ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(32), DOI: 10.17485/ijst/2016/v9i32/86996, August 2016*

Survey on Channel Allocation Techniques for Wireless Mesh Network to Reduce Contention with Energy Requirement

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Abstract

Objective: In Wireless Mesh Networks the spectrum should be utilized effectively with better Quality of Service (QoS), synchronized time management and minimum delay. **Method**: The existing channel allocation methods needs improvement in QoS parameters such as end-to-end delay, ripple factor and time factor in accessing the channel. To improve the QoS further, the admission control drop and block probability, efficient channel reservation approach is the better solution which leads to better QoS even for delay sensitive applications. A performance analysis is made among the existing methods for contention reduced channel allocation methods, energy conservation channel allocation methods and as last method Admission Control Drop_Block probability methods. The networks are analyzed by considering the metrics such as Packet loss rate, End-to-end delay and Throughput. The channel count is virtually increased to support for dense networks by utilizing already used channels and by reserving few channels for dynamic requirement for normal and multimedia traffic data. The channel allocation methods are simulated using NS-2.

Keywords: Block, Channel allocation, Drop Probability, Wireless Mesh Networks

1. Introduction

The WMN provides the best Internet service even to the critical applications in the real world environment. The emergency network area such as military, police, fire-fighters and disaster management need to be connected always using wireless mesh networks which provides the full connectivity to these types of applications. To provide extensive support to these critical applications WMNs have to extend its feasibility during communication. In practice, WMNs have issues due to its multi-hop wireless communication, in deploying the layer protocol in the respective layers to improve its performance. The WMNs are using multichannel for their high-quality data transfer for heavy traffic over the Internet. One of the problems faced is interference, because of multiple overlapping channels during channel access time. In case of non-overlapping channels, very low interference may exist.

The issues generally considered in WMNs are related to the deployment of wireless devices, the range of frequency to be assigned to these wireless devices, proper link scheduling and routing etc. Though the non-overlapping channels are available, they cannot be used for all applications due to government regulations. Due to this restriction, the interference during channel assignment needs to be considered. In dense areas, the data exchange may be enormous; therefore, the usage of channel also increases drastically. The medium access layer is accessed by millions of devices; hence it is to be regularized to avoid collision[1], end-to-end delay and to maintain the reliability

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in packet delivery. The performance of networks depends on throughput and stability maintenance when accessing the channel, therefore, the channel assignment in MAC layer during contention time[2] period is to be regulated. The protocol needs to be designed in such a way to reduce the congestion. The existing mechanisms have a shortfall in controlling the congestion and also in reducing energy consumption during data transmission time period. An optimal mechanism is to be imposed in the MAC protocol to enhance the seamless connectivity and also to reduce the delay during multimedia transmission.

2. Issues in Network Layers for WMN

The critical time bound applications in WMNs makes the researchers to extend their research in designing a protocol for WMNs. The WMN needs the MAC layer protocol to be enriched to support well for mobile communication. Some of the issues in WMNs are discussed in the subsequent sections.

2.1 Design Issues

The communication between the WMN devices is done in half duplex mode, since the wireless devices do have only one radio with a single channel. The communication transfer rate could be increased, if the WMN devices are enriched with multi-radio and allow them to use the multichannel.

2.2 Physical Layer

The commercial deployments of WMNs have some issues in designing the networks with respect to characteristics of WMNs. The large scale networks, public safety networks, transportation, healthcare, industrial application and home networks are some of the huge networks where the congestion issue need to be reduced, so that the Quality of Service of WMNs can be sustained. The interference models[3] can be used along with smart directional antenna[4] to overcome this issue. The antenna with high gain can be placed at receiver side[5] to get the high quality signal with high speed. Full duplex mode can also be enabled to send and receive data simultaneously with proper antenna design and multi-radio. To enhance the wireless mesh network system with respect to range, some of the QoS factors are to be considered when a protocol is deployed in Medium Access Layer (MAC).

