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Dynamic Channel Allocation Technique for Distributed Multi-radio Multi-channel Multi-path Routing Protocol in Wireless Mesh Networks

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Abstract:Wireless Mesh Networks (WMNs) have gained main attraction in providing flexible network services and support to the end users. There are many efforts seen to design robust routing protocol for WMNs and solutions are proposed to standardized channel allocation techniques. There are various approaches dedicated to maximize the network though put and minimize network interface. Existing multi radio multi channel routing protocols utilize only single channel situation and static channel allocation degrades the performance of the WMNs. The challenge is to allocate channel without link interference and to improve end-to-end throughput efficiency in multipath routing for WMNs. In this paper, we propose a dynamic channel allocation technique is proposed for multi path routing protocol for WMNs. Dynamic channel allocation is used to avoid the inter-flow and intra-flow channel competition and interference. The protocol establishes and maintains multiple channel dimensional disjoint points changing frequently and each data flow is separated into multiple paths. NS2 simulations are carried out for the evaluation of the performance of the proposed channel allocation technique and compared with popular routing protocols of Mesh Networks Ad hoc On Demand Distance Vector Routing Protocol (AODV) and Hybrid Wireless Mesh Protocol (HWMP). The simulation results show that proposed dynamic channel allocation technique achieve better adaptability with less overhead and interference. The multipath routing show increase end-to-end throughput significantly.

Keywords- **Wireless Mesh Networks, Dynamic Channel Allocation, Multipath Routing, AODV and HWMP.**

I. Introduction

Wireless Mesh Networks (WMNs) [1] has become very popular and important in wireless technology and industry fields. WMNs are believed to be a promising technology to offer high bandwidth for wireless access to the Internet. The fixed wireless mesh routers and gateways are highly connected each other in a ad hoc manner in WMN. The normal wireless devices are connected for communication services where mesh routers are equipped with functionalities of IEEE standard series [2]. Mesh router performs the role of data aggregator and also role of relay data gateways. WMN gateways are devices with high bandwidth that can provide internet connections to routers. Data flows can be formed in multi-hop manner from wireless devices through each mesh routers to the gateways, or to other mesh routers and devices in other areas. There are many efforts seen to maximize the network throughput in a multi channel multi radio wireless mesh networks. The approaches of the currently available solutions are based on the static or dynamic channel allocation schemes. Multi-radio wireless mesh networks (MR-WMNs) are being increasingly deployed to provide affordable Internet access on large residential areas. MR-WMNs allow the supported mesh clients (MCs) to access the Internet gateway by multi-hop packet forwarding over the mesh routers (MRs), which can be equipped with multiple radio interfaces [3]. There is a need of hybrid multichannel multi-radio wireless mesh networking architecture where each mesh node has both static and dynamic interfaces.

Multi-channel technique can significantly avoid transmission competition and collision in the same channel. There is no interference among orthogonal channels because they use non overlapping frequency bands. Routing protocols assigning diverse channels to each hop of data flow can reduce intra-flow channel interference and competition therefore can improve end-to-end throughput times. Wireless devices are able to equip more radios which are working in a specified channel. The data is switched and transmitted in specified when radio with antenna is used. This makes transmission full duplex and also provides more efficient routing. Multi-path routing strategies are also designed to split and transmit data through two or more different paths to destination simultaneously. However, multi-path routing cannot achieve times of throughput as we expect since inter-/intra-flow channel competition and interference. Therefore it is required to develop multi-channel and multi-path routing protocol in WMNs.
There are two approaches for channel allocation, static and dynamic approach [4]. Each interface of every mesh router is assigned a channel permanently in case of static channel allocation. An interface is allowed to switch from one channel to another frequently in dynamic channel allocation. Static channel allocation interface does not allow switch the channel and have lower overhead. They completely depend on the stable and predictable traffic patterns in the network. In case of static approach, the required exact traffic profile is known in advance and statistical traffic pattern are assumed. In dynamic approach there is always frequently switching of channel takes place and thus have a higher overhead than static approach. This is approach is more suitable when there is frequent change in network traffic and also traffic is unpredictable. In real time environment, the traffic profile is very complex and

unpredictable. There is a large amount of traffic from end-users to Internet through gateways takes place. This traffic contains considerable amount of unpredictable peer-to-peer traffic between end-users due to the emerging new applications within the community. The rigid inflexibility of static channel allocation and high overhead problem of dynamic channel allocation, there is a need to developing hybrid dynamic channel allocation for distributed dynamic multi-radio multi-channel multi-path routing protocol in Wireless Mesh Networks.

