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Performance improvement of unicast reactive routing protocols in MANETs

Abstract

The objective of this research work is to improve the performance of the Reactive Routing Protocols in Mobile Ad hoc Network (MANET). Ad hoc On- demand Distance Vector (AODV) Routing protocol is selected for implementation and analysis in this research. Four investigations are selected for analysis and for applying possible performance improvement strategies. These performance improvement strategies can be applied based on the requirement and the scenario in which MANET is being used. Using these strategies the performance of MANET can be further improved. The continuous improvement in MANET due to the various research findings can make it a suitable alternative for fixed infrastructure based networks in the near future.

Keywords: MANETs, BMS, FMS, QRP and DRP

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Abbreviations: AODV, Ad hoc on- demand distance vector; BSs, base stations; WMN, Wireless MobileAd Hoc Network; FMS, fading management system

Introduction

Traditional wireless networks are high-speed backbones that send signals fromdifferential base stations (BSs) and help all mobile devices in a particular area receive the signals (Pahlavan, K. and Levesque, AH,). 2005). It is given below in the Figure 1. Each cell has a BS. Communicate directly with your mobile phone. Therefore, this network is single-hop communication (Lou W, Fang Y.2004). Wireless MobileAd Hoc Network (WMN) is within restricted range and it's not the backbone of multi- hop communication. Each device has different features. Therefore, ad hoc networks are heterogeneous (Ruay Shiung Chang et.al., 2003). Groups of MANET nodes dynamically form a network called MANET networking.

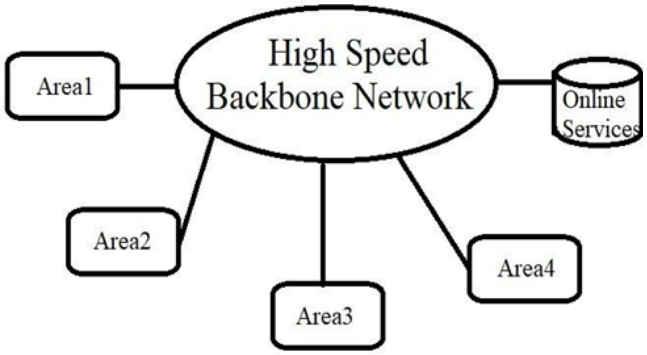

Figure 1 Traditional Networks.

Wireless Mobile Ad hoc network is classified into two types.

i. Wireless Infrastructure networks

ii. Wireless Infrastructure less networks

The objective of this research work is to improve the performance of the Reactive Routing Protocols in Mobile Ad hoc Network (MANET). Ad hoc On- demand Distance Vector (AODV) Routing protocol is selected for implementation and analysis in this research. Four investigations are selected for analysis and for applying possible performance improvement strategies. The first investigation selects as unstable nodes. To find the all the nearest neighbor is calculated the dynamic Threshold value than suitable neighbor nodes assign the Delegation process on the prior path failure recovery in the presence of unstable nodes. This avoids repeated route discovery mechanism, thereby increasing throughput and decreasing transmission time as well as routing overhead.

The second investigation is the QoS parameter based on Reliable pathselection(QRP).Best path selection is done based on minimum transmission time and reliable delivery. A minimum transmission time and reliable delivery are done by route discovery and forwarding data packets. Minimum transmission time is achieved by estimating and reducing the queuing delay. Reliable delivery isachieved without any packet loss. It increases the throughput. Even though there is no centralized control in MANET, the resources such as energy level, bandwidth availability, load sharing is not effectively utilized and it reduces the network performance. Third parameter is the Battery Power of Nodes. Simulation of a network where few nodes are placed at strategically vital locations was done using Qualnet. The results show uneven battery power utilization of the nodes in MANET, whichis mainly due to the location. Therefore a battery power level based priority routing is introduced based on the AODV protocol. This Battery Management System (BMS) enables even utilization of the battery power in MANET nodes; thereby node's lifetime gets increased. Thus BMS helps in overall improvement of the network lifetime. The fourth parameter selected is fading of signals in MANET. Fading causes fluctuations in the signal strength resulting in packet loss and link breakdown. Three different types of fading are analyzed and compared through Qualnet. An alternate path approach is proposed to handle the ill effects caused due to fading. This Fading Management System (FMS) is found to be reducing the Packet Loss even up to fifty percent. These performance improvement strategies can be applied based on the requirement and the scenario in which MANET is being used. Using these strategies the performance of MANET can be further improved. The continuous improvement in MANET due to the various research findings can make it a suitable alternative for fixed infrastructure based networks in the near future.

MANET routing protocols

Routing is determination of routes between of source and destination node (Trilok et.al. 2019). Routing is the basic functionality

of any communication network.MANET is infrastructure less network and it is a decentralized network that required a strong dynamic routing protocol (Trilok et.al. 2019). In terms of transmission mechanism, routing protocol in MANET is divided into Unicasts Routing Protocol and Multicast Routing Protocol (Trilok et.al. 2019). The classification of Routing Protocol is given in the Figure 1.6. Different types of protocols like as periodic or proactive, adhoc or reactive and hybrid or combination of proactive and reactive is utilized to initiate a path from S to D (Meshram et.al.2010, Lalar et.al.2018) is usedby both unicasts and multicast routing protocol.

