Performance Evaluation of AODV and DSDV for Implementing Robot Swarm

Alice Abraham, Ashutosh Tripathy, Jeson Kamalnath, Naresh T., Samarth Bharani, and Narendra Kumar G.

Abstract—**In Mobile Ad-Hoc Networks, routing the data towards a destination node is the most fundamental task. Different routing protocols have been proposed considering specific appli cation and scenario characteristics. The constant change in the positions of the nodes make this task challenging. In the proposed work, a set of agents, here referred to robots, are made to converge towards each other and an external stimulus, fire, using software based sensors that detect heat without knowing prior positions of other robots and starting off at random positions. Agents use input from their peers to make and modify individual decisions which allows for better synergy, more informed and efficient path finding, collision avoidance, etc. For accomplishing this objective, Particle Swarm Optimization(PSO), a population based approach in solving optimization problems, requires an efficient routing protocol which is fast and reliable making the best use of the feeble hardware that comprise the robots. The robots require frequent communication with each other and they have performed well when paired with the routing protocol AODV as compared to DSDV and the simulations performed have given promising results.**

Index Terms—**Adhoc on demand distance vector routing (AODV), Distance sequenced distance vector routing (DSDV), particle swarm optimization (PSO), Swarm robots, wireless sensor networks.**

I. Introduction

A lot of elegant algorithms have found their inspiration from nature and Swarm intelligence is no different. Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) are inspired largely by collective behaviors in nature such as flocking of birds and foraging of ants. Particle Swarm Optimization (PSO)[1] is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions and moving these agents around in the search-space according to simple mathematical formulae over the agent's position and velocity. Each agent's movement is influenced by its local best known position and guided in the search-space which are updated as better positions are found by other particles such that it is expected to move the swarm toward the best solutions.

In a swarm system, the agents need frequent communication to find out the routes to the targets and choose the best feasible among them. Various routing protocols are available and can be implemented in a swarm for routing it towards the target which being Proactive, Reactive and Hybrid-Routing protocols. These protocols are implemented in the swarm system depending on the hardware capabilities of the agents that comprise the swarm and the field of application.

II. Routing Protocols

Network protocols define the syntax, semantics and communication behavior. It is a set of rules defining data transmis sion and reception (in our case, over digital media) between telecommunication devices and or computing devices.

A. AODV

Ad hoc On-Demand Distance Vector (AODV) [2][3] is a routing protocol that is used extensively by Mobile Ad-hoc Networks (MANETs) and several other wireless networks. Paths are not pre-defined by the user; instead the network generates a path cognitively, reducing the complexity of the system and making it more efficient. By forwarding the path decisions to the nodes it avoids looping of the data which helps in error correction reducing data loss.

In an AODV network the source node counts the number of hops for the data packets sent through each node and floods its neighboring nodes with route requests which are acknowledged and forwarded to their neighboring nodes, creating temporary paths between them. Immediately after receiving an acknowledgement from the destination end, the source node finds the route with the minimum number of hops and a path is established between the source and the destination. The route request sent to each node contains a number sequence that is used to identify the data being sent out and if it is necessary to resend it which is useful in multiple ways; if the same data has to be sent again, only the sequence number needs to be sent to the node which in turn will resend the data identified by the sequence. In addition, each request has a certain lifetime or time to live which defines the maximum number of times a data packet can be resent until it expires and also helps in removing temporary paths created at the start of transmission.

B. DSDV

Distance Sequenced Distance Vector(DSDV)[4][5] is a routing protocol that makes use of a table driven routing

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Alice Abraham is with University Visvesvayraya College of Engineering, Bangalore, India (e-mail: alice.abraham@gmail.com)

Ashutosh Tripathy, Jeson Kamalnath, Naresh T, Samarth Bharani are with the Department of Electronics and Communication, University Visvesvaraya College of Engineering, Bangalroe (e-mail: atedsrocks@gmail.com)

Narendra Kumar G is with University Visvesvaraya College of Engineering, Bangalore University, Karnataka, India (e-mail: alice.abraham@gmail.com)

scheme for Mobile Ad-Hoc Networks. The main contribution of the algorithm was to solve the routing loop problem in which two nodes adjacent to each other routes the data continuously to each other in order to reach certain other node. This can lead to a serious overloading of the nodes capacity to handle data and can lead to the failure of the nodes.

In distance vector routing, each router maintains a routing table indexed by, and containing one entry for, each router in the subnet. This entry contains two parts: the preferred outgoing line to use for that destination and an estimate of the time or distance to that destination. The metric used might be number of hops, time delay in milliseconds, total number of packets queued along the path, or something similar. The router is assumed to know the 'distance' to each of its neighbors. If the metric is hops, the distance is just one hop.

