Dynamic Channel Allocation Technique for Distributed Multi radio Multi channel Multi path routing in Wireless Mesh Networks

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Abstract : Recently, demand of extensive and ease remote scope is expanding very rapidly, ranging from a campus to wide zones. It has spurred to develop a highly efficient architecture for multihop wireless communication considering wireless mesh network based on the standards of IEEE 802.11s. In wireless mesh network based communication, channel assignment is an important and crucial task which affects the performance of network. Channel assignment is a process to perform selection of best channels for any individual node or entire network. This process mainly aims on the network performance improvement by increasing the network capacity. This issue of channel assignment has been discussed widely in multi-radio wireless mesh networks. Various approaches have been presented to address this issue but still it suffers in the case of implementation due to its complexity. Despite of this, a new approach for connectivity, routing and frame transmission is introduced by IEEE 802.11s standards. Various unsolved issues and challenges present in multi-channel architecture due to which these architectures are getting less consideration. Various techniques have been proposed to obtain standardize channel allocation schemes with the help of robust routing protocols in wireless mesh networks. Some of these techniques aim on the network throughput maximization and network interference minimization resulting in network performance enhancement. According to existing protocols, single channel information and static allocation is utilized which degrades the network performance of wireless mesh networks. Key challenge for researchers is to provide an efficient approach for channel allocation without inducing interference and resulting in improvement in throughput in WMNs. In this work we try to address this issue by developing an efficient scheme for channel allocation. To address the issue of channel allocation, here we present a dynamic channel allocation scheme for multi path routing protocol for WMNs. WMNs create inter-flow and intra-flow channels which causes interference during communication. To avoid this interference, dynamic channel allocation schemes are widely used to provide reliable communication. This protocol maintains and establishes multichannel communications which are changing frequently and data flow is separated into multipath. Simulation study is carried out using MATLAB simulation tools and performance of proposed channel allocation approach is evaluated. Simulation study shows that proposed approach for dynamic channel allocation scheme is capable to achieve better results in terms of throughput, delay etc. by achieving adaptability, less communication overhead and interference.
Keywords : MATLAB, WLAN, MAC

1.1 Introduction

Wireless mesh networks are based on the IEEE 802.11 communication standards. This technique has been proven a significant approach to provide better solution for wireless communication systems in a flexible and cost effective manner without using any pre-defined infrastructure. WMNs are widely used in real time application such application are internet access, emergency networks, public safety etc. [1,2]. IEEE 802.11s has specified various solutions for wireless mesh networks for multihop communication which is an extended version of IEEE 802.11 WLAN standards [3-4]. According to IEEE 802.11s mesh network configurations, mesh networks consist of various mesh station which operates as routers. These mesh stations are known as Mesh STAs. In mesh networks, packets are transmitted through multi-hop wireless nodes providing internet access to each user. However, due to wireless medium, or communication networks, interference is caused during communication which degrades the communication quality for end users. In the case of multi-hop network, this issue causes drastic performance degradation [5,6]. During real time communication in congested areas where more number of devices is present for communication, these networks face the problem of spectrum sharing and allocation which results in performance degradation. Interference can be considered as of two types: external and internal interference. Generally, external interference will degrade the performance rapidly when two or more wireless networks are operating at the same frequency channel.
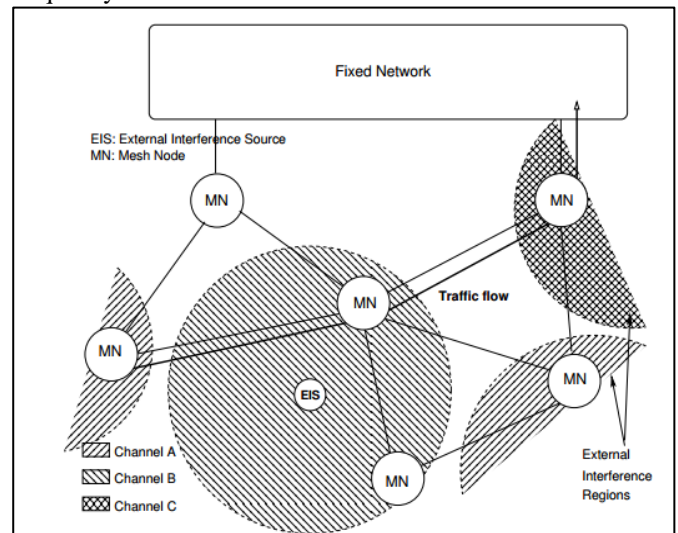
Figure 1.1 Wireless Mesh Network suffering from interference caused by external sources