Classification of routing protocol (both unicasts and multicast)

I. The source node used to predefine the network information by initiating the destination path in the proactive or the table-driven routing protocol (Sharma et.al. 2016).

II. The nodes collect information about the network when required isreactive routing protocols (Fouzan et.al. 2010).

III. In hybrid routing protocols, the predefined information from the network and source gather the network information for the path establishment to the destination (Meshram et.al. 2010) Figure 2.

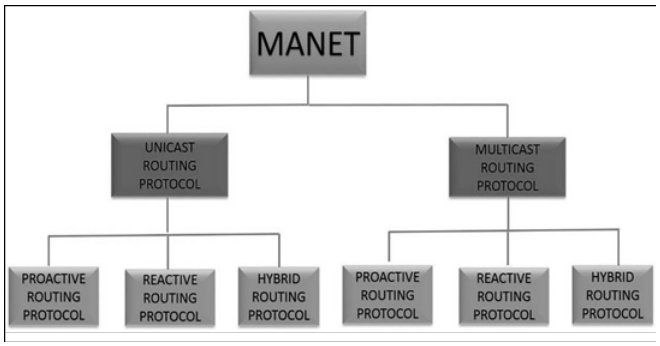

Figure 2 Classification of Routing Protocol.

Unicast routing protocol

Unicast is the least intrusive technique of transmitting informative data packets from S to D. To forward informative data packet, the RT (Routing Table) should maintain (DA) Destination Address (Lalar et.al. 2018). Data packet sends to the respective hops, if the DA is discovered in RT. Due to this, each and every node should maintain RT in the network structure (Lalar et.al. 2018). Most application in communication network depends on Unicasts Routing Protocol since, it can efficiently provide content and data oriented services such as, grids or cloud computing, Internet TV and online movie streaming (Goścień et.al. 2016). Unicasts Routing Protocol can be broadly categorized into table driven or Proactive Routing Protocol, adhoc or Re-active Protocol and Hybrid Routing Protocol or combination of both proactive and reactive (Chirag et.al., 2014).

Proactive protocol

Main goal of proactive protocol is to find the quickest path. All nodes in the network, maintain a structure to retain it nearby nodes information. It helps to transmitting routing information about every other node on a regular basis (Kant et.al., 2010). Example for unicast table driven routing protocol (Kant et.al., 2010),FSR (Fisheye State routing Protocol) (Chirag et.al.2014, Kant et.al.2010), DSDV routing protocol (Destination Sequence Distance Vector), TBRPF (Topology Broadcast Based on Reverse Path Forwarding), and OLSR routing (Optimized LinkState Routing) protocol, are some familiar proactive routing unicast protocols.

FSR

One of famous proactive unicasts routing protocols can be used for large network is Fisheye State Protocol (FSR). Each node in FSR has a capacity to see nearby node accurately rather than far away nodes. Because of this topology, information of nearby nodes is more accurate than distanced placed nodes. The information of distance nodes is not within the range, then the data will be sent to router and collects more information, which is closer to destination packets (Meghanathan et.al., 2009). FSR can be applicable to large network as it reduces overhead.

DSDV

One of efficient unicast proactive protocol is Destination Sequence Vector Routing (DSDV). In advance, the destination has complete information about the nodes in the network routes, so it is a proactive.[1] All the nearby destination node D information is maintained in routing table. Routine table holds destination address, latest sequence number from the destination,[1] when a fresh node is added. RT updates its information frequently impairing with existing sequence number.

OLSR

The OLSR protocol is a variation of the Link State protocols. OLSR use MPRs (multipoint relays) method to decrease the total number of broadcasting communication packet. Routing packet forwarding and the size of link state update packets, resulting in efficient flood of control packets in a MANET. The pure Intermediate Nodes protocol is optimised in two ways by OLSR. First, it reduces control traffic flooding by employing multipoint relays, i.e., using only nominated nodes to disseminate routing data packet. Second, by just announcing a subset of a links to its neighbours, it minimises the size of a control messages. As a result, OLSR significantly minimises network routing overhead and is especially well-suited to dense networks. However, the selection of MPR nodes results in an increased cost.

Reactive routing protocol

This protocol is designed to maintain routing information only when mobile station sends information data packet to the target node D (Patil et.al., 2010). In this technique, routing information is maintained only when required. Examples routingprotocols fall in this category: AODV Routing Protocol (Ad-hoc On-demand Distance Vector protocol) (Chirag et.al., 2014), DSR (Dynamic Source Routing protocol), and TORA Routing (Temporally Ordered Routing Algorithm) Protocol, etc.

