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Location, Energy and Bandwidth Aware Routing Strategy (LEBARS) for Congestion Avoidance in MANET

Babangida Abubakar Albaba
Department of Computer Science, Umaru Musa Yar'adua University Katsina, Nigeria
Email: Babangida.abubakar@umyu.edu.ng

Abdulhamid Usman Nuruddeen
Department of Computer Science, Umaru Musa Yar'adua University Katsina, Nigeria
Email: usman.n.abdul@gmail.com

Abstract: *Due to the advancement and continues research in the area of networking, Mobile Ad-hoc Network (MANET) become one of the focus area of researchers. MANET is self-governing wireless framework which is one of the interesting research areas of networking, that promises connecting multiple nodes without need for a centralized infrastructure, also communication between nodes became possible through radio waves i.e. wirelessly. However, new devices can join, leave or move freely in the network due to the dynamic topological structure of the network. Despite several effort by researchers to enhance communication network congestion is still a challenging issue, many related works have been done on the field but still it need improvement. This research improves on Bandwidth Aware Routing Strategy (BARS) using Location Aided Routing (LAR) which equip nodes with Global Positioning System (GPS). The strategy avoids congestion by monitoring location, residual energy of the nodes and residual bandwidth capacity of the network links. The location, available and consumed energy, as well as available and consumed bandwidth worked out before transmitting packets. The Location, Energy and Bandwidth Aware Routing Strategy (LEBARS) uses feedback mechanism to direct the traffic source to adjust the data rate based on the location, availability of energy and bandwidth in the routing path. Number of simulations were performed using NS 2.35 on Ubuntu, where Tool Command Language (TCL) is used for configuring nodes, deployment, mobility and message initiation, using C language to modify the functionality of AODV. Results were extracted using Perl scripts from trace files, which proves the outperformance of the LEBARS over BARS in terms of Quality of Service (QoS) with Throughput, End-to-End Delay, Packed Drop and Packet Delivery Ratio of 695Kbps, 11ms, 15% and 85% respectively.*

Keyword: *Congestion Control; BARS; LEBARS; MANET; Data Rate; Link Capacity.*

1. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a type of mobile network in which nodes are independent to the central node, i.e., access point is not needed in MANET, which means nodes can freely move in order to leave or join the network [1]–[4], this ability of having right to move freely in the network brought what is called dynamic topology [5], [6]. The network uses wireless communication between devices, as ad-hoc network is in the category of wireless network [7], [8] it allows nodes that are new to the network to be added quickly [9]. The people that mostly used Ad-hoc network are constructors in construction area, military, or a meeting of chiefs at an outside area. In a conventional fixed structure network, to transmit an information from one node to another there is need for base station within the target node. In MANET, every one of these tasks were performed by the nodes themselves [10]. These devices can be Mobile Phones, Personal Computers (PC) MP3 Players, Smart Devices and much more[11].

Routing gives the best way to send information within a network. Nevertheless, routing protocol allows communication of routers by selecting the best path to send and receive information as well as processing the data packets. Routing protocols are categorized into (i) Proactive (ii) Reactive and (iii) Hybrid [12]–[14].

Proactive Routing: Also called table driven, in this type of routing protocol mobile nodes periodically update their routing table by exchanging information between the nodes. The major advantages and disad-

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vantages of this protocol is its faster connection due to availability of the path when ever need arise, and network overhead doe to constantly update of the network.

Reactive Routing: Also called Source Initiated, this protocol takes care of the route discovery and maintenance i.e. It behaves proactively when its outside the region and reactively when it came into the region close to its destination. Advantage of this protocol is its less overhead because the links are created on demand on the other hand there is a short delay when there is need for a link before it became available.

Hybrid Routing: This type of protocols acts as proactive and reactive at the same time. Therefore, they inherit the characteristics of both.

These protocols can solve both the problem of route discovery and maintenance.

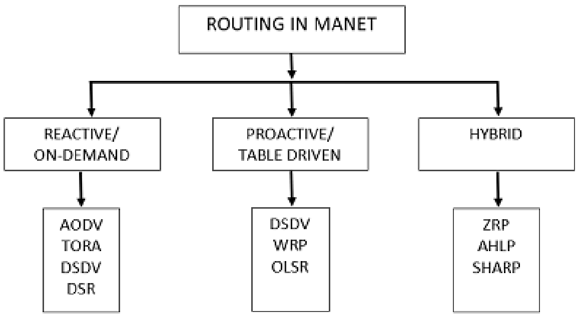

Figure 1 Routing Protocols in MANET

Congestion usually occur when too many packet are competing the same buffer pool in a switch/router, which increase the amount of network traffic [15]. Congestion is a condition in the networks when there are too many data packets present in the subnet which it cannot accommodate. Congestion occurs in a network when network carries more than what a link can accommodate (i.e., number of packets sent to the network). Network Congestion can lead to packet loss [16], [17], energy consumption [12] and bandwidth degradation[9]. Also, Overall network coverage area is affected due to congestion, because congestion does not overload mobile nodes in MANET. If the selected routing protocol is unable to handle congestion, it results to the following within the network [9].

