IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received August 30, 2019, accepted September 18, 2019, date of publication October 2, 2019, date of current version October 15, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2943145

Link-Disjoint Multipath Routing for Network Traffic Overload Handling in Mobile Ad-hoc Networks

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ABSTRACT Mobile Ad-hoc Networks (MANETs) is the network of wireless mobile nodes with self-organizing, dynamic network connectivity without any pre-defined infrastructure for wireless communication. Error-less data broadcasting is the major role in MANET transmission. With the salient feature of dynamic topology and the distributed infrastructure, multipath routing is of great interests in MANETs. Multipath routing methods are dependable on adjacent nodes for finding the shortest path that several data packets are fallen to network traffic. Attention on the adjacent nodes can have the end-to-end delay while broadcasting the data packets into other nodes that finish up being fallen to congestion. It will also reduce network throughput and cause the network optimality problem. In this paper, we propose a new link-disjoint multipath routing method to solve the optimization problem in the real-time network environment. Hence, the proposed method is used to choose the shortest path from multiple paths in MANETs. Simulation results proved that the proposed method performs well in the dynamic network environment.

INDEX TERMS MANET, multipath routing, shortest path, load balancing.

I. INTRODUCTION

MANET nodes can move the network with their mobility factors [23]. The communication range of the wireless network is based on multi-hop source to the destination within the communication area [5]. Nodes transmitted data packets from source to destination nodes through adjacent nodes [4]. MANETs are useful for flexibility and capable of forwarding packets to other nodes [20]. Scalability means that the quality of the network in spite of specifying the capacity of nodes in changing the node delivery process is done successfully [7]. Furthermore, they can utilize the current communication path and establish their routes [6]. Error-prediction protocols are used to reduce the error and increase route proficiency [30]. In Link Scheduling procedure, the nodes are used to upgrade the position data with a relative transmission that is obtained by tracing the location of the nodes [1]. Nodes progress in the direction of the shortest path for various periods and then transform its route arbitrarily with altered paths [21]. As the node's capacity increases, the probability of broadcasting failure is also enlarged and many recipients might experience from feature deprivation [9]. Several error rectification methodologies [11], [30], [36] were implemented to diminish the rebroadcasting rate by allowing the recipient with error rectification methodology. If a recipient identifies any kind of failure in received data packets, it basically needs for rebroadcasting of data packets [24]. These rebroadcasting deserve lots of distributed bandwidth and remaining network parameters and they need not enlarge network capacity [26]. MANETs are normally the errorless network as related to relevant networks owing to self-establishing architecture [31].

Multipath routing is used for military applications and multimedia applications with auto configuration solutions can be provided in all the algorithms are suggested [27]. At the time of MANET communication, the network traffic plays a vital role to design a routing path; it will cause network traffic

The associate editor coordinating the review of this manuscript and approving it for publication was Xijun Wang.

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congestion [16]. To avoid this type of network traffic overload situation, a load balancing approach is established [13]. A huge rate of bandwidth is exhausted owing to packet overhead, predominantly the routing methods where routing tables are modified regularly [24]. In MANETs, load balancing is the concept of reducing the network traffic overload in a particular path that can manage the network balance [2]. To achieve load balancing, multipath routing methods have been proposed in [33]. Multipath routing method creates multiple paths in the system from one node to a different node and distributes the traffic load within all the possible routes [17]. It reduces network traffic congestion in a particular path [15]. Hence, multipath routing methods can increase the route maintenance for reliable data transmission [18], [35]. In spite of achieving the scalability in the MANET multipath routing, the end-to-end delay must be reduced while transmitting data packets [25]. Location-based Routing minimizes the amount of route maintenance between the active paths for reliable network communication within the transmission area [22]. Every packet has an individual structure and can produce dissimilar results based on the parameters [3].

In spite of reducing routing overload, multiple routing protocols do not normally drop the alternate route, because they have to produce the alternate paths to reach the destination [19]. When multipath is used, it is normally not to find the new routes every time [14] because an alternate path can be created if any link failure occurs [28], [34]. Successfully delivered packets are noticed and the position is updated for every delivered packet [32]. After delivering the present packet, a recipient may replicate the successful steps to deliver the remaining data packets [12]. As the particular node is successfully delivered in MANET, probabilities of errorless broadcasting begin diminishing [8]. So as to preserve a dynamic network and to keep the network parameters, we need to diminish the rebroadcasting of incorrect data packets to the destination [10], [29].

The problem to be investigated is that the Multipath routing methods are normally created to discover the link-disjoint paths that may be a complex problem in MANETs. The total number of node-disjoint paths among the source node and the destination node relies on the network topology. Therefore, there are only a few node-disjoint routes are available within the initial nodes. Normally, the node distance will increase frequently. Multipath routing aims to enlarge the network lifetime by increasing the total number of successful delivering of messages. If the message is failed to deliver, then it will be a complex problem [41]–[45]. In a multipath routing method, the data packets are delivered to the destination through directed parameters. Several multipath routing methods can be utilized within the limited parameters. The limitations of the existing studies are that every node broadcast the data packet from the source to the destination node with network capacity. This might require the networks gathering an enormous region. The adjacent nodes are not constantly distributed the data packet between the nodes in the network. Thus, the adjacent nodes may encompass the complexity to determine the position of the present node amongst its transmission range. This will cause the problem of node failure.

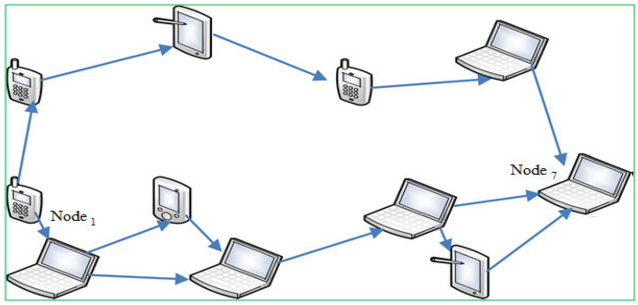

FIGURE 1. MANET.