AODV

This protocol is very familiar reactive routing protocol in the MANETs (Moudni et.al., 2016). It was designed to maintain two major aspects like discovery ofroute and maintenance of route in the network structure. During route detection mode,source node publishes RREQ (Route REQuest) communication packet to its entire neighbour node (Patil et.al. 2010). If neighbour mobile station has usable path to its D, then the communication Route REPly packet (RREP) is sent as acceptance message and source node begins sending packets (Moudni et.al. 2016). The route maintenance node, in case of failure sends RERR (Route ERRor) packet to S and also S again restart the new route detection process (Moudni et.al. 2016). In brief we have discussed in the end of the chapter.

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DSR

It is used to find a paths of source node S and destination nodes D.[1] It consists of two activities such as new route discovery process and old route maintenance process, it gives request to nodes for interaction with each other (Fouzan et.al. 2010). DSR enables multiple paths to any destination, so that load balancing can be achieved. In DSR, every node maintains routing information from S to D.[1] When data's are sent to D node, path is identified by route discovery process. The intermediate node list is maintained in packet header.

Hybrid unicast routing protocol

The mixed grouping of proactive and reactive routing protocol is definedas Hybrid unicast routing protocol.[1] Hybrid Routing Protocol uses proactive routing for broadcasting to nearby neighbour node and uses reactive techniques for sending data packets on the network to far away nodes (Wu et.al. 2018). The hybrid protocol examples are ZRP, ZHLS and CGSR (Cluster Switch Gateway) routing protocol (Hamela et.al., 2016) etc.

ZRP

It is combination of proactive routing and reactive routing protocols are designed by Zone Routing Protocol (Hamela et.al., 2016). The nodes which is placed outside the range of radio frequency works with reactive protocol. Proactive unicast routing protocol is used to identify route nearby neighbouring nodes. The routine is performed by two protocols namely IERP and IARP (Patil et.al. 2010). IERP means Inter Zone and IARP means Intra Zone. Data packets are directly moved from S to D within internal zone range. If D is outside the prescribed zone, then RREQ is sent to bordering nodes. If D destination is found in the bordering node then it replies through RREP message (Hamela et.al., 2016).

ZHLS

Zone based Hierarchical Link State its shortest form is ZHLS Protocol. The node identity (NID) and zone identity (ZID) serve as the foundation for ZHLS. With the help of node identity, NID and zone identity, ZID, each and every node identifies only the network connectivity within it's the prescribed zones. The two-link state protocols preserved by each node are data and communicate State and Zones Link State protocols (Moudni et.al.2016). The main benefit of this strategy is thatzone overlap may be avoided.

Multicast routing protocol

Within a single transmission, same copy of message can be broadcasted to group members using Multicast Routing Protocol (Pavithra et.al., 2014). It is classified into proactive, reactive and hybrid multicast routing.

Proactive multicast protocol

Multicast proactive protocol was maintaining the nodes of routing information of every node and updates the routing information continuously (Chirag et.al., 2014). It can be divided as Ad-hoc Multicasting Routing Protocol (AMRoute) and Multicast Open Shortest Path First (MOSPF) (Garnepudi et.al., 2013).

MOSPF

OSPF (Open Shortest Path First) is used as base of the Multicast Open Shortest Path First (Kaur et.al., 2013). To establish node information, it uses link staterouting. Minimum Spanning techniques are used to calculate shortest path between sender and receiver node. Link State advertisement (LSA's) packets are used tomaintain group membership table information between the nodes (Kaur et.al., 2013).

ADHOC multicast routing (AMRoute) protocol

One of the tree based proactive multicast protocol is AMRoute was proposed by Hamela et.al. 2015. It was established two-way directional path using shared tree mechanism. MZRP is used to create a tree. MZRP (Multicast Zone Routing Protocol), the first step is to look for nodes within the zone, and S sends a CREATE data packet to nodes inside its first round zone R1 complete unicast technique. The receiver node accepting the request sends ACK JOIN_REQUEST packets and by this method it can recognize all its neighbour nodes. Any member who wants to leave this group sends JOIN_REJECT packets to its neighbours. After sending JOIN_REJECT packets, it stops forwarding packets to its neighbours [Hamela et.al, 2015]. If routes are available between group members, a tree can be formed and maintained.

Reactive multicast routing protocol

When requirement occur to send the packet to destination address, the reactive routing protocol selects its route. Thus, on-demand routing takes place in reactive multicast protocol. Reactive multicast protocol can be classified into MAODV and ODMRP acronym On-Demand Multicast (Garnepudi et.al., 2013) routing protocol.

ODMRP

For each multicast group, it is utilised to create a mesh of nodes. A given the task and simulations protocol is used to add nodes to the mesh. In order to maintain gathering involvement, ODMRP uses a delicate state method. As a result, leaving the gathering with a bogus control message is not recommended. It is applicable. On- demand controls a process to avoid channel overhead. The ODMRP steering structure consists of two stages: solicitation and response. It uses two types of control bundles tostructure a transmitting network for multicast gathering: J-Query and J-Reply. In an network any node wants to send message or data, initially it sends a J-Query message propagate throughout the network (Azad et.al., 2009). A J-Reply is created when a J- Query packet reaches the multicast receiver. It checks if the next node address (Vigneshwaran et.al., 2015) of the accesses matches its own address (Azad et.al., 2009).

