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An Interference based Routing Metric In Wireless Mesh Network

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Abstract: Wireless Mesh Networks (WMNs) are consist of mesh routers. Mesh routers are built with multiple radios for improving capacity of network with the assignment of different frequency bands (channels). Establishment of routing is very important for getting good output or achieving good performance in multi radio wireless networks. In this paper we have proposed Weighted Cumulative Consecutive Conflicting Expected Transmission Time (WCCCETT) routing metric for multi radio multi channel wireless mesh networks. Theoretic analysis and simulation verify WCCCETT gives better performance than other relevant metrics with respect to the selection of less interference effecting path.

Keywords: Wireless Mesh Network; Expected Transmission Time; Multi-Hop; Routing Metrics; Multi-Channel; Interference.

1 Introduction

Wireless Mesh Networks (WMNs)[1] are equipped with mesh routers. Mesh routers are the backbone of wireless mesh networks. Mesh clients might be mobile, and might form a network of client mesh among themselves with the help of mesh routers. Three types of wireless mesh networks are available according to their topology and architecture. These are Hybrid Mesh Networks, Infrastructure Mesh Networks and Client Mesh Networks [14].

In recent years routing in wireless mesh network is very important for researches. Different protocols for routing in Mobile Ad-hoc Network (MANET) [10, 11]have already been proposed in the literature. Since WMN is a type of MANET, these schemes can be applied in a WMN. Routing protocols for wireless mesh networks is sub-divided into two categories, namely reactive routing and proactive routing.

Reactive routing protocols are namely DSR [8], AODV [9]. When source node needs to send packet to destination reactive routing protocol creates route between destination and source. Flooding is used for route discovery when it is needed. Route discovery with flooding is needed for Ad-hoc networks because there are frequent breaks of links done by the frequent mobility of nodes. This type of route discovery gives high connectivity in network and also results lesser message overhead. Due to the static character of mesh routers links generally have much longer possible lifetimes. Example of proactive routing protocols is OLSR [12]. Every node maintains tables which containing routing information of each and every other node which is in that network. Each node updates the table to continue a secure view of that mesh network. If the topology changes than nodes circulate update messages all the way through the mesh network to conserve steady routing information about the entire network. Forwarding packets along with the route varies in such type of routing protocol [1,14].A good routing metric must precisely capture the value of network links and serve in calculation of excellent quality paths. One of the most important characteristics of metric in WMNs is interference.

The reminder of this paper is structured as follows. In section 2 routing metric components in mesh networks are given. Section 3 describes metric characteristics. Section 4 reviews the existing related works. The proposed routing metric WCCCETT is shown in section 5. Section 6 shows mathematical analysis and examples. Comparison with some other existing routing metrics with respect to the proposed routing metric is also given

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in section 6. Section 7 shows simulation and analysis. Section 8 gives conclusion.

2 Metric Components

In this section, we have mentioned some key components which compose a routing metric for wireless mesh networks namely Hop Count, Capacity of Link, Quality of Link and Channel Diversity of Channel are discussed.

2.1 Hop Count

In MANET hop count can be introduce as a routing metric. It can be used for serving as a metric in more complex way. Most of the cases it tends to lead more congestion [17].

2.2 Capacity of Link

Link capacity measuring gives capability of immediate throughput of a link. There are a few ways this can be done. One way is probe the link actively for calculating the speed of transfer and to rely on current rate of radio line [16].

2.3 Quality of Link

If the links are of high-quality than the paths have higher transfer speed of data and have lower rate of error. Signal to Noise Ratio (SNR) and Packet Loss Rate (PLR) [2]are the way of calculating quality of link in path.

2.4 Diversity of Channel

It is very insignificant to use same channel in consecutive link of a path. To result good performance non-overlapping channels should be operate in the links of that path with the range of interference. Channel diversity is the only way to solve the problem while using multi-channel multi-radio wireless network [3,18].