Based on the fact of the related researches, this proposed work aims to present a dynamic procedure to fetch a reliable network performance with a centralized methodology for network performance. Dynamic network environment is utilized to perform the best possible route in the network. The proposed method guarantees reliability on real-time implementation, and load balancing by reducing the traffic overload among the nodes and the communication links. The multipath routing delivers the packet within the time period with the total amount of active node in the network. The proposed method has to control the multipath routing and the forwarding packet into the entire network. The proposed link-disjoint multipath routing method is used to choose the shortest path from multiple paths in MANETs. Simulation results will be dome to prove the suitability of the new method in the dynamic network environment.

In Section 2, we will present the solution accompanied by validation in Section 3 and conclusions in the last section.

II. PROPOSED WORK

A. NETWORK MODEL

A MANET is a wireless network that broadcast the data packets within the transmission range using radio connections for better connectivity to facilitate the communication in complex surroundings where there are limited Access Points. Figure 1 illustrates a MANET, where the node Node1 desires to connect with Node7 performed using adjacent nodes.

Data traffic is delivered from the source node to the destination node using dynamic wireless links with the help of adjacent nodes. Let the traffic resource indicates the entire route data of data packet, which is used by every adjacent node on the route to deliver the data packet with every node, preserves a routing table that includes the adjacent node information to deliver the data packet to the destination node. Figure 2 demonstrates the data transmission in MANET within the transmission range.

Let $G_1 = (V_1, E_1)$ be a MANET with a set of vertex V_1 and edges E_1. We determine a path from the node x to the node y by (x, y). A path P is defined in a graph is a progression of $x_1, x_2, \ldots\ldots, x_z$ of nodes of N such that $(x_r, x_{r+1}) \in VinP$, $r = 1, 2, \ldots, z-1$. In every node, a group of unused

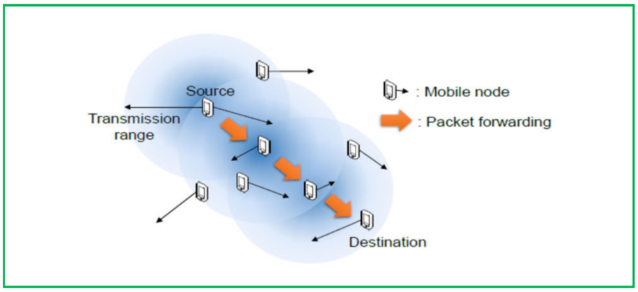

FIGURE 2. Data transmission in MANET.

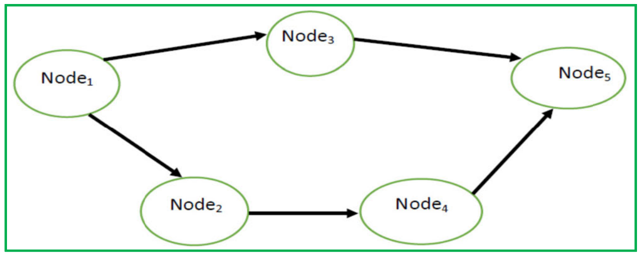

FIGURE 3. MANET congestion links.

time-slots is created for sharing the time-slot of 2 adjacent nodes in the link connectivity

$$Link_{Connectivity}\,(x,y) = free_{slot}\,(x) \cap free_{slot}\,(y). \tag{1}$$

From the above equation, $Link_{Connectivity}$ denotes that the connectivity from the node x to node y. $free_{slot}\,(x)$ is the unused time-slot for node x. We formulate the sequence of P messages, every message z is defined as a tuple (s_z, t_z, τ_z), where $s_z, t_z \in N$ *and* $\tau_z \in N^+$ is the message length. For every message (s_z, t_z, τ_z), *let* P_z *and* P_z^* are the paths from node s_z to node t_z to deliver the message. After delivering the message z, let $\Omega\,(z)\,and\,\Omega^*\,(z)$ be the group of paths connected with the network. For every

$$(x,y) \in P_z,\, let\; l_{xy}(z) = \frac{\tau_2 e_{xy}}{Energy(i)'}, \tag{2}$$

$$Load\,(x,z) = \sum\nolimits_{(x,v)\in P_v} r_{xv}\,(w), \tag{3}$$

$$Load^*\,(x,z) = \sum\nolimits_{(x,v)\in P_v^*} r_{xv}(w). \tag{4}$$

A group of messags is called **feasible** if the path is active for every message. For every message z and every $(x,y) \in P_z^*$,

$$r_{xy}\,(z) \le 1 \quad and\; Load^*\,(x,z) \le 1. \tag{5}$$

For every $x \in N$, let cost(x) is the cost of Energy (i) by a single unit. After delivering message z, we calculate the total cost for the node x using TC(x,z),

$$TC\,(x,z) = cost\,(x)\,x\,Load\,(x,z)\,, \tag{6}$$

$$If\;\; Load\,(x,z) \le 1, \quad then\; TC\,(x,z) = 0, \tag{7}$$

$$cost\,(k_1) = \min_{x\in N} cost\,(x), \tag{8}$$

$$cost\,(k_2) = \max_{x\in N} cost\,(x). \tag{9}$$

For every message z, discovers a path P_z such that (10), (11), (12), as shown at the bottom of this page.

