CHAPTER III

3. LINK UTILIZATION BASED RELAY SELECTION ALGORITHM FOR COOPERATIVE MOBILE AD HOC NETWORKS

3.1 INTRODUCTION

A link utility-based relay selection (LUBRSA) protocol has been proposed in the first phase. This protocol is proposed for selecting the best relays of the network from the selected nodes. The link utilization-based cooperative MAC uses the benefits of cooperative communication, and it avails three transmission techniques, namely one-phase cooperative transmission $CT_1$, two-phase cooperative transmission $CT_2$ and direct transmission $DT_x$ paths. $DT_x$ is said to be the direct transmission path between the sources to the destination.

A source node wants to transmit or send data to the destination node, and it first forwards Request-to-Send (RTS) packet. When the destination receives the RTS packet from the source, the destination nodes acknowledge the source node with the Clear-to-Send (CTS) messages. The neighboring nodes are also overhearing the control messages from source to the destination. Now, the neighboring node that receives the RTS and CTS packets along with the source and destination becomes the partner nodes and relay nodes of the source.

All the partner and the relay nodes calculate their type of transmission (TT), rate, Power (P), link lifetime (LL) and bandwidth (BW) and send it to the forwarder nodes through the Ready to Help (RTH) packets. When the link utility values of the nodes along the direct transmission path have high link utility values than the relay and the other neighboring nodes, then the data transmission is done through the direct transmission path $DT_x$. Otherwise one-phase Cooperative transmission path ($CT_1$) or two-phase cooperative transmission path ($CT_2$) will be selected.

The backoff time can be estimated using an advanced backoff timer algorithm using the nodes along the transmission path. This backoff timer algorithm is mainly based on the total number of nodes and the mobility degree of the nodes along the path of transmission. This prevents the problem of collision and the delay in the network.
3.2 COOPERATIVE TRANSMISSION PATH

The link utilization-based cooperative MAC with advanced backoff timer mechanism uses a cooperative transmission path for the MAC protocol. Normally, nodes are transmitted along the direct transmission path \((DTx1)\). If the direct transmission \((DTx1)\) is not possible, then it goes for either one-phase cooperative transmission \((CT1)\) or two-phase cooperative transmission \((CT2)\).

Every node is calculating its link utility value after the control messages which will be discussed in the later sections. Each node is said to be a partner node as well as relay node to a particular node in the network path. The partner node or the relay nodes are the nodes which overhear the activity of the nodes in the direct transmission path. The partner nodes are different from the relay nodes.

The partner nodes are the nodes which contain the trace or copy of the data packets and this belongs to the one-phase cooperative transmission \((CT1)\). This involves the listening phase of the direct transmission. The partner nodes differ from relay nodes and do not contain the copy of the data packets and they have link with the two-phase cooperative transmission \((CT2)\). During multi-hop transmission of data, if the nodes along the direct path are in different transmission range, then the cooperative transmission path will be triggered.

Link utility values of the network nodes along the direct transmission path \(D\text{trans}\) is known as the Link utility value \(LUt\ (DTx1)\). The link utility values of nodes along the cooperative transmission path \(CT1\) are said to be as \(LUt\ (CT1)\), and the link utility values of nodes along the cooperative transmission path \(CT2\) are said to be as \(LUt\ (CT2)\).

The network nodes send data along the direct transmission path \(DTx1\) initially. When one-phase cooperative transmission \(CT1\) and two-phase transmission \(CT2\) have the higher link utility values than the direct transmission values, then either \(CT1\) or \(CT2\) will be executed for further transmissions. The link utility values will be calculated at each node and the algorithm given below will be evaluated for each time.

3.3 THE PROPOSED SYSTEM

The overall architecture of the proposed link utilization-based rate adaptive system for cooperative MAC protocols in mobile ad hoc networks is shown in Figure 3.1.
The proposed framework describes the best relay node discovery as the initial process. Here, the relay node can be discovered by the link utility mechanism. It is again showing the backoff timer concept for the best node selection and the rate adaptation technique has been followed. The various parameters considered are throughput, energy and delay. The various phases involved in the proposed work are explained below.

