NATURE INSPIRED ROUTING MECHANISMS IN MOBILE AD HOC NETWORKS A REVIEW

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***ABSTRACT*:** Due to dynamic nature of nodes and multiple routing requirements, routing has become one of the most daunting tasks in Mobile Ad hoc Networks (MANETs). In recent past, researchers have proposed a number of mechanisms to overcome challenges of routing. However, many parameter requirements such as minimization of end to end delay, improvement in throughput, and efficient adaptation to changes in network topology with low control overhead are still researcher's major concern. During recent 10 years biological insects and nature inspired mechanism have gained a lot of attention because they offer possible optimized solutions ensuring high robustness in the network, flexibility, and low cost. Moreover, it provides solution to large-scale sophisticated problems without having a traditional centralized control. Swarm Intelligence (SI), more specially Ant Colony Optimization (ACO) meta-heuristic is the most acceptable and successfully applied nature inspired mechanism to balance the various routing related requirements in dynamic MANETs. In this paper, we present a comprehensive survey of nature inspired ACO routing mechanism and comparison of various routing protocols proposed for MANETs. The main contributions of this paper are reviewing of the ACO principle; classification of ACO based routing protocols into three categories 1. Active 2. Reactive and 3. Hybrid. We have reviewed a large number of protocols year-wise and classified them into Active, Reactive and Hybrid category. Moreover, the simulation software for all the protocols are reviewed and described the main performance metrics evaluated for these protocols. Further, we have compared the selected routing protocols from the perspective of classification, simulation software, which will enable researchers to overcome the design and simulation challenges of ACO based routing protocols for routing in MANETs.

Index Terms: **Mobile Ad hoc Networks (MANETs), Swarm Intelligence (SI), Ant Colony Optimization (ACO), Routing.**

I. INTRODUCTION

Nature Inspired more specially, Swarm intelligence (SI) based Ant Colony Optimization (ACO) [1-10], routing mechanisms are novel evolutionary algorithms, which have the characteristics such as positive feedback, negative feedback, distributed computing, stigmergy. ACOs are inspired from real biological insects like ants, bees, bats, elephants, birds and are being applied by researchers to solve complex engineering problems. They possess following characteristics: Scalability – The population changes by local and distributed agent interactions. Fault tolerance - There is no centralized control for the agents, so they are able to sustain even in case of small failure in the links. Adaptation - The agents change, reproduce or die as per requirement in the colony. Speed - The agents communicate very fast through pheromone and others follow. Modularity - Agents act independently. Autonomy – No supervision is needed because each agent follow simple rule. Parallelism – Agents perform the operations parallelly.

Mobile Ad Hoc Networks (MANETs) are built up of a collection of mobile nodes which have no fixed infrastructure. The nodes communicate through wireless network and there is no central control for the nodes in the network. Routing is the task of directing data packets from a source node i.e. transmitter to a given destination node i.e. receiver. The surrounding physical environment significantly attenuates and distorts the radio transmissions since signal quality degrades with distance. Hence, it may be needed for one mobile node to take the assistance of other nodes in forwarding its packets to the desired destination. A node can move anytime in an ad hoc scenario and, as a result, such a network needs to have routing protocols which can adapt dynamically changing wireless topology. However, since there is no fixed infrastructure in a network, each mobile node operates not only as a node but also as a router, forwarding packets from one node for other mobile nodes in the network, which may not be within direct wireless transmission range of each other [9-10]. It is very challenging for the researchers and engineers to develop and implement a routing algorithm to accomplish the task of routing in changing topology of Mobile Ad Hoc Networks.
Further, in this review paper, Section II comprises of nature inspired ACO and Section 3 presents literature review of ACO based routing protocols. In Section IV, we present the classification of ACO based protocols, and Section V is presented with simulation parameters and performance metric analysis. Section VI presents Conclusion.