Increase in delay: the time to deliver the packets will be prolonged, which is one the factors that congestion causes. In such situations, it is best to select an alternate path, although searching and changing to a new path is based on the routing protocol selected.

High overhead: When using multipath routing there is need for many processing. In order to select an alternate path if congestion occurs, there is need for a retransmission, which in the other hand causes high network overhead.

Increase in packet loss: the technique used in order to control congestion is to try as much as possible to minimize network load by dropping packets at the neighboring nodes or reducing transmission rate. The drawback of this method is an increase in packet drop ration which result in decreasing the network throughput.

This research presents a location, energy and bandwidth aware routing scheme, that uses the location of the node so as to adjust the transmission rate of the packets using the residual energy and bandwidth in order to avoid congestion in the network. Also, to test the performance of the proposed strategy, the strategy is implemented in NS2 simulator. Results shows that the proposed routing strategy outperforms the BARS in comparison. The main contribution of the research is as follows;

1) The scheme prevents congestion by adjusting the sending rate whenever network is near to congestion. The research is implemented by modify existing AODV as per location, available energy and bandwidth in the path and residual queue sizes of each node.
2) The proposed routing strategy modifies the RREQ and RREP messages of AODV by embedding location, energy, link bandwidth and queue size in it. Moreover, RERR message is also modified to handle path break.
3) For the provision of Quality of Service (QoS) to the routing strategy the location, energy and bandwidth were used and queue size as a metric for route selection.

The rest of the paper is organized as follows; Section 2 include literature review; Section 3 presents the proposed **LEBARS**. In Section 4, results and analysis were presented. Conclusion and future work are presented in Section 5.

2. REVIEW OF RELATED LITERATURES

Researchers are working tirelessly in order to improve, prevents or reduce network congestion which results in proposing many strategies so for.

A cache placement was proposed [18] by designing a delay-headquartered technique to alleviate delay constraints that gives a disturbed hybrid technique that reduces caching price discipline to the constraints. Three cache approaches were considered; cost based, delay based and hybrid. Despite that, the time it takes for separating the authorized users from unauthorized users may cause delay to the whole network or even congestion, also the energy consumed by the algorithm due to the extensive computation.

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A new congestion avoidance mechanism was proposed to improve load balancing by eliminating congestion after the optimal route is discovered, three mechanisms were enforced in the mechanism; detecting the congested node in order to prepare suboptimal path, update the suboptimal value and transfer data packets to the suboptimal path [19]. However, the protocol did not take into account the throughput parameter of the network, which means the protocol did not consider the successful data packet delivered at a given time.

Congestion control algorithm was proposed, that works by following the method of multipath protocol, that calculate the time frame of each node from sender to receiver, and select the best path with less chance of error [20]. However, the protocol ignores packet loss and end-to-end delay in computing their performance parameters, which might not be good if considered later, also the energy consumed by the nodes is not considered in the scheme.

A hybrid ant routing algorithm was proposed to ensure reliable throughput. The algorithm make use of ANT-like mobile agents, the proposed solution requires six elements; construction of solution, pheromonic updating table, local search mechanism, heuristic information, termination condition and selection of probability [21]. However, the scheme is dependent on the pheromones which leave a trace indicating that a particular node has an error, or there might be chance of congestion on a particular route, if the phorones are not working the whole scheme will cease to work, the work of the scheme is only limited to AODV.

An enhanced dynamic congestion detection and control routing on MAC layer algorithm was proposed, the algorithm uses a node threshold in order to detect the congestion nodes along the routing path and construct the congestion free route for data transmission [22]. However, it is obvious that the time it takes when finding the congestion free route, in order to forward data packets is long, which might cause delay to the scheme, which make the scheme more complex in nature.

Another approach that use a simple congestion control algorithm for mobility models was proposed, by designing an efficient congestion control technique, to reduce the amount of congestion in the network, by working on two congestion control algorithms Random Walk Mobility Model (RWM) and Levy Walk Mobility Model (LWM). The algorithm works by checking if the network is congested or not, if yes, then the intermediate node will inform the sender to limit his packets. If the problem is resolved then it is okay, if not, the algorithm will ignore the issue as it is another attack, not caused by congestion [23].

A congestion control metric called Resource Free Ratio (RFR) was proposed by considering the most recent parameters to provide congestion free route discovery. If a node dynamic buffer size, sending power and bandwidth are below a defined threshold during route discovery such nodes are avoided and discarded in order to balance the load on the network [24]. Despite that, the scheme is not compared with the traditional schemes that are available, which make superiority of the scheme unknown, there is need to compare the scheme with the available schemes in order to know the superiority of the scheme and the traditional schemes.

