

**An Improved Genetic Based Routing Protocol
for VANAETs**

*Dissertation submitted in partial fulfillment of requirement for award of
degree of*

Master of Technology
in
Computer Science and Applications

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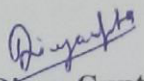
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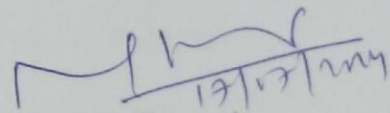
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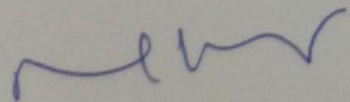
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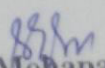

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Abstract

Vehicular Ad-hoc Network (VANET) is a most critical class of mobile ad-hoc network (MANET) that enables roadside vehicles to intelligently interact with one another and with outside infrastructure anytime anywhere in the global network. VANETs are self configuring network where nodes are vehicle and WIFI technologies are used to establish these networks. Routing is the process of sending data packets from source node to destination node with the minimum cost. Routing algorithm organizes and distributes information in the network. In genetic algorithm, any path from starting node to target node is a feasible solution and best possible solution is the smallest path from starting to target. In the beginning a random population of string is generated, this is the string of nodes which represents feasible (admissible) and unfeasible (un-admissible) solution.

The dissertation focuses on routing in VANETs. In this dissertation, genetic algorithm is applied to improve the routing. Genetic algorithm finds the highly optimal (shortest) path for the entire network. A routing tree is formed from fitness function that provides highly optimized and fault tolerant routing. A routing tree is also constructed that allow efficient insertion and deletion of the node. The method was observed for packet delivery ratio, throughput, delay and packet loss. The proposed algorithm which is based on the integration of GA with existing routing protocol allows formation of efficient network with more fault tolerant and enhanced robustness.

List of Figures

Figure 1.1 Processing of VANETs.....	2
Figure 1.2 Flow chart for GA.....	3
Figure 1.3 Fitness Function.....	4
Figure 1.4 Selection Process.....	6
Figure 1.5 Roulette Wheel Selection.....	7
Figure 1.6 Roulette-wheel according to fitness value.....	8
Figure 1.7 Roulette-wheel according to rank.....	8
Figure 1.8 Single-site Cross Over.....	10
Figure 1.9 Two-point Cross Over.....	10
Figure 1.10 Uniform Cross Over.....	11
Figure 1.11 Uniform Cross Over using mask.....	12
Figure 1.12 Mutation Process.....	13
Figure 1.13 Flow Chart of Genetic Algorithm.....	14
Figure 4.1 Cross Over.....	31
Figure 4.2 A crossover applied to a pair of routes.....	32
Figure 4.3 Mutation Operation applied to the path.....	33
Figure 4.4 Transition from Spanning Tree to Routing Tree.....	35
Figure 4.5 NS2 Structure.....	37
Figure 4.6 Flow Chart for Entire Routing Process.....	38
Figure 5.1 PDR for MAODV with GA without GA.....	39
Figure 5.2 PDR for AODV with GA without GA.....	39
Figure 5.3 Packet Loss for MAODV with GA without GA.....	40

Figure 5.4 Packet Loss for AODV with GA without GA.....40

Figure 5.5 Throughput for MAODV with GA and without GA.....41

Figure 5.6 Throughput for AODV with GA and without GA.....41

List of Tables

Table 1.1 Crossover.....	9
Table 5.1 Simulation Table.....	38

Table of Contents

Certificate	i
Acknowledgement	ii
Abstract	iii
List of Figures	iv
List of Tables	vi

Chapter 1. Introduction

1.1 VANETs.....	1
1.2 Genetic Algorithm.....	2
1.2.1 Concept of Genetic Algorithm.....	3
1.2.2 Key Terms for GA.....	4
1.3 Stochastic Operations of Genetic Algorithm.....	5
1.3.1 Initialization.....	5
1.3.2 Reproduction.....	6
1.3.3 Selection.....	9
1.3.4 Crossover.....	9
1.3.5 Mutation.....	12
1.3.6 Termination.....	13
1.4 Genetic Algorithm for Routing.....	13
1.5 Flow Chart of Genetic Algorithm.....	14
1.6 Routing in VANETs.....	15
1.7 Application on VANETs.....	15
1.8 Security Challenges in VANETs.....	16
1.9 Adversaries in VANETs.....	18
1.9.1 Classification of Attacks	18
1.9.2 Distinguishability.....	20

Chapter 2. Literature Survey

Chapter 3. Problem Statement

3.1 Problem Statement.....	28
3.2 Dissertation Objectives.....	28

Chapter 4. Proposed Work

4.1 Genetic Algorithm.....	29
4.1.1 Encoding of the Path.....	29
4.1.2 Roulette-wheel selection.....	30
4.1.3 Cross Over.....	30
4.1.4 Mutation.....	32
4.2 Spanning Tree.....	34
4.3 Routing Tree.....	34
4.4 Network Simulator – NS2.....	34
4.5 Structure of NS2.....	35
4.6 Flow Chart for the process.....	37

Chapter 5. Simulation and Results

5.1 Simulation Table.....	38
5.2 Results and Analysis.....	38

Chapter 6. Conclusion and Future Scope

6.1 Conclusion.....	42
6.2 Future Scope.....	42

REFERENCES.....	43
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PUBLICATIONS.....	48
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Chapter 1

Introduction

This chapter includes basic introduction of Genetic Algorithm and VANETs. It also consist a brief introduction of process of GA, GA for routing, application of VANETs and routing in VANETs.

1.1 VANETs

VANET is an interesting application of mobile ad-hoc network (MANETs). VANET is the powerful technology that can provide authentic vehicle to vehicle (V2V) and vehicle to roadside infrastructure (V2I) communication [17]. VANETs are self configuring network where nodes are vehicle and WIFI technologies are used to establish these networks [4][21]. At the present time cars and other private vehicle are being used daily by large numbers of people. Use of private transportation is rising so much so the biggest problem is to manage the traffic of vehicles to avoid road accident [1]. Road accident is the serious issue that is being confronted by modern society. According to the dissertation of UK department of transport for roadside accidents in Great Britain for first quarter of 2011, there were 24,766 people killed or seriously injured due to road accidents. The number of accidents decreases to 7 percent, as compared to 12 month period [2].

VANETs consist of On Board Units (OBUs) and Roadside Units (RSUs). OBUs are installed on the vehicle to provide the facility of wireless communication with other vehicles or RSUs and RSUs are communication units located aside the road. RSUs are connected with application server and truth authority (TA). VANETs challenges are optimize traffic management, road safety, information inaccessibility and authentication [6]. For example, to reduce the roadside accident vehicle should exchange their speed and position information in the driving time. For this life critical information authentication is very important, which ensure that any received information is send by authorized user and has not been changed. Because of the security reasons, some of the drivers don't want to reveal their driving information like speed and location, because any unauthentic person can track the particular vehicle. Therefore the personal information of the message sender should not be disclosed to other vehicle [18].

VANETs are allowed to create intelligent transportation system (ITS) that focuses on road safety, traveler comfort and traffic efficiency. The success of VANETs depends on the key element such as information routing between nodes and the gateway to the internet. Without any powerful routing methodology, the power of VANETs will be restricted [30].

VANETs application can be classified into two parts:

- Application which are effected by delay, e.g., video streaming, downloading multimedia programs from the nearest internet and connecting to the virtual personal network for video or voice conferencing.
- Application which are tolerable to delay, e.g., sending an advertisement or passing simple text message [11].



Figure 1.1: Processing of VANETs [1]

1.2 Genetic Algorithm

Genetic algorithm (GA) were originally developed by Bremermann in 1958 and popularized in early 1970s by John Holland. Genetic algorithm is potentially huge global search algorithm which is used to solve complex issues by natural selection and natural reproduction of biology. Genetic algorithm is a optimization process that represents the process of natural selection. This process is mainly used to develop efficient solutions [12].

Genetic algorithm start with a set of solution called population and one individual solution is called chromosome. Solutions are taken from the parent population and generate new more

useful offspring. This process is inspired by the hope that current offspring will be improvement of the old parent. Now offspring's are treated like new parents who are chosen to design new population which are selected according to their fitness value [5]. In every step of the GA, the chromosomes will undergo many genetic operations like crossover, selection and mutation [5]. The outcome of genetic operation will become solution of subsequent generation. These steps go on until any solution is achieved or terminating state is found. The main idea behind GA is to find highly optimized solution. At the same time GA maintain varieties so that it can find from the huge search space [21].

1.2.1 Concept of Genetic Algorithm

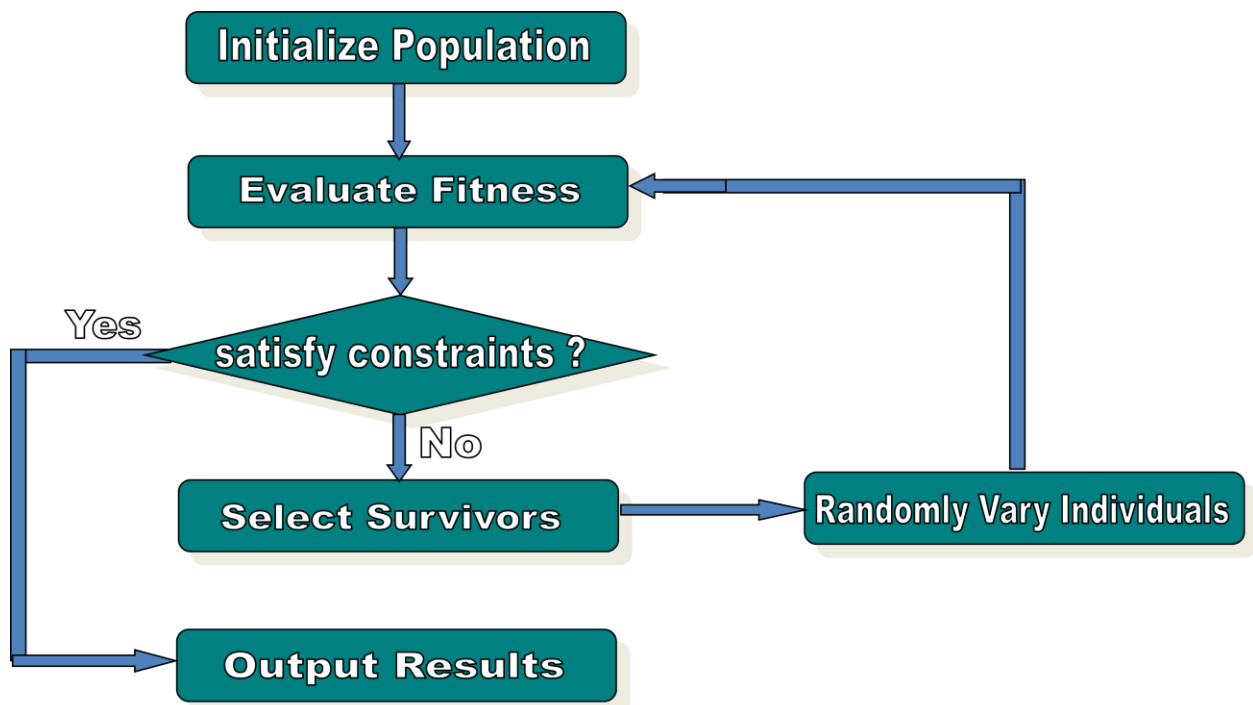


Figure 1.2: Flow Chart for GA [1]

1.2.2 Key Terms for GA

- Population - Group of all individuals
- Search Space - All feasible solutions of the problem
- Chromosome - Blueprint for an individual

Chromosomes could be:

- Bit strings (0101 ... 1100)
- Real numbers (43.2 -33.1 ... 0.0 89.2)
- Permutations of element (E11 E3 E7 ... E1 E15)
- Lists of rules (R1 R2 R3 ... R22 R23)

- Trait - Possible aspect (features) of an individual
- Allele - Possible settings of trait (black, blond, etc.)
- Locus - The position of a gene on the chromosome
- Genome - Collection of all chromosomes for an individual
- Individual - Any possible solution
- Genotype -Particular set of genes in a genome
- Phenotype - Physical characteristic of the genotype (smart, beautiful, healthy, etc.)
- Fitness Function - GA require a fitness function which allocates a score to each chromosome in the current population. Thus, it can calculate how well the solutions are coded and how well they solve the problem [12].