2.3 Medium Access Layer

In medium access sub layer, huge number of wireless devices accesses the medium and they share its frequency with other neighboring devices. The distributions of frequencies among the wireless devices are called as channels. The multiple-channel in IEEE 802.11, IEEE 802.15 and IEEE 802.16 standards enhance the channel utilization. Channel allocation to the wireless devices for all critical applications involved in a heavy traffic exchange is a challenging task. The heavy multimedia traffic exchange may aggravate the performance of WMNs. Many protocols have been designed to improve the MAC layer performance, but still it is a challenging task. The mesh routers and gateways together form the WMN.

The channel switching occurs very frequently in contention reduced channel access algorithm[6] which considers the handoff delay parameter. Due to this the ripple factor problem increases and under utilization of channels occurs. The admitted calls need to be serviced during its handoff time without much delay. The mobility may affect the network performance due to minimum channel availability. Coordination between the channels and among the nodes is the essential component to be considered while designing a MAC protocol. The literature survey with respect to channel allocation is described in section 3. The research issues existing in MAC layer are to achieve a minimum interference range and maximum data rate transmission. The channel assignment has to be dynamically adaptive, to support for dynamic changes in different wireless network integration.

2.4 Factors to Improve the Performance of MAC

The MAC layer is the heart of Wireless Mesh Networks, all Wireless Mesh Devices (WMD) sense the medium to acquire the channel if the channel is idle. Over the idle channel WMD can transmit its data to their destination devices/nodes. If all the nodes are trying to access the medium simultaneously, congestion may exist resulting in packet collision. Initially, the following QoS factors are considered to improve the performance of WMNs: end-to-end delay, throughput, ripple factor reduction, blocking and dropping rate reduction. The MAC layer issues are considered to overcome the packet loss rate. The efficient channel allocation is the most prominent way to improve the MAC layer performance.

The categorization of Channel allocation techniques are discussed in the subsequent sections.

3. Literature Survey on Channel Allocation

The protracted work in wireless mesh networks leads the researchers to give importance to channel allocation problem when the channel switching occurs more frequently. Hence the ripple factor problem increases and therefore utilization of channel degrades system performance. The following existing research work states that the channel allocation problem needs some improvement to achieve guaranteed QoS. The channel allocation procedures generally involve in i) categorization of incoming nodes based on traffic type with QoS satisfaction, ii) estimating the energy requirement for packet transmission, iii) assigning the channel with minimum collision during contention time period. India and some other foreign countries have deployed the mesh connectivity networks in some of their areas partially. The Champaign-Urbana Community Wireless networks formed by community networks[7], SFLan and Bay Area Wireless User Group in San Francisco Municipal Wireless Networks are some of them. The practically implemented WMNs suffer from some of the MAC layer issues which are to be considered while designing a MAC layer protocol. The link failure that occurs in wireless environment is often due to some of the environmental factors such as multipath fading[8], signal quality due to limitations of spectrum and power. The link quality is to be endowed in wireless mesh networks to send seamless real-time data without any interrupts.

In order to achieve the better link quality and to improve the WMN capacity[9], the number of channels available in WMN needs to be assigned efficiently. The network capacity can be increased by controlling the transmission power and by increasing the carrier sense threshold. The analysis proves that, increasing the carrier sense threshold and controlling the transmission power increases the network capacity. Here the communication ratio[10] of a node is defined as p, where $0 \le p \le 1$.The energy consumption of a node is, when it is in sleep mode, $0 \le e \le 1$. The average energy consumed by a node due to this mode is stated as Energy saving ratio, which is $(1-p)(1-e)$. Thus, the energy can be saved considering this type of factor during transmission of packets. The literature survey includes the existing methods projected in contention reduction mechanism, energy efficient packet transmission models and also to synchronize the multimedia calls with QoS effect.

The channel allocation is assigned based on priority queue; the highest bandwidth is assigned to high priority queue[11]. The drawback is starvation problem may exist.

3.1 Contention Reduced Channel Allocation Methods

As discussed in the previous sections, the ripple factor problem arises due to frequent channel switching, which affects the channel utilization. The literature survey focuses the existing methods which include the congestion and contention reduced channel allocation procedures. The common hopping sequence[12,13] and reserving some slots in 2 phases one is conserved as control phase and the other one is considered as data phase. The congestion problem[12] is the result of dedicate channel assignment to a node or to a mesh router. Instead of using single control channel[14,15] usage of two control channels and more than two data channels may control the congestion. The control channels are used as control packet transmitter which helps to reserve the data channel. The data channels broadcast this information. These the Control channels are used to send the control packets to reserve the data channels and to broadcast the information. When number of control channels extend, it reduces the delay due to hand off and the contention period during channel access. The problem due to the congestion in this method, motivated to propose a model which supports to reduce congestion in the network.