3 Metric Characteristics

In this section some characteristics of routing metric in WMNs is illustrated.

3.1 Inter-Flow Interference

It is the interference which is caused by the other flows which are in use on the same channels and also contending for the same medium. This interference can result in starvation of bandwidth for some nodes where busy channels can always be experienced by the nodes [3,7,9].

3.2 Intra-Flow Interference

When radios of more than one links of a single path operate on the same channel this type of interference occur. This type of interference can be reducing by growing number of channels. Non-overlapping channels may be selected for adjacent hops of the path. Interference range of multiple hops is normally bigger than a single hop in mesh network. So, it can be observed in multiple hop network [6,19].

3.3 External Interference

External interference are of two types: Controlled Interference and Uncontrolled Interference. Controlled Interference occurs when other nodes are external to the network using the networking technologies which overlap with those nodes used by the network.Uncontrolled Interference occurs when in the same frequency range other source of radio signals emit , but not performing in the same MAC protocol. Network performance and throughput are seriously affected by these types of Interference [19,20].

3.4 Agility of Metric

This is the ability to take quick efficient action for a metric when the changes in network topology occur.

3.5 Metric Stability

In general,value of metric for a link do not change frequently unless there is a vast change in topology. In low mobility metric become stable[3,15].

3.6 Throughput of Metric

Normally any metric selects routes with greater goodput or throughput constantly.Performance will be better if the throughput is higher [16].

4 Some Approaches of Routing Metrics in Wireless Mesh Network

Some important routing metrics in wireless mesh network would be discussed in this section.

4.1 ETX(Expected Transmission Count)

The Expected transmission count (ETX) [2]is the number of transmissions and retransmission which is required to send a packet through a link. Summation of Expected transmission count of all links in the path is the total Expected transmission count of that path. Calculation of ETX starts with measurements of packet loss probability in forward and reverse directions of the path.

Suppose, A and B are two nodes of a link in a wireless network. Individual nodes are sending probe [14] packet in every second. Suppose, Node X has received eight packets from node Y and node Y has received seven packets from node X in 10sec. After 10sec. node X received an acknowledgement packet which contains number of probes, node Y being received from node X. Based on these count values, node X calculate forward and backward link loss rate as $(10-8)/10$ and $(10-7)/8$ respectively. Here, ETX is 2 in the given link[14].

4.2 ETT(Expected Transmission Time)

The Expected transmission time (ETT) [3,4] is an improvement over ETX. It also take bandwidth while assigning metric to a link. Let size of the packet is M and bandwidth of the link is B.Then following is the equation of Expected transmission time.

$$ExpectedTransmissionTime = ETX \times \frac{M}{B}. \qquad (1)$$

Through ETT successfully transmission time of a packet on link can be calculated.

4.3 Weighed Cumulative ETT(WCETT)

Weighed Cumulative Expected Transmission Time (WCETT)[5] routing metric is being established to improve the quality of ETT metric in consideration with different channels. The Weighed Cumulative Expected Transmission Time metric of a given path p is given as:

$$X_m = \sum_{Hop\ i\ is\ on\ channel\ m} ETT_i \quad 1 \leq m \leq k \qquad (2)$$

$$WCETT_P = (1-\alpha) \times \sum_{i=1}^{n} ETT_i + \alpha \times \max_{1 \leq m \leq k} X_m \qquad (3)$$

$X_m$is the sum of the ETT values of links that are on channel m in a system. The system has k orthogonal channels. Here α is a tunable parameter within the bounds $0 \leq \alpha \leq 1$ that controls preference of channel diversity over path length.

4.4 Weighted Cumulative Consecutive ETT (WCCETT)

The Weighted Cumulative Consecutive Expected Transmission Time (WCCETT) [5] is a metric which is the extension of WCETT metric with better reflection of intra-flow interference. WCECETT metric definition is given as:

$$Y_m = \sum_{Hop\ i\ is\ on\ Segment\ m} ETT_i \quad 1 \leq m \leq k \qquad (4)$$

$$WCCETT_P = (1-\alpha) \times \sum_{i=1}^{n} ETT_i + \alpha \times \max_{1 \leq m \leq k} Y_m \qquad (5)$$

WCCETT metric has also two parts.First part shows summation of ETT in the links of a path P and the second part gives the channel diversity.Here tunable parameter is α.