If the metric is queue length, the router simply examines each queue. If the metric is delay, the router can measure it directly with special ECHO packets that the receiver just timestamps and sends back as fast as it can.

III. Implementation

Behavior of the Robot Swarm: Particle Swarm Optimization (PSO) is an iterative algorithm inspired by bird flocking and fish schooling. In PSO, particles converge to an optimal point in the solution space which is mimicked by the Robot Swarm. Each Robot behaves like a particle in PSO and uses this behavior to move towards the desired location. Eventually all the robots comprising the swarm converge towards the target thus fulfilling the objective. The Robots initially start out at random positions with an identifying code assigned to it. Each individual robot measures an arbitrary quantity, here the heat for the purpose of discussion, and a variable 'x' is assigned to each Robot proportional to the amount of heat measured by the Robot and the heat emitted by the source forms a gradient, having higher values near the source and reduces away from the source.

Hence, the variable x of a Robot near the source of heat will be of a higher value than that of a Robot farther away. Each Robot will keep track of its position; its best value of x called Pbest and the best value of x in the entire swarm Gbest. Once the Robots measure heat in their first iteration, each Robot gets a list of values of the variable x along with the identifying codes of the corresponding Robots along with their positions. The Robot with the highest value of x will be identified and the velocity of other Robots will be varied in accordance with the given formula.

The swarm converges towards the heat source after a suitable number of iterationswith no prior knowledge of either the personal location or thelocation of other robots. After finding the two best values, the robot updates its velocity and positions with following equation (1) and (2).

$$v = v + c_1.rand\ ().(P_{best} - pos) + c_2.rand\ ().(G_{best} - pos) \quad (1)$$

$$pos = pos + v \quad (2)$$

where, v is the velocity of a Robot, *pos* is the current position of Robot. P_{best} and G_{best} are personal best and global best, the highest personal and global values of the quantity being measured. *rand* ()' is a random number between (0, 1). C_1, C_2 are learning factors. Usually $C_1 = C_2 = 2$.

PSO is used as a means for the robot to find each other without needing individual positions and more complex algorithms that may require the use of more sensors and GPS units. PSO can also be modified to suit a number of scenarios by simply changing the required variables or the physical quantity to be measured.

IV. Simulation

The simulation takes two routing protocols AODV and DSDV and compares these two on three different parameters which are explained below. The simulator used for the evaluation of these parameters is NS2. The assumptions made for the purpose of this simulation are that all the robots transfer data with a Constant Bit Rate(CBR) and move towards one pre-defined location in the scenario space.

A. Performance Metrics

The proposed work focuses on 3 performance metrics which are quantitatively measured. Based on the measurement of these parameters an optimal routing protocol is decided for the purpose of implementing a robot swarm. The Performance metrics are:

1) Packet delivery fractions (PDF)

It is defined as the ratio of the data packets delivered to the destinations to those generated by the CBR sources. The PDF shows how successful a protocol performs delivering packets from source to destination. The higher the PDF value of a protocol the better it results in the coordination between the robots of a swarm. This metric characterizes both the completeness and correctness of the routing protocol and also reliability of routing protocol by giving its effectiveness.

Average end-to-end delay of data packets - There are possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC and propagation delays at several instants. This paper calculates the Average end-to-end delay of the data The proposed work focuses on 3 performance metrics which are quantitatively measured. Based on the measurement of these parameters an optimal routing protocol is decided for the purpose of implementing a robot swarm. The Performance metrics are:

2) Packet delivery fractions (PDF)

It is defined as the ratio of the data packets delivered to the destinations to those generated by the CBR sources. The PDF shows how successful a protocol performs delivering packets from source to destination. The higher the PDF value of a protocol the better it results in the coordination between the robots of a swarm. This metric characterizes both the completeness and correctness of the routing protocol and also reliability of routing protocol by giving its effectiveness.

3) Average end-to-end delay of data packets

There are possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC and propagation delays at several instants. This paper calculates the Average end-to-end delay of the data being transmitted and is defined as the total delay caused over an entire simulation process. Once the time difference between every CBR packet sent and received was recorded, dividing the total time difference over the total number of CBR packets received gave the average end-to-end delay for the received packets. The lower the end-to-end delay the better the application performance.

4) Throughput

It is the average rate of successful message delivery over a communication channel. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second. Peak measured throughput is throughput measured by a real, implemented system, or a simulated system. Throughput value is found out by sending chunks of data between several nodes and calculating the time taken for the same. This calculation is done over a short period of time.

