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# A clustering based routing algorithm in IoT aware Wireless Mesh Networks

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ABSTRACT

The Internet of Things (IoT) notion enables embedded devices to connect and share data through IP or the web. Interference routing metric and adaptive load balancing have gained much attention as the key challenges to overcome in IoT based wireless mesh networks (WMN) with the increase in wireless service performance. Moreover, IoT over WMN severely affected by network traffic caused by enormous data generation by a large number of users. Hence, we have proposed a clustering based routing algorithm considering an interference and load balancing routing metric that focuses on minimizing the existing issues of networks. In this study, we propose a scheme that reduces the end-to-end delay but also gives full consideration to both the quality on the entire route to the destination and to the expected lifetime of nodes with bottlenecks from heaped traffic in IoT. Simultaneously, it utilizes mesh station channel interference and queue information appropriately to address the identified challenges. The simulations results show that the proposed scheme performed superior to the existing routing metrics present in the current literature for similar purposes.

## 1. Introduction

The fundamental idea of Wireless Mesh Network (WMN) is a collection of heterogeneous devices that are uniquely addressable, which are capable of identifying and sharing information to support ubiquitous computing (Silva, Khan, & Han, 2017). With the extensive attention, WMN has rapidly approached various fields of interests i.e. smart home, smart healthcare, smart city, smart transportation, and much more. However, a considerable amount of modifications are demanded in each area of interest, in order to ensure WMN service provision. For example, Wireless HART and Bluetooth require a gateway to translate information, since they do not offer native compatibility for IP network functionalities (Han et al., 2013). Wireless Mesh Network (WMN) has become the buzzword in the modern era owing to its ability in providing faster connectivity among devices that are connected to the internet (Kim, Kim, Paek, & Bahk, 2016). Hence, it is crucial to consider the selection of the best link, routing data among mesh stations (MSTA), etc. in order to use WMN services in IoT. WMN provides a layered wireless architecture that consists of two layers. Mesh routers in the first layer create the self-configured ad-hoc wireless network. The gateways are selected among the mesh routers. In the second layer, MSTAs are attached to the ad-hoc network of the first layer. Cost-effective deployment, efficient communication, and ability to self-heal are considered as the main advantages of WMN. Another important characteristic is that communication with mesh network does not lead to an excessive energy consumption of MSTAs. The throughput of WMN is significantly leveraged by ubiquitous communication (Alicherry, Bhatia, & Li, 2006). Facilitating network access in areas where the wired network is unavailable is another key advantage of WMNs. Furthermore, various advantages of WMNs are taken into consideration in many research areas i.e. house networking, community networking, healthcare systems, etc. Even though WMN is extensively studied during the recent past, various challenges still exist in the context of architecture. Especially, scheduling transmissions at the medium access control (MAC) layer are challenging, since WMN generally consists of a large number of nodes. In fact, an optimal scheduling technique is essential to improve the throughput of WMN. A similar scenario is expected in IoT environment as well, where innumerable IoT nodes communicate with each other as shown in Fig. 1. Hence, a larger number of nodes are susceptible to overloading and interference in WMN links (Choi, Jeon, & Jeong, 2010).

In the past few decades, experts proposed many schemes that balance the data flow on routing paths in WMNs. Nevertheless, it is crucial to address latency issues and load balancing issues before designing a realistic scheduling mechanism (Mohammad Hammoudeh, 2015). A routing metric that considers a variety of parameters is an ideal solution to ensure efficient routing among MSTAs and routers. Worthy to note that the architecture of WMN is completely different from technologies such as wireless sensor networks (WSN) (Khan, Silva, & Han, 2016). However, WMNs are widely used in various fields including smart homes, smart hospitals, smart industries, etc. (Aldabbas, Abuarqoub, Hammoudeh, Raza, & Bounceur, 2017). Consequently, it increases the

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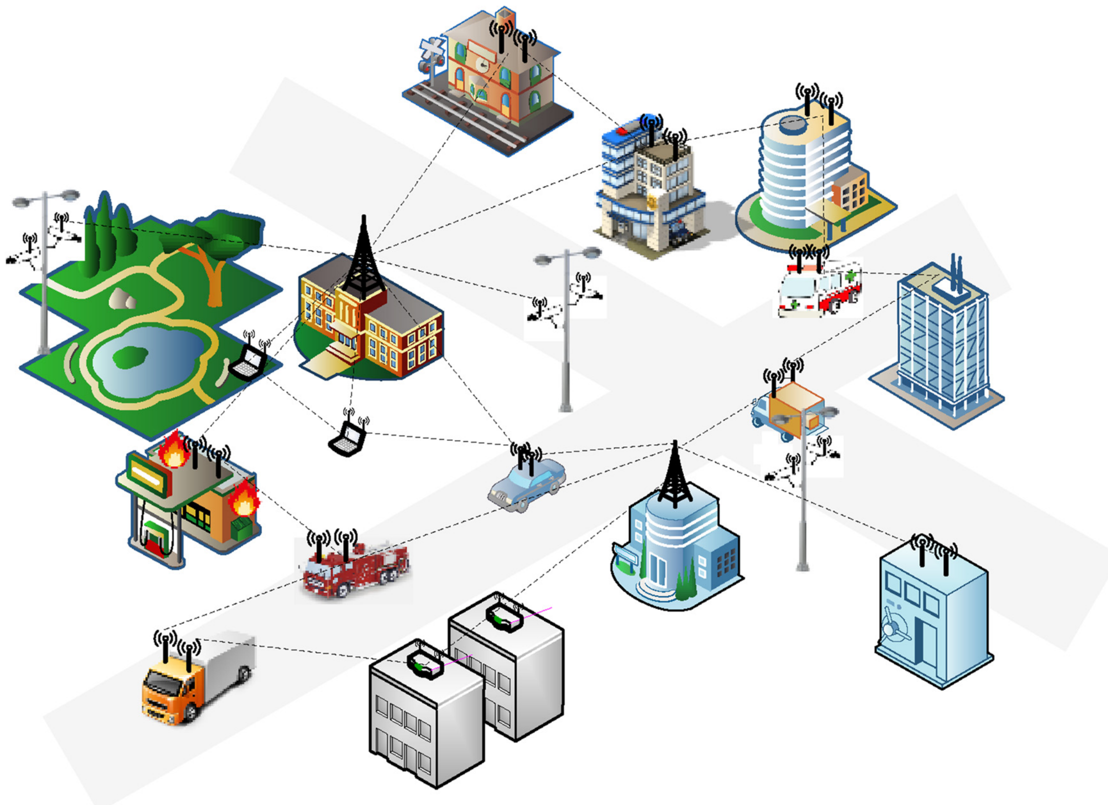

**Fig. 1.** Network architecture of 802.11s WMN LANs.

chances to encounter delay (Jabbar, Minhas, Imran, Khalid, & Saleem, 2015) and throughput (Chilamkurti, Jabbar, & Minhas, 2016) issues when employing existing routing algorithms in WMNs.

