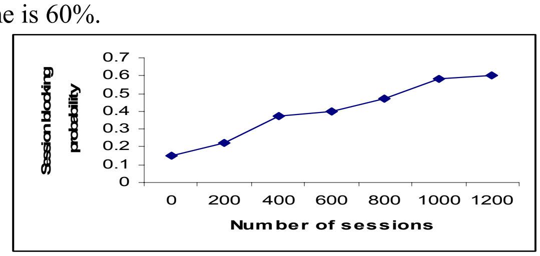

Figure 8: Session blocking probability vs. number of sessions

4.0 CONCLUSION

The proposed work integrates MANET, WLAN and cellular network. It maintains a HA to select an optimal network depending upon the type of session. The route selection algorithm is proposed for all the three networks. The performances of the proposed scheme are evaluated considering only the data class of traffic. It can be extended by considering other traffic classes during simulation.

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