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Combined Optimization of Packet Delay and Link Reliability for Selecting an Optimum Relay Node in Mobile Ad-hoc Networks

Thangavel. P[1], Mohanasundaram. S[2]
[1,2] *Department of Information Technology, Institute of Road and Transport Technology, Erode, Tamilnadu, India.*

Abstract: Mobile Ad-hoc Network (MANET) is an infrastructure-less self-organized wireless network where devices can travel autonomously in any direction. Reliable and robust data forwarding is a very challenging task over time-varying ad-hoc networks. Moreover, the process of a relay node selection is critical and calls for reliable packet propagation approaches to enhance the quality of service (QoS) in MANETs. This study proposes a technique called Ideal Relay Node Selection Approach (IRNSA) for reliable packet delivery in MANETs. This approach picks a node according to link reliability and packet delay for packet propagation. The tradeoff between maximum link reliability and minimum delay is modeled as a combined bi-objective optimization problem. At every instant, this approach finds all potential relays and the parameters of the bi-objective function are updated at each node. Subsequently, the best one is carefully chosen from the set of potential intermediate hops by means of a combined optimization approach. In order to evaluate the performance of the proposed technique, different network configurations of mobile nodes are modeled with the homogeneous Poisson point method. The period of link availability of each device with their adjacent nodes is informed constantly and the relay hop is identified on an online basis. Experiments show that IRNSA provides lower delay and more link reliability (probability of data loss) for packet delivery in MANETs as compared to traditional single-objective optimization approaches. Furthermore, IRNSA also offers additional improvements in terms of coverage distance, message duplication cost, mobility tolerance, and link stability.
***Keywords**: link reliability; MANETs; Optimization; Packet delay; relay node selection;*

I. INTRODUCTION

MANETs are a collection of geographically dispersed mobile devices fortified with wireless equipment which do not mandate any fixed infrastructure or base stations (i.e. access points) to enable communication between them. The fast solicitation and the pervasive access capability of MANET make them apt for media streaming and safety-critical applications like military-strategic network, medical and disaster-rescue scenarios. The ad-hoc network may perform independently or may have openings to attach with static infrastructure-based communication systems. Hence, each host operates as a transmitter, receiver or router of data. Node mobility causes random topology changes and the data forwarding algorithms should be proficient enough for maintaining continuous communication links. The proliferation of real-time applications in the network has resulted in a shift of research interests towards better degrees of QoS instead of the best-effort services. Developing a QoS-aware routing algorithm for MANET is much more problematic and a stimulating task since it has to handle critical conditions like time-variant network configuration, frequent link disconnections, and extreme energy consumption. Link connectivity changes as a node move into or out of the coverage area of other nodes [1]. The transmission channel is also subject to multiple path fading, noise interference, hidden and exposed node problems, and Doppler e□ects [2]. These problems create different uncertainties and lead to higher data loss and changing communication latency.

Scheming reliable packet delivery protocols becomes more challenging and a difficult task while the nodes are movable. Most of the service providers fail to consider these uncertainties in the network. In MANET, the link availability among the nodes varies over time. Hence, these networks need robust and reliable packet forwarding algorithms to deliver end-to-end QoS assurances. A good QoS-aware routing algorithm should select a suitable relay node to fulfill the QoS requirements of applications. Continuous updates of connectivity status (e.g. bandwidth, latency, and packet delivery ratio, etc.,) are vital to make optimal routing decisions, which bring about unnecessary control overhead. This can be unaffordable for bandwidth-constrained MANETs [3]. Even after finding a link that satisfies the QoS requirements, the transmission medium and the time-varying nature of the network make it difficult to guarantee some demands always. The dimension of the MANET is also a primary concern if it is massive, because the computational overhead will be high, and it is very difficult to distribute network updates within given time limits.

Likewise, low delay packet propagation is desired for making quick decisions in MANETs. Low-latency packet propagation shows an important role to design robust and reliable routing algorithms. Propagating the packet from a transmitter to the receiver through intermediary hops will initiate the designing of consistent routing algorithms. In multiple hop transmission, the mobile devices except for source and destination work as relay hops for a message. But, the choice of best relays in time-variant MANETs is a very difficult process. In this research work, we design and implement an algorithm called Ideal Relay Node Selection Approach to achieve quick and reliable routing in MANET. Some routing protocols in the literature take only one performance metric for selecting the best relay [4, 5, 6]. On the other hand, the optimization of more than one performance metrics in a network can bring about enhanced QoS. Packet delay is a key performance measure for most of the routing strategies designed in MANET. In a dynamic ad-hoc communication system, where network topology is unpredicted, the link reliability also considers a significant performance measure. The link reliability is directly associated with the possibility of data loss on that path. It should be high for reducing data loss. Hence, considering the possibility of data loss as a performance metric is also imperative. In this study, we optimize the packet delay and probability of data loss simultaneously for selecting optimal relay node. However, the packet delay may be higher for a consistent communication link. Therefore, there could be a trade-off between a minimum packet delay and maximum link reliability. The contribution of this work is threefold.

1) A mobility-tolerant packet propagation model is developed for selecting the optimal relay node. IRNSA is effective in terms of both link reliability and robustness. For each time instant, the best relay is found by considering a combined optimization problem that enhances two performance measures viz., packet delay and the link reliability simultaneously.
2) A technique that apprises the parameters of the multi-objective optimization function at all the mobile devices and chooses the best relay node from existing hops is employed to resolve the combined optimization problem. The Pareto front of this combined optimization problem is implemented to demonstrate the trade-off between packet delay and the link reliability.
3) Extensive simulation experiments and a complete comparative analysis are carried out on MANET to demonstrate the importance of the proposed mobility-tolerant IRNSA in terms of different performance measures.