If there are only three available channels (A, B and C), to avoid the external interference the mesh network has to be able to find the most suitable channel at each hop. However, it can be alleviated with the help of non-overlapping channels used in IEEE 802.11 standards by assuming that different networks are working on the same channel distribution. Reduction in non-overlapping channels can completely

reduce the effect of external interference by avoiding the interference. Internal interference causes time overlapping transmission which results in collisions or transmission errors. Hence, both internal and external interferences cause performance degradation of the wireless mesh network [7, 8].

1.2 Existing Model

In this section, we present the study about existing technique for channel assignment in wireless mesh network. Various techniques have been discussed for channel allocation which is based on the utilization of MAC layer and routing protocol. For example, layered MAC layer architecture and AODV routing protocols are used in 802.11MAC architecture. In this type of layered architecture, a global topology of the network is considered in the routing where next-hop is estimated. During this process, MAC layer behaves as local channel observation module due to the behavior of 802.11 MAC, since it doesn't show a significant improvement in multi-hop communication scenario. In multi-hop scenario 802.11 MAC architecture suffer from the issue of carrier sensing and channel distribution in dense mesh network environment. In actual scenario, the utilization of CSMA and collision instruments can once in a while cause extensive overheads. However, these execution issues can provide great extent conquer utilizing an on a very basic level distinctive framework configuration approach in which end-to-end way steering is connected to MAC planning under control of a global optimization technique. From this we get two key indications:

* Instead of irregular MAC conflict, transmissions ought to be planned with global data about the end-to-end way choices and resulting impedance relations.
* Also, selection of communication path in routing should consider MAC collision and impedance prompted data transmission decreases notwithstanding typical separation elements, i.e. ways with equivalent or longer lengths might be a superior decision now and again.

1.3 Proposed Model

In this section, we discuss about proposed approach for dynamic channel assignment in wireless mesh networks and we have discussed in previous sections that wireless mesh networks is being widely used for large coverage area communication requirement. During this wide range communication, WMN inherit some issues related to scalability which are known as end-to-end throughput, communication delay, packet delivery rate etc. Another studies presented in [9], shows that throughput of any network can increase or decrease at any point of time of communication.

The main reasons are given below:

* Half-duplex property of the radios: Radios cannot transmit and receive at the same time. As a result, the capacity of relay nodes is halved.
* Collision avoidance issue: In wireless mesh network scenario, hidden and exposed terminals causes collision resulting in performance degradation.
* Wireless medium nature: During communication, broadcast nature of wireless medium also affects the performance of wireless mesh network. In the scenario where all nodes are operating in a common communication channel then to perform communication each node compete with others resulting in increasing the congestion and traffic load.

There are some techniques present in the literature to deal with channel contention and collision issues such as utilization of directional antennas, implementation of power control strategies [135], location information [136] and use of multiple channels. In this work, we develop an effective approach to provide the solution of above mentioned issues in this field of wireless mesh network communication. Our main aim is to improve the network performance with the help of channel utilization schemes. Here we propose a new protocol called as Adaptive multi-path and multi-channel control schemeto enhance the network performance [10].

From literature study, we have concluded that multi-path routing can provide better results by incorporating multi-channel design scheme. Main contributions of this work are as follows:

* In this work we develop a combined scheme for WMN by incorporating multichannel and multipath routing scheme.
* With the help of this protocol, data traffic is decomposed over different channels, time and space resulting in increment of end-to-end throughput of the network
* In next stage, route discovery is performed by proposing $GREQ$ forwarding scheme. This scheme helps to reduce the number of broadcast messages.
* Later, a routing metric is implemented which considers path and interference among links to evaluate the disjoint part of the system.