B. Simulation Scenario

At the beginning, the robots are all scattered throughout the space at random positions and looking for other robots Robots are stationary and idle and there is no exchange of data taking place. As soon as the simulation starts the robots start searching for fire and transfer data as soon as it is encountered in the vicinity.

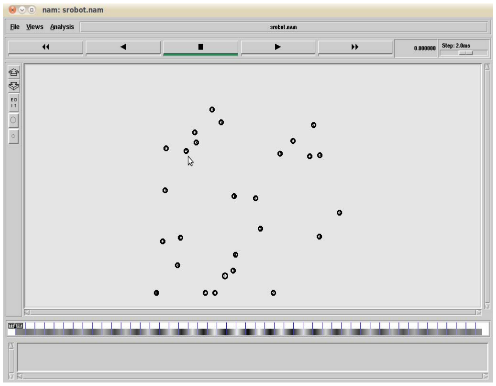

Fig. 1. NS2 simulation of swarm robots communicating over AODV, at t=0.0s

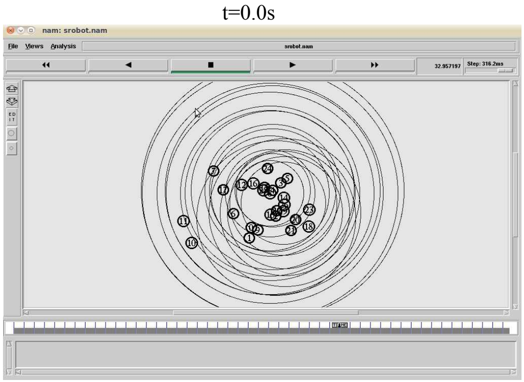

Fig. 3. NS2 simulation of swarm robots communicating over AODV, at t=37.95s

At t=10.77 s, The robots have found the target location in the sample space and are moving towards it with exchange of data taking place between the robots closer to the target. Therobots far away from the location are still not in range and hence are still searching for any fore in their vicinity.

At t=37.95s, all the robots are close to each other and fewcloser ones have already reached the target. Thus all the robots communicate with each other as shown below. The robots are constantly monitoring their location and are sending their positions to all the other robots.

At t=41.75s, all the robots have reached the destination and thus the Scenario is completed.

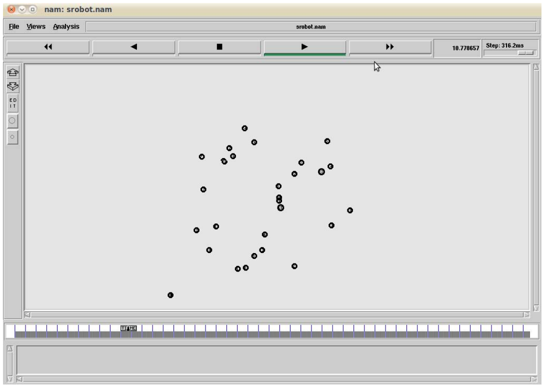

Fig. 2. NS2 simulation of swarm robots communicating over AODV, at t=10.77s

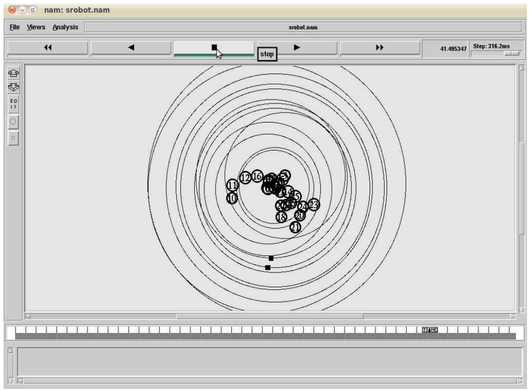

Fig. 4. NS2 simulation of swarm robots communicating over AODV, at t=41.75s

V. Results And Analysis

Performance evaluation was carried out between AODV and DSDV using a scenario file on NS2. An area size of 1000mX1000m was defined, with each of the nodes having an antenna height of 10cm. Parameters such as Delay, throughput, Packet Delivery Fraction were compared to the number of nodes. AODV scales better with larger numbers of nodes and provides reliable throughput.

As seen from Fig. 5, a very significant feature, the average throughput in AODV routing protocol goes down as the number of nodes increases in the swarm. However, in case of DSDV, the average throughput obtained is never satisfactory in comparison with AODV and varies unpredictably with the number of nodes.