The probability of multipath is calculated by

$$Path_x\,(S,D) = \frac{\left(\frac{1}{BD_x(S,D)}\right)}{\sum_{x=1}^{z}\left(\frac{1}{BD_x(S,D)}\right)} \tag{13}$$

B. LINK DISJOINT PATH FORMATION

Traffic prevention with adjacent nodes on the network is an important factor for the route maintenance of MANET. All the nodes in the MANET compute the traffic values including the buffer usage of the mobile node. The buffer usage of traffic values lies between 0 and 1. The traffic value of 1 suggests that the buffer is occupied and every data packet that prolongs to approach will be fallen. A traffic value (TV) of 0 suggests that the buffer is unfilled. The adjacent nodes collect the data about the traffic value (TV) on every other node through the active routing path. We suggest inspection of the Data traffic value for other nodes before any active route is preferred for delivering data packets. When the data packet is delivered to the destination, it computes TV from the source node to the destination node, which is calculated using the formula;

$$\text{Traffic valueshortest path i} = \text{TV}_1\text{xTV}_2\text{x} \ldots \ldots \text{xTV}_\text{n} \tag{14}$$

Figure 3 demonstrates a MANET where few adjacent nodes are used by the source node Node1 to destination Node5, there are several paths are available in the network and the data packet will communicate through (Node1, Node3, Node5) in place of (Node1, Node2, Node4, Node5). An active route that has the minimized traffic stage is selected over one whose traffic stage is in maximum, and therefore the possibility to un-deliver several data packets.

$$TC\,(s_1,z) = \max_{x\in N} TC\,(x,z), \tag{10}$$

$$TC\,(s_2,z) = \sum TC(x,z) \tag{11}$$

$$\text{cost(x)} = 10\text{x}\frac{\tau_z\text{x distance}_{\text{xy}}^2\text{x(Energy(x)} - \text{Energy}_\text{x}\text{(z)} - (\tau_z\text{x distance}_{\text{xy}}^2))}{\text{Energy(x)}^2} \tag{12}$$

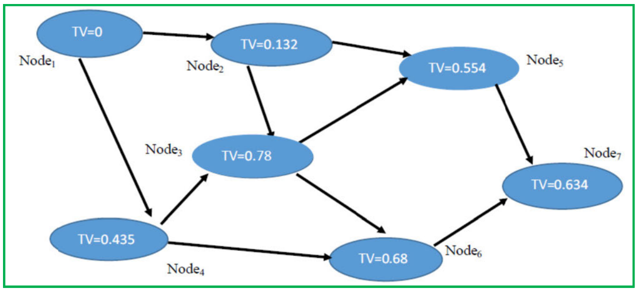

FIGURE 4. TV calculation.

Algorithm Finding Minimized Energy Path

Begin Procedure Min_Energy_Path (G,S,D)
Energy = W_DES (G,S,D);
for every edge $\boldsymbol{E} \in \boldsymbol{G}$;
if weight [E] >max_Energy then
G = G − {E};
Path = Min_Energy_Path (G,S,D);
Restore all E in G;
End Procedure

Begin Procedure W_DES (G,S,D)
Min_Energy (G,S);
Return width [D];
End Procedure

Every node is desired to communicate to every other node through the active routing path. If node1 desires to deliver the data packet to node7, then the data packet will be delivered through a few adjacent nodes until it accomplishes the destination node7. Traffic value (TV) is calculated for every node to reach the data packet to the destination and it is demonstrated in Figure 4. The TV from every node must be computed i.e. traffic value from Node1– Node3 and Node3– Node5 and similarly the traffic value from Node1– Node2, then Node2– Node4 and at last Node4– Node5. The traffic stage for every active path is selected based on the minimum value of the traffic value within the active nodes in the multipath routing technique.

$$\begin{aligned} &\text{The traffic stage for active path:} \quad \text{Node1} - \text{Node3} \\ &\quad - \text{Node5} \\ &= \min\ [\text{TV}(\text{Node1} - \text{Node3}), (\text{Node3} - \text{Node5})] \\ &\text{The traffic stage for active path:} \quad \text{Node1} - \text{Node3} \\ &\quad - \text{Node5} - \text{Node5} \\ &= \min\ [\text{TV}(\text{Node1} - \text{Node2}), (\text{Node2} - \text{Node4}), \\ &\quad (\text{Node4} - \text{Node5})] \end{aligned} \tag{15}$$

C. PATH SETUP

Link Capacity in wireless networks is computed using the parameters of broadcasting capability, current link values, and interference. To maintain the multipath routing, the proposed algorithm created a Link Factor (LF) for every link to

Algorithm Alternate Path Finding

Begin Procedure Alternate_Path (G,S,D)
G: Graph G(V,E);
$\boldsymbol{\delta V}$) : Group of adjacent V;
S: Source node;
D: Destination node;
$\boldsymbol{Path_x}\ (\boldsymbol{S}, \boldsymbol{D}) = \emptyset$;
if $\boldsymbol{S} \neq \boldsymbol{D}$ then $\boldsymbol{q_{next}} = \emptyset$;
$\boldsymbol{Q} = \emptyset$;
$\boldsymbol{Enqueue}(\boldsymbol{Q}, (\boldsymbol{q_{next}}, \boldsymbol{S}))$;
while $\boldsymbol{Q} \neq \emptyset$ **and** $\boldsymbol{Path_x}\ (\boldsymbol{S}, \boldsymbol{D}) = \emptyset$ **do** $(\boldsymbol{q_{next}}, \boldsymbol{S}) = \boldsymbol{Front}\ (\boldsymbol{Q})$;
for every $z \in \boldsymbol{\delta}\ (\boldsymbol{x})$ **do** $\mathbf{e} = (\mathbf{x}, \mathbf{z})$;
if $(\boldsymbol{q_{next}} \cup \boldsymbol{e}) \cap \boldsymbol{edges_{follow}} = \emptyset$ ***then***
if $\boldsymbol{Path_r}\ (\boldsymbol{T_r}, \boldsymbol{z}, \boldsymbol{D}) \cap \boldsymbol{edges_{follow}} = \emptyset$ ***then*** $\boldsymbol{Enqueue}(\boldsymbol{Q}, (\boldsymbol{q_{next}} \cup \boldsymbol{e}, \boldsymbol{z}))$;
end if
end if
end for
Dequeue(Q);
end while;
$\boldsymbol{Q} = \emptyset$;
end if
return $\boldsymbol{Path_x}\ (\boldsymbol{S}, \boldsymbol{D})$;
End Procedure