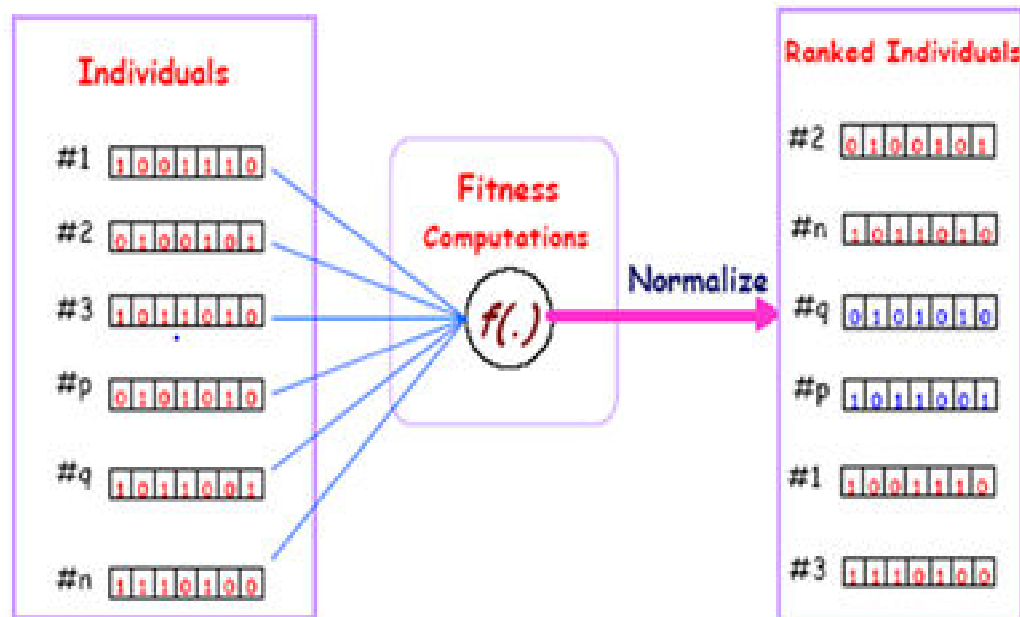


Figure 1.3: Fitness Function[19]

1.3 Stochastic Operations of Genetic Algorithm

A genetic operator is an operator used in genetic algorithms to maintain genetic diversity, known as mutation and to combine existing solutions into others, crossover. The main difference between them is that the mutation operators operate on one chromosome, that is, they are unary, while the crossover operators are binary operators.

1.3.1 Initialization

At the start a lot of individual solutions are generated randomly to make an initial population. Size of the population depends on the type of the problem, but it usually holds a number of hundreds or thousands of feasible solutions. Usually, the population is produced randomly, to cover the whole range of feasible solutions which is search space [1].

1.3.2 Reproduction

After initialization, next step of the process is to produce a second generation population of solutions from those chosen from genetic operators called recombination (which is also called crossover) and mutation. For each and every new solution to be generated, a couple of "parent" solutions are chosen for reproducing from the pool of solutions chosen before. By producing a "child" solution using the below methods of crossover and mutation, a new non existing solution is produced which naturally shares a lot of the properties of its "parents". New parents are chosen for each and every child, and the entire process continues until a new population of solutions of suitable size is produced [5].

1.3.3 Selection

The process of selection is depending on fitness values of population. Chromosomes that are calculated with upper values (fitter) will most likely be chosen to reproduce, while, chromosomes with low values will be discarded. The fittest value chromosomes may be chosen many times, however, many chromosomes chosen to reproduce is equal to the population size, therefore, maintaining the size stable for each and every generation. This stage has a factor of randomness just like the survival of organisms in nature [12]. The most commonly used selection methods are rank selection, roulette-wheel, steady-state selection, and a number of others. Moreover, to improve the performance of GAs, the selection methods are improved by elitism. Elitism is a technique, which first copies a small number of the high scored chromosomes to the

newly created population and after that continues producing the remaining of the population. Therefore, it prevents from losing some finest found solutions [1].

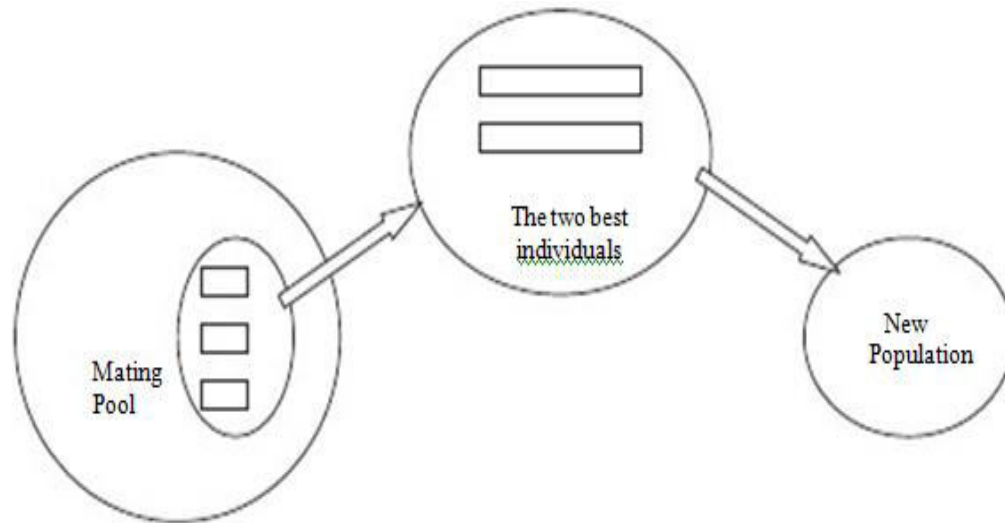


Figure 1.4: Selection Process [19]

1.3.3.1 Selection methods

- **Roulette-wheel Selection:** Roulette-wheel selection is one of the oldest GA selection techniques. The main idea behind roulette wheel is a linear search by a roulette wheel. Roulette wheel contain slots in the wheel, which are weighted in percentage to the individual fitness value. A target value is already set which is sum of all fitness in the population. The population is stepped through until the target value is found. This is simply a quite strong selection technique, while fittest individual are not guaranteed to be chosen for, but somewhat have a better chance. A fit individual contribute high for the final value but it doesn't go beyond it [16].

Roulette-wheel is a straightforward technique of executing fitness-proportionate selection. It is theoretically equal to giving each and every individual a slice of a circular roulette wheel equal in area to the individual's fitness. The wheel is spun M times, where M is the number of the individuals in the population (in our case $M = \text{Size}$). On each rotate, the individual under wheel's indicator is chosen to be in the group of parents for the next generation [1].

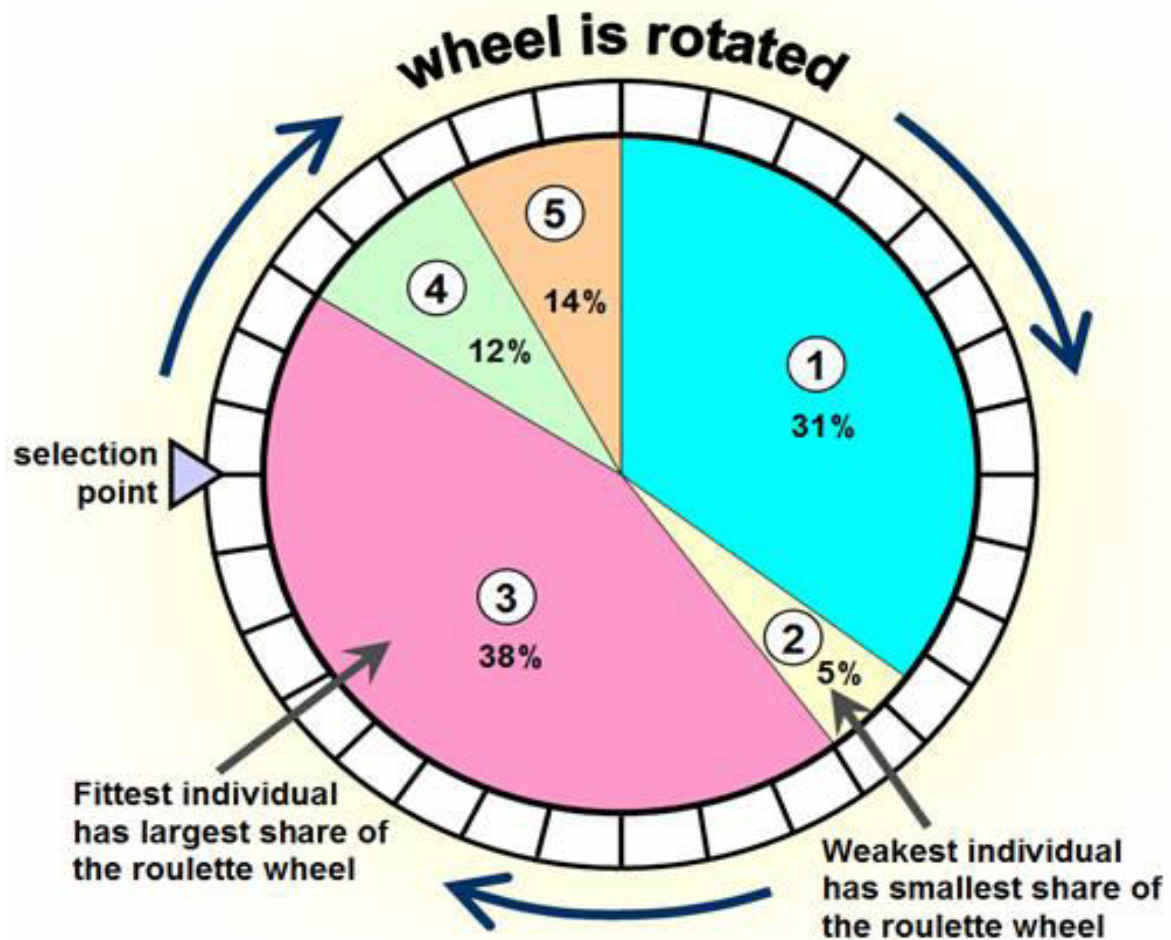


Figure 1.5: Roulette Wheel Selection [19]

- **Random Selection:** This technique randomly selects a parent from the population. In terms of disruption of genetic codes, random selection is a slightly more disruptive, on average, than roulette wheel selection [27].
- **Rank Selection:** The Roulette-wheel will suffer with a problem when the fitness values differ so much. For eg., if the best chromosome fitness is 90%, its circumference take up 90% of the Roulette wheel, and then other chromosomes have very few probability to be chosen.

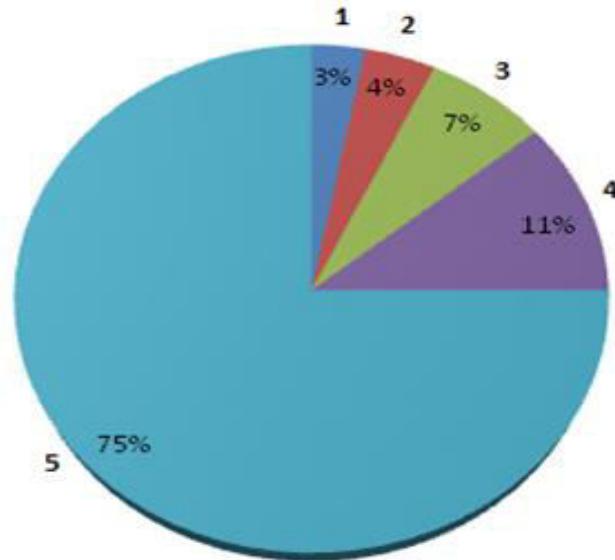


Figure 1.6: Roulette-wheel According to Fitness Value

Rank Selection technique ranks the whole population and each and every chromosome receives fitness from the ranking. The worst value of the fitness is 1 and the best value of the fitness is N (where N is the number of chromosomes in the population). It results in slow convergence but it prevents from too quick convergence. It also maintains up selection pressure when the fitness variance is low. It preserves diversity and therefore leads to a successful search [21].

