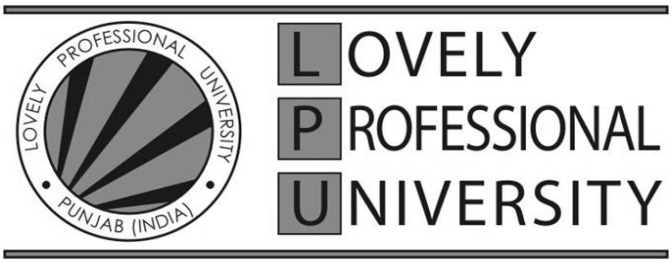

Machine Learning Used in Intrusion Detection and Prevention System

A Dissertation
submitted

By

(Simranjit Singh)

To

Department of Computer Science

In partial fulfillment of the Requirement
for the Award of the Degree of

Master of Technology in Computer Science

Under the guidance of

(Navneet Kaur)

April 2015

CERTIFICATE

This is to certify that "**Simranjit Singh**" has completed M.Tech, dissertation titled **"Machine Learning used in Intrusion Detection and Prevention System"** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the dissertation has ever been submitted for any other degree or diploma.

The dissertation is fit for the submission and the partial fulfillment of the conditions for the award of M.Tech Computer Science & Engineering.

Date: _____

Signature of Advisor

Name: Navneet Kaur

DECLARATION

I hereby declare that the dissertation entitled, "**Machine Learning used in Intrusion Detection and Prevention System** "submitted for the M.Tech Degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: _____

Investigator

Reg. No. 11211304

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I would like to express my deepest and sincere gratitude to my supervisor, “Navneet Kaur” for kindly providing me with a good opportunity to work with her in the area of “Network Security”. I deeply appreciate her guidance, motivation and support during the preparation of this study.

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Abstract

While using the growth associated with computer networks as well as the huge increase in the volume of applications that rely on it, network security is actually gaining growing importance. Sensor systems are heavy wireless systems constituting associated with small and also low-cost sensors that collect sensory files. Wireless Sensor Networks are typically deployed directly into arbitrary topologies. Node self-organizes into a multi-hop network. The attributes of self-organization and also wireless channel make cellular sensor network easy to put together and thus appealing to users. Machine leaning utilized in computer network security to understand malicious network activities and also report them to administrator.

In this research work will describe the intrusion prevention systems used to discover cruel activity, log information regarding node activity, effort to block stop activity, description to network/system administrator and enhance the performance of network in the presence of multiple black hole by using anomaly based machine learning technique with AODV protocol.

We will also discuss some attacks in mobile ad-hoc network and method to prevent network from black hole attack.

- With enhancing violent against computer security, computer systems often continue to stay unprotected during long period of time. Machine learning makes this available for automatically examine of data and causes of damage data. Majority of violent actions against security have been made larger for fun rather than benefits such as crime for stealing of credit card information, the act of spreading of spam messages and denial of service action against server or hosts connected in computer network.

  Therefore, computer system faces new challenges with growing these activities. Now by adding the concepts of computer network security and machine learning, new methods are formed in detecting, analysis and preventing violent action against computer security. Unusual violent actions against computer network security are the big difficulties in the field of information security. Many such unusual violent actions are needed much effort to discover on the principle of examination of basic behavior of the communication protocols such as http (hypertext transfer protocol), soap(simple object access protocol), smtp (simple mail transfer protocol) , etc. or examine on the basis of system calls(alarm generated by system, hosts at the time of intrusions). Obviously, there is a need for methods that help to examine unusual violent actions against computer network more rapidly. If the attackers are fit to fulfill their actions and automatizing their tools, why it is not attemptable in the field of security?

  We can define the intrusion detection system is the process of monitoring the events that has been occurring in the network. Basically it is used to detect the violations that occur in the network due to the activities performed in the computer network. And the system which is used to prevent the intrusion is known as intrusion prevention system.

- **Types of Intruders**

  - **Masquerader:** These are usually outsiders through the dependable users and they are not authorized to make use of the actual computer systems. Most of these intruders sink into the actual system protection using legitimate end user balances**.**

- **Misfeasor:** These are usually insiders in addition to legitimate end user that accesses sources they are not really official to make use of or even they may be official although misuses rights.

- **Clandestine end user**: They are often equally insider in addition to outsiders. This type of intruder gets supervisory having access to the device.

- **Types of Violation Detection System:** There are basically two types of systems are used for intrusion

  - **Violation detectors process**: The machine currently in use to evaluate website traffic within the mobile phone network and discover these intrusions.

  - **Violation prevention process:** The machine currently in use to prevent intrusions which might be detected through the previous system.

- **Detection Methods followed by intrusion detection prevention system**

- **Signature Based Detections:**

  Found in signature depending detection to begin with we're going to mention signature. Your signature is usually a design associated with flaws that is matched in the page views passing throughout the network. And then the strategy utilized to complement them these signature in addition to determine invasion is known as signature depending detection system.

  Instances:

  - Your telnet attempt through root because username.
  - An email through individual any “free.xyz” and / or addition “simran.jpg ;.
  - Bank depending detection themes are quite obvious options who use sequence related because base technique.

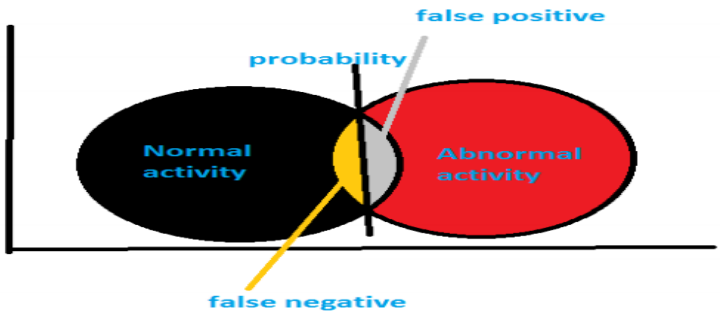
  These records of activity which in turn are manufactured in the time of any pursuit practiced seem to be gathered or go with the packet might be matched in the signatures. Afterward activity is performed if the packet has to be fell and / or accepted.

Anomaly Based Detection

Unusual person established spying strategy is located about the anomalies. Flaws fundamentally summarize the typical action about the owner or perhaps host. And also sense faults depending on anomalies .A information can be construct which often summarize the behavior about consumer picking ordinary or perhaps not. Like because of the spyware phase the vitality utilization of desktop computer increases.

Notifications/Alarms

- **False Positive:** Normal behavior of any activity which is declared as abnormal and IDS send alarms/notifications to the network administrative console are known as false positive alarm.
- **False Negative:** Abnormal behavior of any activity which is declared as normal, and therefore IDS sends a false alarm to the administrative console is known as false negative alarm.



- **Audit Record:** Every computer, networking device has an audit recorder or event monitor administratively tool, which is used to keep track of events and used for look up what is happening on the device. It includes event type, event ID, and source address etc. information of the device.

  Example: Microsoft Management Console (MMC) hosts administrative tool that can use in administrator network, computer, services, and other system components.

- **CLASSIFICATION OF IDPS TECHNOLOGIES**
  - **Network based IDPS**: That intrusion discovery and also elimination structure which is often used to research and also watch laptop or computer system targeted visitors and also system process activities.

- **Wireless Based IDPS:** That intrusion discovery and also elimination structure which is often used to research and also watch wireless system targeted visitors and the system methods activities.
- **Network based analyzer:** This is utilized in order to any disorders and also each and every cynical exercise takes place from the system so we can tell that must be the device which is used in order to system traffic.
- **Host based IDPS:** This is utilized in order to any disorders and also each and every cynical exercise takes place in a web host as well as being utilized recognise any targeted visitors moving past thru individual web host

The network system is an organization more than one PC and even electronic devices which in turn correlated together. It is actually way of change of info to having each individual other. It is actually relationship involved with automated equipment which are correlated using the correspondence facilities [1]. Along the point once PC usually are put together concurrently that will commerce facts these products variety technique and offer assets. Networking may be used to grant know-how like data share. Providing methods may be laptop program and even electronics type. It is actually main organization design [15].

The networks are generally born network and also wi-fi network. Wired network is what utilized cables pertaining to correspondence having a single another's and also wi-fi network is what give you without worrying about the by using cables by way of a medium.

- **Types of Network**
  - Wired Network
  - Wireless Network

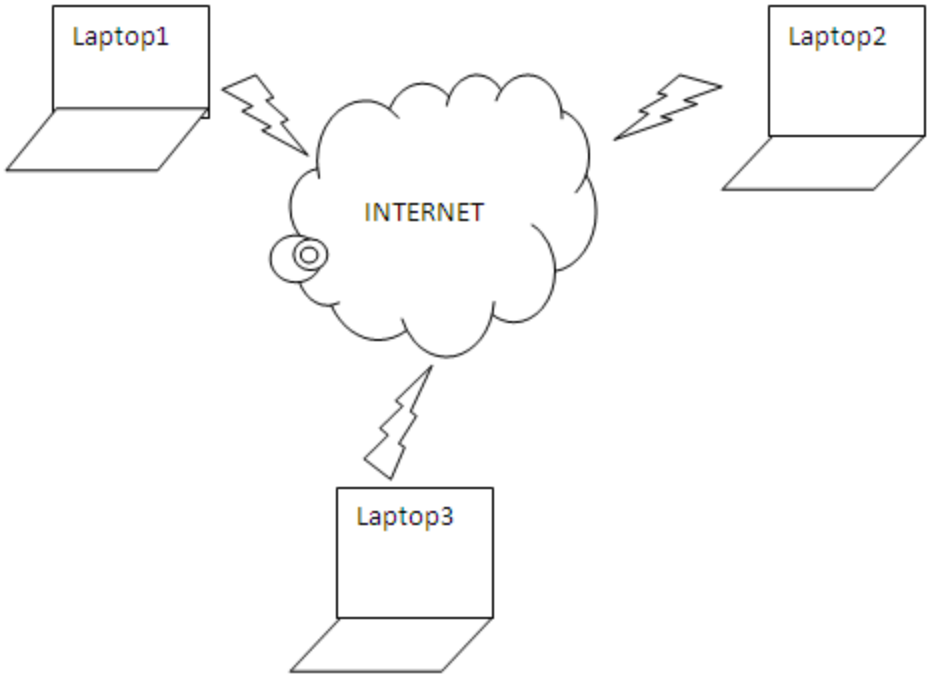


Fig. 1.1 Diagrammatically representation of Computer Networks

There are two type of Wireless Operating mode:

- Infrastructure Mode
- Infrastructure less Mode

- **Infrastructure Networks:** \

In infrastructure based system, conversation is normally develops basically between the mobile nodes/devices plus the connection points. The conversation is simply not straightforwardly develops between the mobile devices. In this case typically the connection point is normally utilized to be in charge of typically the choice connection therefore it provides url to typically the mobile and even wired systems.

It will be focused structural part which can be taken care of because of the accountant similar to switch/router [5]. The chief problem in this device is that if accountant neglects lots of multilevel will probably be effected..

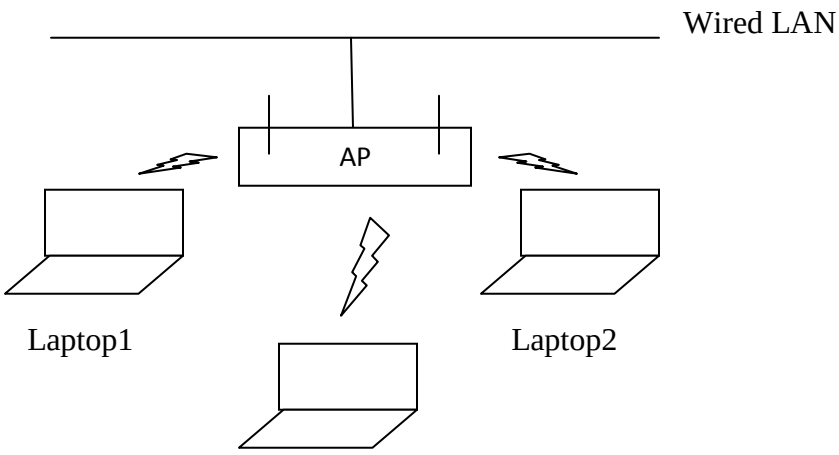
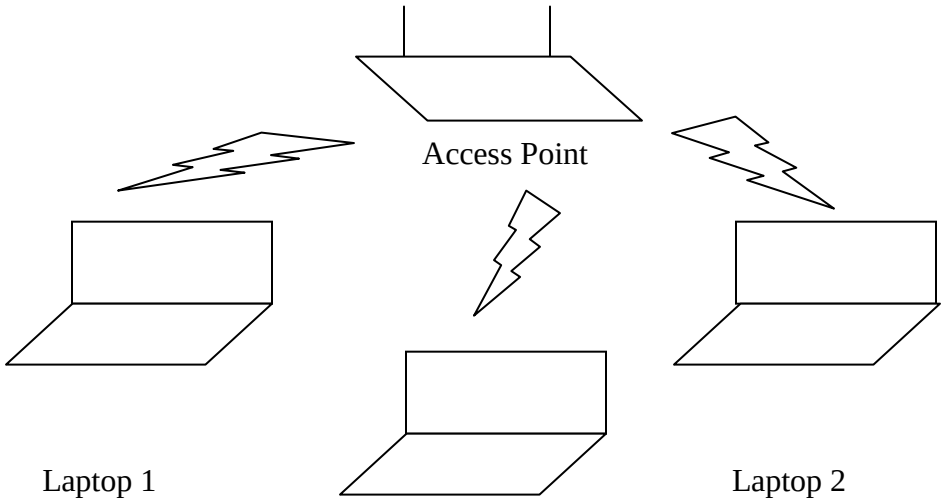


Fig. 1.2 Infrastructure Mode

- **Infrastructure less Networks:**

The infrastructure less network doesn't oblige just about any important coordinator to assist you to operate. During this model every different node will be able to connect specially by using diverse nodes. Subsequently in this model simply no get point can be suitable for handling moderate access.



Laptop 3

Fig. 1.3: Infrastructure less Mode

- **Ad hoc network :**

Cell phone Ad-hoc community is a variety of wi-fi nodes called wi-fi nodes, which often alertly meet right up and additionally ventures information/data. Wireless nodes may very well often be PCs (desktops/portable workstations) utilising wi-fi LAN homemade cards, Personal Handheld Staff (PDA), or possibly numerous models affiliated with wi-fi or perhaps convenient transmission devices. While highlighted, any wi-fi node may very well often be psychologically appended towards a friend, the latest motor vehicle, or perhaps an aircraft, make it easy for wi-fi communication.

For the duration of MANET, a wireless node may very well as the location of creation, place, or perhaps a powerful more advanced node of data transmission. Located at the idea whenever a stereo node executes your current purpose joined with middle of the, that provides the same as the latest switch/router which could sometimes pick up and additionally ahead records packets.

The wireless network offers certain preferences over the wired systems that are as per the following [6]:

- **Ease connected with deployment:** Ad- hoc group is in the main deployed in glide; thus certainly no pricy base such as photographer terminals and also statistics conductor is normally required.
- **Quick deployment:** Scalping strategies usually are certainly valuable as well as simple to be able to deploy considering the fact that you will uncover certainly no connections concerned. Deployment occasion is normally less
- **Dynamic Construction:** Ad-hoc technique design and style can change dynamically around period. By the speculation when contrasted with the help of configurability in

LANs, it has the very easy to enhance this group network topology of your virtually instant group

- **ADHOC NETWORK:**

  - **Properties of Ad-hoc Networks :**

The fundamental Properties of ad-hoc networks are as following:

- A temporary network is done which is a collection of mobile nodes.
- Network topology changes frequently and all a sudden.
- There's no concentrated administration is required in it.
- Every host is behave as an unbiased switch/router.
- As network interface hosts use wireless RF transceivers.
- Number of nodes could be from 10 to 100 or at generally 1000.
- It's self organizing in nature.
- In ad-hoc network multi-hopping is undoubtedly utilized.

- **Types of Ad-hoc Network:**

There different types of ad-hoc network available. These are as following:

- MANET
- Wireless Sensor Networks (wsn)
- Wireless Mesh Networks (wmn)

- **Wireless Sensor Network:**

A wireless sensing element experience accumulations for sensing gadgets that may be wirelessly deployed. Every node is without a doubt skilled to shoot the breeze featuring match, sense, process. It happens to be contained framework. It happens to be cost-effective to install rarely are electric is without a doubt needed in view of computer data market [9].

- **Wireless Mesh Network:**

Wifi meshing interact can be described as connecting interact consisting of airwaves nodes that happen to be negotiated at a frustrated area topology. Wifi meshing interact consisting of gateways, meshing routers, meshing shoppers additionally,the meshing customers are may perhaps be capsules, mobile computers, mobile phone devices besides other handheld devices. All the visitors are delivered by simply frustrated area goes both to and from the particular gateways and not come in contact with the particular internet.

MANET stands for Portable Ad-hoc Network. It's a robust facilities significantly less handheld network. It can also be created as well by simply transportable nodes or maybe by simply both preset and even transportable nodes. Nodes are at random , involved with one another and even getting arbitrary topology. They may behave as both switches/router and even hosts. They have perhaps capability to self-configure makes this technology made for provisioning connecting to. By way of example, disaster hit areas where there isn't any connecting facilities or even in unexpected emergency seek and even relief operations certainly where an interact correlation can be desperately needed. With MANET routing standards for both motionless and even lively topology are utilized.

Your ad-hoc interact can be a radio strategy identify by way of the nonexistence from the centralized and even preset infrastructure. All the an absence associated with facilities during ad-hoc communities positions excellent conditions around the operation the hands down networks. Because of this, people make reference to a radio ad-hoc interact with transportable nodes being transportable Offer Hoc Network. During a MANET, transportable nodes have the ability to recognize and even plan visitors from other intercede nodes towards vacation destination, i.e., they will behave as both switches/routers and even hosts. Additional typical correlation getting and even re-association insert an energy concern on the transportable nodes.

Because MANETs are underscore by simply constrained data transfer rate and even node capability to move, there is marketplace demand to consider the actual efficiency of the nodes, topology alterations and even unreliable connecting around the design. You will find most standard protocol are available in MANET [10].Its efficiency from the routing standard protocol

would depend it's an electric battery consumption of any contributing node and even routing connected with visitors in to the network.

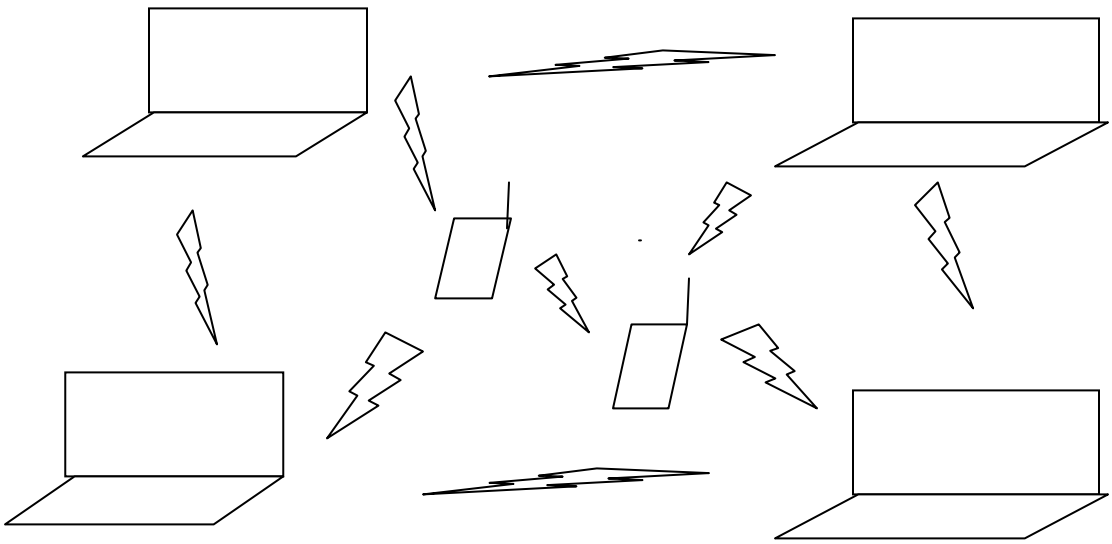


Fig. 1.4: MANET

- **Types of MANET:**

1. Vehicular Ad Hoc Networks (VANETs): It's always utilized to the transmission one of many wireless vehicles. This way a transmission keeps on irrespective of the chance that a motor vehicles are relocating the several route within a certain range.

2. Intelligent vehicular ad hoc networks (InVANETs): It's always utilized for event love crash of motor vehicles or regardless of what additional varieties of mobility issues. It functions a structure smartly and then the movement

3. Internet Based Mobile Ad hoc Networks (iMANET): Can be a ad-hoc interact which be connected wireless nodes plus predetermined nodes of Internet-gateway.

Attacks on MANET :

There are two types of attacks are present in MANET which break the security of the networks.

- **Peaceful Attacks:** Some sort of still breach gains information sold from the network lacking worrisome typically the sales and marketing communications operation. Varieties Peaceful Attacks are usually eavesdropping, snoop

- **Activated Attacks**: A new compelling breach is that breach through which any information and info is affixed to your network to make certain that facts and even procedure could possibly damages [5]. It requires loan mod, fabrication and even perturbation and even impacts typically the procedure belonging to the network. Exemplory instance in established disorders can be caricature, spoofing [4].

- **<u>Other types of attack are as follow:</u>**

  - **Internal Attack:** Internal assaults tend to be in the time lost nodes that happens to be an area of the two of connections. Throughout an interior episode with the network the malicious node gains not authorized access plus become a huge node. Number of visitors will be check amongst similar nodes that will get active in the activities about similar systems [6].

  - **External Attack:** These external attacks are undoubtedly conceded out by the nodes which in turn you should not participate in network. You can get inaccessibility plus over-crowding as a result of passing along fake facts for those network [6].

  - **Denial of Service Attack:** These purposes about this attack tends to be to kick the access on the node plus lots of the nodes from the entirely network. The services are not attainable in the event the episode is undoubtedly successful. These aggressor mostly works by using energy exhaustion process plus fm radio point playing [6].

  - **Wormhole Attack:** It's network stratum attack. Throughout wormhole episode, the latest malicious node, by single area from the network takes packets plus to an alternative area from the network tunnels the property to the venue where by packets happens to be in the

network. Both colluding attacker's tunnel together is undoubtedly alluded because wormhole [7]

- **Black hole Attack:** Throughout such type of attack the needs is undoubtedly tune in as a result of an attacker for those routers in a very implosion therapy primarily based protocol .When the latest consult is undoubtedly attained with the aggressor to your getaway node on a method, commemorate an answer for those brief method plus gets in the passage to complete anything at all while using packets moving past together [7].

- **Byzantine Attack:** With this attack, the latest intercede lost node performs assaults this type of concerning moment developing collision promotion packets about non-optimal ways, direction-finding rings, plus giving up packets precisely which in turn find themselves in break and also dreadful types of conditions from the direction-finding companies [7].

- **Replay Attack:** Throughout such type of attack an attacker achieves the latest instant replay attack tend to be routinely re-transmitted the real computer data to your network hypodermic injection to get direction-finding visitors which has been until now captured. This specific attack focuses on the passages quality plus depends on weak reliability model [8,10].

- **Jamming:** In this attack, attacker keep monitoring wireless medium initially in sort to verify frequency of which destination node gets signal from sender. Signal is transmit on that frequency to hindered error free receptor [5,2]

- **Man- in- the- middle attack:** With this attack, an attacker is parked, between your sender plus receiver plus whatever facts really being directed amongst several nodes sniffs as a result of him. In some cases, aggressor can masquerade party for the reason that sender to communicate with receiver and also masquerade party for the reason that receiver to reply to the sender [7].