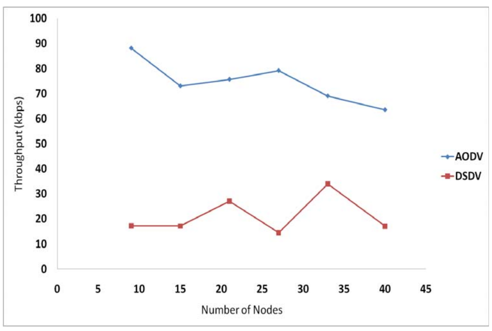

Fig. 5. Throughput versus Number of nodes for AODV and DSDV.

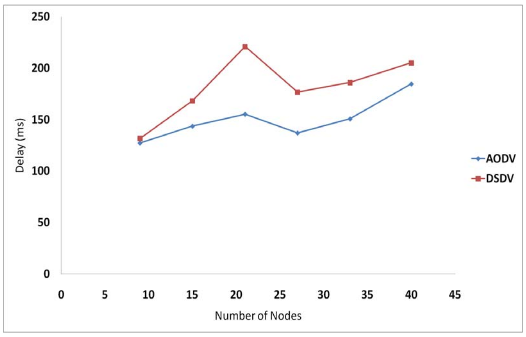

Fig. 6. Delay versus number of nodes for AODV and DSDV.

Clearly from Fig. 6, it can be estimated that AODV performs better than DSDV in terms of time delay. Though DSDV is a proactive routing protocol and the path to a destination is immediately available, it introduces significant time delay when the network topology is constantly changing. Thus in highly dynamic networks, a Robot Swarm, DSDV frequently updates its routing tables and consequently delays the packet delivery. Whereas, AODV is an reactive routing protocol and adapts faster than DSDV to the change of the routing caused by nodes' dynamics.

Fig. 7 clearly depicts the Packet delivery fraction in DSDV is outclassed by that in AODV regardless of the number of nodes which indicates the size of the Swarm. AODV tries to guarantee the delivery of the packet to the destination but in case of DSDV, if it is not possible to deliver the packet it tries to drop it and hence the decrease in the delivery ratio.

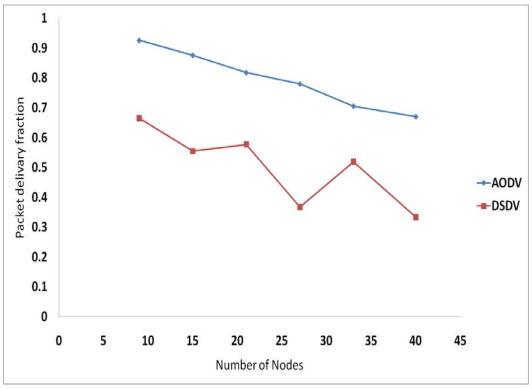

Fig. 7. Delivery ratio versus number of nodes for AODV and DSDV.

VI. Conclusion

Two routing protocols, AODV and DSDV were simulated and compared to choose the most efficient routing protocol in a Robot Swarm. Each protocol has its own advantages as well as its disadvantages making it suitable for some applications and not for others. The simulation results shown in the previous sections substantiates that AODV outclassed DSDV in terms of throughput, delay and delivery ratio.

Considering the crucial resources that make up a Swarm, AODV proves to be the most probable routing protocol that can be implemented in a Robot Swarm. Thus Swarm robots using AODV fare much better than the robots using DSDV as seen from the results generated and as a result AODV is established as the standard routing protocol for the use of the swarm robots to map the route and hence aid in their objective which can vary from fire fighting to locating humans in debris and also for space exploration purposes.

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Alice Abraham is a graduate in Electrical Engineering and a post graduate in Power Electroniis , both from University Visvesvayraya College of Engineering, Bangalore, India. Currently a research scholar in Bangalore University in the Department of Electronics & Communication, she is actively involved in research in the areas energy efficiency and applications of Wireless sensor networks under the guidance of Professor Narendra Kumar G.

Srinath K. S, Sumanth, and Guru Prasad. B. S. are undergraduate students in the Department of Electronics & Communication, University Visvesvaraya College of Engineering, Bangalroe, involved in research in the area of wireless sensor networks under the guidance of Professor. Narendra Kumar G.

Narendra Kumar G. was born in Bangalore on 5th February, 1959. Obtained Masters Degree in Electrical Communication Engineering, (Computer Science & Communication) from Indian Institute of Science, Bangalore, Karnataka, India in 1987. Was awarded PhD in Electrical Engineering(Computer Network) from Bangalore University, Bangalore, Karnataka, India in 2006. Currently Professor in the Department of Electronics & Communication Engineering, University Visvesvaraya College of Engineering., Bangalore University, Bangalore, held the positions of Associate Professor, Lecturer and Director of Students Welfare. Research interests include Mobile Communication, Wireless Communication, E-Commerce, Robotics and Computer Networks.