RSAR: Ring Search based Ant Routing for MANETs

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ABSTRACT
Mobile communication and wireless networks have enjoyed a tremendous rise in popularity and advancement in technology from the previous decades. As the peculiar growth of mobile computing, mobile ad hoc networks (MANET) have emerged as an important field in the wireless areas. As a rapidly changing topology of the network, so the primary challenges of ad hoc network is to design effective routing algorithm in such a way that can adapt its behavior to frequent & rapid changing in the network. In this paper, present an on-demand routing protocol for MANET called Ring Search based Ant Routing (RSAR) using expanding ring search model and third-party reply model to provides optimal path routing, fast route discovery and effective route handling. RSAR based on ant colony optimization is done in terms of throughput, packet delivery ratio, end-to-end delay and routing overhead. Simulation studies show that RSAR provides a better performance than existing ant routing such as ARA and conventional routing algorithm such as DSR & AODV.

Keywords
MANET, ACO, RSAR, AODV, DSR, ARA.

1. INTRODUCTION
Ant colony routing algorithm tends to provide properties such as scalability, adaption, robustness, distributed and multi path routing, which are essential to deal with the challenges of ad-hoc network. MANET [1] is a collection of mobile nodes that establishes communication via wireless links without the aid of any fixed infrastructure. This kind of network is flexible and suitable for applications such as temporary information sharing in conferences, military actions and disaster rescues. The challenges arise from the dynamic and temporary nature of ad hoc network is inherent unreliability of wireless communication, limited resources available in terms of energy, computational capacities and bandwidth.

Ad hoc network routing protocol is divided into three type of routing protocol which are depends on a different routing protocols. They are proactive, reactive and hybrid routing protocol .In proactive routing protocol, to maintain routing information for each node in the network at all time. The overhead cost is high in this case. In reactive routing protocol, it finds new routes whenever it is required. Therefore, it produces less overhead but requires maximum time to set up the routes during communication e.g. AODV [2] and DSR [3]. Hybrid routing protocol combines the features of proactive and reactive routing protocols e.g. ZRP [4].Many optimization exist in MANET routing algorithm but still suffers some problems

- ✓ Lack of efficiency and scalability with respect both to the network size and node movement.
- ✓ Due to exchange of the global or the partial global topology information to maintain routing information.

To address the routing problem of MANET, a new family of algorithm emerged inspired by Swarm Intelligence (SI), which provides a novel approach to distributed optimization problems with the goal to reduce routing overhead. Ant colony optimization (ACO) [5] is a subfield of Swarm Intelligence (SI) [6] which provides emergent behavior to solve distributed optimization problems. SI is inspired from collective behavior of social insect's colonies such as ants, termites etc. In recent years, many approaches of swarm intelligence inspired routing algorithm for MANETs proposed with different performance metrics such as throughput, end-to-end delay and routing overhead. The swarm inspired routing is self- organized in nature and adopting the concept Stigmergy [7] which means indirect communication between mobile agents as that of ants by using pheromone concentration i.e. chemical substance lies on the ground. Through the local interaction in between mobile agents, it provides highly adaptive, efficient, and scalable & reduce end-to-end delay in high mobility network.

In this paper, presents adaptive routing in MANET, using ideas of ACO meta-heuristic to get an on-demand routing protocol for the MANET. The RSAR routing protocol based on ACO meta-heuristic which utilizes a collection of mobile nodes or ants to perform optimal routing using expanding ring search and third party reply model. Through a series of simulation tests, we show that for a wide range of different simulation environments and performance metrics, RSAR performs better than ARA, AODV, and DSR.

In this paper, ant colonies behavior is consider. In nature, ants collectively solve complex problems by cooperative effort. However, collectively ants manage to perform several complex tasks with a high degree of consistency and adaptivity.ACO routing protocol in ad hoc network is different from traditional routing protocols in terms of routing preference, exchange of routing information, routing update, adaption to topology change and routing overhead.

