Computational Algorithm: An approach to Opportunistic Wireless Sensor Routing

Simranjeet Kaur[1], Balwinder Singh[2], Ravinder Khanna[3]
[1]*CSE, PhD Scholar, PTU, Jalandhar (Punjab), India*
[2]*ACSD, Cdac, Mohali (Punjab), India*
[3]*ECE.MM University Sadopur, Ambala India*

Abstract **- Objectives**: The objective of this paper is to implementing a new efficient routing computational algorithm using ACO in Opportunistic wireless sensor network.
Methods/Statistical analysis: The Opportunistic wireless sensor networks are promising as highly efficient prospect technology for communication. The privacy and secure communication is the biggest challenge in opportunistic networks. The parameters like minimum drop packet, minimum delay tolerance, high throughput and time to be considered for routing. Shapley values and the distance between nodes are calculated for finding optimal path.
Findings: Simulated results represents that number of nodes plays an important role in effective routing. The outcomes demonstrate that packet dropped increases linearly as the number of nodes increases. Delivery probability shows variations at different points of number of nodes (min 0.1827 to max 0.2672). Packet abortion increases linearly with increase in number of nodes. HopCount_avg shows variations. Buffertime_avg decreases linearly with increase in number of nodes (max 2314.2170 to min 141.31). ACO is used for finding the optimal path on the basis of shortest path and Shapley value.
Application/Improvements: Further routing is improved with incorporating proposed ACO algorithm with other computational algorithms.

Keywords **-** *ACO (Ant Colony optimization), WSN (Wireless sensor Networks), Routing, Opportunistic network, Nodes.*

I. INTRODUCTION

Opportunistic networks are the wireless sensor networks which are highly delay tolerant. An Opportunistic network is the network with no distinct end-to-end path between nodes for communication[1]. Due to intermittent contacts of nodes the store-carry-forward technique is applied for communication. Two challenges are considered, i.e. the contact opportunity and the node storage with privacy and secure transmission. WSNs consist of small nodes with sensing, computation and wireless communications capabilities[2]. The primary task of WSNs is to measure environmental conditions and organizing the collected data at a central location called a sink[3]. In opportunistic networks, each node acts as a router. Efficient routing is finding the shortest path between two nodes. The advent computational algorithms are very useful in game theory and other computational problems. The Ant Colony Optimization (ACO) is a computational algorithm which is used for finding shortest path. There are a number of reasons that Ant Colony Optimization (ACO) algorithms are a good fit for WSNs routing[3].

1.1 Routing in Opportunistic Wireless Sensor Networks

In opportunistic networks, simultaneous path between receiver and sender is absent [5].There is even no knowledge of topology to nodes which is necessary in traditional networks. Opportunistic networks come at the price of additional delays in message delivery. Routing is a process of finding a path between one node to another for communication [6]. Routing protocols in WSNs work in a different way than in wired networks because of difficulties in structure (dynamic topology, mobility) of WSNs, for example the Internet. Various routing algorithms are used for routing. Some issues must be taken into consideration while developing a new routing protocol [7].

a) **Energy Considerations**: In WSN communication, each node has two functions receiving and transmitting information. While wireless node transmission power is proportional to squared distance or even higher order in the presence of obstacles, thus Multi-hop routing will utilize less energy as compared to direct long communication [8]. So shortest path communication is preferred.
b) **Node Deployment**: Depending upon application, nodes are deployed in deterministic (sensors are manually placed and routes are predefined) or self organizing (sensors are scattered in ad-hoc manner). In self organizing deployment the nodes are placed randomly. Therefore optimistic routing techniques are applied.

c) **Latency**: It is the time required to deliver a packet. In wireless sensor network, the latency is calculated in round trip or one way.

d) **Data delivery models**: The routing protocol is highly influenced by the data delivery models (continuous, event or query driven and hybrid) especially with regard to the minimization of energy consumption and route stability.

e) **Network dynamics**: Routing in moving nodes is more challenging in terms of route stability, energy and bandwidth [9].Depending upon the applications; nodes/base stations are not always stationary.

f) **Network life span**: The necessary lifetime has an excessive influence on the nodes robustness (active or life) and desired degree of energy [10].

Main focus in the research of opportunistic network has been routing and forwarding issues [11]. An efficient routing algorithm should

- Perform limited transmissions than epidemic or flooding based routing schemes.
- Generate low disputation with high traffic jams.
- Provide optimal solution with less delivery delay.
- Highly scalable in terms of network size or node density.
- Be simple in order to ease implementation.