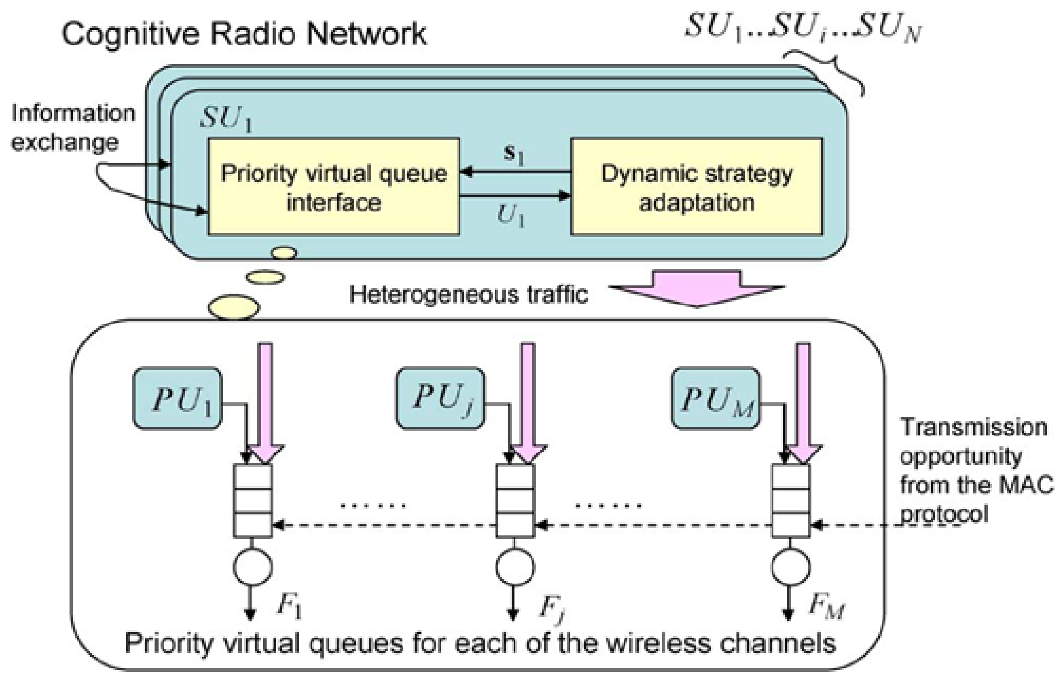

Figure 1. Queue maintenance for Channel Allocation[20].

In the Fixed channel reservation scheme[16] discussed, the interference due to adjacent channel usage is reduced. To a group of routers few channels are assigned, then few more channels are assigned to others. Channels initially assigned to the group of users without suffering from the interference problem[17]. If the users are in mobility status, then only a few channels are borrowed from neighbors or virtually few channels are locked. The locked channels are then used for handoff users. Some authors' in[18] have tried the method of assigning a fixed interface to a control channel, and the other interface is being assigned to data channels, whereas the control channels are not used for data transmission, even if they are idle. To rectify the above problem, the idle control channels are used for data transmission in the proposed method.

In Partial Synchronization Technique [PST][19], one of the node in the path is considered as forwarding node and it is used to exchange the information between the source and the destination. The PST allows to have distributed load within the existing channels. It allows maintaining partial synchronization with the source as well as with the destination node. Here the sender should know the sequence of channel hopping nodes before it sends the information to the receiver. The delay increases due to frequent channel switching. It requires more retransmission.

The Slotted Seeded Channel Hopping (SSCH)[19] method narrates the scheduling of channels among the mesh routers. A parity slot is used to synchronize with other nodes. If free slot is available then synchronization exists with pair nodes with that free slot. the free slot from each channel is searched by the resource needed node. If it exists then it is used for packet transmission and the end of cycle is indicated by the parity slot. All nodes monitor each other and acquire the free slots. The packets may be dropped some times, that could be reduced and rectified by exchanging the Request to Send (RTS) and Clear to Send (CTS) between sender and receiver. It may increase the MAC overhead too including ripple effect problem.