The rest of the paper is organized as; Section 2 discusses related work of reactive based routing protocols for MANETs. Section 3 describes proposed routing protocol. Properties of proposed routing algorithm presented in Section 4 followed by algorithm of proposed routing algorithm in Section 5. Simulation environment is discussed in section 6.Results of different routing protocol discussed in Section 7 followed by conclusion in section 8.

2. RELATED WORK
In Dynamic Source Routing (DSR) [3], the key features of DSR is the use of source routing in which route is listed in the header of each packet that is transmitted to intermediate nodes forward the packet by adding the next node address of the

header in the packet. It can learn more routing information from the traffic, thus it generates fewer route discoveries. In DSR, the destination node generates route reply packets after received route request packets. As the entire route is listed in a packet header and likely to cause significant overhead in larger networks where route longer. Route cache can also help to eliminate the overhead burden.

AODV [2] is improvement of DSDV [8].AODV is an on-demand routing for finding the routes. AODV does not maintain any routing information and routing table. It does not create any loops during route discovery process. It provides unicast, multicast and broadcast capabilities to all nodes and broadcast information about link breakage to its neighboring nodes, which is used to minimize the broadcast of control packets. AODV is the use of sequence numbers to prevent routing loops. It does not allow multi-paths form source to destination. Each route packet only needs to know the address of the next hop node to reach its requested destination. When an active link is broken during communication, AODV initiate a new route discovery process which would incur delay and excessive flooding.

ARA [9] is built upon AntNet and has the same similar operations in terms of route discovery. Route discovery is also achieved by flooding forward ants to the destination. The key difference in ARA is that routes are maintained primarily by data packets as they flow through the network. ARA does not use periodic ants; it establishes the path to the destination using pheromone concentration. This brings higher benefit as flooding of periodic ants can be reduced. Similarly to nature, established paths do not maintain their initial pheromone concentration forever. ARA implements a pheromone evaporation mechanism where its value in the routing table decreases over time. This is to inhibit fast convergence of pheromones on the network edges. In the case of a route failure phase, alternate route is used to send the data packet. Otherwise, it is returned to the previous hop hoping that there exists an alternate route. If the packets eventually return to the source, a new route discovery is launched. The main challenge for ARA is a phenomenon called network saturation. As data packets increased the pheromone of a routing path and at the same instance, pheromone of other alternate routes evaporates, the whole data traffic network will quickly converge to a particular route. The relative pheromone margin among all paths will fluctuate. This easily leads to congestion and bottleneck.

Many researchers proposed on-demand routing protocols for ad hoc network, but they still suffer some problems such as extensive flooding and network saturation. To address these problems, an efficient on-demand routing protocol is proposed in this paper. The proposed algorithm introduces efficient, fast route discovery and reduce flooding of the ants in the network in such a way to provide better performance in the network.

3. RSAR

RSAR algorithm mechanism is an on demand routing algorithm, which is based on swarm intelligence whose design is inspired from collective behavior of social insect. In particular, ant colony meta-heuristic is used as strategy for RSAR.This algorithm tries to optimize the efficient routing in the network. The proposed routing protocol has different phases such as route discovery, route maintenance and route failure handling phase.

The packets used in the network can be divided into two classes like data packets and control packets. Data packets represent the information that an end-users exchange with each other. Control packets like forward ant (FANT) and a backward ant (BANT) are used to update the routing tables and distribute information about the traffic load in the network.

3.1 Route Discovery Phase

In route discovery phase, new routes are created by FANT & BANT.FANT is an agent that establishes the pheromone track to the source node. In contrast, BANT establishes the pheromone track to the destination node i.e. in reverse direction. Each FANT carries in its header a stack listing the address of each visited nodes. Every node visited by a FANT appends its own address to the ant's stack before propagating the ant to other nodes. Nodes are able to distinguish duplicate packets on the basis of stack header and source address of the FANT. RSAR adopts a collection of routing agents called forward ants to search for the destination host. When a path to a new unknown destination is required, the source node would initiate a route discovery mechanism. The source node would disseminate forward ants to all its one-hop neighbors. While destination is still not found, the neighbor would pass on the forward ants to their own neighbors. This iteration continues until a route to the destination is found using expanding ring search method, otherwise it sends a reply message to the source node.

