

# Cooperative Cross Layer Topology for Concurrent Transmission Scheduling Scheme in Broadband Wireless Networks

Gunasekaran Raja, Ramkumar Jayaraman

**Abstract**—In this paper, we consider CCL-N (Cooperative Cross Layer Network) topology based on the cross layer (both centralized and distributed) environment to form network communities. Various performance metrics related to the IEEE 802.16 networks are discussed to design CCL-N Topology. In CCL-N topology, nodes are classified as master nodes (Master Base Station [MBS]) and serving nodes (Relay Station [RS]). Nodes communities are organized based on the networking terminologies. Based on CCL-N Topology, various simulation analyses for both transparent and non-transparent relays are tabulated and throughput efficiency is calculated. Weighted load balancing problem plays a challenging role in IEEE 802.16 network. CoTS (Concurrent Transmission Scheduling) Scheme is formulated in terms of three aspects – transmission mechanism based on identical communities, different communities and identical node communities. CoTS scheme helps in identifying the weighted load balancing problem. Based on the analytical results, modularity value is inversely proportional to that of the error value. The modularity value plays a key role in solving the CoTS problem based on hop count. The transmission mechanism for identical node community has no impact since modularity value is same for all the network groups. In this paper three aspects of communities based on the modularity value which helps in solving the problem of weighted load balancing and CoTS are discussed.

**Keywords**—Cross layer network topology, concurrent scheduling, modularity value, network communities and weighted load balancing.

## I. INTRODUCTION

OF late, IEEE 802.16 standard has been developing drastically in wireless network. Several research studies [1]-[4] are carried out in the field of networking related to broadband wireless networks. The main studies are focused on the technological perspective to develop an efficient networking mechanism. It provides efficient user satisfaction based on high data rate and error free information exchange. Based on the recent research focus on IEEE 802.16 WiMAX (Worldwide interoperability for Microwave Access) in Fig. 1, [1] discusses the interference analysis in mesh network. The authors direct the future work towards the design of network problem discovery and topology update mechanism. Basically,

broadband wireless networks classify the network topologies into two types, Point to MultiPoint (PMP) and Mesh network topologies [2]. In PMP, a single node acts as the central node through which all data transmission exchange occurs and PMP acts as a tree classification structure. In Mesh network, multi-hop communication concept is deployed in which intermediate node between the source and destination act as a relay to provide data exchange without data loss. Basic comparisons of PMP and mesh topology based on the network coverage are clearly explained in [2].

Based on the multi-hop communication concept, PMP topology is overcome by mesh topology. References [3] and [4] discuss the survey on mesh networks in broadband wireless networks. In IEEE 802.16 network, QoS, scheduling and security operations are performed based on the network topology in which scheduling plays a vital role to transmit packets from source to destination.

Interference aware algorithm [2] helps in improving the transmission path and capacity gain. The new interference aware algorithm focuses on the RS location planning in IEEE 802.16 MMR network. The process like transparent mode, path selection, cell throughput and planning algorithms are discussed. During the path selection process, link efficiency between the nodes are measured based on the weight of the particular node. Time slot allocation algorithm [5] is based on the hop count in IEEE 802.16j relay multi-hop network. In IEEE 802.16j, downlink and uplink are considered based on the link weight and time slot assignment calculation is based on the average link weight and number of relay nodes.

Proposed CL-N topology has three phases: master network selection, network grouping and formation, and distributed master connection. Group splitting concept is same as macro/micro concept in which the large problem can be split into sub-problems. It is same as the large network is split into more number of smaller networks and it is easy to improve the overall network performance. First, we select MBS based on various performance metrics like node degree, transmission range, BS Node lifetime and fuzzy membership function. Second, various MBSs are classified as groups which contain serving RS based on Min/Max hop count. Third, MBSs are connected based on the distributed environment. Based on this, three network phases as listed above include fuzzy membership function parameter which helps in reducing network interference based on the network fragmentation index in large network area. Reference [6] uses the concept of Cluster Head Relay (CHR) station concept through DSRC

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(Dedicated Short Range Communication) transmission in WiMAX networks. Fig. 1 represents the overall functioning of WiMAX architecture.

Recent research studies [2]-[4] focus on the topological network structure and update mechanism in dense area network. This paper focuses on the topological network structure to find out the throughput efficiency. By examining the various simulation results, weighted load balancing problem plays a challenging role. BS and RS are considered as nodes in IEEE 802.16 network. We classify the CoTS scheme (modularity) into three aspects such as transmission mechanism in same community, transmission mechanism in different communities and transmission mechanism in identical node community. CoTS scheme has been considered in three aspects to identify the load balancing problem and helps in solving the CoTS problem based on hop count.

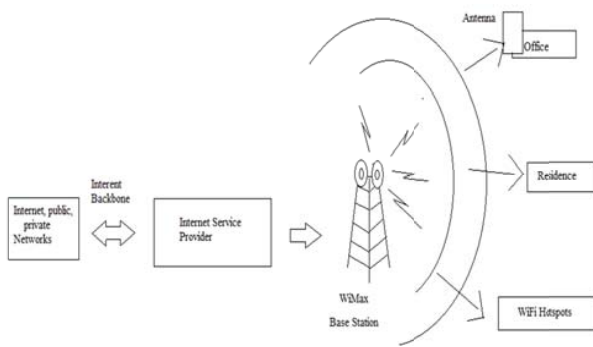


Fig. 1 WiMAX architecture

The rest of this paper is organized as follows. In Section II, we describe various serving metrics in a CCL-N topological network. In Section III, we discuss three stages to develop a CCL-N topology. In Section IV, we discuss the problem formulation in CCL-N topology. In Section V, we discuss the various aspects for CoTS scheme in CCL-N topology. Various performance analysis and results in Section VI. Section VII outlines the related work. Finally, conclusions and future work are discussed in Section VIII.