Algorithm for Cooperative Transmission
Let $LUt\ N_h$ the link utilization value of node $h$ and $LUt\ (DTx1)$ be the Link utilization value of direct transmission

Let $LUt\ (CTx1)$ and $LUt\ (CTx2)$ be the link utilization values of cooperative transmission $CTx1$ and $CTx2$ respectively

The link utilization values can be calculated using the formula

If $((LUt\ (DTx1)) > LUt\ ((CTx1)\ and\ (CTx2)))$

Then

Direct transmission $DTx1$ can be selected

Else if $LUt\ (DTx1), LUt\ ((CTx1)\ and\ (CTx2))$

Then

Cooperative communication $CTx1$ or $CTx2$ selected

End if

The Algorithm for Cooperative Transmission shows the type of transmission selected during the time of transmission. The techniques and the description of the cooperative transmission for the multi-hop network will be explained. The network structure of cooperative transmission in multi-hop networks is explained in the Figure 3.2. In the figure, when a source node $S$ wants to communicate with the destination node $D$, the direct path between $S$ to $D$ is denoted $S\rightarrow A\rightarrow B\rightarrow D$ and it was already established with the help of the routing protocols. In link utilization based MAC protocol, the cooperative path can be constructed with the combination of one-phase cooperative transmission (1 phase $CT1$) or two-phase cooperative transmission (2 phase $CT2$) or direct transmission $DTx1$. In the proposed Link utilization-based protocol, the transmitter and the helper nodes will calculate their maximum link utility independently at the time of transmissions. If the partner node has the maximum link utility, the one-phase transmission or two-phase transmissions are followed. Otherwise the direct transmission will be followed.

The direct link utilities of the nodes are good and the link utility of the transmitter is good, then direct transmission will be followed in the first hop. The Figure 3.2 clearly shows the cooperative transmission in multi-hop networks. Here, $S$ is considered to be the transmitter and $A$ is said to be the receiver. In the second hop, $F$ is acting as the partner node and $F$ has already increased its link utility by overhearing the message at the time of direct transmission. Now the one-phase cooperative transmission is activated. Now, $S$ is the transmitter, $F$ is the partner, and $B$ is the receiver. For sending the data packets to the
destination, the two-phase cooperative transmission is followed in the third hop. Now, B is acting as the transmitter, and L is the relay and D is the receiver. Now, the cooperative transmission path is given to be as,

\[ S \rightarrow \{A, F\} \rightarrow B \rightarrow L \rightarrow D \]

Figure 3.2 Structure of Cooperative Transmission in Multi-hop Networks.

The wireless broadcast property and the diversity in transmissions are correlated through the cooperation of the network nodes in the cooperative type of transmissions. The variations of channels are also considered for finding the routes and that reduces a certain amount of energy consumption, reducing end-to-end delay and the probability of outage.

A cooperative communication link contains separate wireless data encoding factors and transmission of message in coordination with the physical layer. The nodes in the cooperative transmission will be a node from single source and relay nodes or they can be in groups or in relays. Cooperative transmission helps in reducing collision and various routing problems with the help of its simpler networks and its difficult links.

3.4 LINK UTILIZATION-BASED RELAY SELECTION ALGORITHM

The source node S likes to send data to the destination node D, it initially sends the Request-to-Send (RTS) control message and it initiates the transmission. The RTS message is having the unique value that is the length of the data packet value (dpv) and the value will be represented in number of bits.

After the transmission of RTS frame, the source node sets a timer (\(T_{RTS}\)) and it will wait for the Clear-to-Send (CTS) frame. The value of RTS is given as,
\[ T_{\text{RTS}} = RTS_T + \tau + CTS_T \] (3.1)

where the values \(RTS_T\) and \(CTS_T\) give the total transmission times of the RTS and the CTS data frames, and the value of \(\tau\) is meant for the propagation delay.

Even after the expiration of the \(T_{\text{RTS}}\), if the node \(N_i\) does not get any CTS message from the node \(N_{i+1}\), then the particular node \(N_i\) cuts off its signal and quits further transmission. During the transmission of the RTS packet, the source node \(S\) is not having the sense about the transmission type and the data rate of the packets. Because of this issue, it has to reserve a specific channel for the control packets which will be given as follows,

\[ D_{\text{RTS}} = T_{\text{intra}} + T_{\text{inter}} + T_{\text{CTS}} + T_{\text{re}} + T_{\text{RTH}} + 5T_{\text{SIFS}} \] (3.2)

where, \(T_{\text{intra}}, T_{\text{inter}}\) and \(T_{\text{re}}\) denote the duration of time of the maximum inter group, intra groups and re-contention backoff periods respectively. \(T_{\text{CTS}}\) and the \(T_{\text{RTH}}\) values give the time of transmission of the CTS and the Ready-to-Help (RTH) frames respectively. Once when the node \(N_{i+1}\) receive the request-to-Send (RTS) packet, it immediately transmits the CTS packet. There is an inclusion of Signal to Noise Ratio (SNR) and the timer will be set as \(T_{\text{CTS}}\) [8].