The rest of this paper is organized as follows: In Section II we shall give a brief background and motivation of our work and also describes the different routing protocol strategies along with different paths and channel used in WMNs. In section III we discuss related work carried out in this area. The Dynamic Channel Allocation Technique in explained in Section IV. In Section V Multipath Routing Protocol is explained in detail. Section VI is the part of simulations showing evaluation of our proposal. Conclusion and future work will be mentioned in Section VII.

II. Background and Motivation

The motivation of this work is mainly due to multichannel, multi-radio and multipath routing protocol to be developed for WMNs and which allocates channel dynamically. This improves flow end-to-end through put in WMNs and reduces interference and has less overhead due multichannel. There are four routing strategies considering number of radios and paths for WMNs: SRSP (Singe Radio Single Path), MRSP (Multi Radio Single Path), SRMP (Single Radio Multiple Path) and MRMP (Multi Radio Multi Path).

SRSP is simple common method which uses single radio and single path. Dynamic Source Routing (DSR) [5] and Ad hoc On demand Distance Vector (AODV) [6] routing uses SRSP strategy. Here packets travel along the chain of nodes towards their destination and all nodes are working with one radio in the same channel. Due to single chain, there are chances of collision and channel competition in the MAC layer. MRSP was proposed by some researchers to adopted multichannel and multi-radio for receiving and sending data in different channels simultaneously [7][8] and [9]. Here MAC protocol can always select appropriate radio and schedule perfectly. At the same slot, node can transmit packet on one channel and receive packet from another node on another channel. If there are enough radio resources for MAC protocol, all nodes can continuously transmit one packet every time slot.

In SRMP packets are split into two or more disjoints to destinations and there are two paths which performs same as the SRSP. SMR [10] routing and AOMDV [11] routing uses SRMP strategy. Here throughput will be doubled and at the same time interference problem degrades the throughput significantly. Since all nodes are working on the same channel, mainly source and destination nodes get more disturbed due to single channel. Here we can find improvement in end-to-end throughput. In MRMP scenario, the ideal MAC end-to-end throughput can be as high as the effective MAC data rate multiplying the number of paths. The routing protocol can split data flow properly and radios used in transmission are enough and well assigned by the MAC protocol. This improves flow end-to-end through put in WMNs and proposed in [3].

Wireless Mesh Networks face major problem due to wireless interference and there is also capacity and throughput reduction. There is also major challenge in allocation of channels to interfaces to mesh routers. The dynamic channel allocation strategy has higher overhead but more suitable for unpredictable network traffic which changes frequently. The static channel allocation strategy has less overhead and does not support for unpredictable network traffic. This leads to develop suitable channel allocation strategy for multipath multichannel Wireless Mesh Networks.

Related Work

In [12] one potential solution is proposed so that transceivers can utilize multiple channels dynamically. Authors exploit the benefit of multi-path routing in multi-channel WMNs from the aspect of end-to-end throughput. Between medium access control and network layers, they have proposed novel protocol named Joint Multi-channel and Multi-path control (JMM) which combines multi-channel link layer with multi-path routing. Dividing time into slots, JMM coordinates channel usage among slots and schedules traffic flows on dual paths. This scheme efficiently and intelligently decomposes contending traffics over different channels, different time, and different paths, and hence leads to significant throughput improvement. Here they have not considered the overhead and interference issues.