## II. SERVING METRICS FOR CCL-N TOPOLOGY

Generally, topology structure plays a promising role in a network to precede certain processes like packet exchange, packet configuration, etc. Considering various performance metrics related to networking, parameters mainly deal with CCL-N topology. The concept of CCL-N topology has several serving metrics as follows:

### A. Fuzzy Membership Function [ $\mu_A(X)$ ]

Fuzzy membership function [ $\mu_A(X)$ ] is the generalization of the indicator function in classical sets and it is represented as fuzzy. Given Universal Subset  $U = \{P_1(x), P_2(x), \dots, P_n(x)\}$  [7] where P denotes fuzzy dataset with the sequence of weight

$$W_i = \{W_1, W_2, \dots, W_n\}$$

$$\text{Ordered Pair} = \{(P_1(n), W_1), (P_2(n), W_2), \dots, (P_n(n), W_n)\}$$

Based on the threshold operation (Weighted ( $W_i$ )),

Case 1: If Weighted Value ( $W_j$ ) is less than or equal to the threshold value, set to 0.

Case 2: If Weighted Value ( $W_j$ ) is greater than or equal to the threshold value, set to 1.

$$V_i = \sum_{j=1}^n W'_j \quad (1)$$

Based on the rule of summation in (1), a sequence of values  $V_1, V_2, \dots, V_n$  can be calculated based on the set of weight  $W_j \rightarrow W'_1, W'_2, \dots, W'_n$  where  $j = 1, 2, \dots, n$ .

$$\mu_A(x) = \sum_{j=1}^n q_j * V_j \quad (2)$$

where,  $A \rightarrow$  Membership function with fuzzy set ' $\mu$ '.  $q_j \rightarrow$  Order of positive numbers such as  $q_1, q_2, \dots, q_n$  which contains fuzzy datasets of  $\{P_1(x), P_2(x), \dots, P_n(x)\}$ .  $j \rightarrow 1, 2, \dots, n$ .

Fuzzy membership function is formulated in (2). Reference [7] discusses the fuzzy interference systems functionality components referred to fuzzifier dealt with membership function [ $\mu_A(x)$ ]. Reference [7] developed the standard algorithm for implementing fuzzy logic based on membership function in a network and analytical formulation and results are discussed.

Transmission Range (Tx) is formulated based on the Friis transmission equation which provide certain utilities from a node to a certain extent and are represented in [8]. In this paper, scenarios are represented in both urban and suburban transmission range functional values and represented in Table I.

TABLE I  
SAMPLE ( $T_x$ ) NOTATIONS FOR BOTH URBAN AND SUBURBAN ENVIRONMENTS

S.No	Notations	Urban area	Suburban area
1	Base antenna height ( $h_t$ )	100m	200m
2	Frequency (f)	400MHz	500MHz
3	Distance between the antenna (d)	10km	10km
4	Power gain transmitter ( $g^t$ )	10dB	10dB
5	Power gain Receiver ( $g^r$ )	2dB	2dB
6	Power Transmitter ( $P^t$ )	50dBm	50dBm
7	Power Receiver ( $P^r$ )	-101dBm	-101dBm

### B. Interference Index ( $M_i$ )

Interference Index ( $M_i$ ) defined as the number of connected neighboring nodes with interfering links and represented in (3):

$$M_i = \sum_{n=1}^N I_n \quad (3)$$

where,  $I_n \rightarrow$  Sum of the Interference value with 'n' connected neighbor nodes.  $i \rightarrow$  Individual node in a network.

Reference [8] proposed new interference aware schemes to provide high speed wireless mesh networks. Basically, Mesh network improves spectral utilization by selecting minimum interference link path with the existing nodes.

### III. COOPERATIVE CROSS-LAYER NETWORK (CCL-N) TOPOLOGY

Several existing algorithms based on cooperative network topology are discussed in [9]. It consists of three phases,

- A. Master network selection
- B. Network grouping and formation
- C. Distributed master connection

Mainly, network deals with creating topology based on multi hop concept in wide-area environment. In the first phase, selection of master node is based on the several performance terminologies. First the nodes are reordered in a table to select the MBS based on metrics values. In the second phase, each MBS forms network group which contains several RS using both group splitting and multi hop concept with interfering index. Interference index reduces the packet loss and delay time. In the third phase, MBS are connected distributively to improve the network performance and avoid several other problems related to it.

#### A. Master Network Selection

Let us consider various numbers of nodes in a densely populated area that are interconnected based on the mesh structure environment. Nodes are classified as a coverage transmitter MBS and RS based on several networking parameters such as distance between the two stations (D) and transmission range (Tx).

