

Multi-Hop Wireless Networks – Improved Congestion Control Mechanism

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Abstract – Multi-hop wireless networks are the networks in which the communication is performed from one node to another using various intermediate nodes. Such networks are built using existing wireless protocols based on IEEE 802.11 and IEEE802.11e which are having various techniques to handle the congestion in the network.

The basic idea of handling congestion is to use DROPTAIL protocol, which starts dropping packets as soon the as the networks starts congesting.

This research focuses on the issue of handling congestion control by dropping packets, which leads to resend the packets again by the downstream nodes once the congestion is reduced. The process is more verse due to reproduction of packets at random times.

In this paper, a new approach of controlling congestion is being proposed on the basis of a few more information maintained by nodes locally to slow down the network traffic inflow so that information shall not be gathered on a node and hence no need of dropping access packets in the network.

The mechanism proposed is having various threshold values of the queue and flow rates decided in advance locally on each node and on occurrence of RTS (request to send) signal, CTS (clear to send) signal is sent back if and only if queue is not full or on the ratio of flow rates already decided.

Keywords: Mesh Networks, MANET, Packet Count, Queue Threshold, Throughput.

1. INTRODUCTION

LAN networks are changing very fast in respect of technology enhancement from UTP cables to wireless communication. The need for mobile computing has launched a successful wireless LAN market, with WLANs promising to replace most wired LAN infrastructures in the near future. WLANs allow users to roam inside a building without interrupting their communication sessions and avoid the use of cables.

The mostly commercialized WLAN products are nowadays based on the IEEE 802.11 standard [2]. However, the widespread use of multimedia networking applications has brought more requirements to the network, creating a need for end-to-end quality of service (QoS). The latter requires not only QoS support mechanisms in the core IP network, but also in the access network at the user premises. The various problems in LAN such as congestion and security are also getting lot of attention during this enhancement. While the initial IEEE 802.11 standard has little QoS support, a set of QoS enhancements to the Medium Access Control (MAC) form the main part of IEEE 802.11e, which is currently being specified. The Enhanced Distributed Coordination Function (EDCF) adds transmission prioritization to CSMA/CA. On the other hand, a new coordination function named Hybrid Coordination Function (HCF) allows a Hybrid Coordinator (HC) located at the Access Point (AP) to start polling based contention-free access at any time during the contention period as needed to conform to the QoS parameterization.[1]

The IEEE 802.11 MAC defines two transmission modes for data packets: the Distributed Coordination Function (DCF) based on CSMA/CA and the contention-free Point Coordination Function (PCF) where the Access Point controls all transmissions based on a polling mechanism. The DCF and PCF modes are time multiplexed in a super frame, which is formed by a PCF contention-free period (CFP) followed by a DCF contention period (CP), positioned at regular intervals. The AP transmits beacon frames periodically in order to deliver management information to terminals. The boundaries between CFPs and CPs are marked by beacons carrying the Delivery Traffic Indication Message (DTIM). Terminals can use the information present in the beacons in order to associate with the AP, which is performed during the CP. This association is

mandatory if the terminal needs to have its transmissions scheduled by the PCF, which is usually required for QoS sensitive data. [1]

Packet priorities are implemented defining three different length Interframe Spaces (IFSs):

- **SIFS (Short IFS):** This is the shortest IFS. It is used for transmission of high priority frames: acknowledgements of DATA frames, CTS frames, PCF frames and all DCF DATA frames except the first fragment of a burst.
- **PIFS (PCF IFS):** Greater than SIFS. After this interval expires, any PCF mode frames can be transmitted.
- **DIFS (DCF IFS):** Greater than PIFS. After this interval expires, any DCF mode frames can be transmitted asynchronously according to the CSMA backoff mechanism.

However, by use of an existing CSMA/CA MAC in such networks, application sources inject as many packets as possible into the network with no regard for whether the packets reach their final destination; hence, in presence of a bottleneck link, queue build-up and packet-drop happen which result in waste of the system resources utilized to deliver packets halfway through the network.

While a network of only single-hop flows can also suffer from congestion due to overload, the focus of this work is on the congestion caused due to multi-hopping. We design a congestion control scheme which releases the resources that are wastefully used to transmit packets halfway through the network.

2.0 EXISTING SYSTEM

Classification of Wireless LAN: Wireless LANs can be broadly classified into two categories: ad hoc wireless LANs and wireless LANs with infrastructure. In ad hoc networks, several wireless nodes join together to establish a peer-to-peer communication. Each client communicates directly with the other clients within the network. Ad-hoc mode is designed such that only the clients within transmission range (within the same cell) of each other can communicate. If a client in an ad-hoc network wishes to communicate outside of the cell, a member of the cell MUST operate as a gateway and

perform routing. They typically require no administration. Networked nodes share their resources without a central server.