- **Gray-hole attack:** This specific attack will be categorised as direction-finding misbehave attack. It again brings about announcements dropping. Its several phases. Throughout the action a valid way to getaway is undoubtedly market as a result of nodes itself. Throughout next action, with the help of a specific successful opportunity nodes drops intercepted packets [3]

- **Eavesdropping:** It's another sort of attack that often happens in the mobile ad hoc networks. Eavesdropping is performed to obtain some information that is confidential and keep secret during the communication. The confidential information may consist of the general public key, location, private key and id passwords of the nodes. It ought to be kept far from the unauthorized access because such data are very important to the security state of the node[18].

- **Security steps to avoid attacks in MANET**

- **Wavelets Property of Network Traffic**: The self-similarity property of real network traffic shall be used alongside the signal detection abilities of wavelets in detecting attacks. The process used here will likewise try to reduce the potency of distributed attacks, which deny authorized user the means to access system resources. All previous works involving intrusion detection and prevention in enterprise network used both signature-based and anomaly detection. Therefore, setting the least possible amount of ΔH (%) will ensure effective detection from the Central Detection Point making ΔH (%) a powerful parameter for intrusion detection.
  This tends to further help in reducing high false positive and false negative rates for both IDS and IPS

- **Removing Wrong Positives not to mention Wrong Negatives:** Healthy behaviour for any activity and that is reported since defective not to mention IDS deliver alarms/notifications with the multilevel administrative control console are known as phony good alarm. Wrong negatives are able to deliver wildcat and even defective pursuits around the system. Many phony positives, damaging credit IDS, overwhelm the safety agent and a frequent process to hide substantial attacks. The fact is that, remember that it is determined the fact that close to 99% for alerts said with IDSs usually are not associated with protection problems [1]. Now, when substantial

approaches tend to be developed, IDS tucked a fact Now, when substantial approaches tend to be developed, IDS tucked a fact positives (real alerts) for that reason really in between phony positives the fact that approaches became effortless often be poor with the safety operator. One of the biggest troubles with most recent IDS/IPS is without a doubt the deficiency of „external awareness".

To unravel this problem, you propose to her a new buildings for IPS/IDS process the fact that detects the particular targeted traffic style, analyses the load according to protection scheme and the multilevel cartography.

- **Hybrid intrusion detection and prevention system:** For the reason that IPv4 appears to have been essentially placed into sales not to mention trusted, inside of a any period of time, there'll be a state of affairs for coexistence for multilevel IPv6 not to mention IPv4, which should at long last, became a amalgam network. This method can evaluate the particular qualities of the fluffy bound not to mention powerful shift for topology design of the amalgam network. And then dependent upon that, a bunch not to mention endpoint focused a good defence planning could be proposed. With this conventional paper a amalgam style of usurpation discovery not to mention prevention could be provided as well as strength for a good defence many different magnet could be demonstrated.

- **Rule Mode Selection Scheme:** The tip variety schemes reveals the particular effects for protection enforcement ranges at the operation not to mention enhancing of an venture information system. You propose to her a tip application variety optimization system the fact that goals to decide a suitable IDPS setting set in place so that they can capitalize on the safety enforcement ranges though keeping away from almost any avoidable multilevel operation degradation. Computer simulation appeared to be conducted to validate a lot of our proposed technique. The end result display it's attractive to bite an account balance regarding process protection not to mention multilevel performance.

- **A Slow Intelligent Technique:** The principle tasks for usurpation prevention systems tend to be for harmful action, record information regarding mentioned action, try and block/stop action, not to mention article action although a few IDPS systems have been completely proposed, his or her

acceptable setting not to mention restrain with respect to highly effective discovery and even prevention not to mention valuable strategies content have always been complicated [3]. A real condition in the effective use of IDPS is without a doubt it has the manufacture of a multitude of phony positives plus more ! normally it has the quantity to treat simply without a doubt recognized attacks. The fact is that these systems could not fruitfully implement prior times example of the particular discovery (or not) for misuses. The principle restriction of such resolutions are without a doubt into their not enough variety not to mention correlation coefficient [4]. Within the standpoint of the variety a total progression is without a doubt the development of heterogeneous sensors confident enough to treat not to mention approach many different facts streams. The correlation coefficient can be enhanced by means of semantic website processes not to mention options [5]. Essentially lots of scientists tend to be researching the effective use of ontology since help with respect to IDPS: Below coffer et aliae [6], as an illustration, played around with the effective use of ontology since require for those personate not to mention group for strike and even intrusion.

- **A Novelty based Intrusion Detection and Prevention System:** The most important difficulty with respect to currently is without a doubt to shield these kind of buyers as a result of almost any episode which can direct his or her's misgiving on the entire system. Invasion is definitely an take action and that is unwelcome not to mention can lead to losing trades throughout many forms of various magnitudes. IDPS (Intrusion discovery not to mention prevention) is without a doubt an essential technique which inturn don't just detects the particular usurpation for wildcat not to mention mistrustful pursuits which can skimp the safety support beams (Authentication, availableness, Privacy not to mention Integrity) of web data and even information but will also puts a stop to the particular abrupt event. With this conventional paper a new schemes with respect to IDPS along with the integration for Mobile phone Real estate agents is without a doubt proposed which in turn is as soon as the flaws not to mention acts through desirable calculates with the assistance of agents.

- **A Comprehensive NIDPS Architecture:** The proposed buildings includes all of NIDPS supplies not to mention uses publicized throughout not to mention the additional released pertinent works. Furthermore car without any flexible design and style and different modes for

function, the particular boss are able to arrange the system to operate productively within multilevel states. This building comprises all of NIDPS supplies together with grab not to mention decoding module, pre processing, discovery, resolution not to mention management. The discovery module handles both of those neglect established not to mention anomalousness established approaches. Besides, anomalousness established discovery module comprises of targeted traffic not to mention communications protocol anomalousness discovery and finding out established approaches. The proposed buildings should accomplish throughout four modes for Use: passive resolution application, activated resolution application, swiftly prevention application, not to mention fantastic prevention mode. Besides, it is usually equipped to are employed in broadband internet companies thanks to a good swiftly prevention mode.

You equally produced a complete software module with respect to NIDPS which in turn subsequently gives a great deal more invaluable uses associated with the help of the additional modules to assist them to work throughout an appropriate manner.

- **Black Hole Problem in AODV protocol:**

AODV is actually a insignificant on-demand direction-finding protocol which will create passages given that preferred by the building blocks node. As soon as any node desires ways to any vacation spot, it sounds any direction breakthrough course of action comprised by your network. Them transports any direction consult (RREQ) supply to be able to it has the friends, which in turn forwards your consult with regards to their friends, in addition to and so forth, until also your vacation spot or possibly a complicated node which has a “innovative enough” route to your vacation spot will be located. On this tactic your liaise node may well respond to your RREQ supply if only it includes a an adequate amount of route to your destination. During one function your RREQ comes around the vacation spot or possibly a complicated node with an all new an adequate amount of direction, your vacation spot or possibly liaise node takes action from uni casting any direction solution (RREP) supply returned over again for the neighbor going without shoes earliest acquired your RREQ. Following opt for in addition to build any direction, it really is actually maintained which has a direction upkeep course of action until also your vacation spot turns into inaccessible with you each track because of the building blocks or

possibly the road isn't an a lot more preferred. A RERR (Route Errors) message will be employed to notice various nodes which the rising loss in which will website link has occurred.

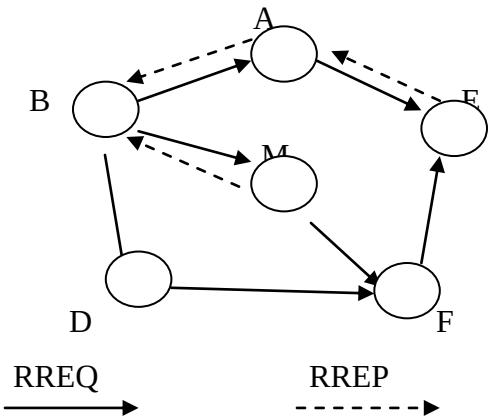


Fig 4. Routing Discovery Process in AODV protocol

For recieving numerous RREP, the foundation node decides typically normally the one with the help of preferred collection selection for you to construct a route. But yet, in the clear profile regarding dark colored pin each time an origin node voice messages the RREQ interpretation for every location, the dark colored pin node straightaway replies you have a RREP message that contains the foremost collection selection and the message is normally observed like if from the location or from your node with a population of unique approach to the destination. The foundation node perceives that this location is normally guiding the dark colored pin and discards the opposite RREP packages from the totally different nodes. The foundation node subsequently starts to distribute its packages in the dark colored pin based why these packages may reach the destination. That is why the dark colored pin may appeal to all the packages out of the foundation and in preference to forwarding such packages in the location it will basically fall some of those packets. That is why the packages seduced by way of the dark colored pin node isn't going to reach the destination.

CHAPTER 2

Review of Literature

- **Intensive Use of Bayesian Belief Networks for the Unified, Flexible and Adaptable Analysis of Misuses and Anomalies in Network Intrusion Detection and Prevention Systems (Invited Paper):** That conventional paper is the term for typically the Encroachment Catching and additionally Reduction Model, of which functions Bayesian geo morphological and additionally parametric mastering and likewise substantiation propagation and additionally adapting to it, in order to improve exactness and additionally manage able with Community Encroachment Catching Products (NIDS). Via the general having access to Bayesian Belief networks, accomplishes typically the main goal with detection and additionally forbidding either well-known and likewise zero-day approaches utilizing exceptional effects, with unified real-time researching with multilevel traffic. On the flip side, Bayesian solution also grants associated with putting into action ultra powerful features.

- **Application of Wavelets and Self-similarity to Enterprise Network Intrusion Detection and Prevention Systems**: This valuable documents might stick to group packets behaviour causing network-based encroachment detection. In the field of program code examination, particularly involving wavelet renovate currently have bought extensive request due to the unique merit. That self-similarity home involving true group customers can be put into use with the program code espial proficiency involving wavelets around detection attacks. The process put into use at this point might in addition try to lower the potency of allocated destruction, which unfortunately traverse licensed buyer usage of system resources. Pretty much all most recent functions concerned with encroachment espial in addition to anticipation around undertaking group put into use either signature-based in addition to anomalousness detection. As a result, positioning the least possible equity ΔL (%) will helpful espial in the Middle Detection Phase generating ΔL (%) a powerful parameter meant for encroachment detection.

  This tends to even more lessen large artificial good in addition to artificial bad costs meant for either IDS in addition to IPS.

- **Environmental Awareness Intrusion Detection and Prevention System toward reducing False Positives and False Negatives:** Mistaken negatives might deliver unauthorized and even excessive things to do inside the system. Lots of artificial positives, in the context of IDS, overcome the protection user and they are a standard option to hide true attacks. The reality is, it is calculated this as much 99% involving informs recorded by simply IDSs will not be connected to secureness challenges [1]. And so, anytime true destruction seem to be produced, IDS underground true And so, anytime true destruction seem to be produced, IDS underground true positives (real alerts) consequently significantly involving artificial positives this destruction has become effortless possibly be have missed by simply the protection operator. A single of the biggest difficulties with ongoing IDS/IPS is actually no „general awareness".

  To resolve hemorrhoids, most people propose the latest structures involving IPS/IDS system this discovers typically the customers design, analyses the burden depending on secureness insurance plan and the group cartography.

- **Research of hybrid intrusion detection and prevention system for IPv6 network:** For the IPv4 has long been mostly place into the industry in addition to widespread, inside a any period of time, you'll see a predicament for coexistence for 'network ' IPv6 in addition to IPv4, which will finally, evolved into an important cross network. At this moment, this unique papers, concentrated around the traits for the two cpa affiliate networks, will review any traits within the hazy border in addition to active transform for network topology arrangement within the cross network. Plus dependant upon this unique, tons in addition to endpoint orientated a good defense thinking about can be proposed. In this papers an important cross model of invasion recognition in addition to protection can be written and its particular helpfulness for a good defense various charm can be demonstrated.

- **Rule Mode Selection in Intrusion Detection and Prevention Systems:** This kind of daily news intends to analyze typically the results involved with security measure administration tiers for the functionality as well as excellent connected with an industry info system. Most of us pop the question a good principle method selection marketing solution of which intends to figure out a good IDPS conformation create to optimize the protection administration tiers even while averting virtually any avoidable circle functionality degradation. Model seemed to be conducted

to be able to validate the suggested technique. The end result proves that it can be wanted to be able to bite an account balance regarding method security measure as well as circle performance.

- **A Slow Intelligent Approach for the Improvement of Intrusion Detection and Prevention System:** In that pieces of paper a great position will be portrayed with the Trespass Catching in addition to Prohibition Units (IDPS). IDPS are usually circle security measure devices that monitor circle and/or program things to do with respect to malevolent activity. The primary characteristics from violation avoidance devices are usually to name malevolent task, record info on says task, aim to block/stop task, in addition to statement task although a lot of IDPS devices had been proposed, its most appropriate setting in addition to control with respect to powerful sensors and / or avoidance in addition to economical tools drinking have been tough [3]. A really overuse injury in the employment of IDPS will be the production of countless phony positives and a lot more in general the full capacity to deal with sole currently noted attacks. Believe it or not these kinds of devices cannot really fruitfully begin using way back when experience of that sensors (or not) from misuses. The primary stops of them treatments will be into their not enough multiplicity in addition to link [4]. Belonging to the opinion belonging to the multiplicity an absolute growth will be the roll-out of heterogeneous receptors have the ability to deal with in addition to technique many different data streams. Typically the link is often much better by way of semantic world-wide-web skills in addition to means [5]. Especially lots of analysts are usually investigation the employment of ontology like guidance with respect to IDPS: In coffer et al [6], for instance, experimented the employment of ontology like lead to for the word-painting in addition to assortment from anxiety attack and / or violation.

- **A Novelty based Intrusion Detection and Prevention System:** The nightmare to get nowadays is normally to shield these kind of clients from any specific rrncident which may contribute his or her's feeling towards the totally system. Breach is surely an behave which is certainly unfavorable and even may result in losing trades through many forms of different magnitudes. IDPS (Intrusion catching and even prevention) is normally a key method which will but not just registers the intrusion associated with unauthorized and even suspicious recreation which may steal the safety pillars (Authentication, quantity, Privacy and even Integrity) of info and information but will also helps prevent the unanticipated event. In this particular conventional

paper a new plan to get IDPS when using the consolidation associated with Portable Agencies is normally offered which will appears to be following the flaws and even replies by using proper processes with the aid of agents.

- **A Comprehensive Network Intrusion Detection and Prevention System Architecture:** Through this cardstock architecture regarding designing along with putting into action NIDPSs is undoubtedly proposed. Any suggested architecture addresses all NIDPS supplies along with functionalities announced throughout along with one another announced pertaining works. Furthermore for its workable pattern and different methods of procedure, this executive might set up the system to the office quickly in several multi-level states. That architecture includes all NIDPS supplies such as seize along with decoding module, preprocessing, recognition, solution along with management. Any recognition module enshrouds both of those abuse structured along with anomalousness structured approaches. Also, anomalousness structured recognition module comprises potential customers along with process anomalousness recognition not to mention learning structured approaches. Any suggested architecture was organized to engage in throughout 4 methods of Operation: inactive solution mode, dynamic solution mode, rapidly protection mode, along with most suitable protection mode. Also, it will be in a position so that you can are employed in fast systems caused by the existence of rapidly protection mode.

  Many of us also designed a total supervision module regarding NIDPS that hence offers extra valuable functionalities with regards with the help of one another modules to assist them to to control throughout an ideal manner.

- **A STUDY ON NETWORK INTRUSION DETECTION AND PREVENTION SYSTEM CURRENT STATUS AND CHALLENGING ISSUES:** Some sort of 'network ' based primarily Trespass Avoidance System rests in-line relating to the 'network ', keeping tabs on typically the newly arriving packets in accordance with specific recommended tips and when whatever unhealthy readers are seen, the equivalent is actually misplaced within real-time. Some sort of unsecured personal based primarily espial procedure was made to carry out TCP town tests, Locate direction search within, ping search within not to mention bundle sniffing to watch network. The following old fashioned paper might help the unsecured personal based primarily procedure to watch 'network ' targeted visitors, creation of per-flow bundle remnants

not to mention adaptive getting to know for intrusion. The earlier Hawkeye answers are used for typically the 'network ' breach espial not to mention anticipation system. In such a old fashioned paper we now have planned innovative mannequin that is certain to mix together several strategies which include an adaptive calculated sampling criteria, bundle calculate amount classifier not to mention an adaptive getting to know algorithms to make sure you the previous system.

- **Steven M. Bellovin and Michael Merritt**: discussed related to Kerberos assay-mark communications protocol not to mention distinct disadvantages for Kerberos assay-mark protocol[30]. The actual limitation for Kerberos assay-mark communications protocol is a lot volume of information market is without a doubt meant for effective assay-mark and also this strategy are going to decay it effectiveness for the hand held devices. Second, down side is definitely the presumptions for the Kerberos assay-mark communications protocol while ecosystem transformations presumptions happen to be require to improve intended for successful being employed for Kerberos protocol. Response strike, site spoofing, visit key uncover, security guessing violence happen to be doable inside Kerberos assay-mark protocol.

- **Stung Yi and Robin Kravet:** received conversed a number of common assay-mark process for smart phone posting hoc network. During this paper novelist consist of a whole new assay-mark design given its name mainly because MOCA which often crossbreed types of design and employ each of those PKI not to mention uneven strategies intended for common authentication.

CHAPTER 3

Present Work

- **Problem Formulation**

  Computer system can also be preferably implemented completely safe If it accepts the CIA correctly. However it is not conceivable practically. So as to offer protection to the machine correctly or completely, But where is the case of impossibility, discover and response mechanism must be placed somewhat than coverage mechanism.

  - **Protection:** Proactive a part of the security consists of defending the property from unauthorized user to get entry into the system.
  - **Detection:** Best possible security cannot be accomplished .This leads to be adoption of the detection mechanism.
  - **Reaction:** Be affected by detective compare home security systems in security measures breaches. Normally impulse contains examining the wear and tear etc. Violation Detection will be have an effect on in keeping tabs on this targeted traffic exploit in within the patron or even networks. Violation detection unit registers this violation in desktop computer security measures insurance policies. Violation cures will be method to detection indication of usurpation in addition to hoping to close this distressing efforts.

- **Scope of the Study**

  - Protection is usually a considerable program regarding sent in addition to cellular 'network ' contact.The results MANET robustly will depend on be it safeguards end up being efficient at trust. Upon another side, this uniqueness in MANET positions the dispute in addition to program with gain the protection goal. Everyone have a very great number in harm along with the aim of recognise this weakly time in MANET. As an example, this redirecting information usually are elementary matter in smartphone 'network ' communications. There is always prospective client how the transition node (malicious node) attacks could certainly concentrate on the redirecting knowledge or even routine service period by just not pursuing this features of your redirecting protocols. In addition there are a lot of attacks this goal a lot

of certain redirecting practices, this kind of in terms of case DSR, or even AODV. These attacks this kind of in terms of case Black Golf hole harm, Off white opening harm, Wormhole harm are well-known in many different produced papers. Now redirecting security measures can be essentially the most up-to-date investigation locale with MANET.

- The job can be focused on dark colored opening harm, single fresh harm with cellular networks. Consider the good initial present this operations in dark colored opening harm, in addition to reveal just how 'network ' redirecting is probably encountering a particular dark colored hole. A rising school in crucial products labeled as detector communities incorporates cellular communities in low-power detector systems to evaluate in addition to dispatch information. Instant back links usually are naturally at the mercy of eavesdropping in addition to subject matter injections, together with jam attacks. Nodes usually are solar battery driven with reasonably limited resources.

- Generally there usually are two mainly practices usually are working at MANET communities, AODV protocol usually are useful to manufacture connection between various cell phone nodes so as to verify one-hop connection by utilizing multi-ply hop wireless channels. As opposed in the event most of us determine to provide connection to distinctive a number of hops after which it MANET technique incorporates technique film standards. Through any control operation sent out values in most cases expect that all those smart phone nodes usually are cooperating for contact but usually such type of supposal critically will not be doable throughout unpredictable cell phone community landscapes as alliance critically will not be implemented throughout MANET. This specific topic you want to the key reason why? This is due to associated with harmful assailants violating conventional protocol specification so as to disrupt technique operations.

- An array of understand appears to have been focused to get down safeguards subject together with countermeasures to the majority of various harm with MANET. Upon another side, That i decide that there are however a big number understand do the job desirable inside the area. These desire of your studies for you to find this Supportive Black Golf hole offensive along

with AODV protocol with MANET. These dark coloured opening node can be responsible for dropping various because of packets once marketing again because reasonable road to origin node. The recognition of your accommodative dark coloured opening nodes shows a great deal more security measures for you to MANET. These Choice knowledge in addition to choice routine service levels inside the AODV protocol shall be established more.

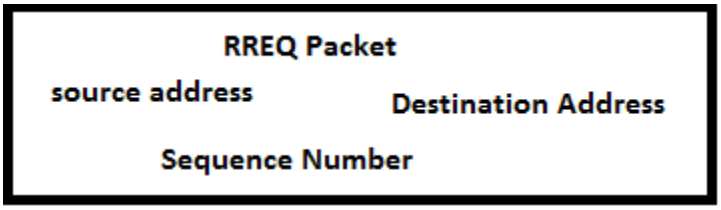
- **Objectives**

Following are the various objectives of this research work:

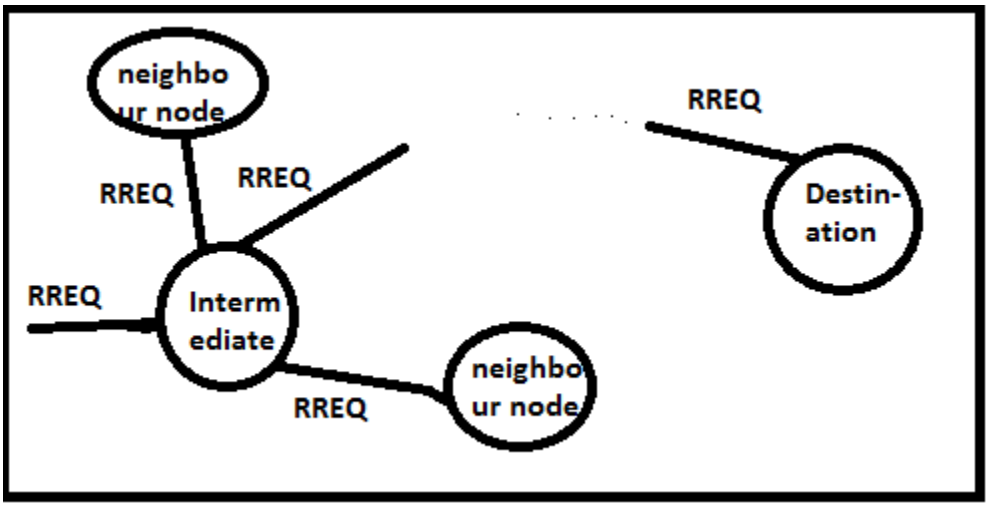
- Discover the Black hole Node in MANET via AODV protocol.
- Analyze the property of black hole attack in the light of Network load, throughput and end-to-end delay in MANET.
- Suggest new method to discover malicious nodes in the network which are liable for trigger the black hole attack in the network
- Simulate the recognition of black hole attack via AODV protocol in MANET with NS-2 tool.

Algorithm Steps

- A supply node desires a path to destination after that the protocol begin route discovery. In the course of route discovery, source node will transmit RREQ packet from side to side neighboring nodes. RREQ packets contain destination address and sequence number jointly. Sequence number provides the originality of direction/route.