In this topology, a node has several performance metrics to select the MBS from the multiple nodes in the network. The performance metrics are,

##### a. Grade Value ( $G_v$ )

The Grade value is to rank the performance level of a node based on the integration of Node degree ( $N_{FD}$ ) and Interference value ( $I_{SV}$ ).

##### b. Node degree ( $FD_x$ )

$$FD_x(n) = \left\{ \sum_{i,n \in \frac{D(i(n))}{T_x}} \right\} * \mu_A(x) \quad (4)$$

Using (5), let us consider  $D(i(n)) \rightarrow D[I(n,a) + I(n,b) + I(n,c)]$ .  $D(i(n))$  represents sum of the interference value of connected neighboring nodes of 'i' and it is denoted in (5). Fuzzy membership function and Transmission range are discussed in Section II.

$$\sum_{i,n \in N} [D(I(n))] = \sum_{i,n \in N} D[I(n,a) + I(n,b) + I(n,c)] \quad (5)$$

where,  $I(n,a)$  represents the number of nodes connected to node 'a' using hop count.

Based on the existing research in various fields like, ad hoc networks, sensor networks, etc. Reference [10] discusses about the proposed design of Connected Dominating Set (CDS) protocol for both single initiator and multi initiator in ad hoc networks. While considering the initiator phase, numbers of nodes are based on the minimum hop count in distributive environment.

##### c. Interference Sum Value ( $I_{SV}$ )

Interference value can be calculated based on the combination of edges and links of the neighboring nodes connected to the node 'i'. Debalina Ghosh et al. [11] discuss about the challenges of multiple link interference related to scheduling and QoS in WiMAX network. Heuristics algorithm based on centralized scheduling with NP-Complete problem is proposed. Interference can be reduced by selecting non-interfering links at time 't' to guarantee bandwidth and delay. Interference sum value ( $I_{SV}$ ) is calculated as,

$$I_{SV} = \sqrt{\sum_{i=0}^N m} \quad (6)$$

where  $m \rightarrow$  Summation of interference value with connected neighboring nodes of node 'i'.

Based on the performance metrics, each individual node table is created and reordered in terms of high order priority and represented in Table II. Fig. 2 explains the algorithm for master selection MBS. In this algorithm, pre header selection is calculated for each node in a network. Based on the performance metrics values, 'Masters' are elected and reordered in a table based on the Timer 'ti'. Master nodes are checked periodically based on the updated table of MBS [12].

Based on the performance metrics in Section III, values are calculated for the individual nodes and represented in Table II.

TABLE II  
COMPARISON BETWEEN TRANSPARENT AND NON TRANSPARENT RELAY  
MODE [14]

	Without RS	With RS	
		Transparent	Non-Transparent
Average throughput (Mbps)	3.234	6.444	6.442
Efficiency	62.83%	98.62%	98.60%

TABLE III  
INFORMATION TABLE FOR SERVING METRICS

No	FR (Membership function)	Interference Metric	Degree
1	0.7	5	17
2	0.3	7	17
3	0.3	6	24
4	0.6	9	22
5	0.6	8	22
6	0.1	3	11
7	0.5	7	20
8	0.6	9	44
9	0.7	8	17
10	0.3	9	22

#### B. Network Grouping and Formation

Based on the performance metrics of a node, nodes are ranked and ordered based on the hop count value to form an RS network grouping. Maximum hop count MBS are given high priority to occupy several serving nodes to form a network group. Minimum hop count MBS nodes are given low priority to occupy remaining serving nodes to form a network group. Selects the multiple MBS based on the network area it utilizes for the process and network groups are created. Based on the updated MBS in Table III, minimum

hop count can be calculated to form RS grouping network [13].

### C. Distributed Master Connection

In a wide area network, two or more master nodes are connected in a distributive manner to exchange data over a long distance. MBS has the ability to communicate with other MBS. The data exchange occurs between the MBS over long distance will reduce data loss and delay.

## IV. PROBLEM FORMULATION IN CCL-N TOPOLOGY

Transparent and Non Transparent relay modes are considered in Table II. Comparative discussions are explained in [14] and comparative analysis in [15].

Table III estimates the average throughput for three cases such as without relay, transparent relay and non-transparent

relay mode [16]. The throughput efficiency of transparent relay is 0.002% more when compare to non-transparent relay mode. Non transparent relay mode has several advantaged like last mile coverage and improved network performance. Placing more number of relay leads to the issue of weighted load balancing problem [17].

The problem formulation based on the CCL-N Topology are discussed below,

### 1. Finding the Missing Nodes in the Total Node Table

During the formation of cooperative RS, there may be a chance of missing nodes in the network. The information of the nodes is stored in a table for further reference. In the case of identifying the missing nodes, there includes the status bit variable into the table to indicate whether the node is placed inside the network communities or not. It is represented in Fig. 4.