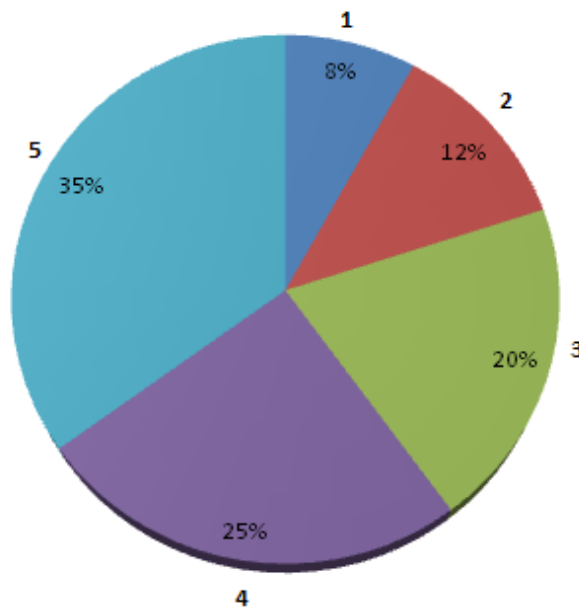


Figure 1.7: Roulette-wheel According to Rank

1.3.4 Crossover

Crossover is the procedure of joining the bits of one chromosome with those of other. Cross over is recombination operator, which is applied to the pool with hope that it would create better population. This is the process to generate an offspring for the next generation that contains characteristics of both the parents. Crossover randomly selects a locus and exchanges the subsequences before and after that locus point between two chromosomes to create two new offspring [18]. For example, consider the following parents and a crossover point at location 4

Table 1.1: Crossover

Parent – 1	1 0 0 0 1 1 1
Parent – 2	1 1 1 1 0 0 0
Offspring – 1	1 0 0 0 0 0 0
Offspring – 2	1 1 1 1 1 1 1

In this example, Offspring 1 inherits bits in position 1, 2, 3 and 3 from the left side of the crossover point from Parent 1 and the rest from the right side of the crossover point from Parent 2. Similarly, Offspring 2 inherits bits in position 1, 2, 3 and 4 from the left side of Parent 2 and the rest from the right side of Parent 1[1].

1.3.4.1 Type of Cross Over

- **Single-site Cross Over:** In single-site cross over, a cross site (locus) is selected randomly along the length of the string of mating pool and bits which are next to the locus are exchanged as shown in the figure. If a suitable site is selected, better off springs can be generated by joining best substance of parents. Since the knowledge of suitable site is not known and it is randomly selected [12].

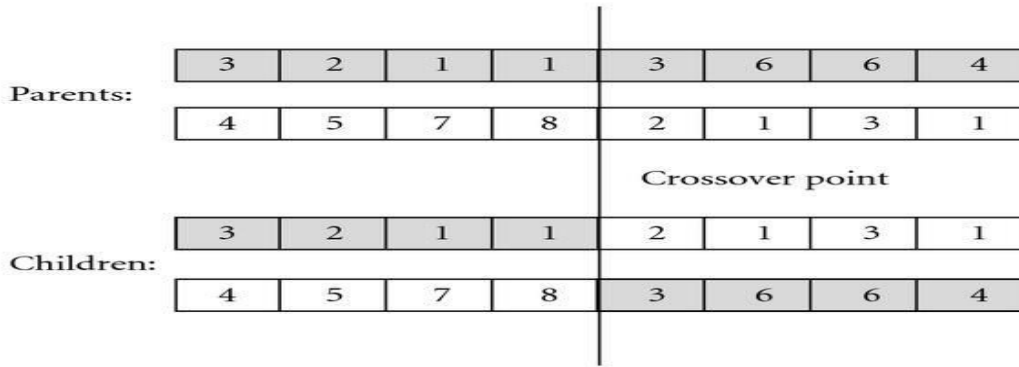


Figure 1.8: Single-site Cross Over [19]

- Two-point Cross Over:** In two-point cross over operator, two cross sites (locus) are selected and contents between these two mated parents are exchanged. If locus 1 is three locus 2 is seven, string between three and seven are exchanged as above in the figure

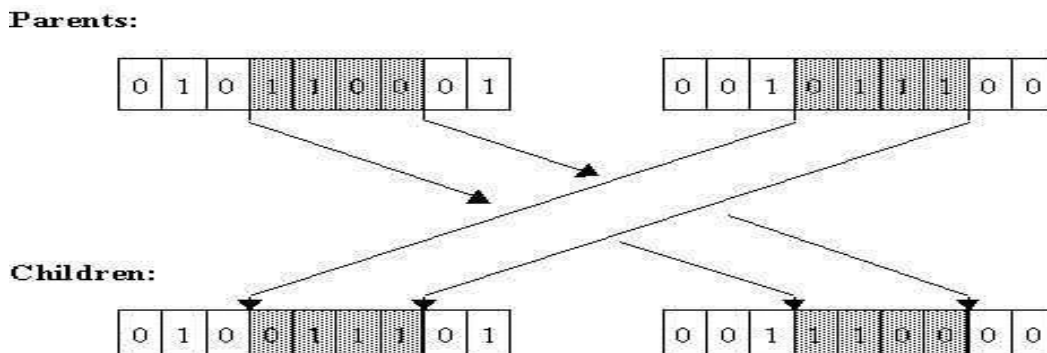


Figure 1.9: Two-point Cross Over [25]

- Multi-point Cross Over:** In multi-point cross over, there are two cases, first one is even number of cross-sites and other is odd number of cross-sites. In the case of even number of cross-sites, the string is treated as a ring without beginning and end. The cross-sites are chosen around the ring uniformly random. Now the content between alternate pair of sites is exchanged. If number of cross-sites are odd, then a different cross-point is always assumed at the beginning of the string [3].

- Uniform Cross Over:** An extreme of multi-point cross over is uniform cross over operator. In uniform cross over, the probability of each and every bit selected from either parent is 0.5 and then interchange [5] as shown in the figure.

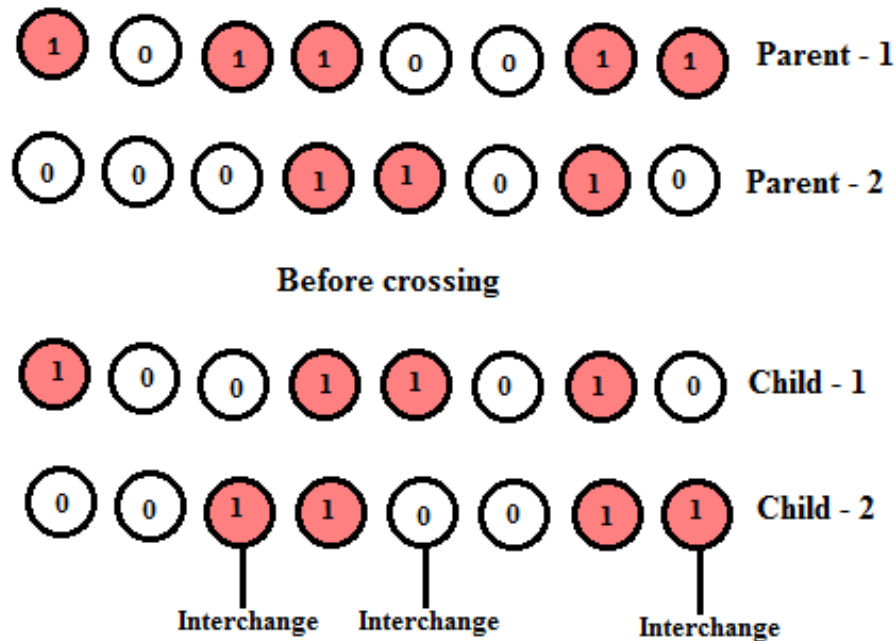


Figure 1.10: Uniform Cross Over

It is shown in the figure that uniform cross over is totally different from one-point cross over. Sometimes gene in the child is created by copying the corresponding gene from one or other parent selected according to randomly created cross over mask. When there is 1 in the mask then gene is copied from 1st parent and when there is 0, then gene is copied from 2nd parent. The process is repeated with the parents exchange to produce second child. A new cross over mask is randomly created for each and every pair of parents. Therefore, child contains mixture of genes from each parent.

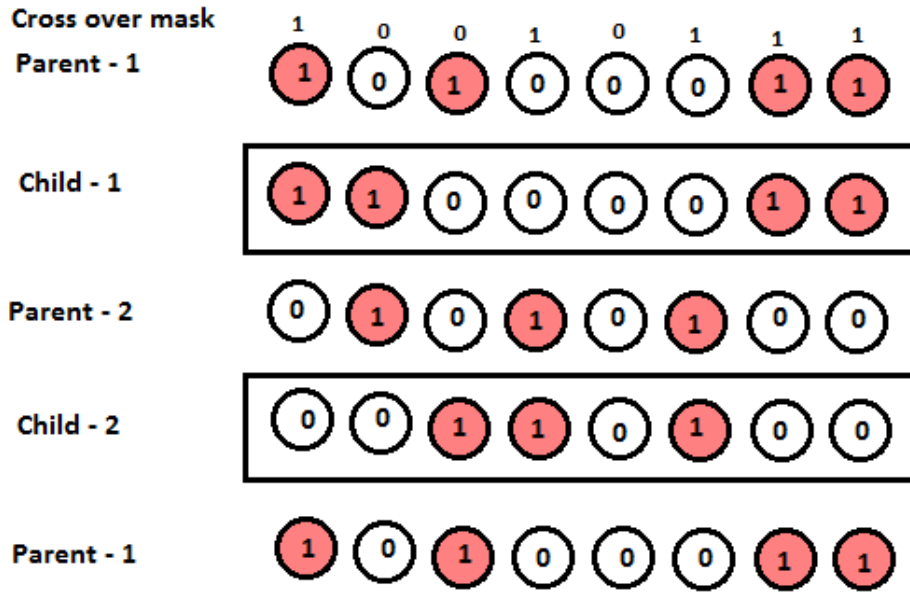


Figure 1.11: Uniform Cross Over Using Mask

1.3.5 Mutation

Mutation is performed after crossover to prevent falling all solutions in the population into a local optimum of solved problem. Mutation changes the new offspring by flipping bits from 1 to 0 or from 0 to 1. Mutation can occur at each bit position in the string with some probability, usually very small (e.g. 0.001)[8]. For example, consider the following chromosome with mutation point at position 2:

Not mutated chromosome: 1 0 0 0 1 1 1

Mutated chromosome: 1 1 0 0 1 1 1

The 0 at position 2 flips to 1 after mutation [2].

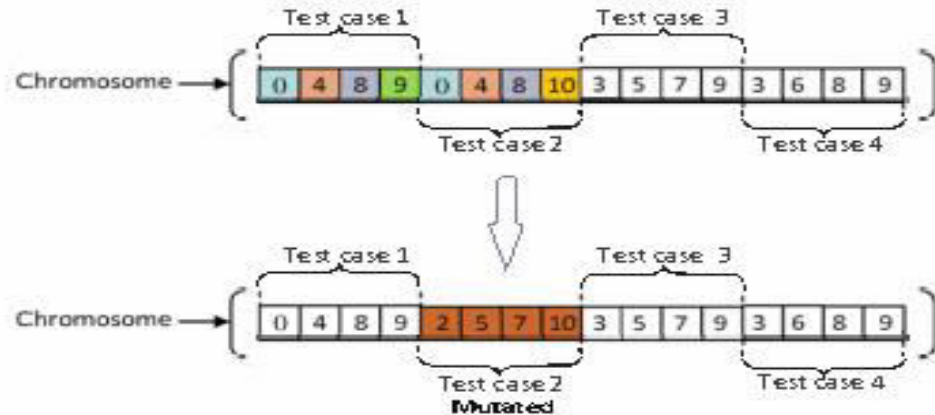


Figure 1.12: Mutation Process [24]

1.3.6 Termination

This generational process is repeated until a termination condition has been reached. Common terminating conditions are:

- A solution is found that satisfies minimum criteria.
- Fixed number of generations reached.
- Allocated budget (computation time/money) reached.
- The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results.
- Manual inspection [1].

1.4 Genetic Algorithm for Routing

Routing is the process of sending data packets from source node to destination node with the minimum cost. Cost factor may be the network throughput of connections between nodes, distance of routers and delay. Routing algorithm organizes and distributes information in the network. Routing generates the feasible routes between nodes and transmits data traffic along the particular selected path. Routing process uses the data structure called routing table at each node to store the information about the topology of network. Router decides which node to choose from the routing table for specific destination [19].

In genetic algorithm, any path from starting node to target node is a feasible solution and best possible solution is the smallest path from starting to target. In the beginning a random

population of string is generated, this is the string of nodes which represents feasible (admissible) and unfeasible (un-admissible) solution. Feasible solutions are string of nodes that reach to destination and unfeasible solution are string of nodes that cannot reach to the destination. Unfeasible solution has zero fitness value and highly optimized solution will have largest value [19].