MAODV

It is very similar to AODV mechanism, only change is it support for Multicast Operation, MAODV operation is designed to provide minimal network utilisation, low processing and storage overhead, and quick response to dynamic connection circumstances (Hamela et.al., 2015). To find a route through which packets can be routed to all group nodes, MAODV uses a tree-based discovery mechanism.

Hybrid multicast protocol (HMP)

The advantage of tree and mesh based technique are interfered in the Hybrid Multicast Routing Protocol (HMP) is proposed in the paper Hamela et.al., 2015. The HMP has a protocol of type OPHMR (Optimized Polymorphic Hybrid Multicast Routing Protocol) (Afsane et.al., 2017).

OPHMR

The reactive routing and the proactive protocol technique are used as basis of this model. It is the efficient model used in term of vicinity

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density level, mobility level, and power remainder (Afsane et.al., 2017). It adopts the technique of ODMRP when it acts as reactive protocol. In a similar way, in case of proactive, it adopts Multicast Zone Routing (MZR) protocol(Kuang et.al., 2017). For obtaining optimize solution for efficient performance, it uses OLSR.

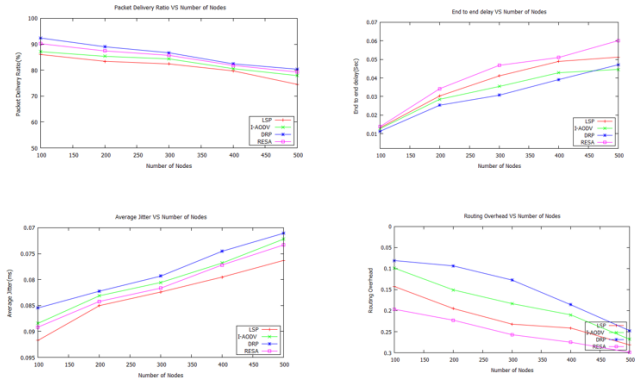
Scope of research

Objective and contributions

The major goal of this research is to enhance Unicast Routing Protocols in MANETs. A four-part approach is used to achieve the performance gains goal. The initial section of the inquiry focuses on the unstable Nodes. A Delegation Reliable Path (DRP) is based on the identification and deletion of unstable nodes from the MANET in order to increase characteristics such as Packet Delivery Ratio and Data Overhead in section 3.2. The second exploration is QRP - QoS based on Reliable Path given in section 3.3. Finest route selection is done based on smallest transmission time and reliable delivery. A minimum transmission time and reliable delivery are done by route discovery and forwarding data packets. The third part is to manage the battery power of the individual nodes participating in the MANET. Proper power management strategies will lead to effective and even utilization of the individual node's battery power. The success of the proposed strategies will lead to improved period of individual nodes and eventually overall lifespan of the MANETs gets improved. This improved lifetime will indirectly prove to be a real performance booster for MANET. The fourth part is analyzing and handling of the phenomenon called Fading. This Fading which causes sudden rapid variations in the signal strength will cause packet loss. Therefore the effects of Fading are analyzed and efforts are taken to contain the same.

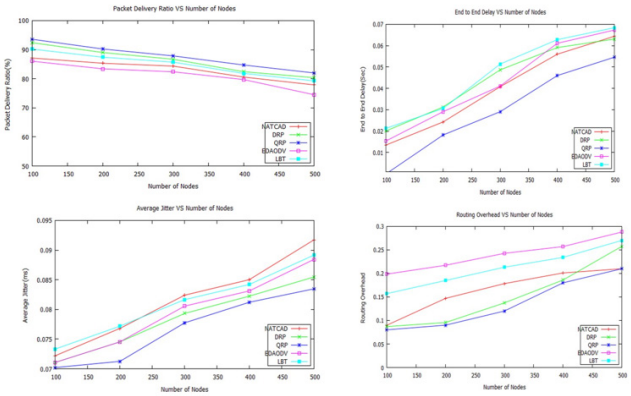
Delegation process for finding out reliable path (DRP)

The first investigation is about the unstable Nodes. In the case of instability nodes, a Delegation Reliable Path (DRP) is built on past path failed restoration. Route discovery and forwarding the data packets a comparative evaluation factor is I-AODV, LSP, RESA as compared to the DRP Routing Protocol.