To quicken the process of route discovery and to further reduce flooding, RSAR adopts the third-party reply model. Any visited intermediate nodes that have a route in its routing table to the same destination can generate backward ant as a route reply. There is no need for the forward ants to continue traveling in search for the destination as shown in Figure 1 , F sends by source node (S) to its neighboring node (N1) towards the destination node (D). While traveling forward ant (F) in the network, N4 node i.e. intermediate node have route in its routing table for same destination node (D),it simply create backward ant (B) at N4 node as a route reply and sends it to the source node .

RSAR utilizes fully the existing information of the network in order to avoid redundant effort. This strategy works efficiently with the ring search to reduce routing overhead.

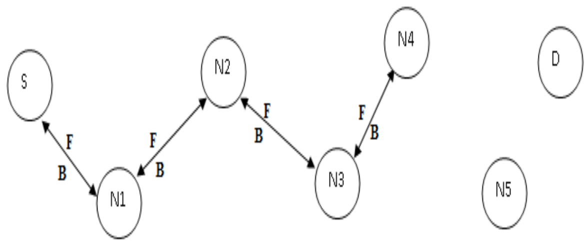

Figure 1: Route Discovery with Third Party Reply Model

3.2 Route Maintenance Phase

The second phase of the routing protocol is called route maintenance phase, which is responsible for the improvement of the routes during the communication. RSAR does not need any special packets for route maintenance. Once the FANT and BANT have established the pheromone tracks for the source and destination nodes, subsequent data packets are used to maintain the path.

As the data packet is transmitted over from one node to node N2, node S would increase the pheromone value for that route entry using the increment function:

$$\Gamma_{new} = \Gamma_{old} + \Psi\, \Gamma_{old}$$

where Γ_{new} is the updated value, Γ_{old} is the previous pheromone value before reinforcement and Ψ is a scaling factor.

Overall, the path to the destination would be further enforced by every transmission of data packets. After a short period of time, data traffic will fully utilize the highest pheromone route as its primary route. This exhibits the quick convergence property of RSAR.

Established paths do not maintain their initial pheromone values forever. All pheromone values in the routing table decreases over time. Through this, the value of pheromone shows the utilization rate of a route. When the pheromone entry reaches a minimum threshold, it is considered a stale route and will be discarded from the routing table. This benefit the network in which the routing table need not keep any unwanted or unused routes that takes up memory space. The evaporation function is defined as:

$$\Gamma_{new} = \Gamma_{old} - \mu\, \Gamma_{old}$$

where Γ_{new} is the updated value, Γ_{old} is the previous pheromone value before reinforcement and μ is an evaporation scaling factor.

3.3 Route Failure Handling Phase

Route failures handling are common in any ad hoc networking scenarios due to the node mobility and dynamic topology of the network. Thus, a good routing algorithm requires a mechanism to handle failures effectively without degrading the overall performance of the network. RSAR recognizes route failure through a link-layer detection scheme. Using the IEEE 802.11 on the MAC layer, RSAR recognizes a route failure through a missing acknowledgement after a transmission of data packet.

The proposed routing protocol is simulated using NS-2[10] under different mobility and network size environment. The extensive simulation carried out reveal that the performance of RSAR which is an on-demand ant based routing protocol is better than ARA, DSR and AODV in all respect.

4. PROPERTIES of RSAR

Distributed Operation: In RSAR, each node own set pheromone value in its routing table.

Loop-Free: The nodes unique address would be appended to the ant stack of route finding packets, FANT and BANT, so they do not generate loops.

Demand-Based Operation: Routes are established by manipulating the pheromone value in the nodes.

Locality: The routing table and the statistic information block of a node are local and they are not transmitted to any other node.