1.5 Flow Chart of Genetic Algorithm

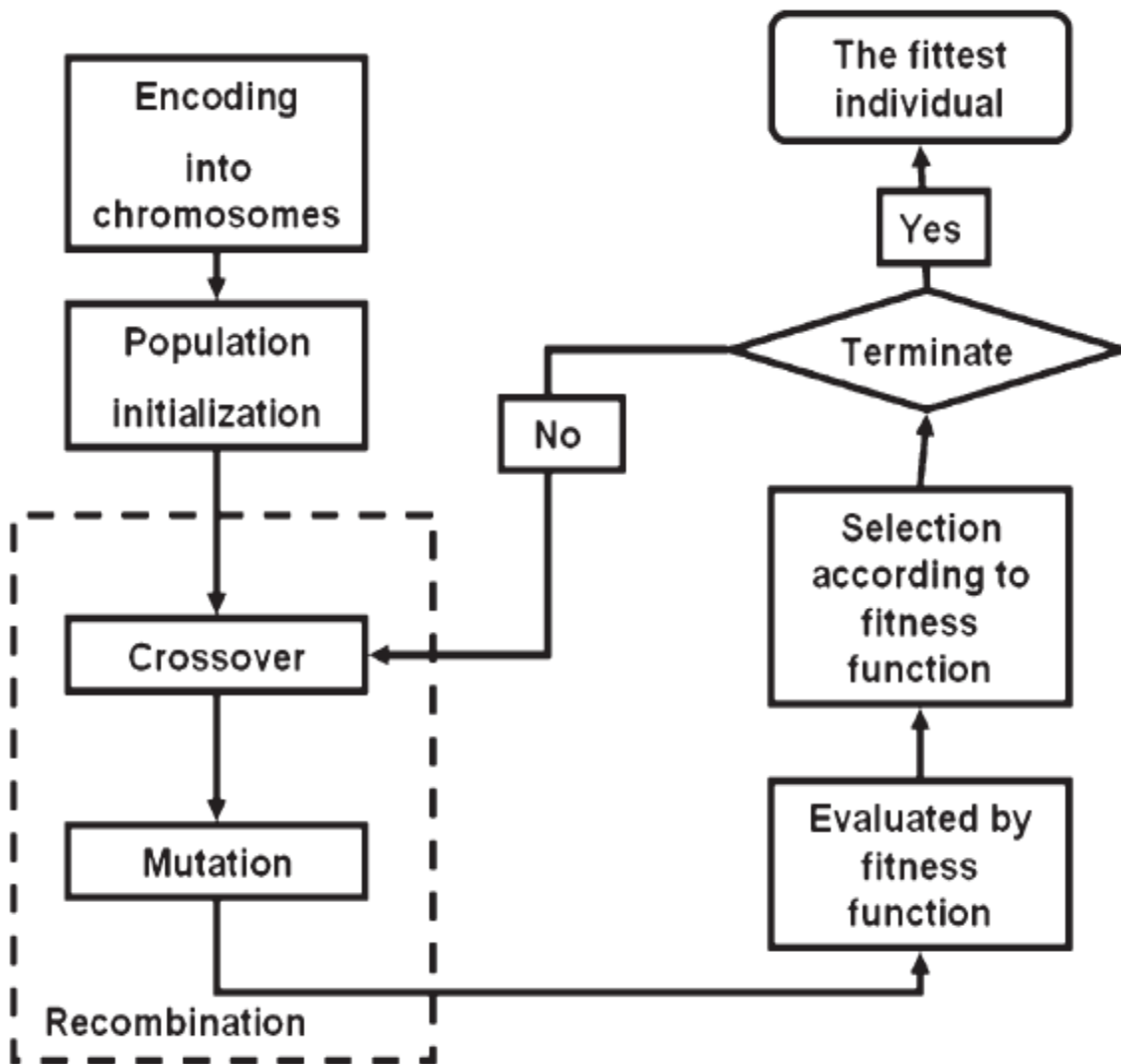


Figure 1.13: Flow Chart of Genetic Algorithm [29]

1.6 Routing in VANETs

Routing is the procedure of transmitting data packets from source to target node with the least rate. Routing in networks is a difficult field in VANETs, and also it is difficult in ad-hoc network. Dynamic topology because of much mobility of nodes, limitation of the shared medium, absence of the central entity to manage the routing information, makes routing problem even harder [32]. Vehicle-to-vehicle links and vehicle-to-roadside communication in VANETs directed to be short-lived, because of the high speed node mobility. Finding an efficient routing strategy that guarantee the minimizing delays, maximizing reliability and exchange of the latest data is an important issue when designing architecture for vehicular communication [1].

Routing methodology should maintain distribute and acquire information regarding the status of network. Routing algorithm must produce efficient routes among nodes and send data along the feasible route. In routing process, each node contains a data structure called routing table which holds the data related to network topology of the network immediately around it [35]. Routers choose which neighbor to prefer from routing table to arrive at particular target. Routing table should be updated time to time because routing table is most important component of the network routing [19].

1.7 Application on VANETs

- **Safety Application:** Safety applications are the application which involves weather, obstacles or dangerous road conditions and warning of accidents.
- **Convenience applications:** These applications involve communication between the car and mobile phone, car and work place, car and car, car and infrastructure.
- **Electronic Toll Collections (ECTs):** Without stopping every vehicle can give the toll electronically when these vehicles pass through a Toll Collection Point. The Toll Collection Point will examine the License Plate of the automobile, and provide a receipt message to the automobile, which includes the toll amount, the position and time of the Toll Collection Point [10].
- **Internet Applications:** Future automobiles will be ready with the ability so that the passages on the automobiles should connect via Internet. In the MAC layer, DSRC service channel used except the control channel for the web applications, with the low priority compared to the preceding applications. In the network layer, to maintain Internet access for VANETs, a

simple method is to offer a unicast connection among the vehicle OBU and RSU, which is having the connection toward the Internet [4].

- **Roadside Services Provider:** A wayside Services Data should install in the local region that should be connected to the subsequent RSUs. e.g., find hotels, petrol pumps, shopping malls, hospitals, etc., in the in close proximity region along the highway. In the MAC layer, DSRC service channels used except the control channel for the street side Services application, with the low priority compared to the security based applications. Each automobile will issue a Service Finder Request message that can be routed to the nearby RSU; and a Response message for the service that can be routed back to the automobile [14].
- **Group Communications:** Several drivers can share a number of similar interests when these drivers are on the identical way to the similar direction, so these drivers can make use of the Group Communications function for VANET. In the MAC layer, DSRC service channels used except the control channel for Communication of the groups, with the low priority compared to the security based applications [11].

1.8 Security Challenges in VANETs

- **Integrity and Authentication of Message:** Communication must be secured from any change and the recipient of a communication must confirm the sender of the communication. Integrity does not essentially involve recognition of the dispatcher of the message [4].
- **Message Non-Repudiation:** The message sender cannot refuse from sending the message [4].
- **Authentication for Security:** The recipient should not just know about that the sender sent a message to him, but also he must have the legal proof of that message so that sender cannot deny about sending the message [14].
- **Access Control:** to access the service offered by the particular nodes is locally approved by the rule. Access control is about what is the role of each and every node in VANET for the authentication purpose [8].
- **Message Privacy:** The information of the message must kept confidential from the nodes which are unauthorized to reach it [3].
- **Availability:** The application and network must remain working still in the occurrence of error or Malicious circumstances. This represents not just protected but also fault-tolerant

structure, flexibility to resource reduction attacks, as well as long term protocols, which start again their usual operations later than the elimination of the defective contributors [4].

- **Anonymity and Privacy:** Restricted privacy should be attained in the logic that the customer correlated information, together with the driver's name, velocity, the license plate, location and traveling path along with the links, has to be secured; whereas the authorities must be capable to disclose the individuality of message senders in the case of a disagreement such as a offense, car accident sight examination, which may be used for witnesses [11].
- **Legal Responsibility for Identification:** Users of automobile are responsible for their purposeful or unintentional actions that disturb the working of additional nodes, or the transportation organization. As a fraction of the "provisional confidentiality", the system must be capable to disclose the uniqueness of message dispatcher because of a disagreement like crime, car accident sight inquiry, which may be to find the witnesses. A number of attack have been recognized which may be categorized depending attacker layer. At the link and physical layers the intruder can alter the whole structure either by congestion or overfilling the channel with messages. Transferring bogus messages or broadcasting an already transmitted message is also a probable attack. At the network layer the intruder can transfer fake routing messages or excess the structure with the bogus messages. The intruder may also cooperation the confidentiality of drivers by tracking and revealing their location. The similar intruder may also be attained using the application layer. In the following, we review the main vulnerabilities and safety warning of VANET [4].
- **Jamming:** The jammer purposely produces intrusive broadcast that stop communiqué with the response range. In the VANET situation, an attacker be able to comparatively simply division the network, without negotiating cryptographic methods and with restricted broadcast power [4].
- **Impersonation:** An intruder can pretext as an emergency vehicle to misinform other vehicles to slow down speed. An opponent can also imitate wayside units, spoofing service announcement or security messages so an impressionist can be a danger. Message fabrication, modification, and replay all these can be used towards masquerade [15].
- **Privacy Abuse:** The set of vehicle-related data eavesdrop from vehicular exchanges will be extremely simple with VANET. Then attacks on the private information of drivers could be made, thus breach the confidentiality of drivers [4].

1.9 Adversaries in VANETs

In this part we will consider the special characteristics of an adversarial attack as well as the power for challenges to use our information updating approach for advantage.

1.9.1 Classification of Attacks

Remind we term any attack in which a node tries to influence new VANET nodes of erroneous information a “malicious data attack”. An erroneous node is winning in such an attack when the destination node or the nodes allow the mistaken data as legitimate one. We present a wide categorization of the harmful data attacks in VANETs. For example, many of the settings contain unchanging nodes and mutual decision building procedure such as voting. In such a network, spoofed nodes may be used for direct the selection as preferred by the harmful node, so that problems like the concurrent contribution of spoofed nodes are extremely significant. In our networks, nodes collect sensor information from different nodes; conclusion is not based on the gathering of approving information but somewhat on the likelihood of some attack situations in a VANET. Hence, we uncover it extra valuable to differentiate attacks on the basis of their nature, objective, impact (hidden, identified, or acceptable) and range (restricted or unlimited) [13].

- **Attacks Nature:** There are many special types of harmful VANET data. An opponent can report bogus data about different components of the VANET (e.g. non existing traffic jams) or fake data about itself (e.g. incorrect position). Since every node takes all the information of VANET that it gathers to calculate the legitimacy of latest data, the compactness of the network and the sensors accessible may create some attacks unavoidable. For example, when nodes may simply sense distance to different nodes rather than accurate position, the collective sensor information may only decrease the position of an opponent’s node to a definite little “territory”. Within its region the opponent may increase the attack at will, generating spoofed nodes and as extended as the attack matches to the copy of the VANET, it will go unnoticed [14].
- **Attack Target:** We permit for tough opponents who are capable to commune over time consuming distances. An opponent by means of such an unlimited communication radius has flexibility in the position of the node or the nodes that it tries to influence of bogus data. With

a local target, the opponent can contain additional victory since the chance of contradictory information from adjacent nodes is compact. The propinquity essential for a local attack is not easy to sustain, therefore we observe susceptibility to a local attack to be fewer troublesome. An opponent can contain extra remote objective potential, but information acknowledged from nodes nearer to the objective node can create such attacks failed [33].

- **Attack Scope:** The range of an unapproved attack is calculated in conditions of the vicinity of nodes that include VANET information of undecided legitimacy because of the attack. We entitle such nodes as the casualty nodes. The range of an attack is partial if the victims contain a tiny part of nodes. Notice with the aim that this area can be a minute area of the harmful nodes, or in the case of a remote target, it can be a minute region remote as of the harmful nodes. We express an attack affecting a bigger region of nodes an unlimited attack [23].

- **Attack Impact:** Once an opponent tries to induce the objective nodes of mistaken statistics there are 3 promising results. The attack can be unnoticed by the objective nodes, it can be identified by individual or supplementary objective nodes but still depart the nodes which contain vagueness regarding received information, and within the major approvable result, the attack can be noticed and approved (i.e. no information ambiguity remains). An unobserved attack may take place while the objective nodes are lonely or totally enclosed by harmful nodes; in this case the objective node will acknowledge erroneous information. When objective nodes contain some admittance to sincere nodes they can be proficient to identify that an attack is in progress during unpredictability in the statistics they gather, but at the similar time they might refuse to approved the attack due to inadequate data, or else danger creation an mistaken analysis via the frugality disagreement in that case the harmful information might still inaccurate [28].

1.9.2 Distinguishability

Distinguishability for significant nodes lies on four assumptions:

- (i) A node can combine observations of its limited surroundings with the message it accepts.
- (ii) A node can inform its fellow nodes apart locally.

(iii) The connections in network are adequately dense.

(iv) In satisfactorily near contact, the nodes may verify their message to one or more. In the next part, we will study these 4 hypotheses and elaborate how they can be satisfied in practice [9].