Two challenges are considered, i.e. the node storage and the contact opportunity [12]. Because of wireless channels and the mobility of nodes, contacts are of unpredicted time. It's very difficult to find how much data can be transferred. Node storage is also a big challenge of opportunistic networks; it causes multiple copies of data and number of messages.

1.2 Routing techniques used in opportunistic Networks

Forward Based approach for Routing: It is the routing technique in which single copy of every message is sent to the intermediate node, once the message is forwarded than the next node become guardian of message data. And this process repeats again and again until the message is delivered to the destination node [5]. This approach reduces the number of messages and the buffering of data. This approach can be further divided into three types:

a) **Direct Transmission**: In this source node, the message is generated and holds the message until delivering to the destination.

b) **Location based Transmission**: In this transmission, nodes select the neighbor nodes which are nearest to the destination to send the message. Closeness represents the probability of the nodes will come into contact.

c) **Knowledge based Transmission**: Here in transmission, the convinced information about the network is used to determine source or intermediate nodes that which node forwards the message and the message should forward immediately or holds to find best node.

1.3 Flood Based Approach for Routing: It is the approach in which multiple copies of message are generated and routed independently. This approach increases the efficiency and robustness with lower delays and high delivery ratio. This approach is further classified into two types:

a) **Epidemic routing**: Spyropoulos, et al. presented a Spray and Wait technique. During Spray phase, the message copies primarily spread across the network to distinct relays. In wait phase, whenever the destination is not detected then nodes execute transmission directly until single copy remains [13].

b) **Prediction Routing**: In this technique, the message is not blindly forwarded to neighboring nodes. Instead, each node estimates the probability of link toward the destination node and uses this information to decide whether the packet should store or wait or forward [14].

To forward the data bridge nodes and nodes within the same cluster of destination nodes are identified.

Centrality: It is the significance of the node structure. Connecting capability of central node with other nodes of the networks is high. There are three measures of centrality i.e. Freeman's degree, Betweenness and Closeness measures. The number of nodes directly connected to the node represented as degree of centrality. The node that has highest degree of centrality contacts with many nodes also called a popular node along with large number of links to others. Closeness is defined as the smallest path between a particular node and other nodes present in its range. Closeness is measured as the time taken to spread the data from a given node to other nodes. Betweenness is the extent to which a node lies on the path of linking other nodes.

Similarity: Social networks or sociologists show a high degree of transitivity [15]. Social networks show that probability of communication between the two peoples (nodes) is more if they have something in common.

Clustering has the same concept. A network is supposed to have clusters if the probability of connecting two nodes by a connection is higher with other node with common neighbor [16].

1.4 Routing with ACO (Ant colony optimization)

The decentralized management structure and complex collective behavior is represented by social insect colonies like honeybees and ants. A dynamic, parallel and distributed system for example computer networks has resemblance with these properties. High performance routing protocols are devised by researchers on the basis of these insects colonies structures. ACO is a kind of optimization algorithm inspired with the natural phenomenon where pheromones are deposit by ants on the surface. These pheromones are deposited by leading ants in a path joining food sources and their colony, so that same path should be pursued by other colony members [17]. With the time, pheromone traces disappear by evaporation. In long path, ants take more time to travel down and back again results in less density of pheromones. Whereas, short opportunistic paths obtain more pheromones deposited for a long time due to fast march of ants between colony and food source. The pheromone is laid down more rapidly in shortest path results in high pheromone density. This positive feedback method ultimately leads the ants to follow the shorter paths [18]. This natural phenomenon with the purpose of inspiring the ACO development meets heuristic. The first ACO algorithm, called the ant system, was proposed by Dorigo, et al [19]. ACO has been widely applied in various fields. The ACO algorithm combines some characteristics like global optimization and quick problem-solving also the high degree of self organization. And these are quite similar to the necessities of self-organization, low-power and quick routing in wireless sensor networks. This forced researchers to investigate the general energy balance of the routing protocol of wireless sensor network based on an ant colony algorithm. In an ACO, it is necessary to update the pheromone information which is given by the leading ants to find optimal path and then frequently using thus the optimal path similarly, in WSNs (using ACO algorithms) it is necessary that the optimal path should be increasingly used for each communication while considering energy depletion (life time of nodes) and frequency of node to route data packets. For sensing devices, their life span relies upon the failure rate of device and/or potentially battery vitality consumption and existing nodes may not save the uniform density of node over the system as nodes age. The ACO routing protocol is made out of three stages:

a) **Neighbour Discovery**: The destination node initiates the Neighbour Discovery. At the point when the destination node gets an intrigue the node dispatches a neighbor discovery mechanism. When routing tables are developed, broadcast packets are overflowed through the whole system until it achieves the source node to discover every one of the routes from destination to source.
b) **Routing and Data Transmission**: The information is transfer from source to destination, utilizing the data from the prior stage. When paths are picked probabilistically as per the path delay, then node frequency and the node energy acting as a router.
c) **Route maintenance**: In this stage surge of request is sent from the destination node to the source node to keep up the activities of all paths and update the routing tables. The node can be standby, if the energy level of node is lower than a certain threshold.

II. PROPOSED METHODOLOGY

In the opportunistic networks, data loss and connection loss of nodes is very common. The communal information plays an important role in routing. A node communicates with another node when a node comes in contact or range of another node. We proposed a new algorithm for determining the opportunistic node used for communication on the basis of communal information. The routing is done with ACO and communal information (based on Shapley value). The simulation of proposed algorithm is done and results are analyzed. The **Shapley value** is a clarification concept in cooperative game theory [11]. It was given name after Lloyd Shapley, who introduced this concept in 1953. Shapley value is the new conception of game theoretic network centrality as it shows the average marginal contribution made by every node to every feasible group of other nodes. Shapley value gives the distance between the neighboring nodes. The shapley value of every node (α) results in the shortest distance (β) in an opportunistic network [20]. The value of α and β are used for forwarding message in ACO. The equation of nth probability of moving of x node towards y is given as:

$$P^n_{xy} = (T^{\alpha}_{xy})(N^{\beta}_{xy}) / \Sigma_{z \text{ to } x}(T^{\alpha}_{xy})(N^{\beta}_{xy}) \quad (1)$$

Where P^n_{xy} representing the *n*th probability that node *x* is moving towards node *y*. T_{xy} is pheromone deposited for transition from state *x* to *y* on *α* value. N_{xy} is is prior knowledge of shortest path based on *β* value and assume $\beta \geq 1$. The value of pheromone T_{xy} is updated for every transition from one state to another by the equation below:

$$T_{xy} = (1-\rho)T_{xy} + \Sigma n\, \Delta T^n_{xy} \quad (2)$$

Here ρ represents the negative prediction. *N* is the n^{th} time transmission of node. ΔT^n_{xy} is trail pheromone. We are extracting the information of destination based on above equations and finding variation in communal information ΔT according to network area.

III. RESULTS AND ANALYSIS

The simulation of proposed algorithm is carried out using ONE (Opportunistic Network Environment) Simulator. The parameters used for simulation and results calculated after simulations are given in the table Table 1. Packet dropped calculated with simulation is minimum (7399.5) when no. of nodes is 25 and maximum (674320) when no. of nodes is 300. The simulations results shows that as the no. of nodes increase in the opportunistic networks the no. of packets dropped also increases as shown in Figure 1.

No. Of Nodes	25	50	75	100	125	150	175	200	225	250	275	300
Sim_Time	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Created	509.0	509.0	509.0	509.0	509.0	509.0	509.0	509.0	509.0	509.0	509.0	509.0
Started	9712	34212	75043	128016	181285	255298	330568	415202	495670	599738	716540	819420
Relayed	5397	20121	44704	74694	103848	148842	188815	229213	277317	331625	406564	455155
Aborted	4313	14083	30327	53303	77410	106409	141709	185930	218274	268007	314861	363119
Dropped	7399.5	28816.5	65026.5	109350.0	152250.0	218904.0	278271.0	338721.0	409530.0	490464.0	594757.5	674320
Delivery_Prob	0.2633	0.2436	0.2672	0.2633	0.1965	0.1945	0.2279	0.2043	0.1906	0.1827	0.1945	0.1886
Hopcount_avg	5.3284	7.0161	8.7206	10.6269	10.7000	12.2222	12.2586	14.9231	14.3119	13.9785	14.4242	14.8125
Buffertime_avg.	2314.2170	1300.9500	888.7743	698.0474	636.9051	526.7492	483.4526	439.0731	141.3119	382.5035	354.7055	339.8849

Figure 2 gives the analysis of aborted packets with respect to no. of nodes. As the no. of nodes increases, the collisions increases results in increase of the packet abortion. No. of packets aborted is 4313 which is minimum when no. of nodes is 25 and number of packets aborted are 363119 when no. of nodes is 300. Figure 3 shows the variation in delivery probability with respect of no. of nodes. As no. of nodes increases the traffic also increases, which results in the packet drop. So, the delivery probability varies, it doesn't depend upon the no. of nodes in the networks.ACO simulation shows delivery probability between 0.1827 and 0.2672. Figure 4 shows that the Hop count average increases with no. of nodes in ACO routing. Numbers of hops in the route increases with increase in number of nodes. Figure 5 gives the analysis of buffer time average with respect to no. of nodes.