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Multi-Path: Each node maintains several paths to certain destinations.

Sleep Mode: In the sleep mode a node snoops, only packets which are destined to it are processed, thus saving power.

5. RSAR ALGORITHM

5.1 Route Discovery Phase

For each FANT

Set MAXHOP count

Stores address & arrival time of visited nodes in FANT stack.

If FANT retries than increase TTL using expanding ring search.

Broadcast one hop neighbor & update pheromone trails.

Once at destination, generate BANT.

For each BANT

Travel same path in opposite direction.

Update pheromone trails.

Stores address in BANT stack.

Once at source, generate FANT.

5.2 Route Maintenance Phase

1. If data packet receives destination node than extract data & send packet to previous node otherwise

Compute pheromone value & probability for all nodes in neighbors list.

2. Decrement pheromone value. If pheromone=0 than call route discovery phase.

5.3 Route Failure Handling Phase

1. Log broken links

2. Delete broken node from Route Table

If alternate path exist to reach destination

than send packets through other route

else

Set pheromone = 0 in routing table

Send route error message to previous node.

3. If route error message reaches source, it calls route discovery phase.

6. SIMULATION ENVIRNOMENT

Network simulator NS-2[10] is used under fedora platform to evaluate the performance of our proposed routing protocol. The routing algorithms were hard coded into C++ programming language. It is compiled in Network Simulator (NS) version 2.30. Simulation environment was developed in OTcl language and ran in NS. The nodes mobility speed is varied as per table-1 and according to the random waypoint mobility model. The simulation time is set as 900 seconds. The mobility model describes the movement pattern of mobile nodes and each node is responsible for computing its own position and velocity. Nodes move around as per defined mobility model. Constant Bit Rate (CBT) is used to transfer data packets. The simulations have been carried using the parameters mentioned in Table-1.

Table 1.Simulation Parameters

Area Size	800m x 800m
Number of nodes	50
Maximum node speed	10,20,30,40,50,60m/s
Pause Time	2s
Simulation Time	900s
Data Rate	4 packets per second
Packet Size	512
Buffer Size	50 packets
Number of connections	2
Communication Range	50m

7. SIMULATION RESULTS

From the simulation results, we analyze the performance of RSAR in comparison with other conventional routing methods, specifically DSR & AODV and ant colony routing algorithm such as ARA. We gave a detailed evaluation and analysis on the results obtained through the random simulations.

As illustrated in Figure 2, the throughput comparison shows that the four algorithms performance margins are very close. However, it clearly shows that the throughput for RSAR in all scenarios is higher than ARA, AODV and DSR. In terms of mobility, all four algorithms reflect the degradation of throughput when the nodes move in a higher speed.

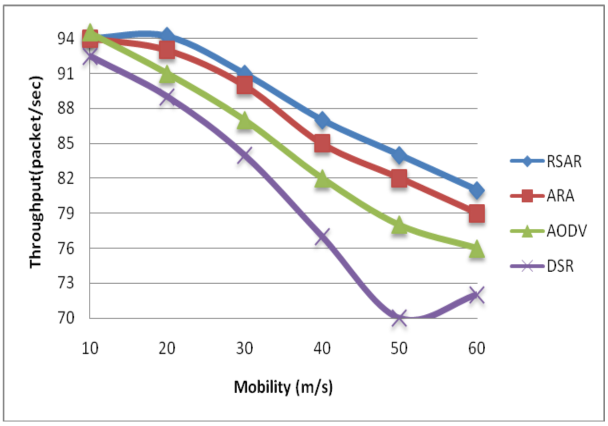

Figure 2: Throughput of RSAR, ARA, AODV & DSR

As shown in Figure 3, RSAR has a lower end-to-end delay in all mobility and network size cases. Even in high mobility, the end-to-end delay for RSAR remains at a stable level. The value of RSAR increase with respect to mobility increase which is not fluctuated as compared with ARA, AODV and DSR.