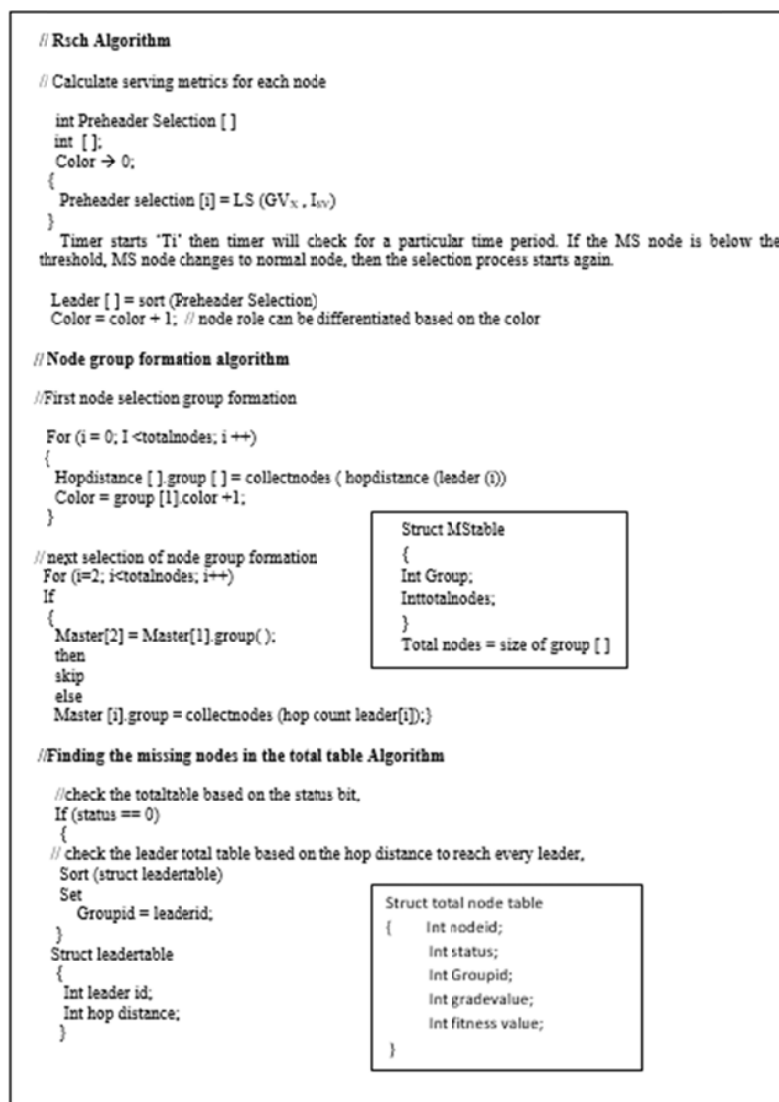


Fig. 2 CCL-N topology algorithm

## 2. Adding the Missing Nodes into the Table

Missing nodes are detected based on the status bit variable in the table. It can be checked whether the MBS is in balance or unbalance based on the problem of load balancing problem. Balancing denotes minimum numbers of serving nodes which occupy with the network communities. Unbalance denotes maximum number of serving nodes which occupy with the network communities.

CCL-N topology supports non-transparent relaying mode. When compared to other networks, adding more number of relays may result in improved throughput and system performance. The network community results in load balancing issue problem [18]. This paper provides the network grouping based on the relay nodes which results in weight load balancing problem. Limitations of more relay may also result in decrease in the throughput based on the weight load balancing [19]. Each group has the capability to add limited number of relays to achieve throughput. [20] Modularity Value (Quality Function Value) denotes the strength of the partitioned network. To compute the modularity value to represent the strength of the partitioned network, three cases are considered in Section V.

TABLE IV  
THROUGHPUT VALUE FOR RELAY AND WITHOUT RELAY

Parameter	Transparent Mode	Non – Transparent Mode
Scheduling	Centralized	Centralized / distributed
Number of hops	2	2 or more
Performance	High	Low
Coverage extension	No	Yes
Cost / Complexity	Low	High
Forwarding framing info.	No	Yes

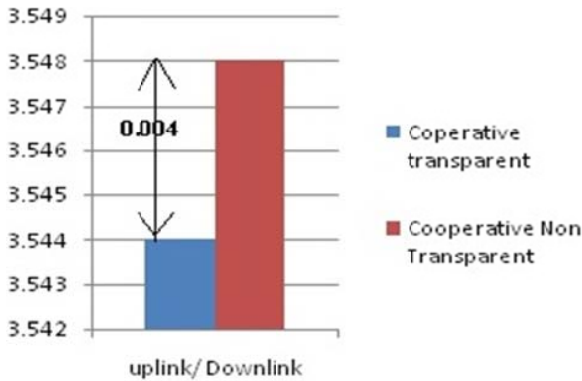


Fig. 3 Throughput value for cooperative relay

## V. CoTS SCHEME IN CCL-N TOPOLOGY

In a large area environment, data transfer from sources to destination with two or more intermediate nodes. Reference [22] discusses an algorithm for subscriber station to attain concurrent transmission for both Uplink/Downlink. It achieves spatial reuse with concurrency and improves throughput in multi hop network. Scheduling problems related to rate-adaptive are based on concurrent transmission.

Reference [23] proposed an algorithm that achieves high network throughput and high fairness with completing flow.