Even though WMNs borrow routing solutions of mobile ad hoc networks (MANET) to satisfy the routing demands, they are not optimized for WMNs (IEEE, 2017). Exiting routing protocols discover paths with aid of the broadcasting method. In consequence, nodes consume more energy, while increasing the rate of message collisions due to network congestion. These drawbacks highlight the need for specifically defined routing protocols. In AODV routing, control traffic is alarmingly high due to global flooding mechanism, In addition, pure AODV suffers from long setup latency, which hinders the applicability of AODV in real-time data transmission (IEEE, 2018). Owing to cluster formation in route discovery phase, scalability issue is solved and the latency before sending a packet is reduced as new nodes can be merged easily (Suba and Satheeskumar, 2016).

Meanwhile, researchers work on deriving solutions to overcome scheduling issues of WMN environment. A Number of routing protocols are proposed to facilitate efficient data routing in WMN environment. The expected transmission count (ETX) is an ideal metric for WMN environment that focuses on improving the throughput (Ahmad, Jabbar, Paul, & Rho, 2014). Even though ETX is promising for throughput enhancement, it lacks performance in WMN environments with high channel variation. Mean loss ratio is considered to determine the best routing path. The drawback of mean loss ratio based path selection is that it works according to average packet loss and its performance reduces with burst loss conditions. In one hand, similar routing metrics such as modified ETX (mETX) and an effective number of transmissions (ENT) achieve network capacity with added overhead. On the other hand, these metrics do not consider the load on the network. As a result, these metrics lead to congestion and imbalanced network flow.

Optimal path selection in WMN relies on route discovery mechanisms, which rarely concern with the quality improvement of paths. In fact, routing metric depicts the snapshot view of the best available path at a certain time. Hence, the initial path remains connected, until a path faces link breakage or the end of the flow. Therefore, we can claim that the path selection also sensitive to the noise level, interference level, and traffic load conditions. Unlike the conventional ad-hoc networks, a majority of WMN applications demand broadband service with a variety of QoS demands. Hence, designing of WMN communication protocols should focus on performance metrics such as delay, jitter, packet loss ratio, and node throughput together with end-to-end (E2E) delay and fairness.

In order to address the aforementioned challenges, in this paper, we have adopted the clustering concept to enhance the performance of the mesh network. In fact, utilizing suitable clustering mechanisms has improved the network performance in terms of routing delay, bandwidth, network extendibility, and node throughput (Suba and Satheeskumar, 2016). The proposed clustering based routing scheme consists of two components i.e. 1) The design of clustering based routing protocol and 2) load balancing component and interference management component. The load balancing component gathers traffic load transmission time of all neighboring MSTAs along a particular path. Similarly, interference management component gathers data related to interference among neighbor nodes of a path. End-to-end delay and hop count measurement values of the proposed scheme are compared with Weighted Cumulative Expected Transmission Time (WCETT). The results confirmed the superiority of the proposed scheme over WCETT metric.

Our contribution to literature is summarized below:

1. In this paper, In order to achieve optimal network throughput, nodes are grouped by a clustering technique. The proposed scheme is used to selectively broadcast RREQ instead of flooding between clusters. Consequently, the RREQ flooding overhead and path search time can be greatly reduced, and the transmission efficiency of the entire network can be improved.

2. In IoT over WMN environment, a Load Balancing and Interference Delay Aware routing algorithm are proposed to decrease the generation of abundant net flows to avoid network traffic jam.
3. The proposed scheme efficiently utilizes the available mesh station queue information and the number of mesh nodes that suffers from channel interference in the available path. This increases the network energy efficiency by managing the interference delay.

The rest of this paper is organized as follows. Section 2 provides an in-depth analysis of the related works. Section 3 presents our proposed load balancing and interference algorithm for IEEE 802.11s networks. Simulation results are given in Section 4 and finally, conclusions are combined in Section 5.

## 2. Related work

IEEE 802.11s is the base architecture for WMN. Fig. 1 clearly illustrates the architecture of IEEE 802.11s (Roofnet, 2018). In other words, MSTA is an entity of 802.11, which is capable of offering WLAN mesh services. MAC Service Data Unit (MSDUs) enter into or exit from the mesh via the logical point known as proxy mesh gate. WMN occupies generic IEEE 802.11 or non-IEEE 802.11 networks to connect WMN with another WMN (Jiang and Meng, 2012). A collection of autonomous STAs builds mesh basic service set (BSS), which is an IEEE 802.11 LAN. All STAs transfer messages mutually, while establishing peer-to-peer wireless links within the mesh BSS. Multi-hop capability further improves message transmission among STAs that are not in direct contact with a single instance of the wireless medium. Hence, all MSTAs in the mesh BSS appears to be directly connected with each other at the MAC layer, even though in reality STAs in mesh BSS are beyond each other's reachability. Consequently, we can claim that multi-hop capability enhances the range of the STAs and provides benefits during wireless LAN deployments (Jabbar, Khan, Silva, & Han, 2016).

### 2.1. WMN routing protocols

Determining the path between the source node and destination node is the utmost responsibility of routing protocols. The path selection procedure should be done reliably, fast and with minimal overhead. Especially, there has to be a path computed if there exists one.

Routing protocols consist of two main categories i.e. topology based and position based. Topology-based routing protocols perform path selection considering topological information such as links among nodes. Geographical

Information with geometrical algorithms is used to select paths in position based routing protocols. Moreover, a combination of both types is favored in some routing protocols. Topology-based routing protocols consist of reactive, proactive, and hybrid routing protocols (Bagci, Korpeoglu, & Yazici, 2015). Even though reactive routing protocols slightly increase the latency of first packet transmission due to on-demand route setup, this mechanism significantly reduces the control overhead.

