An Optimal Capacity-Delay Tradeoff with Appropriate Contention Count based on Correlation of Node Mobility in MANET

Dr. R. Mohandas
Assistant Professor
Dept. of Electronics and Communication Engineering
Jayaram College of Engineering and Technology
Trichy, India
mohandasbe@gmail.com

Dr. M. Rameshkumar
Assistant Professor
Dept. of Computer Science Engineering
Dhirajlal Gandhi College of Technology
Salem, India
mrkkumarsin@gmail.com

N. Sivapriya
Assistant Professor
Dept. of Computer Applications
Cauvery College for Women
Trichy, India
nmsivapriya@gmail.com

Abstract—In MANET, different challenges have been addressed for providing a better performance regarding higher throughput, less delay and reduced transmission overhead. Due to the heterogeneous degrees of correlated mobility of nodes, there was a considerable effect in capacity delay-tradeoff in these networks. Therefore, a medium correlation of node mobility was maintained for optimizing capacity-delay tradeoff. However, this optimal capacity-delay tradeoff was not sufficient for providing better Quality-of-Service (QoS) in MANET. As a result, reliability and link stability are to be selected for providing high bandwidth utilization, high throughput and stable jitter. Hence in this article, a QoS-aware routing metric is incorporated with the correlated mobility. In this scheme, the Link Stability Factor (LSF) is estimated by considering the received signal strength, pertinent contention count and hop count. Based on the estimated LSF, stable link is determined. After that, the node with the highest LSF is elected as a reliable forwarding node. Thus, the proposed scheme improves QoS performance. Finally, the experimental results are demonstrated that the proposed scheme outperforms than the existing method in connection to routing overhead, ratio on packet delivery and end-to-end delay.

Keywords: MANET, QoS aware routing, Link stability factor, Signal potency, Capacity-delay tradeoff, Contention count.

I. INTRODUCTION

Mobile Ad hoc Network (MANET) is basically a wireless and dynamic network with numerous mobile nodes. Such nodes will be able to communicate with each other directly or indirectly and each node is capable to act as host and router since there is no centralized administrator in the network. Also, the packet delivery which depends on the selected path quality was impacted by the nodes mobility and insufficient resources (Gangwar, S., et al. 2012). Mostly, the conventional routing approaches such as Ad-hoc On-demand Distance Vector (AODV) (CPerkins, et al. 2003) and Dynamic Source Routing (DSR) (Johnson, D., et al. 2007) have been
focused on reducing the number of hops on the selected path. However, this condition is not effective for ensuring the QoS. Yoon, J., et al. presented the interrelated mobility into the scaling analysis of infrastructure-less networks in their study. Here, the utmost packet capacity was achieved in cluster sparse regime based on the packet delay and in cluster dense regime, minimum capacity was reached by the equivalent packet delay. However, the issues in the performance of optimal capacity in different delay constraints remain to be determined, that will offer an important insight for the enhanced ad hoc networks working in different delayed conditions. However, the upper bound up to a logarithmic factor was not achieved since this approach does not have a scheduling policy. Therefore, Jia, R., et al. initiated an optimum capacity-delayed swapping by considering the correlation of node mobility (OCDT-CNM). In this approach, the characteristics of correlated mobility were explored and the essential relations among the scheduling parameters and network performance were also illustrated. By using this approach, the overall upper bound of capacity-delayed swapping in the major sub-case of correlated mobility was established. Finally, the possible lower bound was obtained by recognizing the most favorable scheduling parameters on specific constraints. As a result, the consistency and link stability were required for further improving the QoS performance.

Hence in this paper, QoS aware routing metric is introduced and incorporated with the correlated mobility to improve the QoS performance. Initially, LSF is estimated based on the hop count, received signal strength and contention count. The group of nodes that locate inside the transmission range of nodes and assigned by transmitting the packets periodically to one hop neighbors is defined as Contention count. The sender node establishes the number of its neighbors based on the received periodic packets from all the neighbor nodes. Then, the received signal strength is estimated by cross-layer interaction technique. Once the LSF is determined, then the node with the highest LSF is selected as a forwarding node this improvement is called as Optimal Capacity-Delay Tradeoff with Reliable Forwarding based on Correlation of Node Mobility (OCDT-RF-CNM). Additionally, the QoS performance is improved by selecting an appropriate contention count and an optimal capacity-delay tradeoff. The contention count enhanced approach is called as Optimal Capacity-Delay Tradeoff with Appropriate Contention Count and Correlation of Node Mobility (OCDT-ACC-CNM).