compute the communication range. The LF value from 'x' node to 'y' node is calculated by

$$\mathrm{LF_{xy}} = \left[(1-\beta)\ \mathrm{x}\ \alpha_{\mathrm{xy}} + \beta\ \mathrm{x}\ \left(1 - \theta_{\mathrm{y}}\ (\mathrm{t})\right)\right] + \left[\Psi\ \mathrm{x}\ \left(1 - \delta_{\mathrm{xy}}\ (\mathrm{t})\right]\right. \tag{16}$$

such that

$$\beta = \frac{\mathrm{Energy_i}}{\mathrm{Energy_M}}, \tag{17}$$

$$\alpha_{xy} = \frac{Distance_{xy}}{Range_M}, \tag{18}$$

$$\delta_{xy}\ (t) = \frac{Z_t^{xy}}{\left(Z_t^{xy} + \gamma_t^{xy}\right)}, \tag{19}$$

$$\theta_{\mathrm{y}}\ (\mathrm{t}) = \frac{-\sum_{\mathrm{z} \in \mathrm{F_y}} \mathrm{P_z}\ (\mathrm{t}, \Delta_\mathrm{t})\ \mathrm{x} \log \mathrm{P_z}\ (\mathrm{t}, \Delta_\mathrm{t})}{\log \mathrm{C}\left(\mathrm{F_y}\right)}, \tag{20}$$

$$\mathrm{P_z}\ (\mathrm{t}, \Delta_\mathrm{t}) = \frac{\mathrm{a_{y,z}}}{\sum_{\mathrm{x} \in \mathrm{F_y}} \mathrm{a_{y,x}}}, \tag{21}$$

$$\mathrm{a_{y,x}} = \frac{1}{\mathrm{LF}}\mathrm{x} \sum_{\mathrm{l}=1}^{\mathrm{LF}} \left|\mathrm{Vv}\ (\mathrm{y}, \mathrm{x}, \mathrm{t_l})\right|, \tag{22}$$

$$\mathrm{Vv}\ (\mathrm{y}, \mathrm{x}, \mathrm{t_l}) = \mathrm{Vv}\ (\mathrm{y}, \mathrm{t}) - \mathrm{Vv}\ (\mathrm{x}, \mathrm{t}), \tag{23}$$

$$0 \leq \theta_y\ (t) \leq 1. \tag{24}$$

If the value of $\theta_{\mathrm{y}}\ (\mathrm{t}) = 1$, then the route to the adjacent node y is stable. If the value of $\theta_{\mathrm{y}}\ (\mathrm{t}) = 0$, $\Psi_{\mathrm{xy}}(\mathrm{t})$ is the link xy's trust value. When the calculated energy of the node x is not useful due to the overload of the traffic, the selection of path is mainly focussed on remaining energy of broadcasting the data. A smaller value of β is maintained by energy

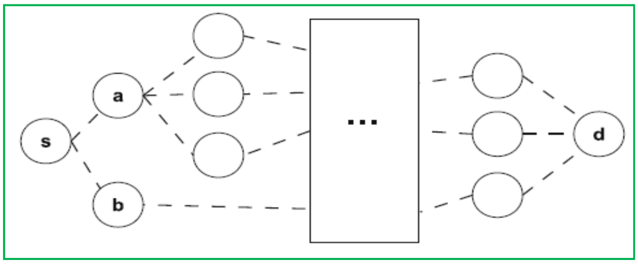

FIGURE 5. Alternate path selection using link factor (LF).

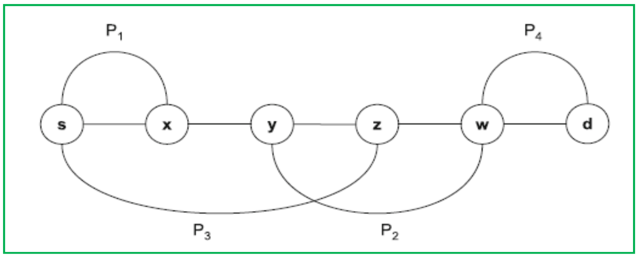

FIGURE 6. Selection of shortest path using node-disjoint path.

consumption $\left(\frac{Energy_i}{Energy_M}\right)$ rate. The β value of the node x is randomly generated the actual value of the calculated energy per initial energy.

Furthermore, the current network parameters can have a real-time implementation. The network parameter γ is the trust value of the dynamic link. In this paper, to stop the packet loss, every link's trust value is used to determine the LF value, the value of γ is always 1. The LF value can be determined by the actual communication rate of every active link. With the value of LF, we determine the active path rate parameter (PR) to compute the total active path cost. PR is calculated as the total of every link cost in the network. According to the value of PR, the proposed method constructs a dynamic multi-hop routing path in the network. At the time of beginning, the routing functions can use the source node to transmit its beginning value of PR. With the communication range, the message is reaching from the source nodes personally compute the cost of the current link. The PR value is computed as PR + LF. Figure 5 demonstrates Alternate path selection using Link Factor (LF).