As the no. of nodes increases, the more and more packets are created within the opportunistic network, nodes becomes active most of the times and communicate with other nodes and sent packets frequently. So, less buffer time and less delay in communication show within the network. The simulation results show continuous decrease in the buffer time average with increase in number of nodes.

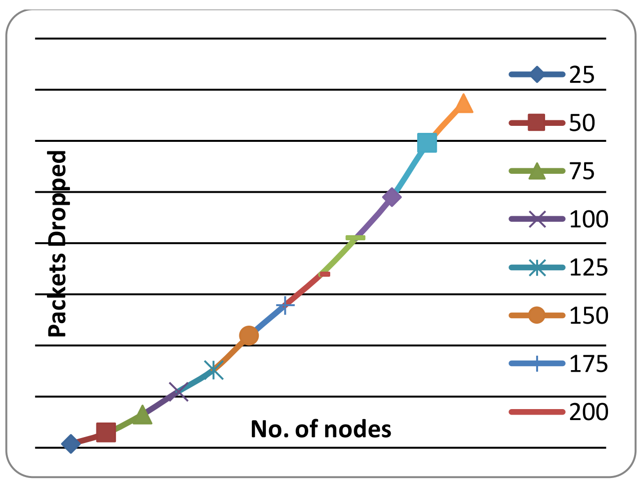

Figure 1. Packets dropped in ACO routing in Opportunistic Network.

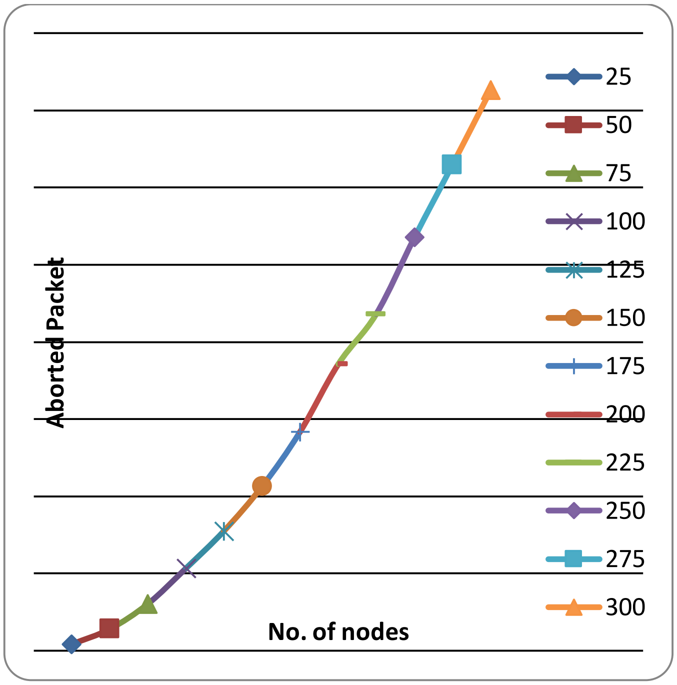

Figure 2. Aborted Packets in ACO routing in Opportunistic Network.