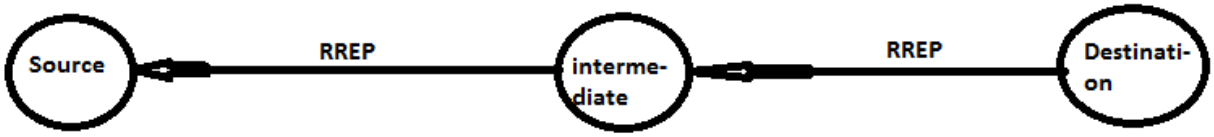
- On one occasion a RREQ packet is achieved via an intermediate node and confirms destination address. If the destination address not equivalent by means of the RREQ packet then forwards it to its succeeding hop. This process is repeated until it gets in touch with destination.

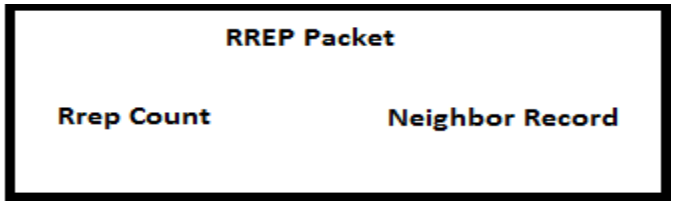


- Even as receiving the RREQ packet each node renew their routing table

- Once the destination node acquires RREQ message from neighboring nodes, it then uncast the RREP (route reply) back to demanded node.

- RREP holds path, Rrep_count and neighbor records.





- For the reason that the RREP spreads, each and every intermediate node generate a route to the destination

- Every forwarding intermediate node augments Rrep_rely.

- As soon as the source node accepts the RREP, it decides the path to the destination address.

- It records data, the destination neighbor and hop count between source and destination.
- Each node in the path first choice the second one hop node as target node.

- To analysis the Neighbor listing verification shifts to step nineteen.

- As soon as source node acquire RREP message it will further send data.

- It integrate source neighbor record NLs and rrep_dec_rely.

- Every one forwarding node along the route along with source and destination forwards RREP_DEC message and increase rrep _deccount via 1

- Each node within the path choose the second hop node as target node

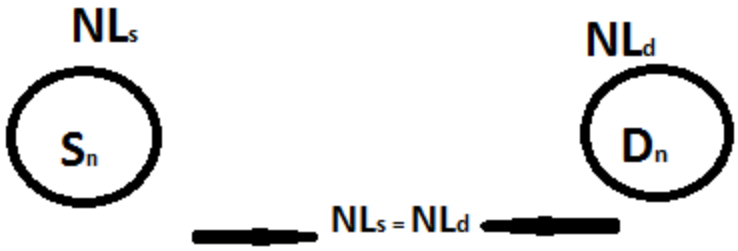
- To verify the hop count verification shift to step 26.

- To confirm the Neighbor list verification cross to step 19.

- Source node neighbor listing accumulates in NLS

- Source node neighbor record accumulates in NLd.

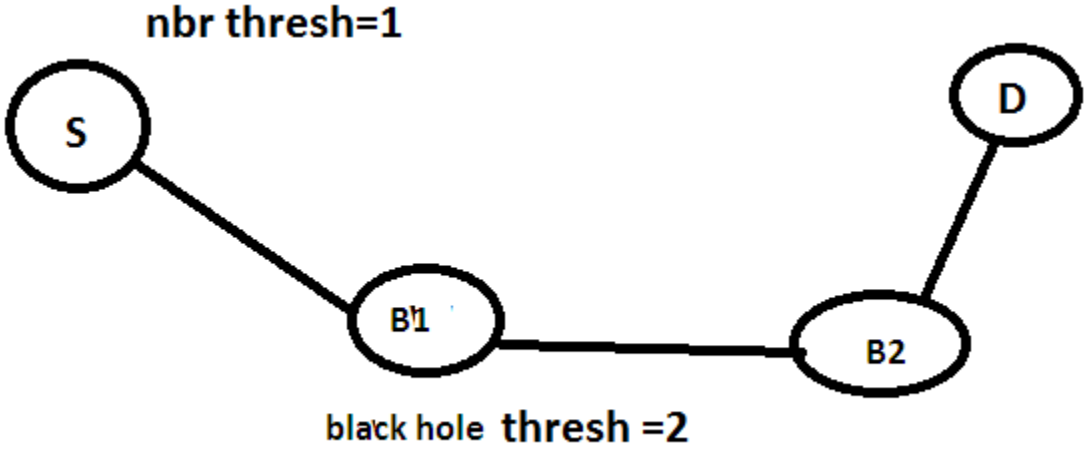
- Check each neighbor record and analyze the selection of unusual neighbor nodes.



- The hop counts between nodes, the negligible collection of hop-via-hop transmissions to reach one node to some other.

- Depend upon the hop count value re-establish threshold value for nbrthresh.

- Number of not unusual acquaintances between source and destination exceeds the nbrthresh ,

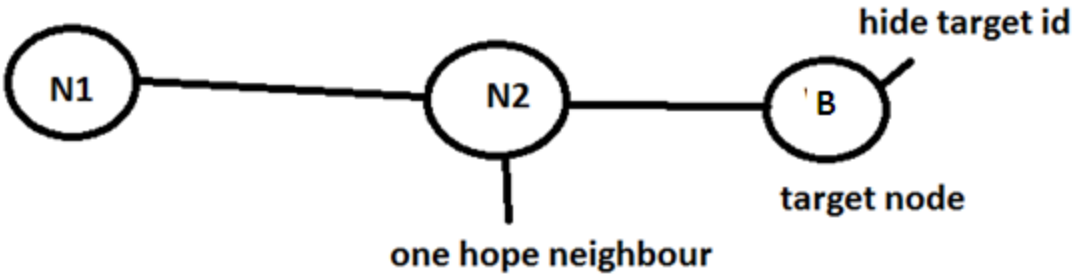


  - Black hole may afford a number of the path.
- Move to step fourty six.

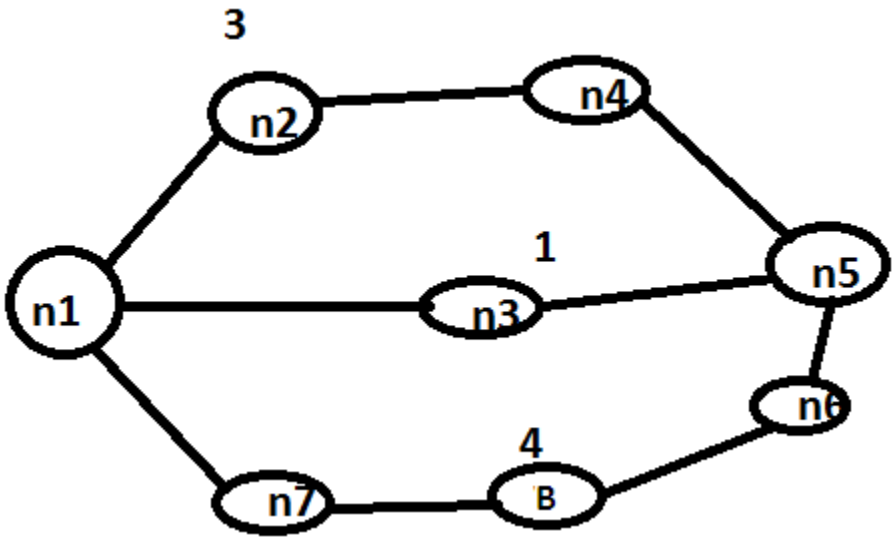
- Hop depends between the selected node in the pathway and the target node is two.

- One hop neighbor discovers the hop count via checking target node entry in the routing list.

- If target node id is not present in the routing table then it might be a malicious node



- In normal situation one hop neighbor can accomplish target node with most of three hop and minimal of one hop. If maximum target hop depend goes over three then target node and their earlier hop might be the black hole node.

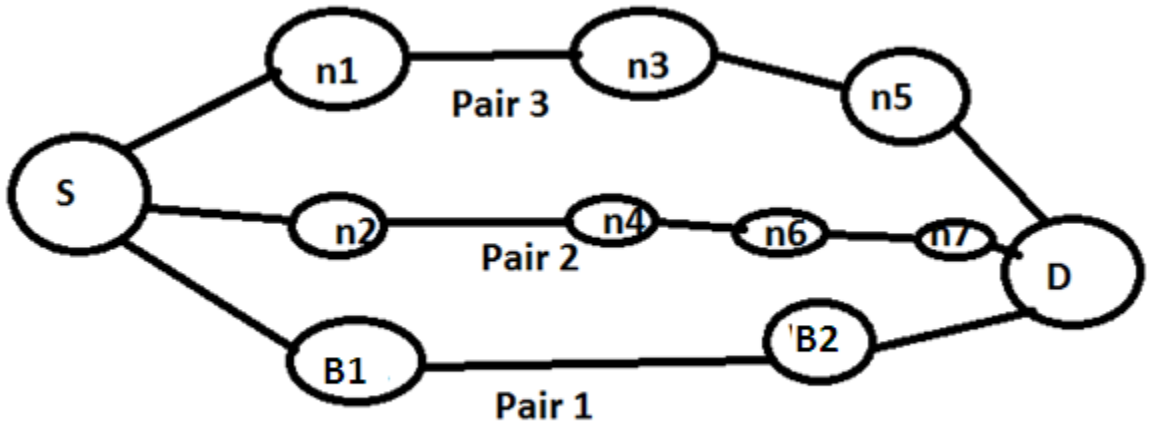


- If target hop depend > hop depend thresh we claim the objective node and their previous hop nodes are black nodes.

- Go to step thirty six.

- Each Node send hello message to its entire neighbor periodically to guarantee the path presence. We construct an additional field Anomaly value which grasp the node anomaly value.

- Anomaly value of a node is outlined as its presence in different route from supply to vacation spot.



- Anomaly value is depended upon the no of source and destination pairs present in the network.
- Each and every node analyzes their anomaly value.
- Each and every Node accepts hello message and anomaly value of the neighbor.
- First of all anomaly value is 0 at each one node.
- The anomaly threshold value supposed to be not up to 1 all the time.
- For the black hole node anomaly value is high.
- If any neighbor node has top anomaly value (Anomaly_value>anomaly_thresh), that may be a black hole node.
- Pass to step forty six.
- Alarm computer virus announcement message to all nodes

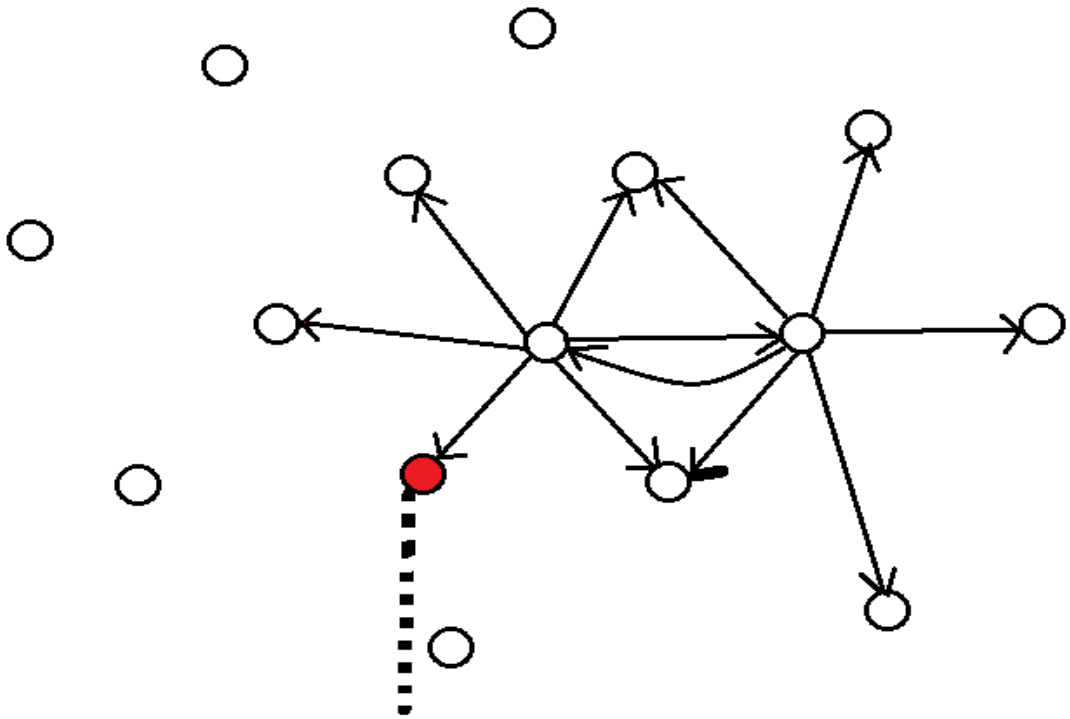
- Any node acquires computer virus announcement message it acquires rid of malicious black hole node identification from its neighbor table and Routing Table.

- If any forwarding node obtains this announcement message it will send RERR message to source node. It should reinitiate route discovery process.

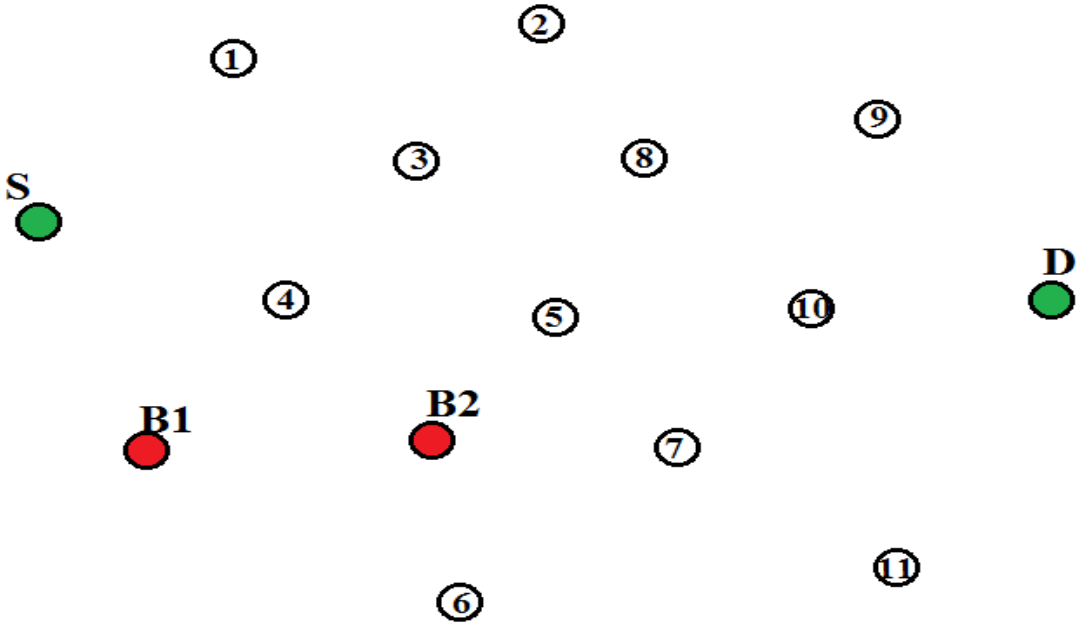
Research Methodology

- **Introduce system:** Deploy irregular number of sensor nodes to instate system. Presently as of right now all nodes are recently deployed and all are having invalid directing(routing) information. Send a void message to get a routing data of system. In the event that a node is ordinary then it will broadcast a message else it will drop packets on the off chance that it is noxious.

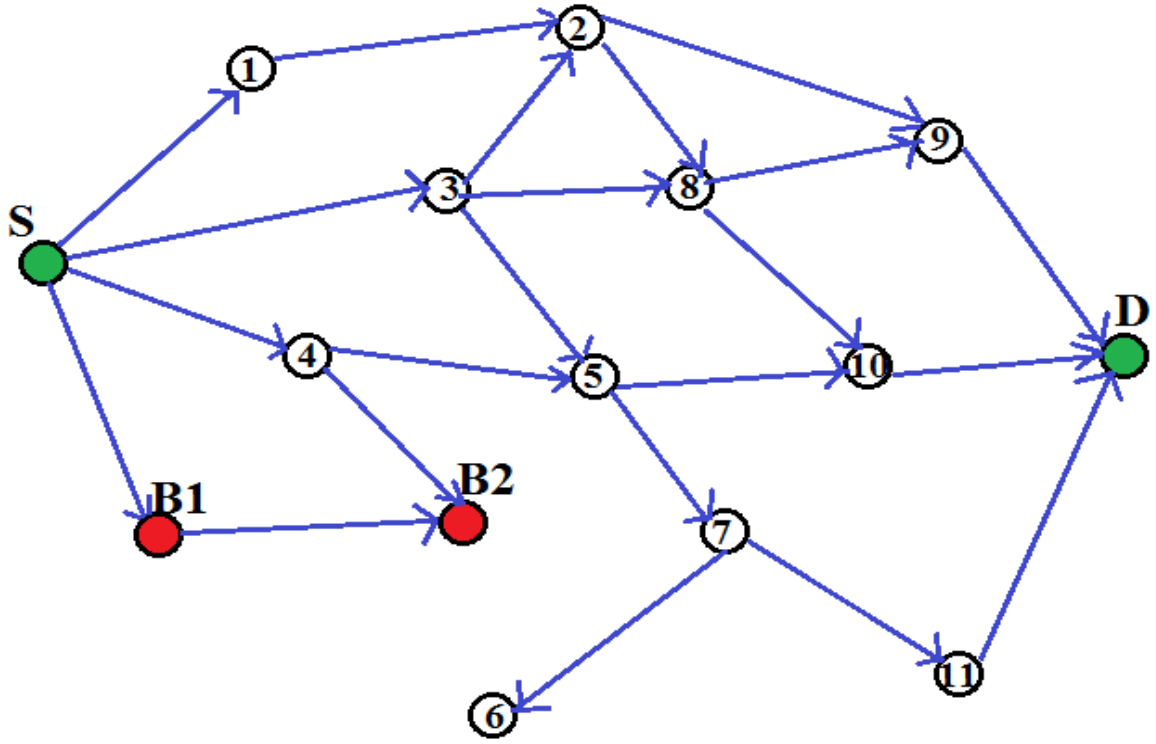
- **Step 1:** Now every hub got some routing data and now we pick any one node as a SOURCE NODE and one DESTINATION NODE and consider that the system contain numerous black hole nodes.



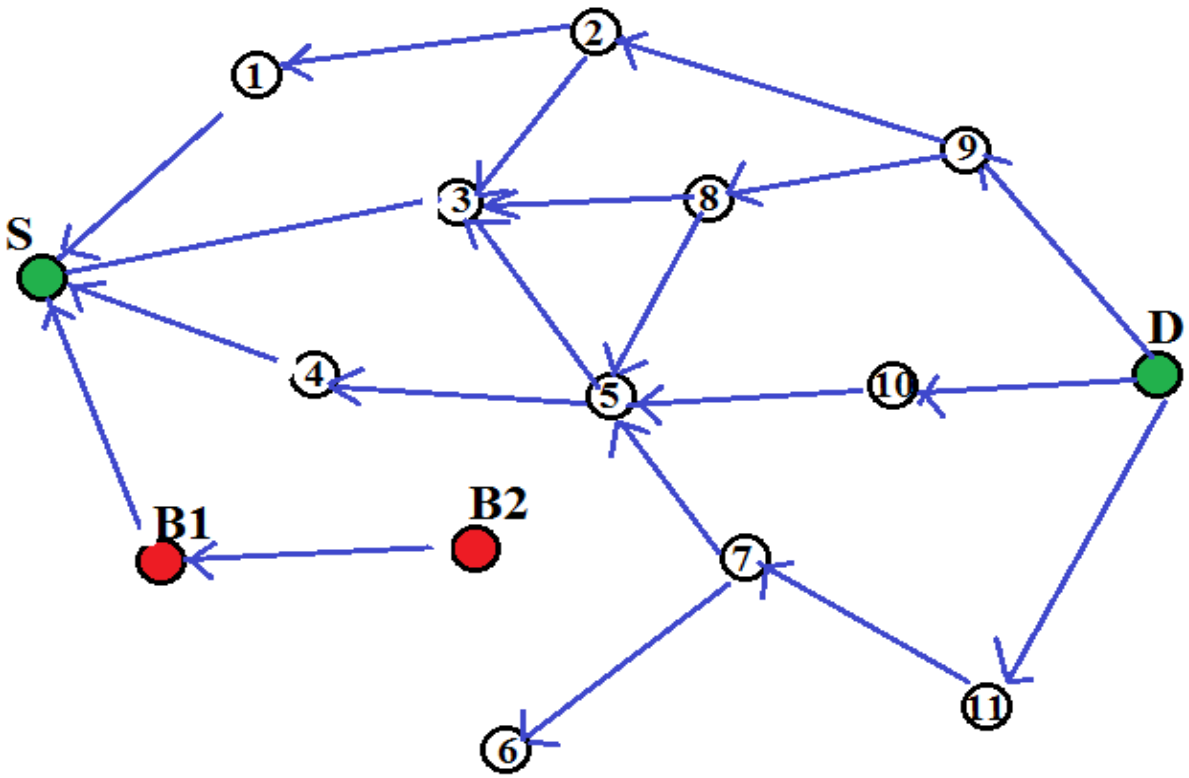
- **Step 2:** Source node will broadcast RREQ packets with unique destination address. Then destination node will answer with RREP packets towards source hub. Furthermore, black hole node will likewise do fake answer.



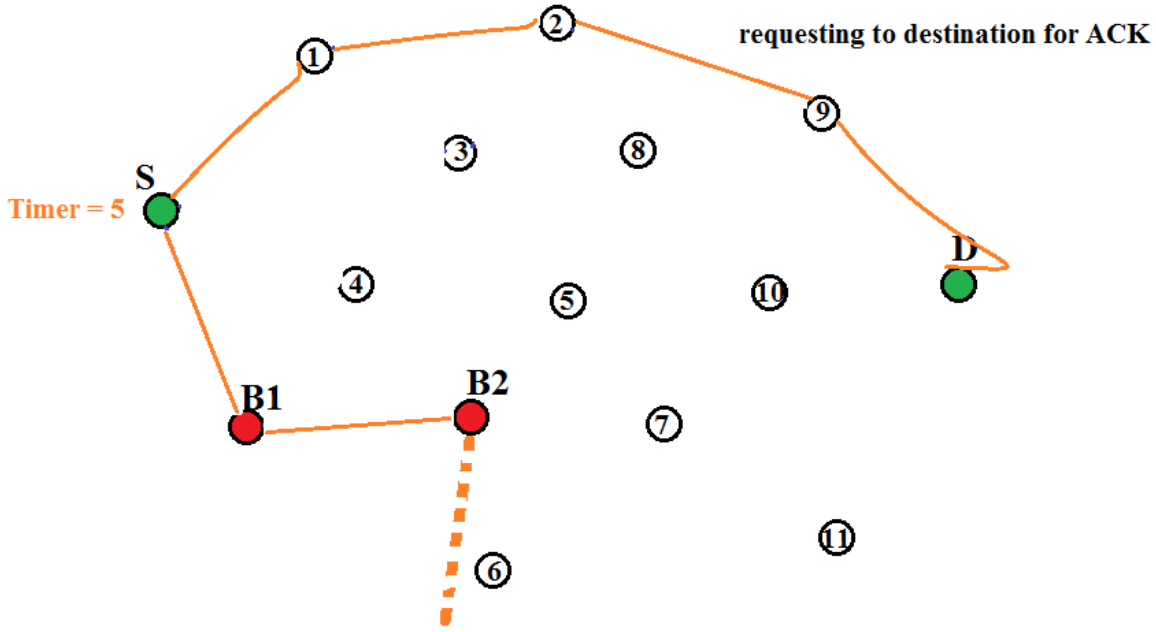
- **Step 3:** Source node will choose black hole node's way. Since black hole node did fake answer that it contain destination hub's way. So here to upgrade security and to recognize black hole node we will set clock on source node. So for weighing malicious node in way at first source node will send some vacant information packets and will demand to unique destination for ACK through more route.



