A New Cross-Layer Protocol Based Ad Hoc Wireless Networks

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A grouping of two or more devices with networking and wireless communication capabilities is known as an ad hoc wireless network. These devices can communicate with any node within or outside of their radio range (peer-to-peer communication) by utilizing an intermediary node or nodes to relay or forward the packet from the source (sender) toward the destination (receiver).
In the framework of reactive routing, the goal of this paper is to design the Cross-Layer Ad Hoc Routing (KLAHR) protocol, which is utilized in multihop wireless ad hoc networks and implements the Route Discovery Phase and Send Data Phase methods.
The KLAHR protocol enhances the performance of ad hoc networks by utilizing cross-layer factors from the physical and network levels. A time-predicting technique is used in the Send Data Phase to start the Route Discovery Phase again before a transmission connection break is introduced due to node mobility. This reduces the number of transmissions required for broadcasting ROUTE REQUEST messages.
The obtained results concluded from building KLAHR protocol are: partial flooding of ROUTE REQUEST messages that give low routing overhead which is reduced to 22-34% and very good link reliability compared to the other protocols and position-based ad hoc routing protocols. The KLAHR is implemented by using Microsoft Visual Basic.Net 2015.

Keywords: Routing protocol, cross-layer, ad hoc wireless networks

1. Introduction

A network of mobile radio nodes without infrastructure, such as base stations, gateways, and access points, is called an ad hoc network.(Figures 1 and 2). Separating a network protocol into layers based on the OSI model is the traditional, accepted method of doing so. In wired networks with dependable communication channels, where the functionality of each protocol layers is independent of each other's state, this is an incredibly efficient method. The isolation of the layer results in suboptimal network performance for mobile ad hoc networks with dynamic topologies (if the radio channel is subjected to noise, interference, no line of sight, etc.). Ad hoc network protocols that are developed using cross-layer techniques provide the best possible performance. Assume that the cross-layer technique lacks joint layer management, intense information interchange between levels, and inter-layer separation.

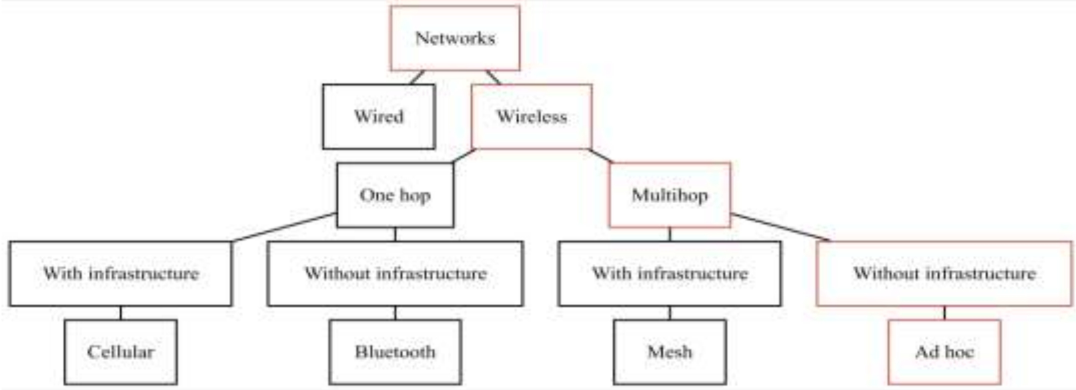


Figure 1. Classification of networks.

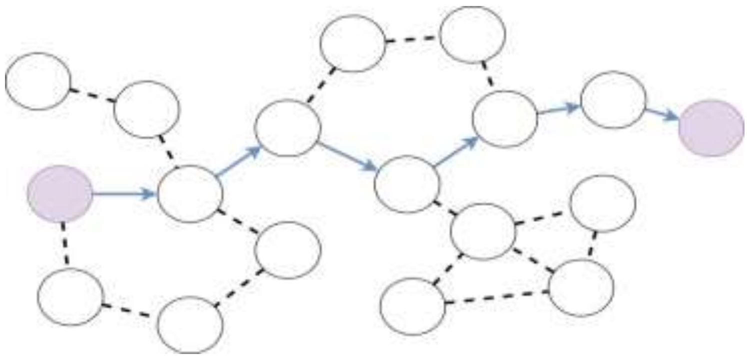


Figure 2. Ad hoc network.