WCCETT metric gives better result than WCETT metric. The first part is multiplied by $(1-\alpha)$ and the second part is multiplied by α . The value of n is the number of links on path p. k is the number of orthogonal channels. The term Segment is newly included in the metric and only consecutive channels are incorporated in calculation for better result in comparison with other relevant metrics. Here, segment is considered as consecutive hops with same channel. Dissimilar segments do not interfere with each other. Thus, WCCETT's path selection has more channel diversity (small segments) compared to WCETT with less intra-flow interference. Y_m is the summation of the Expected Transmission Time values of the links which are on segment m in that system .Here, there are n hops with $k$channels, and α is used as tunable parameter where range of tunable parameter is $0 \leq \alpha \leq 1$.

5 Proposed Metric

We have proposed a routing metric, which is capable of work through multi-channel multi-hop environments. The Weighted Cumulative Consecutive Conflicting Expected Transmission Time is the proposed metric with less intra-flow interference, WCCCETT can be expressed as:

$$Z_m = \sum_{Conflicting\ link\ on\ Channel\ m} ETT_i \quad 1 \leq m \leq k \qquad (6)$$

$$WCCCETT_P = (1-\alpha) \times \sum_{i=1}^{n} ETT_i + \alpha \times \max_{1 \leq m \leq k} Z_m \qquad (7)$$

Here we considered consecutive conflicting hops on the same channel interfere with each other for WCCCETT. We have considered this as segment for

WCCCETT. In Figure 1, path 3 has one segment including hop {4,5} while path 4 has no segment. In this proposed metric segments do not interfere with each other. WCCCETTs path selection has more channel diversity compared to WCCETT [5] with lesser intra-flow interference. Z_m is the summation of the ETT values of links that are on segment m for the system .There are$n$ hops with k channels, and α is a tunable parameter. Here is the range of tunable parameter $0 \leq \alpha \leq 1$.

6 Mathematical Analysis and Examples

A simple wireless mesh topology is given in Figure 1. Four paths are there from source to destination. In each path there are six hops. In each link there are some calculated Expected Transmission Time(ETT).We have applied three channels in this topology.Some consecutive links are there with same channels as shown in the Figure 1.In table 1, table 2 and table 3 there are calculations of WCETT, WCCETT and WCCCETT metric. In Figure 2, Figure 3, Figure 4, Figure 5, Figure 6 we have shown the calculation of WCETT, WCCETT, WCCCETT metric where tunable parameters are 0.1, 0.3, 0.5 0.7 and 0.9 respectively.

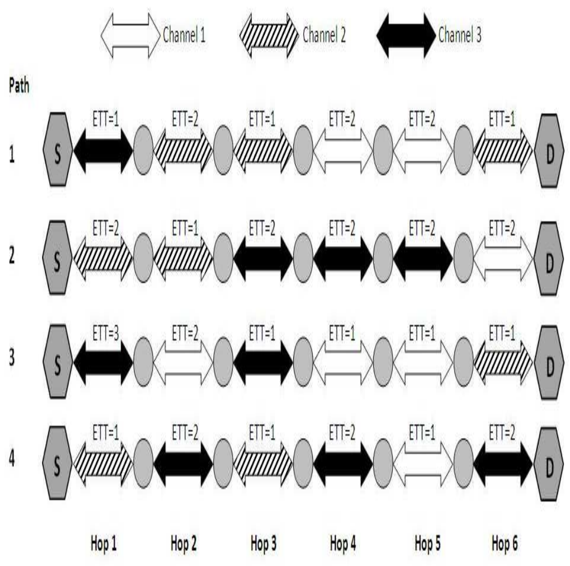

Fig. 1: Comparison of WCETT, WCCETT and WCCCETT in multi-channel paths.