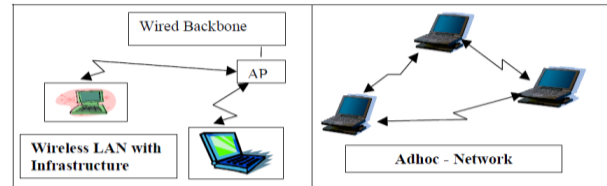


Figure: Classification of Wireless Networks [3]

In wireless LANs with infrastructure, there is a high-speed wired or wireless backbone. Wireless nodes access the wired backbone through access points. These access points allow the wireless nodes to share the available network resources efficiently. Prior to communicating data, wireless clients and access points must establish a relationship, or an association. Only after an association is established can the two wireless stations exchange data. [3]

EDCA & HCCA

In IEEE 802.11, access to the shared wireless channel is controlled through two MAC layer mechanisms: pollingbased PCF (Point Coordination Function) and contentionbased DCF (Distributed Coordination Function). DCF is based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). With CSMA/CA prior to a frame transmission the wireless channel must be sensed idle for a time interval called interframe spacing (IFS), which can be different for different frame types; hence, for data frames the interval is a DCF-IFS (DIFS), and for acknowledgements it is a short IFS (SIFS).

In wireless networks, unlike in Ethernet LANs, collision detection is not possible or is too costly. For this reason the DCF mechanism uses collision avoidance: Before initiating the transmission of a frame, a station selects a random backoff period from the interval $[0, CW - 1]$, where CW is referred to as contention window. The station waits for the channel to be idle for a total time equal to this backoff period, after which it senses the channel to see if it is idle for an interval DIFS, in which case it can transmit a data frame, when the basic CSMA/CA procedure is used, or an RTS frame, when the RTS/CTS procedure is used. The contention window has an initial value CW_{min} , and

is doubled when a collision occurs, up to the maximum value CW_{max} . IEEE 802.11e is a supplement to the 802.11 standard that addresses the issue of QoS support in wireless LANs. The MAC protocol of 802.11e is the Hybrid Coordination Function (HCF), which supports both contention-based and controlled channel access [2]. The contention-based access of HCF is implemented by the Enhanced Distributed Channel Access (EDCA) mechanism, which is an extension of the DCF mechanism that enables distributed differentiated access to the wireless channel with the support of multiple access categories (ACs). A higher priority access category has a smaller minimum contention window CW_{min} , thus has a higher probability to access the channel.

Additionally, different access categories can have different values for the maximum contention window CW_{max} and the interframe spacing interval (IFS). An important addition of EDCA is the capability of a station, once it captures access of the channel, to deliver data up to a maximum time interval called EDCA transmission opportunity (TXOP). The HCCA (Hybrid Coordination Function - HCF - Controlled Channel Access) mechanism is based on polling, similar to the basic PCF mechanism [2]. A difference of the HCCA mechanism is that when a station is polled, it is allowed to transmit packets holding the channel up to a maximum time interval referred to as HCCA or polled transmission opportunity (TXOP). The standard allows the definition of a contention period, where the EDCA mechanism is typically used, and a contention free period, where the HCCA mechanism is used for channel access.

2.4 Multi-Hop Networks

Congestion is severe problem in any network, but specially in wireless network this problem is acute as they are having relative to wired network less speed of data transfer and limited bandwidth available for communication. In Wireless Multi-hop networks the same problem occurs and must be addressed. Multi-hop wireless networks such as Mobile Ad-hoc Networks (MANETs) can be divided into two main categories: 1) organized or closed networks, and 2) self-organized or open networks [2]. In a self-organized network, nodes are autonomous; they may free ride and may not cooperate properly in network operations to save their

resources. Such nodes are called selfish or misbehaving nodes and their behavior is termed selfishness or misbehavior [3].

Packet drops is a possible solution but data packet dropping not only affects the network connectivity, but also can widely waste the network resources such as battery power of network nodes and available bandwidth of network links [4].

Several techniques have been proposed to encounter such misbehavior in MANETs. These methods can be classified into two main categories:

- 1) Incentive-based schemes, and
- 2) Detection and Punishment-based schemes.

Incentive-based schemes use some mechanisms such as virtual (electronic) currency [5] to provide incentives for nodes to perform network operations whereas Detection and Punishment-based models use detection tools such as watchdog [6] and two hops ACK [7] to detect misbehaving nodes and cut them off from the network with the use of mechanisms like reputation systems [8].