\[ T_{A1} = T_{\text{CTS}} + T_{\text{RTS}} + T_{\text{SIFS}} \] (3.3)

Just like the RTS control packets, CTS packets are also reserving the path for transmission of data packets on a particular link. Here, the reservation of path is very much helpful in preventing the hidden node problem. The reservation of path will be done as follows [15],

\[ D_{\text{CTS}} = T_{\text{intra}} + T_{\text{inter}} + T_{\text{re}} + T_{\text{RTH}} + T_{\text{ACK}} + 5T_{\text{SIFS}} + \frac{L}{R_{\text{DT}}} \] (3.4)

where \(T_{\text{ACK}}\) is the total transmission time of the acknowledgement frame, and \(R_{\text{DT}}\) denotes the novel rate of transmission of the link and \(L\) stands for length of data packets.

During the time of transmission of the RTS and CTS control signals over the node \(N_i\) and the node \(N_{i+1}\), nodes which are receiving the RTS and the CTS signals are said to be the associate nodes. These associative nodes are again classified as Partner Node (PN) and the
Relay Node (RN). These relay nodes as well as the partner nodes are having the capability of improving the performance of the overall network.

3.4.1 Best Relay Selection
Selecting the best node for transmission is mainly based on the link utility values. Best node selection helps in improving the network performance by reducing end-to-end delay in the network and the wastage of data. Initially, source sends RTS frame to destination. After receiving the CTS signal from the receiver, all the associate nodes as well as the neighboring nodes start calculating their link utilization value. The link utility values can be calculated by jointly considering the type of transmission, transmission rate, power, lifetime of the current link and the bandwidth.

The advanced backoff timer is set to every node after calculating the link utilization values which will be explained in the later section. The node which first expires the backoff timer is said to be the best node for further transmission of data. The best node which is selected by calculating the link utility values is either a partner node or a relay node. If the best node selected is partner node or a relay node, then they must broadcast Ready-To-Help (RTH) message to the forwarded nodes.

The RTH message is having the details about the optimal parameters including the transmission type, transmission rate, optimal power, link lifetime, bandwidth and the value of time duration. The time duration can be calculated as follows,

\[ D_{RTH} = \begin{cases} \frac{L}{R_{01}^{CT}} + T_{ACK} + 2TSIFS & \text{for partner} \\ T_{0}^{CT2} + T_{ACK} + 3SIFS & \text{for relay} \end{cases} \]  

\[ T_{0}^{CT2} = \frac{L}{R_{01}^{CT2}} + \frac{L}{R_{02}^{CT2}} \]

where \( R_{01}^{CT1} \) is the optimal transmission path selected for the partner node and \( T_{0}^{CT2} \) [19] is the optimal transmission path selected for the relay node.

In the above equation, \( R_{01}^{CT2} \) and \( R_{02}^{CT2} \) are the two optimal transmission rates for both the phases which are evaluated by the relay node. In addition to this, the timeout of the data packets \( T_H \) set by the partner node as well as the relay node is given as follows,
The proposed link utilization-based relay selection algorithm transmits the packets of data in the following three ways such as direct transmission (DTx1), one-phase cooperative transmission CTx1 and two-phase cooperative transmission CTx2. Since the type of transmissions, rate of transmissions and the power are calculated with the help of node that maximizes the link utility value, the classification based on the data transmission process is explained below.

1) If the partner node is having high link utility values, then one-phase cooperative transmission CTx1 will be triggered for the transmission of data packets. After receiving the Ready to Help (RTH) frames, the node A is supposed to transmit the packets of data with the partner node with an optimal rate of transmission and power. Here, node A acts as antenna 1 and node F acts as antenna 2, and they transmit data packets at the same time according to the Alamouti 2x1 coding mechanism. The time duration area of the data packets and the ACK about the timeout set by the nodes A and node F will be written in equation as,

\[
T_H = \begin{cases} 
0 & \text{for partner} \\
T_{RTH} + L/R_{O1}^{CT2} + T_{SIFS} & \text{for relay}
\end{cases} \quad (3.7)
\]

\[
D_{DATA} = T_{ACK} + T_{SIFS} \quad (3.8)
\]