In [13] a network model is proposed for multiple orthogonal channels and nodes with the ability to simultaneously communicate with many neighbors using multiple radios (interfaces) over orthogonal channels. Here network model is developed which captures the key practical aspects of such systems and characterize the constraints binding their behavior. Authors have provided necessary conditions to verify the feasibility of rate vectors in these networks, and use them to derive upper bounds on the capacity in terms of achievable throughput, using a fast primal-dual algorithm. They have developed two link channel assignment schemes, one static and the other dynamic, in order to derive lower bounds on the achievable throughput. Authors claim that the dynamic link channel assignment scheme performs close to optimal on the average, while the static link channel assignment algorithm also performs very well. This is not acceptable in all cases.

Authors had presented distributed channel assignment and routing protocol that achieves good multi-path performance between every node and one or more designated gateway nodes in a dual-radio network called ROMA [14]. ROMA assigns non overlapping channels to links along each gateway path to eliminate intra-path interference. ROMA reduces inter-path interference by assigning different channels to paths destined for different gateways whenever possible. Evaluations on a 24-node dual-radio test bed show that ROMA achieves high throughput in a variety of scenarios.

In [15] interference-aware topology control and QoS routing in IEEE 802.11-based multi-channel wireless mesh networks with dynamic traffic was developed. Here it was based on the concept of effective heuristic for the minimum Interference Survivable Topology Control (INSTC) problem which seeks a channel assignment for the given network such that the induced network topology is interference-minimum among all *K*-connected topologies. Authors present a polynomial time optimal algorithm to solve the BAR problem under the assumption that traffic demands are splittable and claim that their scheme improves the system performance by 57% on average in terms of connection blocking ratio.

In [16] authors propose and evaluate one of the first multi-channel multi-hop wireless ad-hoc network architectures that can be built using standard 802.11 hardware by equipping each node with multiple network interface cards (NICs) operating on different channels. Idea of exploiting multiple channels is particularly appealing in wireless mesh networks because of their high capacity requirements to support backbone traffic. They developed a set of centralized channel assignment, bandwidth allocation, and routing algorithms for multi-channel wireless mesh networks.

III. Proposed Dynamic Channel Allocation Technique

The dynamic channel allocation technique is proposed at link layer of the network protocol stack. The link layer covers two functionalities such as channel scheduling and packet scheduling. The channel scheduling is connected with selection of the channel on which transceiver tied up on. The packet scheduling is linked with when the packet can be sent.

Definitions:

The frame with *k* fixed slots on the time axis is referred to as *linkframe*. The slots are designated as *sending slot (S)* or *receiving slot (R)*. The channel allocation is based on received-based. The structure of *linkframe* is shown in the figure 1.

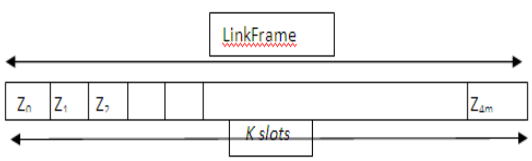

Figure 1. Frame Structure of Link Frame

Each *linkframe* consists of *4m+1* slots, named as z_0, z_1, z_2….., z_{m+1} where m is an integer. Here slot z_0 is reserved for *broadcast slot* where only beacons and broadcast messages are sent. Further broadcast slot has *beacon window* and *information window*. Mainly beacons are used to serve for synchronizing the node's clock. It is also used to ensure network connectivity and make sure that all nodes are on a pre-defined common channel in the slot z_0. The remaining 4m slots are known as dynamic slots where channels are allocated dynamically.

Operation:

The receiver-based channel assignment allows to two nodes to change the same channel for communication. The dynamic slots are organized into sending/receiving slots. When a node selects *receiving channel* for receiving slots, nodes nearby will try to avoid using the same *receiving channel* there by avoids collision.

In case of sending slot, a node can change its receiver's receiving channel and will stay on that channel until the end of the slot. Thus, any two nodes can communicate only if one node is in a sending slot and other is on receiving slot. When a new channel is selected, node first remains idle for a duration which is equal to the maximum packet transmission time. This avoids the multichannel hidden terminal problem which is due to improper time synchronization.