This metric is used for selection of two maximal disjoint path and reduces the interference in the network.

1.3.1 Proposed Protocol Architecture

Architecture of proposed protocol is discussed in this section. It is assumed that each node is equipped with an 802.11 wireless adaptor using half-duplex radio. This radio is allowed to switch among different channels and executes 802.11 MAX protocol. Proposed approach is a cross-layer architecture which doesn't demand for change in MAC layer configurations and hardware structure of network model.

This scheme is a combination of multi-path and multi-channel link layers which are cooperation each other for improved communication. Functionalities are given as:

* Neighbourhood information is used for channel reception purpose.
* Gateway to each node, connection is established using a communication link path.
* Superframe technique is introduced for assigning the slots in the network.
* Packet forwarding, scheduling and ratio of slot transmission and reception is adjusted for better It schedules and forwards packets and adjusts the ratio of transmitting slots to receiving slots for each node.

Multi-Channel Link Layer Part

Link layer architecture has two main functionalities based on scheduling which are known as channel scheduling and packet scheduling. First approach is used for controlling the channel for the transceiver and second one is applied for scheduling the packets for transmission over network. In this section we discuss about the proposed architecture which consists of following sub-modules:

* Super frame architecture model
* Data transmission and receiving patterns
* Dynamic tuning of transmission or receiving patterns during communication
* Packet Queue modeling

- Slot arrangements
- **Super frame architecture model**: In this model, the time axis is portioned into fixed slot lengths as l which are organized into super frames. These slots can be assigned as a slot for transmission and receiving slot. Here we determine the number of channels to be used in slots of a super frame using receiver based channel assignment strategy.
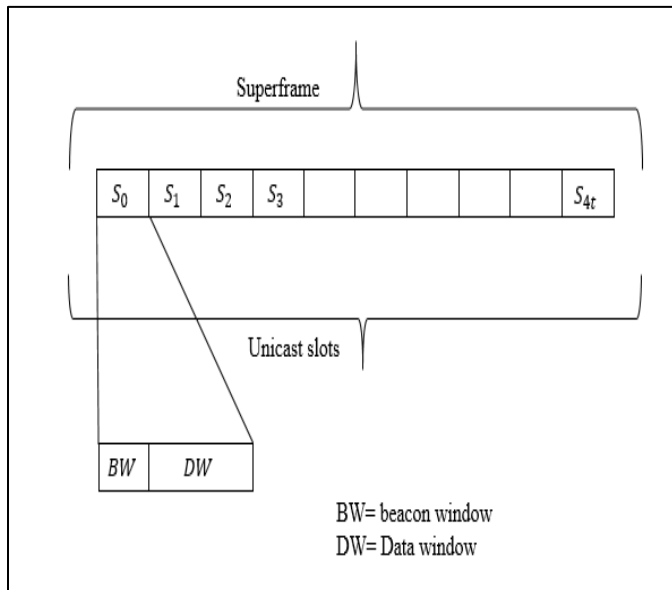
Figure 1.2 The Super frame structure.

Figure1.2 shows the structure of super frame used in this work. Super frames are inexactly synchronized in time. According to the super frame structure as presented in figure 4.7, each super frame consists of total $4t + 1$ slots which are marked as $s_0, s_1, ..., s_{4t}$ where t is an integer. Later these slots are categorized according to their working procedure and network requirements such as s_0 denotes broadcast slot which is used for transmitting beacons and broadcast messages. This process of message broadcasting is comprised into two stages such as beacon window (leading process) and data window (following process). For network connectivity analysis a pre-defined common channel slot is assigned during communication and it is assumed that all the node are staying in the assigned channel slot s_0 whereas remaining total number of slots are assigned to unicast slots. In the unicast slots, dynamic channel assignment is performed.

In order to obtain the better communication performance, receiver based techniques for channel assignment is considered more robust. These techniques provide flexibility between nodes which helps to switch between similar channels during on-going communication.