2) If a relay node (assume node N) is having the high link utility values, then the two-phase cooperative transmission CTx2 will be selected for forwarding the data packets. After getting the Ready to Help (RTH) frames, the node A is supposed to transmit the data packets to the node N and N, again forwards the data packets to node B. The time duration fields for the data packets say A and node N will be given as,

\[
D^A_{DATA} = L/R_{O2}^{CT2} + T_{ACK} + 2T_{SIFS} \quad (3.9)
\]

\[
D^N_{DATA} = T_{ACK} + T_{SIFS} \quad (3.10)
\]
3) If the path between the nodes say A and B is good for transmission, and A maximizes its link utility, then direct transmission DTx1 will be followed. In this direct transmission case, the node A transmits data packets to B, and the node B is directly using the optimal transmission rate and the power and sets the time duration field as follows,

\[ D_{DATA} = T_{ACK} + T_{SIFS} \]  \hspace{1cm} (3.11)

### 3.4.2 Link Utilization Computation

Link Utilization-Based Relay Selection Algorithm (LUBRSA) calculates the link utilization based on the type of transmission, the rate of transmission, power and the lifetime of the particular link and the bandwidth. The following sections give the calculation of each optimal parameter and the computation of link utilization in detail.

#### 3.4.2.1 Estimation of Link Lifetime

The optimal lifetime of a channel shows the status of the end-to-end state of the channel. The state of the channel will be altering continuously; the end-to-end path is having some temporary interval for which it is valid in the path. The lifetime of the link is helpful in defining the time interval for which the link associated for a particular flow of data is valid or exists.

The link condition at the end-to-end path is said to be the lifetime value of the link (LL\textsubscript{value}). Consider LL\textsubscript{value} \textsubscript{i}, LL\textsubscript{value} \textsubscript{j}, ..., LL\textsubscript{value} \textsubscript{n} will be the link life time values for the nodes between i to n. The link life time value along the path can be given as

\[ LL_{value} = \min(LL_{value}\textsubscript{i}, LL_{value}\textsubscript{j}, ..., LL_{value}\textsubscript{n}) \]  \hspace{1cm} (3.12)

The minimum cumulative value of link life along the path among the nodes is said to be as link lifetime value LL\textsubscript{value}. The link lifetime value is also said to be the interval of continuous time of connection among the node and its neighbor node.

Consider \( N_1 \) as the node with the transmission range \( TX_R \), and \( N_2 \) as another node that is within the transmission range of node \( N_1 \) at the time \( t_n \). Assume at \( t_{n+1} \) (\( t_{n+1} > t_n \)) the node \( N_2 \) moves away from the transmission range \( TX_R \) of \( N_1 \). Now, \( t_n \) is said to be the origination time of the link, and \( t_{n+1} \) is said to be the termination time of the link. The link lifetime will be calculated as the difference between the origination of the link and the termination time of the link. The residual link lifetime is given to be,
In the above equation, \( N_L \) is said to be the total number of links with the duration of the link in \( t \) seconds, and \( L \) is said to be the duration of the link \( a \) is said to be the positive coefficient to compare duration of the link.

\[ L_{\text{value}} = \frac{\sum_{t>a}(N_L \times t)}{\sum_{t>L}(N_L)} - L \quad (3.13) \]

3.4.2.2 Estimation of Bandwidth

An important parameter for calculating the link utility value will be the available bandwidth of a link or an end-to-end path. The available bandwidth of a particular link is having relation with the unused capacity of the particular link on a certain period of time. Even though the capability of the link fully depends on the transmission mechanism and the medium of propagation, the bandwidth of a link depends in addition with the traffic load of the particular link and the time varying metric.

Bandwidth usage between two nodes is assumed as node A and node B and bandwidth is calculated by considering the total number of packets of data executed per unit time in the bandwidth estimation technique. Accurate estimation of the available bandwidth will allow a node to make correct decision before sending a data frame in the networks.

The proposed link utilization-based relay selection algorithm takes much effort on reducing the delay and the collision in the network. During the specific instant in time, a link is transmitting a data packet with a high link capacity or it is idle. This shows that the instantaneous usage of the link can be either 0 or 1. The bandwidth available will be calculated by averaging the time of the instantaneous utilization between the time intervals.