II. NATURE INSPIRED - ANT COLONY OPTIMIMZATION

Almost all the routing protocols being proposed and developed by researchers for MANETs are based on nature inspired mechanism. The foraging behavior of insect societies is regarded as the major inspiration to design highly efficient and sophisticated routing protocols for MANETs. Ants, during process of foraging, collectively explore the environment to find traces of food sources, and once food source is located, ant's setup paths between the nest and food sources to effectively transport the food back to nest. Therefore, the collective foraging behavior of ants includes distributed exploration, route discovery, setting and use of highly optimized routing paths in dynamic environments. ACO, algorithms considering the optimization and efficiency has become an important source of foundation for researchers to develop algorithms for Routing Protocols for MANETs. ACOs have also been applied to various other engineering disciplines and other areas of computer science for solving complex problems and determining optimized solutions. Ant Colony Optimization (ACO), was discovered by M. Dorigo and colleagues for finding solutions to varied Hard CO problems in early 1990s. The basic foundation of ACO

algorithms are real ant colonies. Ants roam randomly in the environment to determine food source and find the shortest path between food source and nest. In order to exchange information regarding which path to follow, ants communicate via use of chemical substance called Pheromone. As ants move from nest to food source, lay a trail of pheromone and other ants follow the same trail, creating a pheromone trail. The more ants follow a given trail, the more attractive that trail becomes to be followed by other ants. Using this mechanism, ants are able to transport the food from source to nest in an efficient way.

The basic models of Ant Colony Optimization:

- A set of concurrent computation agents (ANTS)
- Each ant moves based on stochastic local decision based on:
  - Trails (globally affected)
  - Attractiveness (locally affected)
- Global mechanisms
  - Trail evaporation
  - Daemon actions

Algorithm explaining Ant Colony Optimization:

Initialize Parameters
Set pheromone trails
Create ants

While Stopping criteria is not reached do

Let all ants construct their solution
Update Pheromone trails
Allow Daemon Actions

End While

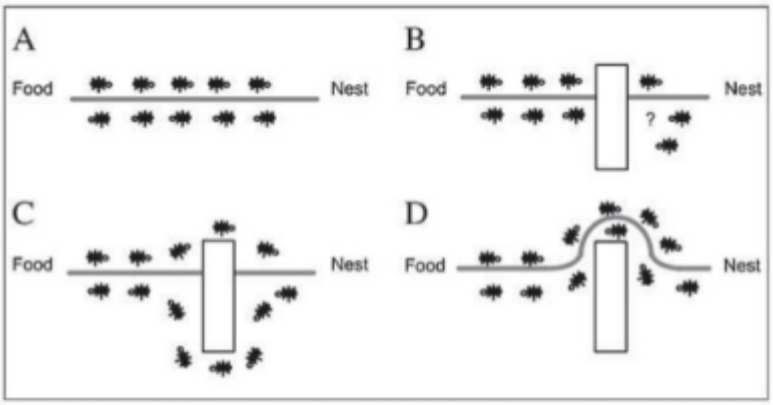

Fig.1: Basic Working of Ants in Real World

When searching for food, ants basically explore the area surrounding their nests in random manner. As soon as an ant finds a food source, it determines both the quantity and quality of food and picks up some of the food back to the nest. During the return of the ant from the food source to the nest, the ant deposits a chemical called Pheromone on the ground which depends on the quantity and quality of food, which acts as navigation path for the rest of ants from the nest to the food source. The complete scenario is shown in Fig. 1.
It is given as Combinatorial Optimization (CO) problem:

$$P = (S, f) \text{ ----------(1)}$$

where S= Search Space in which finite set of solutions are there and f= objective function S→ R+ which assigns a positive cost value to each of the solutions, the goal is to find either solution of minimum cost value or if it is the

- Ants iteratively constructs the solution by local choices from state i to state j
- At each step σ, ant k computes a set of feasible expansions A_k^{σ} (i) from its state.
- Probability of moving from state i to state j p_{ij}^k depends on:
- Attractiveness n_{ij} of the move
- Trail level t_{ij} of the move

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{k \in allowed_k}[\tau_{ik}(t)]^{\alpha}[\eta_{ik}]^{\beta}} & \text{if } j \in \text{allowed}_k \\ 0 & \text{otherwise} \end{cases} \quad \text{-----(2)}$$

Ant Colony Optimization Algorithm is as appended in Fig.2 below:

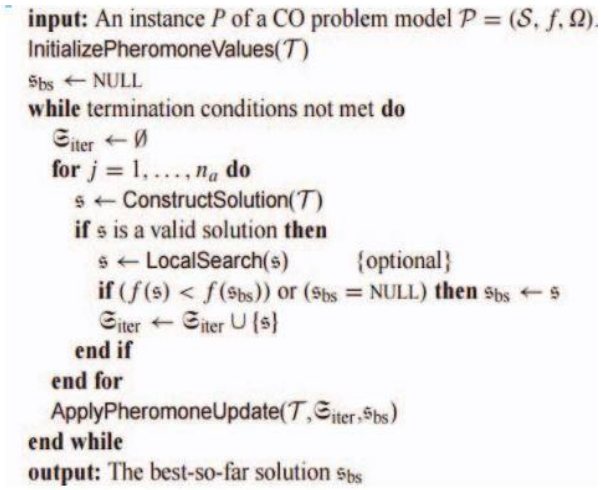

Fig.2: ACO Algorithms steps

The probability of moving of ants from food to nest and nest to food is given in equation 1 and 2. Also the basic ACO based routing algorithm is computation presentation, which can be written in the language preferred by researcher.

III. LITERATURE REVIEW OF ACO BASED ROUTING PROTOCOLS

In the paper by Li Layuan et al [11] presented the MANET which is a combination of wireless mobile nodes communicating with each other. It uses multi-hop wireless links without any existing network or centralized administration. This paper systematically explains the performance evaluation and comparison of four typical routing protocols of ad hoc networks with the different simulation model and metrics, and also drew more complete and valuable conclusions. Vanita Rani et al [12] proposed the Ad Hoc network and different types of working protocols, in which, simultaneously all these nodes could act as host or router. Jagtar Singh et al [13] proposed the concept of Mobile Ad hoc Technology. This routing protocol was quite reliable and effective to solve complex problems. In paper, Dweepna Garg et al [14], the main aim of this protocol was to decrease the overhead problem. Bahuguna Renu et al [15] proposed that the mobile ad-hoc network comprises of wireless nodes that communicate each other by exchanging information. Thus this paper, gives a review work done on existing protocols of MANET and comparison between them. W.J. Yu, et al. [16] in Ant colony optimization for routing in mobile ad hoc networks described ACO-AHR and examined the routing protocols and evaluates these protocols on the basis of parameters. Shaik Jaffar and M.V. Subramanyam [17] reviewed different routing protocols used in previous years. The simulation gives performance, which concludes that recommended technique outperforms in terms of different types of nodes in the system. Chien-Chung Shen et al [18] described about the ANSI project which hired the Swarm Intelligence. Swarm intelligence refers to complex behaviors that emerge from very simple individual behaviors and interactions. It was used to construct or design the multicast routing, topology control, energy conservation and for control procedure in MANET. Ankit Mehto et al [19] brought the attention of researchers in the instant growth of communication. A network has been categorized with connecting media. This paper contributes by discussion on various attacks which are possible in the mobile ad-hoc network. Milos Stojmenovic [20] proposed about the SI based solutions for MANET routing. With the help of swarm intelligence, many of the problems like data centric routing or multicasting were overcome. The ideas coming from existing swarm intelligence based routing in communication networks were incorporated into the wireless domain, with some new techniques which were typical of the wireless domain (such as flooding, use of position, monitoring traffic at neighboring nodes) being incorporated. Finally this technique solution provided a lot of benefits with respect to other solutions of traditional methods.

G. Di Caro et al [21] described the method or an algorithm, which make the inspiration from the swarm intelligence solution. The role of routing is to move or travel the packets of data from one location to another location. This task was particularly hard in mobile ad hoc networks: due to the mobility of the network elements and the lack of central control. In this, it described an algorithm, which draws inspiration from swarm intelligence to obtain the characteristics such as mobility of the network elements and central control. Moreover, compared the proposed routing algorithm with the existed method and it has concluded that introduced techniques results are best. Alexandros Giagkos et al [22] examined the Swarm Intelligence Routing protocol with the newly proposed Bee Routing Protocol for providing multi-path routing in wireless ad hoc networks of mobile nodes. It gives a significant level of adaptability and efficiency that, under several network conditions, allowed the protocol to outperform traditional approaches.

Shruti Dixit et al outlined [23] swarm intelligence techniques that are part of artificial intelligence takes inspiration from the behavior of insects. These algorithms provide a solution to the complex problems in mobile ad hoc networks. Moreover, the paper presented future directions of these protocols in environmental conditions in order to acquire an effective routing protocol for mobile ad hoc networks.