### 2.2. Clustering for Wireless Mesh Network

In computer networks, clustering is widely used to implement resource sharing in terms of computing. In general, clusters combine resources of independent computing devices, in order to work towards a common goal. Generic architecture of a wireless network is enforced by dividing wireless network nodes into clusters with a prominent cluster head (CH) selection mechanism. Subsequently, the network ensures fundamental performance characteristics i.e. latency and throughput of a large number of mobile nodes. Nevertheless, WMN infrastructures do not consider energy resources and mobility as considerable challenges. Enhancing network performance and database access are added advantages of introducing clustering algorithms (Jan et al., 2015).

### 2.3. Routing metrics for Wireless Mesh Network

Proper routing metrics should ensure various demands in network performance i.e. scalability, load balancing, throughput management, reliability, and flexibility. A metric to measure the link bandwidth is proposed in (Hasan, Al-Turjman, & Al-Rizzo, 2017; Hasan, Al-Rizzo, & Al-Turjman, 2017). This mechanism employed a probing technique in transmitting a pair of packets to its neighbors. Once the sent packets are received, the receiver computes received time difference between two packets and send it to the sender. Finally, the sender calculates the bandwidth of the link by dividing the packet by the time sent by the receiver after a minimum of 10 samples. Even though it measures the bandwidth, such measurements directly influence the packet transmission time. In (Li, Khan, Lee, & Han, 2017; Sun, Liu, & Zhang, 2011) the authors proposed a routing metric named Weighted Cumulative Expected Transmission Time (WCETT). The WCETT metric considers the interference among multiple links that utilize the same channel by combining individual link weights into a single path. Nevertheless, WCETT lacks performance in handling link load explicitly and in minimizing intra-flow interference. Another key issue with WCETT is that it does not consider the number of links that occupies a single channel, even though it facilitates multi-radio support. Furthermore, WCETT is not isotonic and, therefore, it does not preserve the weights of two paths. In summary, the literature reveals that available routing metrics are not promising to offer significant improvement in terms of data transmission in WLAN aware WMN environments. Therefore, IoT based routing protocol for WMN environment is highly demanded with the technological advancements. Table 1, the comparison of existing routing metrics.

## 3. Proposed solution

### 3.1. Cluster formation and data forwarding basic operation algorithm

This subsection describes necessary assumptions and definitions for the proposed scheme. The proposed routing algorithm helps in finding the best and optimal path in an IoT-aware environment for efficiently transferring data over less congested paths.

We presumed to have only two wireless interfaces on a mesh node. Mesh nodes are generally equipped with several wireless radio interfaces. Only one among multiple interfaces of a mesh node is used for communication with other mesh nodes on the same channel, while another radio interface is used for communication with other nodes on different channels.

The definition for the cluster formation: cluster formation algorithm is utilized to organize the network into clusters. In a cluster, cluster head node, several cluster member nodes, and cluster relay nodes are its constituents. Cluster formation algorithms generally define the cluster head to be one hop away from all member nodes. So that, the cluster becomes a neighbor for each member node.

Cluster forming is an effective way to reduce the routing cost of a large-scale WMN. Where two hierarchies are designed i.e. cluster at the lower hierarchy and interconnected clusters of the network in the upper hierarchy. We floated an idea of a reactive routing protocol to show the advantages of a cluster in the design of routing protocol.

**Table 1**
Comparison of existing routing metrics.

| Routing Metrics | ETX | ETT | WCETT |
|---|---|---|---|
| Path length | Yes | Yes | Yes |
| Loss ratio | Yes | Yes | Yes |
| Link capacity | No | Yes | Yes |
| Intra-flow interference | No | No | Yes |
| Inter-flow interference | No | No | No |
| Load Balancing | No | No | No |

**Table 2**
Node information message and definition.

| ID | CL | TY | N | $ID_{NH}$ | $CL_{NH}$ | $TY_{NH}$ | $N_{NH}$ |
|---|---|---|---|---|---|---|---|

*ID*: Identification numbers of MN.
*CL*: Belong to a cluster group head *ID*.
*TY*: Mesh node type.
*N*: The number of neighbors of MN.
$ID_{NH}$: Belong to a cluster group *ID* of neighbor MN.
$CL_{NH}$: Belong to a cluster group head *ID* of neighbor MN.
$TY_{NH}$: Neighbor mesh node type.
$N_{NH}$: Number of neighbors of neighbor mesh node.

All nodes broadcast its information to neighbors in the cluster formation phase. The information indicates the status of the node that helps to build the neighbor list. Table 2, presents identification information and message definitions by the nodes. Mesh node local *ID* is node himself *ID* or neighbor node ($ID_{NH}$), mesh node belong to a cluster group head ID is cluster (*CL*) or neighbor cluster ($CL_{NH}$), mesh node type (*TY*) belong to a cluster or neighbor cluster node type ($TY_{NH}$), number of neighbors of mesh node (MN) is *N* or neighbor $N_{NH}$. Apart from it, it is a worth noticing that except the mesh cluster relay node, there is the execution of clustering algorithm on each mesh node of the network. The mesh cluster relay node has its own state i.e. *CR*. The aforementioned four states are as follows.

a) Cluster Head (CH) State: The responsibility of cluster member management is upon cluster head that is selected from the list of neighbor node information.
b) Cluster Member (CM) State: It refers to a node that belongs to a cluster. It changes its state from CM to null/joins. This state change is directed by CH through a Hello message.
c) Cluster Relay Node (CR) State: A mediating node that bridges the gap between two neighboring clusters and is in direct vision of these clusters. Since it is positioned at a place where it can work as a relay node to set up the communication between two neighboring clusters.
d) Null/Joins State: This state refers to non-affiliating of mesh node to any cluster.

Initially, all the mesh node are in the "Null/Joins" state. Every mesh node is periodically broadcast the hello messages to establish a connection. Mesh node determines the number of neighboring nodes *n* via hello message information exchange. If the neighbor nodes *N* is greater than the number of nodes of head $N_{NH}$ ($N > N_{NH}$.) node selects himself as the group cluster head and broadcasts hello messages to its neighbors.

All adjacent nodes linked to the group head become the members of the group. If a mesh node becomes a *CM* when it receives a hello message for the first time from a group *CH*. If *CM* receives a hello message from another group *CH* $TY_{NH} = CH$ or more group *CH* $CL_{NH}1, 2, \ldots n$ or different neighboring *CH* member nodes $TY_{NH} = CM \neq TY_{NH} = CM$, then *CM* becomes a *CR* that acts as a relay node.