Our approach can be categorized as Detection and slow-down based approach. We use overhearing of MAC layer acknowledgments [9] as a novel detection tool to detect misbehaving data packet-dropper nodes; so, in our system, such misbehaving nodes can be isolated from the network using the common reputation systems as used in previous methods. Since we describe and analyze our technique as an add-on for Dynamic Source Routing (DSR) protocol [10], the main idea of our detection system is as follows; when a forwarder node on a source route sends back a MAC-layer CTS signal against a RTS received by it then it first check its queue status and its corresponding flow rate. According to the flow rate, it will decide the ratio of the CTSs to be sent to the previous nodes.

Predecessor node will collect, filter, and combine these reports to calculate the deviation of the behavior of its next node on the source route.

If its calculated deviation is greater than some value, it will send back a report to the source of the route. With the receipt of this misbehavior report, source node will

look for another route, containing no misbehaving node, to send its packets toward the destination node.

3. PROPOSED SYSTEM

A lot of work has been done in the area of wireless multi-hop networks, where packet dropper node is punished by evaluating the network. In this proposed algorithm a scenario is being taken in which a new mechanism will be added to slow down the downstream nodes to get high throughput by adjusting flow rate dynamically. This will not only provide a high throughput but will also save the energy on nodes by avoiding sending unnecessary packets in a congested network.

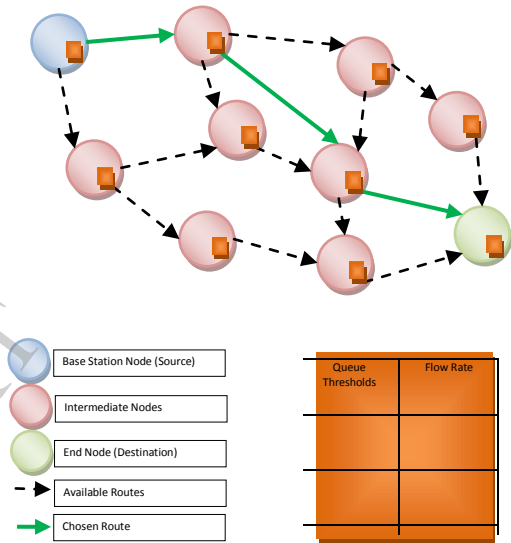
In the process of protocol designs and deployments, it is important to understand the performance of the protocol so that the protocol parameters can be tuned to achieve an optimum operation in an actual network environment. To make the performance analyses tractable, most presented performance analyses introduce some assumptions to simplify the protocol operation and/or the traffic arrival process. As a result, the obtained analytical results may not be realistic and their applications are somewhat limited.

In this work, the performance of EDCA has been improved by providing an algorithm which is based on the pre decisions related with the congestion in the network. This not only improves the performance but also increases the throughput of the network.

Proposed Algorithm will work as follows:

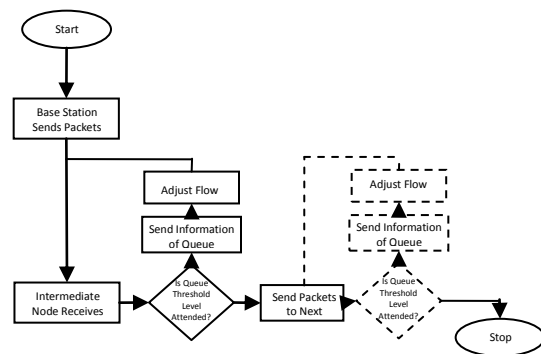
1. Queue threshold Value and acceleration /deceleration rates are decided on each node.
2. Base station will start sending data packets towards destination at its full speed.
3. Packets will follow the available dynamic route to reach towards destination.
4. If queue at any intermediate node reaches to threshold value then it informs to its downstream node about the congestion by slowing down acceptance of the RTS signals.

5. Downstream node slows down the flow of data packets to maintain the queue filling rate on its upstream node automatically.
6. We can set multiple queue thresholds and acceleration / deceleration rates for managing flow of data packets more efficiently.
7. If the congestion is released on the upstream node(s) then they inform the same to the downstream nodes to increase the flow rate of packets towards the upstream nodes.