All the nodes can get a variety of PR values, such as PR_1, $PR_2, PR_3, \ldots., \ldots.., PR_k, \ldots.., \ldots, PR_{N_i}$, where PR_k is the receiving PR value of message transforming to adjacent node $Z(1 \leq Z \leq N_x)$. PR_x is calculated as

$$PR_x = \sum\nolimits_{Z=0}^{N_i} (PC_Z + LF_{xz}). \tag{25}$$

The node x finds one adjacent node as the transforming node while reducing PR_i value which naturally includes a lot of information about the current network. The calculated PR value is repeatedly transmitted to generate the routing path. The route generation procedure is continued until every multipath from the source node to the destination node is connected. Figure 6 demonstrates the selection of the shortest path using node-disjoint path. The mathematical method is proposed to get the optimization solution to find the solution for the multipath routing. The main concept of the proposed method is to reduce the traffic on every active path based on the transmission capacity. To broadcast the process, every node finds an adjacent node according to PR value. From the current value of node x, Computational Probability (CP) of the adjacent node Z([CP]_Z) is determined as,

$$CP_Z = \frac{TC_Z}{\sum_{y=1}^{n} TC_y}. \tag{26}$$

According to the CP values, an adjacent node is selected. The Optimum Probability (OP) is computed as,

$$OP = e^{\frac{-[(N)]_{PR} - C_{PR})}{F(t)}} \tag{27}$$

F(t) is a Functional parameter to formulate the value. $[N]_{PR} - C_{PR}$ is the alternate path generation. If N_PR > C_PR, then the latest adjacent node replaces the current node. If N_PR < C_PR, then the latest adjacent node may not replace the current node. Figure 7 illustrates the example of Node-disjoint Paths.

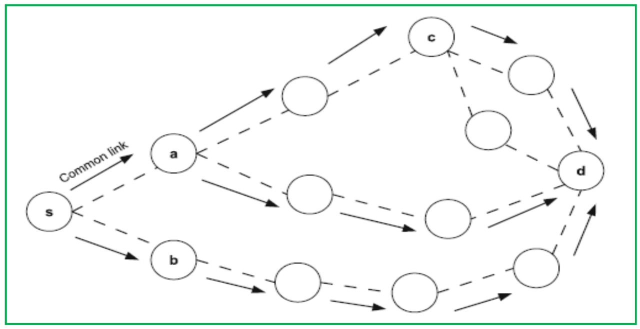

FIGURE 7. Example of node disjoint paths.

D. PATH SETUP

Figure 8 illustrates the flowchart for the proposed work. The node is created for transmitting the mobile nodes in the network. Every node is assigned to broadcast the data packets from the beginning node to the destination node. If any link breakage in the network then discovers the traffic congestion otherwise forward the data packets into the adjacent node in the network. Every adjacent node discovers the alternate path in the network to reduce the traffic congestion by sending the notification into the network. Update the alternate path in the network and then forward the data packets to the recipient node through the alternate path. If the beginning node has the details about the alternate node then send the data packets through the path else stop the process of transmission. The transmission should be done within the transmission range.

E. PATH STABILITY

The fields in the data packet are as follows: packet type, a source field, destination list, the sequence of sources, path

TABLE 1. Demonstrates the notations used in this proposed work.

Notation	Description
x	node x
y	node y
α	cost of communication
β	fixed value
Ψ	trust value
δ	number of successful broadcasting
$Energy_i$	initial energy
$Energy_M$	maximum energy
$Distance_{xy}$	distance from node x to node y
$Range_M$	maximum coverage area
$\theta_y(t)$	entropy for the node y at time t
Z_t	total amount of packets
γ_t	relay node at time t
Δ_t	time interval
(F_y)	group of adjacent nodes
$C(F_y)$	degree of group of adjacent nodes
$a_{y,x}$	measurement of transitive mobility
Vv(y,t)	velocity vectors of node y at time t
Vv(x,t)	velocity vectors of node x at time t
t_l	The number of discrete time period
N_i	total number of Reachability
CP	Computational Probability
F(t)	Functional parameter
PR	Active path route maintenance
OP	Optimum Probability
Load	Load
TC	Total cost
cost	cost
S	source
D	destination
BD	broadcasting delay
SV	signal value
CV	coefficient-variation
PS	path stability
A	discrete variable
RV	random value

information, the bandwidth required for a source to the destination, the total number of links, route path bandwidth, and time to live. After the bandwidth calculation, the most common adjacent nodes are selected. Path Stability is the main factor in multipath routing, the routing overload of the nodes that produce the active path. The Path Stability formula can be generated using probability distribution. The discrete variable coefficient-variance CV(A).

$$PD\{|A - PE(A)| < \varepsilon\} \geq 1 - \frac{CV(A)}{\varepsilon^2}. \quad (28)$$

Algorithm Steps for Routing

Step 1: Every node randomly computes all real-time values.
Step 2: The LF value is computed.
Step 3: In the beginning time, the source node transmits the PR value to all the adjacent nodes. Every node computes its PR value by Step 4.
Step 4: According to the value of PR, the route maintenance phase continuously connected until every multipath routing is performed successfully.
Step 5: To broadcast data packets, every node finds an adjacent node with the Computational Probability.
Step 6: If $N_{PR} > C_{PR}$, then the latest adjacent node replaces the present node.
Step 7: If $N_{PR} < C_{PR}$, then the random value is computed. If the computed value is less than the Optimum Probability then the latest adjacent node is not selected as the current node.
Step 8: The multi-hop communication process repeatedly continues up to the data packet is reached to the destination node