Traffic on mesh networks are considered to be stable and slot assignment will not change so frequently. This helps us in assigning dynamic slots of a linkframe as sending/receiving slots. We can divide the dynamic slots z_1 to z_{4m} into two parts, first part from z_1 to z_{2m} (upstream) and second part from z_{2m+1} to z_{4m} (downstream). The lengths of these two parts are same as we assume node is a relay node.

To calculate the ratio *S/R* of the number of sending slots *S* to the number of receiving slots *R* which can be adjusted dynamically, the two parts are considered as *Sending First (SF) sequence* and *Receiving First (RF) sequence.* The first half is all sending slots and second half is all receiving slots. With this, we can have four types of linkframe patterns, namely SF-ST, RF-RF, SF-RF and RF-SF types.

Channel Allocation Algorithm

1. *Let S be the number of sending slots and R be the number of receiving slots.*
2. *Initialize S = R = m*
3. *Assume $S_{perfect}$ and $R_{perfect}$ are sending and receiving exact traffic on the upstream part respectively*
4. *Compute new weighted average values S_{avg} and R_{avg} :*
   $S_{avg} = \delta * S_{perfect} + (1 - \delta) * S_{avg}$
   $R_{avg} = \delta * R_{perfect} + (1 - \delta) * R_{avg}$
5. *Now, the value of S and R can be slowly changed using the following condition:*
   If $(S_{avg} / S) \ / (R_{avg} / R) > T_h$ and R > 1 the S = S+1; R = S-1;
   If $(S_{avg} / S) \ / (R_{avg} / R) < T_n$ and T > 1 the S = S - 1; R = R+1;
   Where T_h and T_n are Threshold values for utilization ratio of transmitting to receiving slots.

(If the utilization ratio of transmitting to receiving slots is higher than a threshold T_h then S is increased by 1 and R is decreased by 1 and if utilization ratio of transmitting to receiving slots is higher than a threshold T_n then reverse calculation is performed. This allocates the channel dynamically)

IV. Multipath Routing Protocol

Before describing the proposed multipath routing protocol, we present two important routing protocols of mesh networks AODV and HWMP which are used for performance study.

A. Ad hoc On Demand Distance Vector Routing Protocol (AODV)

This protocol performs Route Discovery using control messages route request (RREQ) and route reply (RREP) whenever a node wishes to send packets to destination. To control network wide broadcasts of RREQs, the source node uses an *expanding* ring search technique. The forward path sets up an intermediate node in its route table with a lifetime association RREP. When either destination or intermediate node using moves, a route error (RERR) is sent to the affected source node. When source node receives the (RERR), it can reinitiate route if the route is still needed. Neighborhood information is obtained from broadcast Hello packet.

As AODV protocol is a flat routing protocol it does not need any central administrative system to handle the routing process. AODV tends to reduce the control traffic messages overhead at the cost of increased latency in finding new routes. The AODV has great advantage in having less overhead over simple protocols which need to keep the entire route from the source host to the destination host in their messages. The RREQ and RREP messages, which are responsible for the route discovery, do not increase significantly the overhead from these control messages. AODV reacts relatively quickly to the topological changes in the network and updating only the hosts that may be affected by the change, using the RRER message. The Hello messages, which are responsible for the route maintenance, are also limited so that they do not create unnecessary overhead in the network. The AODV protocol is a loop free and avoids the counting to infinity problem, which were typical to the classical distance vector routing protocols, by the usage of the sequence numbers.