Azzedine Boukerche [24] presented an analysis over the different techniques proposed by different researchers. Moreover, they focused on the ad hoc network due to their advantages over the fixed infrastructure. The Ad hoc network has used because of the different constraints presented in traditional protocols of routing such as energy limitations and physical location of the nodes etc. The author of this paper has focused on the taxonomies of ad hoc routing protocols and their comparison with each class of protocols. Moreover, different protocol's requirements, their limitations and design constraints were also considered in this paper.

Gibson Chengetanai, et al [25] discussed that mobile devices such as Personal Digital Assistance (PDA), laptops, smart phones are rapidly increasing. These mobile devices also have high market penetration rates in developing countries. A mobile ad hoc network (MANET) is formed when two or more mobile devices within a wireless coverage area can communicate

with each other. These devices are typically battery powered and use multi-hopping technology to communicate with each other's device without the help of an infrastructure such as a base station. If immediate infrastructure does not exist, MANET is usually introduced if temporary emergency communication such as medical rescue or battlefield communication is required. Group intelligence technology inspired by biology and Ants, termites, and bees are artificially simulated that can be used to solve real wireless network problems. In this paper, the author outlines the group intelligent routing technology applicable to MANET. In this paper, the author discussed a group information algorithm method that can be used to effectively route data packets over wireless MANET.

Dan-Yang Qin et al [26] proposed that MANET is a center less packet Radio network that does not use permanent transportation. In recent years, enormous attention has been drawn for self-configuration and self-maintenance capabilities, especially in public safety and disaster recovery situations. However, because attenuation and interference caused by node mobility and radio channel sharing weakens the stability of the communication link, routing protocol designs cause important problems such as broadcast storms, old paths and delays. The effective Sustainable Routing Strategy (SRS) proposed in this paper mitigates the negative impact of link discontinuity on communication. The SRS is achieved by limiting the route request (RREQ) zone on the intermediate forwarding node according to the solution of the optimal search formula. Simulation results based on Network Simulator 2 (NS 2) showed that in order to recover throughput, reduce average end-to-end delay during route maintenance, and enable continuous packet transfer of fault resilience, Rate and this strategy will be obtained. Ioannis Broustis et al, [27] discussed that a vehicle network is a set of surface transport systems capable of communicating with one another. Several networks are conceivable for configuring automotive computing systems. Potential proposals enclose inter-vehicle ad hoc networks, wired vertebras by wireless last hops, or hybrid topology using inter-vehicle communication to emphasize road-to-vehicle communication transportation. Some special characteristics of these networks, such as high mobility, network partitioning, constrained topology, are distinguished from other types of wireless networks. The author discussed in aspect significant research related to architecture design and routing of such a network and also discussed the most important security concern that is found in vehicle networks.

Min-Woo Ryu et al, [28] proposed that Vehicle ad hoc network (VANET) consists of vehicles forming a network without additional infrastructure, enabling communication between vehicles. VANET has its own characteristics including high node mobility and rapidly changing network topology. Appropriate to these characteristics, routing algorithms based on greedy forwarding such as greedy peripheral stateless routing (GPSR) that are recognized to be very suitable for VANET. However, greedy transfer only selects the node closest to the destination node as a relay node within its transmission range. This increases the likelihood of maxima and link loss due to the high mobility of the vehicle and urban road characteristics. In this paper, proposed a reliable location information routing (RIPR) algorithm to decipher these problems. The RIPR algorithm predicted the position, the speed, and the moving direction of the vehicle after receiving the message, estimated the information on the road characteristics, and selects the relay node. Therefore, local maxima and the possibility of link corruption reduced. Simulation results using NS - 2 revealed that the proposed routing protocol exerts superior performance over existing routing protocols based on greedy transfer. Petteri Kuosmanen et al [29] discussed cataloguing of ad hoc routing protocols and also present some specific protocols according to that classification. The importance of this paper was not to present protocols in aspect but to present major features of an extensive variety of dissimilar protocols and estimate their appropriateness and tradeoffs.