3.4.2.3 Link Utilization Value Estimation

Link utility can be defined as the ability of the nodes to cooperate in the network. Link utilization values can be calculated in this work as follows,

\[ \text{LUT} (TT, TR, P, LL, BW) = U_t - C_f \quad (3.14) \]

where \( TT \) represents the type of transmission, \( TR \) denotes the transmission rate, \( P \) shows the power, \( LL \) denotes the link lifetime value, \( BW \) shows the bandwidth calculated. \( U_t \)
represents the utility function value, and $C_t$ represents the value of the cost function. Every node in the network is trying to improve its link utility value by jointly adjusting the values of transmission type, transmission rate, link lifetime value, power and the bandwidth values.

The cost function $C$ can be defined as the linear function of consumption of energy at the time of transmission. The cost function $C$ can be given as,

$$C (TT, TR, P, BW) = CP * R_{EC}$$

(3.15)

where $C$ is the cost function, $CP$ is said to be the positive constant for the above cost function, and $R_{EC}$ is said to be the energy consumption rate at the time of transmission. The average throughput values at the time of data transmission are also considered in the link utility function values.

Once receiving the Clear-To-Send (CTS) frame, each partner node should start calculating the maximum achievable link utilization values. Every partner node should calculate the instantaneous Signal-to-Noise (SNR) values of the receiver and the partner node by sensing the signal strength of the CTS frame. This also traces the instantaneous Signal to Noise Ratio (SNR) of the channel of transmitter and the receiver of the Clear-To-Send frame.

After detecting the Clear-To-Send (CTS) message, all relay nodes also start calculating their most achievable link utility value of the two-phase link. Each relay node calculates the Signal to Noise Ratio (SNR) of the relay of the transmitter node and the relay of the receiver with the signal strength of the CTS and the RTS control frames. Moreover, every relay node estimates the transmissions powers like $TP_{m1}^{ct2}$ and $TP_{m2}^{ct2}$. These transmission powers are needed to support for the transmission rate of data $TR_{m1}^{ct2}$ and $TP_{m2}^{ct2}$ in the transmitter relay and the receiver relay. These values can be given as follows,

$$TP_{m1}^{ct2} = Px/10^{(SNR - \theta_{m1})/10}$$

(3.16)

$$TP_{m2}^{ct2} = Px/10^{(SNR - \theta_{m2})/10}$$

(3.17)

The values of SNR$_1$ and SNR$_2$ are the instant SNR values of the relay transmitter and the relay receiver values.
Considering the maximum constraint of power of every node, the utility value of each node will be calculated by the relay node. The transmission power of the data packets can be given as,

$$Pt = \min(PX, (1 + \alpha)PO)$$  \hfill (3.18)

The value of $Po$ shows the transmission power determined by the best node during the transmission.

### 3.4.3 Advanced Backoff Timer Concept

Link utilization-based relay selection algorithm is using an advanced backoff timer algorithm for assigning the backoff timer to the nodes which receive the RTS and the CTS frames. The backoff timer concept used here is based on considering the number of nodes and the mobility of nodes. The advanced backoff timer algorithm is verifying which node to consider for accessing the channel for preventing the collision in the network.

The time allotted for the backoff timer is increased or decreased when the path is free for a Distributed Inter Frame Space (DIFS) in the advanced backoff timer mechanism. The advanced backoff timer mechanism will be calculated as follows,

$$Backoff_T = \varphi \times Bcount$$ \hfill (3.19)

where $\varphi$ the time constant, and Bcount is is said to be an integer from a uniform distribution. The value of the uniform distribution will take place between the intervals $(0, Cw)$. $Cw$ is the contention window value, and the contention window minimum value ($Cmin$) and Contention window maximum value ($Cmax$) are explained in advance.

The value of contention window will be increased during the unavailability of the channel using the following formulas.

$$m \leftarrow m + 1$$

$$Cw (m) = (Cw_{min} + 1) \times 2^m - 1$$ \hfill (3.20)

$$Cw_{min} \leq Cw (m) \leq Cw_{max}$$
where \( m \) is said to be the number of retransmissions. The number of nodes and the mobility of the nodes are the two parameters considered here. These are the two parameters used in the advanced backoff timer algorithm.