After switching to a new channel, a node first remains silent for a duration equals to the maximum packet transmission time so as to avoid the multichannel hidden terminal problem which is resulted by loose time synchronization. Therefore, proposed adaptive architecture does not require very precise clock synchronization.

During communication, two stages occur in this work such as receiving slot and transmitting slot. If node stays in its own channel then it is considered under receiving slot and if node is switching based on its receiving channel and waits for next switching until the slot ends, is considered as transmitting slot. This assumption makes a communication model where one receiving slot and transmitting slot is required for

communication purpose. Moreover, this technique provides efficient communication because once the channel is switched to another channel then it remains unchanged until all the packets are transmitted successfully. This technique helps to avoid the multichannel hidden terminal problem by using efficient time synchronization. Hence, the proposed technique doesn't need of any clock synchronization.

- **Data transmitting and receiving patterns**: As discussed before those unicast slots of a given super frame are assigned as transmitting and receiving slots. Since traffic is stable in mesh network which doesn't cause frequent changes in slot assignment strategy. Super frames consist of evenly divided parts of unicast slots where first slot is $s_1 to s_{2t}$ and second part is considered from $s_{2t+1} to s_{4t}$. These two parts are designated as upstream and downstream part for communication. Upstream part is used for communicating with upstream nodes and downstream parts are used for communicating with downstream communication nodes.

Since, the unicast frame is designed and categorized into two slots which represents the upstream and downstream communication. In order to generalize the data transmitting and receiving patterns, we introduce two term which are called as transmitting first and receiving first. A pictorial representation of transmitting first or receiving first is depicted in figure 4.8.
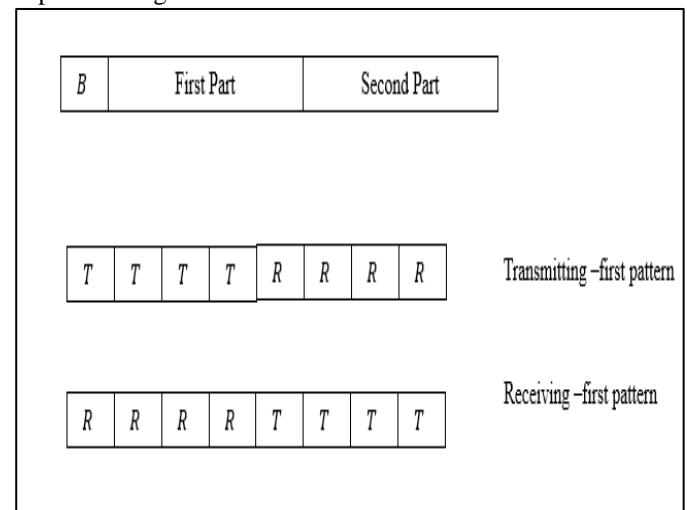
Figure 1.3 The TF and RF patterns

In figure1.3 in a TF pattern, first half is considered as a transmitting slot and remaining second half is considered as a receiving slots. In contrast to this, in RF pattern, first half are considered as receiving slots and second half are known as transmitting slots. By considering this assumption we obtain four patterns which are known as: TF-TF, RF-RF, TF-RF and RF-F. Ratio of transmitting slots and receiving slots can be tuned dynamically.

- **Dynamic tuning of transmission or receiving patterns during communication:** Thesuper frame has two streams which are known as upstream and downstream communication. Ratio of transmitting and receiving slots is denoted by $\frac{T}{R}$ which can be adjusted dynamically during communication. In relay node, traffic amount is equal for both upstream and downstream nodes hence it requires that number of transmitting slots and receiving slots should be equal.

Let T be the number of receiving slots and R be the transmitting slots for downstream part. Since the ratio of T/R

is adjusted dynamically where initially $T = R = t$. Let us assume that transmitting and receiving traffics are denoted as T_{actual} and R_{actual}.