Based on the cooperative relay estimation in Fig. 3, proposed CoTS scheme is formulated while two or more transmission occurs at an individual node. Several multi hop transmission schemes are proposed in various networking areas such as Personal Area Networks, ad hoc networks, etc. References [14] and [15] reduce interference while transmitting data concurrently between the nodes in Wireless Personal Area Networks (WPANs). It will improve the capability of resource utilization. In this CoTS scheme, CoTS problem can be formulated into three aspects,

1. CoTS scheme with same network community
2. CoTS scheme with different network communities
3. CoTS scheme with identical node community

Generally, CoTS can be solved using (7),

$$C_T = Q_T \text{ and } H_{(A,B)} \quad (7)$$

where,  $C_T \rightarrow$  Concurrent transmission;  $Q_T \rightarrow$  Quality weight transmission;  $H_{(A,B)} \rightarrow$  Hop count between A and B.

### A. Quality Weight Transmission ( $Q_T$ )

Generally, these three cases are formulated based on the finite state automation concept. Large network structure can be partitioned into sub-groups based on the dense and sparse connections between the nodes. Modularity plays a key role to measure the strength of network communities which is formulated in [30]. Weighted network can be represented as weight assigned to the link by adjacency matrix and pictorial representation of the weighted network is discussed in [19]. Modularity is calculated in Section V and representation is shown in (8):

$$Q_T = \frac{1}{2\omega} \sum_{a=1}^n \sum_{b=1}^n [W(a,b) - \frac{W_a W_b}{2\omega}] \quad (8)$$

where  $W_a \rightarrow$  Weight of the node 'a';  $W_b \rightarrow$  Weight of the node 'b';  $W(a,b) \rightarrow$  Weight of the particular network for both 'a' and 'b'.

Modularity focuses the problem of identifying and characterizing the community structure in network systems. Modularity measures the true structure community based on the arrangements of the link in a network which should be indicate in large value. Equation (10) represents the quality weight transmission and [19] modularity value to represent the strength of the community in the network. It contains weight of the link, degree of the node, edges, etc. to represent the modularity function.

Weight of a node 'a' is represented as number of interference node attached to it and Sum of the weight between the two nodes are denoted as  $2\omega$ ,

$$2\omega = 2[W_a + W_b] \quad (9)$$

Weight of a particular network  $W(a,b)$  is calculated based on the sum of nodes, links, odd nodes and even nodes of an individual  $W(a)$  and  $W(b)$ .

$$W(a, b) = [W(a) - W(b)] \quad (10)$$

where,  $W(a) \rightarrow$  Weight of the network 'a' node;  $W(b) \rightarrow$  Weight of the network 'b' node.

Based on the Kronecker delta function [23], we have considered two Boolean integers 0 and 1. By considering the two cases,

1. The integer may be '1' if two variable  $C_a$  &  $C_b$  and  $D_a$  &  $D_b$  are present.
2. The integer may be '0' if two variable  $C_a$  &  $D_b$  are present.

$$\delta(C, D)_{a,b} = \begin{cases} \text{Region} & 0 \text{ if } C_a \& C_b \text{ and } D_a \& D_b \\ & 1 \text{ if } C_a \& D_b \end{cases} \quad (11)$$

where  $\delta(C, D)_{a,b} \rightarrow$  Delta function;  $C, D \rightarrow$  Different group 'C' and 'D';  $a, b \rightarrow$  Nodes in the network.

By considering same and different community cases, quality function can be modified with the integration of fuzzy degree of a network. Degree of a node characteristics helps in identifying the community in a network and values can be classified into dense and sparse environment. The graphical representation of fuzzy degree values is shown in Fig. 4.

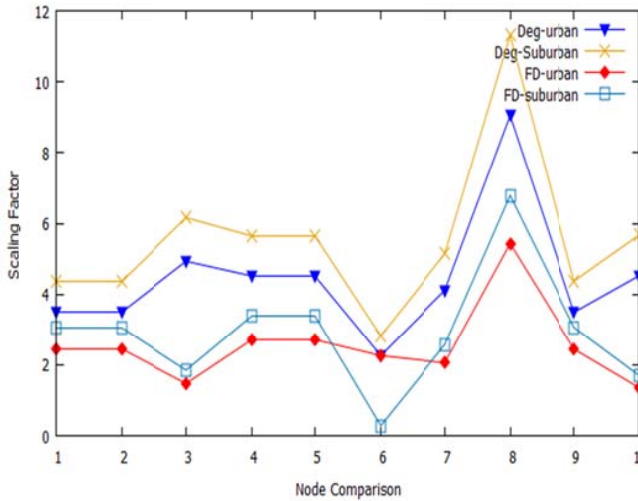


Fig. 4 Comparison of degree and fuzzy degree for two scenarios

Based on the Delta function of network grouping,  $Q_T$  can be formulated as,

#### 1. CoTS Scheme with Different Network Grouping

Data exchange occurs between the source and destination which are present in two different groups 'C' and 'D'. In this case,  $\delta(C_i, D_j)$  is represented as '1' based on the delta function condition in (12) and CoTS scheme is formulated as,

$$Q_T = \frac{1}{2\omega} \sum_{a=1}^n \sum_{b=1}^n [W(a, b) - \frac{W_a W_b}{2\omega}] + (\delta(C, D)_{a,b} * (Deg(C_a) - Deg(C_b))) \quad (12)$$

where,  $E(C_a)$  and  $E(D_b) \rightarrow$  Degree of group C and D where 'a' and 'b' node present in different group.