Increase in number of nodes in the network leads to some collisions in the network. The collisions of the network become more frequently occurring with a backoff time interval. This is because of the chance to have two or more nodes which choose the same value in a regular interval. Let \( K \) denote this interval and its size be \( Sk \). Let \( Pr(k, x) \) be the probability of the node where \( k \) chooses the \( x \) value in the interval \( k \). Here, the problem arises is how to ensure the values for any two nodes \( k \) and \( x \) in the network.

\[
|Pr(k, x) - Pr(i, x)| = y \quad \text{with } y! = 0. \quad (3.21)
\]

The \( Sk \) value must be greater in the backoff timer mechanism. To make a higher \( Sk \) value, it is a must to make the size of \( Sk \) adaptable with the total number of nodes in the network. Then, one of the values of limits of the interval will be intervened. Again, the \( Cw_{max} \) limit of the value will be proposed.

Let \( n \) be the number of nodes in the network, and the \( Cw_{max} \) expression will be given as,

\[
F(n) = \log(n) \quad (3.22)
\]

The term \( \log(\ ) \) is used above for the effects of large values of the number of nodes on the performance of TCP more or less equal. Mobility of nodes is also considered as an important metric of the backoff timer algorithm. But mobility of the nodes often causes the breakage of connectivity among the nodes. This breakdown leads to loss of TCP packets and performance degradation in the performance parameters like average throughput and the end-to-end delay in the network.

The loss of packets is identified at the Medium Access Control (MAC) protocol. Then, the MAC protocols are having access to the collision problem. But this is not a problem here. If the mobility of the nodes increases, then the backoff timer interval will also increase. But this was not happening here because there is loss of packets of data due to some breakage of connectivity in the network and not by the collision in the network.
Mobility of nodes is considered as the second parameter of the backoff timer mechanism. Mobility of node can be mainly calculated by its speed and its angle of movement. The speed and the angle of movement are the two factors which estimate the impact of mobility degree based on the loss of packets.

Let it be considered that a node $i$ which is in communication with another node $j$, then they can be noted by using the above two parameters.

$\alpha_i$: The angle between the line $(i, j)$ and the direction of the movement of node $i$.

$W_i$: Speed of the mobile node $i$.

The impact of mobility due to the packet loss is the same on considering the impact of the above two parameters $\alpha_i$ and $W_i$. By considering the impact of speed $W_i$ of the mobile node for the case of number of nodes, a logarithmic function will be used. This is because for greater values of mobility, the results may change. If the node $I$, is in communication with node $j$, then $\alpha_i$ be angle between the line $i$, $j$ and direction towards the movement of node $i$ and $W_i$ be the speed of the mobile node $i$. Then, the mobility of the node will be given as.

$$H'(W_i) = 1/(\log(W_i + 1))$$  \hspace{1cm} (3.24)

But for making the impact of the speed $W$ is positive in the advanced backoff timer algorithm, one must modify the equation as follows,

$$H(W_i) = \log(W_i + 1)$$  \hspace{1cm} (3.23)

Further, the node movement direction shows the mobility degree for packet loss. Loss of packets will be shown in the equation below,

$$G(W_i, \alpha_i) = \begin{cases} 1 & \text{if } -\frac{\pi}{4} \leq \alpha_i \leq \frac{\pi}{4} \\ 1/\sqrt{(W_i + 1)} & 0 \end{cases}$$  \hspace{1cm} (3.24)
Note that the value \( G(W_i, \alpha_i) = 1 \) when the value of \( W_i = 0 \) (without mobility). The value 1 is added to \( G \) to be defined for all the \( W_i \) values. For getting a positive effect for \( G \) on the advanced backoff timer algorithm, a ratio with the \( W_i \) value will be maintained.

Based on the above equations, it is found that if the mobility of the nodes is a must, the adaptation of the backoff algorithm is least important. The criteria are mainly because the mobility of nodes is very much possible for the cause of loss of many data packets. With a weak mobility value of nodes, the above same equation will make it possible for a major adaptation to the backoff mechanism. This is because the collision between the data frames will be more probable for the cause of the loss of data packets. By using the above three equations, the determined expression for the backoff timer algorithm will be presented as,

\[
C_{w_{\text{max}}} (n, W_i, \alpha_i) = C_{w_{\text{max}0}} + F(n) \times H(W_i) \times G(W_i, \alpha_i)
\]  

(3.25)

where \( C_{w_{\text{max}0}} \) is the initial size of the contention window which was initiated by the medium access control protocol.

The backoff timer approach is fully distributed with the mobile ad hoc networks. Each node was determined along the values of \( n, W, \alpha \) and they can calculate the \( C_{w_{\text{max}}} \) according to the formula 3.23. The value of the variable \( n \) is always changing because there may be some new arrival of nodes or some nodes are leaving from the network.