Later, updated weighted averages are, T_{smooth} and R_{smooth} are computed as

$$T_{smooth} \leftarrow \alpha * T_{actual} + (1 - \alpha) * T_{smooth} \quad (4.1)$$

$$R_{smooth} \leftarrow \alpha * R_{actual} + (1 - \alpha) * R_{smooth} \quad (4.2)$$

The values of T and R will be changed slowly by the following rules:

If $(T_{smooth}/T)/(T_{smooth}/T) > Threshold_h$ and $R > 1$
$T \leftarrow T + 1$;
$R \leftarrow R - 1$;
End if
If $(T_{smooth}/T)/(R_{smooth}/R) < Threshold_l$ and $T > 1$
$T \leftarrow T - 1$;
$R \leftarrow R + 1$;End if

Utilization of transmitting and receiving slots is given as T_{smooth}/T and R_{smooth}/R respectively. This utilization ratio is compared with the pre-defined threshold for parameter tuning. If ratio of transmitting t receiving slot is higher than threshold then T is increased by one and R is decreased by 1. In another case where utilization is lower than the threshold then reverse process is performed for parameter tuning.

➢ **Packet Queue modeling:** This model defines the packet queuing technique. During communication, packets arrive continuously so we perform allocation of packets in transmitting slots for further transmission. As presented, proposed approach sends packet into broadcast queue. According to this approach, it is assumed that there are three non-overlapping channels present. In order to transmit the packets, packets are placed in broadcast queue. Similarly, unicast packets also placed in the broadcast queue followed by packet classification as first part and second part of the packets. This queue modeling is carried out with the help of channel and receiver modeling. Number of queue and channel are equal in each part of the communication system. Since we have classified unicast packet in two categories as first part and second part. First part packets are served in a round-robin manner where total slots are considered from $1\ to\ s_{2t}$ and second part slots are considered from s_{2t+1} to s_{4t}

➢ **Slot arrangements:** In above section we have discussed about the queue model of transmitting and receiving slots where transmitting and receiving slots are clustered together. In order to obtain the degree of randomness, permutation is performed among the communicating slots.

1.4   Multi Path Routing

In the next stage, we develop multi-path routing scheme for better communication. Main aim of this work is to develop a routing scheme by constructing two paths to gateways. Finding best path depends on channel information which is provided by link layer part. First of all we describe the node

selection model. Then we present multi-path route discovery mechanism and path section metric. Finally we develop packet scheduling approach to improve the network performance with the help of multi-path routing.

• **Receiving   Channel   selection   process**: During communication, when a node mode is turned on, then it selects any channel as receiving channels. Intermittently, 2-hop neighbors receive broadcast from its corresponding nodes. This can be obtained by transmitting a HELLO message. Here a neighbor table is maintained by each node which contains the information of receiving channels. Another hand, a channel usage table is maintained which contains the count of number of node using each channel.

• **Dual-Path Route Discovery**: In this work, main aim is to achieve two paths for from each node to its gateway. Later we develop an efficient approach for dual path discovery to each gateway. For this purpose, we utilize a gateway request packet which is denoted as $GREQ$. This packet model follows a specific pattern as presented in table 1.1

Table 1.1 Packet model pattern

Field	Initial value considered	Notation
$pathRecord$	$\{S\}$	List of node records in the path
$srcAddr$	S	Source address
$seqNum$	Number of sequence at S	Number of sequences
$hopCount$	∞	Smallest number of hop
$gwAddr$	Unknown	Gateway address

In this work, efficient model is presented for route discovery. According to this model, a gateway request is generated. This request is denoted by GREQ and if this request is generated then it can be concluded that gateway paths are occupied by the communicating node. For this communication, sequence number, address of the data source, gate way address, number of hops and path records are initialized and computed during communication. In the next stage, scheduling mismatch is computed which is caused due similar neighbouring node which are having same transmit first –receive first type of request. Packet forwarding can be estimated with the help of gate way address and hop counts i.e. if the packet is transmitted then the number of gateways decreases. This technique helps to reduce the overhead and rebroadcast the GREQ packet without causing any network congestion.