B. Hybrid Wireless Mesh Protocol (HWMP)

This protocol has the flexibility of combining the on demand and proactive features and work well with any kind of topology. HWMP routing protocol make use of AODV for on demand protocol primitives and destination sequence distance vector DSDV [10] for proactive protocol primitives. This protocol is used as default routing protocol in IEEE 802.11s in MAC layer. The path selection is done in IEEE 802.11s using air time link metric which is also a default link metric [16]. Routing metric airtime is radio aware metric which can measure the amount of channel resource consumed when a frame is transmitted over a wireless link. There are four control messages are specified in HWMP which are the root announcement (RANN), path request (PREQ), path reply (PREP) and path error (PERR). It also contains three important fields such as destination sequence number (DSN), time-to-live (TTL), and metric except for PERR. The count to infinity problem is prevented using DSN and TTL and the metric field helps to find a better routing path than just using hop count.

As in case of AODV reactive routing mode, the process of broadcasting of route request packet is similar to PREQ broadcast by source Mesh Point (MP) to a destination MP. Thus, the received PREQ packets are newer or better path to the source, MP will again broadcast the updated PREQ. The destination MP in turn will reply back with PREP. During forwarding the control packets PREQ, in case if intermediate MP has no path to destination MP, it just forwards the PREQ element. The few mesh points in WMN will receive the large proportion of the traffic which is destined and offers access to a wired infrastructure and the Internet. A proactive tree based routing mode will be useful in building the same distance vector methodology as used in Radiometric AODV (RM-AODV) and the root node will periodically broadcasts a PREQ element in case of proactive mechanism. An MP in the network receiving the PREQ creates/updates the path to the root, records the metric and hops count to the root, updates the PREQ with such information, and then forwards PREQ. Thus, the presence of the root and the distance vector to the root can be disseminated to all MPs in the mesh. In the proactive RANN mechanism, the root node periodically floods an RANN element into the network. When an MP receives the RANN and also needs to create/refresh a route to the root, it sends a unicast PREQ to the root. When the root receives this unicast PREQ, it replies with a PREP to the MP. Thus, the unicast PREQ forms the reverse route from the root to the originating MP, while the unicast PREP creates the forward route from the originating MP to the root.

C. Multipath Routing Protocol

The multipath routing protocol constructs multiple paths to the user node to the gateway. In this developed protocol three paths to gateway is discovered. To find the best three paths requires channel information which is provided by the link layer. Node broadcasts its receiving channel through HELLO Message to 2 hop-neighbors. Each node maintains two tables: *NeighborTable* for receiving channels of 2-hop neighbors and *ChannelUsageTable* to count the number of nodes using each channel. A node will choose the least used channel as its receiving channel. To prevent unnecessary fluctuation, when a node finds a better channel than its current receiving channel, it will only switch to that channel with a probability *p*.

It is required to find from each node three paths to its gateway that is as disjoint as possible. Network-wide flooding of route search packets needs to be avoided and at the same time it is not fair to discard many route search packets being discarded. An efficient route discovery strategy to find multiple path to each gateway in network is proposed. RREQ_GW (Gateway RREQ) packet is flooded into the network with limited rebroadcast. RREQ_GW consists of sequence number, source address, gateway address of the mesh network, hop count and list of nodes records on the path. The route discovery is performed in an incremental way. When a node issues a RREQ_GW, it is assumed that each existing node has already established three paths to its gateway. The multipath routing algorithm is listed below:

Multipath Routing Algorithm

Start

If RREQ_GW sequence number < non gateway node R sequence number then discard and exit

Else assign RREQ_GW sequence number R to non gateway node sequence number S

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If the slot schedules of non gateway node and node S mismatch then

discard and exit

if RREQ_GW gateway address is not known and RREQ_GW gateway address is not equal to non gateway node R address then discard and exit

if RREQ_SW hop count < non gateway node R hop count then check whether non gateway node belongs to RREQ_GW path record then discard and exit

***send** RREQ_GW with its (sequence number, source address, non gateway address, hop count and path record)*

End

This forwarding strategy can significantly reduce the rebroadcast overhead while traversing most wireless links. Finally, the node rebroadcasts the *RREQ_GW* packets