The advanced backoff timer algorithm which is considering the parameter number of nodes and mobility of the nodes is given to be as,

\[
m \leftarrow m + 1
\]

\[
C_w (m) = (C_{w_{\text{min}}} (n) + 1) \times 2^m - 1
\]

(3.26)

\[
C_{w_{\text{min}}} \leq C_w (m) \leq C_{w_{\text{max}}} (n, W_i, \alpha_i)
\]

(3.27)

where \( m \): denotes the number of retransmission of packets

\( n \): the total number of nodes utilized for relay selection

Cooperation among the nodes is an important aspect of the multi-hop network. Relay nodes are always involved in the cooperation of the network. Reducing collision in the network best relays are selected and eligible relays participate in transmission. Link utility technique is used to improve cooperation in the network by jointly adjusting the type of transmission, power and link lifetime. The parameters taken for these link utilization techniques are
delivery ratio of packets, average consumption of energy, total drop of packets and end to end delay. The link utilization-based technique with the novel back off algorithm helps in reducing the collision in the networks.

3.5 IMPLEMENTATION

3.5.1 Simulation Model and Parameters
The link utilization-based relay selection algorithm is simulated through the Network Simulator 2 (NS2) environment. The various simulation parameters are given in the Table 3.1. The nodes are placed in a uniformly distributed fashion. Initially for considering the parameter transmission rate, the number of nodes is set to be as 50. The energy levels of the nodes are assigned and the transmission range of the node is varied from 230 meters to 500 meters. The capacity of the channel for the mobile host will be set to be 2 Mbps. The MAC protocol of IEEE 802.11 is used as the wireless LAN for the Distributed Coordination Function (DCF). The Constant Bit Rate (CBR) is used as the simulated traffic. The table below is showing the various simulation parameters for the NS2 simulation.

<table>
<thead>
<tr>
<th>Number of nodes</th>
<th>50, 100, 150, ……, 250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Size</td>
<td>1000 x 1000</td>
</tr>
<tr>
<td>MAC</td>
<td>802.11</td>
</tr>
<tr>
<td>Radio range</td>
<td>230 m</td>
</tr>
<tr>
<td>Simulation time</td>
<td>50 sec</td>
</tr>
<tr>
<td>Traffic rate</td>
<td>Constant Bit Rate</td>
</tr>
<tr>
<td>Packet size</td>
<td>512</td>
</tr>
<tr>
<td>Model of mobility</td>
<td>Random way point</td>
</tr>
<tr>
<td>Speed</td>
<td>5 ms</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>AODV</td>
</tr>
<tr>
<td>Error Rate</td>
<td>0.01, 0.02, ……, 0.05</td>
</tr>
</tbody>
</table>

3.5.2 Performance Metrics
The performance of the proposed Link Utilization-Based Relay Selection Algorithm (LUBRSA) is compared with the Relay-Based Cooperative Data Exchange (RB-CDE)
algorithm. The performance of the above two algorithms are evaluated according to the following performance metrics.

3.5.2.1 Average End-To-End Delay
End-to-End delay is calculated as the difference of time between the starting to the ending of data packets to reach the destination.

3.5.2.2 Throughput
Throughput is defined as the ratio between the numbers of data packets successfully transmitted to the total number of transmissions.

3.5.2.3 Average Energy Consumption
Energy consumption is defined as the average energy consumed by the network nodes for the sending and the receiving of data packets.

3.6 EXPERIMENTAL RESULTS

3.6.1 Based on Number of Nodes
The effect of network contention and the collision in the network can be found by increasing the number of nodes. The numbers of nodes initially starts with 50 nodes, and then they are increased as 50, 100, 150 and so on. The graph will be plotted between the number of nodes and the other performance metrics like delay, throughput and the average energy consumption. The proposed Link Utilization-Based Relay Selection Algorithm (LUBRSA) is compared with the existing Relay Based Cooperative Data Exchange (RB-CDE) algorithm.

<table>
<thead>
<tr>
<th>Delay (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Number of Nodes</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>250</td>
</tr>
</tbody>
</table>

**Figure 3.3 Simulated Results for Delay in LUBRSA**

The Table 3.2 and the Figure 3.3 shows how the delay occurs for both the proposed LUBRSA algorithm and the existing RB-CDE MAC protocols, when the number of nodes increasing the end-to-end delay is also increasing. As the number of nodes is increasing, the
link utility value will be calculated in many nodes, and many nodes are having the high link utility values.

