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THROUGHPUT OPTIMIZATION FOR CONGESTION AVOIDANCE IN WIRELESS MESH NETWORK

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ABSTRACT

Wireless Mesh Network (WMN), is a upcoming promising technology, that is continuing to boom because of its various advantages like low deployment cost, scalability, efficiency, characteristics of each node being to function as a router, etc.. But there are many challenges that are not addressed, which includes congestion prevention and avoidance. Congestion in any network will or may result in packet loss, delay in queuing, blocking of new connections and resulting in reduced Quality of service. In this paper, a novel Congestion Notification Algorithm is proposed, that will notify the occurrence of congestion and therefore help in avoiding a congested network. Once the congestion is notified, technique for preventing and avoiding congestion is also suggested. Performance evaluation is done based on the metrics to prove the efficiency of the proposed work.

Keywords: wireless mesh networks (WMN), congestion, throughtput, qos.

INTRODUCTION

When early wireless networks like 802.11 (WLAN), to mediate a wireless connection, needed a central access point, which would usually be a wireless router, WMN enabled each node to directly communicate with its adjacent nodes. Along with it, each node can operate as a node or as a router and can forward packet in place of routers, whose destination may not be within the direct wireless transmission range. WMN constitutes of three important components, namely, mesh client-which could be any node, mesh router-helps to route packets from source node to destination node, and mesh Gateway-to enable the whole network to request and receive data from the internet. For practical use, heterogeneous WMN is to be taken in to consideration, as the communication could be between devices with various specifications or between networks. To enable routing of packets between any two nodes, Wireless Access Points (AP) is used. AP's could be Client APs (to which many client nodes are connected), any mesh node or even an Internet Gateway.

WMN is spoken for its advantages like being less expensive, highly adaptable and scalable, able to support high demand, self-organized, self healing etc. These properties enable WMN to widely cater variety of needs, from communication needs in tough environments like battlefield surveillance, emergency situation, tunnels, to VoIP. By using QoS scheme, the WMN can support local phone calls to be routed through the mesh [1]. Although WMN has an edge over other technology, it comes with its own challenges. One of the major challenges is to overcome congestion in WMN. Congestion is a state in network where a link or a node in the network carries more than the specified limit, thereby deteriorating the QoS. In other words, congestion eventuates when there is an insufficient bandwidth and data traffic in network exceeds capacity [2]. This may result in queuing delay, packet or frame loss. It also results in reduced response time and degradation of network throughput. There are two prominent techniques for congestion avoidance they are Implicit Congestion Signaling (ICS) and Explicit Congestion Signaling (ECS) [3]. In ICS, with the increase in congestion, the transmission delay also increases. The packets are discarded. These implicit indications of congestion are detected by the source. It is useful for connection less networks. In ECS, the end systems are alerted by the network about the increasing congestion. Steps to reduce the offered load are taken by the end system. There are many techniques adopted and deployed in order to avoid congestion in WMN. Drop Tail Algorithm in which if the buffer queue is full, it will drop the packets from the tail [4]. (ii)Random Early detection algorithm wherein a metric called Exponential Weighted Moving Average (EWMA) is used to calculate the average queue size, on the arrival of each packet. The EWMA is compared with the minimum and maximum threshold to make next decision [5]. (iii) CHOKe Algorithm, where, whenever a new packet arrives at congested gateway router, from FIFO buffer, a packet is randomly drawn. The drawn packet and the arriving packet are compared. In the network, if they belong to the same flow, they are dropped. Else, the randomly chosen packet is kept integral and the new packet is put into the buffer with a probability that directly depends on the level of congestion [6]. (iv) Random Exponential Marking Algorithm that gives high utilization of link capacity [7]. (v) Fair Queuing Algorithm, wherein, because of its fairness and delay bounding in the flow, it is used for multimedia integrated services. Weighted Round Robin is a frame based class of Fair Queue, where router queue works in the round robin fashion [8]. (vi) Virtual Queuing Algorithm, which is a radical technique where virtual queue maintains the arrival rate as the real queue. Virtual queue's capacity is lesser as compared with the real queue. When the virtual queue becomes full, the packets present in the real queue and the incoming queue are marked, until the real queue becomes empty [9]. Network congestion avoidance is to predict network congestion and to reduce the data rate of the source. Some of the techniques for congestion avoidance