Using Kronecker delta function condition  $\delta(C_a, C_b)$  denoted as zero if the nodes are present in the same community and degree of community 'C' is not considered in this aspect (same community) based on (10)-(12). Summation of values for 'a' and 'b' is denoted between 1 to n and 'a' and 'b' values should not be same. References [24] and [25] deal with weighted adjacency matrix  $W(a, b)$  is represented by adjacent weighted matrix.

$$\text{Weighted Adjacent matrix between 'a' and 'b' } = W_{a,b}$$

It can be calculated as the summation of the individual weight of node 'a' and 'b' and total strength of the node 'a' and 'b' is denoted as  $2\omega$ . The link connection between the two nodes in a same community checks whether the community can withstand the process to be performed between them based on the load balancing concept are represented in (12). To calculate the strength of a community in a network, "modularity" Quality function helps in measuring the strength for this. The community can be represented as C in which node 'a' is assigned.

#### 2. CoTS Scheme with Same Network Grouping

The link connection between the two nodes in a different community checks whether the community can withstand the process to be performed between them based on the load balancing concept. To calculate the strength of a community based on the condition when two individual nodes present at different community, "modularity" can be calculated based on (13). Data exchange occurs between the source and destination which are present in same group 'C'. In this case,  $\delta(C_i, C_j)$  is represented as '0' based on the delta function condition in (12) and COTS scheme is formulated as,

$$Q_T = \frac{1}{2\omega} \sum_{a=1}^n \sum_{b=1}^n [W(a, b) - \frac{W_a W_b}{2\omega}] + (\delta(C_a, D_b) * (Deg(C_a) - Deg(C_b))) \quad (13)$$

Using Kronecker delta function condition  $\delta(C_a, D_b)$  denoted as one if the nodes are present in the different communities and degree of community 'C' and 'D' is considered in this aspect (different community).

Expected nodes are present in two different communities 'C' and 'D'. They are computed using the concept of configuration models and are identified based on (12)-(14). The configuration models concept is defined to identify the community in which the two nodes are present. Configuration model is considered as degree distribution, in which number of nodes and degree of a node can be calculated. Degree distribution is discussed in Section II.

$$E(C_a) \text{ and } E(C_b) \rightarrow \text{Degree of group C where 'a' and 'b' node present in same group}$$

In both cases,  $E(C_a)$  and  $E(C_b)$  is represented as high value and low value from (13),

$$E(C_a) - E(C_b) \rightarrow [\text{high value} - \text{Low value}]$$



Degree of the community 'C' and 'D' can be calculated as difference between the higher community values minus the lower community value.

Based on the sample input values in Table IV, Table V is calculated and it denotes as the modularity value for all possible inputs.

TABLE V  
SAMPLE INPUT DATA'S FOR TWO ASPECTS

Different group	(9,6)	(8,3)	(2,3)	1,4)
Same group	(3,14)	(3,13)	(6,10)	(4,14)

### 3. CoTS Scheme with Identical Node Community

When identical nodes occur while transmitting the data from source to destination, modularity value may be constant for all the combinations of integers from 1, 2 ... n. This case is not possible to calculate the network grouping strength of the network. The formula to calculate the network grouping for all the combinations of integer values is the same as,

$$Q_T = \frac{1}{2\omega} \sum_{a=1}^n \sum_{b=1}^n [W(a) - \frac{W_a W_b}{2\omega}] + (\delta(C_a, C_b)) \quad (14)$$

where  $\delta(C_a, C_b)$  cannot be considered in this case of identical node community and it is denoted as zero.  $W_{a,b}$  is discussed and based on the equation the value is 0.1875 constant for all the combination of integers are represented in Fig. 5.

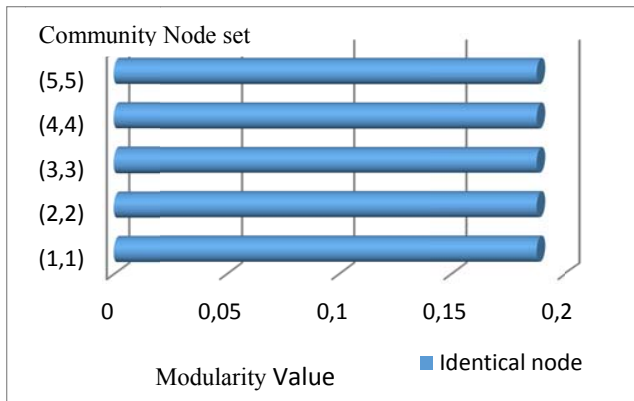


Fig. 5 Identical node aspects

Case (1) and (2) are compared in the graph and based on the graph different community case (2) has high modularity value when compared to same community case (1). This leads to the best grouping of sub-network from the large network and is can be identified by the modularity value (strength of the network grouping) for IEEE 802.16 network.

### B. Interference Metric $M(a,b)$

Interference metric is added to the CoTS scheme in concurrent transmission process to reduce interference in the network. Interference metric can be calculated as the summation of both source and destination and intermediate nodes in which the neighboring nodes are attached and represented in (15):

$$M(a,b) = [I(a,c) + I(c,d) + I(d,b)] \quad (15)$$

where,  $I(a,b) \rightarrow$  Interference value of 'a' and 'b' node; a, b, c, d  $\rightarrow$  Nodes in the network. Based on these equations, CoTS scheme is formulated as concurrent transmission ( $C_T$ ).