The remainder of the article is prepared as follows: Section 2 explains about QoS-aware routing and mobility constraint based protocols for MANETs. Section 3 illustrates about the projected technique. Section 4 demonstrates the overall performance valuation of the proposed technique. Section 5 concludes the research work.

II. RELATED WORK

Cognitive Agent-based Resource Prediction scheme considering the Mobility (CA-RPM) (Chaudhari, S. S., & Biradar, R. C., et al. 2016) was introduced for predicting the resources by using agents via the two resource prediction agencies such as one static agent and one cognitive agent. In this approach, agents were used to predict the liveliness, mobility, traffic, bandwidth and buffer space efficiently which is essential for well-organized resource allocation to support multimedia and real-time communications. However, the forecast approach was not used in before transmission at network and MAC layer.

Multipath Battery and Mobility-Aware routing approach (MBMA-OLSR) using MP-OL SRv2 (Jabbar, W. A., et al. 2017) was introduced in MANET. A MCNR (Multi-Criteria Node Rank) metric makes use of the residual battery energy and the speed of nodes was exploited by this approach. The main aim of this approach was ranking the link stability which is found with the support of link assessment function and also by choosing the best, efficient and stable paths to the destination. Thus, Energy and Mobility Aware Multi-Point Delay (EMA-MPR) selection scheme was proposed for setting the willingness of nodes. But, the performance of this approach in large scale network was less.

A multipath QoS routing protocol (Kumar, C. N., & Satyanarayana, N, et al. 2015) was presented in MANET. At first, multiple disjoint paths were identified and the packets were transmitted through the data paths. The paths satisfy the routing constraints according to the delay, stability of the path and bandwidth. If the routing constraints were not satisfied by the paths, then the traffic and delay will be dispersed with the multiple disjoint paths by making use of the traffic splitting algorithm. However, scheduling or forwarding of the traffic by the intermediate nodes was not performed by this approach.

QoS routing enhancement (Mandhare, V. V., et al. 2016) was proposed by using meta-heuristic approach in MANET. In this approach, the constraint of Quality of Service (QoS) in MANET was focused and improved based on the enhanced Cuckoo Search (CS) algorithm by using on-demand (reactive) protocol. The QoS path was selected based on the calculation of best fitness value rather than shortest path for Route Replay (RRPLY) packet of AODV protocol. The fitness value was calculated with residual energy, hop count and routing load. But, the robustness of this approach was less. A cross-layer TCP enhancement (Mbarushimana, C., et al. 2013) was introduced in QoS-aware-MANET. Initially, the performance of Transmission Control Protocol (TCP) in IEEE 802.11e MANET when competing with high priority of Voice oriented Internet Protocol (VoIP) traffic was evaluated. Then, a novel TCP-friendly scheme known as IEDCA was proposed for improving IEEE 802.11e EDCA mechanism. However, the throughput value of this mechanism was less.

A novel scheme (Moussaoui, A., et al. 2014) was proposed for establishing the constant and sustainable paths between all pairs of nodes in MANET. In this mechanism, a constancy function was utilized as the main path selection criteria according to the computation of the mobility scale of a
node relative to its neighbor. This mechanism was applied on the OLSR protocol for selecting the stable and sustainable MPR topology and nodes. Here, the recalculation of MPR and the routing tables were minimized and other QoS metrics such as packet loss and response time were ensured. But, the estimation of the link stability was not the unique parameter for evaluating the robustness and the availability of the path.

A markov swarm mobility model (Li, L., et al 2012) was proposed for characterizing the time-dependent changes in the network topology according to the degree of optimized collaboration. This approach was examined through the statistical hypothesis testing of simulation data. The unique performance of this approach was studied in terms of routing overhead, hop count and average end-to-end delay of a data packet. However, model verification by real-life data traces was not focused by this approach.

A Fuzzy-cost based Multi constrained Quality of service Routing (FCMQR) protocol (Santhi, G., & Nachiappan, A., et al 2012) was introduced for selecting an optimal path based on the consideration of multiple independent QoS metrics similar the uninterrupted delay, number of intermediate hops and bandwidth. This approach was proposed based on the multi criterion objective fuzzy measure. By using this method, all the available resources of the data path were converted into the single metric fuzzy cost. Moreover, mobility prediction was achieved for discovering the time life of the data path. Then, the optimum path will be identified by the utmost lifetime and least fuzzy cost and that path is utilized for transmission. But, other QoS parameters like buffer length and power consumption rate were not considered in this approach.

III OCDT WITH RELIABLE FORWARDING BASED ON CORRELATION OF NODE MOBILITY (OCDT-RF-CNIM)

In this section, QoS aware routing metric is described which is incorporated with correlated mobility for determining the reliable forwarding node. In this method, the reliable forwarding node is determined based on the link stability.