A technique based on back propagation algorithm was proposed to calculate error of each link from source to destination and select best path with minimum error using Boltzmann learning [25]. However, at a times the scheme is not sure of the cause of congestion, it just halts the data packets transfer and leave the problem as it is, also the mobility speed of the nodes most be at a controlled situation, otherwise increase in mobility speed might degrade the performance of the network.

An agent-based congestion control technique was proposed that collect information about the network congestion and distributed to the Wireless Agent (WA) nodes to help select a less loaded node to attain dynamic network topology [26]. However, the scheme is totally dependent on wireless agents (WA), when an agent fails to do its work, the system will crash or might not do what it is desired for, also the scheme ignores whether there is a packet drop rate or not.

A routing protocol that addresses congestion issues was proposed, that works by ensuring the availability of a primary path as well as alternate path, for reducing the route overhead. If congestion occur at any primary node the intermediate node will warns the previous node about the situation of the node, then the previous node will use the alternate non-congested route [27]. Despite that, the scheme might not be a good candidate for a network that make packet drop a crucial issue, because this scheme ignores packet drop along the route of packet delivery.

An adaptive congestion control method was proposed. The algorithm works by ensuring that it warns each previous node that appears on a route when there is congestion, to leads the previous node use non-congested route on the main route. It also helps the new route to avoid congestion by finding the less congested route by dividing the load and forwarding a portion to less congested route and reducing load to the congested route [28]. However, the scheme makes it obvious, that the protocol will work efficiently only in a heavy traffic, such as multimedia streaming, but in a lighter traffic the algorithm is not a suitable candidate.

A mobile agent-based framework routing and congestion control in MANET was proposed, by adapting the cross-layer design approach, were multiple intelligent agents deal with finding the efficient route from source to destination as well as controlling the congestion. The framework has three main modules; agent based congestion detection (ACD) that detect the con-

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gestion and inform the mobile agents based control aware routing (MACAR) which is based on AODV and uses a 'no return' policy and mobile agents based control (MACC) that takes the necessary action to resolve the issue, either by controlling, avoiding or doing both to solve the congestion [29]. Despite the effort of the researchers, the time it takes to forward data packet from source to destination is long, when the desired route is far from the sender, there are certain procedures to follow. Also, packet drop rate is neglected by the algorithm.

A novel rate-based end-to-end congestion control scheme was developed, to efficiently and reliably support the transport service in MANET. A sublayer is added under TCP to control the rate of transmission on the network layer feedback at the congested node. The traditional TCP suffers severe performance degradation and unfairness' due to poor interaction between the TCP and 82.11 MAC which leads to proposing this scheme by the researchers [30]. However, the scheme did not take into account packet delivery ratio, which even after the congestion is controlled there might be a chance of failure to deliver the data packets to the intended users. although the scheme utilizes network and has less packet drop rate.

A new approach was developed in order to decrease packet loss using dynamic path congestion estimation. The proposed protocol uses a new cross layer solution that make use of results of a route request process from routing protocol in order to early detect the end-to-end congestion and dynamically select the path with less congestion from source to destination. The protocol has two modification phases, on the destination node before generating the route reply message and at the sender during the connection[31]. However, the scheme might cause incomplete data packets delivery, due to the termination of connection before even congestion occurs, also for the algorithm to be effective, node dense of the network must be high, low node dense might degrade the algorithm performance.

An innovative routing algorithm based on Mobile Agent (MA) by focusing on the AODV routing protocol and enhancing the protocol based on mobile agent. Unevenly distributing flow density is one of the causes of flow congestion in MANET, in order to lessen this the scheme integrated mobile agents to update traffic density at each node of the network, which helps to reduce the traffic density of routes passing through the specific node over the sum of routes in the network[32]. However, even after the congestion occurs there is need to know about the situation of each node before updating the routing table about the condition of the network, which might cause delay and network overhead, it is also obvious that at small number of nodes the algorithm is not effective, it also ignores average latency.

Congestion aware multi-path routing protocol for load balancing in MANET was proposed based on demand of nodes to forward packet from source to destination, by using reactive route discovery technique and multi-path Dijkstra algorithm, the approach combine a multi-path routing protocol and load balancing concept in order to improve performance in the presence of congestion [33]. Despite that, it is obvious that the speed of the node must be at a certain condition between maximal and minimal for the algorithm to be effective, also packet drop rate and throughput where not take into account.

A cross-layer based congestion control scheme was proposed to reduce packet loss in a network, the scheme has four phases; cross design, congestion detection scheme, congestion control using cross-layer and new packet format. The work allows data to be shared between protocol layers dynamically to avoid dependency of physical and upper layers of traditional MANET[34]. However, the algorithm is very complex in the sense that any change makes enforce during design of the protocol stack when adding variety of layers can have effect on the whole system, which make it a very cautious approach when dealing with cross-layer design.