- **Local Distinguishability:** We suppose that a node may inform its nearer node apart locally. More accurately, when a node P accepts messages from 2 different nodes Q and R those are satisfactorily near to P, node P can confirm that all these communication messages arrive from separate physical units. If this confirmation not succeeded, P will have to suppose that all communication messages arrived from a distinct node that declare to be both Q and R. The hypothesis of local distinguishability permits a node to apply the frugality heuristic surrounded by the local region where the nodes will have the capability to differentiate neighbors. To show how local distinguishability can be accomplished, we recommend the subsequent instance [8].
- **Extended Distinguishability:** We have simply shown how nodes may create local region of distinguishability. Now we confer how to enlarge distinguishability in both time and space, outside the instant region in which a node can make change the survival of further nodes by straight physical sensing. This extension is accomplished by letting nodes exchange information to one another about what they sense in their local neighborhoods. Data exchange over larger space may be restricted by latency and bandwidth consideration [9].
- **Privacy:** Our centralized approach for information confirmation is made to present high-quality confidentiality protection for nodes in VANETs. Information is verified for stability in a scattered fashion, so that confidential information not necessarily runs to a central place. In order to follow a particular vehicle, an attacker has to possess nodes close to that vehicle at every time, which is a expensive attack. Legitimate communication make possible extended distinguishability of the nodes, but no time-consuming recognition of nodes is necessary. Nodes may modify their recognition often by creating new keys on the usual basis, thus creationing it complex to link information over large time phase and conclude the uniqueness and route of each and every vehicle. There is a exchange between confidentiality and the capability to identify and approved harmful information. Routinely changing keys enhance the confidentiality but presents fewer data to identify and approved harmful data. Some concern should be taken while changing keys to avoid the latest and older characteristics from being related. For example, if a single vehicle that regularly and repeatedly informs its

location modifies its key, after that the 2 routes (one route is authenticated by the older key, the other one is authenticated by the new key) will probably be simply connected. To raise the uncertainty and create it more hard to connect routes, nodes can utilize one or other of the following: 1) Altering keys at coordinated times, 2) Set up space in information reported by closest key changes and 3) altering keys while nodes are near to one another node [30].

Chapter 2

Literature Survey

Jamal Toutouh *et al.* proposed an approach intelligent OLSR routing protocol optimization for VANETs based on finding upgraded routes between the nodes to permit the relevant transfer of data specifically in the case of OLSR protocol. For this cause article deals with optimizing OLSR routing protocol. This procedure has been adapted since it represents a chain of characteristics that make it usable for extremely dynamic ad hoc network and also for VANETs [4].

L.M.R.J Lobo *et al.* proposed use of genetic algorithm in network security based on a strong network model for security function. A gene for network packet is defined through fitness function and a model to calculate fitness function is explained. The basic attacks encountered can be categorized as buffer overflow, array index out of bound, etc. The main aim of this paper is threat detection, time optimization, performance increase in terms of accuracy and policy automation [5].

Salman Yussof *et al.* commenced parallel genetic algorithm for shortest path routing problem, which is used to find the minimal route. In the computer networks, shortest path routing is widely used. Genetic oriented routing has been identified to be more scalable and intensive application in network topologies. In this paper, the aim is to reduce computation time of genetic algorithm for solving the problem of shortest path routing [21].

S. Raghay *et al.* proposed an approach genetic algorithm for management of data stream in VANET for managing the data flow and genetic algorithm is used to determine the sufficient number of vehicle to generate knowledge from data gathered by the population. Different types of information can be exchanged in the context of VANETs, especially to alert drivers of the occurrences of significant, possibly life threaten events. As a result, during their travel, the vehicles are flooded by information provided by others. The relevant data are then used locally to inform or alert the driver [12].

Chang Wook Ahn *et al.* commenced an approach genetic algorithm for shortest path routing problem and the sizing of populations to solve the problem of shortest path (SP) routing. Chromosomes (string) and their parameters (genes) have been used for encode the issue. The crossover operator exchanges fractional chromosomes at locus point and sustains the genetic diversity of the whole population. Simple repair function is used in proposed algorithm to eliminate all infeasible chromosomes. This paper also develops equation for population size that facilitates a desired quality solution. The results are relatively independent on the problem types for all source-destination node pairs [34].

Mitsuo Gen *et al.* proposed spanning tree based genetic algorithm for bicriteria topological network design which is focused on networking problems. LANs are mainly considered as the communicational structure that satisfies the demand of the customers in local area. Bridges are used to connect several LAN segment together in the network. Loop free paths between the LAN components are the main use of these transparent bridges. Spanning tree structures are considered as active LAN configurations. The paper attempts to the issue of network structural design with bicriteria for reducing the cost and the delay of message using spanning tree on the basis of GA. The main objective of this paper is to reduce the cost of maintaining the networks structure and also decrease the average delay of message for the network [35].

Gihan Nagib *et al.* work on network routing protocol using genetic algorithm which is focused to resolve a network routing protocol issue using genetic algorithm. This algorithm finds the minimal way from starting node to target node. This routing difficulty is resolved by the approach of searching graph technique to discover minimal path. In this paper GA is differentiated against Dijkstra's algorithm and MATLAB is used for simulations of these two algorithms. In genetic algorithm chromosome length depends on counting of nodes in the structure of network. This algorithm is used to resolve the network routing of 10 nodes and initial one as the starting node. The already constructed genetic algorithm is used to search the outcome for similar routing problem [19].

Avleen Kaur Malhi *et al.* commenced simulation and analysis of dropped packets for DSR Protocol in VANETs in which main aim is to simulate and examine the behavior of DSR

protocol in VANET. DSR protocol is used with practical situations by taking mobility model as a consideration. In this, experiments were performed according to simulation tools of open-source on practical situations of traffic by taking NS-2, SUMO and MOVE as operating platform. The characteristics of DSR protocol is checked for the amount of data packets at the time simulation and outcomes are too differentiated by changing the number of nodes used for simulation. Here research was implemented using 4, 10, 15 nodes to understand behavior of the packets. The study with respect to various numbers of characteristics like throughput, sum of dropped packets and size of packet and analysis indicates that number of dropped packets and by increasing the number of nodes throughput of dropping packets is also increases [6].

Bijan Paul *et al.* work on VANET routing protocols: pros and cons to classify the advantage and disadvantage of routing protocols that can be taken for future improve and develop latest routing protocol. The routing protocols which are already developed for VANETs are not effective to satisfy each traffic scenario. Moreover, the implementation of an effective routing protocol has considered major attention. Thus, there is a need to classify advantage and disadvantage of routing protocols. In this paper, comparison is done among the routing protocol [13].

Hanan Saleet *et al.* proposed intersection based geographical routing protocol for VANETs to presents a class of routing protocols for vehicular ad hoc networks (VANETs) called the Intersection-based Geographical Routing Protocol (IGRP), which outperforms existing routing schemes in city environments. IGRP is based on an effective selection of road intersections through which a packet must pass to reach the gateway to the Internet. The selection is made in a way that guarantees, with high probability, network connectivity among the road intersections while satisfying quality-of-service (QoS) constraints on tolerable delay, bandwidth usage, and error rate. Geographical forwarding is used to transfer packets between any two intersections on the path, reducing the path's sensitivity to individual node movements. To achieve this, this paper mathematically formulates the QoS routing problem as a constrained optimization problem. Numerical and simulation results show that the proposed approach gives optimal or near-optimal solutions and significantly improves VANET performance when compared with several prominent routing protocols, such as greedy perimeter stateless routing (GPSR), greedy perimeter coordinator routing(GPCR), and optimized link-state routing (OLSR). In this paper, a

new approach for routing messages in city-based environments that takes advantage of the roads layouts to improve the performance of routing in VANETs. This paper, also derived analytical expressions for the four performance metrics in a two-way street scenario. Using both analytical and simulation approaches, compared proposal with GPSR, GPCR, and OLSR. IGRP achieves better performance and it selects routes that are connected and, at the same time, satisfies thresholds on the end-to-end delay, hop count, and BER. As such, our solution stands out as a promising candidate for large-scale ad hoc networks, such as VANETs [14].

Saleh Yousefi *et al.* work on vehicular ad hoc networks (VANETs): challenges and perspectives. Vehicular Ad hoc Network (VANET), a subclass of mobile Ad Hoc networks (MANETs), is a promising approach for future intelligent transportation system (ITS). These networks have no fixed infrastructure and instead rely on the vehicles themselves to provide network functionality. However, due to mobility constraints, driver behavior, and high mobility, VANETs exhibit characteristics that are dramatically different from many generic MANETs. This article provides a comprehensive study of challenges in these networks, which we concentrate on the problems and proposed solutions. This paper presents a state of the art survey in networking challenges in vehicular ad hoc network which is a promising technology for intelligent transportation system (ITS). Although many problems are not yet solved, the general feeling is that vehicles could benefit from spontaneous wireless communications in a near future, making VANETs (Vehicular Ad-Hoc Networks) a reality [31].

Josiane Nzouonta *et al.* commenced VANET Routing on City Roads using Real-Time Vehicular Traffic Information which presents a class of routing protocols called road based using vehicular traffic (RBVT) routing, which outperforms existing routing protocols in city-based vehicular ad hoc networks (VANETs). RBVT protocols leverage real-time vehicular traffic information to create road-based paths consisting of successions of road intersections that have, with high probability, network connectivity among them. Geographical forwarding is used to transfer packets between intersections on the path, reducing the path's sensitivity to individual node movements. For dense networks with high contention, optimize the forwarding using a distributed receiver-based election of next hops based on a multi criterion prioritization function that takes non uniform radio propagation into account. This paper, designed and implemented a

reactive protocol RBVT-R and a proactive protocol RBVT-P and compared them with protocols representative of mobile ad hoc networks and VANETs. Simulation results in urban settings show that RBVT-R performs best in terms of average delivery rate, with up to a 40% increase compared with some existing protocols. In terms of average delay, RBVT-P performs best, with as much as an 85% decrease compared with the other protocols. This paper has presented RBVT, which is a class of VANET routing protocols for city-based environments that takes advantage of the layout of the roads to improve the performance of routing in VANETs. RBVT (road-based using vehicular traffic) protocols use real-time vehicular traffic information to create road-based paths between endpoints. Geographical forwarding was used to find forwarding nodes along the road segments that form these paths. To improve the end-to-end performance under high contention, we have also proposed a distributed next-hop self-election mechanism for geographical forwarding. Simulation results have shown that our two protocols, namely RBVT-R and RBVTP, outperform existing approaches in terms of the average delivery ratio and average delay. The RBVT protocols forward data along the streets (not across the streets) and take the real traffic on the roads into account; thus, they perform well in realistic vehicular environments in which buildings and other road characteristics, e.g., dead-end streets, are present. These results show that distributed applications that generate a moderate amount of traffic can successfully be implemented in VANETs. Furthermore, these applications can use RBVT-R when throughput is their main requirement and RBVT-P if they are delay sensitive [22].

Jan Kohout *et al.* proposed an approach Two-Phase Genetic Algorithm for Social Network Graphs Clustering. The structure of a social network can be naturally modeled by a directed graph. This approach transforms clustering of the users into searching for highly connected subgraphs in such a social network model. An important and useful task of a social network analysis is partitioning of its users into clusters. Many different approaches and algorithms for this problem exist; one of the possibilities is to utilize genetic algorithms for solving this type of task. In this paper, analysis of several different genetic operators and propose evolutionary based algorithm for clustering in the domain of directed weighted graphs. As it can be seen from the histograms of sizes of clusters, TPGC was able to detect well-formed clusters in both the artificially generated graph and the real-life Twitter graphs. The two-phase evolutionary process

brings significant improvement in performance of the clustering algorithm. This algorithm is able to detect existing communities even if no additional knowledge about the inter-user similarity is available. If we have more information about the users, it can be used for setting appropriate weights of the edges which leads to better accuracy in clusters detection and the discovered groups of users could be even more finegrained. Lower number of clusters in the final solutions can be forced by setting lower limit for maximal number of clusters, but if the limit is too small, the produced clusters do not characterize their members very well because of high generality [3].

Chapter 3

Problem Statement

3.1 Problem Statement

Routing algorithms for VANETs are already developed but packet delivery ratio (PDR) and packet loss and throughput can still be improved. Without including genetic algorithm in routing PDR was very low, throughput was not good enough and packet loss was very high. Make easy insertion and deletion of nodes in the path.

So we have to implement a technique to improve the routing performance of VANETs. Thus, protocol will give efficient results.