The following characteristics of ad hoc networks exist[1]: Self-management. Networks are created by nodes, which oversee the network autonomously and dispersedly without the need for centralized intervention. As a peer network, every node serves as both a user and a router[1]. With constrained resources, all ad hoc network nodes are equivalent and carry out the same tasks [1]. Typically, ad hoc networks are made up of mobile devices with minimal memory, processing power, battery life, and network resilience. In contrast to the classic network's central router failure [2, 3], a network node's failure is unlikely to impact the network's overall performance. Nodes in a network move in relation to one another. Consequently, node connections and paths between nodes are shown [2,3], and the wireless line's ever-changing capacity is no longer constrained. Neighboring nodes, outside noise, multipath fading, doppler effects, and shared channel resources can all cause interference on radio lines [4]. Node congestion on channel resources, which results in a lack of dedicated channel resources, lowers network bandwidth [4], makes the network more vulnerable to assaults, and causes interference and packet collisions. In a traditional network, a single, strong firewall processes the entirety of one subnet's data; however, the firewall is unaffected by external threats. It is only aimed at the firewall. Every node in an ad hoc network is equally susceptible to outside attacks[5] and offers a substantial amount of service data needed for routing. Due to the ad-hoc network's dynamic topology, more service information—such as line status and other details must be sent than with static networks. Often, network fragmentation is used to determine network paths [4]. Ad hoc networks may become divided into separate subnets due to network mobility[4], which would complicate QoS provisioning. As a result of the unpredictable instability of radio lines, node interference, frequent route breakage, and delays in discovering new routes, it is very challenging to provide quality of service (QoS) in ad hoc networks [4]. The following domains frequently employ ad hoc networks [1]: military application. In a conflict zone, it is challenging to set up a cellular network; Nevertheless, an ad hoc network may set up very quickly for search and rescue missions. The infrastructure in a place is destroyed in the event of a disaster, Moreover, when conducting a search and rescue activities in remote, underpopulated places, there is initially no infrastructure. Ad hoc networks can be quickly deployed to provide distributed file sharing, instant search and rescue operations, and other features. A network can be swiftly set up during a conference or meeting to share files and presentations.

Cross-layer techniques enhance the performance of ad hoc networks by leveraging multi-layer interaction to collaboratively design protocols [6, 7]. The cross-layer strategy, in contrast to the layered OSI approach, permits interaction between layers, reading and changing the properties of certain other layers [8–11]. To ensure that several layers interact and are optimized jointly, cross-layer techniques have been developed [12]. To satisfy the demands of the application layer, the physical layer, for instance, can choose the data rate, power, and coding. Because energy consumption and latency are dependent on all layers, cross-layer design is also required to enhance end-to-end latency for real-time applications and extend battery life (minimize energy consumption).

2. Related works

This section goes on earlier analyses of cross-layer techniques in ad hoc networks.

The topic of Ad hoc network cross-layer routing protocols is covered by Azlan and others in 2017 [13]. The approaches that were studied and the metrics and layers that each method uses were put into a table by the authors. After providing an overview and discussing the issues of routing, a brief description of singlelayer routing is presented, with a particular emphasis on geographic routing. The details of cross-layer routing protocols are then covered. The paper goes on to discuss cross-layer design problems, cross-layer routing parameter selection, and some benefits and drawbacks of the current routing techniques. Lastly, a few unresolved research issues are emphasized regarding the creation of effective routing protocols in VANETs.

In 2019, Goswami and Sultanah [14] proposed a few methods to enhance TCP performance in wireless ad hoc networks. Wireless network performance is enhanced by cross-layer design, which exchanges data between multiple layers. In order to enhance TCP's performance, this study focuses on cross-layer techniques between the network layer and transport layer. They only pay attention to the transport layer (the changes made to the TCP protocol) and how the transport layer interacts with other layers to enhance the functionality of transport protocols.