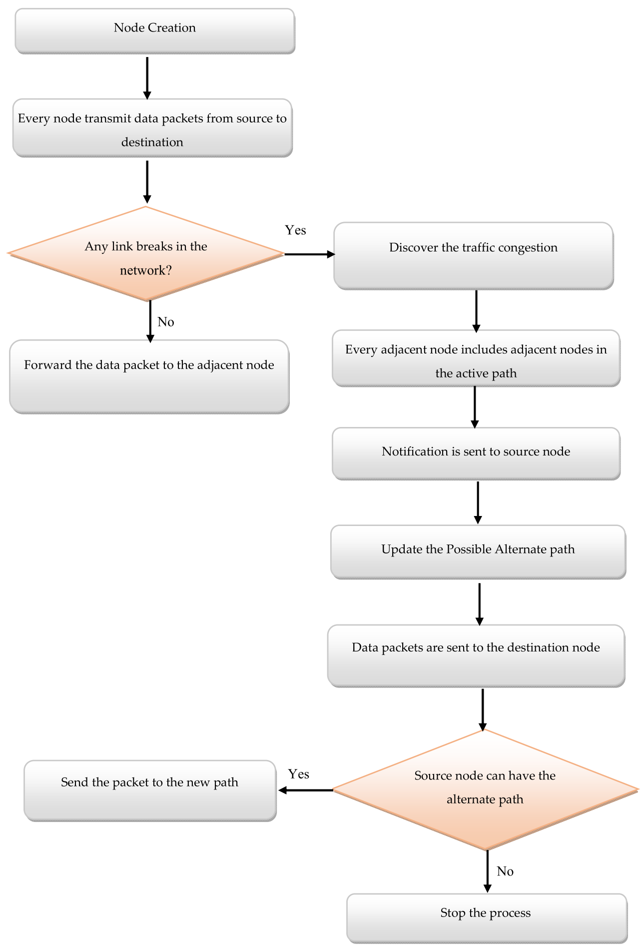

FIGURE 8. Flowchart for proposed work.

With $\varepsilon = 0.00695$, the probability distribution is:

$$PD\{|A - PE(A)| < \varepsilon\}. \quad (29)$$

Algorithm Broadcasting the Nodes Using Adjacent Node.

Step 1: After receiving transmitting message RREQ, send packet at node S.
Step 2: Finding the number of adjacent node$\boldsymbol{S}\left(\boldsymbol{Adj_x}\right)$.
Step 3: Computing the middling value of adjacent nodes$\boldsymbol{Mid}$.
Step 4: Every source node discovers the adjacent nodes in the active path
Step 5: If RREQ packet is received then
  If $\boldsymbol{S}\left(\boldsymbol{Adj_x}\right) \leq \boldsymbol{Mid}\,(\boldsymbol{network})$ ***then***
    DP = DP1;
  end if
  if $\boldsymbol{S}\left(\boldsymbol{Adj_x}\right) \geq \boldsymbol{Mid}\,(\boldsymbol{network})$ ***then***
    DP = DP2;
    until DP1 > DP2;
  end if
end if
Step 6: Generate a random value RV [0.0, 1.0]
  if RV ≤ DP1 then
    Retransmit the message RREQ
  else
  discard the message RREQ
  end if

Algorithm Shortest Path Finding

Begin procedure Shortest_Path( )
  L(x,0) = 0, for every $\boldsymbol{x} \in \boldsymbol{N}$;
  z = 1;
  while ($z \leq \boldsymbol{d}$) do
  begin
    for every $(\boldsymbol{x}, \boldsymbol{y}) \in \boldsymbol{S}$
      calculate $\boldsymbol{cost^z_{xy}}$;
    discover a shortest path $\boldsymbol{SP_z}$ from node $\boldsymbol{t_z}$ using $\boldsymbol{cost^z_{xy}}$;
    for every $\boldsymbol{x} \in \boldsymbol{N}$ do
     begin $\boldsymbol{Load}\,(\boldsymbol{x}, z) = \boldsymbol{Load}\,(\boldsymbol{x}, z-\mathbf{1}) + \boldsymbol{l_{xy}}\,(z)$, ***forevery*** $(\boldsymbol{x}, \boldsymbol{y}) \in \boldsymbol{SP_z}$;
$\boldsymbol{Load}\,(\boldsymbol{x}, z) = \boldsymbol{Load}\,(\boldsymbol{x}, z-\mathbf{1})$, ***forevery*** $(\boldsymbol{x}, \boldsymbol{y}) \neq \boldsymbol{SP_z}$;
  end
  z = z + 1;
  end

If the coefficient-variance is zero then we have

$$1-\frac{CV\,(A)}{\varepsilon^2}\approx 1\rightarrow CV\,(A)\approx 0, \tag{30}$$

$$CV\,(A) = PE\left(A^2\right) - PE\,(A)^2, \tag{31}$$

$$PE\,(A) = \sum\nolimits_k \frac{A_k}{n}, \tag{32}$$

$$CV\,(A) = \left(\sum\nolimits_k \frac{A_k^2}{n}\right) - \left(\sum\nolimits_k \frac{A_k}{n}\right)^2, \tag{33}$$

where k is the number of nodes, A_k is the received signal from every adjacent node, it is calculated from various time slots. The two adjacent nodes X and Y are transferred the data from the MANET nodes.

$$PS_{XY} = CV\,(A_Y), \tag{34}$$

$$PS_{XY} = \left(\sum\nolimits_k \frac{A_{YZ}^2}{n}\right) - \left(\sum\nolimits_k \frac{A_{YZ}}{n}\right)^2, \tag{35}$$

$$PS_{XY} = \left(\sum\nolimits_k \frac{SV_{YZ}^2}{n}\right) - \left(\sum\nolimits_k \frac{SV_{YZ}}{n}\right)^2. \tag{36}$$

TABLE 2. Demonstrates the notations used in this proposed work.