The method of select *CR* is the same way as for select group head. If *CH* becomes a *CM* when *CH* is outside the group receive a hello message from another *CH*. After the head left the group, the remainder member nodes are according to the number of neighboring nodes to determine the group head.

In this paper, we construct a cluster using a hierarchical routing protocol. In order to minimize network congestion and energy consumption, intra-cluster data transmission is facilitated by single-hop mode and inter-cluster data transmission is facilitated by multi-hop mode. In addition, to reduce the number of nodes participating in data transmission, only the cluster header, and the relay node participates in data transmission.

In single hop mode, each node communicates with *CH* in a single hop. That is, the communication between the *CMs* and the *CH* is directly performed. However, data communication between clusters is made through intermediate CRs in multi-hop mode. That is, the data communication between the CH is performed through the *CR*.

The data-forwarding scheme is as follows. Upon receiving a data packet from a CM, it first checks whether the destination address and the local address are same. If it is the same as the destination local address, it receives the packet. If it is not the destination address, determines belongs cluster. If it is a *CM* in the cluster, the *CM* forwards its data packet to the *CH*. But, if oneself is the head of the cluster, its checks oneself routing table. The packet is forwarded on a specified route to the next hop *CR* in case there exists routing information in its own routing table entry else it sends RREQ message to find the optimal path to the destination.

In existing MANET (Mobile Ad-hoc Networks) environment, proactive algorithms have been studied to consider node mobility. In proactive routing, mobile nodes manage information regarding routing path for all destinations in the network. It shows effective performance with small network size and there is less mobility of the nodes of constituting the network. However, with the increase in network size, the amount of information of the nodes to be managed in the routing table increases exponentially. At this time, due to the characteristic of the proactive method, many nodes periodically flooding route update messages to all network nodes. This causes each mesh client node to consume more energy and cause message collisions and network congestion.

We proposed a clustering-based routing scheme is used to minimize unnecessary control messages that cause network congestion. If the destination node is within the cluster, use the proactive routing method. The networks occupy reactive routing methods when the destination node is out of the cluster region. Thence, we proposed a routing scheme, which merges both proactive and reactive routing schemes.

When using clustering based routing method, cluster head operates proactive routing method only for own cluster member mobile node, it is possible to prevent unnecessary control packets from being flooded to the network. Furthermore, by adopting the reactive method for finding a way to the destination node, when necessary the way to find the destination paths it is possible to compensate the disadvantage that the control packet flooding to the entire network.

The path discovery method is as follows. Firstly, the *CH* checks its routing table when *CH* receiving the data transmission request message from the *CM*. In the presence of routing information in the routing table, the optimal path is selected according to the routing metric value and transmits the data to the destination. If there does not exist any route, RREQ message is floated from source *CH* to search a route to the destination node.

Secondly, cluster *CMs* check their type when receiving RREQ message from *CH* and discard RREQ message if they are *CM* belonging to one cluster. This approach reduces network flooding occurred from control message broadcasting.

Thirdly, if a *CR* node belonging to one or more cluster heads receives an RREQ message, it broadcasts the RREQ message received from the *CH*. In this scenario, the RREQ message broadcasts through the *CH* and *CR* nodes in order to search for the path, and the *CM* discards the RREQ message, thereby limiting the flooding to the entire network.

### 3.2. Clustering based routing metrics

Multiple radio interfaces on the same node that are assigned to distinctive channels can operate concurrently. In fact, this mechanism leverages on network throughput improvement with a single radio system. Distinct interference topologies are formed by radio interfaces that are working on different channels. However, due to the limited frequency band and same channel utilization, adjacent nodes suffer

**Table 3**
Description of symbols used in equations.

| Terms | Description |
|---|---|
| $P(K)$ | The interference power from the neighbor $K$ nodes |
| $P_{max}$ | Maximum reception power |
| $R_i$ | Interference degree of node $i$ |
| $B_i$ | The available bandwidth for link $i$ |
| $X_i$ | Packets transmission time over link $i$ |
| $L$ | Packet length |
| $P_i$ | The transmission failure probability |
| $W_i$ | Number of packets in the queue at node $i$ |
| $D_i$ | End to end delay time |

from high interference, data loss, and error rate. Moreover, data transmission delay occurs between terminals due to traffic congestion. This causes degradation of transmission efficiency of the network. Therefore, a suitable routing metric scheme is proposed to reflect the characteristics of the clustering wireless mesh network designed in this dissertation.

The terms that are used in equations and their description is shown in Table 3. In this work, the physical interference model presented in (Tahir Rashid, 2016) is used for describing interference between different hops. The degree of neighboring interference is estimated by the received power monitored by all nodes. The following equation defines $R_i$ as the interference ratio.

This ratio is between nodes $u$ and $v$ through link $i$. $P_{\max}$ is the maximum allowable interference power from node u to receive the transmission signal at node $v$. $P(k)$ is the total power of the unwanted signal from neighbors at node $v$.

The utilization of the channel that is assigned to Link $i$ is reflected in this ratio. $R_i$ is 0 in case of no interference demonstrating that the total bandwidth is free of interference and that the full channel bandwidth allocated to link $i$ is available. On the other hand, if $R_i$ is 1, it means that the channel of link $i$ is fully occupied and there is no remaining throughput left. Link $i$ cannot be used until $R_i$ is less than 1.

Physical interference model is referenced for the measurement of interference degree ratio in Eq. (1). In 802.11 environment, RSSI is a relative received signal strength. Between actual received power and RSSI value, the accuracy and mapping value is provided by different vendors. A receiver can obtain the path loss value and the transmission power through channel monitoring and message exchange. This is done by calculating the signal power at the recipient end (Halperin, Hu, Shethy, & Wetherall, 2010).

The receiver estimates interference power based on the signal-to-interference-plus-noise ratio (SINR) measured by the wireless card. In studies that are conducted on static wireless networks, a method is developed to measure the signal strength at the receiver from Eq. (1). For this purpose, instances with minimal interference are scheduled for RSSI measurements.

$$R_i = \frac{\sum_{k=neighbors} P(k)_i}{P_{max\, i}} \tag{1}$$

Based on the above definition, we evaluate the expected time of packet transmission according to the influence of interference power of link $i$ on maximum throughput.

$$X_i = \frac{L}{(1-R_i)B_i} \tag{2}$$

Where $B_i$ represents the channel bandwidth of link I for the transmission under the channel interference, and $L$ indicates the packet size. The product $(1 - R_i)$. Eq. (2) expresses the net bandwidth usage reflecting the impact of interference power, considering a $X_i$ estimated times of transmitting a packet successfully on the link.