QoS parameter based on reliable path (QRP)

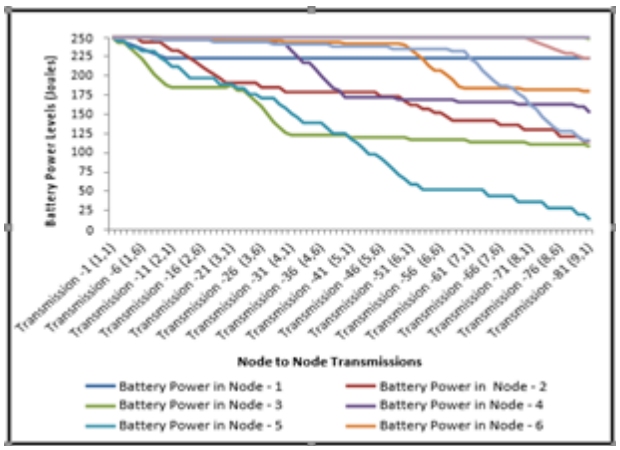
The second study is QRP. To find good path selection is done based on least transmission time and reliable delivery. A minimum transmission time and reliable delivery are done by route discovery and forwarding data packets. For route finding and data packet forwarding the comparative evaluation factor is NCTCAD, EDAODV, LBT and DRP as compared to the QRP Routing Protocol. Without any packet loss, a trustworthy delivery is obtained. Despite the lack of centralized control in MANET, it improves throughput. Resources such as energy consumption, bandwidth availability, and load - balancing are underutilized, resulting in poor network performance.



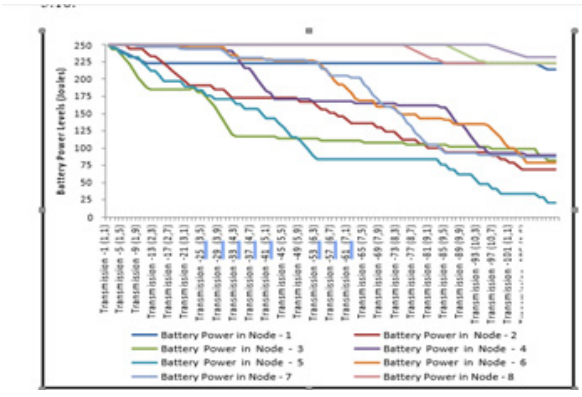
Battery management system (BMS)

As MANET nodes are working in energy constrained environment, the need to handle the battery power sources of all the nodes in a balanced manner is a vital part of all the protocols. New features are added to existing AODV protocol which helps to improve the lifetime of the network by power balancing. A detailed analysis is done and the results and conclusions are given.

Battery Power of nodes before BP-AODV routing



Battery Power of nodes after BP-AODV Routing



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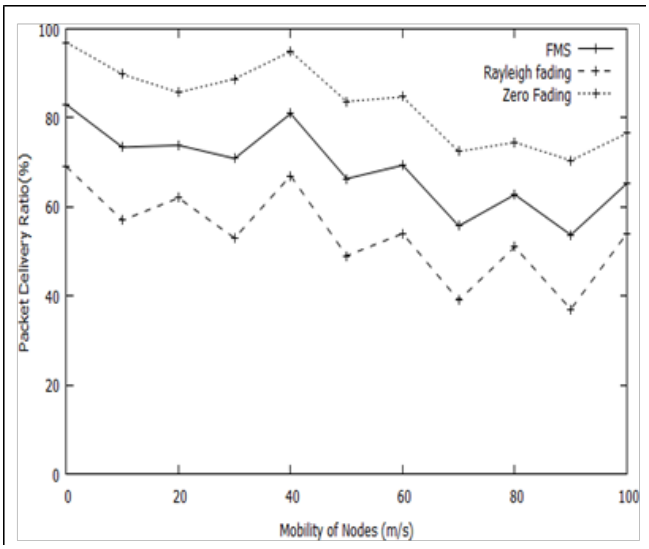
Fading management system (FMS)

Mobile ad hoc networks used in urban environment undergoes signal strength degradation phenomena called fading. This fading will result in packet loss, delay and frequent route searches. The frequent route searches will increase the network overhead and again increase the delay. This fading is analyzed through the Qualnet simulation tool and the comparison is done for three different types of fading.



An alternate path approach is suggested that will help in maintaining or saving the packet delivery ratio from going low. During the fluctuations caused due to fading, the data traffic needs to be rerouted through an alternate path. Then after some time the fading intensity tends to come down and the original route can be used again. Thereby the MANET would not miss the benefits of the best route selected. Thus the fading effects are tackled to maintain the packet delivery ratio.

Summary

Finally the conclusion is written with a brief account of the key benefits that can be achieved using the four performance improvement approaches. The exact performance improvement in the parameters selected is explained in detail. Future scope and possible strategies for further improvement are given. These suggestions can be taken up as further research to continue the performance improvement goals in MANET.

Performance evaluations

Qualnet Simulator used to simulate the QoS factor based on reliable route collection mechanism using AODV mechanism. In this model 500 nodes are traditional nodes are placed in the area size 1200 X 1000. In this model a wireless channel with IEEE 802.11 has been used by the MAC layer protocol. The parameter is used to create this scenario in Table 1 as follows.

Performance metrics

The four evaluation metrics utilized in the research work are as follows

PDR: It's characterized as proportion between effectively received packets and generated packets to those by CBR traffic source as seen in Equation (1).

$$\text{Packet Delivery Ratio} = P_{DN}/P_{SN} \quad (1)$$

Here PDN is the profitably received data's from destination and PSN generates data's by source.