A link failure and congestion aware reliable data delivery mechanism that increases data delivery performance. Upon detecting link failure, a route destination notification (RDN) was created and send toward source node, by receiving the RND all intermediate nodes will stop delivery of data packets and store the incoming packets in their local transport layer queue and wait for a new partial path to the destination. When routes are found, another message is sent to the source called route successful notification (RSN) in order to resources transmission. Nevertheless, the algorithm uses local buffering at transport layer and multi-level congestion detection and proactive control [35]. However, there is an incomplete data delivery by the scheme, upon receiving Route Destination Notification (RDN) message, all nodes halts from delivering packet to the desired destinations.

Another technique was proposed to control congestion in MANET using mobile agents. In the proposed work, information about the network is collected and distributed by Mobile Agents (MA). When routing through the network, mobile agents can help the node select a less-loaded route and transmit packets. In this technique a node is categorized as one of the four classes depending on the traffic belongs to; background, best effort, video and voice [36]. However, it is obvious that the scheme is entirely dependent on Mobile Agents (MA), when an agent or multiple gents are down another issue might arise, that can even lead to whole network breakage.

A predictive congestion control mechanism for MANET was proposed to avoid congestion from occurring from the first place, by dealing with congestion through discovering the alternate path bi-directionally. Also, every node warns its neighbours about the situa-

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tion of the current node before congestion based on the three zones; safe zone, likely to be congested and congested zone respectively [37].

A work to improve the performance of TCP using signal strength based cross layer approach, was proposed which assumes resolves congestion. The work enhanced packet losses by halting transmitting of packets and keeping the link alive until the packets arrived at their desired destination. It checks for congestion by considering inter packet delay and short-term throughput using (RSD) relative sample density technique [38]. However, due the splitting packets into two halves, when forwarding it may lead to delay, because of the time it takes for calculating the congestion before taking action which may lead to another delay.

An improvement over route discovery of the AODV was proposed to avoid congestion. The protocol works by selecting route on the basis of traffic load on the node and resets path as the topology changes. It transmits data by finding new efficient paths from time to time instead of transmitting the entire data through one route. The proposed algorithm shows an improvement over the traditional protocol by retaining the link for 38 seconds before the link expires [39]. However, the scheme only works good for a connection that requires long lifetime and multiple routes for delivering data packets, reverse of that leads to network overhead and lack of network utilization.

A solution to the traditional AOMDV failure was proposed to provide solution to the congestion and load balancing in a network, by incorporating the idea of queue length and hop count, to select route from source to destination. When the queue length meats a constraint, load balancing will be conducted through alternate route. Also, broadcasting of route request will be avoided if route is already congested by the intermediate nodes. They also consider the queue length of each node in order to avoid congestion and balance the load [40]. However, establishing multiple routes by the scheme come with a cost, which leads to an average delay to increase, as well as network overhead by trying to extend the lifetime of the links after the successful delivery of data.

Akhtar et al. Proposed an algorithm that works by giving a notification about the status of the of the bandwidth that the current network can accommodate in order to avoid congestion [9]. Despite that, energy of the nodes is not taken into consideration.

A cross layer congestion control approach was proposed using fuzzy logic control congestion by using behavioral model for detection and fuzzy system for correction [41]. However, the time it takes for calculating the route distance before sending data packets on the routes is much, which may lead to a longer delay, also the scheme is very complex due to an intensive computation needed before taking an appropriate action to control congestion.

2.1 Literature Review Matrix of Some Selected Papers

The table below outline the strength and weaknesses of some of the previous works based on ad-hoc on-demand distance vector (AODV):

TABLE I LITERATURE REVIEW MATRIX

Protocol	Description	Strength	Weakness
RBCC [30]	*It is rate-based transport control scheme (MANET).	*It utilizes network accurately *It has less packet drop rate	* It ignores the packet delivery ratio
ABCC [36]	*It is an agent-based congestion control (MANET) *Based on AODV protocol	*Good in load balancing *Has high delivery ration	*Dependents on mobile agents *Complex in nature
ABCC [26]	*It is a congestion control scheme (MANET) *Based on AODV	*High delivery ratio *Good at selecting minimum congested route.	*Ignores packet drop *Dependent on wireless agents (WA)
FCLCC [41]	*It is a fuzzy cross layer congestion control (MANET) – Based on Fuzzy Logic.	*It is good at routing packet before sending. *Good congestion control policy.	*It consumes time before sending packet *Very complex.
CCWMN [18]	*Congestion control in wireless mesh network *Based on AODV	*Good at separating authorized and unauthorized users *Minimum query delay and maximum data availability.	*Delay due to separating users *Energy consumption
CCCT [20]	*It is an improvement of congestion control (MANET) *Based on AODV and cryptography technique	*It provides security against active attack *Good throughput and packet delivery	*It ignores packet loss and end-to-end delay *Energy consumption.
BARS [9]	*It is a congestion avoidance	*Knowing situation of link before	*Dependent on hello message

	for smart devices (MANET and IoT) *Based on AODV	sending request *Efficient congestion avoidance scheme.	*Energy consumption is not considered.