Owing to the unreliable communication paths in dynamic MANETs, the tactic of packet propagation requires to be updated at each node. Thus, IRNSA is an online task. The online choice of relay hops creates a link for data propagation. The task of selecting relay hop for a particular data is continuous until that meets its intended receiver. Besides, a time limit is fixed to each data to be alive which is known as Time-To-Live (TTL). For a packet, according to the remaining TTL and the probability of data loss of all the existing relays, an ideal one is selected to transfer the packet. The link reliability is calculated according to the link availability status. The duration of link availability is informed constantly. For the minimum link reliability among two nodes, the fluctuation in the duration of link availability should be less. A device that offers ideal packet delay and link reliability is designated as the relay hop.

In this work, IRNSA is employed at each node to identify an appropriate intermediate node to relay the packet. The best packet propagation route is then established over all these selected hops. Then, the effect of variations in coverage distance, node mobility, node intensity and the duration of link connectivity on packet delay and link reliability is evaluated. Finally, the performance of IRNSA is related to single-objective optimization approaches. The organization of this article is as follows. Section II explores substantial relevant methods for relay node selection. In Section III, we discuss the dynamic network model of MANET. A detailed description of the proposed work is presented in Section IV. We discuss the performance analysis in Section V. Section VI concludes this article.

II. RELATED WORK

Robust and reliable packet delivery plays an important role in MANET. Multi-hop transmission assists in designing such packet delivery schemes using the notion of relay hop selection. Several relay selection methods have been found in the literature. Laurindo et al. proposed a relay selection technique that permits only a limited amount of relay hops in MANET. This approach also guarantees that each device is linked to at least one relay [7]. The authors consider a MANET with star network configuration which is normally not possible in real-world scenarios. Luo et al. proposed a technique for relay selection in Vehicular Ad-Hoc Network (VANETs) with a single dimensional queue installed along the roadside. Each vehicle transfers its information to these roadside entities. These infrastructures effectively transmit that information to the access point. But, it has narrow services to VANETs data transmission [8]. Several routing algorithms take the link reliability into account for robust packet delivery. Liu and Kim designed a stability-based density-adaptive routing protocol to achieve robust packet delivery as well as to ensure the effectiveness of the data forwarding task so as to decrease the control traffic of the routing procedure. The hops which have smaller reliability than a predefined value are prohibited to propagate the packets. Based on various node intensities in the network, the proposal implements the routing procedures to assure the efficiency and reliability of packet delivery. [9]

Al-Akaidi and Alchaita developed three algorithms that exploit the node heading direction angle to choose a stable and reliable communication link. Results demonstrate that the negative impacts of control traffic and packet flooding are reduced if a cautious selection of the relay hop is made; this choice of relay node depends on its heading direction angle related to the present hop. This approach effectively handles the time-changing topology of MANETs owing to node mobility. The approach can work as a separate tool or can be implemented by other data forwarding approaches to improve their effectiveness [10].

Wang and Lee proposed a link stability-based on-demand routing algorithm. This proposed algorithm also considers throughput as a metric to select relay hop where it detects shared free slots on a communication path. This study employs two performance metrics namely throughput and connection stability for relay selection. The performance of the proposed algorithm is analyzed in the networks with both homogeneous as well as heterogeneous links [11]. Boussoufa-Lahlah et al. discuss a state-of-art of the data forwarding algorithms based on the location of the mobile nodes. The authors explore the merits and the demerits of these algorithms by discussing the motivations of the proposal of such algorithms and describe some potential domains for future research associated with the exploitation of this type of algorithms. [12]. Moussaoui and Boukeream present a review of different packet forwarding algorithms that considers connection reliability as a major constraint [13]. Some aforementioned packet forwarding algorithms proposed for MANETs and VANETs consider a single parameter for selecting relay hop. Consequently, these algorithms may not increase the end-to-end performance of mobile ad-hoc networks.

III. NETWORK MODEL

Assume a MANET (NET) with m mobile nodes and it is represented as $NET = \{M_1, M_2, M_3, \dots M_m\}$. The symbol M_i denotes the i^{th} mobile devices in the MANET. Generally, ad-hoc networks can be denoted as a graph. Every mobile device is considered as a vertex of the graph and each edge denotes the connectivity among the mobile nodes. If the Euclidean distance of a node pair (M_i, M_j) is smaller than the coverage distance(C_{dist}), then there is link connectivity between two nodes M_i and M_j and it is defined as

$$L(M_i, M_j) = \begin{cases} 1, & if \ \|M_i - M_j\|_2 \le C_{dist} \\ 0, & Otherwise \end{cases} \qquad (1)$$

In Equation (1), $\|M_i - M_j\|_2$ denotes the Euclidean distance $\mathcal{E}_{ij}$ among two nodes M_i and M_j. In a MANET scenario, a host can be stationary or movable. The graph $(\mathcal{G})$ of a dynamic network can be considered as a snapshot sequence of stationary graphs $\langle \mathcal{G}_1, \mathcal{G}_2, \mathcal{G}_3, \dots \mathcal{G}_{T_l} \rangle$ at respective periods. Lifetime or Time limit of the packet is represented by T_l.

A. Mobility in MANET

The mobility of the devices in a MANET varies arbitrarily. Hence, this work uses a random waypoint mobility (RWM) pattern to define the node mobility and random spatial patterns to model the arbitrary position of each host [14], [15]. Each host in a particular region is considered as a random point. Therefore, Poisson point processes (PPP) are employed for defining node mobility. Assume that a limited subset $\mathcal{W}$ on a Euclidean surface $\mathbb{E}^2$. In the beginning, the mobile devices are expected to be placed in a region $\mathcal{W}$, based on a homogeneous PPP ψ such that $\psi = \{M_1\} \subset NET$ with node density δ. Each hop travels arbitrarily as well as autonomously in the system.