Table 1 Simulation parameters

Parameters	Metrics
Execution Time	900 S
Total number of nodes	500 nos
Area Size	1200 X 1000
Layer 2 protocol	802.11
Signal strength	250 m
Traffic	CBR
Load	512 bytes
Deployment	Random
Mobility Model	RWP
Velocity	2 m/s
Flows	20

Average Delay: it is the time taken by information packet to reach target.

Average Jitter: it's characterized as variety in the delay of received packets. The latency is increased due to network congestion, incorrect queuing, or setup issues. The latency in between transmission in this steady flow of messages can change rather thanremaining constant.

Routing Overhead- A number of times Route Discovery (RD) happens again and again due to the node failure to Deliver Packets.[2–60]

Conclusions and future work

This experimental study work is done focusing on finding ways to improve the performance of on demand routing protocols in MANETs. Wireless MANETs are an upcoming technological expanse in the field of communication. MANET may become an alternative to infrastructure based communication. Due to the unique nature of MANET with respect to being infrastructure less, mobile with random movement it has various areas of improvement. Four areas are selected in this research and efforts are made to improve the MANET reactive routing protocols performance in those areas. The reactive routing protocol selected in this research is Ad hoc On-Demand Distance Vector (AODV) Routing. The proposed concepts of DRP, QRP, BMS and FMS applying the various factors are analyzed for the representation by effect of varying nodes in the fixed network area, effect of variation in Number of links with fixed nodes and effectof variation in unreliable node % with fixed area and mobile nodes in which the different parameters like routing overhead, packet delivery ratio, delay, and average jitter are analyzed and produce outcomes. The packet delivery ratio increases the node stability and link stability, which is considered as a reliable path. It reduces the routing overhead. If the number of reliable nodes is increased then the data delivery also increases.

The four parameters selected for performance improvement can be further analyzed and improved. In future various routing protocols will be applied to a combination of ant as well as bee's algorithm using Clustering in MANETs. It provides improved performance in the overall network. Additional feasible ideas are provided in the future scope. A genuine application of these concepts will be implemented and kept on improving the performance in MANET. Attempts can be made to further minimizing miss detection probability and reduce innocent node booking. Though public key encryption and decryption algorithms have not been incorporated here, it can be added as an

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additional layer of security. In addition, cross layer design could be exploited to improve the performance in all metrics.

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Conflicts of interest

The author declares there is no conflict of interest in this job.