In Common hopping sequence [CHS][12] method, the hidden terminal problem is reduced by assigning the channel simultaneously to both the sender and receiver.

The concurrent assignment and hopping to the same channel reduces the hidden terminal problem. The exchange of messages with the neighbors reduces collision. The hop movement happens when a node receives its clear collision avoidance message and these messages are RTS and CTS. One of the channels is used as common channel to exchange the control packet information. The hop action performs after a node receives avoidance message from its neighbors. The drawback of CHS method is that whenever a hop action takes place the nodes have to hop to the common channel for their entire communication.

In Enhanced mesh coordinated channel access eMCCA[22] the mesh points are used to relay the heavy traffic. The collision in eMCCA is avoided by reserving some slots for its future transmission. It guarantees channel access without collision. The traffic indication message is used to assign the slots. Two groups are involved in channel reservation process. One is Reservation category(RC) and the other one is Non Reservation Category (NRC). The RC group nodes alone can do the reservation for future communication and it reduces the contention also during channel access where as the other group cannot do it. The preemption method of channel access supports for RC nodes, because of preemption the NRC nodes gets delayed it accessing the channel for its packet transmission. The path efficiency is calculated using link quality[21] metrics.

Dynamic utilization of multiple channels with synchronized pattern is used in Multichannel MAC (MMAC)[14]. The channel switching occurs very frequently, but with synchronized manner among the nodes. The communication starts after the sender nodes synchronized with receiver. The beacon is transmitted on common control channel once both sender and receiver are synchronized with each other. The data channel is selected based on lowest preferred channel by the nodes. The channels are grouped under three levels depends on preference list. HIGH, MEDIUM and LOW are the three preference levels and each node analysis the channel's preference level. The node which is in need of channel is checking the each level count, which has least count that channel is preferred to have fast transmission. The limitation is to maintain the preference channel list information by collecting the channel requirement from all the requested nodes before channel assignment process.

The Multi-Control channels Medium Access Control (MCMAC)[23], method uses multiple control channels. The control channels are used to send the control packets among the communicating nodes. Dynamically the number of control channels is either increased or decreased. In the existing list of control channels, one of the control channel acts as a default control channel. The data channels are subdivided into 'Y' channels and these 'Y' channels are distributed to control channels C_c. The data channel belongs to C_{Ci}

is used for data communication, whenever a node is sending a control packet to $C_{Ci.}$ If no data channel is free then after distributed inter-frame space (DIFS) time the sender is allowed to use the channel again. Channel Contention is problem is more in MCMAC.

In channel splitting strategy method the Single Control Channel (SCCH)[24] is used to send the control signals it may increase the control channel overhead. The Common Control Channel (CCCH) includes control channel and data channel. During handoff period the common control channel is used for exchanging the control information. The congestion could be reduced by reserving the data channel for future use whenever it is idle. Future usage details are to be predicted to avoid under utilization of channel.

3.2 Energy Efficient Channel Allocation Methods

The proposed TDMA based Multi-channel MAC (TMMAC)[25] with two data structures Channel Usage Bitmap [CUB] and Channel Allocation Bitmap [CAB]. The time is divided as slots, the slots may be busy or idle which depends on the usage of wireless nodes. If a $slot_i$ is acquired by a node, then the corresponding bit in CUB_{ij} will be set to one as it represents i^{th}slot j^{th} channel is busy. The CAB_{ij} is also set to one. The Adhoc Traffic Indication Message acknowledgement (ATIM-ACK) and broadcast (ATIM-BRD) messages are exchanged for communication. The S_i and D_j is a pair of nodes trying to access the channel, the bit map information is exchanged among the neighbors. The bitmaps are also updated to avoid channel contention. The energy conservation specified by[25,26] is comparatively high.