Working Diagram for Proposed Algorithm

Following Flow Chart depicts the flow of working of the proposed algorithm



For implementation of the proposed system, it is required to communicate about the current queue status to all the nodes to each other. To achieve this, a slight

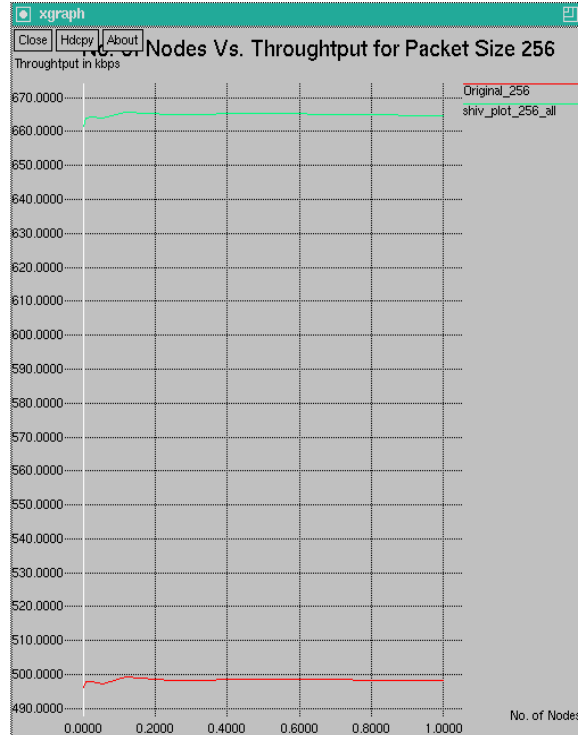
modification has been done in ACK of DCF named as QT (Queue Threshold) which shall be received on each predecessor nodes. The predecessor node if communicating further with this node then will slow down communicating to the successor node about this information.

The algorithm works as follows:

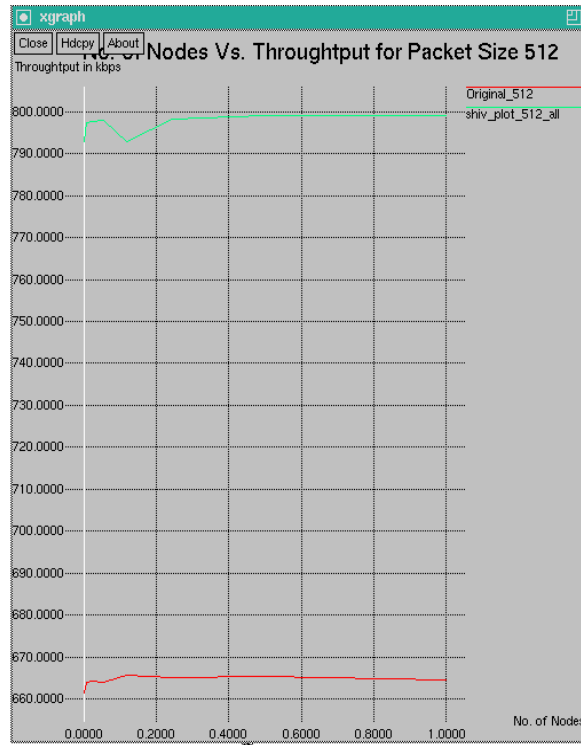
Every node by default carries a QT of value 0 indicating full queue is available for communication. If the incoming packets are more than the outgoing packets on a particular node than the QT field is set to the particular value from the QT-FR (Queue Threshold-Flow Rate) table. This QT value is received by the predecessor and successor nodes both. The successor nodes will ignore this but predecessor nodes will use the QT value to decide the flow rate for communication to its successor nodes.

4. RESULTS

Implements of proposed algorithm using NS2 simulation environment has been successful and results have been drawn as in the figure. Existing IEEE 802.11e EDCA was used to generate the results without application of the changed algorithm for comparison. Throughput has been used for comparison of the performance of the existing algorithm and proposed algorithm. Simulation was performed using scenarios created by increasing the no. of stations (2, 4, 8, 16, 32, 64,128 and 256). Simulation has been performed for every scenario for packet sizes of 256 and 512 bytes. A traffic generator with CBR distribution to provide offered load in this simulation shall be applied.



No. of Nodes	Threshold value in KBPS (Proposed Algorithm)	Threshold value in KBPS (Original Algorithm)
2	661.53	496.32
4	664.06	497.76
8	664.31	497.90
16	664.08	497.24
32	665.59	499.42
64	665.06	498.44
128	665.51	498.78
256	664.67	498.41



No. of Nodes	Threshold value in KBPS (Proposed Algorithm)	Threshold value in KBPS (Original Algorithm)
2	792.81	661.53
4	797.41	664.06
8	797.67	664.13
16	797.96	664.08
32	792.89	665.59
64	798.12	665.06
128	798.98	665.51
256	798.96	664.67

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