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include DEC bit, which could be applied both for TCP and IP [10]. The responsibility of congestion avoidance is equally split to both router and the end nodes. Each router monitors its load and notifies explicitly to the end nodes about the probable occurrence of congestion. For notifying, in every packet that flows through the router, the binary congestion bit is set. The congestion bit is copied in the ACK by the destination host and is sent back to the source. This enables the source to adjust the rate of sending to avoid congestion. Random Early Detection in which all the routers are programmed and they monitor their own queue length. When it detects the probability of congestion, it notifies about the congestion to the source for it to adjust the congestion window. Source based congestion Avoidance where, as in TCP, the congestion window increases. For every two round trip delays, the algorithm checks to find if the present Round Trip Time (RTT) is greater than the average of the maximum and the minimum RTTs measured so far. If yes, then the congestion window is decreased by one-eight of its original size. There are many factors that influence congestion [11]. Some of which include, insufficient memory, fixed memory, slow processor, low bandwidth etc. Congestion in WMN can occur between nodes, that is, in links, at routers and gateways. Bottle necks are usually encountered in the gateway nodes. As the usage of internet is ever increasing, the data being transmitted to and from the gateways is enormous. The concurrent requests put forth and increasing number of requests leads to congestion therefore degrading the quality of the network. Security of the data should also be taken into consideration [12]. Hence it necessitates having an effective congestion avoidance mechanism for improved performance. In this paper, a novel explicit congestion notification algorithm is proposed in order to avoid congestion in the network, especially in the gateway node.

This paper is organized as follows. Second section deals with some of the important related work carried out to prevent or control congestion. In third section, a detailed description about the Explicit Congestion Notification Algorithm is described. In the fourth section, the proposed algorithm to avoid congestion is described in details. The obtained result is compared with existing Load Balancing Adaptive Scheduling with Minimum Packet Loss LBASMPL [13] in order to show the better performance of the proposed technique.

RELATED WORK

Congestion primarily occurs because of the following two factors:

Congestion because of Load Imbalance in the Network

Kruti N Kapadia and Dayanand (2015) have proposed a routing metric called Airtime Congestion Aware Metric, which is defined as the quantity of channel resources used by the frame transmitted over a particular link, with an improved load balancing technique. This enables transmission of node on an optimal path and thereby improves the efficiency of the network. The proposed metric ACA is better than the conventional Expected Transition Time (ETT) as it is able to support multiple radio nodes. This metric monitors the medium usage and thereby obtains the link quality. For load balancing, the metric uses Round Trip Time (RTT) which is got by sending a unicast message to the neighboring nodes. The neighboring nodes acknowledge. If the RTT goes high, it is understood that the network is imbalanced and is causing congestion. Queue utilization is computed for multiple interfaces to bypass heavily loaded nodes [14].

Awadallah Mohammed Ahmed Ali (2016), in his Thesis suggests that, one of the most important issue in WMN is unbalanced network. It is further stated that the optimal placement of the mesh router and gateways is very crucial for having a balanced network and to achieve this is very challenging. For instance, if the router is far away from the gateway, the packet has to take multiple hops to reach the gateway. There is a higher chance of timeouts and therefore packet drops, leading to less throughput. Moreover, the router close to the gateway will be given more priority than the farther one leading to starvation. So the Gateway Placement problem required a near optimal solution. The solution is obtained using Genetic Algorithm, Simulated Annealing and Particle Swarm Optimization techniques [15].

Huyao Da-Nhuong Le *et al* (2013) have proposed that for increased throughput in WMN, the gateway placement optimization is mandatory and is very challenging. A novel algorithm contingent on Ant Colony Optimization (ACO) is proposed for optimal placement of gateway. ACO algorithm is generated from the behavior of ant in searching of food based on pheromone. The gateway locations are randomly and independently generated by calculating the probability. Then the ant's pheromone value is chosen to navigate from 'i' which denotes the present gateway to 'j' which denotes the next client. The pheromone values are continuously updated by the ants that reach the optimal solution by reaching the destination successfully [16].

Juan J Galvez and Pedro (2013) have suggested a fast heuristic algorithm JRCAR for efficient Rate Allocation, joint routing and Channel Assignment that works with dynamic traffic flow. In order to implement the work, many routers along with one or more gateways are taken into consideration, wherein the gateway provides access to the internet. With the ever growing use of the internet, most of the traffic exists and is exchanged between mesh routers, gateways and the internet. To get right balance between the fairness and efficiency, the use of proportional fairness metric is proposed. In their proposed work, the prior knowledge of the network is not taken into consideration. Rather, the constantly changing channel allocation, rate allocation and the set of routes is captured using the proposed heuristic algorithm that is aimed to be implemented in the centralized controller [17].