Parameters	Values
Node distribution	Random
Data message	CBR traffic
Network Performance	50 simulation per second
Bandwidth	5.0 Mb/s
Mobility	0 to 10 m/s
initial energy	5 J
traffic type	Different
model of physical layer	PHY 802.11b
battery model	Linear
network size	1250 m x 1250 m
broadcasting range	290 m
node density	22.5
average hop-count	6.2

The proposed method LDM implements five algorithms to perform the multipath routing. The first algorithm is used to find the reduced energy path by utilizing the weight of the destination graph to find the path from the source to the destination. Every edge in the graph has a weight greater than the maximum energy and the edge is removed from the graph. The second algorithm is used to find the alternate path routing or the path from the source to the destination. The third algorithm is used to implement the multipath routing by using real-time values that are randomly computed from the node. The Link Factor value is calculated from the beginning period. The source node transmits the active path value to every adjacent node in the route maintenance phase. The computational probability is used to discover the alternate path in the network. This process is continued until the data packet is reached to the destination. The fourth algorithm is used to broadcast data packets in the network using the adjacent node. The receiving transmission range request (RREQ) sends the packet at the node from the beginning node. To discover the total number of adjacent nodes, we generate a random value by computing the data packet: if the random value is less than the value of the data packet, we retransmit the RREQ message; else discard the message.

III. PERFORMANCE EVALUATION

The simulation of the network is done using Network Simulator 2. The network is simulated with a limited number of nodes from 50 to 1000. The parameters of the simulation are displayed in Table II.

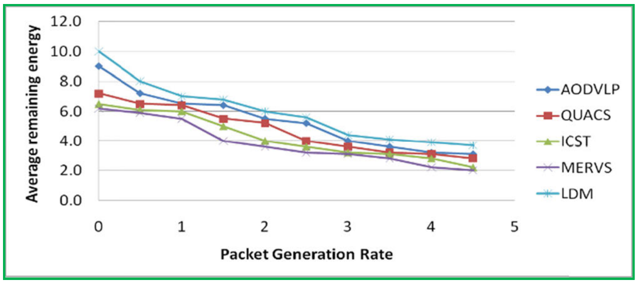

FIGURE 9. Comparison graph for packet generation rate v/s average remaining energy.

The Simulation compares the proposed work (LDM) with AODVLP [37], QUACS [38], ICST [39] and MERVS [40]. The existing methods AODVLP, QUACS, ICST and MERVS have used techniques of multipath routing in MANETs. The Packet generation rate is the basic parameter for validating the proposed work. The Packet Generation Rate is computed as the parameter unit of 1 packet per second. The average energy and residual energy are computed by the parameter unit of Joule. These methods have some disadvantages:

i. Existing methods may not dynamically capture the latest conditions of the network. Every node is unsure about the shortest routing paths to forward the packet to the destination.
ii. Due to the network traffic, several nodes have the lowest throughput to forward the data packets.
iii. Existing methods are using centralized methodology.

A. PACKET GENERATION RATE V/S AVERAGE REMAINING ENERGY

Figure 9 shows the comparison graph for the Packet Generation Rate v/s Average Remaining Energy. The performance of the average remaining energy of MANET nodes is compared to the existing works. To prolong the lifetime of the network, the remaining energy is the main parameter. The proposed method finds the adjacent routing link by using the information about the remaining energy.

B. PACKET GENERATION RATE V/S AVERAGE REMAINING ENERGY

Figure 11 shows the comparison of Packet Generation Rate v/s Probability of packet failure. The packet failure is defined as the failure of broadcasted packets to accomplish their destinations. When the increased load of traffic, MANET nodes have the minimized energy or capability for data communication and the data packets are dropped. Moreover, the probability of the packet loss will increase due to the heavy traffic load. Our proposed work will increase the network reliability to achieve the minimized packet loss rate compared to the other related methods.

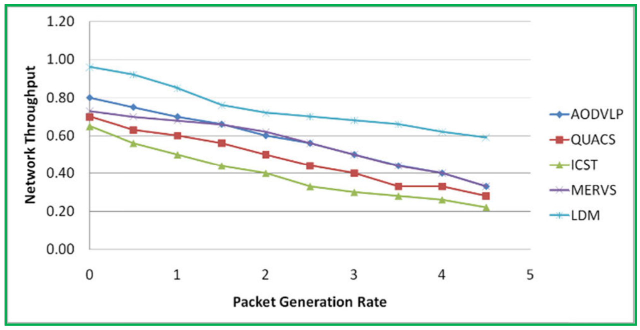

FIGURE 10. Comparison graph for packet generation rate v/s probability of packet failure.

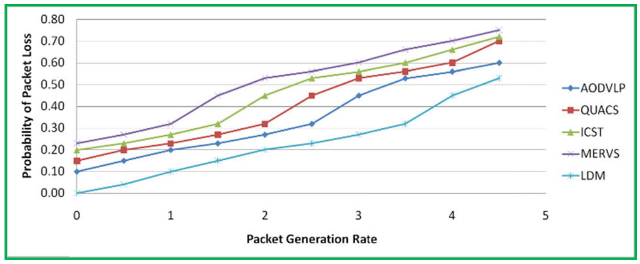

FIGURE 11. Comparison graph for packet generation rate v/s probability of packet failure.

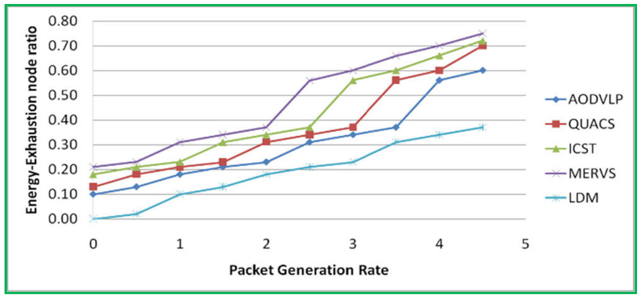

FIGURE 12. Comparison graph for packet generation rate v/s energy-exhaustion node ratio.