Dorigo, M. et al, [30] focused first on new meta-heuristics for optimization. Experimental studies had shown a practical attention in how to attempt to deepen the understanding of the function of the method, not only through more sophisticated experiments but also through efforts to build theory. Finding answers might help to improve its applicability, so it was important to tackle problems like "Methods and Reasons". The ant colony optimization introduced as a new technology to solve the hard combinatorial optimization problem in the early 1990s was currently discovering itself at this point in its lifespan. In this article investigated theoretical results on ant colony optimization. First, consider some convergence results, Next discussed the relationship between Ant colony optimization algorithm and other approximation methods for optimization. At the end, main focused on some research efforts to gain a deeper understanding of the behavior of Ant colony Optimization Algorithm. Authors identified several unresolved issues with certain interests to be resolved in the near future.

Singh et al. [31] proposed Probabilistic Ant Routing (PAR) for MANET routing. When HELLO MESSAGE is received, each node sustains a list of neighbors. Forward ant agents are used to collect network traffic information. The FANT is unicast if the destination node is available as existing node otherwise it is broadcasted. Saleem et al. [32] stated an extensive review of an area of SI especially with regard to Bee-Inspired routing protocols and Ant Colony Routing with regard to SI. Fatih et al. [33] mentioned various different matters with regard to scalability, complexity, and adaptability issues. Routing protocols was proposed to resolve these issues. Babu et al. [34] explains different energy efficient routing protocols based on SI network, and proposed ACO metaheuristic to overwhelm routing issues. To find out an optimal path, Energy Efficient Ant Based Routing Protocol is used.

Zungeru et al. [35] explains routing protocols classical to swarm intelligence, which is based on structure, complexity and energy efficiency. MATLAB protocols are used based for measuring performance. Chandra Mohan et al. [36] mentioned review of working of ACO and its research and proposed a improved ACO model which removes routing problems as compared to other traditional Ant Colony Optimization algorithms. Al Salami et al. [37] suggest hybrid algorithm so that some combinatorial optimization problems can be solved via usage of genetic programming and ant colony and to propose different effective resolutions for systematic networks. Dorigo et al. [38] explains the concept of Ant Colony Optimization and the relation between ACO optimization algorithms and other approximation methods. Monteiro et al. [39] defined Ant Colony Optimization technique along with its algorithms to examine the behavior of natural ants.

Rault et al. [40] defined the issue of energy efficiency in Wireless sensor Network and the survey of various energy conservation schemes to increase the lifespan of network. Ali et al. [41] mentioned the survey of comparison of routing protocols of Swarm Intelligence and Ad Hoc and in terms of route optimality, energy consumption and routing Overhead. S Kannan et al. [42] described a hybrid algorithm which is the combination of an ant algorithm and multi agent systems known as Multi agent Ant Based Routing Algorithm (MAARA). This algorithm provides the better results than AODV, DSR, ANTHOCNET, the packet delivery ratio, time delay, more connectivity and less packet loss. Sethi et al. [43] proposed a reactive protocol and multipath routing that combines the blocking expanding ring search with ACO. The protocol is simulated by NS2. It gives performance of DSR and AODV in terms of the packet delivery ratio, overheads, end to end delay and reliability etc. Gyanappa

A. et al. [44] presented a review paper on hybrid routing mechanisms in mobile ad hoc networks. Authors present an overview of analytical, network, and simulation model used in the design of hybrid routing mechanisms. This review paper classifies some of hybrid routing mechanisms into four categories named as mesh, tree, zone, and multipath structure with their relative performance. Hang Zhang et al. [45] present a Survey of Ant Colony Optimization Based Routing Protocols for Mobile Ad Hoc Networks. This paper presents a comprehensive survey and comparison of various ACO-based routing protocols in MANETs. Authors have sorted the approaches into five main categories and have briefly reviewed each selected protocol. Also, presented a detailed comparative analysis in terms of protocol design and simulation parameters for all reviewed protocols
Apart from above mentioned research paper review, we have gathered information about a large number of ACO based protocols in section IV of this review paper.

IV. CLASSIFICATION AND COMPARISON OF ACO BASED ROUTING PROTOCOLS FOR MANETs

All the protocols proposed by researchers are classified into Active, Reactive and Hybrid category. These protocols are tabulated with Authors name and year of publication as the ACO based routing protocols for MANETs in Table.1. There are forty protocols we have taken up for comparison on the way in which these protocols initiate route discovery. It is found that highest number of protocols out of these reviewed protocols is implemented in Hybrid mode of route discovery. Very few research papers suggest the Active method of route discovery. More specifically it can be summarized from this table that the percentage of Active protocol is13%, Reactive protocol is 42% and that of Hybrid protocol is 45%.