V. Simulation Environment

The performance of different routing protocols in WMN environment is simulated using Qualnet 5.2 [18]. The simulation software Qualnet 5.2 is software that provides scalable simulations of wireless networks. The network topology of 100 static node are created and placed randomly within area of 1000 m x 1000 m. Each scenario simulation is ran over for 800 seconds and data collected over those runs are averaged. The 802.11 a/g is used as radio type and 802.11a standard as MAC protocol without using RTS/CTS. The broadcast data rate in this simulation is 54 Mbps with Constant Bit Rate (CBR) traffic source, sending at a rate of 1 packet per seconds. The packets with 512 bytes size is scheduled on a first in first out (FIFO) basis [17]. A constant shadowing model with two-ray propagation path loss model is used in this simulation. The default simulation parameters used are shown in Table I.

TABLE 1: Simulation Parameters

Parameter	Value
Simulation area	1000 x 1000 meter
No of Nodes	100
Radio Type	802.11 a/g
Routing Protocol	AODV, HWMP and Multipath
Transmission range	250 meters
Slot size *K*	25 ms
Number of Slots in a quarter of linkframe	4
Data packet size	512 bytes
Weight between perfect and avg traffic δ	0.3
High Threshold T_h adjusting S/R ratio	3
Low Threshold T_n adjusting S/R ratio	0.6
Path Loss model	Two-ray propagation
Channel Frequency	2.4 GHz

VI. Results and Discussions

The comparison of AODV, HWMP and Multipath Routing Protocol carried out with varying traffic load and slot size *k*.

A. Performance evaluation against number of hops and distance

The performances of routing protocols are evaluated with varying number of hops from the gateway to the destination and observe the end-to-end throughput. The CBR traffic is continuously sent from gateway to the destination. The results are shown in Fig. 2(a) and 2(b).

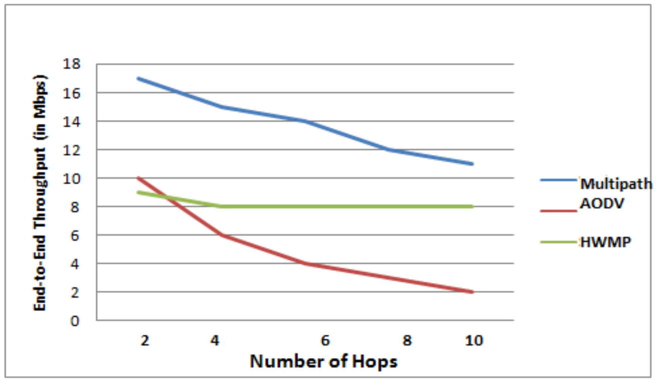

Figure 2 (a) End-to-End Throughput vs. Number of Hops

It can be observed that AODV throughput decrease dramatically as the number of hops increases. HWMP routing is found to be slightly better than AODV since it is designed to withstand the scalability for Mesh Networks. Over a period of time it is found to be constant. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput. The throughput of Multichannel and Multipath Routing is almost 40% more than HWMP and 70% higher than that of AODV.

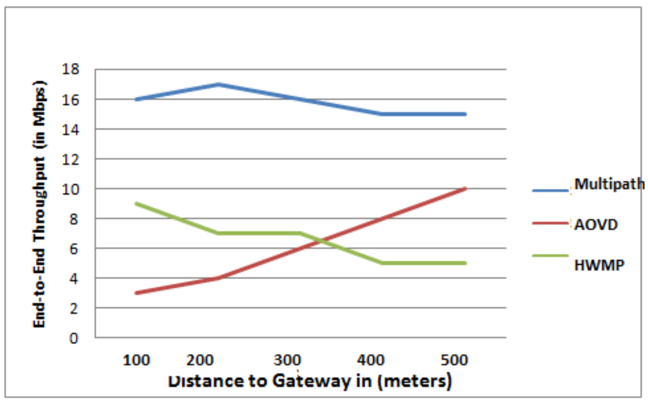

Figure 2 (b) End-to-End Throughput vs. Distance to Gateway

The figure 2 (b) shows that AODV throughput decrease dramatically as the distance increases. This is due to higher and higher contention between the three paths. HWMP routing is found to be slightly better than AODV since it is designed to withstand the scalability for Mesh Networks. Over a period of time it is found to be constant. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput. The packets are distributed to three parallel paths on which the transmissions are well interleaved. The throughput of Multichannel and Multipath Routing is almost 55% more than HWMP and 70% higher than that of AODV.