Based on the model of PPP, the moved point ψ' also takes the Poisson distribution [16]. Hence, the movement of devices is defined by PPP. The node intensity (δ) in a region is expected maximum to circumvent the disconnected devices. In the RWM model, movement and the direction of a device get transformed to arbitrary distances. In conjunction with direction, the speed of every device also varies arbitrarily.

The node mobility variations lead to an unstable link with the adjacent nodes. Hence, the link connectivity status of the nodes can be used for modeling the network. By considering the duration of link connectivity, a link $L(M_i, M_j, t)$ between two nodes M_i and M_j at time t is defined as

$$L(M_i, M_j, t) = \begin{cases} d_{ij}^t, & \mathcal{E}_{ij} \le C_{dist} \\ 0, & Otherwise \end{cases} \qquad (2)$$

where d_{ij}^t is the duration of link connectivity between two nodes M_i and M_j at time t.

B. Estimation of the Duration of link Connectivity

Duration of link connectivity d_{ij}^t between two nodes M_i and M_j at time t is measured by evaluating graphs $\mathcal{G}_t$ and $\mathcal{G}_{t-1}$ at time t and t − 1 correspondingly. Let the mobile devices M_i and M_j are traveling in random directions. According to the Cartesian coordinate system, a circle is defined as

$$(a_x - a_i)^2 + (b_y - b_i)^2 = C_{dist}^2 \quad (3)$$

here a_i and b_i represents the parameters of M_i and assumed as the centre of a circle with C_{dist} as radius and a_x and b_y represents the axis coordinates. The calculated communication distance among node pair (M_i, M_j) at instant t is $\mathcal{E}_{ij}^t$ which is defined as the Euclidean distance. It is calculated by finding the meeting point of the trajectory of the mobile device and circle. Considering the linear trajectory of mobile device M_j, the equation of the direct link is determined by the parameters at instant t and $t-1$. The trajectory of the mobile node is defined as

$$b_y = \frac{b_j^t - b_j^{t-1}}{a_j^t - a_j^{t-1}} a_x + k \quad (4)$$

here (a_j^t, b_j^t) and (a_j^{t-1}, b_j^{t-1}) are the parameters of M_j at instant t and $(t-1)$ correspondingly. k is y-intercept of the straight line. The parameters of the meeting point (a_z^t, b_z^t) are calculated by Equations (3) and (4). Furthermore, the $\mathcal{E}_{ij}^t$ among M_i and M_j is computed by the aforesaid meeting point and is defined as

$$\mathcal{E}_{ij}^t = \sqrt{(a_z^t - a_j^t)^2 + (b_z^t - b_j^t)^2} \quad (5)$$

The fraction Δd/Δt defines the instantaneous velocity $(\mathcal{V}_j^t)$ of M_j at instant t. Δt is the difference between two successive periods when a device moves the distance of Δd. Therefore, the duration of link connectivity d_{ij}^t between M_i and M_j is $\mathcal{E}_{ij}^t / \mathcal{V}_j^t$. For this calculation, M_1 is assumed to be a stationary one. Nonetheless, it can be calculated when M_1 and M_j are moving with relative velocity. For a device M_i, the duration of link connectivity with its adjacent hops is $(d_{i1}^t, d_{i2}^t, d_{i3}^t, \dots d_{in}^t)$; where $n \in N_i^t$ and N_i^t is a group of all the adjacent hops of M_i at a particular instant t.

$$d_{in}^t = \begin{cases} \mathcal{E}_{in}^t / \mathcal{V}_{jn}^t, & for\ all\ n \in N_i^t \\ 0, & Otherwise \end{cases} \quad (6)$$

The hops that are not linked with n_i at t have zero link connectivity. In this manner, the duration of link connectivity for each node with their adjacent nodes are estimated. The matrix of the duration of link connectivity D^t is defined as

$$D^t = \begin{bmatrix} 0 & d_{12}^t & d_{13}^t & \dots & d_{1M}^t \\ d_{21}^t & 0 & d_{23}^t & \dots & d_{2M}^t \\ d_{31}^t & d_{32}^t & 0 & \dots & d_{3M}^t \\ \dots & \dots & \dots & \dots & \dots \\ d_{M1}^t & d_{M2}^t & d_{M3}^t & \dots & 0 \end{bmatrix} \quad (7)$$

where D_i^t denotes the duration of link connectivity of the hop i with all other nodes. The link among nodes M_i and M_j is weighted with the duration of link connectivity at the corresponding period.