Initialization of route discovery
    If $gateway\ request(sequence\ number) <$ $R\ (Sequence\ Number[source\ address]$ then
Discard route discover and exit
Else
$R(SequenceNumber)[source\ address]$
            $\leftarrow gateway\ request\ (sequence\ number)$
End if
If
$slot\ schedules\ of\ tranmitre\ and\ recevier\ mismatch\ then$
Discard route discover and exit
If $gateway\ request\ (gateway\ address) \neq unknown$ and $gateway\ request\ (gateway\ address) \neq$ $R(gateway\ address)$ then

Discard route discover and exit
End if
If $gateway\ request(hp\ count) < R.(hope\ count)$ then
Discard route discover and exit
Else   if $gateway\ request\ (hope\ count) = R(hope\ count)$then
If $R \in Gateway\ request(path\ record)$ then
Discard and exit
End if
End if

Send
$gateway\ rquest(\ gateway\ request\ (sequencenumber),$
        $gateway\ request(\ source\ address)$
end

1.5 Simulation results and discussion
Simulation setup

In this section, simulation setup is described to evaluate the performance of proposed approach. This simulation study is carried out using MATLAB simulation tool. In order to carry out the study, we deploy a network topology of 100 static nodes in the network area of 1000mx1000m. This simulation is performed for 800 seconds and simulation data is collected during simulation. In this simulation, 802.11 a/g standards is used as radio type. Broadcast data rate is considered as 54 Mbps with constant bit rate traffic.

The default simulation parameters used are shown in Table 1.2.

**Table 1.2 Simulation parameters**

Parameter	Value
Simulation area	1000x1000 meters
Number of nodes	100
Type of communication radio	802.11 a/g
Used outing protocol	AODV, Integrated Routing and Multipath
Data transmission range	250 meters
Communication Slot size	25 ms
Number of slots in a quarter of link frame	4
Size of tx or rx data packet	512
Weight between perfect and average traffic	0.3
Higher threshold value (to adjust S/R ratio)	3
Lower threshold value (to adjust S/R ratio)	0.6
Path loss model	Tow-ray propagation
Channel Frequency	2.4 GHz

The comparison of AODV, Integrated Routing and proposed approach

Protocol carried out with varying traffic load and slot size *k*.

- **Performance evaluation against number of hops and distance**

In this section, performance is carried out by varying number of communication hops and end-to-end throughput is computed. Constant Bit Rate traffic is considered for packet transmission.
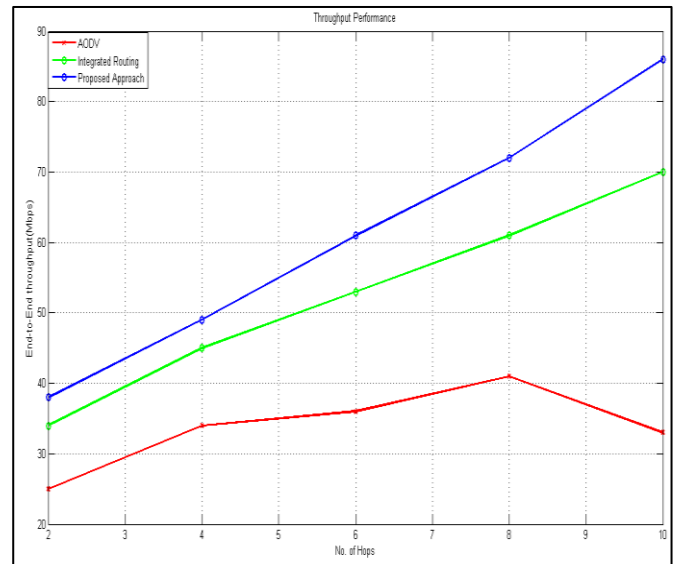
Figure 1.4End-to-End Throughput vs. Number of Hops