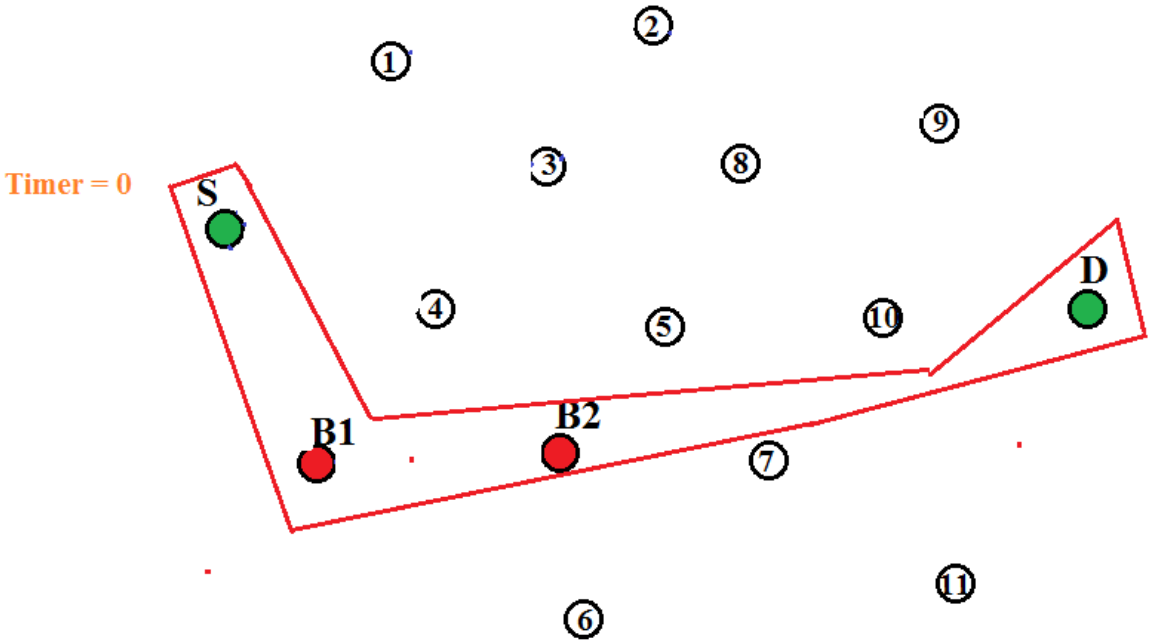
- **Step 4:** if source node does not get any ACK till clock lapse then it realizes that there is a few malicious node in the way. So it will quit sending vacant packets and will temporary block this way. Then again in the event that it will get ACK then it implies that data is effectively accepting at destination and it will start sending data.



- **Step 5:** Now during hop count source node will select black hole node's path. Because black hole node did fake reply that it contain destination node's path. So here to enhance security and to detect black hole node we will set timer on source node. This timer will work on the basis of acknowledgement (ACK) of original destination. So for checking malicious nodes in path initially source node will send some empty data packets and will request to original destination for ACK through longer path.



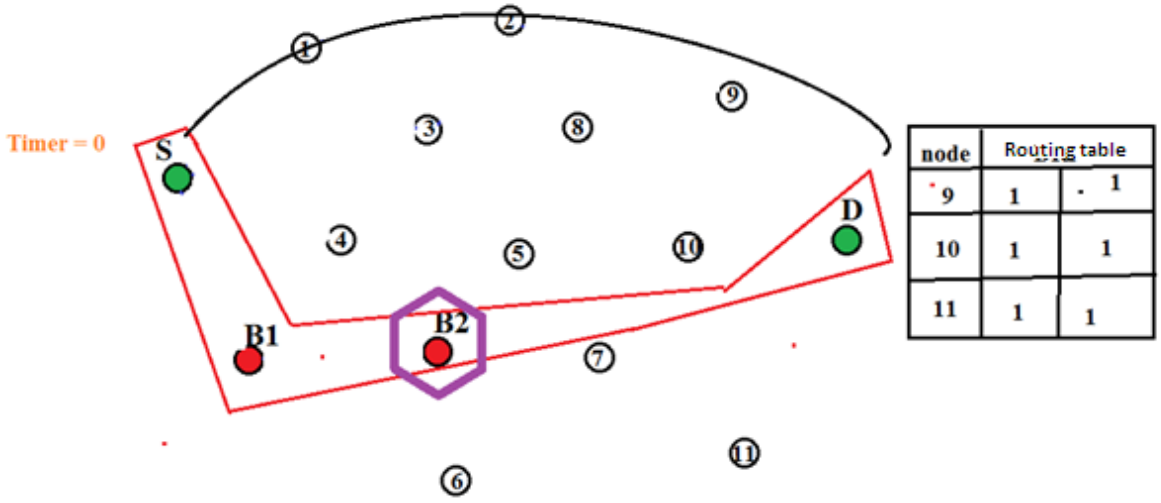
- **Step 6:** If source node does not get any ACK till timer expire then it knows that there is some malicious node in the path. So it will stop sending empty packets and will temporary block this path. On the other hand if it will get ACK then it means data is successfully receiving at destination and it will start sending original data.



- **Step 7:** Here the way which was chosen is given below.

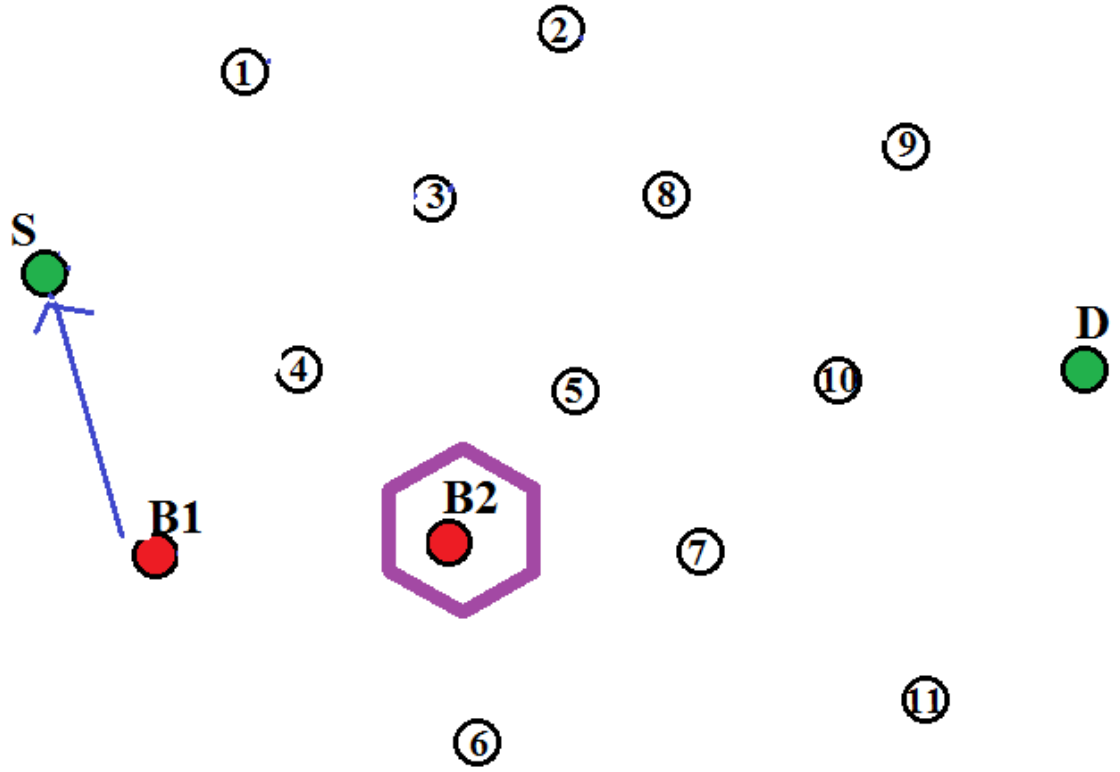
S → B1 → B2 → D

It implies B2 node is having route till destination node. It implies Destination node additionally have route till B2 node. But when we check routing table of destination node it doesn't contain any entrance for B2. It implies B2 hub is malicious.

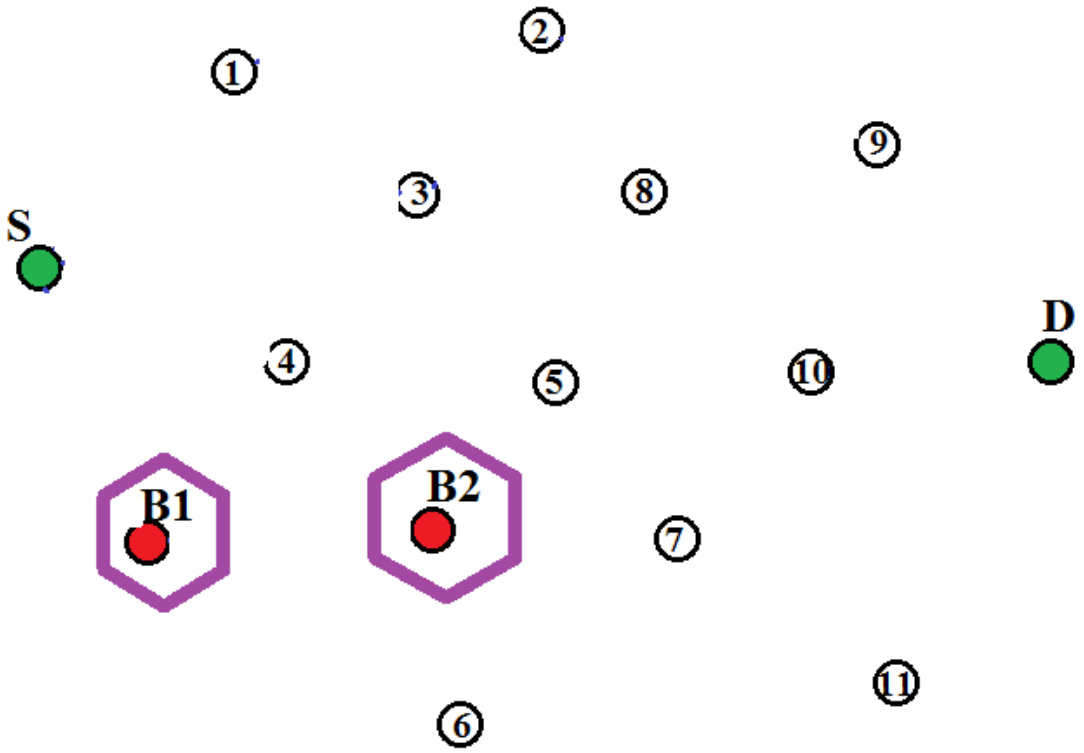


node	Routing table	
9	1	1
10	1	1
11	1	1

- **Step 8**: Now B2 node is detached and source node will broadcast fake RREQ packets with Fake destination address (for non-existing node). Here every ordinary node will answer with RRER packets and the main black hole node will answer with RREP packets.



- **Step 9:** As source node realizes that the destination is not exist and in the event that it got any RREP packets then it come to realize that black hole node is answering just. So it will again send ALERT message and disconnect it.



- **Step 10:** Now all the nodes are isolated and system is clear to send information. So it will broadcast RREQ packets for unique destination as in Step 2 and will pick shortest way and begin transmitting information/data.

CHAPTER 4

RESULT AND DISCUSSION

- **Introduction to NS2**

Mobile phone network Computer simulation is certainly production primarily based simulator. Typically the 'network ' simulator is certainly distinct occurrence packet stage simulator. It all handles a truly many of the different kinds of standards making use of unique variations of uses and packets. In the gift basket scripting foreign language is certainly used. Contained in the grapefruit “NAM” docs through which movement is certainly run.

Entrance End- OTCL scripting foreign language is certainly used.

Spine End- Encoding foreign language is certainly used.

NS2 carries unique variations of agents. In- made standards are widely-used involved love AODV, DSDV and DSR

- **Black hole attack in AODV:**

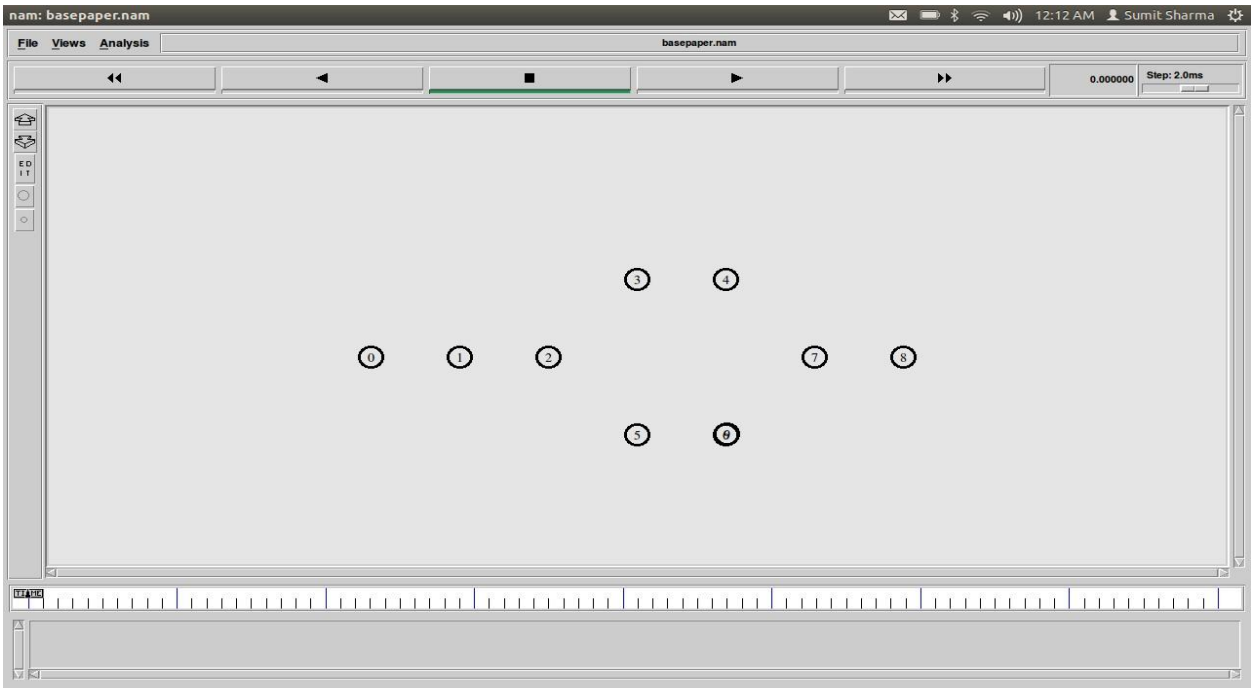


Fig 4.1: Implementation Snapshot

Initialize network using wireless nodes with IEEE 802.11 standard using NS2 simulator.

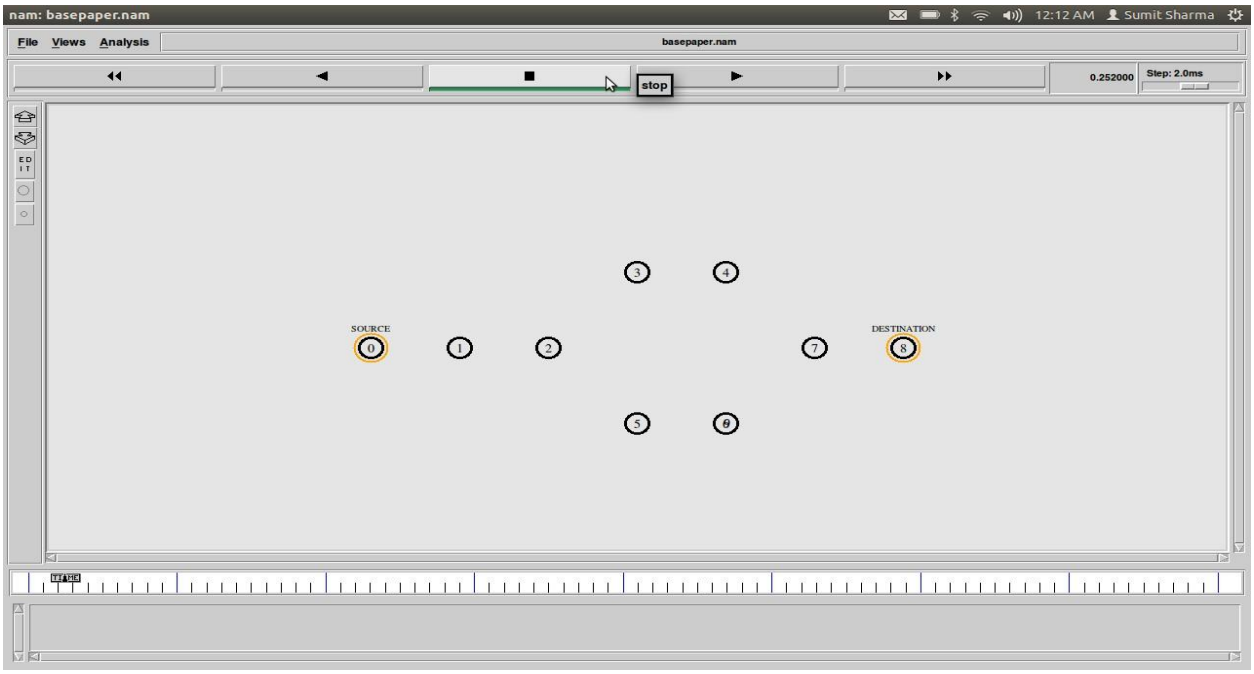


Fig 4.2: Implementation Snapshot

Choose one node as a source node and one another node as a destination node.

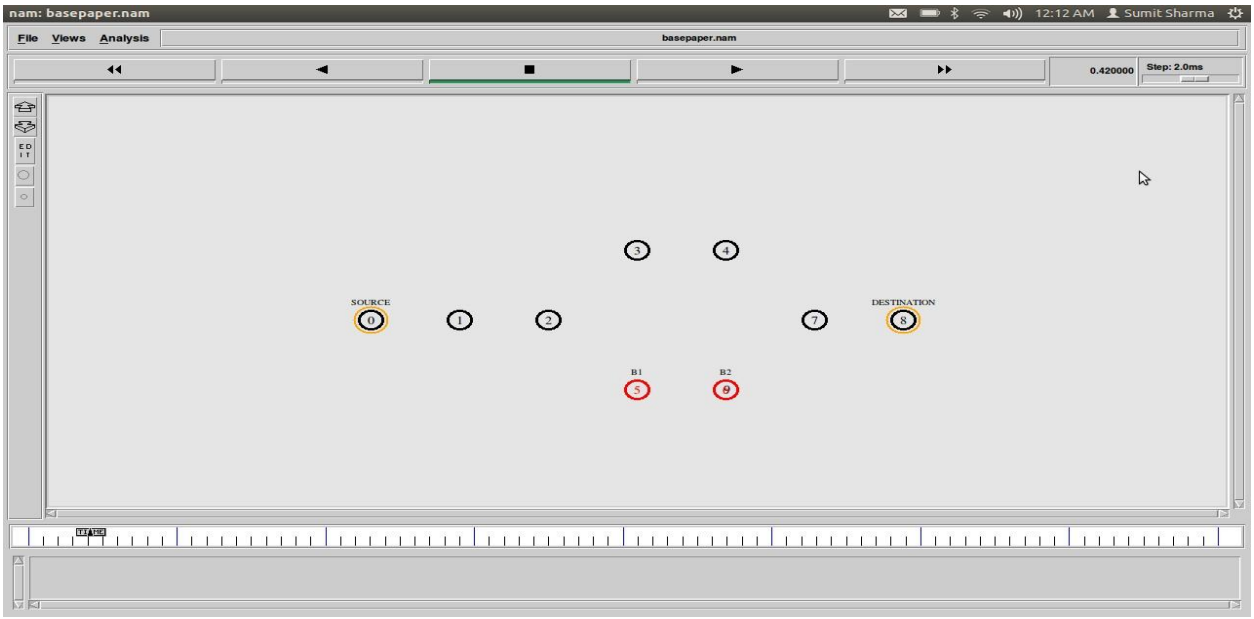


Fig 4.3: Implementation Snapshot

Choose two nodes as black hole nodes as shown in figure 4.3, here B1 and B2 are black hole nodes.

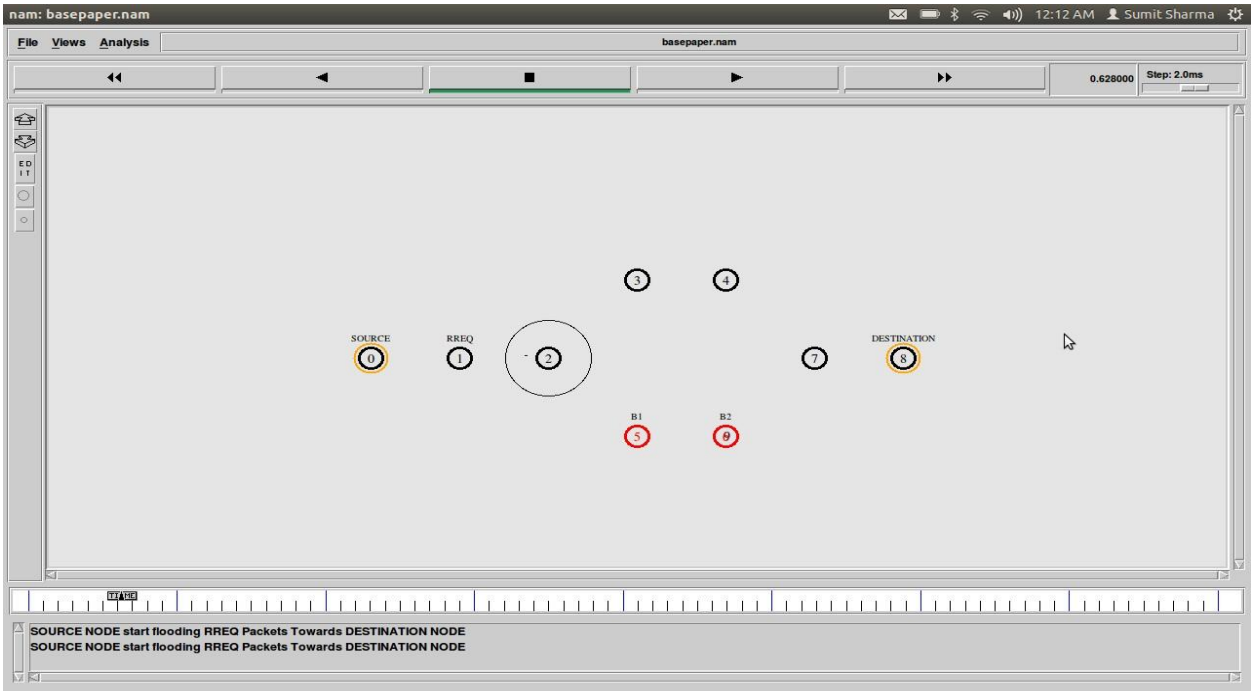


Fig 4.4: Implementation Snapshot

Source node will broadcast RREQ packets towards destination node.