C. PACKET GENERATION RATE V/S PROBABILITY OF PACKET FAILURE

Figure 11 shows the comparison of Packet Generation Rate v/s Probability of packet failure. The packet failure is defined as the failure of broadcasted packets to accomplish their destinations. When the increased load of traffic, MANET nodes have the minimized energy or capability for data communication and the data packets are dropped. Moreover, the probability of the packet loss will increase due to the heavy traffic load. Our proposed work will increase the network reliability to achieve the minimized packet loss rate compared to the other related methods.

D. PACKET GENERATION RATE V/S ENERGY-EXHAUSTION NODE RATIO

Figure 12 shows the comparison of Packet Generation Rate v/s Energy-exhaustion node ratio. Traffic load

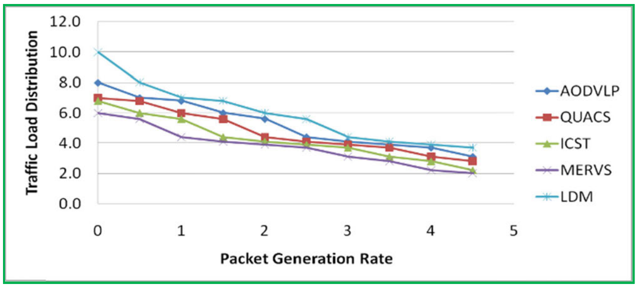

FIGURE 13. **Comparison graph for packet generation rate v/s maintenance of traffic load distribution.**

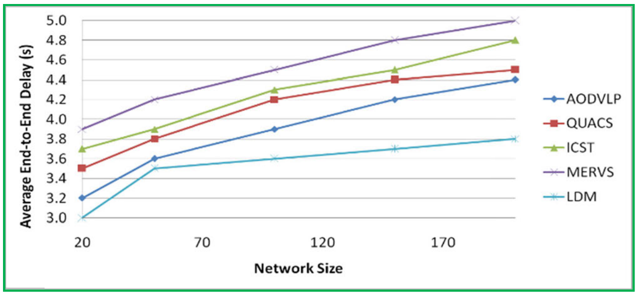

FIGURE 14. **Comparison graph for network size v/s average end-to-end delay.**

maintenance denotes that the average rate of network traffic with MANET nodes.

E. PACKET GENERATION RATE V/S MAINTENANCE OF TRAFFIC LOAD DISTRIBUTION

Figure 13 shows the Packet Generation Rate v/s Maintenance of Traffic Load distribution. In a distributed network environment, the intermediate node in our proposed work controls the network condition and appends all the parameters frequently for the multipath routing. Furthermore, with all the network parameters, the proposed work is capable of minimizing the amount of energy expiration nodes and frequently forwards the data packets to minimize the network traffic is the main objective of MANET multipath routing.

F. NETWORK SIZE V/S AVERAGE END-TO-END DELAY

Average End-to-End delay is demonstrated in Figure 14 shows that the minimum value in spite of the size of the network of the proposed method LDM is compared with the related methods such as AODVLP, QUACS, ICST and MERVS methods. Whenever the size of the network improves about 200 mobile nodes, the end-to-end delay is improved by 21%. The Figure proved that the proposed method LDM is having the reduced amount of average End-to-End delay compared to AODVLP, QUACS, ICST and MERVS methods.

G. NETWORK SIZE V/S TRANSMISSION OVERHEAD

The transmission overhead parameter determines that the proposed method LDM is having the minimum value compared

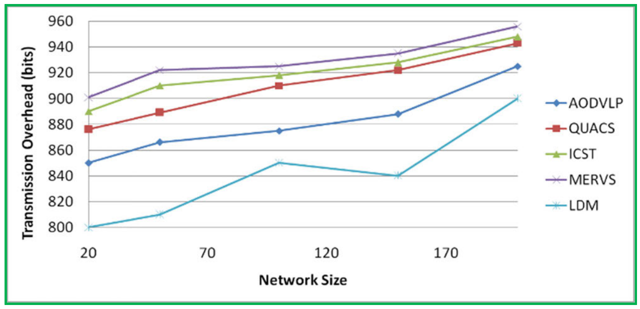

FIGURE 15. **Comparison graph for network size v/s transmission overhead.**

to the methods of AODVLP, QUACS, ICST and MERVS as demonstrated in Figure 15. This happens due to LDM routing are developed as the shortest path in the MANET, whenever the latest routing path is including in the network, it will cause the transmission overhead.

H. SUMMARY

The simulation results determine that the proposed work of the multipath routing technique normally provides the best performance compared to other related methods. According to the proposed work, network traffic overload has been minimized and provides better solutions. With all the simulation results, the proposed work is proved that it provides a better solution for the complex multipath routing problems for a dynamic routing environment.

IV. CONCLUSION

Latest advancements in wireless networks and the mobile computing-based devices have frequently used in MANETs. For these kinds of MANETs, the main objective is to select the shortest routing path using multipath routing technique. For the real-time network environment, the proposed work is created in self-maintaining, dynamic network parameters. Hence, every intermediate node is used to give a more dynamic control technique and selects the best possible path. Using this kind of dynamic network parameters, the proposed work can dynamically find an efficient path to observe the dynamic network challenges. Based on the simulation results, the proposed work performed well compared to other related methods by energy efficiency, reliability, traffic load and so on.

In the future, we will strengthen our method to be very much useful to develop the novel multipath routing algorithms. In specific, the optimization method can be implemented to use all kinds of online data services.

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