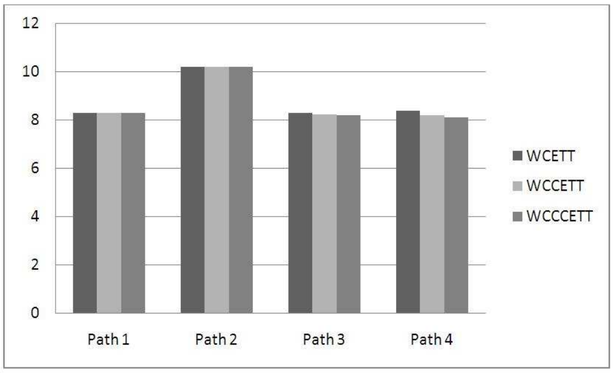

Fig. 2: WCETT, WCCETT and WCCCETT comparison where α is 0.1

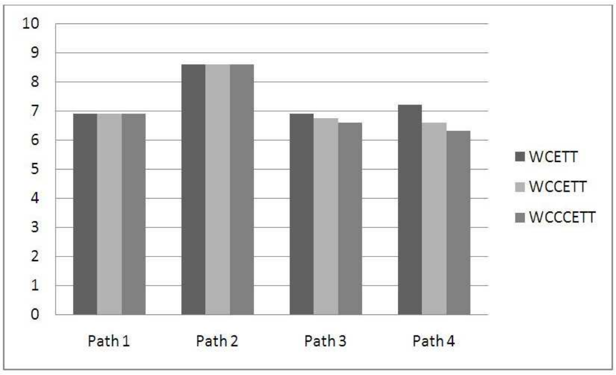

Fig. 3: WCETT, WCCETT and WCCCETT comparison where α is 0.3

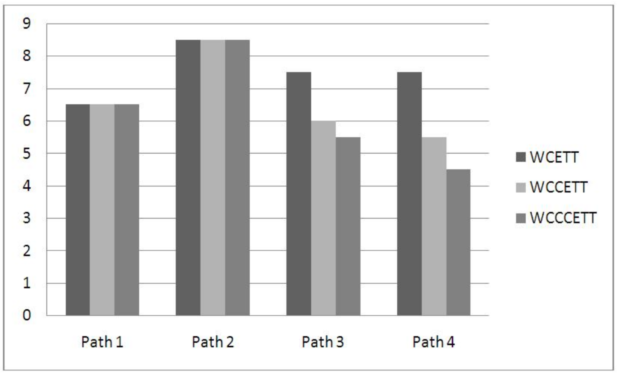

Fig. 4: WCETT, WCCETT and WCCCETT comparison where α is 0.5

Table 1: Calculation of Metrics using α as 0.5

Metric	Path	Calculation
WCETT	1	(0.5)×9 + (0.5)×max{(1),(2+1+1),(2+2)}=6.5
	2	(0.5)×11 + (0.5)×max{(2+1),(2+2+2),(2)}=8.5
	3	(0.5)×9 + (0.5)×max{(3+1),(2+1+1),(1)}=7.5
	4	(0.5)×9 + (0.5)×max{(1+1),(2+2+2),(1)}=7.5
WCCETT	1	(0.5)×9 + (0.5)×max{(1),(2+1),(2+2),(1)}=6.5
	2	(0.5)×11 + (0.5)×max{(2+1),(2+2+2),(2)}=8.5
	3	(0.5)×9 + (0.5)×max{(3),(2),(1),(1+1),(1)}=6
	4	(0.5)×9 + (0.5)×max{(1),(2),(1),(2),(1),(2)}=5.5
WCCCETT	1	(0.5)×9 + (0.5)×max{(1),(2+1),(2+2)}=6.5
	2	(0.5)×11 + (0.5)×max{(2+1),(2+2+2)}=8.5
	3	(0.5)×9 + (0.5)×max{(1+1)}=5.5
	4	(0.5)×9 + (0.5)× 0=4.5 (no conflicting link)(max is zero)