C. Estimation of Packet delay in MANETs

In MANET, the best link at a particular time may not be the best in the subsequent period. Hence, an end-to-end packet propagation path between a transmitter and the AP cannot be selected in prior. Therefore, an appropriate packet propagation link requires to be calculated at each node. Hence, the process of selecting the packet propagation link becomes the selection of the best relay hop problem. Similarly, the link reliability is also taken into account for selecting suitable relay hop in MANETs. The process of selecting the best relay node founds a robust packet propagation link in these networks. The best relay hop can be designated by considering weighted packet delay and link reliability. Due to the network dynamics, the nodes are less feasible to stay in the same link after a time instant. Hence, minimum weights are assigning to links that are at the end of a path. For a link *L*, the end-to-end packet delay PD_L^t at time t is calculated as

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$$PD_L^t = PD^t(m_s, m_r^1) + \gamma^{h_{m_s m_r^2}-1} PD^t(r_1, m_r^2) + \gamma^{h_{m_s B}-1} PD^t(m_r^R, B) \quad (8)$$

where $h_{m_s m_r^i}$ is the hop count from a mobile device m_s to an intermediate hop m_r^i for a link L. γ is the reduction factor and it is selected from [0, 1]. Also, the probability of data loss (ρ_{loss}) of a link L at time t is calculated by

$$\rho_{loss}{}_L^t = \rho_{loss}{}^t(m_s, m_r^1) + \gamma^{h_{m_s m_r^2}-1} \rho_{loss}{}^t(r_1, m_r^2) + \gamma^{h_{m_s B}-1} \rho_{loss}{}^t(m_r^R, B) \quad (9)$$

The probability of data loss $\rho_{loss}(M_i, M_j)$ of a connection among two nodes (M_i, M_j) is measured as the history of link variation. The probability of data loss is higher when a deviation in the duration of link connectivity is more. $\rho_{loss}(M_i, M_j)$ of a connection among (M_i, M_j) is designated as the reduced sum of link fluctuation (ΔL) for earlier T' periods and is defined as

$$\rho_{loss}{}^t(M_i, M_j) = \Delta d_{ij}^t + \gamma \Delta d_{ij}^{t-1} + \cdots \gamma^{T'-1} \Delta d_{ij}^{t-T'+1} \quad (10)$$

$\Delta d_{ij}^t = \left| d_{ij}^t - d_{ij}^{t-\Delta t} \right|$ is the variation in the duration of link connectivity among two time instants. The value of Δt represents the change in link connectivity states. Recent link availability changes are given more priority than older links.

IV. PROPOSED SYSTEM

The proposed algorithm finds the optimal link for robust and reliable packet propagation. This algorithm selects the link with maximum link reliability with small packet delay for packet propagation in MANETs.

A. Selecting a Relay Node for Robust Packet Propagation

This research jointly optimizes packet delay and the probability of data loss for reliable packet delivery. The combined optimization function can be formulated as

$$\begin{aligned} & Minimize\langle PD_L^t, \rho_{loss}{}_L^t \rangle \\ & Subjected\ to \\ & \quad d_{M_i,M_j}^t > PD_L^t(M_i, M_j) \\ & \rho_{loss}{}^t(M_i, M_j) \leq \mathcal{T}_{\rho_{loss}} \\ & \sum_{M_i,M_j \in L} PD_L^t(M_i, M_j) \leq \mathcal{T}_{PD}^L \qquad (11) \end{aligned}$$

$PD_L^t(M_i, M_j)$ is a packet delay of two nodes M_i and M_j at instant t. The constraints given in the optimization function guarantee the minimum packet delay and maximum link reliability for packet propagation. The given constraint $d_{M_i,M_j}^t \geq PD_L^t(M_i, M_j)$ guarantees sufficient link duration among two nodes to relay the data. The link reliability is certified by $\rho_{loss}{}^t(M_i, M_j) \leq \mathcal{T}_{\rho_{loss}}$. The probability of data loss $\rho_{loss}{}^t(M_i, M_j)$ is limited to be smaller than the predefined value $\mathcal{T}_{\rho_{loss}}$ for each connection of a route. $\sum_{M_i,M_j \in L} PD_L^t(M_i, M_j) \leq \mathcal{T}_{PD}^L$ limits the end-to-end packet delay $PD_L^t(M_i, M_j)$ of a link to the predefined value a $\mathcal{T}_{PD}^L$. In order to relay a packet from a randomly selected device, an intermediate hop is selected from its set of possible adjacent hops according to the restraints given in Equation 11. An adjacent hop which meets the first two conditions are assumed as a reliable relay hop. Moreover, the function formulated in Equation 11 which is a bi-objective problem is resolved by the conventional weighted sum approach. Consequently, Equation 11 can be modified as

$$\begin{aligned} & Minimize\langle o\, PD_L^t + (1-o)\rho_{loss}{}_L^t \rangle \\ & Subjected\ to \\ & \sum_{M_i,M_j \in L} PD_L^t(M_i, M_j) \leq \mathcal{T}_{PD}^L \qquad (12) \\ & n \in N_i^t \text{ for all } (M_i, M_j) \in L \end{aligned}$$

(M_i, M_j) is the successive pair of a link L. σ and $(1-\sigma)$ are weights assign to the function. For a choice of static weight (σ), the trade-off among two parameters is defined by the Pareto front. The minimum limit denotes the best relay selection which is known as Pareto front. N_i^t is a group of all the existing hops to M_i at instant t and $M_j \in L$. Every point in Figure 1 indicates the values of objectives for a specific weight. AR_i^t is a group of existing relay hops to M_i at t and $M_j \in L$.