2.2 Problem Formulation

Despite effort of the researchers in locating and finding lapses and gaps, and trying their best in order to fill them, many gaps were left unattained. Such as, end-to-end delay, packet drop, packet delivery, throughput and many other noticeable issues might arise.

BARS is one of the newly proposed protocols that is mainly for avoiding congestion before even it occurs, and has good policy of knowing the situation of the link before even sending request to the neighboring nodes requesting a path to forward a data packet. It is concluded that a certain percentage is achieved on the parameters of throughput, end-to-end delay, packet drop rate and packet delivery ratio. Due to the increase in need of high-speed network and successful data delivery as well as periodic increase in communication devices, that might case network congestion due to the exchange of information from heterogenous devices, which make BARS and ideal candidate for such a huge task.

Our main concern for this work, will be enhancing the BARS [9], based on AODV protocol for congestion control, in order to improve the end-to-end delay, throughput, packet delivery ratio and packet drop rate.

3. LOCATION, ENERGY AND BANDWIDTH AWARE ROUTING STRATEGY (LEBARS)

In this section, an efficient Location, Energy & **B**andwidth **A**ware **R**outing **S**trategy (LEBARS) for identifying path between sender and receiver was presented. The Location, residual Energy, available bandwidth and residual queue size were analysed to decide about recommending a suitable location, energy & bandwidth value for data exchange. The following features were worked in the AODV.

1) Ability to equipped all nodes with G.P.S, and estimate energy of the nodes. The source node will have a knowledge of coordinates of destination node as well as the available energy.
2) Estimate the transmission range and energy of the nodes in order to make choice if the destination is within quadrats toward the destination or not.
3) The route recovery process immediately performs route recovery whenever there is a broken route in network.

To implement the proposed method, all nodes will have knowledge about the current location, residual bandwidth and energy of the nodes of all links along the path. The work is divided into two parts as illustrated in Figure 1 and notations were listed and presented in Table II.

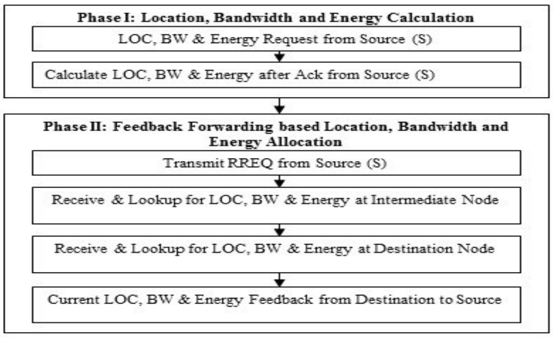

Figure 2 Main Phases of LEBARS

TABLE II LIST OF NOTATIONS FOR LEBARS

Notations	**Description**
N_i	Sender Node
N_j	Neighbor Node
Ts, Tr	Sending and Receiving Time
Ack	Acknowledgement
P_{size}	Total Packet Size
T	Time difference of Tr and Ts
BW_{Res}	Residual Bandwidth
$BWcon$	Bandwidth Consumed
t_{ib}	Time Period for Bandwidth
sid	Session Identity
α	Weightage of Residual Bandwidth
Dest	Destination Node
Sn_id	Sensing Node ID
seq_num	Sequence Number
Last_BW	Last Bandwidth used at source
BW_Rec	Bandwidth Calculated on Ack Receive
hop_{count}	Hop Count in the path
LOC_{cur}	Current Location
LOC_{pre}	Previous Location
Last_LOC	Last Location at Source
LOC_Rec	Location Calculated on Ack Receive
NGR_{Rem}	Residual Energy
NGR_{con}	Energy Consumed
t_{ie}	Time Period for Energy
σ	Weightage of Residual Energy
Last_NGR	Last Energy Used at Source
NGR_Rec	Energy Calculated on Ack Receive

3.1 Detailed Stage of LEBARS

1. The proposed research aims at enhancing BARS, to make use of Location Aided Routing (LAR). It is well known that, if any node forwards the data over a longer distance, it would take time and consume energy for the successful transmission. Therefore, nodes in mobile Ad-hoc networks are assumed equipped with Global Positioning System (G.P.S) and the source node has the knowledge of coordinates of destination node.

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2. According to this concept, the nodes in mobile ad hoc networks are assumed equipped with Global Positioning System (G.P.S) and the source node has the knowledge of coordinates of destination node.
3. While forwarding the Route Request (RREQ) packet the node will forward the information about location coordinates of the destination to the neighbor node.
4. Upon receiving the destination coordinates, nodes can make a choice if they are located in quadrant towards destination or not. If any node is located outside the quadrant, it will not forward the RREQ packet.
5. Therefore, in the proposed scheme, if any node has less bandwidth and energy available then it would transmit the packet over a lesser distance. The transmission range would be adjusted according to residual bandwidth and energy of the nodes.
6. When destination receives the RREQ packet, the destination node will sort out the path according to: a highest available bandwidth, highest battery level, least hop count, least delay and least speed of intermediate nodes.
7. The destination will reply to source node via best optimized path through which the source node will send the data.