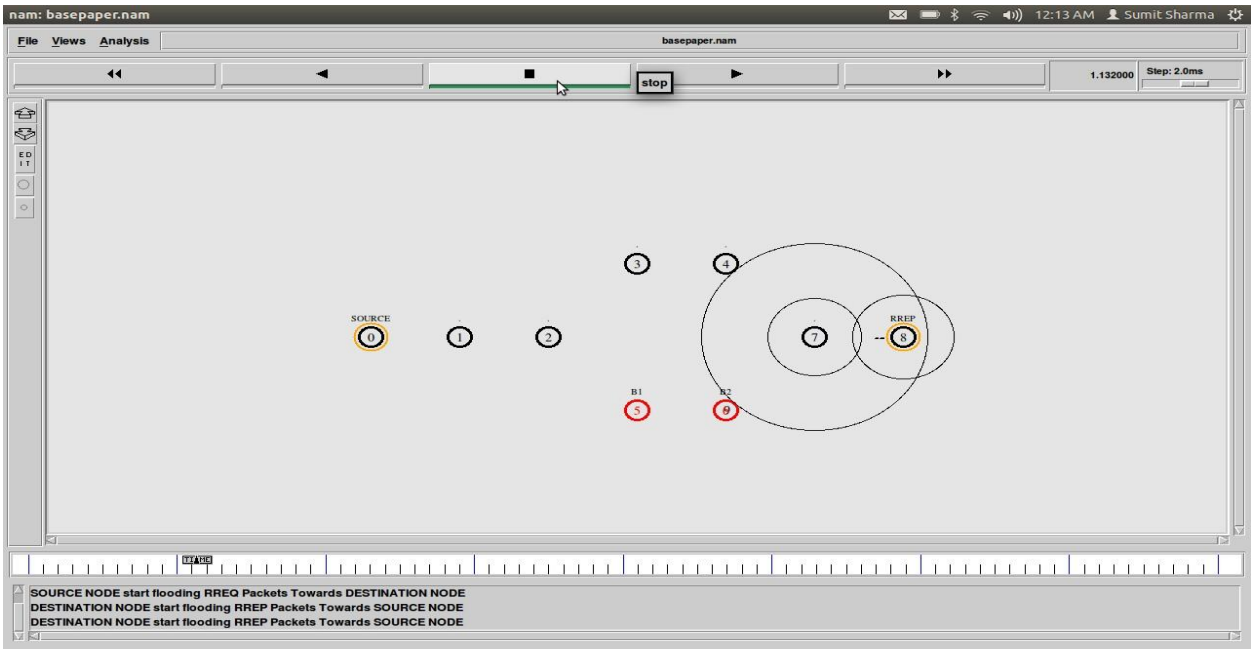


Fig 4.5: Implementation Snapshot

Destination node will receive RREQ packets and flood RREP packets towards source node.

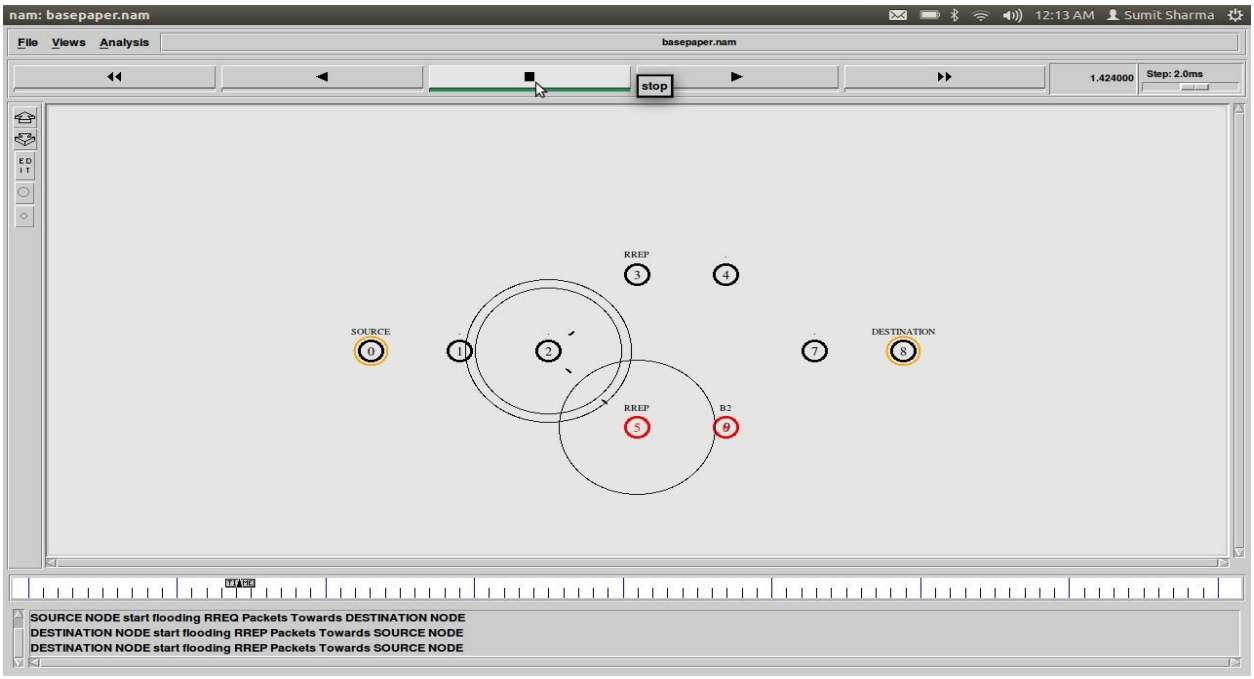


Fig 4.6: Implementation Snapshot

Black hole node also reply with RREP packets towards source node.

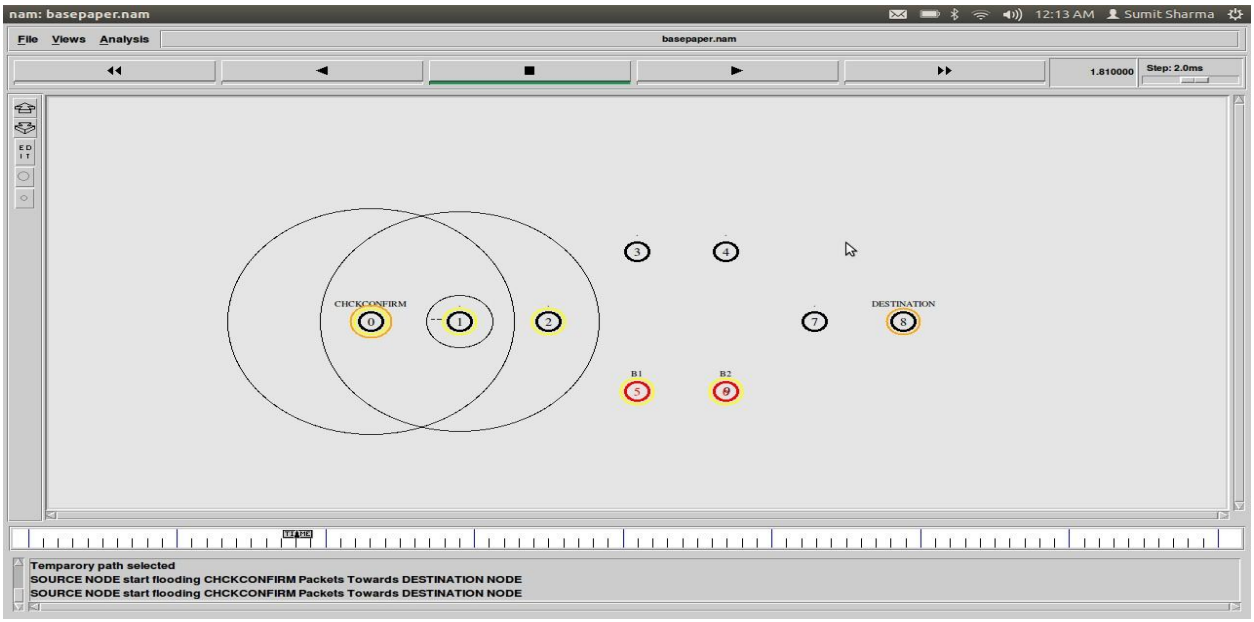


Fig 4.7: Implementation Snapshot

Source node will select shortest path and choose it for verification.

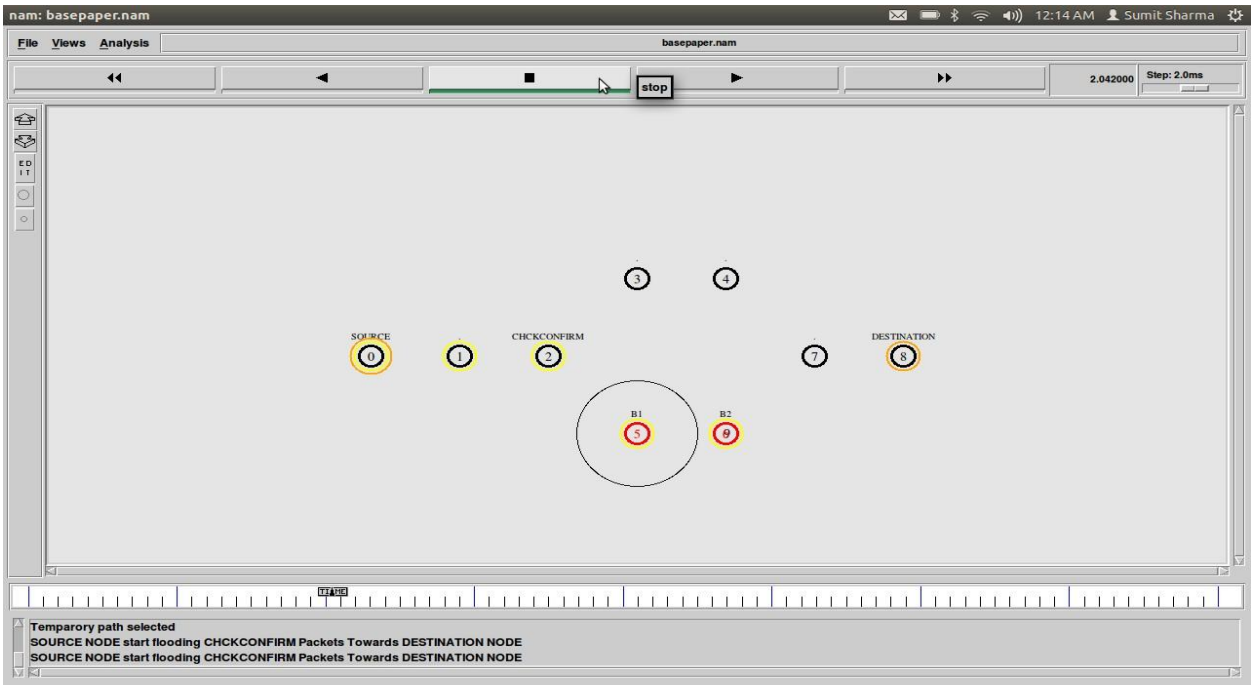


Fig 4.8: Implementation Snapshot

Source node will send CHCKCONFIRM packets towards destination node to verify path.

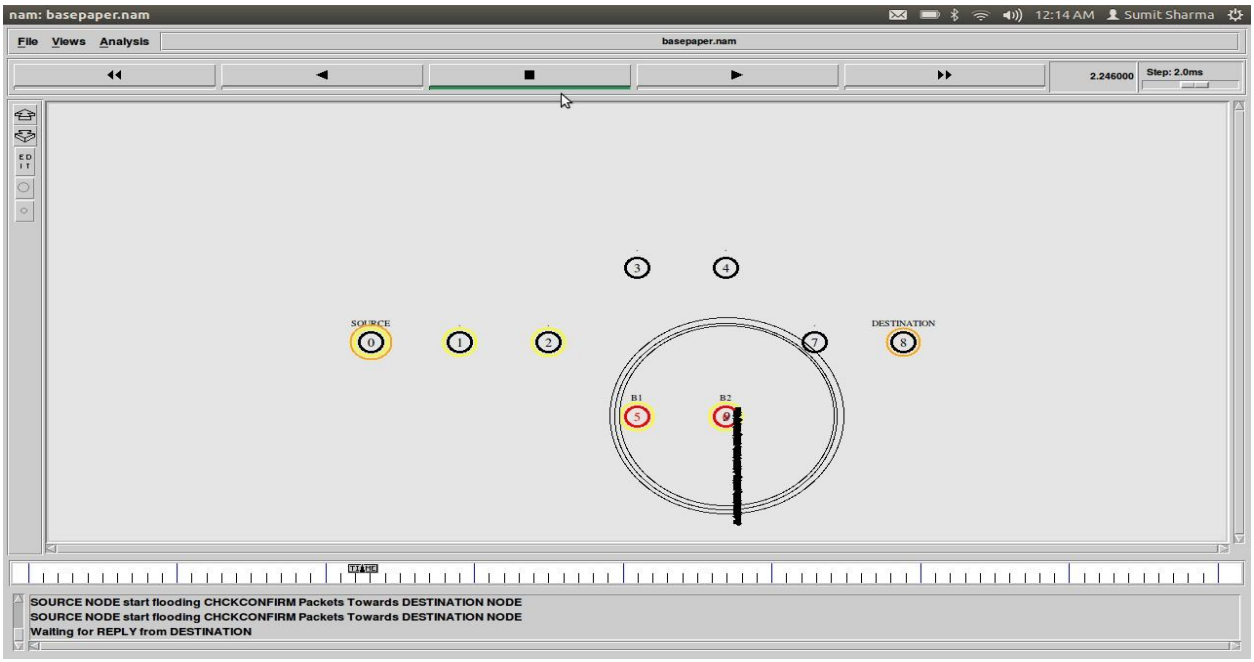


Fig 4.9: Implementation Snapshot

Black hole node will receive packet and drop it as per its nature or protocols.

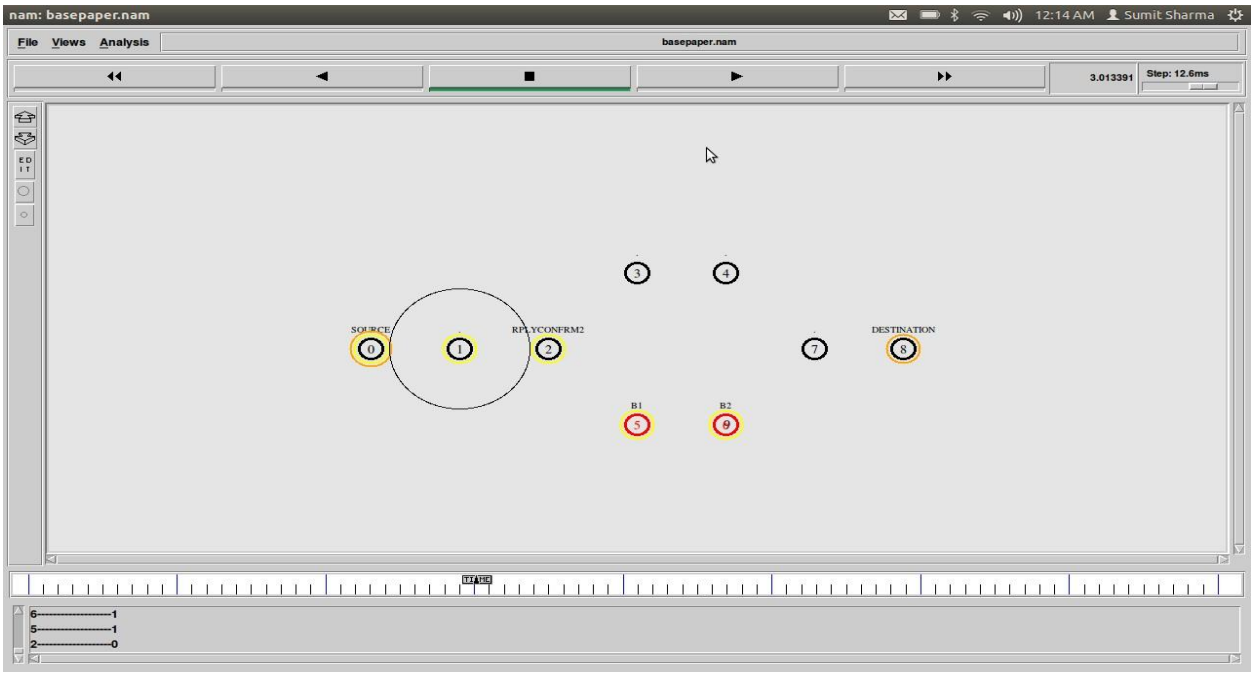


Fig 4.10: Implementation Snapshot

Another black hole node will reply to source node with REPLYCONFIRM packets.

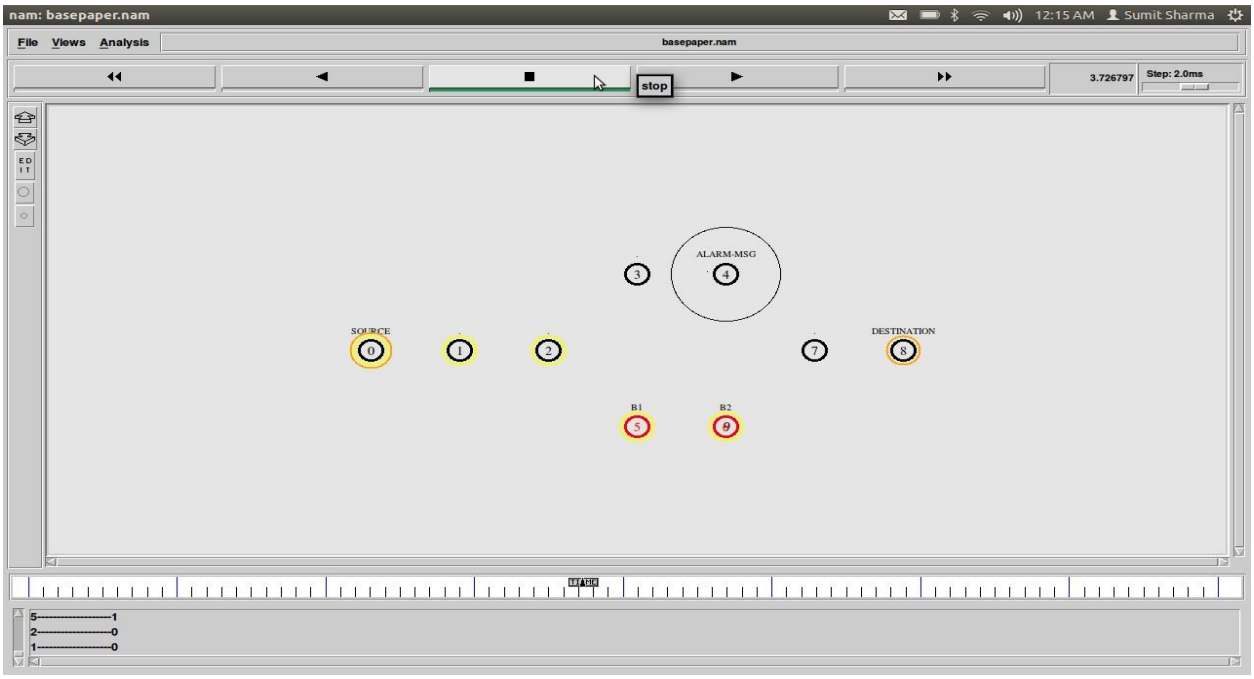


Fig 4.11: Implementation Snapshot

Source node will send ALARM MSG to destination for cross verification from destination node.

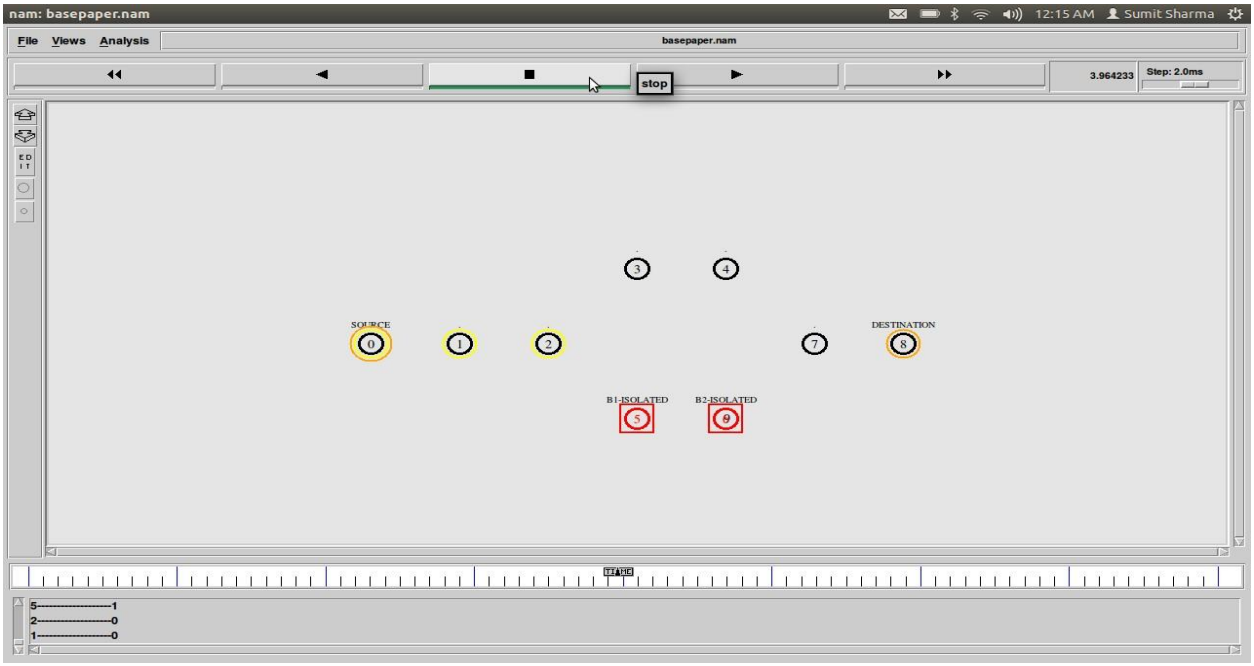


Fig 4.12: Implementation Snapshot

Destination node will deny and source node will block the malicious nodes and isolate them.

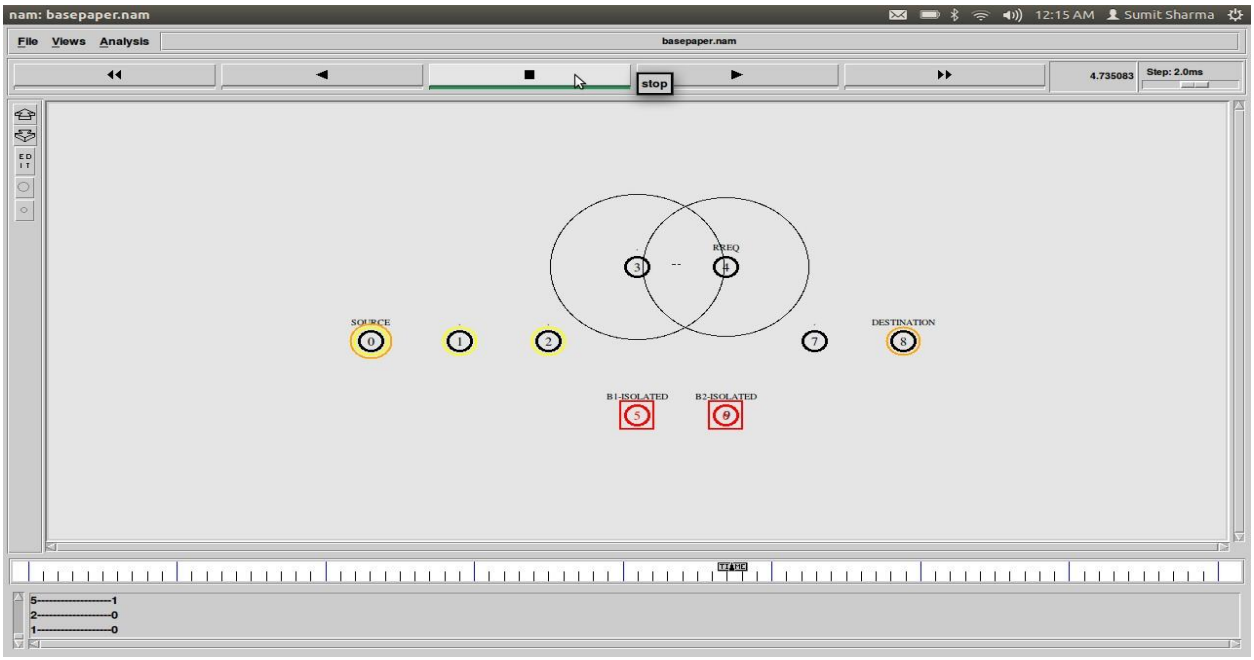


Fig 4.13: Implementation Snapshot

Now source node will again broadcast RREQ packets towards destination node.