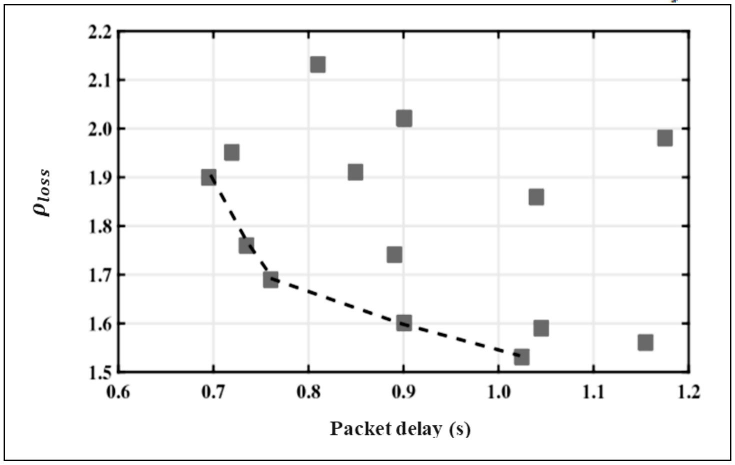

Fig.1. Pareto front for corresponding packet delay and ρ_{loss}

B. Finding Existing Relay Nodes

According to the restraints specified by Equation 11, all the existing relays are selected for all the nodes in the system. The task for finding the existing relays at a hop M_i is given in Algorithm 1. It offers a set $ER_i^t \subseteq N_i^t$ of existing relays for a hop M_i. The value $|N_i^t|$ denotes the cardinality of N_i^t which is the number of adjacent hops for M_i at instant t. Therefore, R_i^t is calculated for node M_i.

Algorithm 1: Finding Existing Relay Nodes
Function: Existing relay nodes $(M_i, N_i^t, d_i^t, I_i^t, dist_i^t, T_{\rho_{loss}})$;
Input : Set of adjacent nodes N_i^t for M_i, the duration of link connectivity d_i^t, the number of the data packet (Information) I_i^t to be distributed, $dist_i^t$ denotes the distance between node M_i and its adjacent nodes, the predefined value of Probability of data loss $T_{\rho_{loss}}$
$ER_i^t = \{\}$
Compute $PD_L^t(M_i, M_j)$, $\forall M \in N_i^t$
Calculate $\rho_{loss}{}^t(M_i, M_j)$, $\forall M \in N_i^t$
for M = 1 to $\lvert N_i^t \rvert$
if $(d_i^t \geq PD_L^t(M_i, M_j))$&& $\rho_{loss}{}^t(M_i, M_j) < T_{\rho_{loss}}$
$ER_i^t == \{R_i^t, N_i^t(M)\}$
else
$ER_i^t - \{ER_i^t\}$
end if
end for
Output: Existing relay nodes ER_i^t at node M_i at time t.

C. Updating the Weight

In order to propagate the packet in the network, the delay for its link should go on reducing with each node. The same notion is described by the third condition in Equation 12. The maximum limit on end-to-end packet delay on a link L is $\mathcal{T}_{PD}^{L}$. If a packet cannot reach the access point within this predefined time is assumed as data loss. Hence, the reduction rate in packet delay of a link should be sufficient. Due to the dynamic ad-hoc nature of the MANET, assigning a static weight for the optimization process leads to poor choice of relay hops. Therefore the value of σ essentials to be appraised constantly to preserve a suitable rate of reduction in packet delay. The value of σ is increased as long as the reduction rate in packet delay is not adequate. Suppose that a packet is originated from source node N_s and creating the link L at relay hop N_i^r. The packet delay of this link up to the present relay is defined as

$$PD_L^i = PD(N_s, N_i^1) + PD(N_s, N_i^2) + \cdots + PD(N_s, N_i^r) \quad (13)$$

The reduction rate in packet delay till the present relay for a data on link L is calculated as

$$ARR_s^i = \frac{PD_L^i}{h_{m_s m_r^i}} \quad (14)$$

$h_{m_s m_r^i}$ is the node count from source m_s to the present relay N_i^r. The parameter ARR_s^i provides the available reduction rate in packet delay per node. The required reduction rate in packet delay (RRR_s^i) is calculated as

$$RRR_s^i = \frac{\mathcal{T}_{PD}^{L} - PD_L^i}{h_{m_r^i AP}} \quad (15)$$

$h_{m_r AP}$ denotes node count from present relay m_r^i to the access point (AP). For a current link L, RRR_s^i provides the required reduction rate in delay per node. The data loss befalls owing to end-to-end packet delay can be circumvented by keeping $ARR > RRR$. A faster link is selected to improve the ARR. This is achieved by selecting the maximum value for σ which prioritizes the packet delay reduction.

D. Choice of Optimal Relay

At each node, the best relay needs to be chosen from all the existing relay hops. By exploiting the status of existing relay hops, all potential links are identified. Amongst all these links, an ideal link is selected for a particular instant. The first hop of that link is designated as the ideal relay. The value of σ is updated at every hop. Then, packet delay (PD_L^i) till the present relay is calculated by Equation 13. The data is considered as lost if $PD_L^i > \mathcal{T}_{PD}^{L}$. Hence, the subsequent relay hop is not identified and the data is discarded. Otherwise, a relay hop is calculated.

V. EXPERIMENTAL RESULTS AND DISCUSSION

This section presents the performance evaluation of the IRNSA. Investigation of packet delay and the probability of data loss are carried out in a MANET scenario. The effect of the number of nodes, coverage distance, link availability status, and node mobility is examined. The present combined optimization process for relay selection is related to the single parameter optimization approach.

A. Simulation Set Up

A MANET with dynamic topology is implemented in an area of 100m × 100m. The devices are originally sampled from a Poisson distribution with various node densities (40-120 nodes). The density of Poisson distribution hinges on the number of hops in the network region. The effectiveness of IRNSA is assessed by MATLAB. Initially, the movement of nodes is achieved and then the link status was calculated using the mobility traces.

After that, this method is employed for calculating the packet delay and connection reliability. Simulation studies are carried out by enabling the mobile nodes to have homogeneous (5, 6, 7m) and heterogeneous (4-8m) coverage distance. In a heterogeneous scenario, every host has a diverse coverage distance.