The algorithm for the broadcasting of the Route Request packets, which includes changing the transmission range according to the location, available energy and available bandwidth of the nodes, has been described below:

3.2 Pseudocode: LEBARS

1. *N_i: Set source id (sid) and destination id (destid) {N_i is intermediate node}*
2. *N_i: if the immediate cache update takes place then set communication type to Unicast else to Broadcast*
3. *N_i: set values in reply header*
4. *$N_i \rightarrow N_j$: equip nodes with G.P.S, transmit residual energy and bandwidth request and save values of transmission time and location of number of message retransmissions*
5. *N_j: receive message & extract data*
6. *$N_j \rightarrow N_i$: transmit location, residual energy & bandwidth response*
7. *N_i: receive response message and calculate distance between N_i& N_j*
8. *N_i: calculate Queue utilization-based location, residual energy and bandwidth*
9. *N_i: set location, energy and Bandwidth between N_i and N_j*
10. *S: Assign requested **LOC, NGR & BW** and related parametric values*
11. *S: **if** sn_id AND Last location are NULL **then***
12. *   **if** sn_id & Dest Not in RT via Lookup **then***
13. *   Set requested LOC**,** NGR&BW and last_LOC**,** last_NGR & last_BW to 0*
14. *   **else** Discard the Request **endif***
15. *   **else***
16. *   Lookup for Data Rate for the Destination in **RT***
17. *   Set requested LOC**,** NGR**,** BW and last_LOC, last_NGR, last_BW to Data Rate*
18. ***endif***
19. *$S \rightarrow N_i$: Transmit **RREQ** message towards Dest*
20. *N_i: Lookup route between currNode and Dest*
21. *N_i: if Dest is not neighbor AND currNode != Dest **then***
22. *   Find neighbor where Current**LOC,** Residual **NGR, BW**> Requested **LOC, NGR, BW***
23. *   **elseif** Dest is not neighbor **AND** currNode not Dest*
24. *   Set location, Energy & bandwidth of Node by Look up in neighbor List*
25. *   **else if** Dest is not neighbor*
26. *   Set location, energy & bandwidth of node by Lookup in Neighbor List*
27. *   **end if***
28. *N_i: **If** CurrNode is Not Dest **then***
29. *   **If** sn-id and Dest found via Lookup **then***
30. *   Save Dest, source, sn_id last_**LOC**, last_NGR & last_BW in repository*
31. *   Update last_**LOC**, last_NGR & last_BW by Lookup for source*
32. *   Set src_adrs to CurrNode,*
33. *   Set hop count, seq_num*
34. *   **Else***
35. *   Update sn_id and set src_adrs to CurrNode*
36. *   Update hop count and seq num.*
37. *   **End if***
38. *   **Else if** CurrNode is Dest*
39. *   **If** sn_id and Dest ID found via Lookup **then***
40. *   Update seq_num, last_**LOC**, last_NGR & last_BW*

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*Save Dest and src ID, sn_index, last_**LOC**, last_NGR and last_BW*
*Send response to source where **LOC**, NGR & BW= last_LOC, last_NGR & last_BW*
Else
***LOC**_Rec, NGR_Rec & BW_Rec = Current_LOC, Residual_NGR & residual_BW/ hop_{count}*
***LOC**_Rec, NGR_Rec & BW_Rec = Evaluate, Adjust residual Queue size*
IfLOC**_Rec, NGR_Rec & BW_Rec is not within the quadrat and less than the requested NGR & BW **then
Update seq_num, Send to source
*Set **LOC**, NGR & BW to **LOC**_Rec, NGR_Rec & BW_Rec*
Else
Update seq_num, save Dest and src ID, sn_index
*Send response to source where **LOC, NGR & BW**= **LOC**_rec, NGR_Rec & BW_rec*
End if
End if
S: lookup for route to Dest and transmit packet

3.3 Simulation Environments

Network simulator NS2.35 has been used to test the performance of proposed scheme. The radio propagation model is Two Ray Ground while Queue type is Drop tail with maximum length of 50 packets. Transmission range is set to 250m and interference range is set as 550m. Constant Bit Ratio (CBR) is used as the type of traffic flow which streams over User Datagram Protocol (UDP) with packet size of 1024bits. Location, energy consumption and residual bandwidth is achieved by modifying the existing implementation of Ad-hoc On-demand Distance Vector (AODV) in C language. Location, energy consumption and the residual bandwidth is being monitored and then shared to the above layers. During simulation mobility was considered in transmitting the CBR using UDP. Number of simulations were performed to test the performance of the proposed scheme by changing number of mobile nodes from 10 to 50, and packet size of 1024b. Parameters of proposed LEBARS are shown in Table III by varying number of nodes and packet size, comparison have been made with the previous work [9].