References

1. Ahmad M, Ikram AA, Lela R, et al. "Honey bee algorithm–based efficient cluster formation and optimization scheme in mobile ad hoc networks*". International Journal of Distributed Sensor Networks*. 2017;13(6):15501477177.
2. Aslan S. A comparative study between artificial bee colony (ABC) algorithm and its variants on big data optimization. *Memetic Computing*. 2020;12(2):129–150.
3. Abolhasan M, Wysocki T, Dutkiewicz E. "A review of routing protocols for mobile ad hoc networks". *Ad hoc networks*. 2004;2(1):1–22.
4. Albayrak Z, Zengin A. Bee-MANET: "a new swarm-based routing protocol for wireless Ad Hoc networks". *Elektronika ir elektrotechnika*. 2014;20(3):91–97.
5. Aburada K, Morita K, Okazaki N, et al. "Proposal of a robust zone-based hierarchical routing method for ad hoc networks". *In 2006 Asia-Pacific Conference on Communications*. 2006:1–5.
6. Ahmed I, Tepe KE, Singh BK. "Reliable coverage area based link expiration time (LET) routing metric for mobile ad hoc networks". *In International Conference on Ad Hoc Networks*. 2009:466–476.
7. Ahlehagh H. "Techniques for Communications and Geolocation using Wireless Ad Hoc Networks". *Master of Science thesis*. Worcester Polytechnic Institute. 2004. p. 1–152.
8. Ali A, Shah GA, Arshad J. "Energy efficient techniques for M2M communication: A survey". *Journal of Network and Computer Applications*. 2016;68:42–55.
9. Anuja M, Shree SJ, Gobinath S. "Maximizing the Network Lifetime of MANET Using Efficient Power and Life Aware Routing Protocol", *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*. 2014;3(3):1028–1031.
10. Arvind S, Mytri VD, Attikeri S. "Power scheme for Ad-hoc on Demand Distance Vector routing for Mobile Ad Hoc Networks". *International Journal of Engineering Research & Technology (IJERT)*. 2012;1(5):1–4.
11. Asma A. "Energy Efficient Routing Algorithm for Maximizing Network Lifetime of MANETs". *International Journal of Innovative Research in Computer and Communication Engineering*. 2013;1(8):218–223.
12. Bai R, Singhal M. "Salvaging route reply for on- demand routing protocols in mobile ad-hoc networks". In Proceedings of the 8th ACM international symposium on Modeling, analysis and simulation of wireless and mobile systems. 2005:53–62.
13. Balakrishnan K, Deng J, Varshney PK. "TWOACK: Preventing Selfishness in Mobile Ad Hoc Networks", *Proc. of IEEE Wireless Communications and Networking Conference, New Orleans*. 2005;4: 2137–2142.
14. Biradar SR, Sarkar SK, Rajanna KM, et al. "Analysis QoS Parameters for MANETs Routing Protocols". *International Journal on Computer Science and Engineering*. 2010;2(3):593–599.
15. Bala A, Bansal M, Singh J. "Performance analysis of MANET under blackhole attack". *In First International Conference on Networks & Communications*. 2009. p. 141–145.
16. Basabaa A, Sheltami T, Shakshuki E. "Implementation of A3ACKs intrusion detection system under various mobility speeds". *Proc. of 5th International Conference on Ambient Systems, Networks and Technologies*. 2014. p. 571–578.
17. Bharathi M, Sairam R, Sundar S, et al. "Securing AODV Protocol from Selfish Node Attack". *ARPN Journal of Engineering and Applied Sciences*. 2015;10(12):5286–5290.
18. Blough DM, Santi P. "Investigating upper bounds on network lifetime extension for cell-based energy conservation techniques in stationary ad hoc networks". In Proceedings of the 8th ACM International Conference on Mobile Computing and Networking (MobiCom); 2002. p. 183– 192.
19. Broch J, Maltz DA, Johnson DB, et al. "A Performance Comparison of Multi Hop Wireless Ad- Hoc Network Routing Protocols". In Proc. of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM '98); USA. 1998. p. 85–97.
20. Buchegger S, Le Boudec JY. *"Nodes Bearing Grudges: Towards Routing Security, Fairness, and Robustness in Mobile Ad Hoc networks"*. In Proceedings of the 10th Euromicro Workshop on Parallel, Distributed and Network-based Processing; Spain. 2002. p. 403–410.
21. Buchegger S, Le Boudec JY. *Performance Analysis of the Confidant Protocol (Cooperation of Nodes: Fairness in Dynamic Ad-hoc Networks)"*. In Proceedings of IEEE/ACM Workshop on Mobile Ad Hoc Networking and Computing (MobiHOC), Lausanne; Switzerland. 2002. p. 226–236.
22. Buttyan L, Hubaux J. "Stimulating Cooperation in Self- Organizing Mobile Ad Hoc Networks". *Mobile Networks and Applications*. 2003;8:579–592.
23. Butun I, Morgera SD, Sankar R. "A Survey of Intrusion Detection Systems in Wireless Sensor Networks". *IEEE Communications Surveys & Tutorials*. 2014;16(1)266–282.
24. Cai Q, Zhou X, Jie A, et al. Enhancing Artificial Bee Colony Algorithm with Dynamic Best Neighbor-guided Search Strategy. In 2020 IEEE Congress on Evolutionary Computation (CEC). 2020. p. 1–8.
25. Chen X, Jones HM, Jayalath D. "Channel-aware routing in MANETs with route handoff ". *IEEE Transactions on Mobile computing*. 2010;10(1):108–121.
26. Camp T, Boleng J, Williams B, et al. "Performance Comparison of Two Location Based Routing Protocols for Ad Hoc Networks". *INFOCOMM IEEE*. 2002;3:1678–1687.
27. Chakeres ID, Belding Royer EM. "The utility of Hello messages for determining link connectivity". *Wireless Personal Multimedia Communications*. 2003;2:504–508.
28. Chakeres ID, Klein Berndt L. "AODVjr, AODV Simplified". *Mobile Computing and Communications Review*. 2002;6(3):100–101.
29. Chang RS, Chen WY, Wen YF. "Hybrid Wireless Network Protocols". *IEEE Transactions on Vehicular Technology*. 2003;52(4):1099–1109.
30. Chen TW, Gerla M. Global state routing: "A new routing scheme for ad-hoc wireless networks". In ICC'98 IEEE International Conference on Communications. Conference Record. Affiliated with SUPERCOMM'98 (Cat. No. 98CH36220). *IEEE*. 1998;1:171–175.
31. Cheng Z, Perillo M, Heinzelman WB. "General Network Lifetime and Cost Models for Evaluating Sensor Network Deployment Strategies". *IEEE Transactions on Mobile Computing*. 2008;7(4):484–497.
32. Chin K, Judge J, Williams A. "Implementation experience with MANET routing protocols". *Computer Communication Review*. 2002;32(5):49–59.
33. Das SK, Tripathi S, Burnwal AP. "Fuzzy based energy efficient multicast routing for ad-hoc network". Proc. of the Third International Conference on Computer, Communication, Control and Information Technology. 2015. p.1–5.

34. Demestichas PP, Stavroulaki VAG, Papadopoulou LM, et al. "Service configuration and traffic distribution in composite radio environments". *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*. 2004;34(1):69–81.

35. Dietrich I, Dressler F. "On the Lifetime of Wireless Sensor Networks". *ACM Transactions on Sensor Networks*. 2009;5(1):1–39.

36. Dube R, Rais CD, Wang K, et al. "Signal stability- based adaptive routing (SSA) for ad hoc mobile networks". *IEEE Personal Communications*. 1997;4(1):36–45.