B. Performance evaluation against different traffic loads

The performances of routing protocols are evaluated against varying traffic loads from the gateway to the destination and observe the aggregate throughput. The CBR traffic is continuously sent from gateway to the destination. The results are shown in Fig. 3(a) and 3(b).

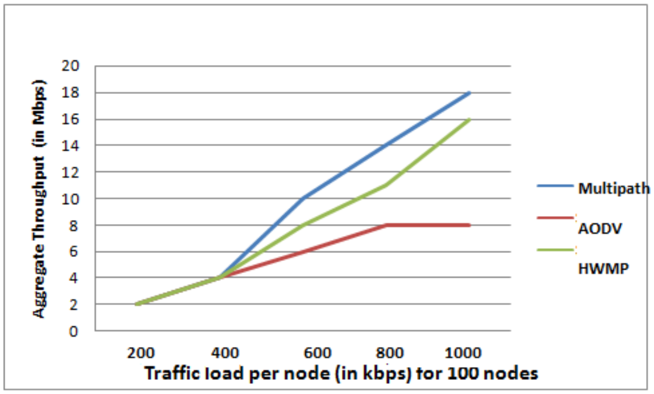

Figure 3 (a) Average Throughput vs. Traffic node (in kbps) for 100 nodes

It can be observed in figure 3 (a) that AODV throughput decrease dramatically as the number of hops increases. HWMP routing is found to be slightly better than AODV since it is designed to withstand the scalability for Mesh Networks. Over a period of time it is found to be constant. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput. The throughput of Multichannel and Multipath Routing is almost 50% more than HWMP and 80% higher than that of AODV depending on the traffic load.

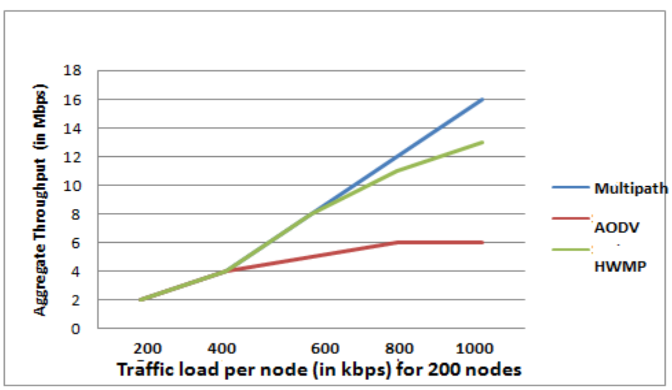

Figure 3 (b) Average Throughput vs. Traffic node (in kbps) for 200 nodes

The figure 3 (b) shows that AODV throughput decrease dramatically as the distance increases. This is due to higher and higher contention between the three paths. HWMP routing is found to be slightly better than AODV since it is designed to withstand the scalability for Mesh Networks. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput of 16 Mbps. The packets are distributed to three parallel paths on which the transmissions are well interleaved. The throughput of Multichannel and Multipath Routing is almost 20 % more than HWMP and 60% higher than that of AODV. Multipath Routing Protocol adds up with the overheads of broadcast slots and channel switching latency.

C. Performance evaluation against Slot Size

The performances of routing protocols are evaluated with varying slot size from the gateway to the destination and observe the aggregate throughput. The CBR traffic is continuously sent from gateway to the destination. The results are shown in Fig. 4(a) and 4(b).