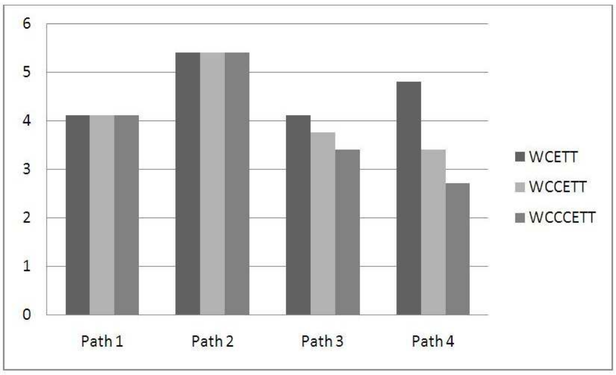

Fig. 5: WCETT, WCCETT and WCCCETT comparison where α is 0.7

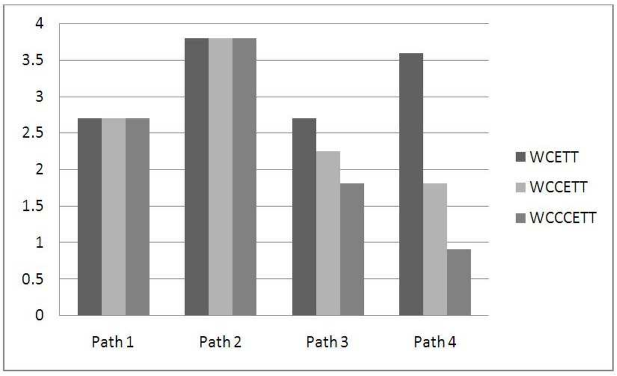

Fig. 6: WCETT, WCCETT and WCCCETT comparison where α is 0.9

Table 2: Calculation of Metrics using α as 0.1

Metric	Path	Calculation
WCETT	1	(0.9)×9 + (0.1)×max{(1),(2+1+1),(2+2)}=8.3
	2	(0.9)×11 + (0.1)×max{(2+1),(2+2+2),(2)}=10.2
	3	(0.9)×9 + (0.1)×max{(3+1),(2+1+1),(1)}=8.3
	4	(0.9)×9 + (0.1)×max{(1+1),(2+2+2),(1)}=8.4
WCCETT	1	(0.9)×9 + (0.1)×max{(1),(2+1),(2+2),(1)}=8.3
	2	(0.9)×11 + (0.1)×max{(2+1),(2+2+2),(2)}=10.2
	3	(0.9)×9 + (0.1)×max{(3),(2),(1),(1+1),(1)}=8.25
	4	(0.9)×9 + (0.1)×max{(1),(2),(1),(2),(1),(2)}=8.2
WCCCETT	1	(0.9)×9 + (0.1)×max{(1),(2+1),(2+2)}=8.3
	2	(0.9)×11 + (0.1)×max{(2+1),(2+2+2)}=10.2
	3	(0.9)×9 + (0.1)×max{(1+1)}=8.2
	4	(0.9)×9 + (0.1)× 0=8.1 (no conflicting link)(max is zero)

7 Observation and Simulation

Performance of WCCCETT with compared to ETT, WCETT and WCCETT is described in this section. The metrics are implemented in routing protocol as routing metrics for path selection with lesser interference. Network Simulator 2 (NS-2)[13] has been used as simulator.