Generally, CoTS frequently occurs at MBS while transmitting data from source to destination. Quality function and hop count are parameters used for the CoTS [26]. Considering three scenarios, modularity value helps in finding the weighted load balancing problem. It occurs when more number of RS is present in a community and unbalancing state occurs and gets corrected.

## VI. NUMERICAL PERFORMANCE EVALUATION

Let us consider 20 nodes with 28 linking paths between them and they may be classified as MBS and RS based on the behavior and property as interference metric value and degree of a node. It is represented in Fig. 6.

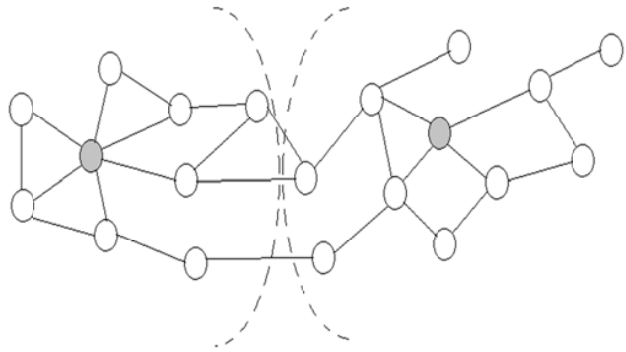


Fig. 6 Sample CCL-N Topology network structure where grey color node is represented as MBS, remaining nodes are represented as RS

### A. Modularity

According to the communities of the network group, we have considered two main cases and one exception case. Generally, modularity deals with measuring the strength of the network community group from large network. The analytical values are calculated based on the sample network deployed and network topology information is represented in Table VI.

TABLE VI  
NETWORK COMPONENT INFORMATION

S.No	Components	Quantity
1.	Number of nodes	20
2.	Number of link path	28
3.	Communities	2
4.	Modularity range (same community)	0.5 to 1.5
5.	Modularity range (different community)	Infinity

Several performance metrics like degree, interference metrics, etc. are calculated based on the sample network topology and metrics are tabulated in Table III. Based on the modularity function, weighted matrix of the transmission from source to destination is determined that denotes the

potential of network group. Based on the modularity, we have considered two cases: 1) Same community and 2) Different community and they are explained in Section V.

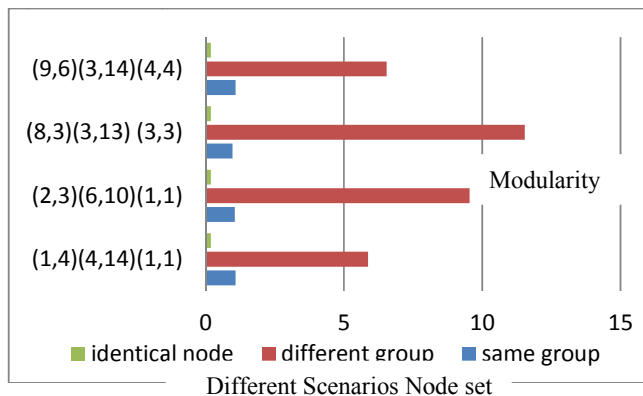


Fig. 7 Quality Function based on modularity

“Analysis of the structure of complex networks at different resolution levels” represents the modularity as reflected in the strength of the network transmission between the two nodes and network group partitioning. By considering the figure, the value of the modularity (different group) is higher when compared to the modularity (same group) as represented in Fig. 8. According to the exception cases, two identical nodes are present and the modularity function is constant for all combination of integers 1, 2, ... n. In the graph, the identical node value is 0.1875 for all combinations.

When considering the percentage of error possibilities, modularity value is inversely proportional to the error percentage possibilities.

When comparing Figs. 7 and 8,

1. When modularity condition occurs, modularity value is low in same community when compared to that of different community.
2. When error possibilities occur, error possibilities are high in same community when compared to that of different community.

On the other side, the modularity value that identifies the strength of the link of those two nodes connected to it. This modularity value can also be considered for the CoTS problem for IEEE 802.16 network based on the hop count. Reference [4] dealt with transmission scheduling related to the hop count mechanism and hop count is referred as the number of intermediate when transmission has to pass through to reach from source to destination.

Modularity value with the pair of two nodes can also be compared with the number of hop count it passes from source to reach destination as shown in the graph. Mainly the modularity (Quality function) formulation in Section V deals with the number of neighboring nodes attached to it so that the modularity gets random value for different hop count and difference between hop count = 2, 3 and 5 have randomized values which are represented in Fig. 9.