The power control mechanism proposed by[27] for IEEE 802.11, exchanges the RTS, CTS and ACK signals to transmit and receive data. Initially maximum power is set to sender side and minimum power is set to receiver side. If a node X is ready to send a packet to the receiver Y, then the first process X sends an RTS message along with its transmission power. If so, it also receives the CTS message with the same power. The data and the ACK message are exchanged with reduced power. The key note of the maximum and minimum power calculation during the data exchange is to conserve the energy during the period of the complete packet transmission. If the nodes X and Y are in transmission range, the above process is used. If the nodes X and Y are not in transmission range, then the problem arises and the collision will occur along with the nodes which are not in the range transmission, but they may be in the range of the carrier sense. The collision problem faced in conventional method is reduced in power controlled MAC (PCM) mentioned by[27]. The transmission power is not reduced when exchanging the ACK and DATA packets, instead of reducing the power; it gets increased to the maximum power level gradually.

The methods such as group allocation, reservation of channels with bandwidth management[28], channel allocation with the contention reduced approach. The distributed dynamic channel assignment[2] uses dropping and blocking probability factor to increase as well as to decrease the reservation factor level. The reservation factor is used in channel assignment. Many channel assignment algorithms are used currently as specified in stated[29,22].

The proposed methods such as Minimum Energy Local Topology (MELT)[30] and full connectivity maintenance are used to conserve the energy during the transmission period.

The shortest path is selected and the node propagates its power accessible to their neighbors along with its transmission power indicator (TPI) number. For example, if nodes a,b and c exist in the network then if a node 'b' is in need of transmission, before doing so, 'b' compares the power of 'c' and power of 'a'. Then, whichever the node has a least value, that particular power path will be selected for further communication. The drawback of MELT is finding the shortest path for transmission instead of link capacity of each path.

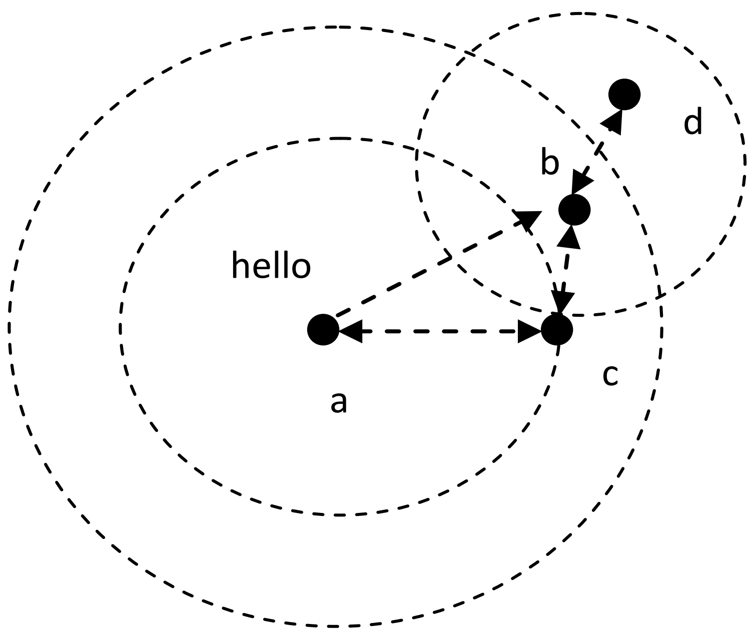

Figure 2. Passing Hello message to 'b' with full transmission power[30].