The speed of hops is varied (4-10 m/sec) and different movement range is set (2-5m) for studying the effectiveness of this approach. For each movement, the node pauses for an arbitrary period (0-0.1 sec). In order to compute the probability of data loss, the history of link availability is fixed to 0.6 sec. The reduction factor is varied (0.2, 0.5, and 0.8) to simulate the results.

B. Analysis of packet delay

The effectiveness of the IRNSA is analysed for different network topologies. Packet delay of a dynamic MANET is evaluated by changing the velocity of hops from 4 to 10m/sec. For different mobility, the impact of coverage distance and number of nodes in the network area is studied. The effect of variation in coverage distance of hops in homogeneous networks is analysed in various network scenarios. The mean packet delay of this ideal relay hop selection approach for various coverage distances of hops is given in Figure 2.

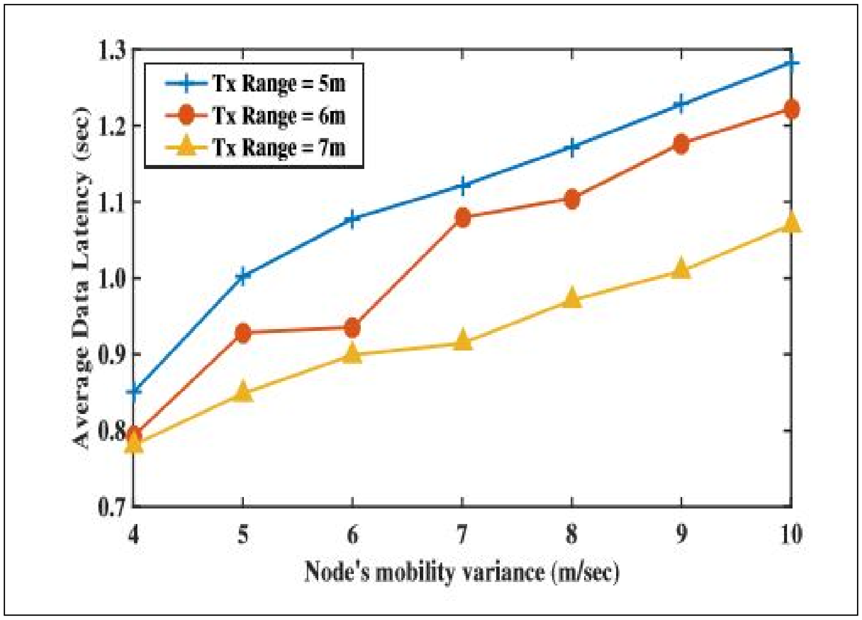

Fig.2. Node mobility Vs Average Packet delay for different coverage distances

The node density is fixed as 40 for this communication topology. It is observed that the mean packet delay increases with the coverage distance of hops. The mean packet delay also rises with the rise of hop velocity. The mean packet delay of a network for various node intensities is illustrated in Figure 3. With the rise in device intensity, the mean packet delay is increased. Figure 4 illustrates the comparative analysis of node density versus average packet delay for different network scenarios. It is noted that the heterogeneous scenarios show poor performance for lower node density. But, the mean packet delay decreases in intense heterogeneous network scenarios.