A. SYSTEM MODEL

In this study, n nodes transferring over an extended square of area n are considered. The entire nodes are separated into \( n = \theta(n^q) \) groups, where \( 0 \leq q \leq 1 \). The circular area of radius covers every group \( R = \theta(q^p) \) where \( 0 \leq q \leq 1 \). Particularly, each group is called as cluster. Each cluster has \( q = m/n \) nodes on average and even though the q value differs for each cluster the outcome would not get altered, that is \( \theta(n^q/m^q) \) remains unchanged.

Time-Scale

Time is subdivided into many slots of equivalent duration of units. Nodes move over slots and identify the following a correlated mobility fashion and remain static at every slot. Additionally, the slow mobility time scale is considered i.e., the packet transmission is faster than the speed of node movement.

Correlated Mobility

Consider specific center of cluster as \( j \) and member of cluster as \( i \). By using the features of correlated mobility, the term motion is defined as given below:

- **The Cluster Center Motion**: End of each slot, the scheduler of network determines the node of every cluster center \( j \) in the upcoming slot. In every slot, the node of cluster center \( j \) is uniformly and randomly chosen within all network area independently comparing from other cluster centers. Once it is decided, the scheduled positions in the next slot receive the entire cluster centers.

- **The Cluster Member Motion**: The cluster center \( j \) is chosen the new position, the new region close to \( j \) receive the entire nodes in this cluster. Following this, randomly and uniformly, the position of cluster member \( i \) is selected within the new region which is independent from other nodes in the same region.

The analysis is classified into three different regimes based on the values of \( \beta \) and \( \nu \) as follows:

- **Cluster sparse regime** \( \beta + \nu < 1 \): \( m^2 \) is the area that is covered by all the clusters is \( O(n) \) which denotes strong correlation of node mobility.

- **Cluster critical regime** \( \beta + \nu = 1 \): \( m^2 \) is the area that is covered by all the clusters is \( O(n) \) which denotes medium correlation of node mobility.

- **Cluster dense regime** \( \beta + \nu > 1 \): \( m^2 \) is the area that is covered by all the clusters is \( O(n^q) \) which denotes weak correlation of node mobility.

Traffic Pattern

Every node is assumed as a source node that is connected with a destination node which is randomly and independently identified from all the other nodes in the mobile ad hoc network. And also, the destination is selected from all the clusters. After that, the sources packets are sent to the respective destination via a common wireless channel.

B. CLUSTER SPARSE REGIME

Policy for Scheduling

In a traffic stream \( s \rightarrow d \), \( s \) indicates the source and \( d \) indicates the destination. \( C_s \) and \( C_d \) indicate clusters with \( s \) and \( d \) correspondingly, where \( C_s \neq C_d \). Opportunistic broadcasting method is applied for completely utilizing the correlation of node mobility.

1) While \( S \) meets a cluster \( C_k (k=1,..., R^2_2) \), where \( R^2_2 \) is the maximum number of clusters which contain messages of \( S \), a relay will be produced in \( C_k \) with a single hop unicast. This process is called as inter-cluster duplication and this process will proceed until one of the relays meets \( C_d \).

2) If any one of the relays meets \( C_d \), a new relay will be produced in \( C_d \) through one-hop unicast. If not, go to step 1.

3) The newly generated relay in \( C_d \) will generate relays within \( C_d \) by using broadcast \( R^2_2 \) (denotes the number of relays). This process is called as intra cluster duplication.

4) If any one of the relays in \( C_d \) is captured within the range \( l^2 \) by the destination, the message of \( S \) will be sent to the
destination by $h^5$ hop unicast transmission. If not then, go to step 3.

**Upper Bound of Capacity-Delay Tradeoff**

In this section, the upper bound of capacity-delay tradeoff in cluster sparse regime (Yao, S., et al. 2014) is reviewed.

**Achievable Lower Bound**

A unit slot is divided into three sub-slots. The operation of every sub-slot is given below:

- Nodes generate inter-cluster duplications and $C_d$ receive messages from the inter-cluster duplications by using one hop unicast transmission. Every hop utilizes the transmission range of $r^2$.
- $R^2_d$ intra-cluster duplications are generated through broadcasting in $C_d$.
- If one of the intra-cluster duplications is captured within the transmission range $R$ by the destination, then the message of $S$ will be delivered to the destination through $h^2$ hop unicast transmission. The transmission range for every hop is $r^2$.