Equation (7) represent the expected transmission time of a path with minimum interference. Figure 1shows comparison of expected transmission time of routing metrics. Path-2 is a 6-hop path. In each hop there is a link between two nodes. Each link also have designated channel in which the communication would be done for calculating ETT we are taking ETT summation of the links of respective path. Here value of ETT metric is 11 units. Here, Table1. Table2. and Table3. give the values of WCCCETT for path-3 and path-4 are lesser than WCETT and WCCETT metrics. Tunable parameter is set as 0.5. Here we have shown the metric values for 4 paths of a mesh networks. So, we observed that path selection with less interference through WCCCETT metric is possible. In Figure 7 we found simulation of network with 2-channel and 2-hop, In Figure 8 we observed simulation

Table 3: Calculation of Metrics using α as 0.9

Metric	Path	Calculation
WCETT	1	$(0.1)\times 9 + (0.9)\times\max\{(1),(2+1+1),(2+2)\}=2.7$
	2	$(0.1)\times 11 + (0.9)\times\max\{(2+1),(2+2+2),(2)\}=3.8$
	3	$(0.1)\times 9 + (0.9)\times\max\{(3+1),(2+1+1),(1)\}=2.7$
	4	$(0.1)\times 9 + (0.9)\times\max\{(1+1),(2+2+2),(1)\}=3.6$
WCCETT	1	$(0.1)\times 9 + (0.9)\times\max\{(1),(2+1),(2+2),(1)\}=2.7$
	2	$(0.1)\times 11 + (0.9)\times\max\{(2+1),(2+2+2),(2)\}=3.8$
	3	$(0.1)\times 9 + (0.9)\times\max\{(3),(2),(1),(1+1),(1)\}=2.25$
	4	$(0.1)\times 9 + (0.9)\times\max\{(1),(2),(1),(2),(1),(2)\}=1.8$
WCCCETT	1	$(0.1)\times 9 + (0.9)\times\max\{(1),(2+1),(2+2)\}=2.7$
	2	$(0.1)\times 11 + (0.9)\times\max\{(2+1),(2+2+2)\}=3.8$
	3	$(0.1)\times 9 + (0.9)\times\max\{(1+1)\}=1.8$
	4	$(0.1)\times 9 + (0.9)\times\ 0=0.9$ (no conflicting link)(max is zero)

Table 4: Simulation Parameters

Parameter	Values
Network Size	10
Topology Size	1000m × 1000m
Packet Size	512 byte
Model of Propagation	Two Ray Ground
Antenna	Omni Directional
MAC Type	IEEE 802.11b
Simulation Time	200 second
Runs	10

of network with 2-channel and 3-hop, In Figure 9 and, Figure 10 we found 3-channel 2-hop and 3-channel 3-hop simulation respectively. In every analysis the performance of proposed metric is better than other metrics. Proposed metric, WCCCETT has low routing overhead. In WCCCETT, Intra-flow interference is low comparing to Expected Transmission Time, WCETT, and WCCETT.

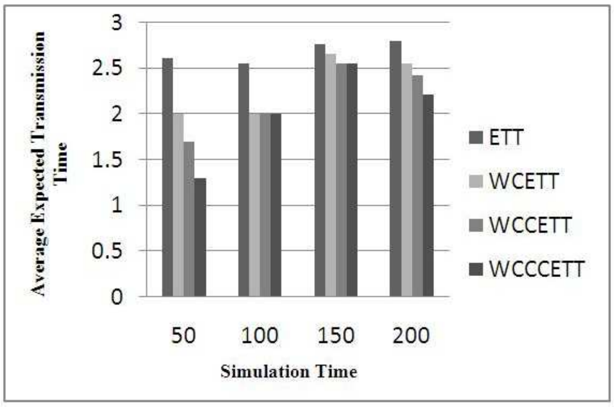

Fig. 7: Comparison of ETT, WCETT, WCCETT and WCCCETT metrics in 2-channel 2-hop path.