In 2022, Vivek and Vijay [15] A hybridization framework with multiple layers is suggested. To create hybridization between various control channel design approaches, cross-layering has been done between the network and MAC layer. Generally speaking, control channel designs fall into two categories: specialized unlicensed out-band methods and licensed in-band methods. Through the intelligent use of the data channel as a control channel, the in-band control channel design solution complies with the criteria of CR technology. The in-band approach performs poorly as soon as the principal user activity in the data channels increases. However, even though the dedicated unlicensed out-band control channel design plan offers continuous availability and worldwide coverage, it is vulnerable to intruder attacks and channel saturation. The usage of out-of-band design is limited by interference in the control channel. This encourages writers to create a hybrid MAC protocol that allows access to the control channel by switching between licensed in-band and unlicensed out-band designs. CR nodes sharing a principal user free channel list (PCL) enables hybridization.

3. Overview of the Cross-layer Ad hoc Routing Protocol Proposed

A new physical-network cross-layer design is produced in this paper by utilizing an interaction between the physical and network layers with various pertinent characteristics, as illustrated in Figure (3). Next, an explanation of the new physical-network cross-layer design's impact is provided in order to put the suggested, highly effective ad hoc routing protocol into practice.

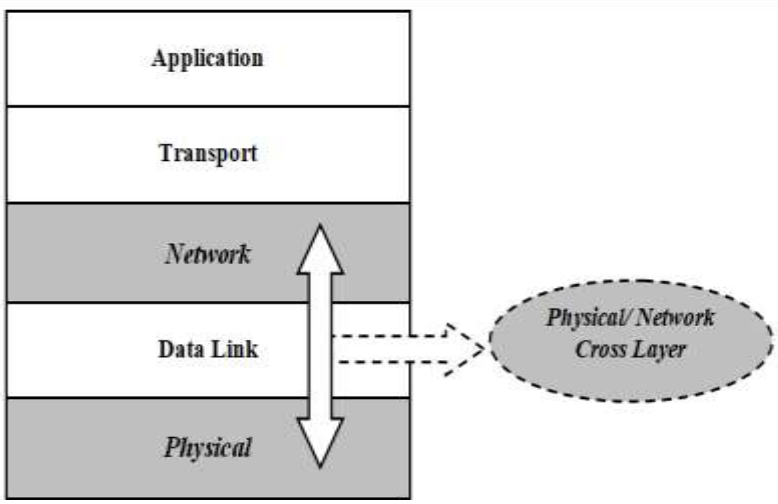


Figure (3): The suggested ad hoc network routing protocol's cross-layer design

As seen in Figure (4), the proposed Cross-Layer Ad Hoc Routing (KLAHR) protocol will incorporate two mechanisms for on-demand routing algorithms: the Route Discovery Phase and the Send Data Phase. The physical layer and network layer cross-layer characteristics are used by these two methods.

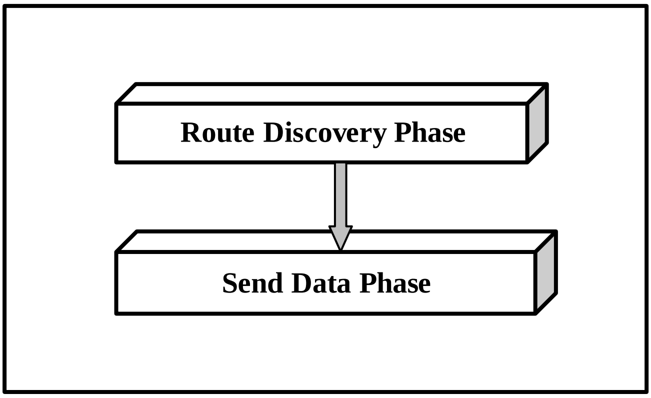


Figure (4): The Mechanisms for the Proposed Cross-layer Ad hoc Routing Protocol

4. Experiment Scenario

A. Assumptions

Every node in an ad hoc network has the same kind of wireless network interface when it is configured and deployed; this enables straightforward routing between nodes across any order of network nodes.