Congestion caused due to queueing delay and packet loss

Payal Grover *et al* (2015) have suggested that one of the major cause of congestion is packet loss. This leads

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to retransmission of data leaving the network congested. In their work, multiple pairs of source and destination for sending and receiving of data are considered at the same time. RREQ message is broadcasted to all its neighboring nodes to establish the route. The node that has the path to the destination sends a unicast RREP message back to the source node through the intermediate node, thereby creating a path from the destination to the source. The packets are routed and the availability of buffer in each intermediate node is checked to ensure that it is less than the threshold value. If it is greater, number of packets, in the buffer, number of packets for a particular destination is checked. If the number of packets is equal or greater than the threshold, an alternate path is considered for transmission else the same route is chosen for transmission [18].

Sanjay Kumar Dhurandher et al, have suggested that in order to guarantee QoS for multimedia services, Admission Control is considered to be the most promising technique. It is so because, it is a key management function wherein, only if the QoS necessities of all the existing flows in the network are met, a new flow is admitted. A Rate Adaptive Routing Cliques Admission Control protocol (RA-RCAC) which gives message to the application layer anytime congestion happens in the network, is proposed. The design feature of RA-RCAC is a combination of Interface Aware Routing Control (IAAC) and Distributed Admission Control Protocol (RCAC) [19].

Maheen Islam *et al* (2014) have said that channel tends to get saturated due to variation in traffic. Also, factors like buffer overflow and concurrent transmissions may stir up congestion. A distributive congestion control scheme is proposed by the authors that would avoid congestion and the inter-flow fairness, where there is a coexistence of non-real time and real time traffic, would be maintained. Congestion is handled by narrowing the available rate of transmission of the downstream nodes, based on the basic three parameters, buffer occupancy, packet arrival rate and service rate. In order to treat the non-real time and real time traffic differently, prioritized queues are introduced. This helps in congestion avoidance [20].

Adnan K Kiani *et al.*, suggested that Mobile Client's (MC) energy level falls quickly leading to unstable links (2015). Continuous change of traffic patterns can also lead to congestion resulting in degradation of network services. A new routing metric called Energy Load Aware Routing Metric (ELARM) is proposed. Based on the network load condition and link stability, ELARM picks up the best route. In ELARM algorithm, HELLO packets are sent periodically to the routers and clients of WMN with the information about the remaining energy level. For AODV, the reserved bit present in the Route Reply (RREP)'s control packet is updated to hold this information. After receiving RREP or HELLO packet, every client updates its remaining energy value. Through the Queue Discharge Interval (QDI), the Interface Queue Length (IFQ) is available locally. This information enables the router in making decision on routing, thus avoiding congestion [21].

PROBLEM STATEMENT

In spite of WMN being the technology needed for the present hour, the challenges of using WMN as a primary technology are vast. Among many, congestion is considered to be one of the main challenges. To narrow down, congestion caused due to load balance needs an effective solution. Another important factor that leads to congestion is insufficient bandwidth. It is a known fact that lesser the bandwidth, higher the data rate, greater would be the congestion. All of the said factors would definitely degrade the Qos. This makes it mandatory to improve the utilization of the bandwidth. In order to improve the throughput and increase the QoS of the network, an effective congestion avoidance technique should be implemented. For achieving this, a Novel Explicit Congestion Avoidance is proposed, that would decrease the probability of packet drops to a very greater extend and therefore prevents the network from being congested. The comparison is done based on the metrics namely, Latency, Throughput and Packet Delivery Ratio.

PROPOSED SOLUTION

The detailed block diagram explaining the sequence of flow for the proposed method is pictorially represented as given below:

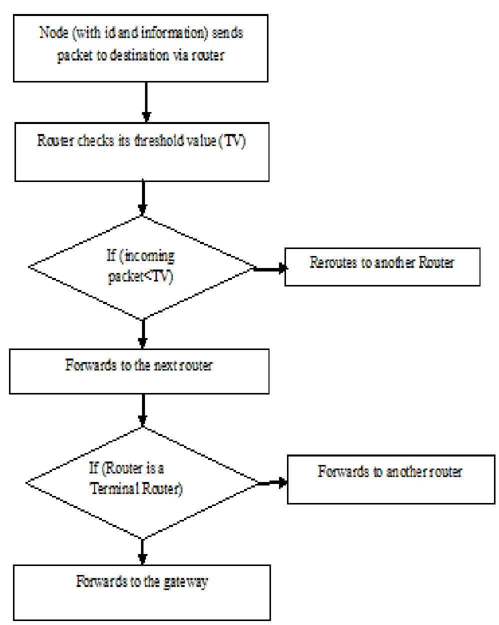

Figure-1. Process at every intermediate node.