$D_i$ denotes the summation of delay experienced by the packet at each node from source to destination is the end-to-end delay. Considering the multi-radio multichannel path for evaluating the delay performance, an end-to-end metric value is computed. For this end-to-end value calculation, the number of packets is monitored at each node that are waiting for the service in the buffer. Same is applied to measure the transmission failure probability. On failure of MAC-layer transmission due to either poor channel quality or collision, it is considered as transmission failure probability.

$$D_i = \sum_{i=1}^{n}\left\{(W_i+1)\cdot\left(\frac{1}{1-P_i}\right)\cdot X_i\right\} \tag{3}$$

$W_i$ denotes the number of packets remaining in the queue at node i. Once a packet enters to the link $i$ queue, when it already has $W_i + 1$ packets in the queue that can be estimated as the average delay over link $i$. Where, $1/(1 - P_i)$ is number of packet transmission attempts. In order to the packet successful transmission needs evaluate number of attempted transmitted. Thus, packet service time can also be said as delay. Total delay of a link can be expressed as the summation of transmission delay and queueing delay. The $D_i$is the total delay time from the source to the destination. $D_i$ is a flexible metric that considers various characteristics of networks i.e. quality of link, interference, collisions, etc. that influence delay.

Influence of channel interference is considered in the first term of $D_i$. Total delay occurs from MAC collisions and link quality are indicated in the second term. $D_i$ metric indicates E2E delay to transmit a single packet. Moreover, $D_i$ metric represents block transmission delay due to bottleneck bandwidth. Thus, we can claim that $D_i$ metric is an optimal candidate to find shortest paths, while minimizing both short-term and long-term delays (Figs. 2–4).

Fig. 5 illustrates the flow diagram that gives a clear picture of the operation of the proposed scheme. The *CH* follows steps shown below, in order to derive the best path for data delivery from source to destination. Once a *CH* received an RREQ packet from a node, the *CH* lookups at the routing table to find a path to the destination. If there exists a route, RREP is sent to source *CH*. However, in the absence of an existing path, route discovery is initiated by the source *CH* with an RREQ packet that holds destination node. Consequently, RREQ is broadcasted to the network. If it is a cluster member node, discard the control message. If itself is cluster relay node calculate queuing delay $W_i$ and transmission time $X_i$ and rewritten to the RREQ and broadcast.

Each intermediate *CR* or *CH* node checks to identify access path to the destination on the routing table. If an intermediate node identifies an accessible route to the destination, the intermediate node immediately notifies the *CH* by sending an RREP packet along with the current metrics values. Upon receiving multiple RREPs that gives access to the destination node, *CH* determines the optimal path based on