In figure1.4, we show a comparative analysis among three protocols named as AODV, integrated routing and proposed approach. For first simulation study, we have considered varied number of hops which are varying from 2 to 10 and end-to-end throughput is computed. As the number of hops are varied, end-to-end throughput also increases but when compared to all protocols the proposed approach achieves better end-to-end throughput.
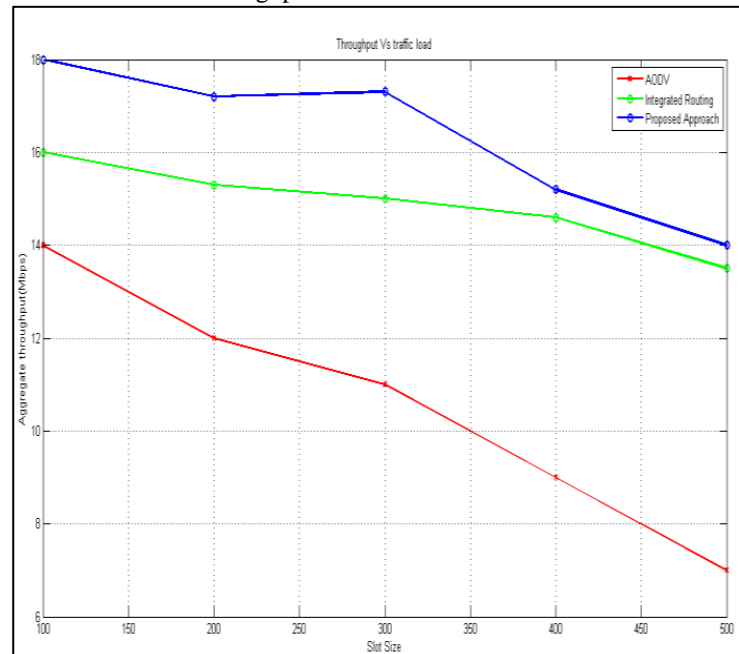

Figure 1.5 End-to-End Throughput vs. Distance to Gateway

The figure1.5 we show the comparative study of three protocols in terms of throughput by considering gateway distance variations. According this study, as the distance from gateway is increasing, the throughput of all three approaches decreases. The overall performance comparison shows that proposed approach outperforms when compared to existing techniques. Maximum throughput achieved by proposed approach, integrated routing and AODV[12 13] is 18 Mbps, 16 Mbps and 14 Mbps respectively.

- **Performance evaluation against different traffic loads**

In another simulation case, we have considered traffic load variation scenario. This traffic is varied from 200 kbps to 1000 kbps and simulation study is carried out. In figure 4.11 we show the comparative analysis of proposed approach and existing AODV, integrated routing protocol.
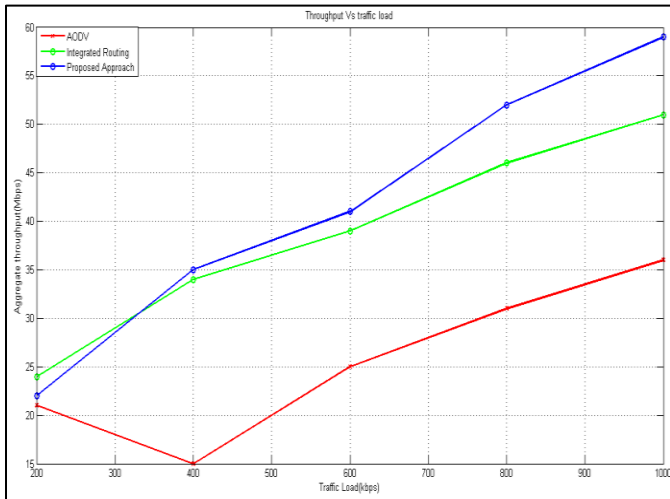
Figure 1.6 Average Throughput vs. Traffic node (in kbps) for 100 nodes