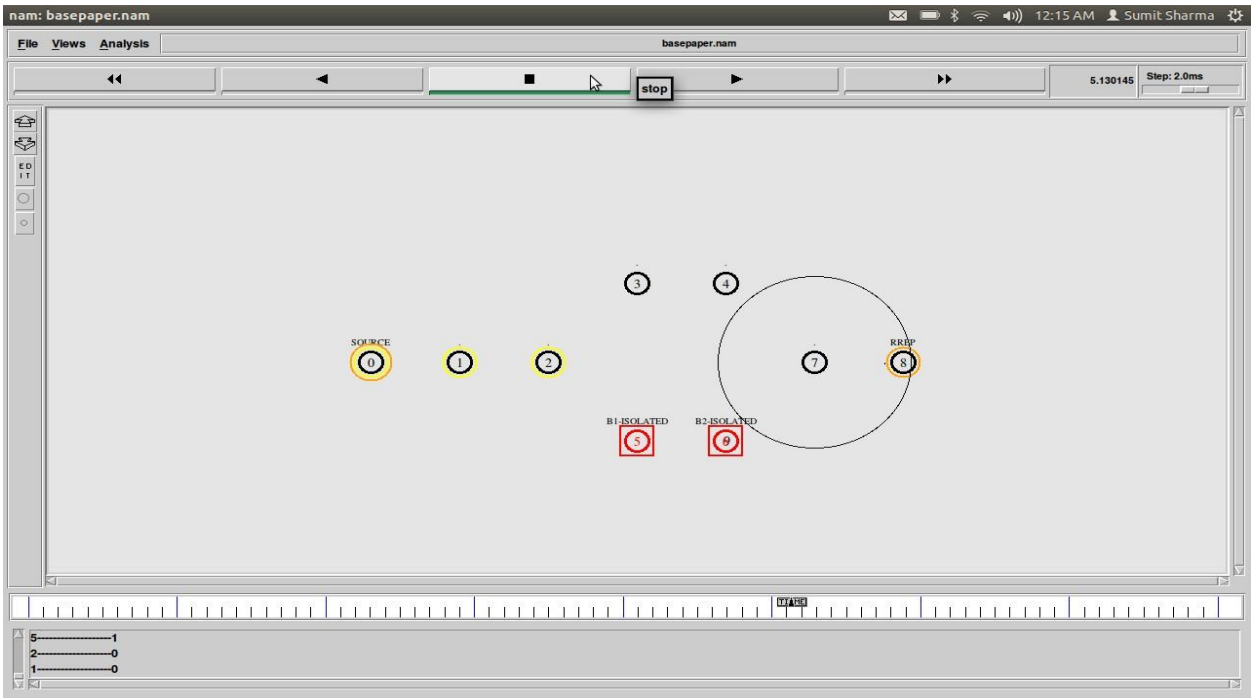


Fig 4.14: Implementation Snapshot

Destination node will reply with RREP packets towards source node.

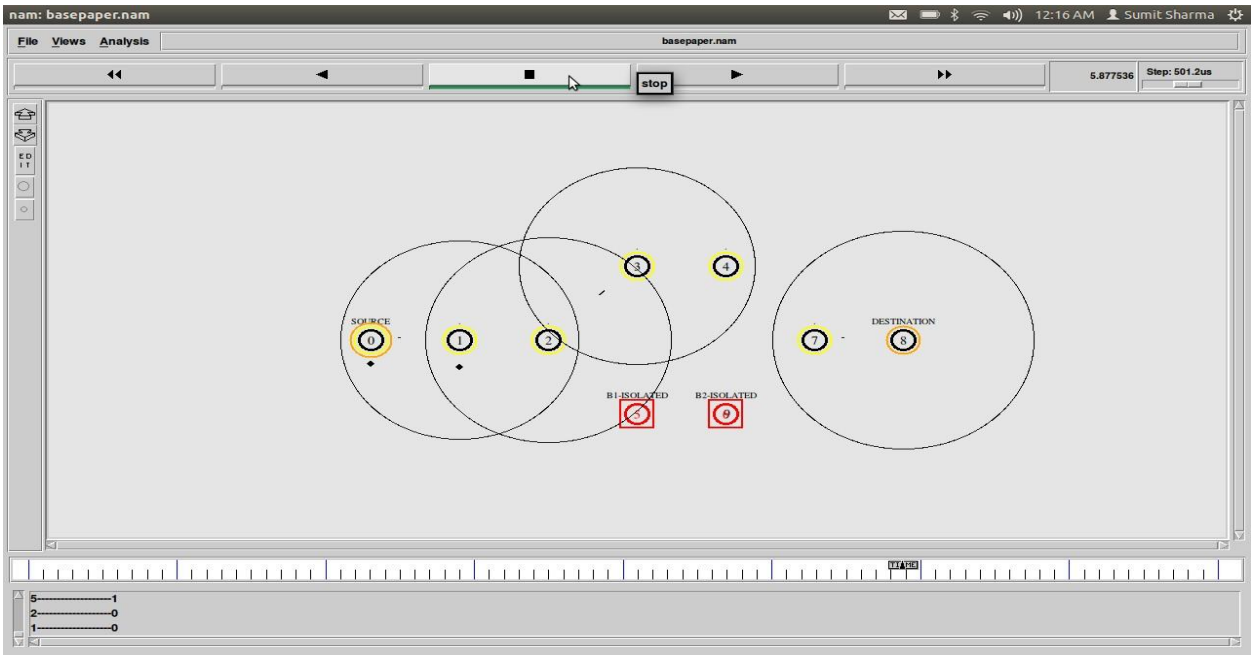


Fig 4.15: Implementation Snapshot

Source node will choose path and start transmitting data towards destination node.

- **SOLUTION TO PROTECT NETWORK FROM MULTIPLE BLACK HOLE NODE:**

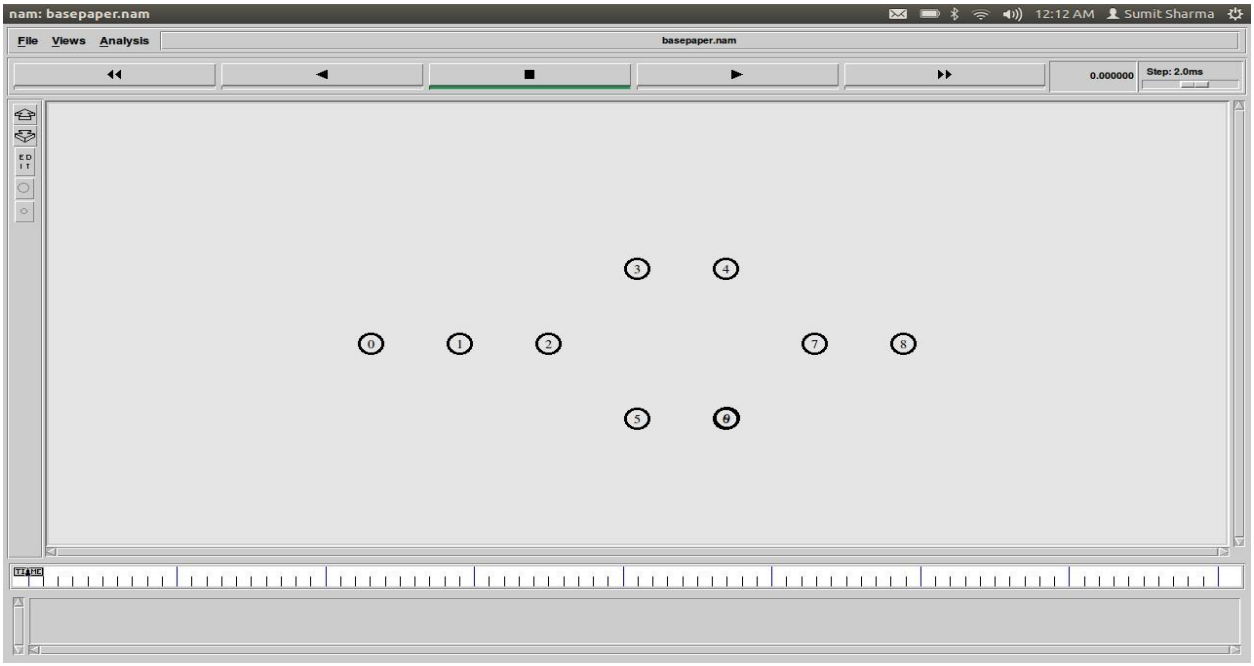


Fig 4.16: Implementation Snapshot

Initialize network using wireless nodes with IEEE 802.11 standard using NS2 simulator.

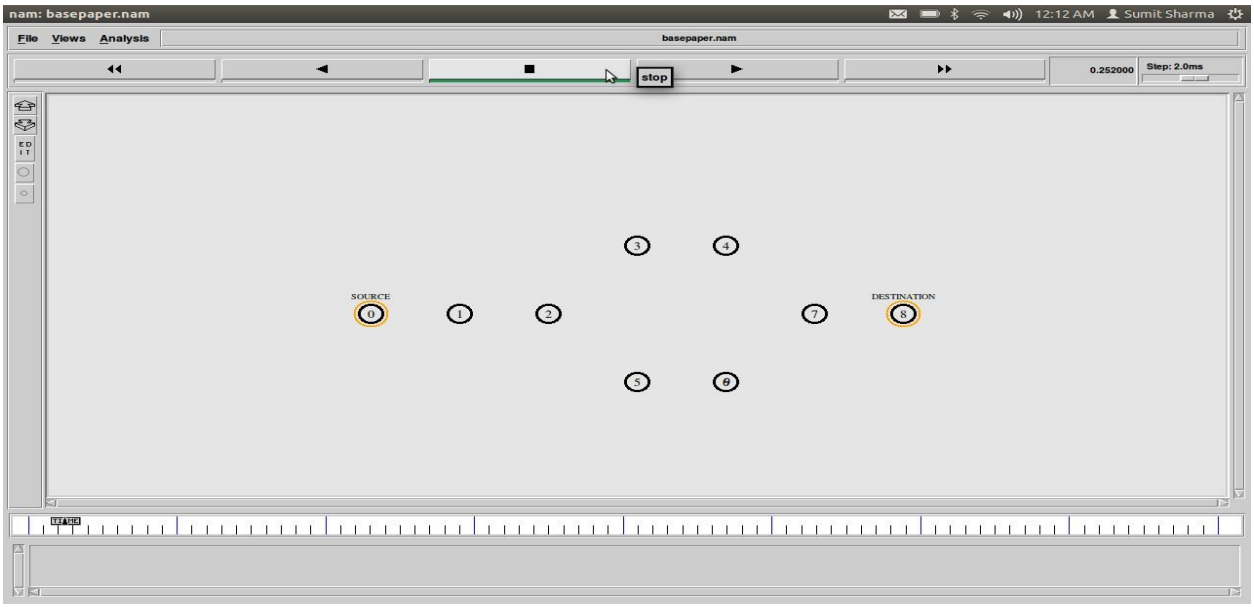


Fig 4.17: Implementation Snapshot

Choose one node as a source node and one another node as a destination node.

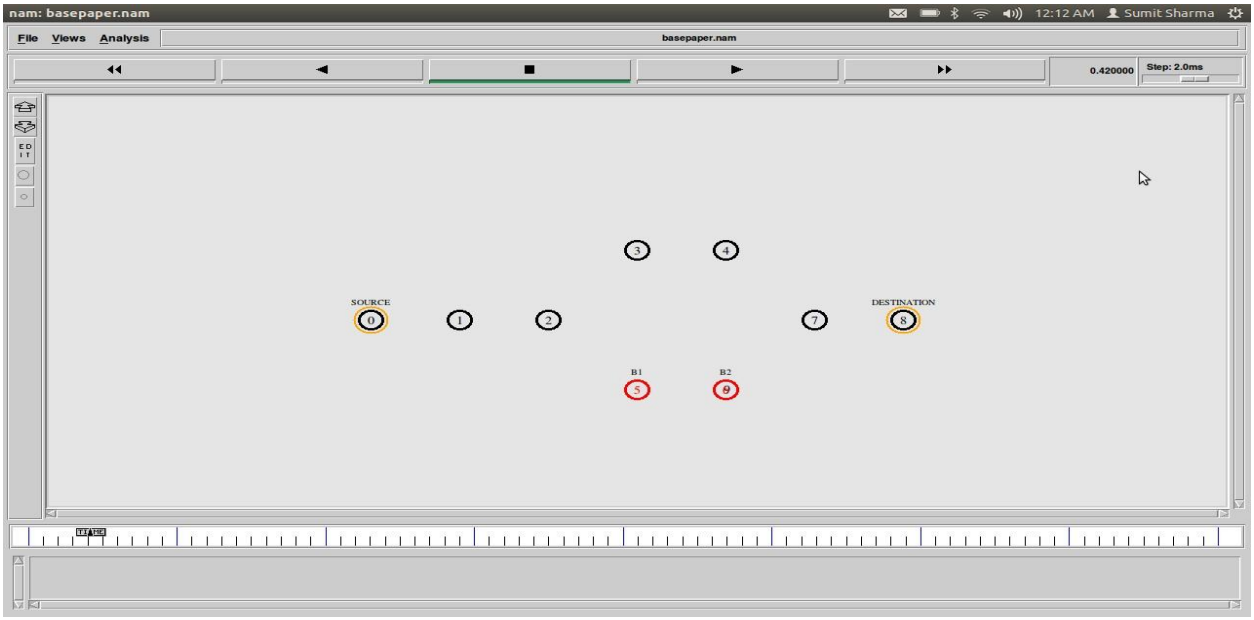


Fig 4.18: Implementation Snapshot

Choose two nodes as black hole nodes as shown in figure 4.3, here B1 and B2 are black hole nodes.

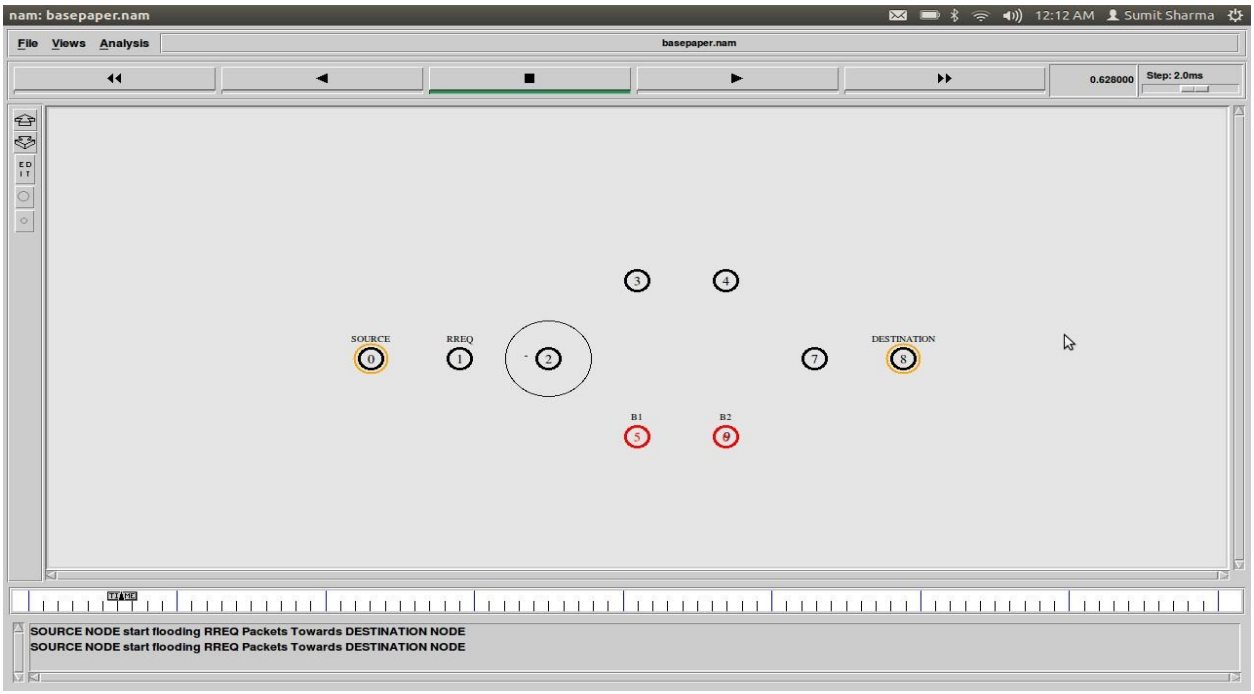


Fig 4.19: Implementation Snapshot

Source node will broadcast RREQ packets towards destination node.

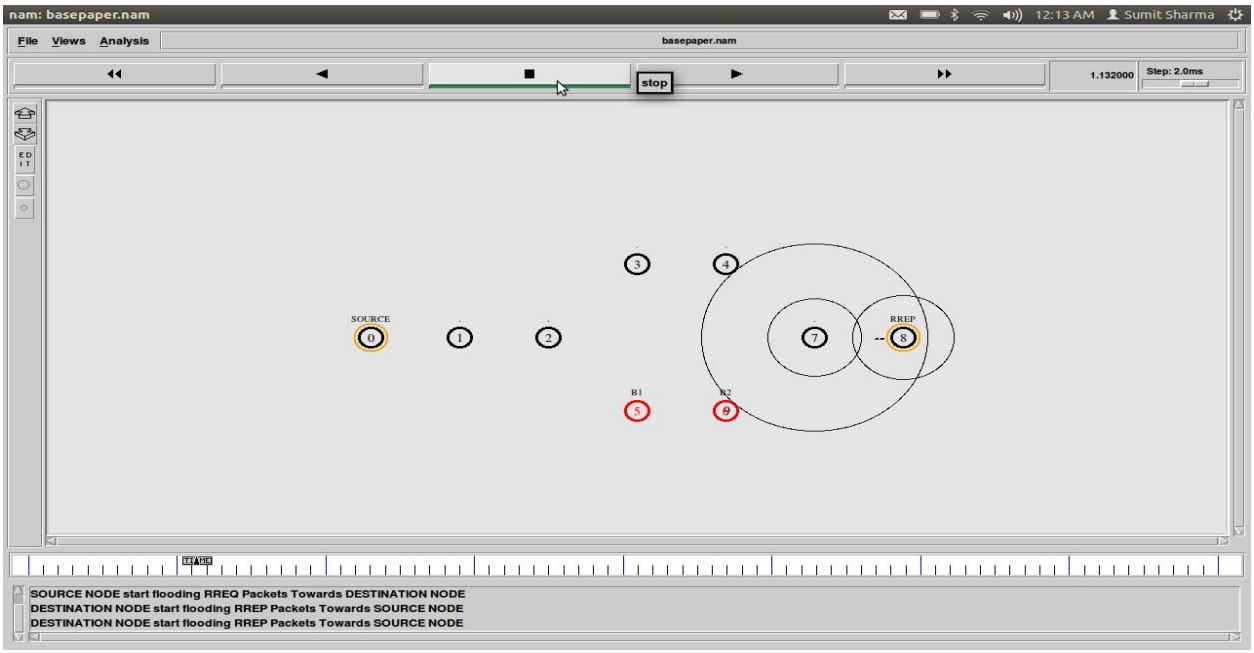


Fig 4.20: Implementation Snapshot

Destination node will receive RREQ packets and flood RREP packets towards source node.

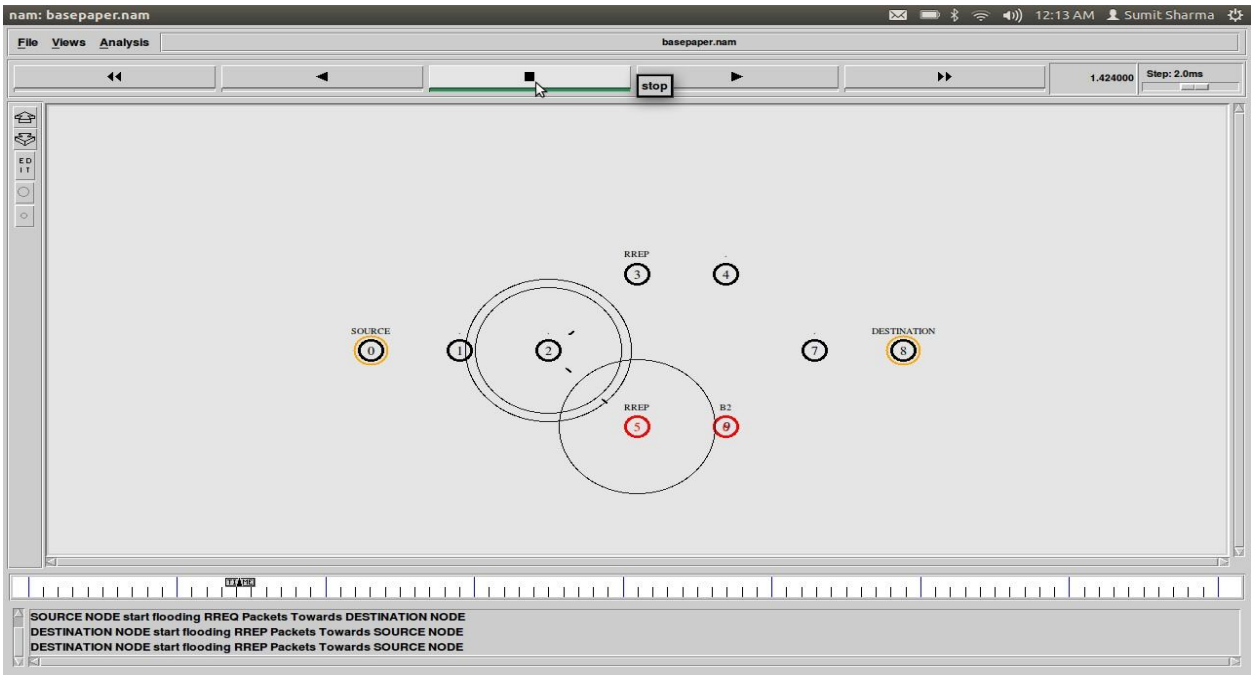


Fig 4.21: Implementation Snapshot

Black hole node will also reply with fake RREP packets toward source node.