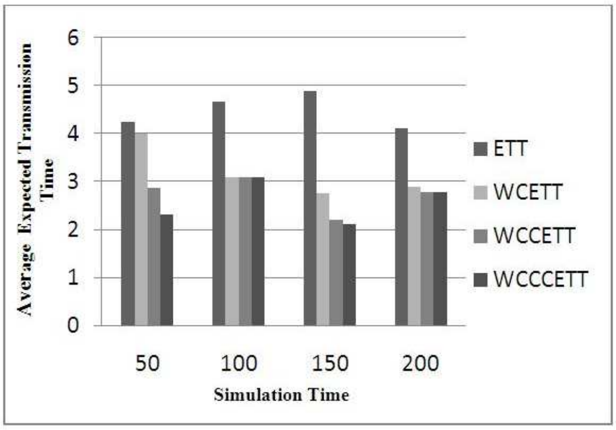

Fig. 8: Comparison of ETT, WCETT, WCCETT and WCCCETT metrics in 2-channel 3-hop path.

In figure 7 and in figure 8 we get the comparison between the metrics in the network where 2 channels are used. In these two graphs the value of WCCCETT is better than other metrics. In figure 9 and figure 10, 3 channels are being used. Here, we have also seen the value of WCCCETT metric is better than ETT, WCETT, and WCCETT metrics.

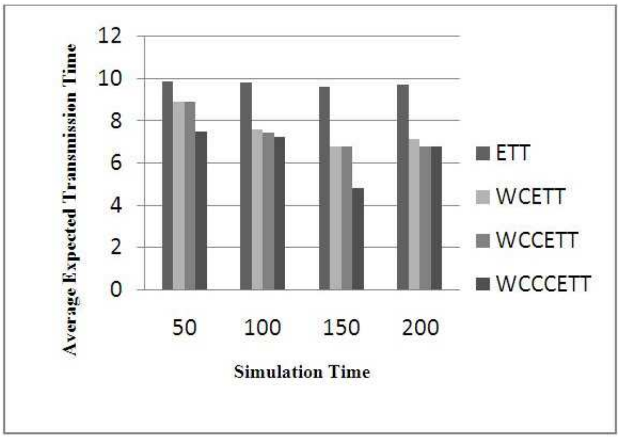

Fig. 9: Comparison of ETT, WCETT, WCCETT and WCCCETT metrics in 3-channel 2-hop path.

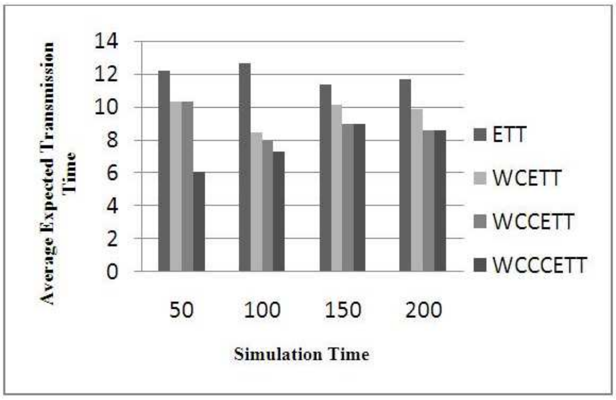

Fig. 10: Comparison of ETT, WCETT, WCCETT and WCCCETT metrics in 3-channel 3-hop path.

8 Conclusion

In this paper several routing metrics for routing algorithm for Multi Hop Multi Channel in Wireless Mesh Network are discussed. These types of routing metrics are generally used to calculate source to destination transmission time calculation through various equations. Minimum end to end delay is considered to send packet to its destination. In this paper mathematical equation for the routing metrics is formed and analysis is done with various criteria. Proposed metric Weighted Cumulative Consecutive Conflicting Expected Transmission Time (WCCCETT) performs good result in so many cases. Simulation and numerical analysis prove that the WCCCETT metric has lesser interference when selecting a path and have better performance than other metrics.

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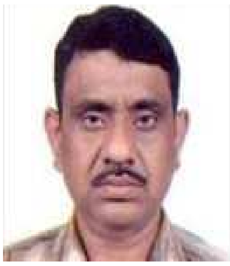

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