Table.1. Classification and Comparison of ACO Based routing protocol

Proposed Protocol	Proposed by	Year	Classification
AntNet [21]	G. Di. Caro et al.	1998	Active
ARA [47]	M. Gunes et al.	2002	Reactive
ARAMA [48]	O Hussain et al.	2003	Active
ANSI [18]	Chien-Chung Shen et al	2006	Hybrid
AntHocNet [2]	G. Di. Caro et al.	2005	Hybrid
ANT-E [43]	S. Sethi et al.	2010	Reactive
ACO-AHR [16]	W. J. Yu et al.	2008	Hybrid
ACO-EEAODR [4]	I. Wongang et al.	2013	Reactive
AntHocMMP [49]	P. Vijaylakshmi et al.	2015	Active
ACECR [50]	J. Zhou et al.	2016	Active
ANTNET [51]	S. Pal et al.	2014	Reactive
ABPKM [52]	P. Memarmoshrefi et al.	2013	Reactive
Cluster-based ACO [53]	S. Balaji et al.	2013	Reactive
CEHR [54]	Farooq et al.	2014	Hybrid
DBA-ACO [55]	K. Sowmya et al.	2012	Reactive
EAAR [56]	S. Misra et al.	2010	Reactive
FTAR [57]	S. Sethi et al.	2011	Reactive
HARP [58]	Nikaein et al.	2001	Hybrid
HMARP [59]	Ait. Salem et al.	2012	Hybrid
HoDGRP [60]	Mahmood et al.	2016	Hybrid
HOMDV [61]	Senthil Kumar et al.	2016	Hybrid
HOPNET [8]	J. Wang et al.	2009	Hybrid
Hybrid ACO [62]	S. B. Prabhahran et al.	2016	Hybrid
MAR-DYMO [63\	S.L.O.B Correia et al.	2011	Reactive
MAZA-CORNET [46]	H. Rana et al.	2013	Hybrid
GMZRP [64]	Cheng et al.	2009	Hybrid
MZRP [65]	Sharma et al.	2016	Hybrid
PERA [66]	J.S. Baras et al.	2003	Active
PACONET [67]	E. Osagie et al.	2008	Hybrid
POSANT [68]	S. Kamali et al.	2007	Reactive
QAMR [69]	P.V. Krishna et al	2012	Reactive
QAMRP [70]	Shanti et al.	2010	Hybrid
QoRA [71]	A. D. Al-ani et al.	2016	Reactive
ROBUSTNESS ACO [72]	D. Kadno et al.	2010	Hybrid
S-AMCQ [73]	M.H. Eiza et al.	2016	Reactive
SAR-ECC [74]	V. Vijaylakshmi et al.	2007	Reactive
SPA-ARA [75]	S. Mehfuz et al.	2008	Reactive
SBDT [76]	G. Indirani et al.	2012	Reactive
SAMP-DSR [77]	E. Khosrowshahai et al.	2011	Hybrid
ZBMRP [78]	Zhou et al.	2008	Hybrid

V. SIMULATION SOFTWARE AND COMPARISON OF ROUTING PARAMETER

Based on the protocols reviewed in this paper we find that out of forty protocols reviewed, a large number of protocols are simulated using freely available Network Simulator NS-2. Very few researchers have developed their own simulator for finding the routing parameters such as throughput, End to End Delay and Overhead. All the forty proposed protocols are compiled into table.2 as Simulation Software and routing parameter comparison for ACO based routing protocols. We have compared only

three factors of each protocol i.e. throughput, End to End Delay and Overhead. It is found that generally a number of the researchers have analyzed their routing protocols for all the three performance metrics.

Table.2: Simulation Software and Routing Parameter comparison of ACO Based Protocols.