**C. CLUSTER DENSE REGIME**

In cluster dense regime ($\theta + \phi > 1$), whenever and wherever the node mobility illustrates weak correlation, it is observed that either the area of every cluster becomes larger or it covers many number of clusters compared with cluster sparse regime. Therefore, clusters are not disjoint and they overlap with every other cluster with maximum probability. Hence, the scheduling policy is described in cluster dense regime.

- Nodes containing a message will create relays through $k^6$ broadcast and the broadcast area is $a[b = 1...b]$. It indicates the overall number of inter-cluster duplications.
- If any one of the relays is attained by a node in $C_d$ in transmission range $R^2_d$, then the communication will be sent to the node with $h^2$ hop unicast transmission. Link stability is calculated by using received signal strength, median contention count and hop count. It is computed as,

$$LS = \frac{SS_{max} - SS_{min}}{SS_{max} - SS_{med}}$$

If not, then go back to the previous step.

- The captured relay in $C_d$ will generate new intra-cluster duplications by broadcast ($R^2_d$ indicates the total number of intra-cluster duplications in $C_d$).
- If any of the intra-cluster duplications is captured via destination within the range $L^2_d$, the communication will be sent to the destination through $h^2$ hop unicast transmission. If not, then go back to the previous step.

**Network Model**

A MANET network can be defined in double vector space model $(G(V, E), P_2, \theta(R))$ where

- The graph $G(V, E)$ denotes the network.
- The node set $V$ and $E$ edge sets are available in the network.
- $\forall (e) \in E$, link(e) is active when two nodes are in communication range (CR) of one another.
- $S$ and $D$ is source set $S = \{S_1, S_2, S_3, ... , S_d\}$ and destinations set $D = \{D_1, D_2, D_3, ..., D_d\}$ in the network.
- $\varphi(e), \eta(i,j), \rho \in V, e \in E$ is signal strength of link, node's contention count and hop count.
- $P_{r}^{i,j} = \{\varphi(e), \eta(i,j), \rho\}$ is the Probability of the link $(P_r)$ at route $R$, for any source $i$ to destination $j$ which depends on signal strength, contention set and hop count.

**Probability Model**

Link quality $(l_q)$ is measured between X and Y$(X<Y)$. X and Y denote the lower and an upper value of route cost factor. The probability of a reliable link $(P_{r})$ is computed through normalized $l_q$ in the range 0 and 1. The probability of a path (R) is the summation of logarithmic probability of all active link

$$P_{RF} = 1 - \min_{i=1}^{n}(P_r)$$

In above equation, $l_q$ denotes the number of links in among Sources and Destinations. Log of every link probability gives negative outcome; as a result the negation of this value will create it a positive value.

Thus the probability of stable route $S_R$ is the minimum of all presented paths.

$$S_R = \min_{i=1}^{n}S_R$$

In above equation, $P$ denotes the whole number of paths among Source and destination.

**Link Stability Factor:**

---

15704
In this approach, Upper Bound - Lower Bound on signal strength, contention count and an Upper Bound on hop count have been applied. The normalized values of hop count, received signal strength and contention count have been mapped into a LSF and by using LSF, the link stability is calculated.

\[
\text{LSF}_i = \frac{SS_{\text{norm}}}{HC_{\text{norm}}} - \left[CC_{\text{norm}} - CC_{\text{med}}\right]
\]  

(7)

In the above equation, \(SS_{\text{norm}}\) denotes the normalized received signal strength at a node, \(HC_{\text{norm}}\) indicates the normalized hop count at any node, \(CC_{\text{norm}}\) denotes the normalized contention count at any node, and \(CC_{\text{med}}\) indicates median contention count.

IV. OCDT WITH APPROPRIATE CONTENTION COUNT BASED ON CORRELATION OF NODE MOBILITY (OCDT-ACC-CN)

Contention Count Estimation: To calculate reliability, each node must have knowledge regarding its neighboring nodes in addition to received signal strength. The neighboring nodes count may be computed with help of periodic packets (PPKTs). PPKTs are simple packets which are used to test connectivity in the network. Employ of PPKTs transmission to gather information concerning neighbor nodes.

\[\rho_N = |S|\]  

(8)

In the above equation, \(|S|\) denotes the cardinality of contention set \(S\).

Estimation of Received Signal Strength and Hop Count: The signal strength indicates the quality of the link between two closest nodes. High signal strength denotes minimum power loss through the transmission and also the link quality is considered to be stable and strong. The received signal strength increases with any pair of adjacent nodes that move towards every other pair and vice versa. Received Signal strength can be computed as the received power for packet to noise.