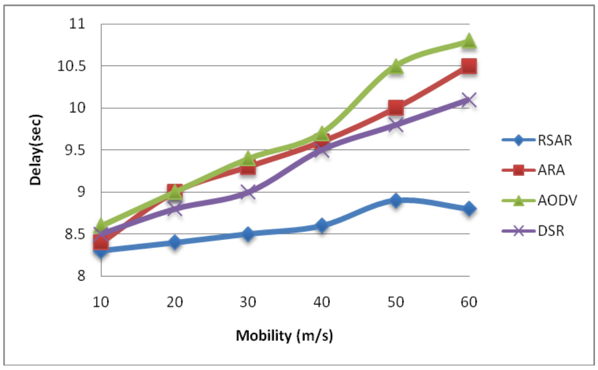

Figure 3: End-to-end Delay of RSAR, ARA, AODV and DSR

Figure 4 validates that RSAR has a higher PDR even in cases of high mobility. When the nodes are static, the tested algorithms show approximately 100% success rate for packet delivery. However, only RSAR, ARA and DSR ensures more than 95% packet delivery success rate when mobility increases. All their results are above 90% and within the range of 95% and 100%. On the other hand, AODV suffers badly in high mobility network with a drastic drop in its performance.

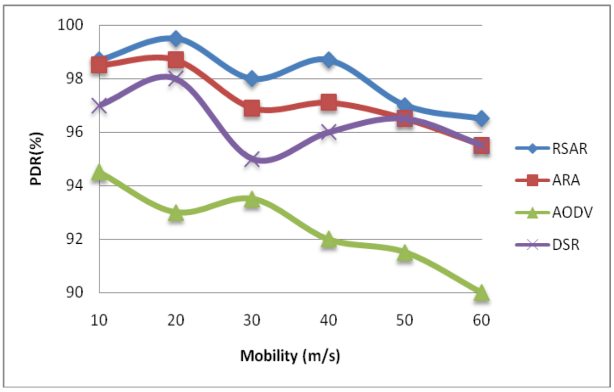

Figure 4: PDR of RSAR, ARA, AODV & DSR

As shown in figure 5, an RSAR method generates the most routing overhead with a total of 6847 bytes. ARA, AODV and DSR have a closer value of total overhead 6210, 5197 and 5933 bytes respectively.

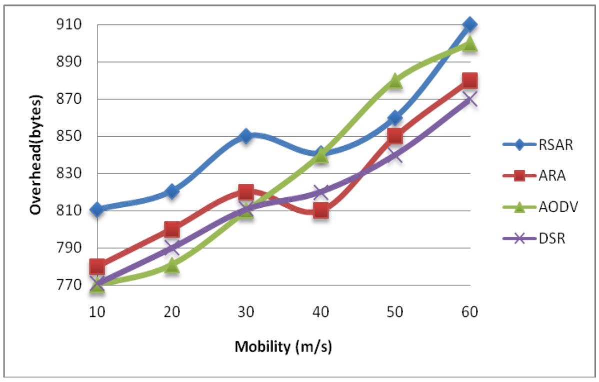

Figure 5: Overhead of RSAR, ARA, AODV & DSR

8. CONCLUSION

The growing demand for increased networking interoperability has spawned a requirement for MANETs. In this paper, present a new on-demand routing protocol for MANETs called RSAR. The proposed RSAR algorithm improves the efficiency, robustness, scalability and reliability. The efficiency of proposed routing protocol RSAR is shown to better performance than other three on demand routing protocols ARA, AODV and DSR. The proposed RSAR routing protocol uses expanding ring search model and third party reply model along with principles of ant colony to reduce the end-to-end delay. It offers higher throughput and higher PDR.It enables optimal path routing and fast route discovery with better PDR and Delay. However, the trade-off with RSAR is that it entails higher routing overhead. This overhead is contributed mainly by the periodic transmission of updates ants. RSAR is adaptive and efficient enough to handle different network scenarios and conditions. It is able to scale to large networks and still performs well even in high mobility network.

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