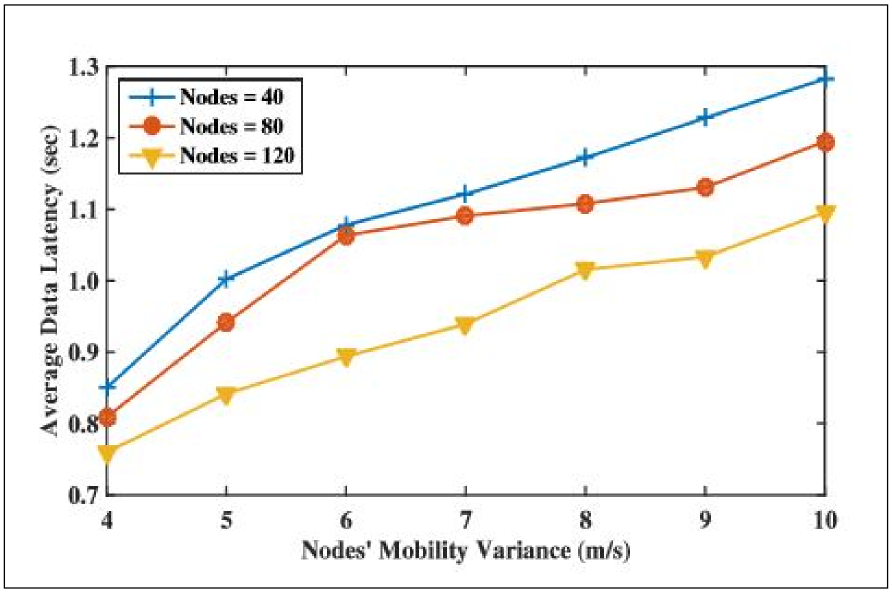

Fig.3. Node mobility Vs Average packet delay for different node densities

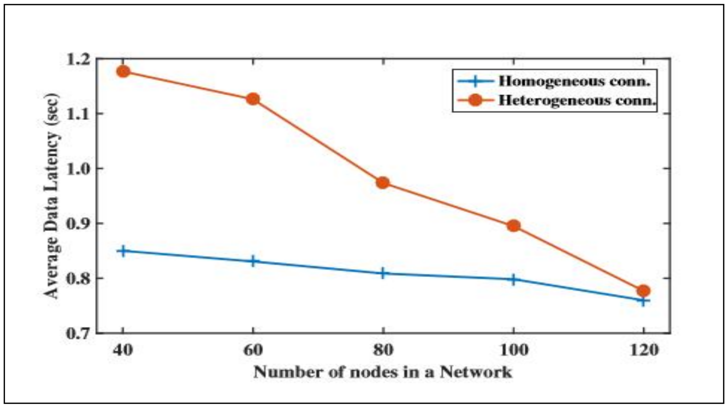

Fig.4. Node density Vs Average packet delay for different network scenarios

C. Analysis of the Probability of Data Loss

The dynamic topology of MANET causes frequent packet loss. Link reliability in terms of probability of data loss is examined for different network topologies. The impact of coverage distance and hop intensity is assessed by changing node mobility. Figure 5 shows the mean data loss risk for a network with different coverage distance. In this topology, 40 nodes are employed. It is observed that the mean data loss risk decreases with the rise in the coverage distance of hops. With the rise in coverage distance, the possibility of link failure rises in a dynamic network. The risk of mean data loss rises with mobility as shown in Figure 6. The performance of different network scenarios is compared in Figure 7.

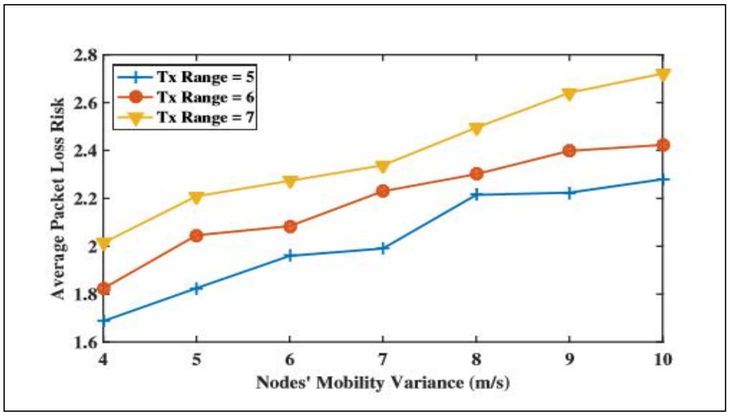

Fig.5. Node mobility Vs Average packet loss for different coverage distances

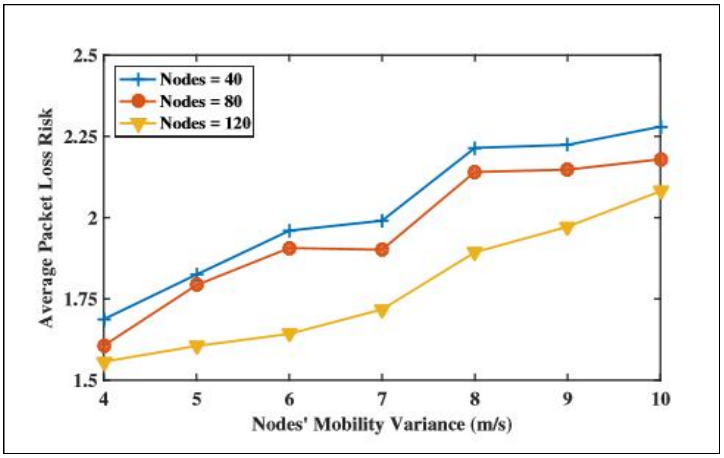

Fig.6. Node mobility Vs Average packet loss for different node density

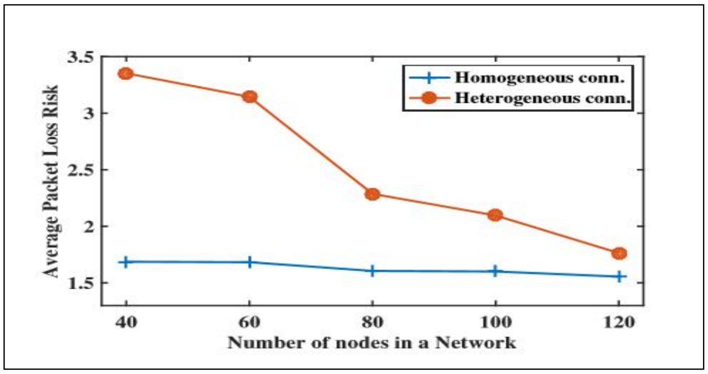

Fig.7. Node density Vs Average packet loss for different network scenarios

D. Combined Vs Single Optimization

The performance of IRNSA is related to single parameter optimization techniques. The bi-objective relay selection method cooperatively optimizes the packet delay and probability of data loss of MANET. Figure 8 illustrates the outstanding behavior of bi-objective optimization as compared with the single parameter optimization.