A node with a node id and information sends a packet to destination via router. A channel bandwidth threshold value and a buffer size threshold value is set. As it passes through every intermediate router, the router checks its threshold value (TV). If any one of the threshold is reached, then a decision for rerouting is taken. If the

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incoming packet is less than the TV, the present router forwards to the next router. Else it reroutes the whole path. If the present router is a terminal router, it passes the packet to the gateway. In Figure-2, at the gateway node, if two packets arrive at the same time, Gateway forwards the packet based on its size. Else the first arrived packet is served first.

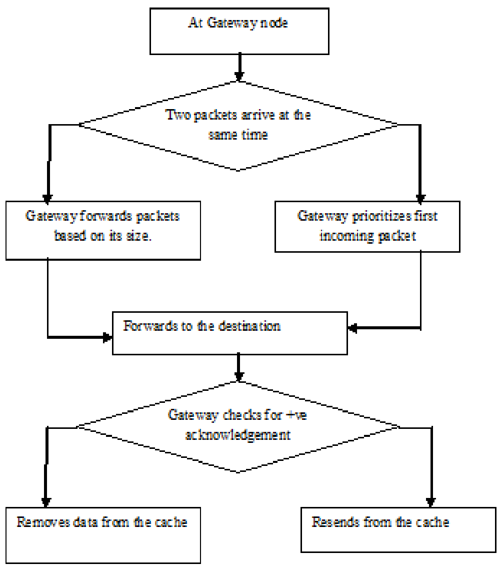

Figure-2. Process at gateway node.

Techniques

To implement this technique, we consider the congestion caused in the gateway node of WMN. In a WMN, all the mesh routers forward the packet to a gateway node in order to send and receive data from the internet, raising the probability of the gateway node to be congested and thereby leading to load imbalance in the network. The following 3 strategies are taken into consideration.

A channel bandwidth threshold and buffer size threshold is set in the router that is to forward data to the gateway node. If any one of the threshold is reached, a notification is sent to the sender about the expected congestion. Then the sender would either slow down the rate of sending or to reroute the remaining packets. For notifying about the future congestion, A Novel Notification Algorithm is proposed and is explained.

The pseudocode of the proposed technique is given below.

Step 1: Each node initializes a threshold waiting timer with a value WTi(0) ∈ (0, Tmax) and initial status Si = none (i = 1, 2, 3, …)
Step 2: Decrease all threshold waiting timer WTi(k)
Step 3: Gateway-check:
If the threshold waiting timer expires, WTi(k) = 0
(a) Si = Re-transmit
(b) broadcast a message M1 with multiplication factor α
(c) delete the waiting timer
end
Step 4: Establish and update the notification identification:
if node Sj receives a message M1 at time step k
(a) if Sj = positive-ack
Sj = negative-ack
else
Sj = positive-ack
end
(b) transmit messages M2 to subsequent nodes, considering the between node i and node j
(c) WTj(k + 1) = α × WTj(k)
(d) if WTj(k + 1) > Tmax
delete the backup when call the positive-ack
end
end
Step 5: Termination conditions check:
if the waiting timers of all nodes are deleted retransmit
else
k = k + 1 and go to step (2)
end

Process

The proposed algorithm will avoid packet drops and therefore delays. It is to be understood that the packet drops reduces the Qos as the data will not reach the destination on time. Moreover, when the sender is told about the packet drop, it resends the packets. More the number of packets dropped, more the number of packets resent. Therefore the overhead in the network will tend to increase considerably, thereby causing congestion. The proposed technique avoids packet drop will result in increased throughput and capacity. In this work, gateway router node is taken into consideration. In WMN, the source node forwards packets to the gateway node. As all the nodes acts as a router by itself, the neighboring node forwards the data to the gateway router. If the gateway node receives equal or more than two packets at the same time, it gives priority to the packets based on its size. For packets arriving at discrete time, priority is given based on the arrival time of the packet using TDMA.

RESULTS AND DISCUSSIONS

The proposed technique is compared with LBASMPL: Load balancing adaptive scheduling with minimum packet loss and the following results were obtained.