3.2 Dissertation Objectives

In this dissertation main objective is to apply genetic algorithm to improve the routing and genetic algorithm finds the highly optimal (shortest) path from the entire feasible path. A routing tree is formed from fitness function that provides highly optimized and fault tolerant routing. We also make the routing tree from spanning tree for easy insertion deletion of the node and observe throughput, PDA and packet loss for AODV and MAODV protocol.

Chapter 4

Proposed Work

This dissertation proposes an improved genetic based routing protocol for VANETs, using spanning tree and routing tree. The main aim of this dissertation is to minimize the delay from source node to destination by using genetic algorithm. To improve the quality of genetic algorithm various parameters are used. To fulfill the requirement of improvement of algorithm we have designed our approach in three phases. The first phase contains genetic algorithm for routing to find the optimal path from source to destination node and to find fitness value of each node. In second phase, a spanning tree using fitness values of each node is constructed and the third phase is to make routing tree from the spanning tree so that insertion and deletion of the node become easy and efficient.

This approach is different from others in the way that other algorithm only concern about routing path but here we are applying genetic algorithm for efficient routing to minimize the delay.

4.1 Genetic Algorithm

Genetic algorithm starts form initial population of randomly generated individuals. Many solutions are chosen from the existing solutions and multiple operations are performed on that population to form new population. Following are the different operations:

4.1.1 Encoding of the Path

We can encode the route by creating the list of node ids, beginning with the source node till the destination is found, based on the connection data of the network. For example, a path from node id 1 to node id 10 is encoded as a list of nodes along with the route (1 9 12 5 7 3 10). We cannot encode the routes which do not exist in the network, because each and every step for the path must pass to already existing link of the network. Encoding of the path is totally depended on the location of all the path in the routing table that should start with source node id. For example, string should begin with “1” in node 1.

4.1.2 Roulette-wheel Selection

In this a string from the large solution space is chosen with the probability which is proportional to E_i where E_i is the fitness value of the string. Size of the population is preset such that addition of the probabilities of every string being chosen for the pool has to be one. The probability p_i of the i^{th} selected string is [26]

$$p_i = \frac{E_i}{\sum_{j=1}^m E_j} \quad \dots (4.1)$$

where ‘m’ is the size of population. The fitness of population is calculated as roulette-wheel is spinn ‘m’ times, every time it chooses an instance of the string which is selected by roulette-wheel stick, since the boundary of the wheel is marked by the fitness value of the string.

4.1.3 Cross Over

After selection stage is ended, population is full of improved solutions. Selection creates clone of high-quality string, but not make new ones. Crossover operation is subjected to the string by the expectation that it would create improved string of path.

Cross over processed in three steps. First it randomly selects a pair of two valid solution string, then a locus point is chosen randomly and positions of values are swapped between 2 child strings to create new parent string.

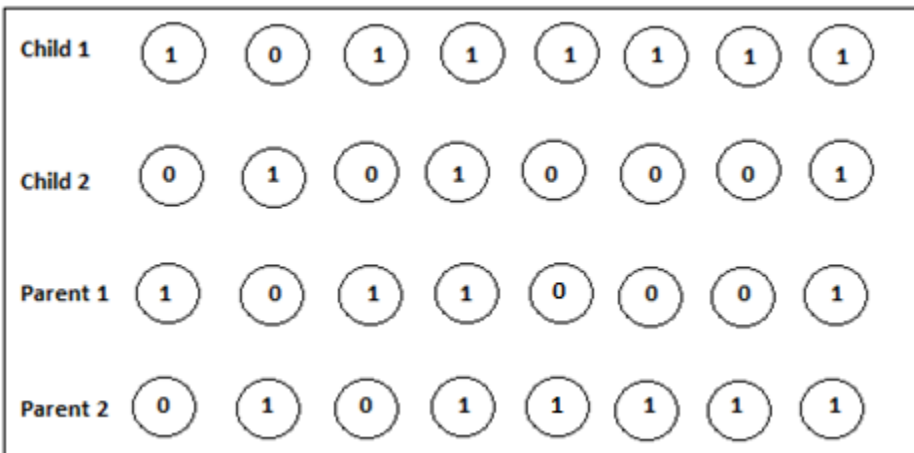


Figure 4.1: Cross Over [26]

In cross over, better children are obtained by combining good substances of parents and that will continue in the subsequent generation also. But if high-quality strings are not formed by cross

over, they will not serve beyond next generation reproduction and we will not select those string for the next mating pool [26].

Let us consider $Y_i^{(j)}$, $Y_i^{(k)}$ values of design variables Y_i in two parent string j and k . The cross over between these two values may produce the new value as

$$Y_i^{new} = (1-\beta)Y_i^{(j)} + \beta Y_i^{(k)} \quad \dots (4.2)$$

Here, the parameter β is a random number between 0 and 1.

The above equation computes new result bracketing the above two parent values. These computations executed for every variable in the string. Crossover operator interchanges the sub route between two routes. In this, path must have same source and destination node. Figure 4.2 shows the functioning of the operator.

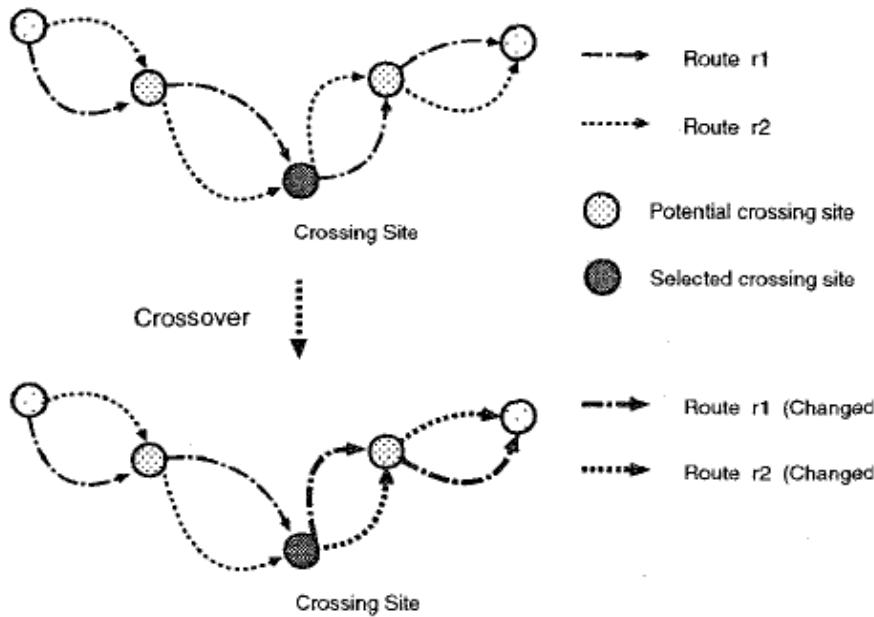


Figure 4.2: A Crossover Applied to a Pair of Routes

Crossing sites of the path crossover operator are limited to the nodes contained in both routes. We randomly select a node as a crossing site from the potential crossing sites and exchange sub-routes. When we apply the crossover operator to a pair of routes r_1 and r_2 , the operation proceeds according to the following sequence:

- List up a set of nodes N_c , included in both r_1 and r_2 (excluding source and destination nodes) as potential crossing sites.
- Select a node n_c , as a crossing site from the N_c .
- Crossing over the routes by exchanging all nodes after the crossing site n_c .

Suppose we apply a path crossover for a pair of routes r_1 and r_2 from node 0 to node 20 in the following sequences:

$$r_1 = (0 \ 2 \ 3 \ \boxed{7} \ 9 \ \boxed{11} \ 12 \ \boxed{15} \ 17 \ 18 \ 20),$$

$$r_2 = (0 \ 4 \ 5 \ \boxed{7} \ 10 \ \boxed{11} \ 13 \ \boxed{15} \ 16 \ 20).$$

Their potential crossing sites are nodes 7, 11, and 15. When we select the node 11 as a crossing site, the new routes are generated by exchanging the subroutes after the crossing site:

$$r_1 = (0 \ 2 \ 3 \ 7 \ 9 \ \boxed{11} \ 13 \ 15 \ 16 \ 20),$$

$$r_2 = (0 \ 4 \ 5 \ 7 \ 10 \ \boxed{11} \ 12 \ 15 \ 17 \ 18 \ 20).$$

If there is no common node in a pair of routes, we cannot select a crossing site and crossover is not performed. A pair of routes without any similarity is not worth crossing-over because the operator may generate routes far from their parents for such routes, which means random regeneration of routes.

4.1.4 Mutation

After the stage of cross over, strings are applied to mutation operation. Mutation of bit is like flipping the bit, 0 is converted to 1 and 1 is converted to 0 with a small probability of mutation q_i . Strings bits are muted separately, because mutation of bit does not affect the probability of mutation of other bits.

Non muted chromosome- 0 1 0 1 1 0 0 1

Muted chromosome- 1 0 0 1 0 0 1 1

Here, we are using genetic algorithm with population size 10 to 50 with the mutation rate varying from 0.001 to 0.05.

Mutation operator is applied in the path to generate an optional route. To execute mutation, select a node randomly from the path. This random node is called mutation node. Then select

other node which is chosen from the nodes those are directly linked with mutation node. Now we can produce an alternative path by linking initial node (source node) to selected node which is neighbor node of the mutation node and selected node to final node (destination node).

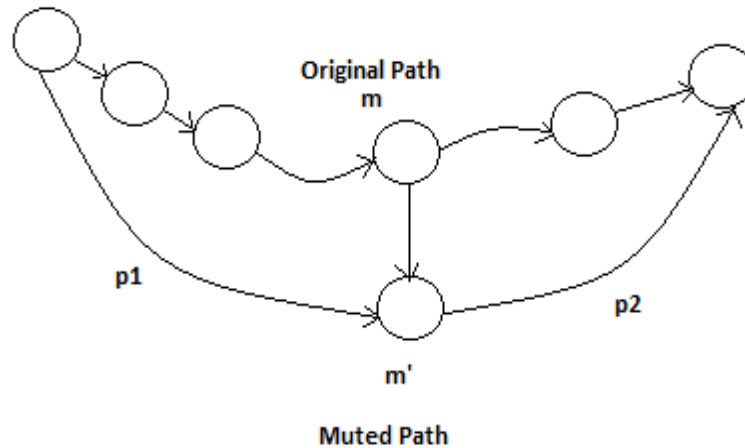


Figure 4.3: Mutation Operation Applied to the Path

Mutation operation on the path proceeds in following sequences where p is the original path and p' is the mutated path.

- (i) Randomly chose a mutation node from all nodes present in the path p .
- (ii) Chose a node p' , which is the neighbor node of the mutation node.
- (iii) Create a minimal route p_1 from source node to m' and create other minimal path from m' to destination node 4. If any replication exists in between p_1 and p_2 , then we eliminate the path and that path will not participate in mutation. Otherwise, link the paths to get a muted path $p = p_1 + p_2$

For example, if mutation is applied to the path $p = (1\ 5\ 2\ 10\ 3\ 6\ 8\ 4\ 9)$. Firstly, we are randomly selecting node 10 as a mutation node. Secondly, we are selecting node 7 as a neighbor of the mutation node. Then by applying shortest path algorithm, we link source node 1 to selected node 7 to generate route $p_1 = (1\ 5\ 2\ 7)$ and also link node 7 to destination node 9 to generate other path $p_2 = (7\ 3\ 6\ 8\ 4\ 9)$. Now we complete mutation by linking the path p_1 and p_2 to have $p' = (1\ 5\ 2\ 7\ 3\ 6\ 8\ 4\ 9)$. We will not create path p' if there exist any duplication in between p_1 and p_2 . The reason behind this is to avoid the loop in a path.

4.2 Spanning Tree

After applying genetic algorithm spanning tree is formed by using the matrix of fitness values (weight). The main concept behind using the spanning tree is optimized and fault tolerant data forwarding. If the nodes are not connected like spanning tree, each node will infinitely duplicate the first broadcast packet heard. When we are performing the routing in the network, one of the biggest issues is loop prevention. If a loop is occurred in the routing network, the amount of traffic pass through the nodes will quickly utilize the entire bandwidth. So we have used spanning tree which eliminates the links that cause loops so that it makes the paths for the data transmission.

4.3 Routing Tree

In this phase we will make a routing tree from the spanning tree. Now the links of spanning tree becomes the node of routing tree. Routing tree formation allows optimal operations for insertion and deletion. Routing tree is used to store all the information of the node.