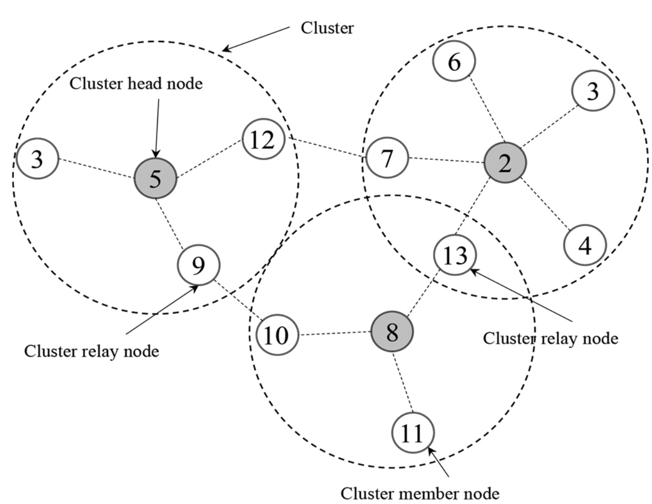


**Fig. 2.** Cluster Structure of Mesh Network.

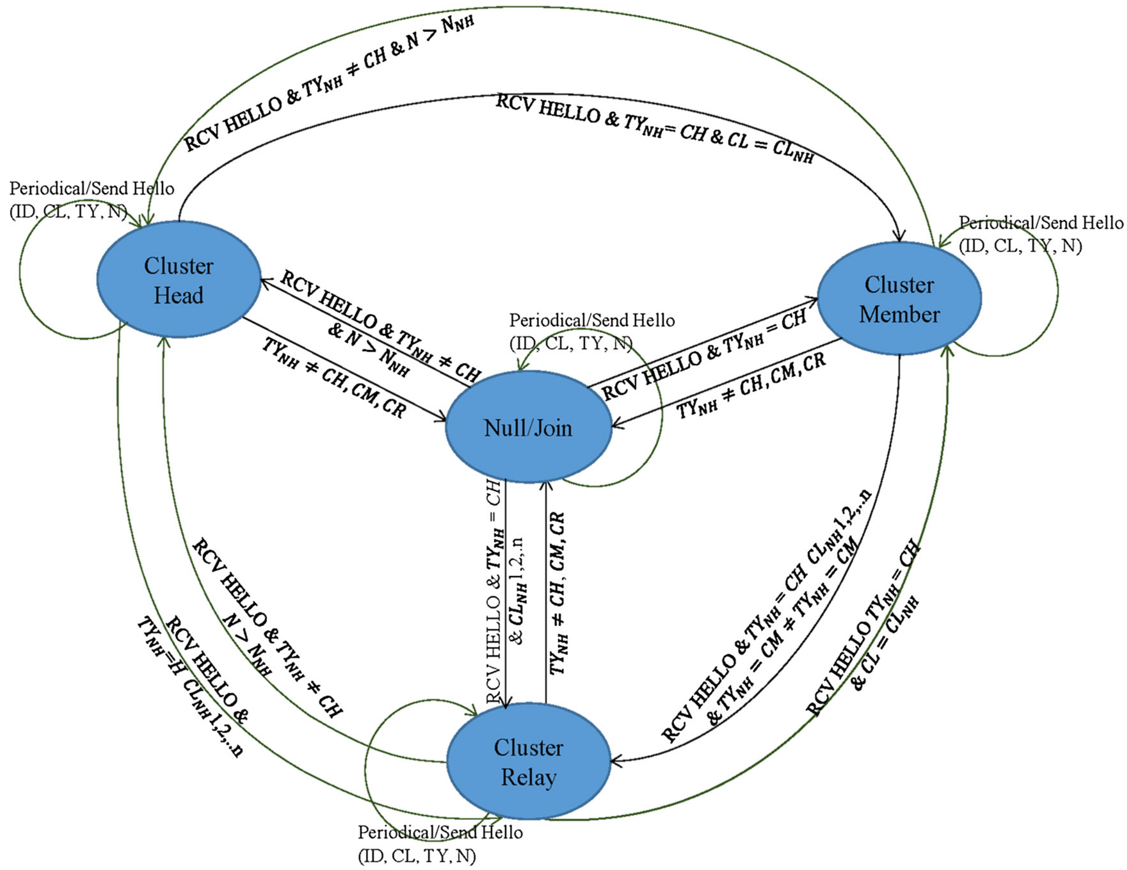


**Fig. 3.** Clustering state diagram in wireless mesh networks.

received multiple metric values. On the other hand, if *CH* does not get any RREP, that indicates no entries for the destination. Hence, *CH* will rebroadcast the RREQ message with the destination node.

Upon receiving an RREQ, the destination node appends $W_i$ and $X_i$ values and create the new RREP packet. Then, destination node transmits RREP messages until the timeout.

All the nodes in the forward path update multiple metric fields by comparing with the values on the received link and the RREP header. Until the timeout expires, source *CH* waits to receive RREP. After storing all paths, the *CH* determines the best by evaluating multiple metric values of each path.

## 4. Performance evaluation

In order to study the overall performance of a clustering based routing algorithm in WMN, the simulation tool is using C++ programming language. We divide the performance evaluation into two parts. In the first part, e describe the simulation environment in detail using Fig. 5. In the second part, we presented the performance of proposed scheme routing metric against the clustering based WCETT metric by incorporating these metrics in AODV protocol.

The simulation environment for WMN is shown in Fig. 6. The scenario consists of 30 MSTA which are randomly deployed in a 6 × 6 grid in a 600 m × 600 m square region. It is assumed that each MSTA in the network has 50 m transmission range. Since all mesh routers have similar transmission power, the interference range is almost equal. Constant Bit Rate (CBR) traffic is sent from the source node using the User Datagram Protocol (UDP).

The packet size is 1024 bytes with a sending rate of 100 packets/second. For calculation of WCETT, the value of $\beta$ was taken as 0.3. The value $\beta$ is taken as an optimum value because of its previous usage in clustering based WCETT algorithm.

The performance tests the difference of the network among clustering based WCETT and proposes clustering based routing metrics while there are different traffic flows 50, 100, 150, 200, 250, 300 different number of nodes 30 and a different number of available channels 3 in the wireless mesh network. The default simulation parameters are shown in Table 4.

As shown in Fig. 7, that the number of RREQ messages of AODV_WCETT increase with the increase in a number of nodes while there is a significant decrease of RREQ control message flooding in case of the proposed scheme.

Since it selectively broadcasts the RREQ control message from the source to sink node to lessen the RREQ control message flooding. Moreover, AODV-based routing scheme selectively broadcast RREQ instead of flooding between clusters. Consequently, the RREQ flooding overhead and path search time can be greatly reduced, and the transmission efficiency of the entire network can be improved.

As shown in Fig. 8, different tests were performed for packet loss ratio among Propose scheme and WCETT routing metrics. The results reveal that the packet drop rate increases with the increase of traffic flow. Nevertheless, Proposed routing metric takes account of the channel interference and load balancing. Hence, the number of drop packets in the Propose metric is lower than that of clustering based *WCETT* routing metric. On the hand, clustering based *WCETT* is suffered from high packet loss, since it does not consider the load balancing on a link in WMN.

It is clear from Fig. 9, that network throughput first increases with the increase in traffic load and later it decreases. This state is due to an introduction of congestion with the increase of traffic load. In the proposed routing metric we not only consider channel interference between clusters but also consider the actual assigned load for each link in the network. Simulation results are shown in Fig. 5 and indicate that propose routing metric is superior to the clustering based WCETT routing metrics.