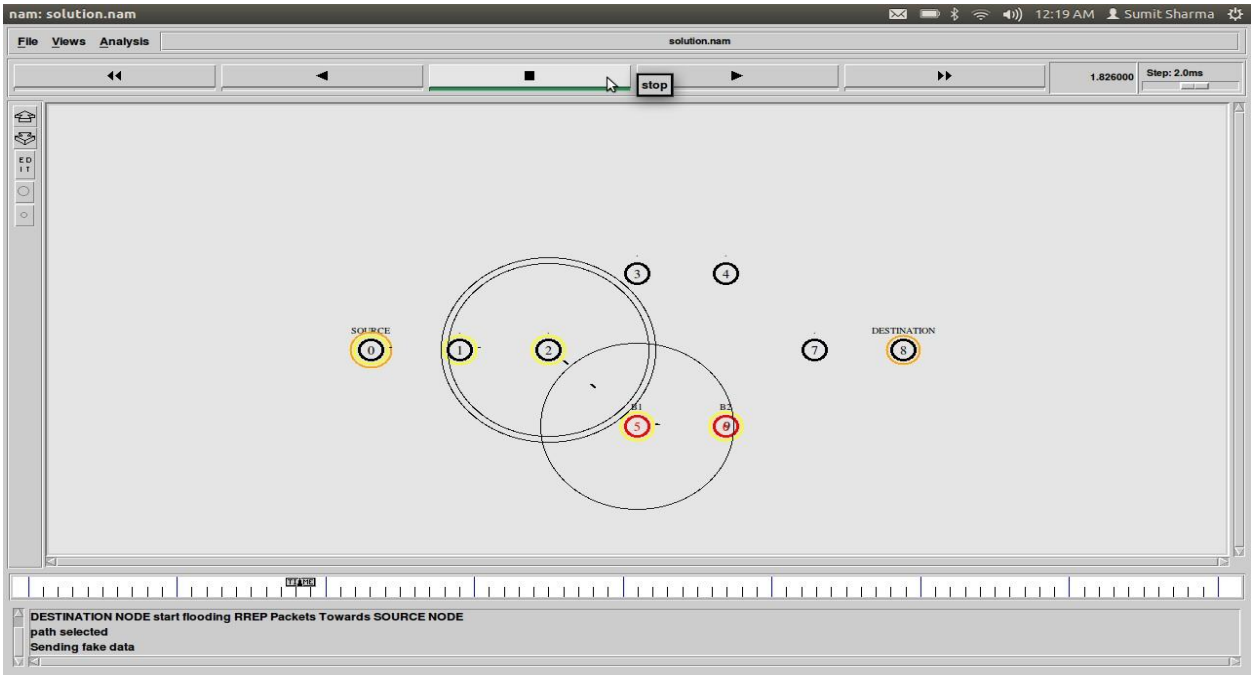


Fig 4.22: Implementation Snapshot

Source node will send fake data to selected node and will check dynamic routing information.

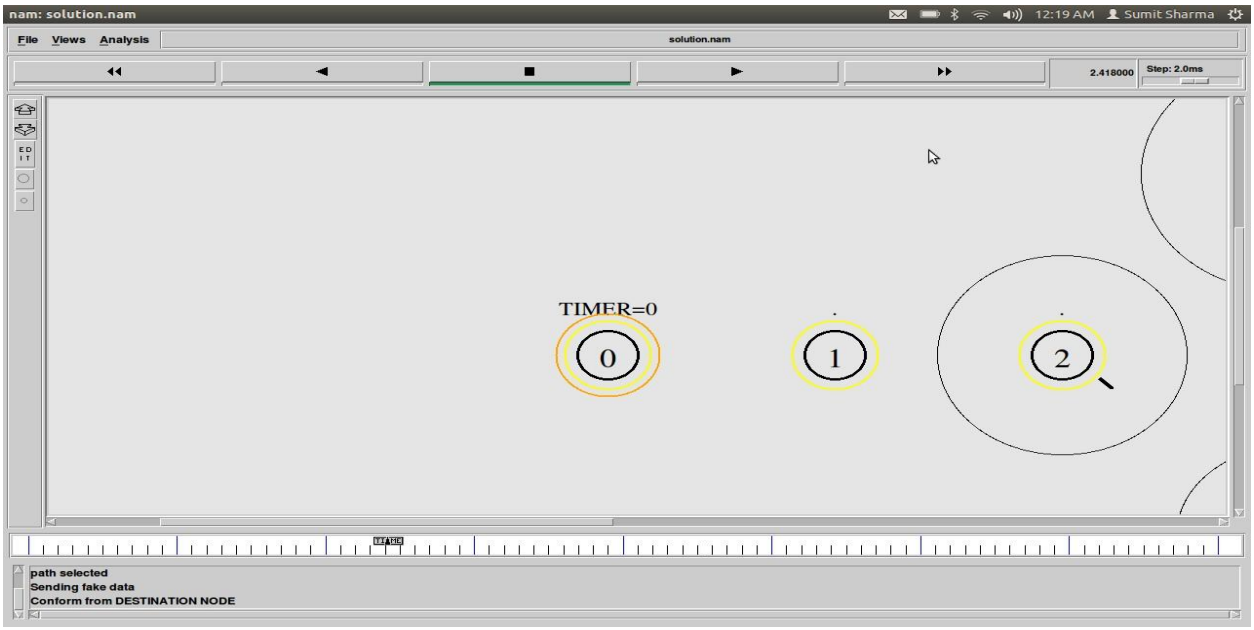


Fig 4.23: Implementation Snapshot

Now after sending data it will verify from destination that weather its receiving data or not, it will wait for the response of destination till timer expire.

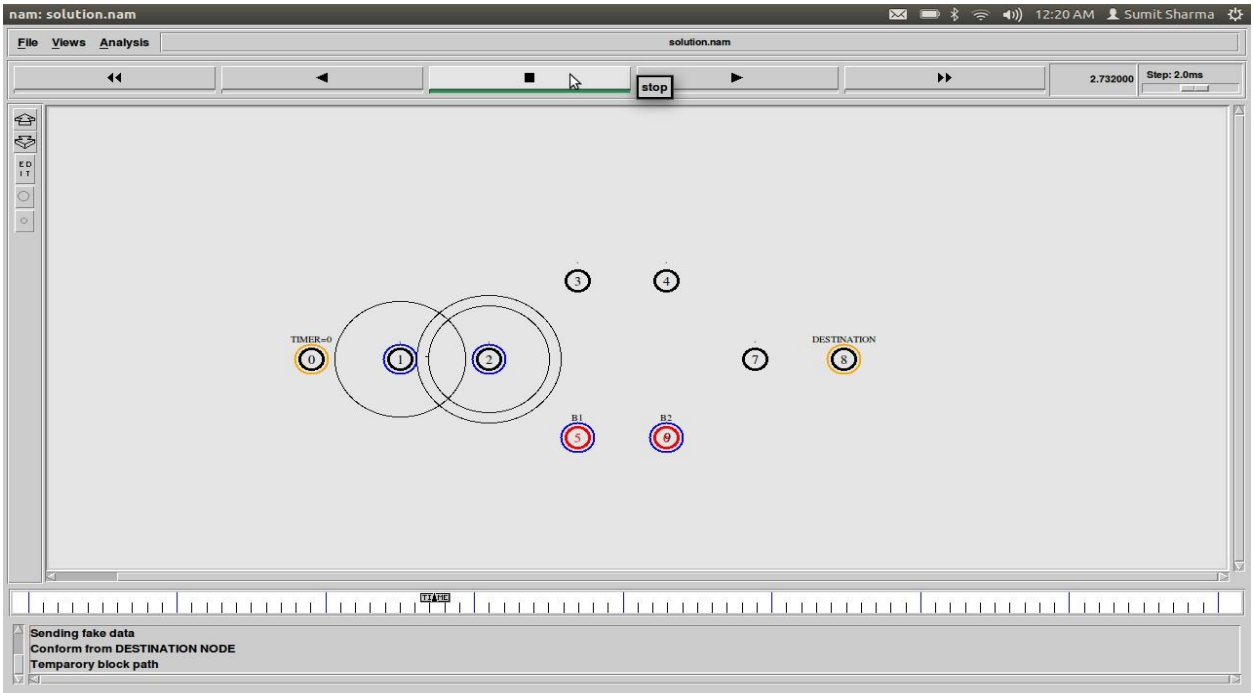


Fig 4.24: Implementation Snapshot

When timer gets expired it will temporary block the path to find malicious nodes.

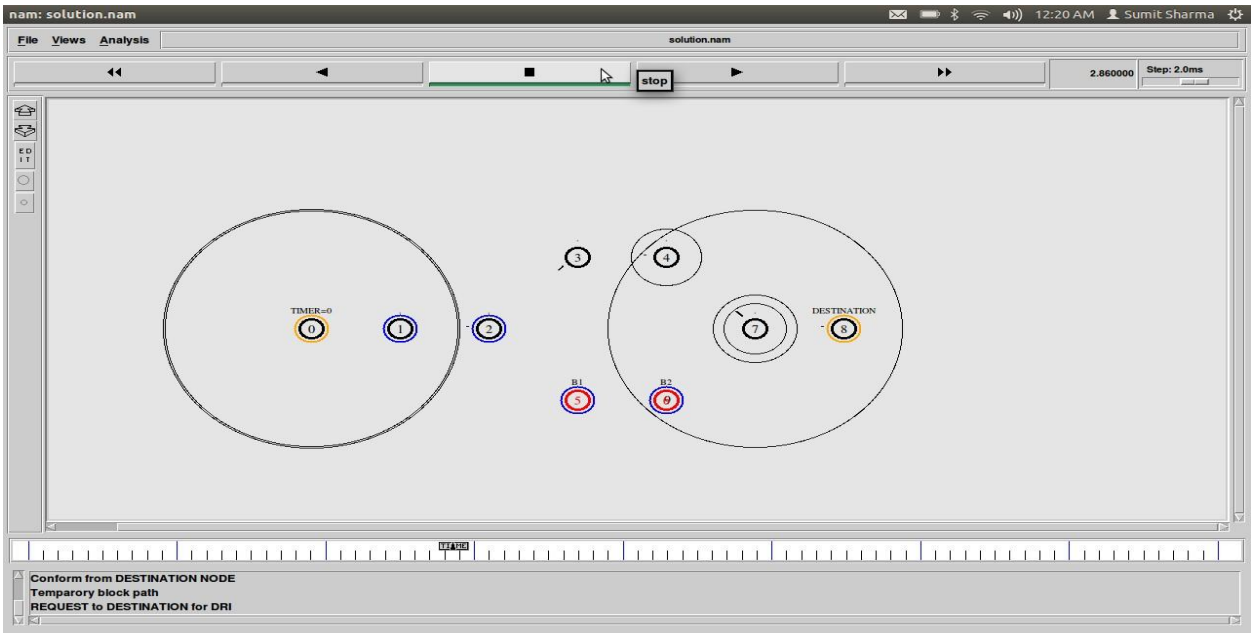


Fig 4.25: Implementation Snapshot

After blocking path it will request to destination to show its DRI tables.

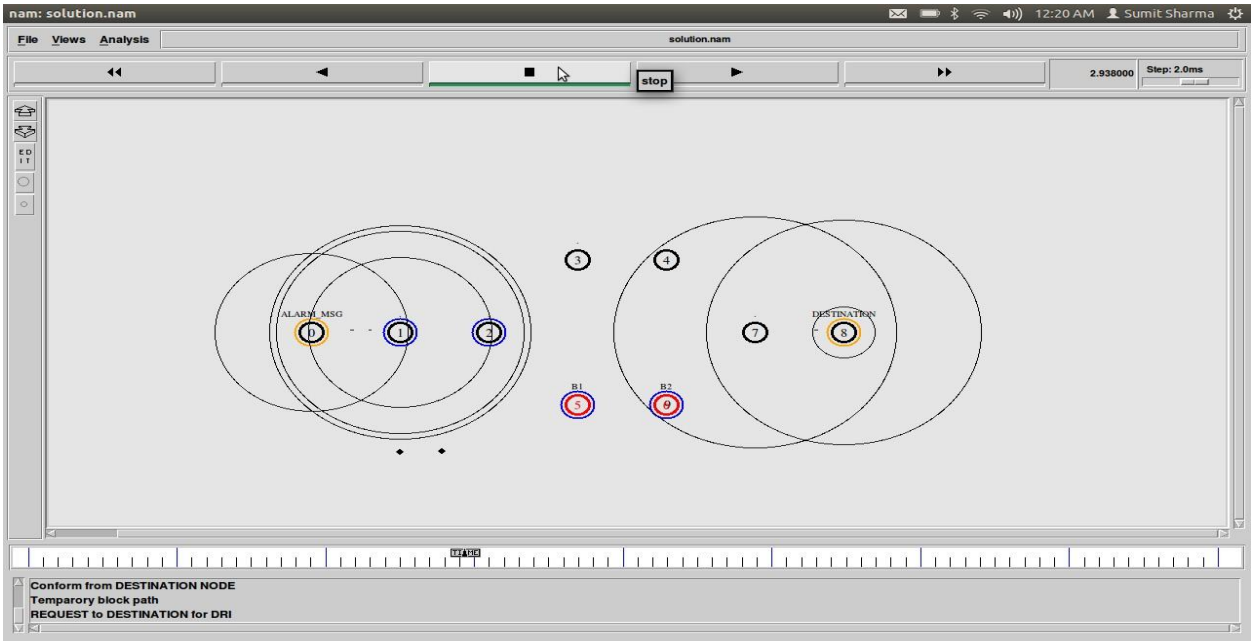


Fig 4.26: Implementation Snapshot

It will send ALARM message to destination and destination will send his DRI table to source node.

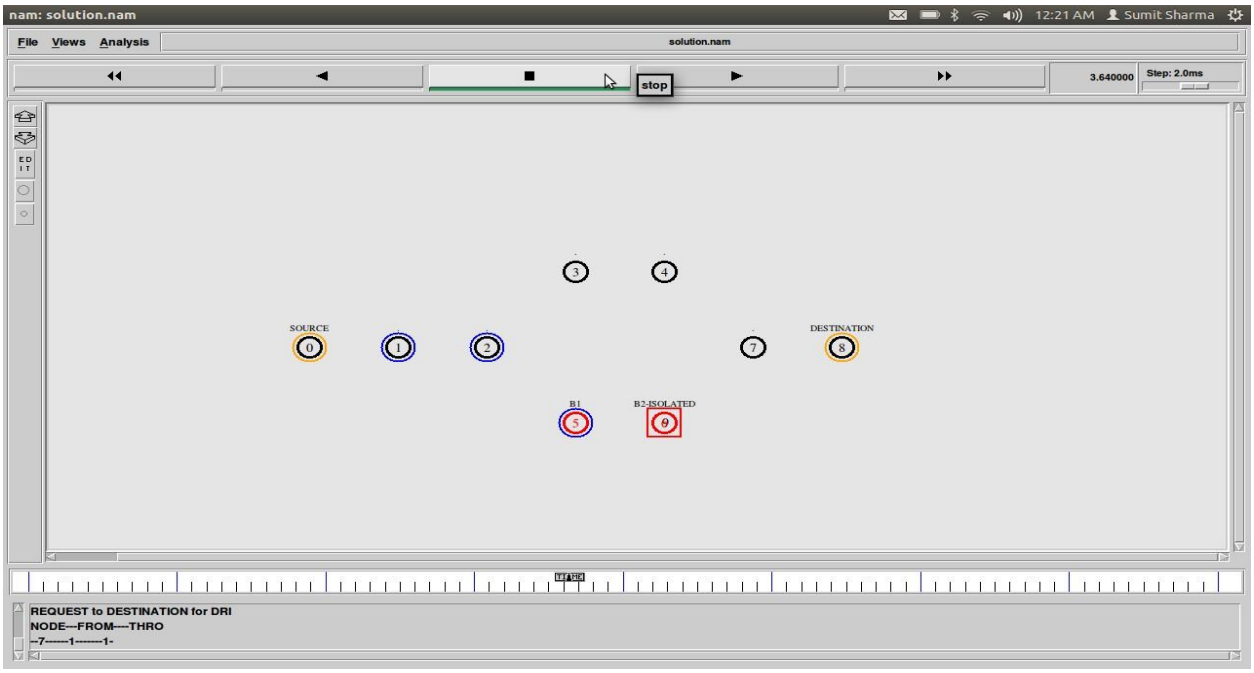


Fig 4.27: Implementation Snapshot

It will not found last node in its DRI table, so it will consider it as malicious and isolate it.

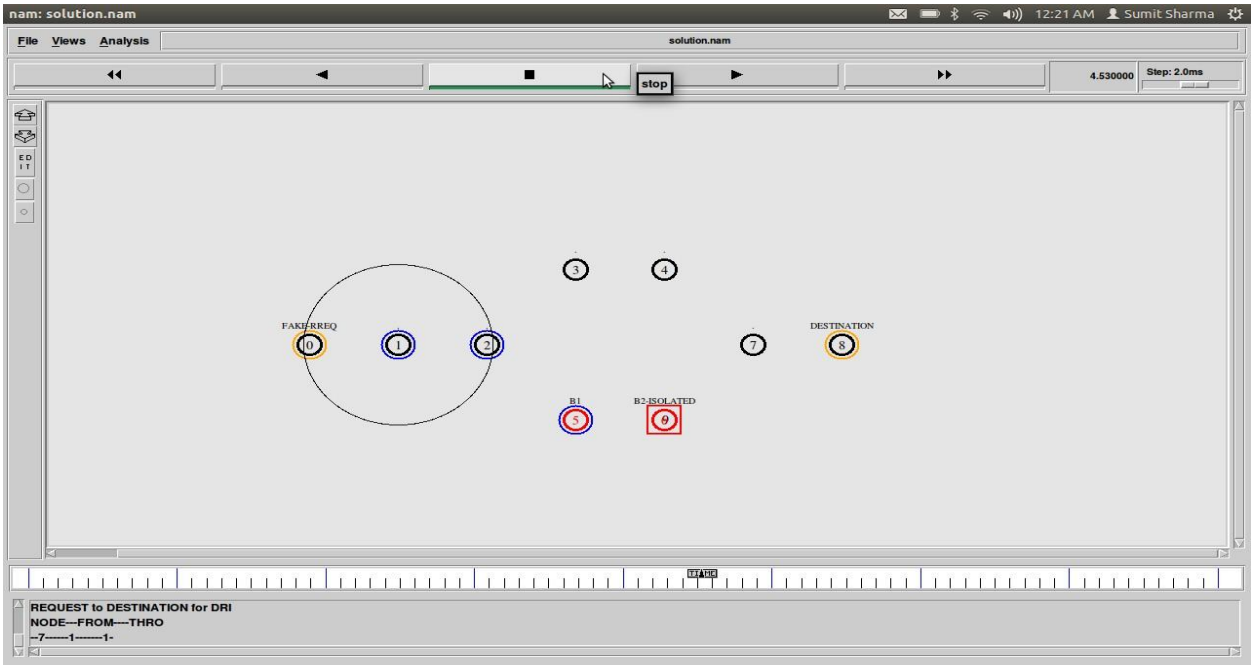


Fig 4.28: Implementation Snapshot

Source node will broadcast fake RREQ packets with fake destination address.

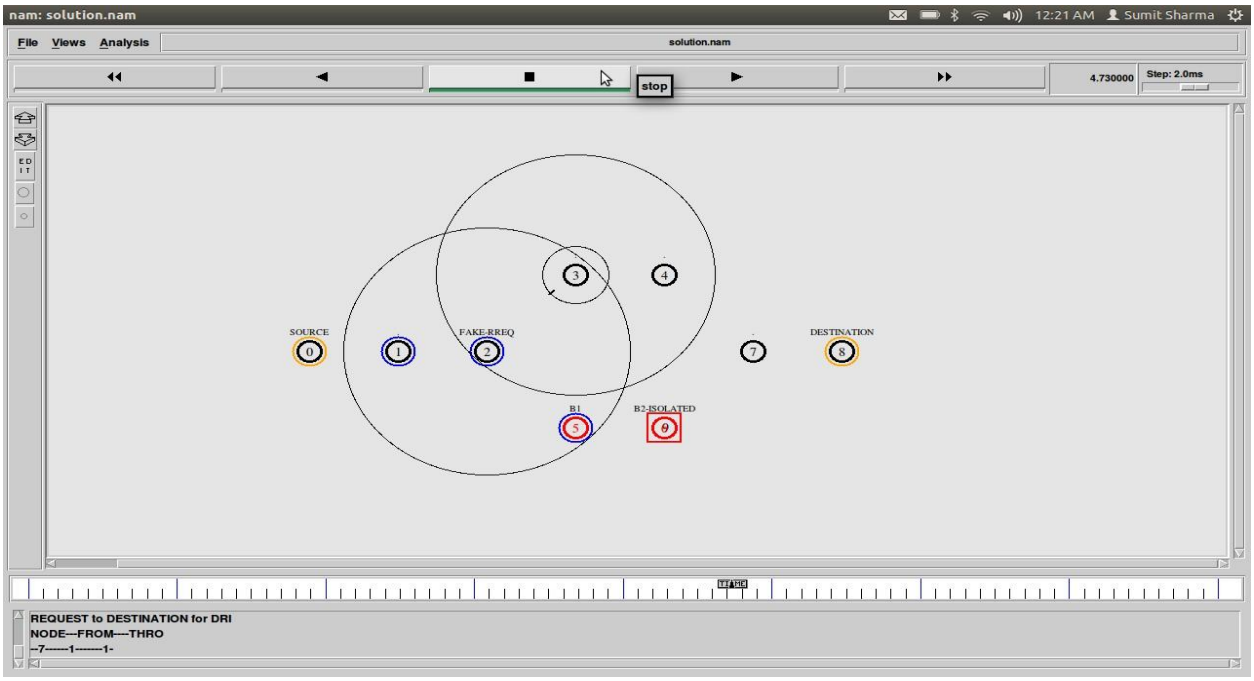


Fig 4.29: Implementation Snapshot

Source node will broadcast fake RREQ packets with fake destination address.

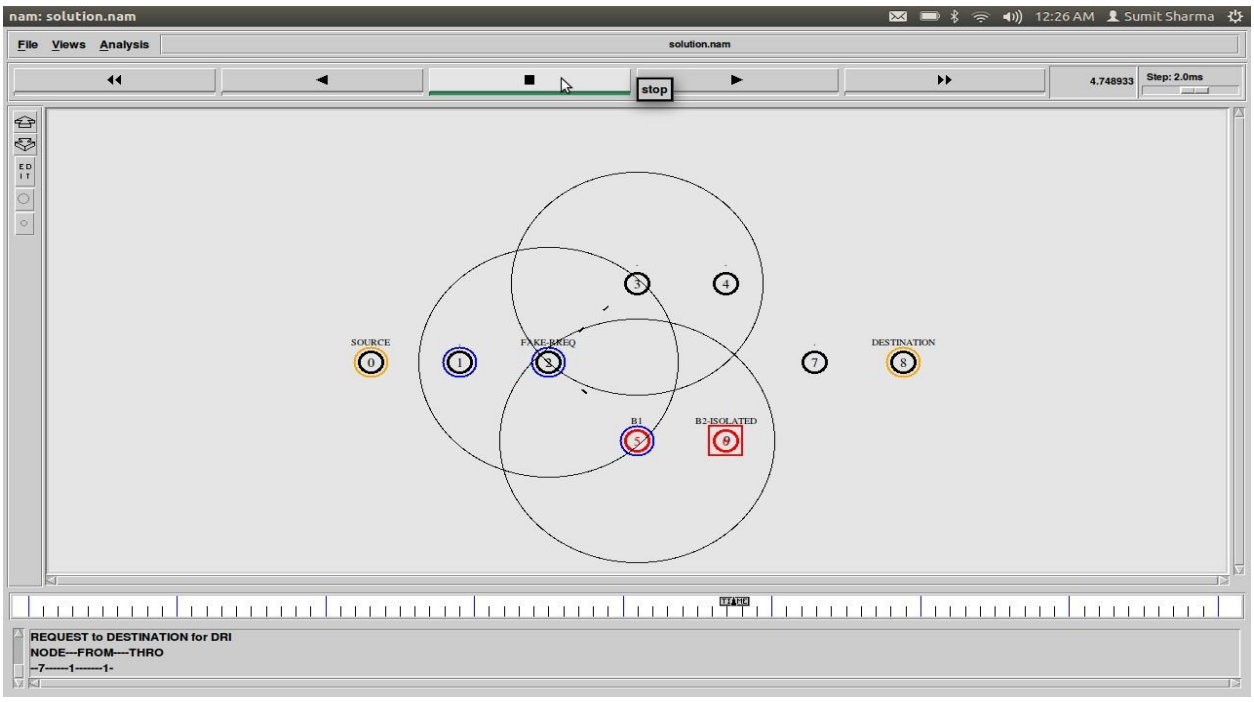


Fig 4.30: Implementation Snapshot

Fake RREQ packets will flood into whole network.