B. Ad hoc Network Model

It is believed that the network coverage area is circular. Peers can stay in the system while they are immobile or they can move around and enter or exit the system. The state of nodes in an ad hoc network is depicted in Figure (5), where they can be in an idle or active state for communication.

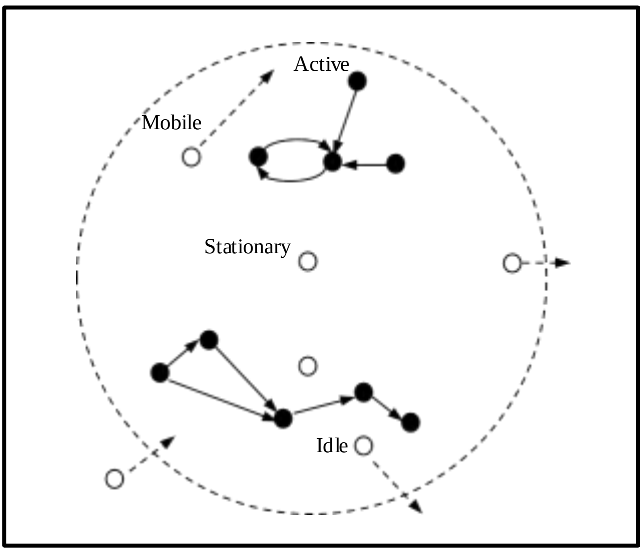


Figure (5): The State of Nodes in Ad hoc Network

The two most important characteristics in randomized techniques for ad hoc network mobility modeling are direction and speed. They can be regarded as independent of their prior values at any point when they change. Sharp variations are the outcome, and this is not how movement behaves really. Mobility models can be made more realistic by adding a degree of correlation with the prior values (speed and/or direction) and by making small changes over time.

The incremental model of mobility is employed in wireless ad hoc network experimentation, presuming a correlation between the speed and direction values in past and current intervals.

5. Implementing the Proposed Cross-layer Ad hoc Routing Protocol for multi-hop transmission

In wireless ad hoc networks, two communicating nodes must rely on multi-hop broadcasts when they are not within communication range of one another. Routing, also known as packet forwarding, is required in certain situations.

A. Rout Discovery Phase

Figure (6) depicts the interface of the ad hoc route discovery phase. In this network, the wireless ad hoc network topology is dispersed at random over a space of roughly 600 m2. Ten nodes with diversely connected hosts make up the wireless ad hoc network.

To begin the route discovery process, the user can enter the IP addresses of the source and destination nodes in the fields and click the start button. Any node on the map that the user presses will reveal its signal strength.

To find the route from (1) to (8), the user would press the start button, for instance, if the source node's IP address is node (1) and the destination node's IP address is node (8). There must be a path from node (1) to node (8) via the intermediary nodes as they are not within the same transmission range as node (1).