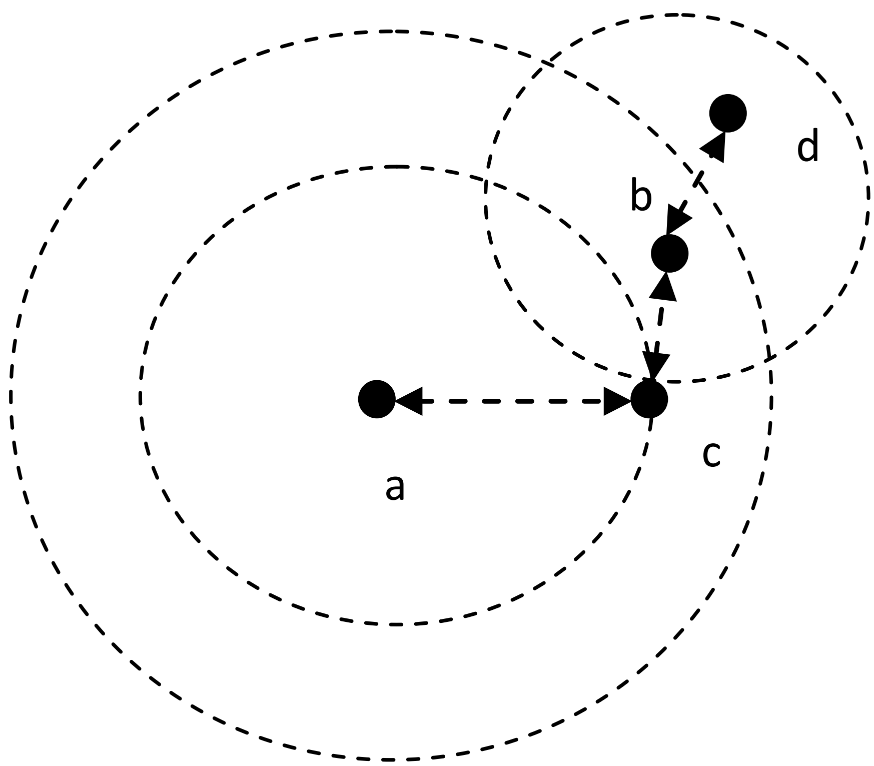

Figure 3. Topology to view with a minimum energy path[30].

The Energy Aware Channel (EAC)[31] allocation algorithm, data transmission is based on transmitting power in which the routing technique is also used to find the optimal path. The vertex coloring algorithm is used to avoid the interference and these vertices are queued according to the degree of each vertex. The flow request of all nodes is serviced one by one if a free slot is available, otherwise it will be placed in queue. The drawback of EAC is starvation, which arise since it is queued.

The author in[32] proposed a method which involves energy efficient potential communication with calculation of flow rate between the pair of nodes. The radio, which is idle, is switched off; it overhears the information from the neighbors which are in the same power. The overhearing helps to select the path which consumes less power.

The authors in[33] proposed to optimize the scheduling, by maximum independent set to utilize the channels efficiently. The radio link channel tuple 'p' includes a number of radios assigned to source and destination and their corresponding link capacity. The common radio interface is assigned to common channel inorder to avoid disconnection in communication.

In recent years, the internet usage in WMN makes the researcher to focus on energy conservation to maintain a continuous exchange of huge multimedia application data among the users. In WMN, the Quality of Service (QoS) is to be increased by considering the end-to-end delay, packet loss, collision and efficiency of channel utilization.

The energy conservation specified by[34] is a metric considered to balance the channel assignment and achieve the throughput without much packet loss. The objective of the energy efficient channel allocation is to optimize the channel time duration assignment to perform packet transmission with minimum loss rate. The existing work related to channel allocation goal is in throughput improvement as focused in[23,35] without considering the energy conservation.

The authors in[25,5] proposed Double Sense Multiple Access (DSMA) with contention reduced medium access control and they focused the energy conservation with mandatory waiting time, which forces the nodes to be in the waiting state. If a slot is in busy mode, the DSMA method tries to keep the node in waiting state, before it competes for the channel slot in order to reduce the idle listening energy. It doesn't analyze the packet loss rate and also the delay time.

The WLAN Access Points (APs) are designed in an effective method to reduce the energy usage when it transmits the data. Power consumption is recorded using two modes of operation such as Awake mode and Doze mode states as mentioned in[36]. When a client node is in Awake mode, it is powered, completely ready to send, receive and to sense the medium to select the channel. When a node is in Doze mode, the client doesn't have any power to do the activities hence, it is in the power save (PS) mode. Traffic Indication Map is used to indicate, that some packets are being buffered, as it can be retrieved in PS mode using polling method. The client can retrieve the packets one by one. The pending messages are notified using a delivery traffic indication map. Those messages are forwarded after beacons time period. This power saving mechanism uses Automatic Power Save Delivery (APSD).

The author in[37] proposed the power saving mechanism includes Network Allocation Map (NAM) which indicates the unavailability of a node. The NAM message is broadcasted during beacon period and it indicates that the corresponding AP is in power save mode.