Proposed Protocol	Simulation Tool	Throughput	End-to-End Delay	Overhead
AntNet	Self made	No	Yes	Yes
ARA	NS-2	Yes	No	Yes
ARAMA	OPNET	Yes	No	No
ANSI	QualNet	Yes	Yes	Yes
AntHocNet	QualNet	Yes	Yes	Yes
ANT-E	NS-2	Yes	Yes	Yes
ACO-AHR	NS-2	Yes	Yes	Yes
ACO-EEAODR	GloMoSim	No	No	No
AntHocMMP	NS-2	Yes	Yes	Yes
ACECR	NS-2	Yes	Yes	No
ANTNET	NS-2	No	No	No
ABPKM	QualNet	Yes	Yes	Yes
Cluster-based ACO	NS-2	Yes	Yes	Yes
CEHR	NS-2	Yes	Yes	Yes
DBA-ACO	NS-2	No	No	No
EAAR	GloMoSim	No	No	No
FTAR	NS-2	Yes	Yes	Yes
HARP	NS-2	Yes	Yes	Yes
HMARP	NS-2	Yes	Yes	Yes
HoDGRP	NS-2	Yes	Yes	Yes
HOMDV	QualNet	Yes	Yes	Yes
HOPNET	GloMoSim	Yes	Yes	Yes
Hybrid ACO	NS-2	No	Yes	No
MAR-DYMO	NS-2	Yes	Yes	Yes
MAZA-CORNET	NS-2	Yes	Yes	Yes
GMZRP	GloMoSim	Yes	Yes	Yes
MZRP	NS-2	Yes	Yes	Yes
PERA	NS-2	No	Yes	No
PACONET	GloMoSim	Yes	Yes	Yes
POSANT	Self made	Yes	Yes	Yes
QAMR	NS-2	Yes	No	Yes
QAMRP	NS-2	Yes	Yes	Yes
QoRA	NS-2	Yes	Yes	No
ROBUSTNESS ACO	Self made	Yes	Yes	Yes
S-AMCQ	OMNet++	Yes	Yes	No
SAR-ECC	NS-2	No	No	No
SPA-ARA	SWANS	No	No	No
SBDT	NS-2	Yes	Yes	No
SAMP-DSR	OMNet++	Yes	Yes	Yes
ZBMRP	OPNET	Yes	Yes	Yes

VI. CONCLUSION

Apart from introducing nature inspired mechanism in routing challenges of MANETSs, we have carried out comprehensive review of a large number of previously ACO based routing protocols year-wise and classified them into Active, Reactive and Hybrid category. There are forty protocols we have taken up for comparison on the way in which these protocols initiate route discovery. It is found that highest numbers of protocols out of these reviewed protocols are implemented in Hybrid mode of route discovery. Very few research papers suggest the Active method of route discovery. More specifically it can be summarized from the chart that the percentage of Active protocol is13%, Reactive protocol is 42% and that of Hybrid protocol is 45% as shown in Fig.3.

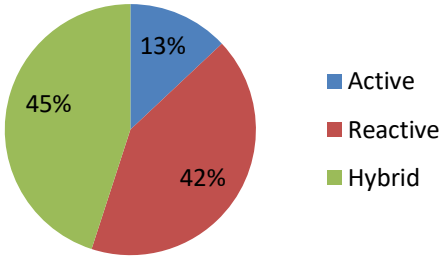

Fig.3: Classification of ACO Based protocol used for routing in MANETs

Simulation Software and routing parameter comparison for ACO based routing protocols is carried out and it is found that highest number of protocols are simulated using Network Simulator NS-2. The NS-2 is used in research papers for 23 protocols. Simulation Software GloMoSim is used for 5, QualNet for 4, OMNet++ for 2, OPNET for 2, SWANS for 1and Self made simulation software have been used for 3 protocols out of forty ACO based protocols reviewed. The simulation software used in research papers are shown in Fig.4.

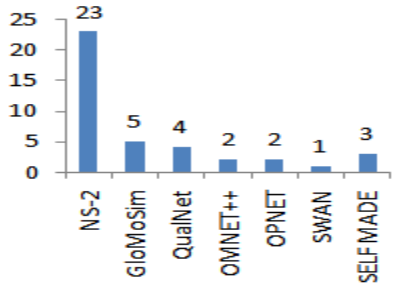

Fig.4: Simulation Software used in ACO Based protocol

The review paper categorization of nature inspired ACO Based routing protocol for MANET will help researchers in deciding the choice of active, passive and Hybrid mode of route discovery. Further, the simulation software review may be useful for deciding the simulation software and simulation for measurement of the performance metrics of nature inspired ACO based routing protocols.

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