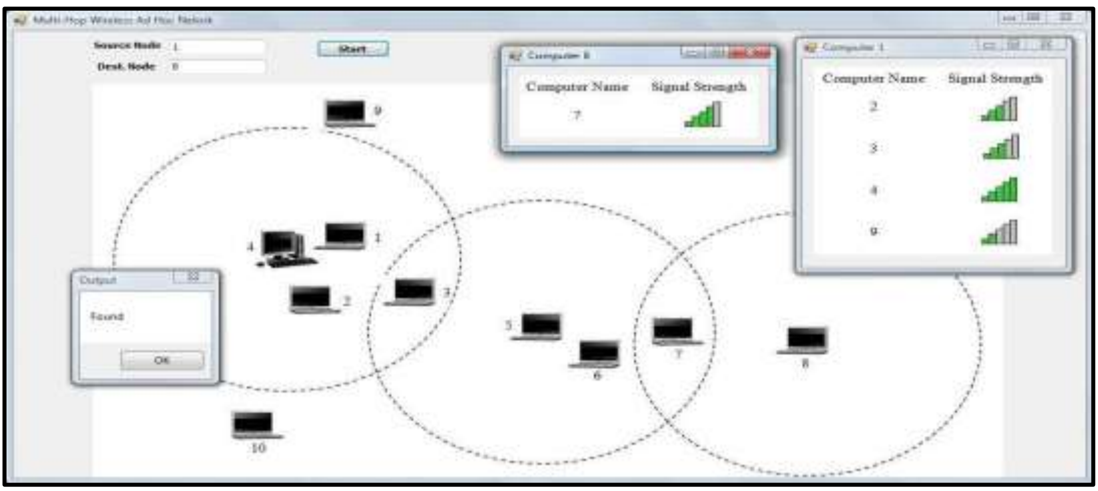
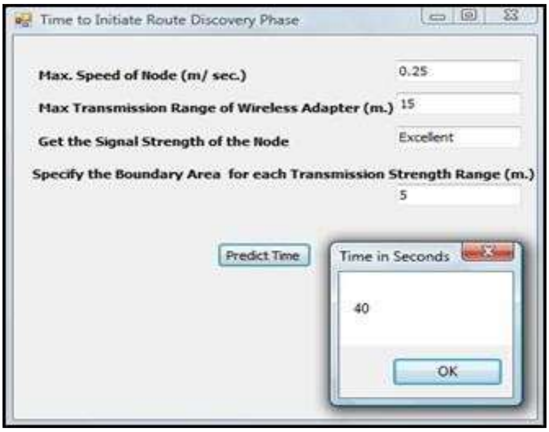


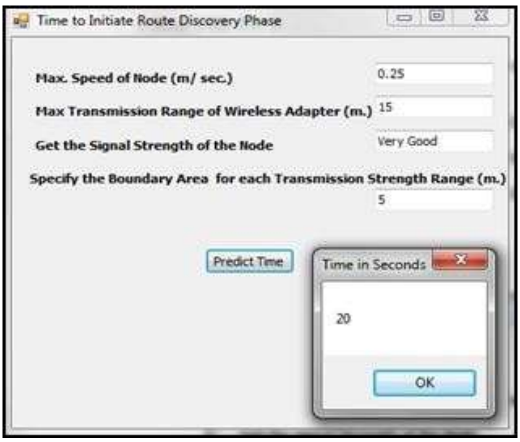
Figure (6): Ad hoc Map : The Interface of the Ad hoc Route Discovery Phase

B. Time Predicting

The time required to predict a link breakage to start the route discovery phase must be determined before the send data phase is put into practice. Figure (7) outlines the parameters that are utilized in the computation when a node has "excellent" and "very good" signal strength.



A



B

Figure (7): (A): Calculations for Predicating the Time to Initiate the B Route Discovery Phase for a Node that has "Excellent" Signal Strength (B): Calculations for Predicating the Time to Initiate the Route Discovery Phase for a Node that has "Very Good" Signal Strength

C. Send Data Phase

The data will be delivered via the wireless network and received by the destination receiver as indicated in Figure (10), once the sender user writes the message or data and presses enter, as illustrated in Figure (8).

Figures (8), (9) and (10) illustrate how blocking methods work. Multiple senders can send data to the same destination, but when one host starts sending, the others must wait until the first one is done.