Three metrics were chosen to measure the quality of the proposed technique. Latency can be defined as the time taken for a data packet to travels from a source to destination. It also indicates the delay in data communication. Lesser the delay, low is the latency. Higher the delay, greater is the latency.

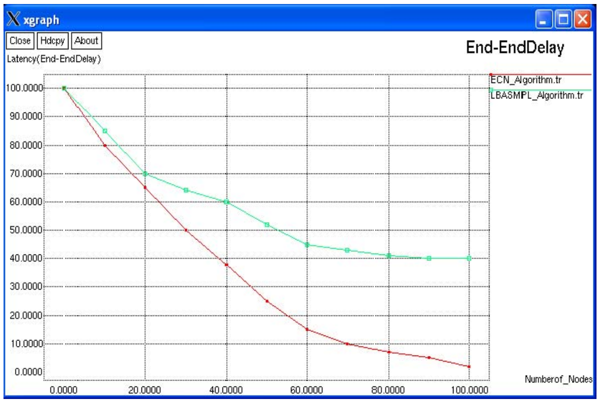

Figure-3. Graph depicting end to end Delay.

Figure-3 clearly depicts that the delay in packet transfer is considerably less in the proposed NECN technique as compared with the existing technique. Therefore, the proposed technique has a lower latency.

Throughput: Throughput can be defined as the amount of data that is successfully transmitted from source to destination in a given period of time. It is usually measured in Mbps.

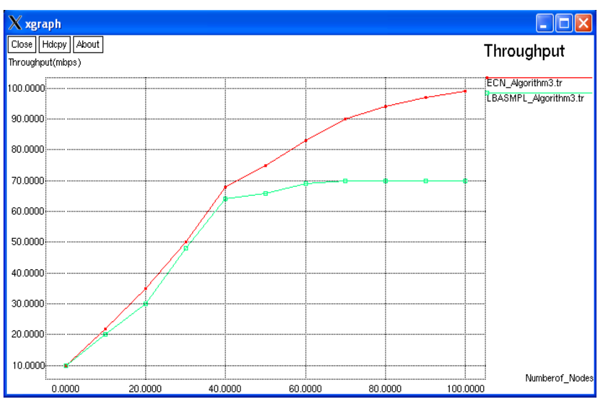

Figure-4. Graph plotted for the throughput of both techniques.

The throughput of each technique was measured in mbps and was compared. The Figure-4 shows a sharp contrast in throughput. The throughput of NECN technique is found to be much higher than the existing technique taken for comparison.

Packet Delivery Ratio can be given by the formula PDR=T/P. Where T is the sum of time taken to deliver packets to each destination. And P is the number of packets received by all the destination nodes.

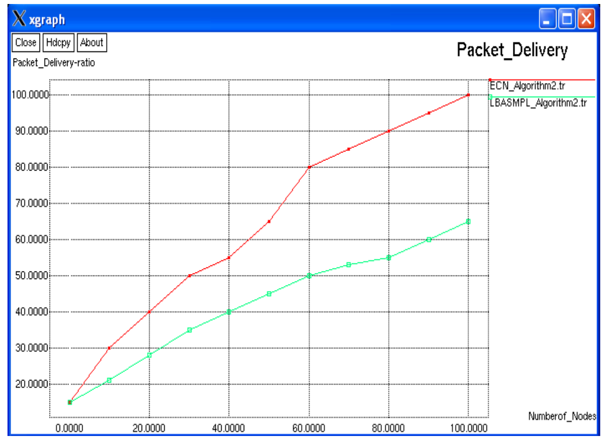

Figure-5. Graph showing comparison of packet delivery ratio.

The graph very clearly shows that the Packet Delivery Ratio is notably higher compared to the present technique. It is known that the higher the packet delivery ratio the greater will be the QoS. The performance between the existing algorithm and the proposed algorithm in made taking three metric into consideration. The plotted graphs for the above said metrics show that the proposed NECN technique is more efficient than the existing technique.

CONCLUSION AND FUTURE WORK

In this paper, a novel congestion avoidance algorithm is suggested and the algorithm is compared with the existing techniques based on three metrics namely, Latency, Throughput and Packet Delivery Ratio. In all three metrics, the resulting graphs show that the proposed algorithm stands better from the existing one. Introducing an efficient clustering algorithm to implement divide and conquer way for congestion avoidance could be of a big benefit. Also, if there are multiple sources, many parameters should be taken into consideration. This makes making decision on the choice of router difficult. Therefore choosing soft computing tools would help to decide on the choice of the hopped on router and this is considered to be work on in the future.

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