Then, every node is in different range and so delay will be gradually increasing while the number of nodes is increasing. From the above figure, it is found that delay of the proposed LUBRSA algorithm is less when compared with the existing RB-CDE algorithm. This improvement will be achieved by the advanced backoff timer algorithm which gives the accurate timer for the nodes to expire.

**Table 3.3: Throughput calculation for the Proposed LUBRSA Algorithm**

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Throughput Relay Based Cooperative Data Exchange (RB-CDE) (Existing)</th>
<th>Throughput Link Utilization Based Relay Selection Algorithm (LUBRSA) (Proposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.294672</td>
<td>0.323242</td>
</tr>
<tr>
<td>100</td>
<td>0.270375</td>
<td>0.301218</td>
</tr>
<tr>
<td>150</td>
<td>0.239621</td>
<td>0.289736</td>
</tr>
<tr>
<td>200</td>
<td>0.218368</td>
<td>0.263851</td>
</tr>
<tr>
<td>250</td>
<td>0.177464</td>
<td>0.253421</td>
</tr>
</tbody>
</table>
Figure 3.4 Simulated Results for Throughput in LUBRSA

Table 3.4 Energy Calculation for the Proposed LUBRSA

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Relay Based Cooperative Data Exchange (RB-CDE) (Existing)</th>
<th>Link Utilization Based Relay Selection Algorithm (LUBRSA) (Proposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>17.83643</td>
<td>17.03536</td>
</tr>
<tr>
<td>100</td>
<td>18.28364</td>
<td>17.45323</td>
</tr>
<tr>
<td>150</td>
<td>18.56347</td>
<td>17.77845</td>
</tr>
<tr>
<td>200</td>
<td>18.96346</td>
<td>18.32635</td>
</tr>
<tr>
<td>250</td>
<td>19.28795</td>
<td>18.64743</td>
</tr>
</tbody>
</table>
The above Table 3.3 shows the throughput calculation of LUBRSA and the Figure 3.4 show the simulated results of the proposed Link Utilization-Based Relay Selection Algorithm (LUBRSA) and the existing Relay-Based Cooperative Data Exchange concept (RB-CDE). Here, the parameters used for plotting the graph are the number of nodes and throughput. When the number of nodes increases, there is a slight decrease of throughput value in the cooperative networks. But the proposed LUBRSA algorithm is performing with a high output when compared with the existing Cooperative Data Exchange algorithm.

![No. of nodes Vs Energy](image)

Figure 3.5 Simulated Results for Energy in LUBRSA

The Table 3.4 shows the energy calculations for the proposed LUBRSA algorithm. The Figure 3.5 shows the simulated values of the proposed Link Utilization-Based Relay Selection Algorithm (LUBRSA) over the existing Relay-Based Cooperative Data Exchange concept (RB-CDE). The parameters used for plotting the graph are number of nodes and energy (J). When the number of nodes increases in the network, the total energy consumption will increase. This is because the nodes of the ad hoc networks are in different range and energy will be obviously increased. The simulated results are given in the Figure 3.5. When comparing the result of the proposed LUBRSA algorithm with the existing algorithm, the energy consumption is low in the proposed system. This is because additional energy wasted due to the packet collision will be greatly reduced in the proposed LUBRSA algorithm due to
the presence of advanced backoff timer algorithm. The transmission power will be included in the utility function.

3.7 SUMMARY
The Link Utilization-Based Relay Selection Algorithm (LUBRSA) is mainly proposed for reducing the end-to-end delay in the network. The proposed LUBRSA algorithm makes use of the cooperative communication technique with three kinds of transmissions like one-phase cooperative transmission $CT1$, two-phase cooperative transmission $CT2$ and the direct transmission $DTx1$ between the source and the destination. When direct transmission fails, then $CT1$ or $CT2$ type of transmission will be selected. The cooperative path can be selected based on the link utility values. The link utility values can be calculated by jointly adjusting the transmission type, transmission rate, power, link lifetime and the bandwidth. For reducing the collision and the end-to-end delay in the network, an advanced backoff timer algorithm is proposed. The two parameters for the backoff timer concept are the degree of node mobility and the number of nodes. With the help of simulation and the implementation results the efficiency of the proposed work will be proved. The proposed system outperforms well than the existing cooperative data exchange algorithm.