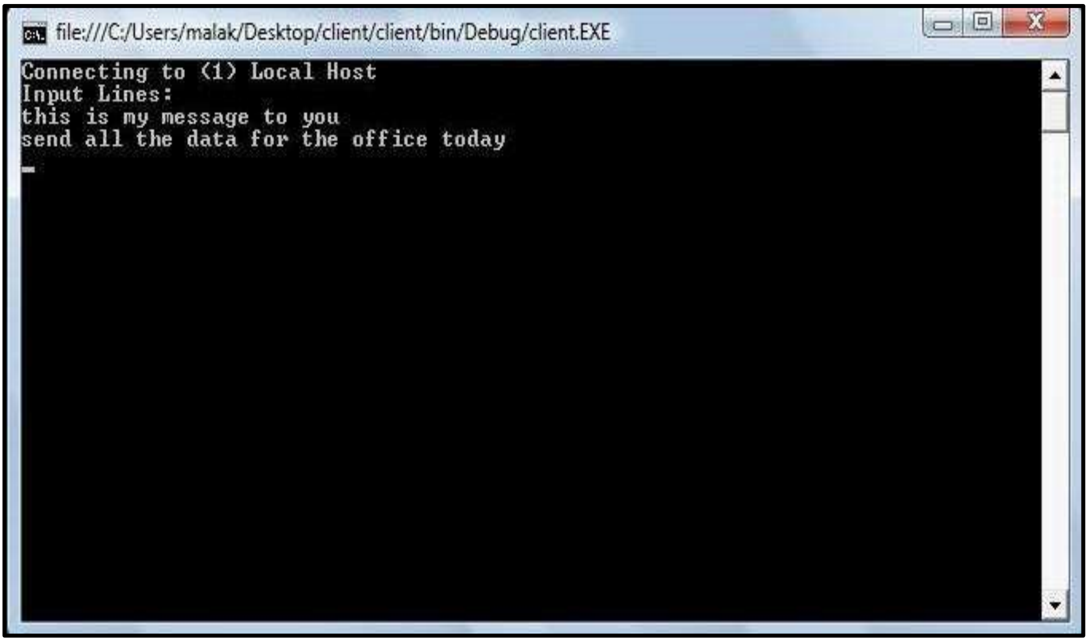


Figure (8): The Interface for the First User Host that will Send the Data

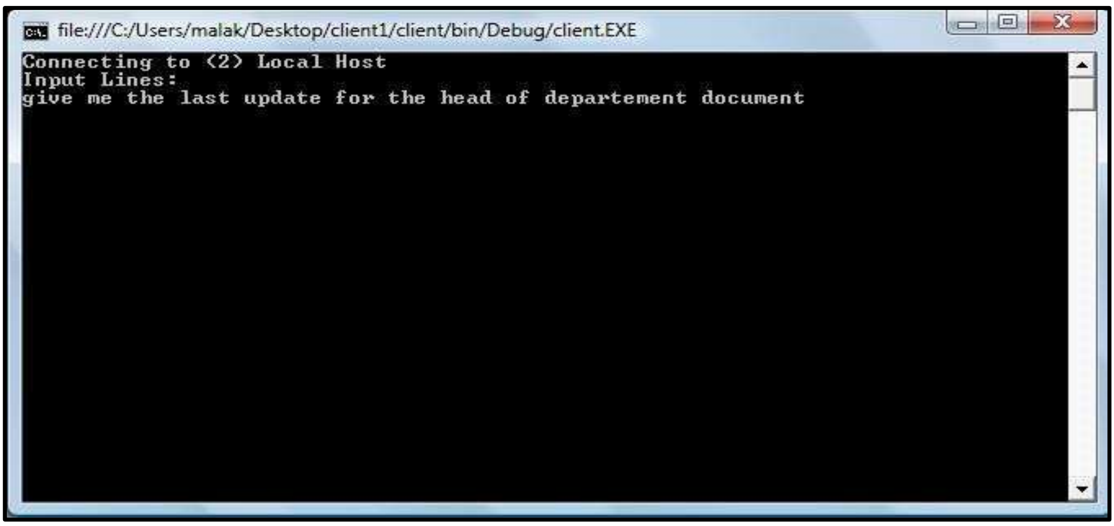


Figure (9): The Interface for the Second User Host that will Send the Data

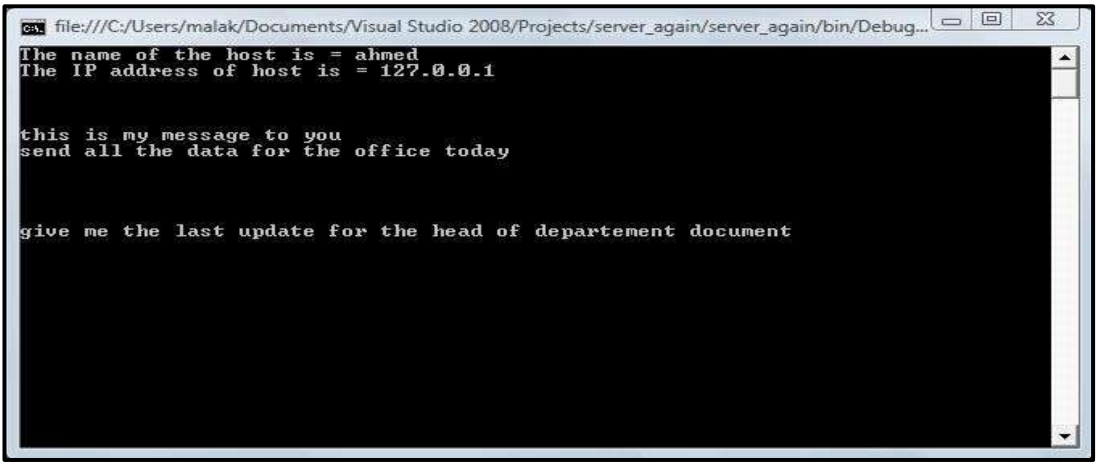


Figure (10): The Interface for the Third User Host that will Receive the Data from the First and Second Users

6. Results

The suggested ad hoc routing protocol is assessed using the following characteristics of ad hoc networks:

1. Flooding: A query dissemination method is typically implemented as part of the route discovery process. Numerous on-demand routing protocols now in use flood control packets, such as Route Requests, to discover a viable path that satisfies the necessary constraints. Control packet flooding results in a large traffic load, wastes bandwidth, and raises the frequency of collisions. High mobility and frequent topological changes may cause a broadcasting storm to occur.

Instead of choosing every neighbor node to broadcast ROUTE REQUEST messages, the proposed cross-layer ad hoc routing protocol optimizes the search space during the route discovery phase by choosing only some of the transmitting node's neighbors.

Table (1): Optimized Flooding for Ad hoc Map

Node no.	No. of Neighbor Used in KLAHR Protocol	No. of Neighbors Discarded in KLAHR Protocol
1	2	2
2	3	1
3	5	0
4	3	2
5	2	1
6	2	1
7	3	0
8	1	0
9	0	2
10	0	2
Total	21	11

When compared to the DSR routing protocol, which will deliver the ROUTE REQUEST messages to all of its neighbor nodes, the optimal flooding percentage is lowered to 34% in Table (1). This proportion is dependent on the overall number of nodes in the ad hoc network as well as the nodes' present topology, which varies depending on the node's location within the network and signal strength relative to the sending node.

2. Routing Overhead: The total amount of packets that are sent during the simulation in terms of routing. Each transmission of a packet (each hop) counts as one transmission when the packet is sent over several hops.