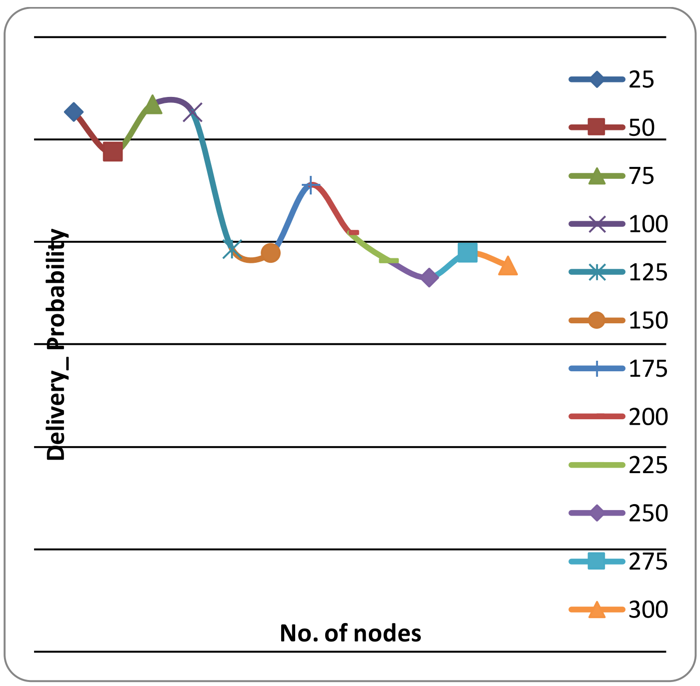

Figure 3. Delivery probability in ACO routing in Opportunistic Network.

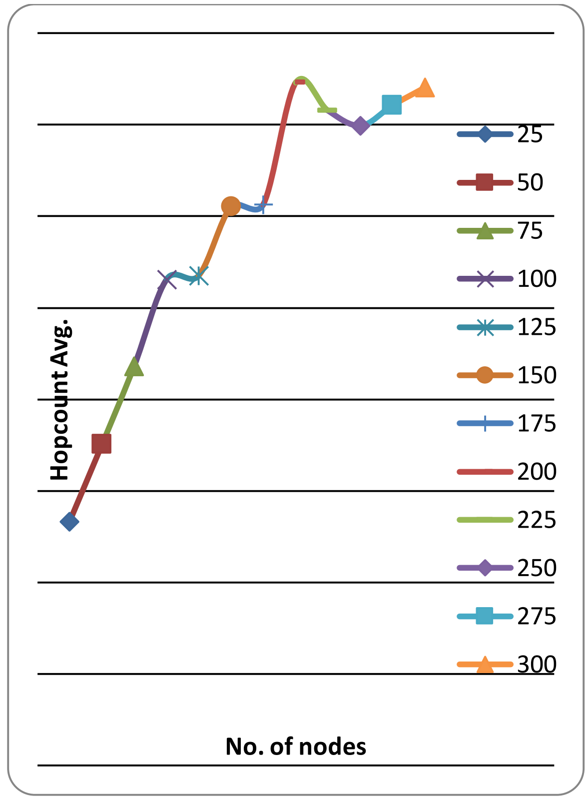

Figure 4. Hopcount average in ACO routing in Opportunistic Network.

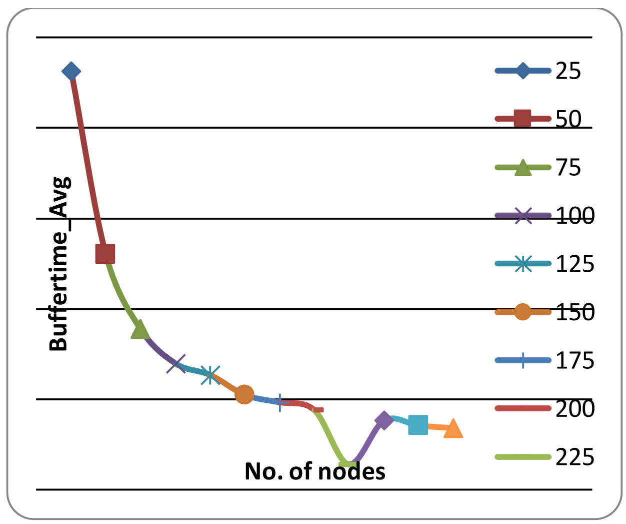

Figure 5. Buffertime Average in ACO routing in Opportunistic Network.

IV. CONCLUSION

The routing in opportunistic Wireless Sensor networks using ACO is done. The simulation results show that effective routing depends upon the no. of nodes in opportunistic Network. With analysis of simulation results we concluded that ACO is useful in finding the routes and packet delivery within opportunistic networks. Simulation is done taking no. of nodes as 25,50,75,100,125,150,175,200,225,250,275,300. Packet dropped count increases with no. of nodes from 76% to 82%. Delivery probability varies between 0.1827 and 0.2672 which is not continuous. Packet aborted increases with increase in no. of nodes but the percentage of started packets and aborted packet is same. The Simulation results give about 2.77 times increase in Hop count average from 5.3284 to 14.923. There is decrease in buffer time average from 14131 to 2314

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