Multi-objective Optimization by Normalization: Any link is said to be stable, if it’s received signal strength is maximum, contention count has to be a middle value and hop count should be minimum. All these objectives cannot be fulfilled with either a minimum or a maximum value concurrently, therefore trade-off is required. These kinds of issues are usually called as multi-objective optimization issues. To avoid this issue, normalization technique has utilized on the entire three objectives.

Lower Bound Normalization: This approach bounds the lower value to zero, and upper value is left unbounded.

\[f_L = \frac{f(x)}{f_{\text{min}}}\]  

(9)

Upper Bound Normalization: This approach bounds the upper value and lower value is left unbounded.

Upper-Lower Bound Normalization: It offers both upper and lower bound to the objective and can be computed as follows.

\[f_{UL} = \frac{f(x) - f_{\text{min}}}{f_{\text{max}} - f_{\text{min}}}\]  

(11)

The established signal strength, contention count and hop count are decide the LSF. The neighbor node which has high LSF is selected as forwarder node.

V. SIMULATION RESULTS

The simulation is carried by network simulator (NS-2) to appraise the performance of the proposed approaches OCDT-RF-CN and OCDT-ACC-CN with existing OCDT-CN. The simulation parameters for creating MANET are given in Table 1.

TABLE 1. SIMULATION PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>50</td>
</tr>
<tr>
<td>Node’s speed</td>
<td>0.01 m/s</td>
</tr>
<tr>
<td>Network simulation area</td>
<td>1500 X 1500 sqm</td>
</tr>
<tr>
<td>Frequency</td>
<td>2.4GHz</td>
</tr>
<tr>
<td>Radio range</td>
<td>250 m</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>802.11s</td>
</tr>
<tr>
<td>Packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Packet type</td>
<td>RTP/UDP</td>
</tr>
<tr>
<td>Transmission Power</td>
<td>15dBm</td>
</tr>
<tr>
<td>Number of channels</td>
<td>2</td>
</tr>
<tr>
<td>Channel capacity</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Transmission rate</td>
<td>4 Mbps</td>
</tr>
<tr>
<td>Packet internal</td>
<td>2 ms</td>
</tr>
<tr>
<td>Traffic source</td>
<td>CBR</td>
</tr>
<tr>
<td>Node mobility</td>
<td>0 to 20 m/s/sec</td>
</tr>
<tr>
<td>Traffic rate</td>
<td>4 packets/sec</td>
</tr>
</tbody>
</table>

The created MANET with AODV routing protocol is enhanced with OCDT-CN, OCDT-RF-CN and OCDT-ACC-CN. The following performance metrics are calculated and performance is evaluated and proved that proposed protocols performs better than existing protocols.

Routing overhead

Routing over head is calculated as ratio between number of packets used for finding route from source to destination and the number of packets sent from source to destination during data transmission. During packet transmission the routing information is exchanged among nodes for which some bandwidth utilized which reduce the data packets transmission. Routing overhead is changed periodically based on link quality and contention count.
Figure 1 shows that the comparison of OCDT-CN, OCDT-RF-CN and OCDT-ACC-CN methods in terms of Routing overhead. The X-axis indicates number of connections. Y-axis indicates the Routing overhead value. The Routing overhead is reduced for proposed methods compare to existing method.

**Packet Delivery Ratio (PDR)**

PDR refers the fraction among total number of data packets received and total number of data packets transmitted over the communication medium.

![Packet Delivery Ratio](image1)

**Figure 2. Comparison of Packet Delivery Ratio**

Figure 2 shows that the comparison of OCDT-CN, OCDT-RF-CN and OCDT-ACC-CN techniques in terms of Packet Delivery Ratio. The X-axis denotes mobility speed. Y-axis indicates the PDR value. The PDR value increased for proposed methods compare to existing methods.

**End to End Delay**

Delay refers the fraction among total delay for packets received by the destination to total number of packets received by the destination.

![End to End Delay](image2)

**Figure 3. Comparison of Delay**

Figure 3 shows that the comparison of OCDT-CN, OCDT-RF-CN and OCDT-ACC-CN techniques in terms of delay. The X-axis denotes mobility speed. Y-axis indicates the delay value. The delay value decreased for proposed methods compare to existing method.

**VI Conclusion**

In this paper, a QoS aware routing metric with correlated mobility is introduced for determining the reliable forwarding node. This technique determines the reliable forwarding node using the link stability. The link stability determines by considering the appropriate contention count. Finally, the simulation is analyzed for the proposed approach based on the Routing Overhead, Packet Delivery Ratio and Delay. The simulation results proved that our proposed methods are providing better results.

**References**