Less ROUTE REQUEST messages are used during the route discovery phase of the suggested cross-layer ad hoc routing protocol, which reduces routing overhead.

3. Link Reliability: This indicates how robust the link is in comparison to other connections between two nodes that will be utilized for routing.

Because nodes with weak or no signal are excluded from routing, the suggested ad hoc routing protocol is able to establish a dependable link. These nodes could break the transmitting node's range and create weak links, which means that when routing starts, the data would be lost. Additionally, the link dependability is increased by the forecasting time algorithm, which starts the route discovery phase before the link breaks when the send data phase starts.

7. Conclusion and Recommendation

It is demonstrated that there is no need to create a Route Maintenance Phase, as there is in other reactive routing protocols, by designing a cross-layer ad hoc routing protocol with two mechanisms: Send Data Phase and Route Discovery Phase, along with an algorithm to forecast when to commence Route Discovery Phase. By choosing partial neighbor nodes of the transmitting node rather than choosing all neighbor nodes for broadcasting ROUTE REQUEST messages when those neighbors' signal strengths are taken into account, the suggested cross-layer ad hoc routing protocol reduces the search space in the Route Discovery Phase. Because fewer ROUTE REQUEST messages are utilized during the Route Discovery Phase, the proposed ad hoc routing protocol reduces routing overhead. Routing yields a reliable link since KLAHR discards the nodes.

These nodes might move out of the transmitting node's transmission range, creating weak links that will cause the data to be lost when routing starts. Since KLAHR discards some nodes from routing, the overall number of neighbor nodes needed for broadcasting decreases, reducing the burden on the ad hoc network. A reliable path for data transmission is always found by the algorithm that determines when to start the Route Discovery Phase in the Send Data Phase before the communication link breaks.