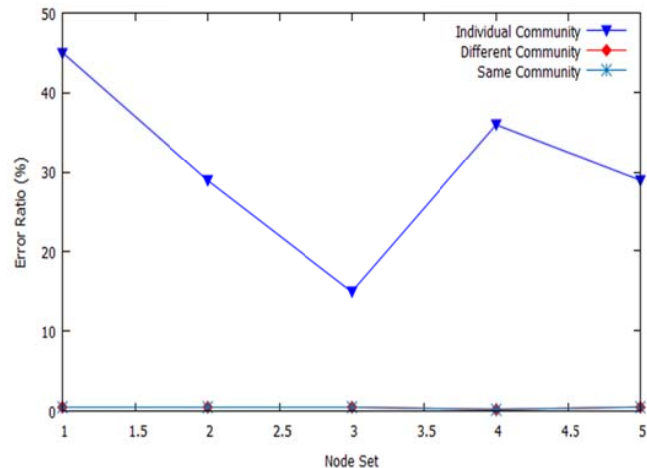


Fig. 8 Error possibilities for three aspects in CCL-N Topology

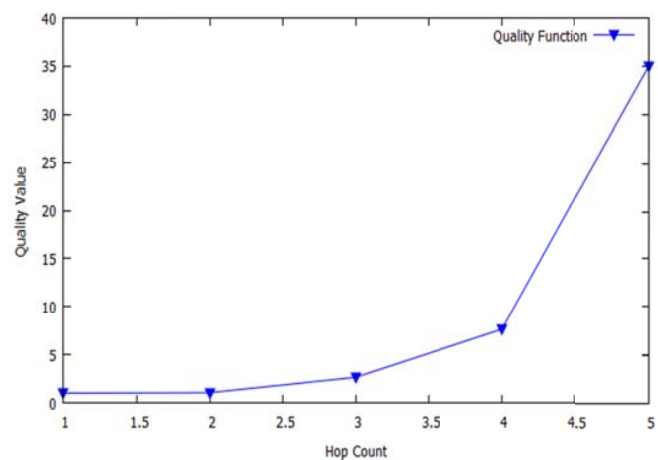


Fig. 9 Quality function based on hop count

Fig. 9 deals with how hop count number is related with the modularity value. The modularity value can also be considered in the concurrent transmission problem especially for IEEE 802.16 network.

## VII. RELATED WORK

There is a significant literature survey related to the topological network for master selection. References [2] and [5] dealt with the traditional method for master selection in a particular network and various methodologies are adopted. Reference [25] adopted a new election mechanism to select leader node and his contribution of work is materialized as standard basic algorithm named bully algorithm in distributed computing systems.

To deal with the problem of multi initiator in a network, [12] proposed CDS protocol to handle nodal mobility and recovery procedure. They have adopted this protocol in two cases, such as, single initiator and multiple initiators. To construct CDS protocol, the steps are

1. First elects a number of initiators in distributed environment.



2. To construct CDS from initiators by utilizing timer with minimum localized information
3. CDS protocol maintains the changes in the network topology.

In a wide area network, interference plays a major role and [29] dealt with it. Reference [23] proposed interference aware election algorithm with time complexity of  $O(n \log n)$  and main contribution of this paper deals with leader selection problem in fully distributed systems. Virtual backbone construction method uses bipartite and tri-partite graph. Reference [27] mainly focused on the scheduling concept in PMP mode based on fast and simple round robin scheduling. Based on these various scheduling algorithms such as, First in First Out (FIFO) and Last In First Out (LIFO), CoTS plays a vital role in a networking topology. "Interference-Aware, Fully-Distributed Virtual Backbone Construction and its Application in Multi-Hop Wireless Networks [28]" discuss about the directional slotted aloha with random topologies which lead to packet loss due to the coordination failure. For the interference problem, Friss transmission equation is discussed to calculate the power signal in receiver side.

Reference [21] discussed the components in QoS architecture and scheduling problem in the network that is capable of allocating slots based on the QoS requirements bandwidth in IEEE 802.16 network systems. They have various complex schedulers such as Earliest Deadline First (EDF) and Weighted Fair Queuing (WFQ) and scheduler in 802.16 to achieve accurate fair resource allocation. Reference [11] focused on the topological network changes and design algorithm for SS and achieve concurrent transmission for both uplink/downlink scheduling. Designed algorithm mainly provides simple, less cost efficient network setup and scheduling schemes in mesh network. Reference [14] utilized the concurrent transmission strategy for multi-hop wireless mesh network. Newly designed scheduling algorithm improves the throughput in multicast network and interference reduction based on the emission-group construction method. Based on the proposed cross layer topological network structure, it definitely helps in mitigating the problem of concurrent transmission in multi-hop wireless mesh network and improves throughput and system performance of the network.

Reference [29] proposed an algorithm to measure the quality of the community structure in which a number of communities can be formed. "Fast algorithm for detecting community structure in networks" proposed an algorithm in detecting the network community. Reference [30] discussed complex network topology in various scenarios like resolution time and topological scales and multiple resolution time. Modularity (quality function) formula is discussed to find the quality measure of a grouping network into modules.

#### VIII. CONCLUSION AND FUTURE WORK

In this paper, we have used a CoTS scheme in the CCL-N Topology in IEEE 802.16 network. Taking various performance metrics, we have designed CCL-N Topology and CoTS Scheme has been classified into three aspects.

Based on the CCL-N Topology, system improved can be based on the classification on the nodes as MBS and RS. Based on this CCL-N Topology, we have designed a CoTS scheme to formulate the CoTS process. CoTS scheme has three phases namely, Same Network Community, Different Network Communities and Identical Node Community. The group formation phases can be used in CCL-N Topology which results in three cases of formulation in CoTS scheme. In this paper, we have used modularity factor analysis which results in the quality function which is inversely proportional to the error possibilities and quality function based on the hop count has been analyzed. Various results are measured in terms modularity metrics for the purpose of concurrent transmission process and relate the generated values to load balancing concept. Future research can contribute towards updating the network topology to perform various scheduling scheme.

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