37. Elkin M, Lando Y, Nutov Z, et al. "Novel Algorithms for the Network Lifetime Problem in Wireless Settings". *Wireless Networks*. 2011;17(2):397–410.

38. Fuchsberger. "Intrusion Detection Systems and Intrusion Prevention Systems". *Elsevier J Information Security Technical Report*. 2005;10(3):134–139.

39. Garcia Luna Aceves JJ, Spohn M. *"Source-tree routing in wireless networks"*. Proc. of Seventh International Conference on Network Protocols, Canada. 2002

40. Gong Z, Haenggi M. "Interference and Outage in Mobile Random Networks: Expectation, Distribution, and Correlation". *IEEE Transactions on Mobile Computing*. 2014;13(2):337–349.

41. Hellman K, Colagrosso M. "Investigating a wireless sensor network optimal lifetime solution for linear topologies". *Journal of Interconnection Networks*. 2006;7(1):91–99.

42. Hernandez Orallo E, Olmos MDS, Cano J, et al. "A fast model for evaluating the detection of selfish nodes using a collaborative approach in MANETs". *Wireless Personal Communication*. 2014;74(3):1099–1116.

43. Heydari V, Yoo. S. "E2EACK: An end to end acknowledgment based scheme against collusion black hole and slander attacks in MANETs*"*. *Wireless Networks*. 2016;22(7):2259–2273.

44. Huang Y, Lee W. "A cooperative intrusion detection system for ad hoc networks", Proceedings of the 1st ACM Workshop on Security of ad hoc and Sensor Networks; USA; 2003. p. 135–147.

45. Jeyarin PJ, Sheeba G. "Distribution of Channels for Communication in Wireless Sensor Networks". *Australian Journal of Basicand Applied Sciences*. 2014;8(17):552–558.

46. Joshi RD, Rege PP. "Implementation and analytical modelling of modified optimised link state routing protocol for network lifetime improvement". *IET Communications*. 2008;6(10):1270–1277.

47. Kang N, Shakshuki EM, Sheltami TR. *"Detecting Misbehaving Nodes in MANETs", Ad Hoc & Sensor Wireless Networks*. The 12th International Conference on Information Integration and Web-based Applications & Services (iiWAS2010); France; 2010. p. 216–222.

48. Kathirvel A, Srinivasan R. "Self umpiring system for security in wireless mobile ad-hoc network". *Journal of Wireless Sensor Networks*. 2010;2(3):264–266.

49. Kathirvel A, Srinivasan R. "A system of umpires for security of wireless mobile ad hoc network". *International Arab Journal of e-Technology*. 2010;1(4):129–134.

50. Kathirvel A, Srinivasan R. "Performance analysis of propagation model using wireless mobile ad hoc network routing protocols". *International Journal of Wireless Communication*. 2011;1(1):1–8.

51. Kathirvel A, Srinivasan R. "ETUS: enhanced triple umpiring system for security and robustness of wireless mobile ad hoc networks*"*. *International Journal of Communication Networks and Distributed Systems*. 2011;7(1–2):153–187.

52. Khokhar RH, Ngadi MA, Mandala. S. "A Review of Current Routing Attacks in Mobile Ad Hoc Networks". *International Journal of Computer Science and Security*. 2008;2(3):18–29.

53. Kim D, Garcia Luna Aceves JJ, Obraczka K. "Power-Aware Routing Based on The Energy Drain Rate for Mobile Ad Hoc Networks". *IEEE Transactions on Mobile Computing*. 2002;2(2):161–173.

54. Kirubakaran K, Kathirvel A. "Performance Improvement of Security Attacks in Wireless Mobile Ad Hoc Networks". *Asian Journal of Information Technology*. 2014;13(2):68–76.

55. Ko Y, Vaidya. N.H. "Location-Aided Routing (LAR) in mobile ad hoc networks". *Wireless Networks*. 2000;6:307–321.

56. Kouyoumdjieva ST, Karlsson G. "The Virtue of Selfishness: Device Perspective on Mobile Data Offloading". Proc. of IEEE Wireless Communicationsand Networking (WCNC). New Orleans; USA; 2015. p. 2067–2072.

57. Kumar A, Kadam V, Kumar S, et al. "An Acknowledgement- Based Approach for the Detection of Routing Misbehaviour in MANETS*"*. *International Journal of Advances in Embedded Systems*. 2011;1(1):4–6.

58. Sudha D, Kathirvel A. "The Effect of ETUS in Various Generic Attacks in Mobile Adhoc Networks to improve the Performance of AODV Protocol". *International Journal of Humanities, Law and Social Sciences*. 2022;9(1).

59. Sudha D, Kathirvel A. "An Intrusion Detection system to Detect and Mitigating Attacks Using Hidden Markov Model (HMM) Energy Monitoring Technique". *Stochastic Modeling & Applications*. 2022;26(3):9.

60. Sudha D, Ayyaswamy Kathirvel, Naveneethan S, et al. "AI Based Mobile Bill Payment System using Biometric Fingerprint". *American Journal of Engineering and Applied Sciences*. 2022;15(1):23–31.