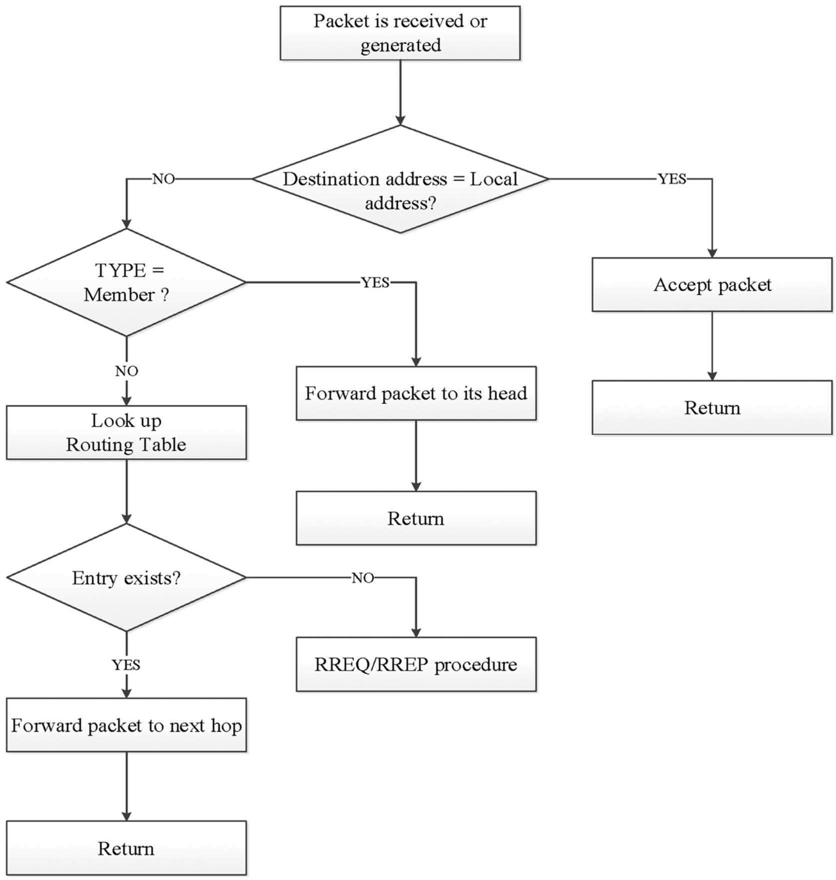


**Fig. 4.** Flowchart of data receiving and forwarding basic operation.

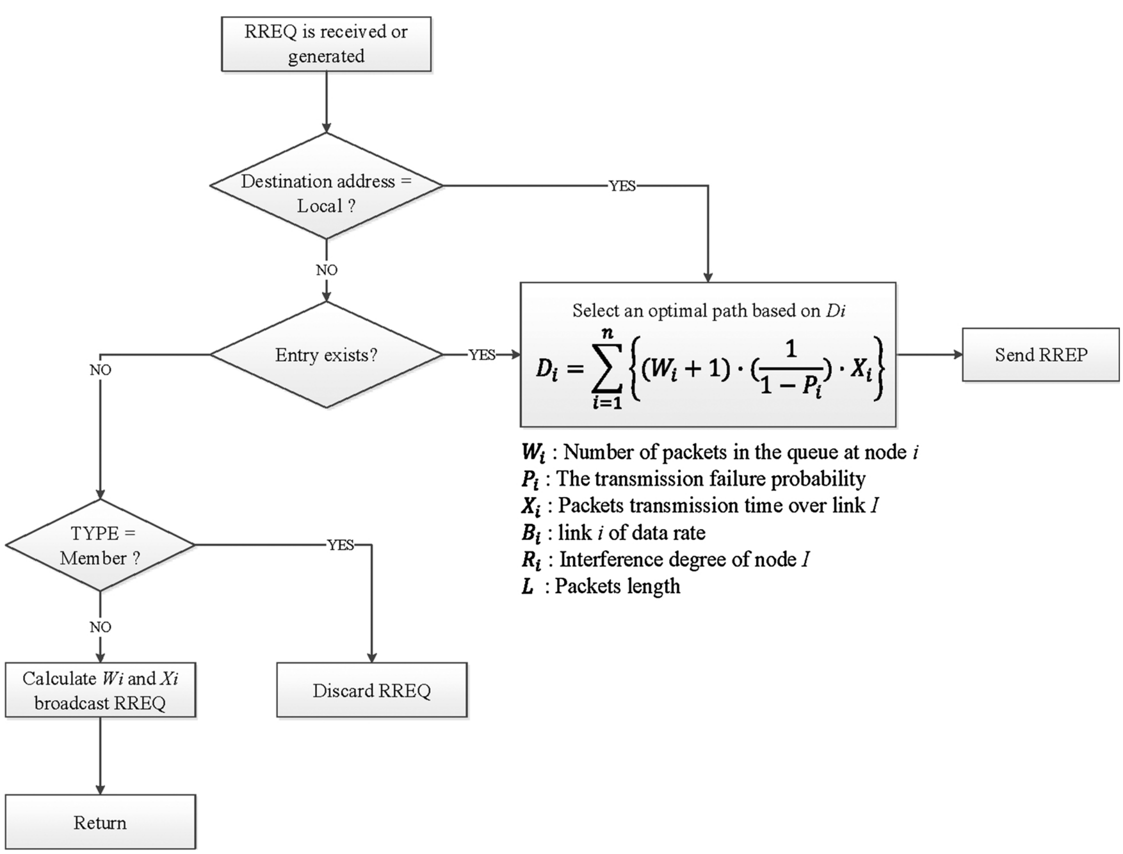


**Fig. 5.** Flowchart of path discovery process.

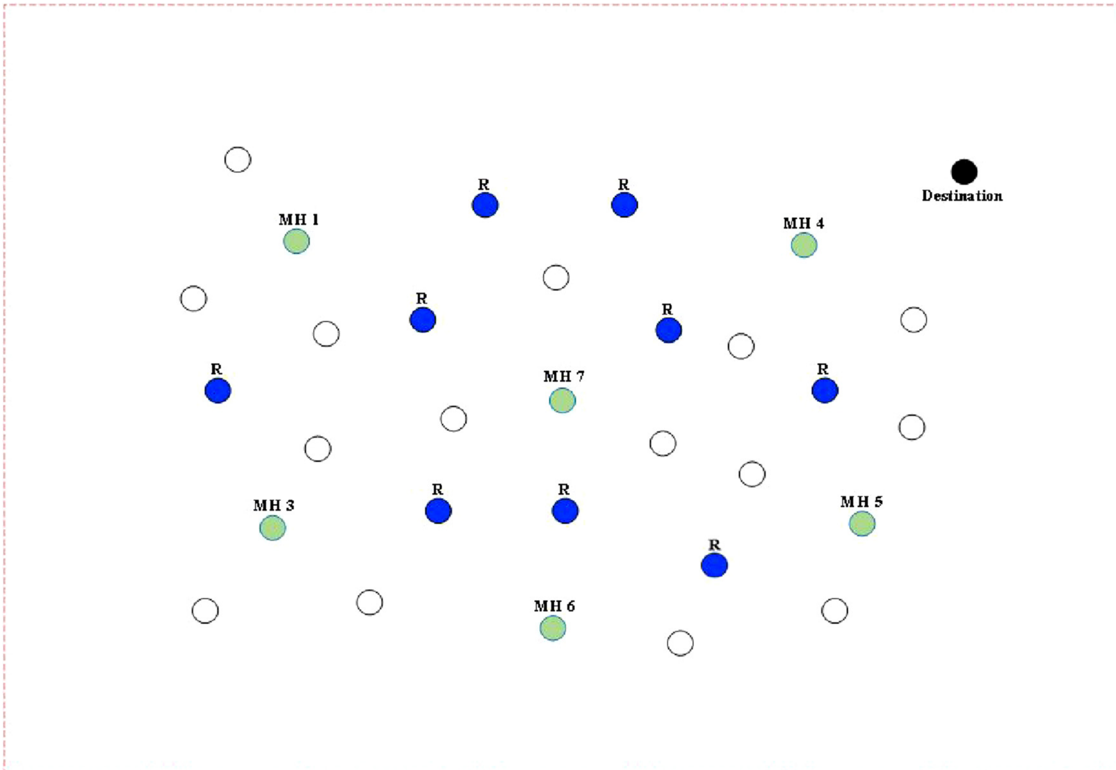


**Fig. 6.** Simulation environment.

**Table 4**
Simulation Parameters.

| Parameters | Values |
|---|---|
| Network topology size | 600 × 600 m |
| Number of mesh stations node | 60 |
| Number of node radios | 2 |
| Number of node channels | 3 |
| Packet size | 1024 bytes |
| Interference range | 100m |
| Signal to noise ratio | 0.5–1 |
| Traffic model | Constant Bit Rate (CBR) |
| Queue size at mesh stations | 50 Kbytes |
| MAC protocol | IEEE 802.11 |
| Bandwidth | 10Mbits/s |