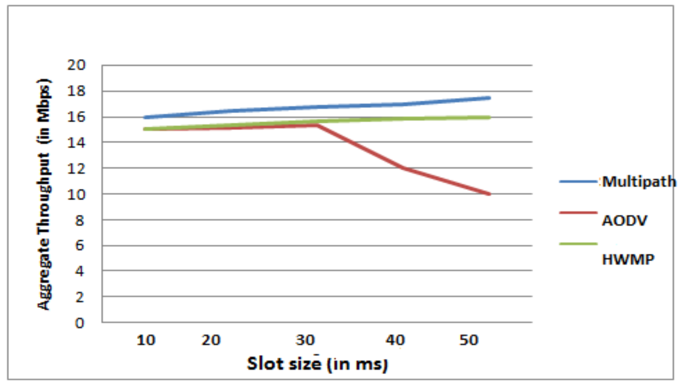

Figure 4 (a) Average Throughput vs. slot size for 100 nodes

It can be observed in figure 4 (a) that AODV throughput decrease dramatically as the slot size increases. Longer *k* may result in increased end to end delay as well as buffer requirement at each node. HWMP routing is found to be better than AODV since it is designed to have less overhead and more suitable for Mesh Networks. Over a period of time it is found to be constant. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput. The throughput of Multichannel and Multipath Routing is almost 10% more than HWMP and 60% higher than that of AODV. If the length k is too short, the channel switching overhead becomes considerable ad degrades the performance of the system.

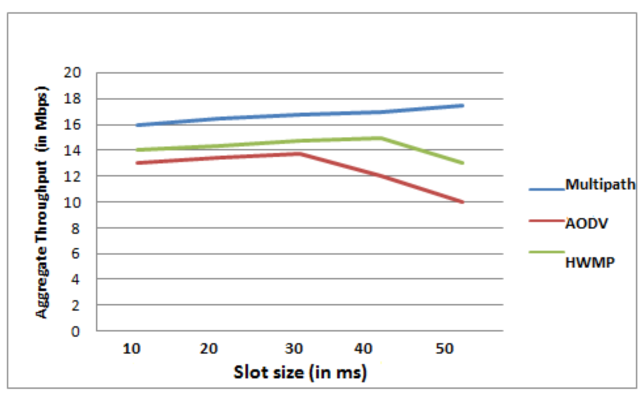

Figure 4 (b) Average Throughput vs. Traffic node (in kbps) for 200 nodes

The figure 4 (a) shows AODV throughput decreases dramatically as the slot size increases. Longer *k* may result in increased end to end delay as well as buffer requirement at each node. HWMP routing is found to be better for 40 ms and starts degrading like AODV, since it is designed to have less overhead and more suitable for Mesh Networks. There is a clear advantage of Multichannel Multipath Routing that there are which three paths which do not interference and also there is high throughput. The throughput of Multichannel and Multipath Routing is almost 10 % more than HWMP and 40% higher than that of AODV. If the length *k* is too short, the channel switching overhead becomes considerable ad degrades the performance of the system.

VII. Conclusion

In this paper, it clearly shows that multichannel multipath routing has great potential to achieve good performance for Wireless Mesh Networks. The protocol can dynamically establish multiple paths with diverse channel assignment, which are topology-dimensional and channel-dimensional disjoint for data transmission, and the routing initialization works in a distributed manner. The design combines the benefits of multi-channel link layer and multi-path routing for Wireless Mesh Networks. Dividing the time into slots, protocol coordinates channel usage among slots using a receiver-based channel assignment and schedules transmissions along three paths. In the route discovery phase of RREQ_GW forwarding strategy to reduce broadcast overhead is proposed. QualNet 5.2 simulations are carried out to evaluate the proposed protocol compared with other routing protocol: AODV and HWMP. Multichannel and Multipath Routing protocol can make significant enhancement on achievable throughput in WMNs if the network is initially idle, and it performs still better than AODV and HWMP in scenarios where there is also other concurrent ongoing flow. The simulation results show that Multichannel and Multipath routing protocol yields a significant end-to-end throughput improvement in WMNs as compared to single channel and multipath scenarios. The protocol efficiently increases the performance by decomposing contending traffic over different channels, different time, and different paths with high throughput and less interference.

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