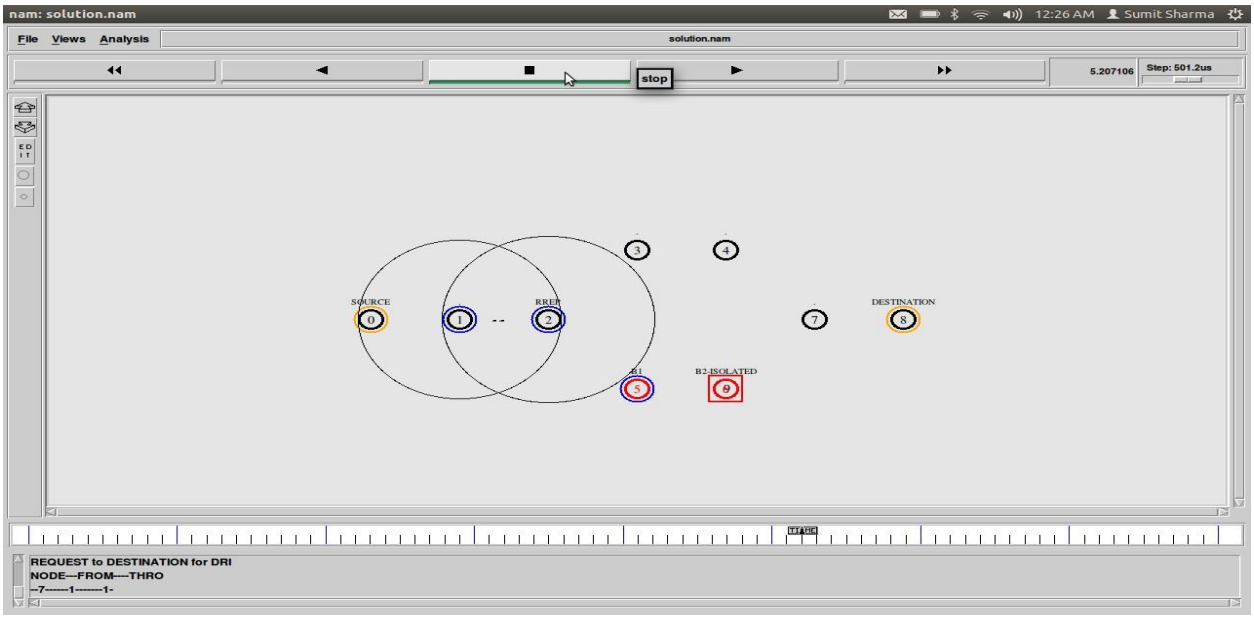


Fig 4.31: Implementation Snapshot

Now only black hole node will reply with RREP packet.

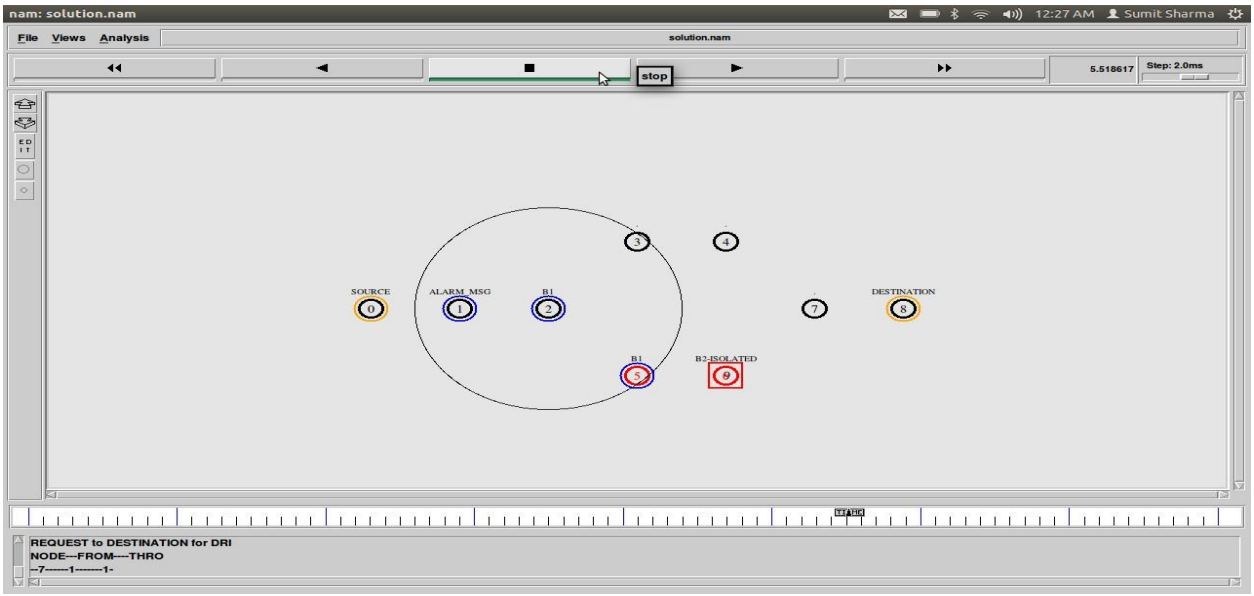


Fig 4.32: Implementation Snapshot

Source node will detect black hole node and it will forward ALARM message to isolate it.

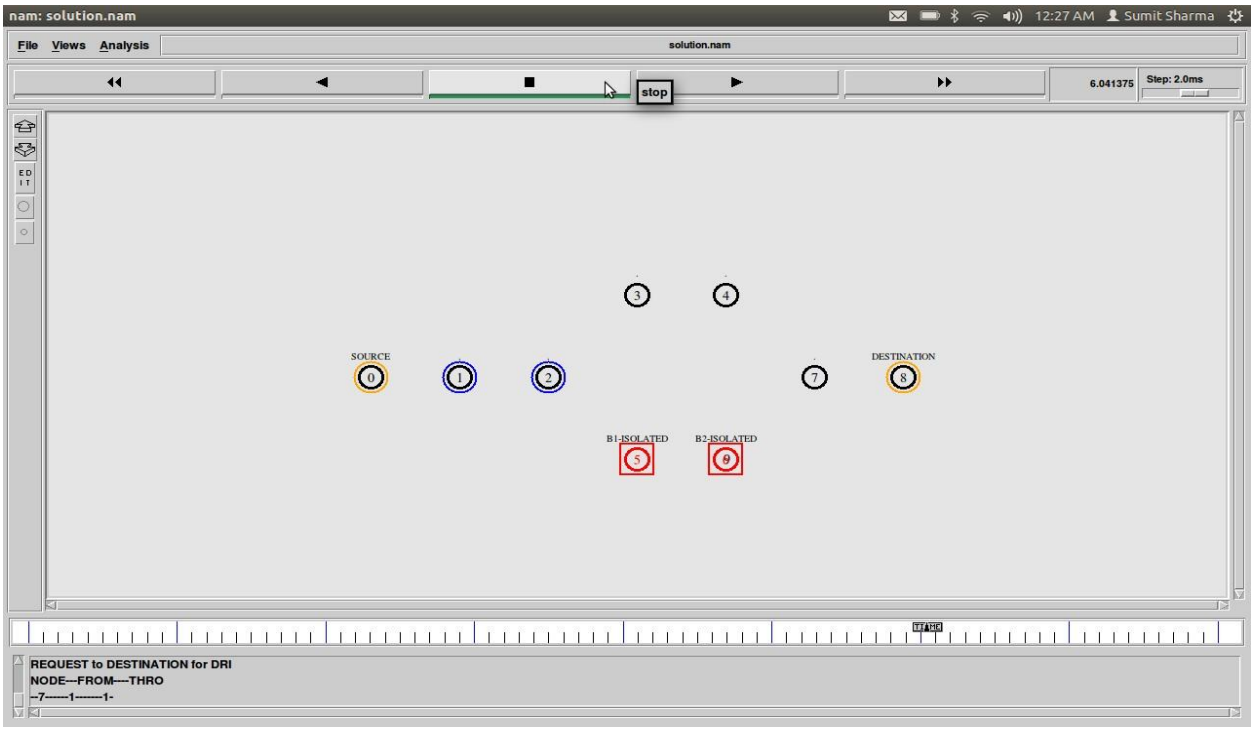


Fig 4.33: Implementation Snapshot

Now second black hole node is also got isolated from network.

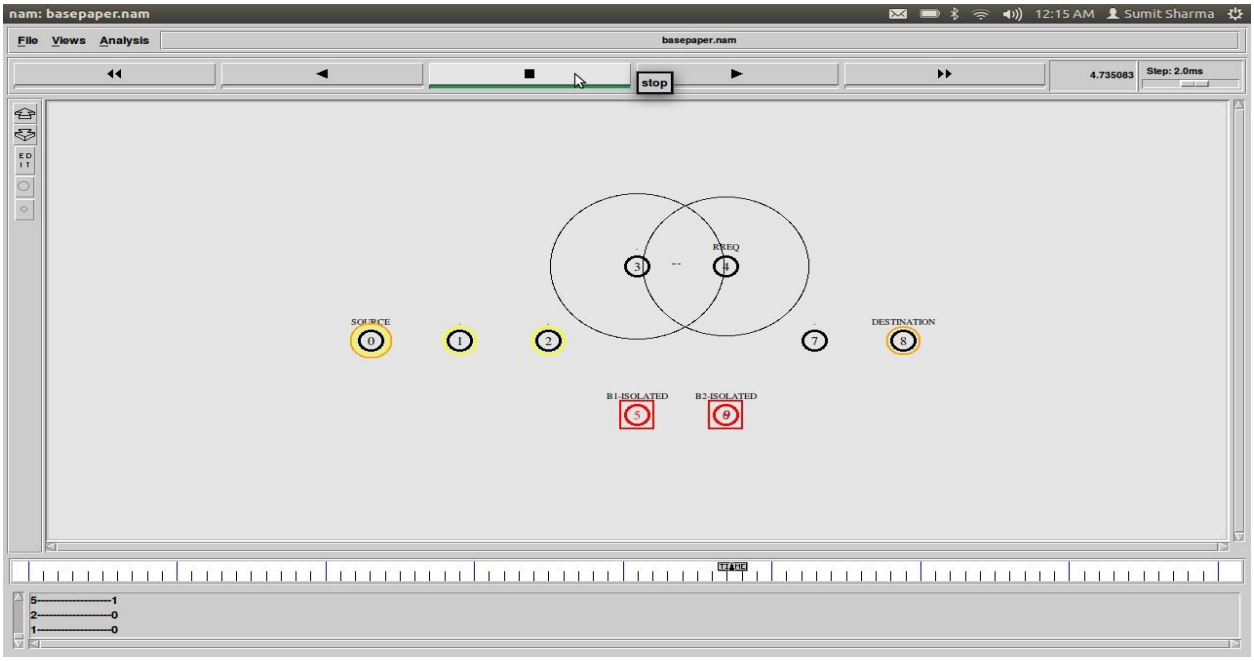


Fig 4.34: Implementation Snapshot

Now source node will again broadcast RREQ packets towards destination node.

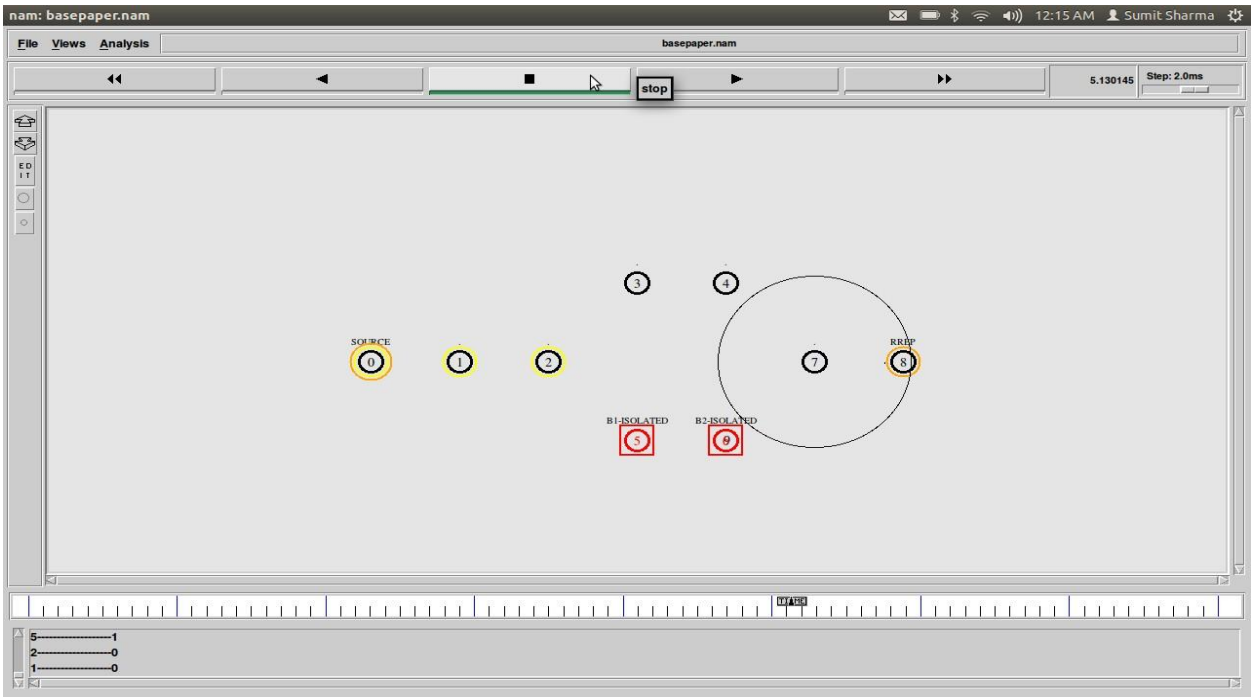


Fig 4.35: Implementation Snapshot

Destination node will reply with RREP packets towards source node.

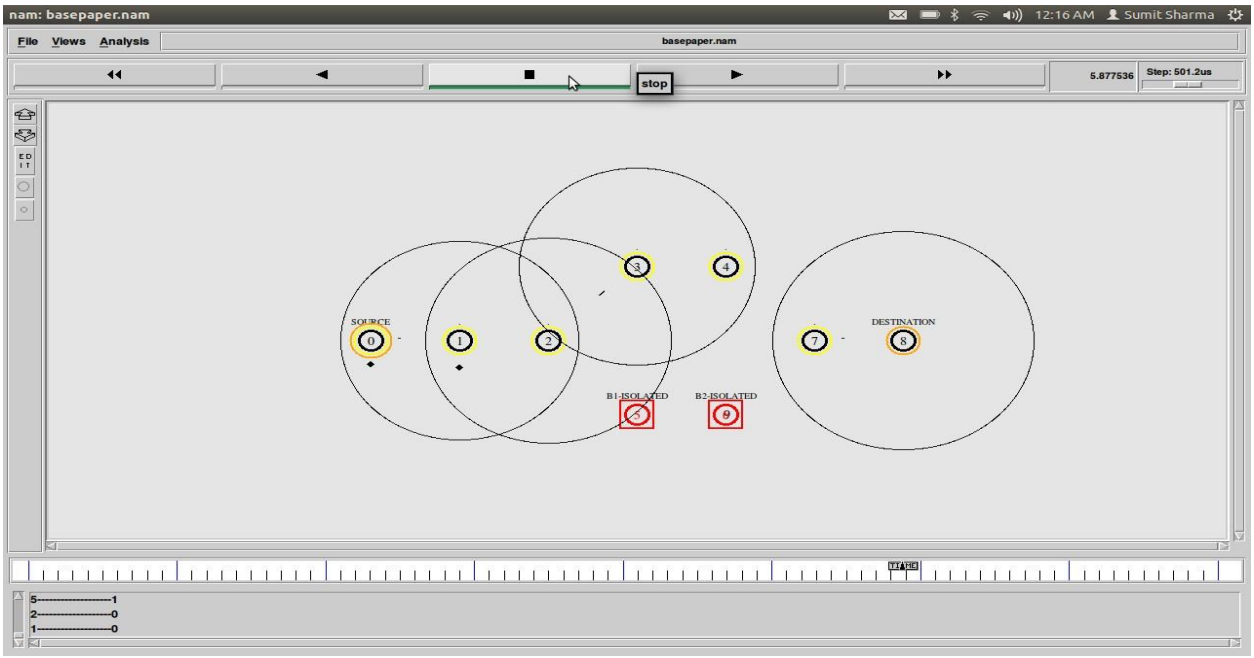


Fig 4.36: Implementation Snapshot

Source node will choose path and start transmitting data towards destination node.

- **RESULTS**

- **DELAY GRAPH:** This diagram reflects the fresh delay while contrasted along with that old system. The following green collection illustrates delay around unwanted structure and even alternative collection illustrates delay around brand-new case. In this particular unwanted court case delay enlarged in view connected with packet boat deprivation however by employing brand-new method everyone increase this matter and even computer simulation reaction to delay are actually proven this particular diagram.

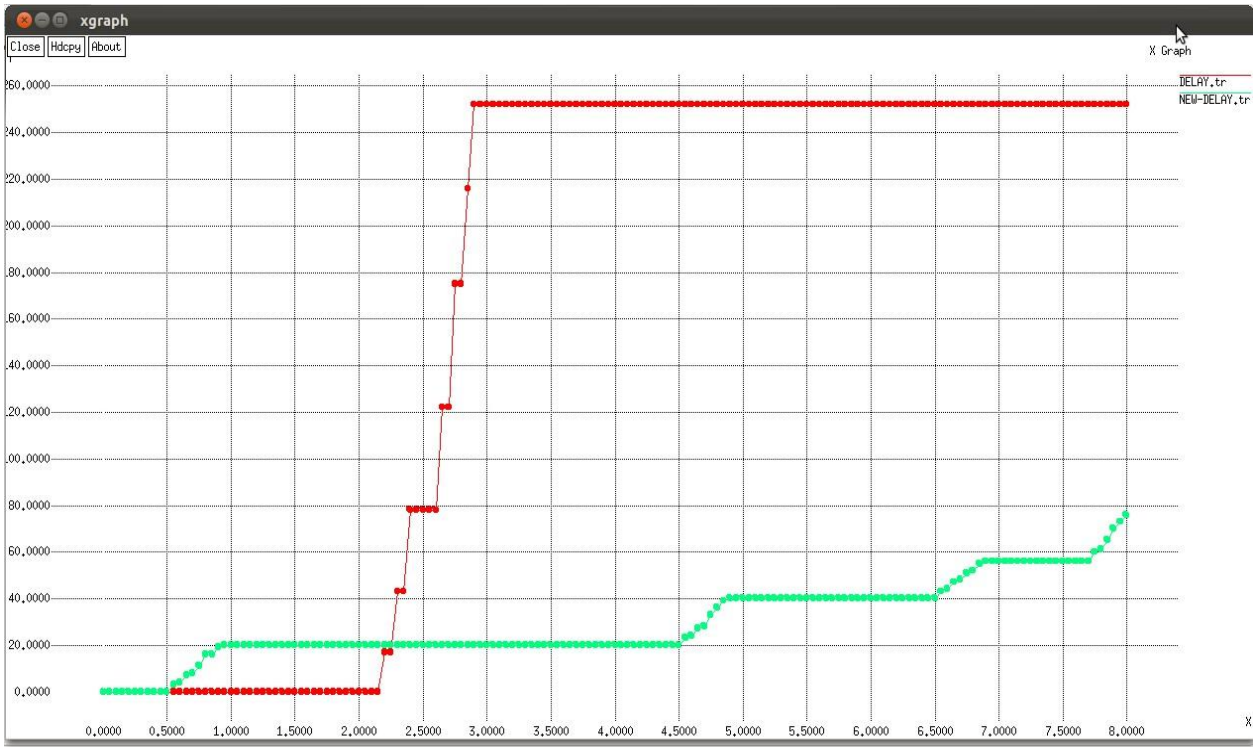


Fig 4.37: Delay graph

- **PACKET DELIVERY RATIO GRAPH:**

This diagram presents packet delivery presentation ratio. That is to say draw eco-friendly tier denotes new PDR along with reddish colored tier shows good old PDR. This Distinction during eco-friendly along with reddish colored tier shows that by investing in the consist of device zinc heightens PDR.

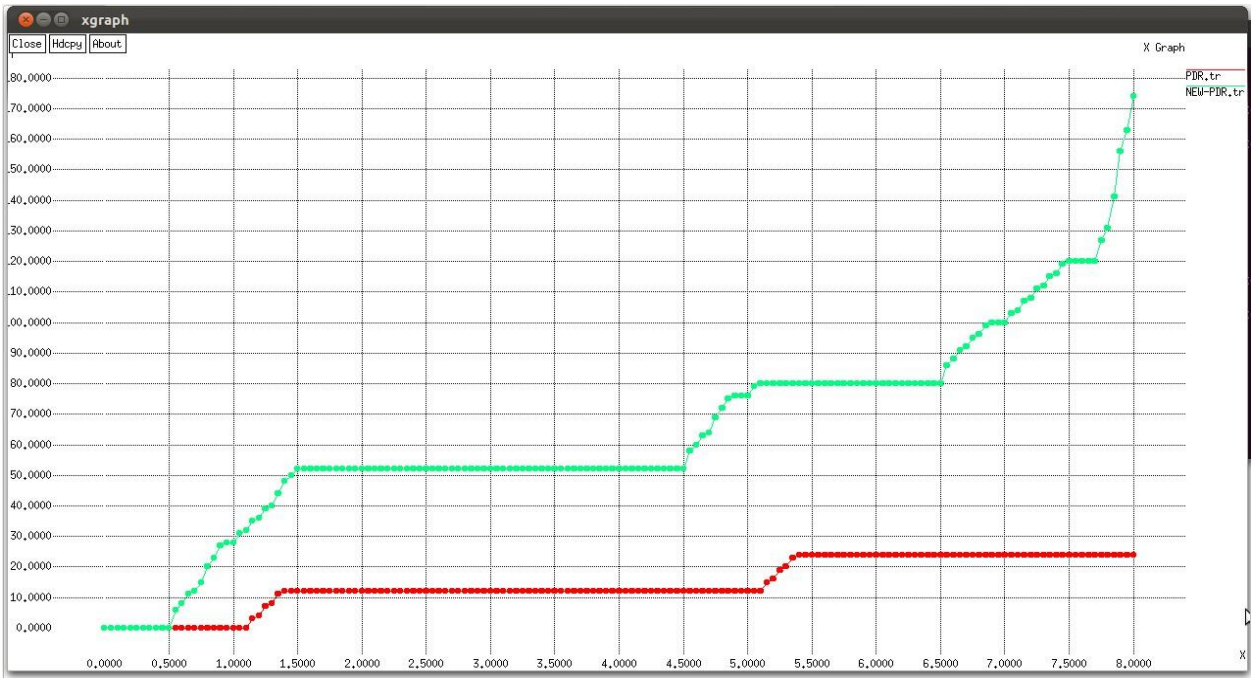


Fig 4.37:PDR graph

CHAPTER 5

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