4. RESULTS AND ANALYSIS

In this section, simulation parameters and results were presented.

4.1 Network Model of the Proposed Work

Simulation scenario consists of 10 to 50 nodes placed in random manner. number of simulations were performed on mobile (dynamic) network topologies, our algorithm was evaluated using mobility in nodes. Comparison of this work with [9] have been made by varying number of nodes and packet size.

TABLE III SIMULATION PARAMETERS

Parameters	**Value**
Simulation Time	1000s
Number of Nodes	10 - 50
Network Region	1000m × 1000m
Transmission Range	250m
Packet Size	1024b
Routing Protocol	AODV
Mobility Model	Random Way Point
Traffic Type	Constant Bit Rate (CBR)
MAC	IEEE802.11
Data Rate	2048 – 10,240 bits/sec

4.2 Throughput

Throughput is the number of packets acknowledge at destination at a unit time, it is normally measured in Kbps. Represented mathematically as:

$$Throughput = \frac{Number\ of\ Received\ Datapackets \times Packet\ Size\ in\ bits}{1000} \quad (1)$$

Fig.3 elucidates the throughput where packets transmission is varied from 1000 to 2000 bits per second. Results show that by increase in packets transmission throughput also increases. Throughput is also inversely proportional to congestion in network. In the proposed scheme, congestion is being handled successfully that's why throughput of the proposed scheme is much greater than BARS. Results depict that average throughput is 600 kbps and 695 kbps in BARS and LEBARS respectively for a packet transmission of 8000 bits/sec. Results proves the outperformance of LEBARS.

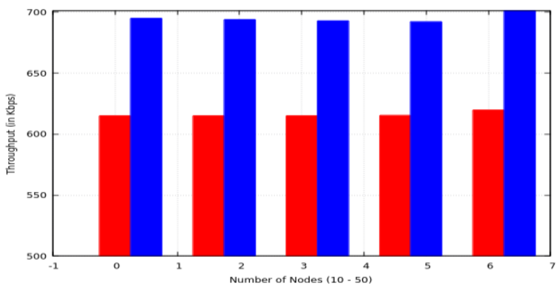

Figure 3 Throughput

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4.3 End-to-End Delay

Average End-to-End Delay is the packet receiving time over the packet sending time. It can be mathematically expressed as:

$$End\_to\_End\ Delay = Packet\ Receiving\ Time - Packet\ Sending\ Time \quad (2)$$

Fig.4 illustrates the impact of packets transmission on end-to-end delay. Thus, increase in packet loss increases number of re-transmissions which results in increase in end-to-end delay.

In the proposed scheme number of packet drop have been reduced by controlling packet transmission on basis of location, available energy and available bandwidth of the nodes. This packet controlling method avoids congestion which ultimately reduces delay in network. It elucidates that for a packet of 8000 bits/sec, average end-to-end delay is 18ms and 11ms in BARS and LEBARS respectively. In this scenario LEBARS outperform the counterparts in end-to-end delay.

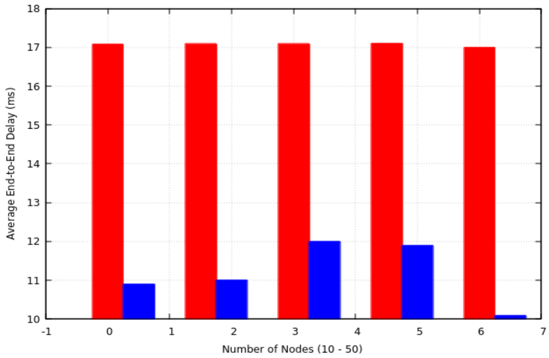

Figure 4 End-to-End Delay

4.4 Packet Delivery Ratio

Packet Delivery Ratio is the number of received data packets by number of sent data packets. It can be mathematically represented as:

$$PDR = \frac{Number\ of\ Received\ Datapackets}{Number\ of\ Sent\ Datapackets} \quad (3)$$

Increase in packets transmission effects negatively on packet delivery. In BARS scheme when packet transmission increases packet loss become higher due to frequent overflow of queues. While in the proposed scheme packet transmission on the basis of location, available energy and available bandwidth was adopted rather than queue.

Number of packets drop have been observed in the proposed scheme which is much less than that of BARS scheme. Fig.5 elucidates the impact of packets transmission on packet delivery ratio for mobile nodes. Proposed scheme provides rapid path re-establishment right after dis-connectivity between mobile nodes. It indicates that packet delivery ratio is 79.90% for BARS whereas in case of the proposed scheme it is 85%. Results show that the proposed scheme outperforms the counterparts.