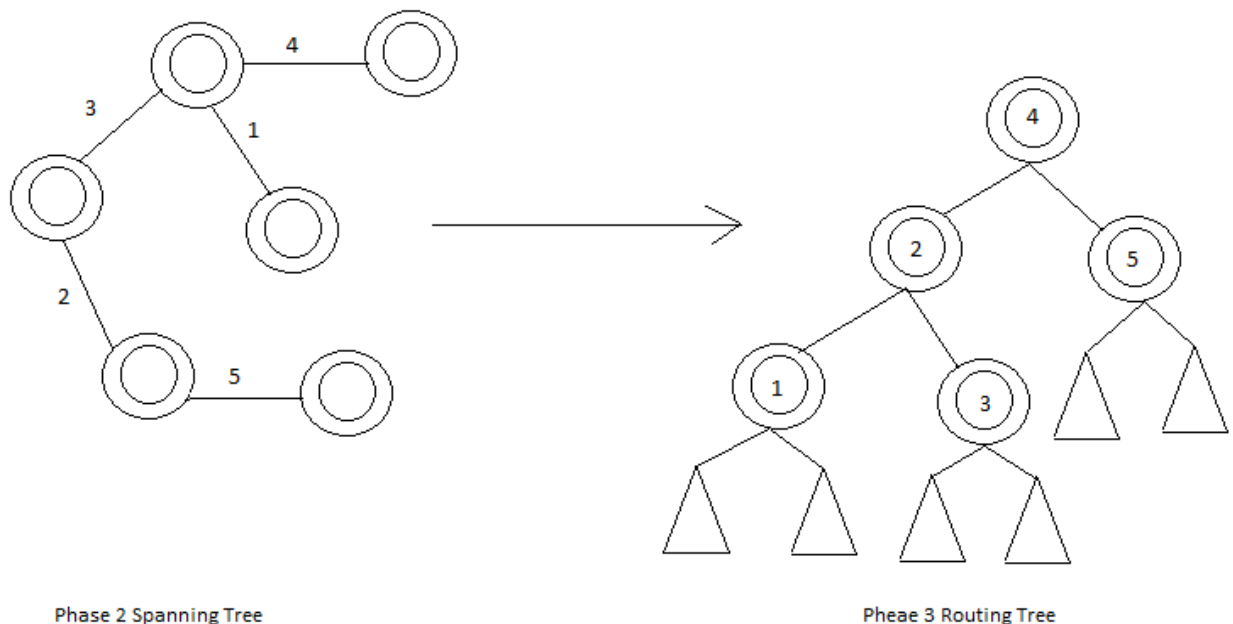


Figure 4.4: Transition from Spanning Tree to Routing Tree

4.4 Network Simulator – NS2

NS2 is a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing and multicast protocols over wired and wireless networks. It

consists of two simulation tools. The network simulator (NS) contains all commonly used IP protocols. The network animator (nam) is used to visualize the simulations. NS2 fully simulates a layered network from the physical radio transmission channel to high-level applications. NS2 is an object-oriented simulator written in C++ and Tcl. The simulator supports a class hierarchy in C++ and a similar class hierarchy within the Tcl interpreter. There is a one-to-one correspondence between a class in the interpreted hierarchy and one in the compile hierarchy. The reason to use two different programming languages is that Tcl is suitable for the programs and configurations that demand frequent and fast change while C++ is suitable for the programs that have high demand in speed. NS2 is highly extensible. It not only supports most commonly used IP protocols but also allows the users to extend or implement their own protocols. It also provides powerful trace functionalities, that store various information needed to be logged for analysis. The full source code of NS2 can be downloaded and compiled for multiple platforms such as Unix, Windows and Cygwin. NS2 is a popular simulator in scientific environment. We have some other network simulators such as Qualnet, GloMoSim, OPNET, etc. The advantage of NS2 in comparison with other types of simulators is that it is an open source program which is suitable for low level applications. Tcl is a short for MIT object Tcl and is an extension to Tcl/Tk for object oriented programming. Tcl is used to build the network structure and topology which is just the surface of the simulation. Also it is easy to configure the network parameters.

C++ is the kernel part of the NS2. It is used to implement the kernel of the architecture of the protocol designs. From the packet flow view, the processes run on a single node. Also C++ is used to change or comment out the existing protocols running in NS2. NS2 uses two languages because we have two requirements in simulation:

- Detailed simulation of the protocol: Run-Time Speed.
- Varying parameters or configuration: Easy to Use.

4.5 Structure of NS2

The structure of NS2 contains four different parts:

- NS2: The simulator itself
- NAM: Visualized trace tool of network animator
- Pre-processing: Traffic and topology generator
- Post-processing: Simple trace analysis, often in Awk, Perl or Tcl

The directory structure of NS2 is shown in the figure 4.5:

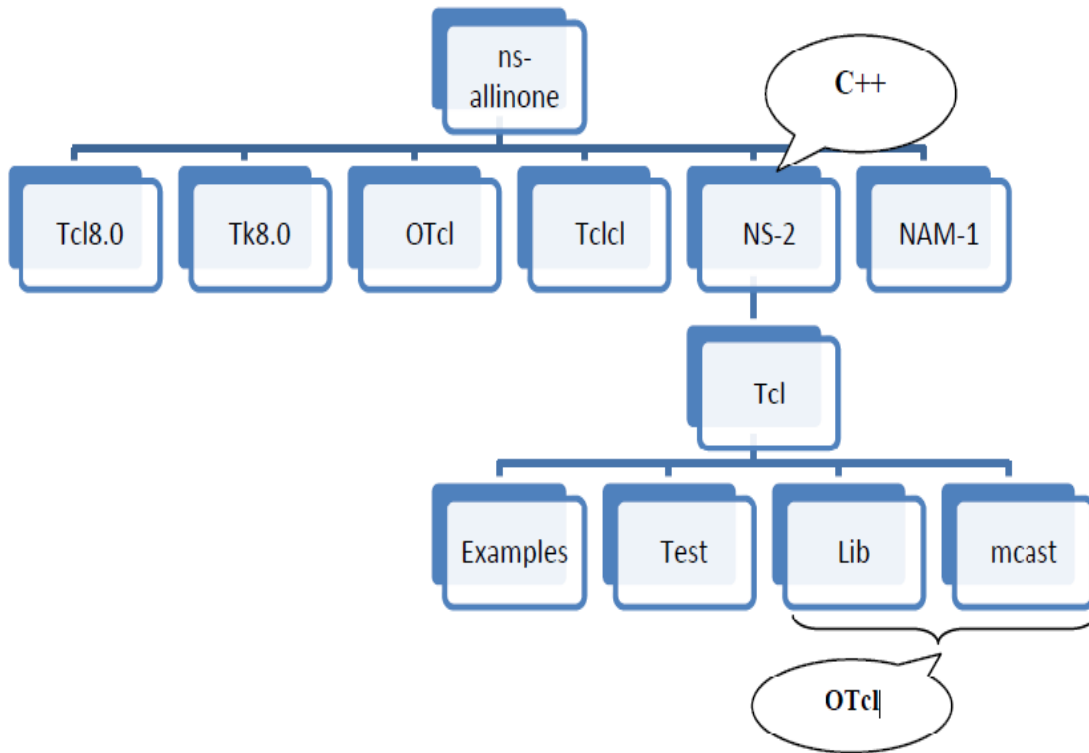


Figure 4.5: NS2 Structure

4.6 Flow Chart for the Process

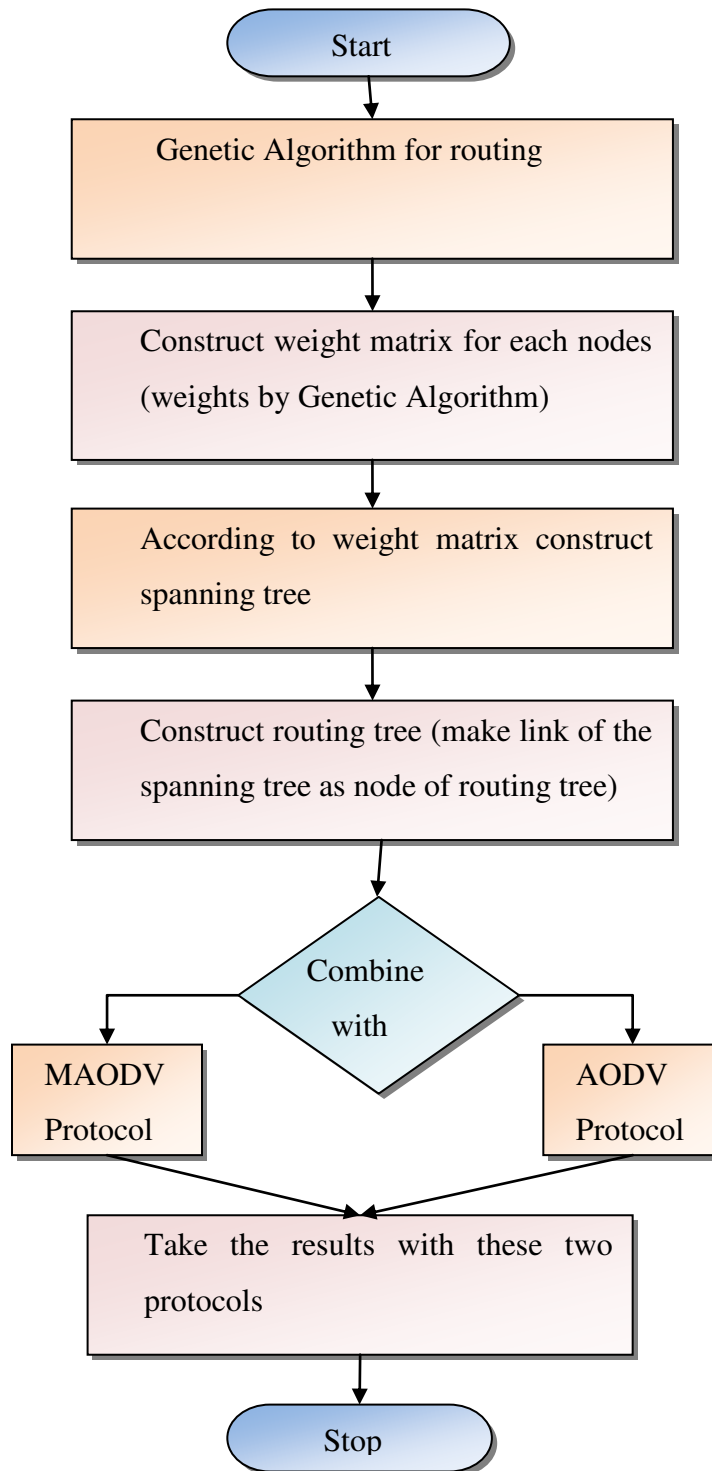


Figure 4.6: Flow Chart for Entire Routing Process

Chapter 5

Simulation and Results

5.1 Simulator Configuration

In this we evaluate our performance through simulation by using Network Simulator of version 2 (NS-2.35). 20 simulation runs were performed for different no of nodes. The area for simulation is 1500X1500. The other parameters for simulator configurations are shown in table 5.1.

Table 5.1: Simulation Table

Parameters	Value
Nodes	5,10,15,20,25,30,50
Connection type	CBR
Area	1000x1000
Minimum connections	10-30
Speed	50
Version	2
Mobility Model	Random Way Point
Number of Packets	2000
Simulation Time	1000
Protocol used	AODV, MAODV

5.2 Results and Analysis

The results were evaluated using simulation over MAODV and AODV as base routing protocols for the following parameters.

A. Packet Delivery Ratio (PDR) for MAODV and AODV with GA and without GA

Graphs shown in figure 5.1 and figure 5.2 illustrate the improvement in packet delivery ratio by integrating Genetic Algorithm with MAODV and AODV protocol.

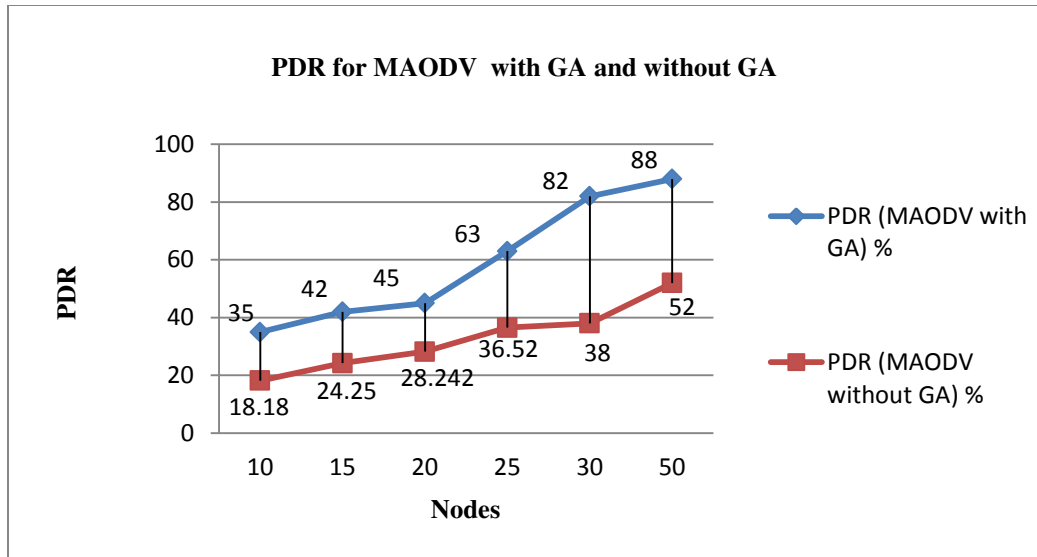


Figure 5.1: PDR for MAODV with GA without GA

INFERENCE: PDR increase for MAODV protocol by incrementing the nodes. Packet delivery ratio is more when GA is integrated with MAODV protocol.