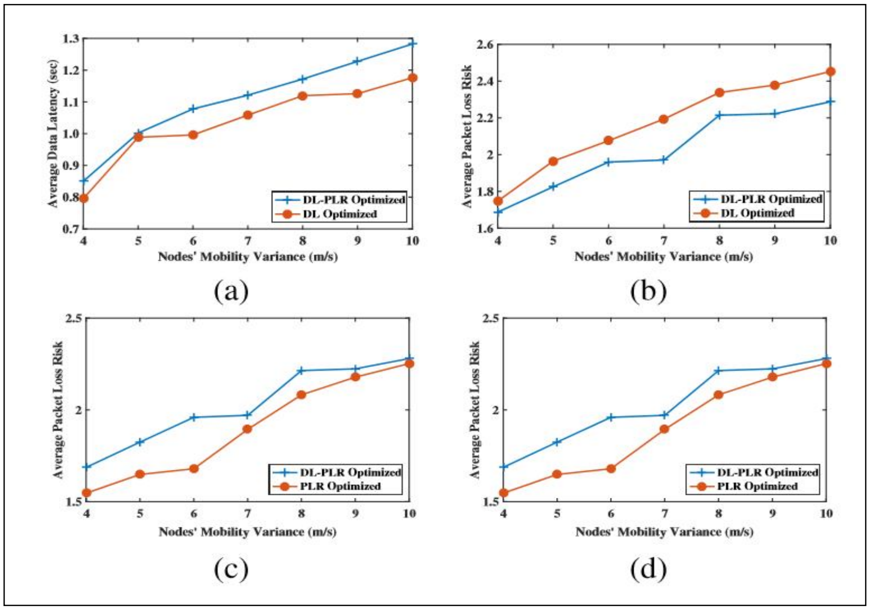

Fig.8. Combined optimization Vs single objective optimization

VI. CONCLUSION

Reliable and robust data forwarding is a very challenging task over time-varying ad-hoc networks. Moreover, the process of a relay node selection is critical and calls for reliable packet propagation approaches to enhance the QoS in MANETs. This study proposes an ideal relay node selection technique for reliable packet delivery in MANETs. This approach picks a node according to link reliability and packet delay for packet propagation. The tradeoff between maximum link reliability and minimum delay is modelled as a Pareto front of multiple parameters optimization problem. At every instant, this approach finds all potential relays and the parameters of the bi-objective function are informed to each node. Subsequently, the best one is carefully chosen from the set of potential intermediate hops by a combined optimization approach. In order to evaluate the performance, random spatial configurations of mobile nodes are modelled with the homogeneous PPP methods. The period of link availability of each device with their adjacent nodes is informed constantly and the relay hop is identified in an online way. Experiments show that this approach enhances delay and the link reliability for packet delivery over MANETs, when related to traditional single factor optimization approaches. This packet propagation approach provides additional improvements in terms of coverage distance, message duplication cost, mobility tolerance, and link stability.

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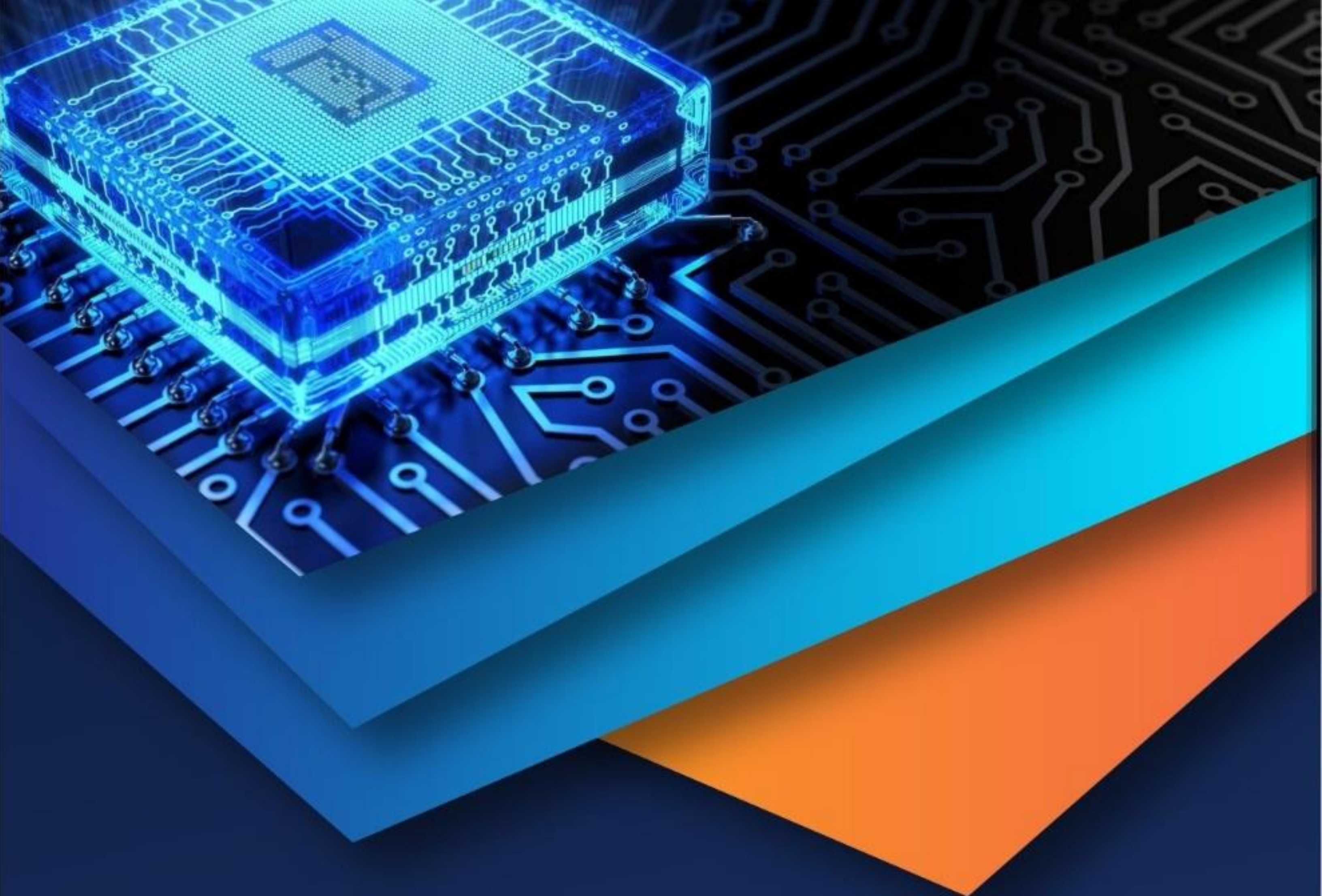

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