The author in[38] approaches the method to reduce the exposed terminal problem by Exposed Terminal Free (ETF). The traffic and control channels are used for communication. The status of channel is maintained using 'Tch' to indicate the signal as sbusy/no-busy, to give indication to their neighbors. If it is busy, then one of the conflict free channels is selected; if no such channel exists, then the node needs to be in the wait state. The total time required to send all packets are calculated. The CAEC method is the combination of GWI and MCLP affirms well for energy conservation to reduce the energy requirement for all packet transmissions as discussed in chapter4.

3.3 Admission Control Channel Allocation Methods

To enrich the Qos parameters the dynamic changes need to be adapted in an impeccable manner to the Wireless Mesh Networks. The same channel can be reused in different parts of the networks without interference. The multimedia handoff calls[28,39] should not be interrupted during its communication. The queuing model[39,40] is proposed for real time and non real time traffic type. The group allocation[40] method allocates initially a few channels to each group, that assigned channel can be reused according to dynamic traffics requirement. The channels are virtually increased to reuse the channels[39] to different mesh routers without co-channel interference. To multimedia handoff calls exclusive channels are assigned to ameliorate its performance.

In Breadth First Search channel assignment[3] the channels are assigned with interference aware model. One of the nodes is considered as a controller which acts as a center node and it decides which channel to be assigned to the requested node. The other nodes should on the center node. The exchange of messages between the controller and to the requester is less, but complexity increases due to waiting time of requesters.

The spectrum allocation for video on demand is proposed in[41] concentrates on QoS metrics such as link failure rate and collision due to dynamic channel assignment. The re-connectivity of networks happens automatically whenever the link failure occurs. To reduce the collision video services are serviced with session based algorithm besides that the sender and receiver may not attain the synchronization between them.

The priority virtual queue[20] is used as channel assignment algorithm for multiple radios mesh networks. Dynamic learning method is associated with the existing method. The current assigned channel to the radios is used for subsequent packet transmission. The list coloring method[42] considers the priority factors such as link degree and color degree to assign the channels to the concern nodes in WMN. The least interference degree is chosen to have good communication with sender and receiver.