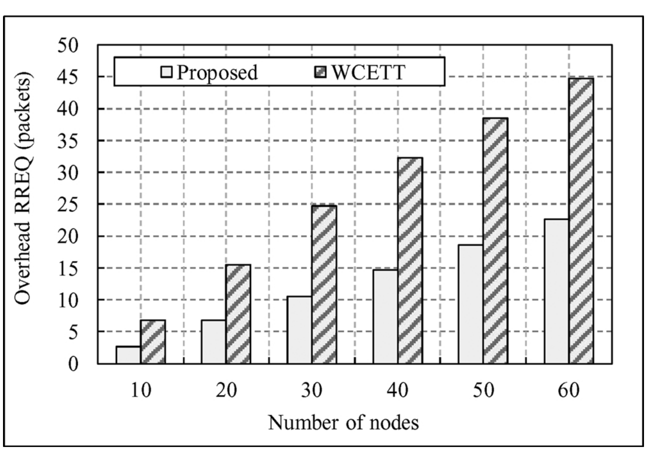


**Fig. 7.** Overhead of RREQ messages.

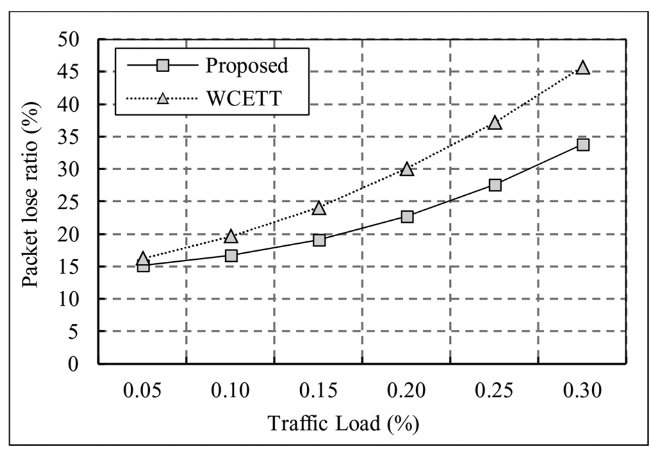


**Fig. 8.** Packet loss ratio versus traffic load in a 30-node network.

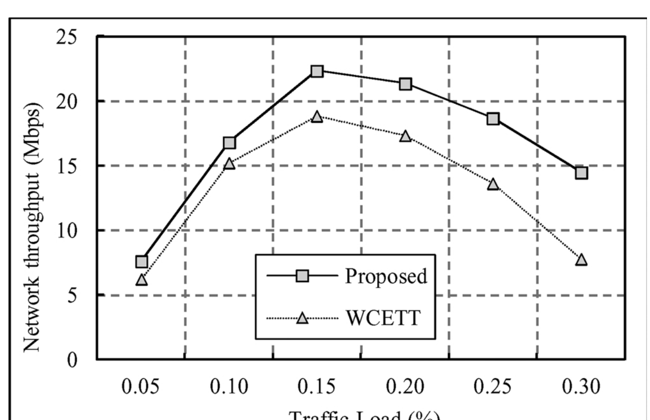


**Fig. 9.** Network throughput versus traffic load in a 30-node network.

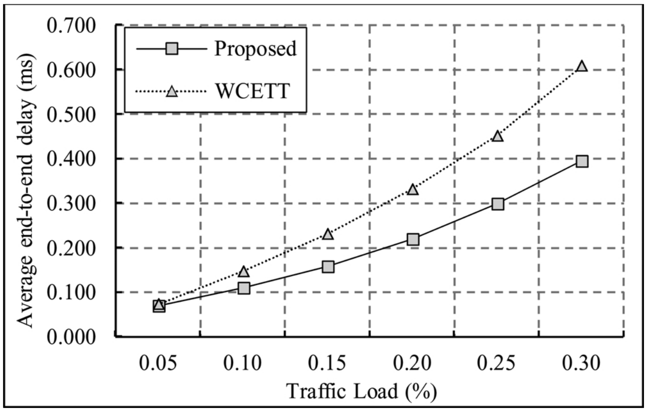


**Fig. 10.** Average end-to-end delay versus traffic load in a 30-node.

The Proposed routing metric is compared with clustering based WCETT in the context of average End-to-End delay as shown in Fig. 10. Various traffic loads are injected into the network, and we found that the Proposed metric selects the route with less interference as compared to clustering based WCETT routing metric. As the flow of data increases into the network, the End-to-End delay also increases because the End-to-End delay directly depends on the interference level on a link. Proposed shows less End-to-End as compared to clustering based WCETT because the clustering based WCETT always calculate ETT on each link. Therefore, the clustering based WCETT shows greater delay. However, the Proposed new scheme always considered load on a link and therefore avoiding congestion in the network. Thus, significantly reduces the End-to-End delay on a link.

## 5. Conclusion

In this paper, we proposed a new clustering based routing metric for multi-channel and multi-hop IoT aware WMNs. This metric obtains information of intra-flow interference, inter-flow interference, and traffic load to uplift the network performance. The proposed scheme efficiently reduces the interference delay and balances the load among different links in IoT WMNs. The proposed scheme in-concatenates the new routing metric with the AODV protocol for testing in an environment of IoT aware WMN. In an IoT environment, we believe that our results are able to provide in-depth insight into the routing algorithm design for multimedia communication service in IoT. The proposed scheme performs efficiently by selecting optimal routes in the network.

The simulation results show that the proposed scheme can be incorporated into a load balancing path discovery algorithm. This algorithm will be used to design a load balancing protocol which will choose a path that will deliver a high throughput, reduce the average end to end delay with minimized interference and can help in increasing the network capacity effectively (Sun et al., 2011). Finally, the proposed scheme is compared with the existing scheme in the literature and it shows better results and hence improves the network performance.

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