It can be observed in figure 1.6 that initial throughput of AODV and integrated routing is similar to the proposed approach but during simulation when traffic load is increased in terms of kbps then performance variation occurs. In this simulation study, we have reported that proposed approach performs better that other state of art technique and an optimal performance is obtained at 1000 kbps load.
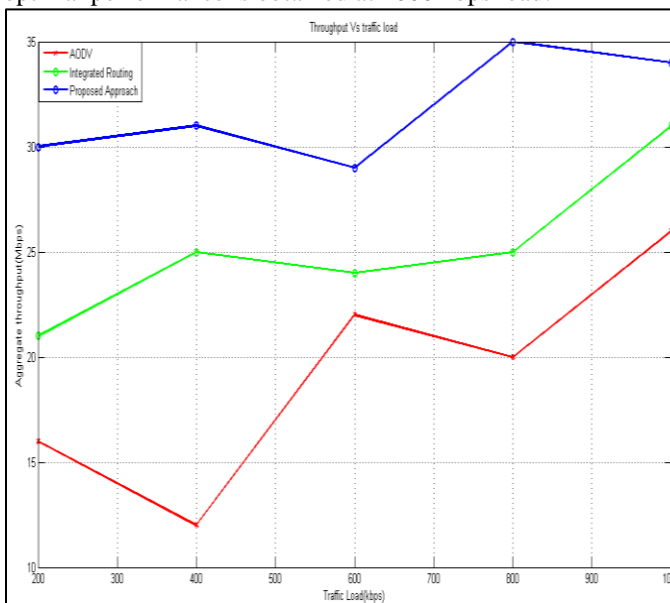

Figure 1.7 Average Throughput vs. Traffic node (in kbps)

The figure1.7 shows that AODV throughput is lesser than other protocols as the distance increases. This is caused due to more contention among multiple paths. Existing protocol, integrated routing gives better performance when compared

with AODV model. Furthermore, the performance is improved using proposed protocol for multichannel multi radio wireless mesh network using multi path routing schemes.

- **Performance evaluation against Slot Size**

In this section we evaluate the performance of proposed approach and compare it with existing techniques for wireless mesh network. This performance is carried out by varying the size of slots. This is measure from gateways to the destination. In this experiment, constant bit rate traffic is assumed and the performance comparison is depicted in figure 1.8.
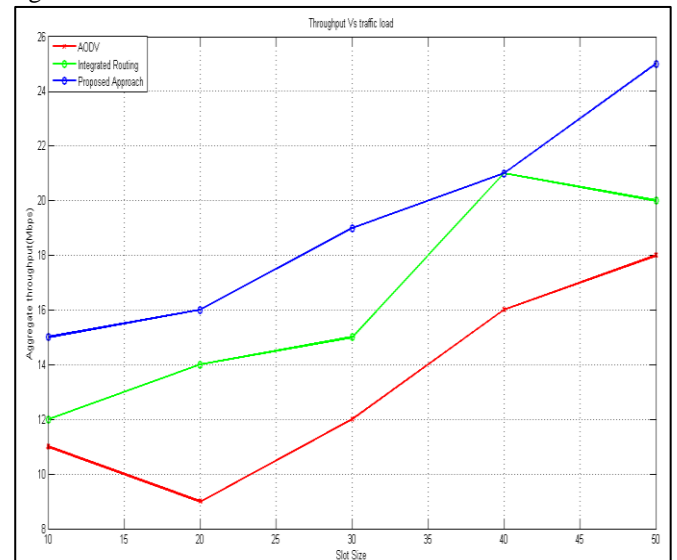
Figure 1.8 Average Throughput vs. slot size for 100 nodes

It can be observed in figure1.8 that proposed approach achieves better performance in terms of average throughput when compared with other existing protocols.

Conclusion

This work shows that multi-channel multi-path routing is an efficient technique and it is capable to improve the network performance in wireless mesh network scenario. Proposed approach uses channel assignment technique for data transmission using multipath model. In this technique a distributed routing technique is proposed which helps to reduce the network overhead. Moreover, it is a combination of link layer and multi-path routing for WMN. Here communication time is divided into multiple slots which are used for slot assignment and route discovery. Further, packet forwarding strategy is developed which is responsible for path discovery and efficient packet transmission in the network. MATLAB is used for experimental analysis and compared with existing AODV and integrated routing schemes. Experimental study shows that proposed approach gives a significant performance in terms of throughput, delay network overhead etc.

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