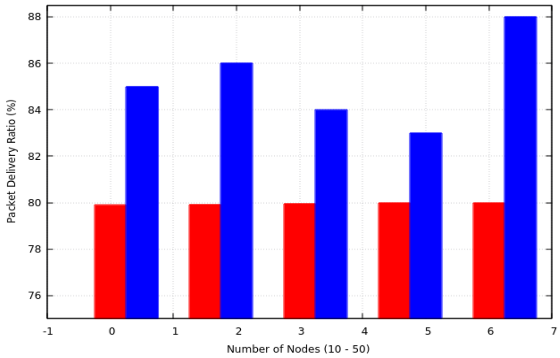

Figure 5 Packet Delivery Ratio

4.5 Packet Loss

Packet Loss is the total number of sent packets over the total number of received packets by 100%. It is represented mathematically as:

$$PL = \frac{Total\ Number\ of\ Sent\ Datapackets - Total\ Number\ of\ Received\ Datapackets}{Total\ Number\ of\ Sent\ Datapackets} \times 100\% \quad (4)$$

Packet loss occurs when sending node becomes unable to forward packet to destination node. Congestion is one of main reasons of packet loss.

Fig.6 illustrate the packet loss with respect to change in packet transmission. In the proposed scheme location, energy and residual bandwidth have been taken as a parameter to avoid occurrence of congestion. Packet loss has been observed much less than BARS, for a packet transmission of 8000 bits/sec, packet loss ratio is 21.5% and 15% in BARS and LEBARS respectively. Results indicates that packet loss in the proposed methodology is much lesser than its counterparts.

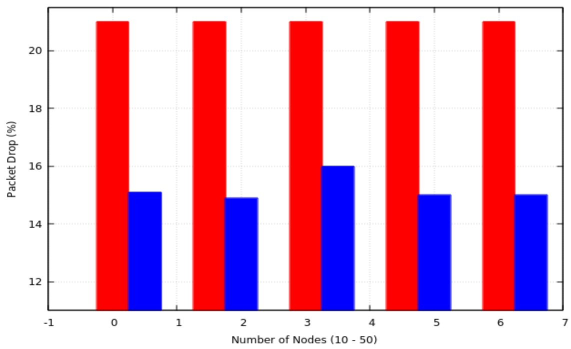

Figure 6 Packet Drop

TABLE IV PERFORMANCE PARAMETERS

PARAMETERS	BARS	LEBARS
Throughput	600 Kbps	695 Kbps
End-to-End Delay	18ms	11ms
Packet Delivery Ratio	79.90%	85%.
Packet Drop	21.5%	15%

5. CONCLUSION

The proposed work presents the Location, Energy and Bandwidth Aware Routing Strategy (LEBARS), where by the current network condition is evaluated by considering the location, available energy and available bandwidth. The packets from source node to destination node can suffer from mutual interference between packets in the same flow that can cause congestion. However, to avoid congestion, location, available energy and available bandwidth is used on a link by taking average of most recent values of location, residual energy and residual bandwidth. Also, the estimation of location, consumed energy and bandwidth involves the maximum amount of energy and bandwidth that each node can support. Nevertheless, the location, residual energy and residual bandwidth of the source node transmits data packets accordingly and manages re-establishment of broken links. To detect route break during neighbor discovery Hello message is used at neighbor node. To check the performance of the proposed LEBARS, a number of simulations were performed using NS 2.35. C language has been used to implement the functionalities, Perl scripts is used to extract results from a number of trace files of BARS and LEBARS. Results show the outperformance of the proposed LEBARS in terms of throughput, end-to-end delay, packet delivery ratio and packet loss.

For future work, security mechanisms will be included to detect and prevent attacks such as black hole, gray hole worm hole etc.

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Authors Biography

Babangida Abubakar Albaba, PhD, MSc, FIMC, AFHEA UK, MIEEE, MNCS, MBCS, MNCP, is the Rector of Katsina State Institute of Technology and Management (KSITM), Katsina, Nigeria. Before his appointment, he was a Research Fellow, Security Engineering, Secure and Dependable Software System (SenSe) Research Cluster, University of Brighton, UK. He holds MSc in Computer Systems and Network Engineering (University of Greenwich, UK) and PhD in Computer Networks (University of Brighton, UK). He is a certified CISCO academy (CCENT). Dr. Albaba published many high-quality research papers in pronounce IEEE conferences and Journals. His research interest is in Computer Network Security, Network Architecture and Design, Routing Protocols and Mobile Ad hoc Networks. He is a recipient of several national and international awards.

Abdulhamid Usman Nuruddeen, is a PG Student of Department of Computer Science in Umaru Musa Yar'adua University Katsina. He completed his B.Sc. in Computer Science Department at Umaru Musa Yar'adua University Katsina. He is a student member of IEEE. His research interests are IoT, Distributed System, Cloud Computing, Network Security and MANET.

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