In the future, we can use appropriate security mechanisms in the wireless network domain to protect the data from attackers and the ad hoc routing protocol. Alternatively, rather than using software tools, we might implement the wireless connection's signal strength as a hardware device and use the results as an input to the suggested methods. In another kind of ad hoc network, such as a Bluetooth ad hoc network, same suggested cross-layer ad hoc routing protocol with its two processes is also used.

References

1. Raza, N.; Umar Aftab, M.; Qasim Akbar, M.; Ashraf, O.; Irfan, M. Mobile ad-hoc networks applications and its challenges. Communications and Network 2016, 8, 131–136.
2. Kirubasri, G.; Maheswari, U.; Venkatesh, R. A survey on hierarchical cluster based routing protocols for wireless multimedia sensor networks. Journal of Convergence Information Technology 2014, 9, 19.
3. Sennan, S.; Somula, R.; Luhach, A.K.; Deverajan, G.G.; Alnumay, W.; Jhanjhi, N.; Ghosh, U.; Sharma, P. Energy efficient optimal parent selection based routing protocol for Internet of Things using firefly optimization algorithm. Transactions on Emerging Telecommunications Technologies 2021, 32, e4171.
4. Zemrane, H.; Baddi, Y.; Hasbi, A. Mobile adhoc networks for intelligent transportation system: comparative analysis of the routing protocols. Procedia Computer Science 2019, 160, 758–765.
5. Pandey, M.A. Introduction to mobile ad hoc network. International Journal of Scientific and Research Publications 2015, 5, 1–6.
6. Goldsmith, A.; Wicker, S. Design challenges for energy-constrained ad hoc wireless networks. IEEE Wireless Communications 2002, 9, 8–27. https://doi.org/10.1109/MWC.2002.1028874.
7. Alshbatat, A.I.; Dong, L. Cross layer design for mobile ad-hoc unmanned aerial vehicle communication networks. In Proceedings of the 2010 International Conference on Networking, Sensing and Control (ICNSC). IEEE, 2010, pp. 331–336.
8. Cruz, R.L.; Santhanam, A.V. Optimal link scheduling and power control in cdma multihop wireless networks. In Proceedings of the Global Telecommunications Conference, 2002. GLOBECOM'02. IEEE. IEEE, 2002, Vol. 1, pp. 52–56.
9. Merz, R.; Widmer, J.; Le Boudec, J.Y.; Radunovi´c, B. A joint PHY/MAC architecture for low-radiated power TH-UWB wireless ad hoc networks. Wireless Communications and Mobile Computing 2005, 5, 567–580.
10. Toumpis, S.; Goldsmith, A.J. Capacity regions for wireless ad hoc networks. IEEE Transactions on Wireless Communications 2003, 2, 736–748.
11. Neely, M.; Modiano, E.; Rohrs, C. Dynamic power allocation and routing for time varying wireless networks. In Proceedings of the IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428), 2003, Vol. 1, pp. 745–755 vol.1. https://doi.org/10.1109/INFCOM.2003.1208724.
12. Zorba, N.; Skianis, C.; Verikoukis, C. Cross Layer Designs in WLAN Systems; Troubador Publishing Limited, 2011.
13. Awang, A.; Husain, K.; Kamel, N.; Aissa, S. Routing in Vehicular Ad-hoc Networks: A Survey on Singleand Cross-Layer Design Techniques, and Perspectives. IEEE Access 2017, 5, 9497–9517. https://doi.org/10. 1109/access.2017.2692240.
14. Goswami, C.; Sultanah, P. A Study on Cross-Layer TCP Performance in Wireless Ad Hoc Network. In International Conference on Intelligent Data Communication Technologies and Internet of Things (ICICI) 2018; Springer International Publishing, 2018; pp. 56–70. https://doi.org/10.1007/978-3-030-03146-6_6.
15. Rajpoot V. , Tripathi V. , Cross-layer design based hybrid MAC protocol for cognitive radio network, Physical Communication Volume 50, February 2022, 101524.