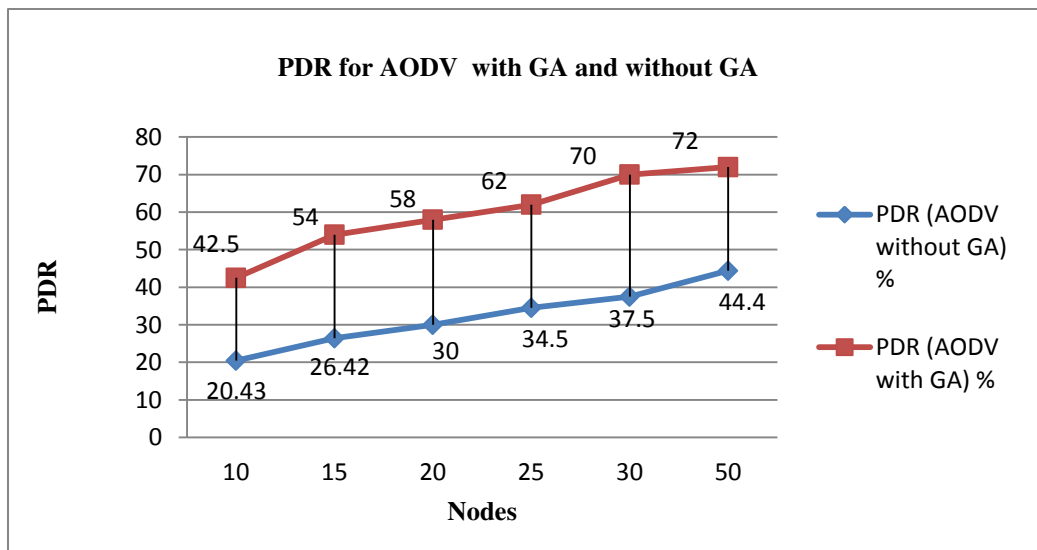


Figure 5.2: PDR for AODV with GA without GA

INFERENCE: PDR increases in AODV protocol by incrementing the nodes. PDR is more when GA integrated with AODV protocol.

B. Packet Loss for MAODV and AODV with GA and without GA

Graphs shown in figure 5.3 and figure 5.4 illustrate the reduction of packet loss by integrating Genetic Algorithm with MAODV and AODV protocol.

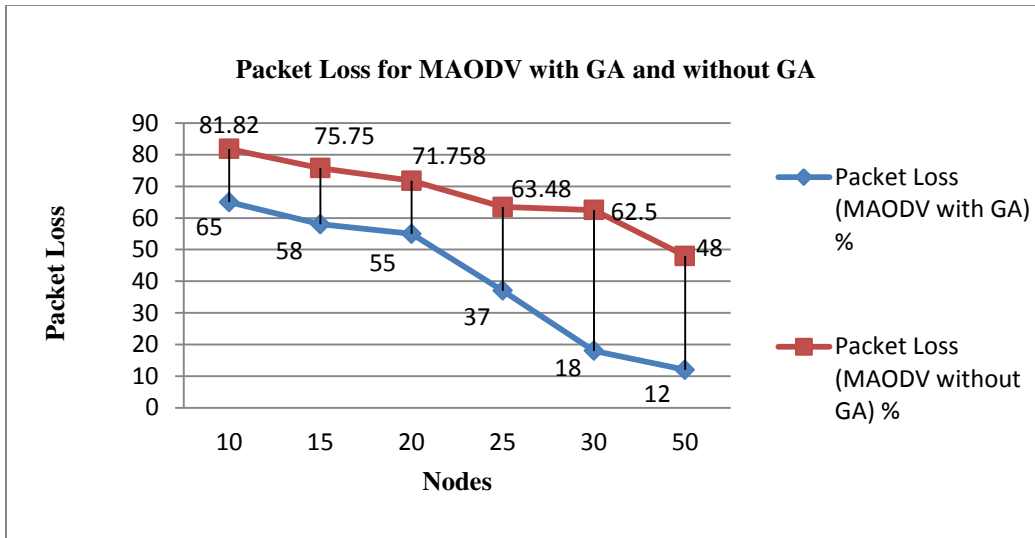


Figure 5.3: Packet Loss for MAODV with GA without GA

INFERENCE: Packet loss decreases for MAODV protocol by incrementing the nodes. GA integration with MAODV protocol decrease the packet loss in the network

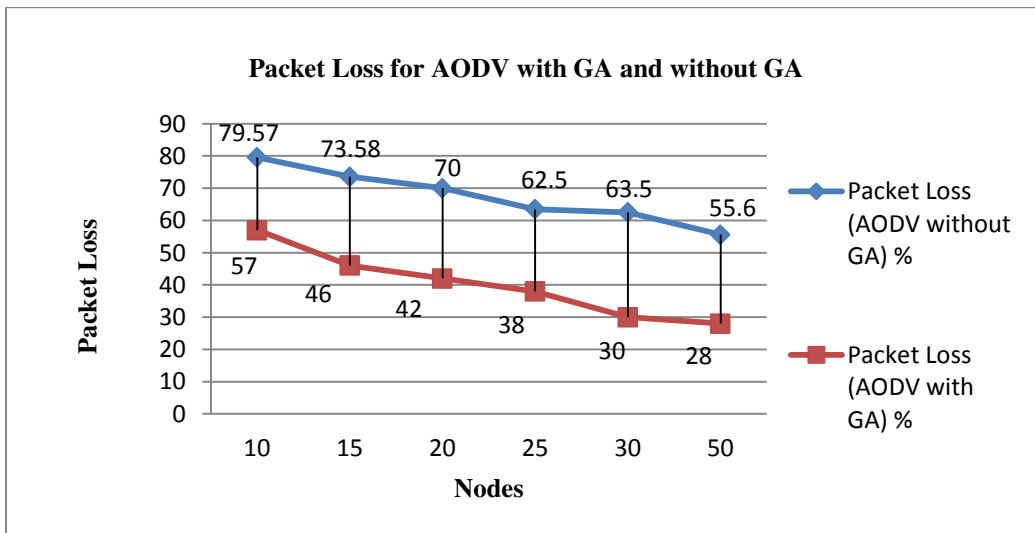


Figure 5.4: Packet Loss for AODV with GA and without GA

INFERENCE: Packet loss decreases for AODV protocol by incrementing the nodes. GA integration with AODV protocol decrease the packet loss in the network

C. Throughput for MAODV and AODV with GA and without GA

Graphs shown in figure 5.5 and figure 5.6 illustrate the improvement in packet throughput by integrating Genetic Algorithm in MAODV and AODV protocol.

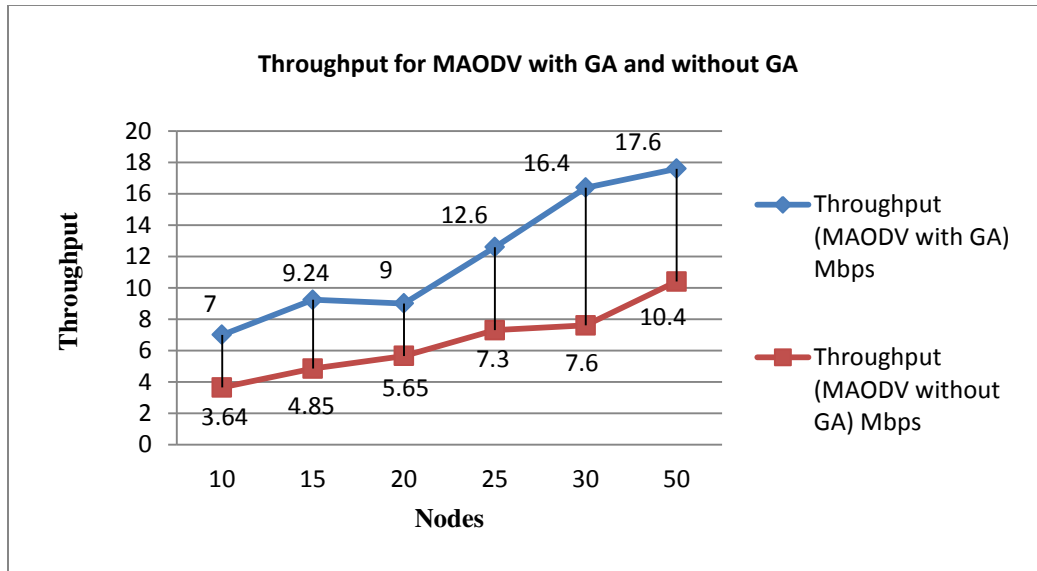


Figure 5.5: Throughput for MAODV with GA and without GA

INFERENCE: Throughput increases for MAODV protocol by incrementing the nodes. Throughput is more when GA integrated with MAODV protocol.

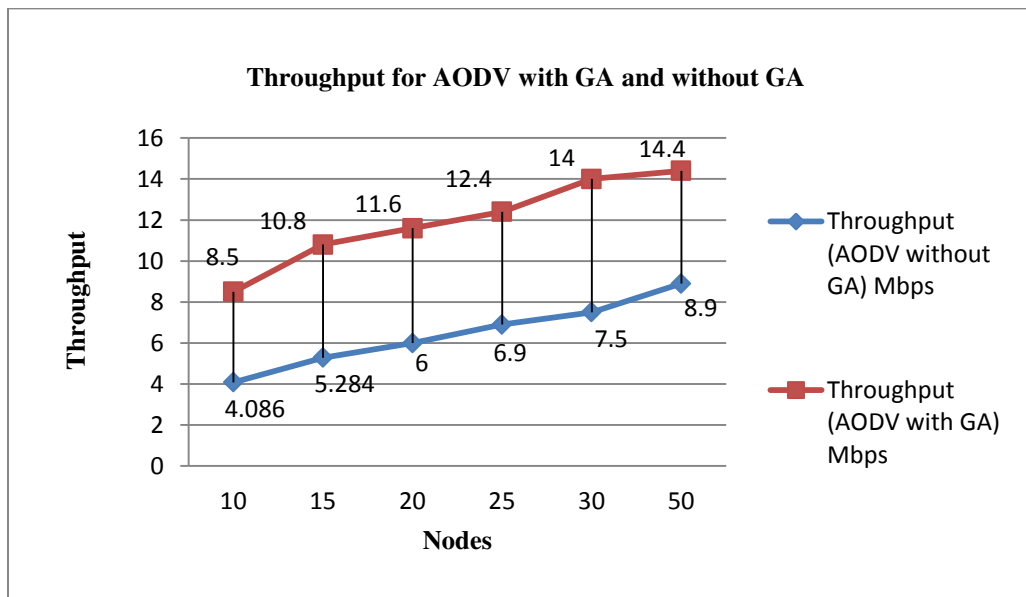


Figure 5.6: Throughput for AODV with GA and without GA

INFERENCE: Throughput raises for AODV protocol by incrementing the nodes. Throughput is more when GA integrated with AODV protocol.

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

Routing in VANETs is an important research issue as it includes heterogeneous nodes. MAODV and AODV both are reactive routing protocols and are extended on VANET for simulation using NS-2. In this dissertation, a genetic based routing strategy is proposed which is capable enough to be incorporated with existing routing protocols. For analysis, proposed algorithm integrated with AODV and MAODV routing protocol. From simulation, it is observed that integration of GA with routing protocol (AODV and MAODV) improve the packet delivery ratio, increase the network throughput and lower the packet loss. GA also allow optimal path that reduces routing cost of the overall network.

6.2 Future Scope

- In future, work can be done in the real time environment and can be tested with real time RSUs.
- Also, more fault tolerant features can be integrated with the proposed algorithm.

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