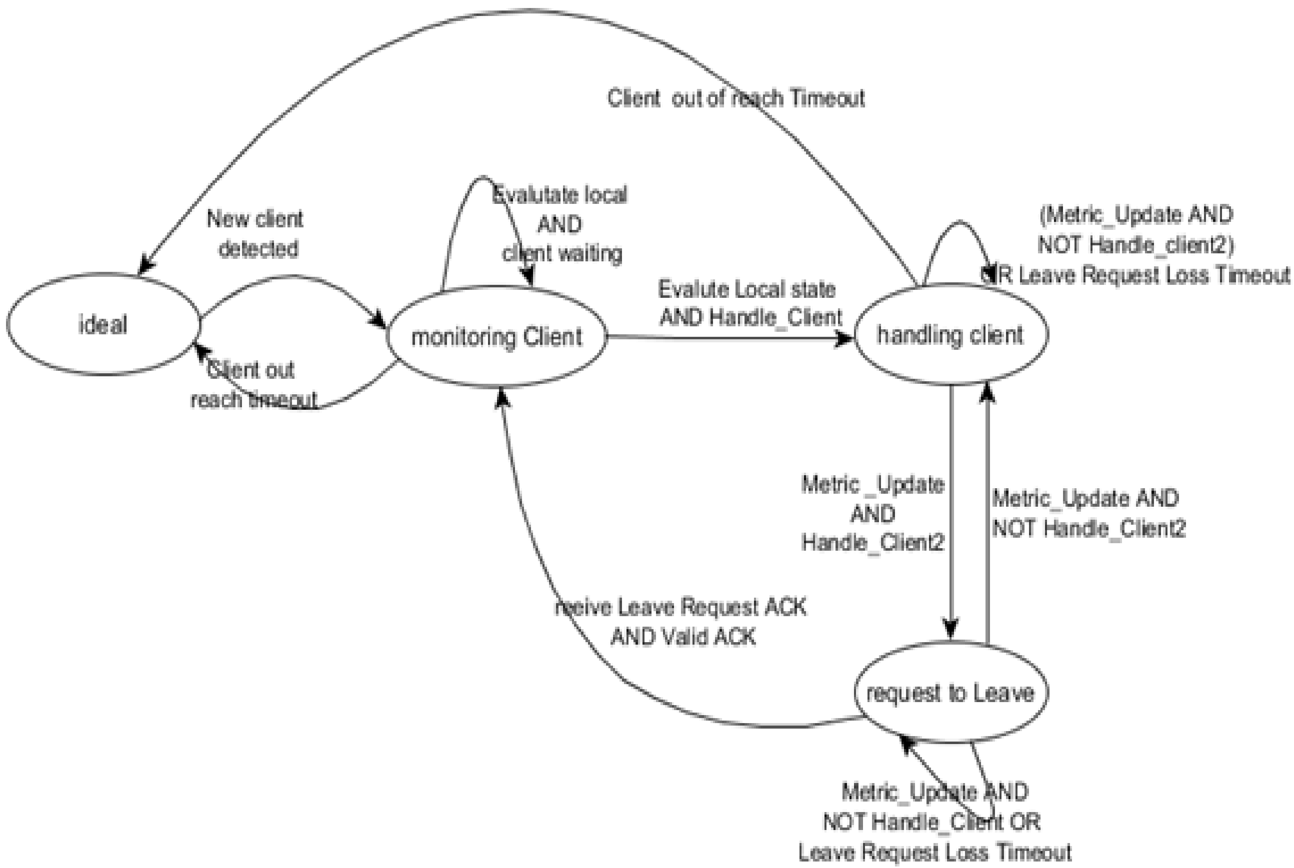

Figure 4. State Diagram of Smesh Channel Allocation Techniques[44].

Co-operation Management in Handoff (CMH)[43] method considers the uplink and downlink time of each mesh routers. The heavy load channel is not preferred by the channel requester. The holding time[43] is the factor considered for channel selection. The dropping rate gets increased in CMH method.

The communication between sender and receiver exists simultaneously in Gateway scheduling[33] based handoff method. The different channels such as data channels and control channels are used for communication. the overhead occurs because of 2 channels are used at a time by a node. The delay factor increases due to acquiring the channel simultaneously.

The Seamless Wireless Mesh network SMesh proposed in[44] assigns the channel to requester based on message communication. SMesh assigns the better quality channel to the requester. The frequent channel exchange degrades the system. The Figure 3, shows the state diagram of the channel allocation procedure involved in SMesh techniques. Spines daemon on each mesh nodes are used to forward the messages and maintain the neighbor's information by sending the messages periodically. Link-state information is updated by Smesh which maintains the connectivity and reduces the overhead and hidden terminal problem. The real- time applications need quality packet delivery without much loss. When a client node is in mobility, it sends its virtual address to the remaining clients until it receives acknowledgement message from others. The handoff process starts its activity, when it receives the best connectivity signal with other APs.

The dynamic channel allocation method is focused as channel allocation method for WMNs to reduce the interference as well as to reduce call dropping rate. Some authors have focused on improvement of quality-of-service for multimedia data transmission and their handoff system[28]. To improve the QoS the proposed works are, to reduce the Connection Drop Block Probability ($CDBP_r$) also with sustained synchronization between source and destination at the time of channel assignment. The QoS guarantees are expected in many real-time applications, their service requirements are to be fulfilled for proper transmission without much loss and delay.

The spectrum[45,46] needs to be used properly in WMN to avoid call disconnectivity problem during handoff among the mesh clients. The transmission between wired networks and wireless mesh clients is through the mesh routers and gateways. The different layers involved in these communications require guaranteed QoS. The proper channel allocation is required in WMN to assign the channels to the mesh nodes without much interference between the assigned channels. The delay sensitive data needs full connectivity until the completion of data transfer and the Non-Real time data needs to transfer without much packet loss. These factors are considered to assign the frequency to the required nodes, which are all in demand in the service request.

4. Conclusion

The techniques related to contention reduced channel allocation with minimum energy utilization and collision control mechanisms are studied in detail. The deprivation with respect to existing methods is analyzed and it is explicated in the literature survey. The disparate techniques described earlier provide clear information on channel allocation techniques. The thesis enhances the wireless mesh networks existing channel allocation techniques with significant enhancements to improve the QoS metrics.

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