Report 1 for Cooperative MAC Protocol Design — A Initial Overlook

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Abstract

Cooperation in wireless networks has shown significant performance gains in comparison to legacy wireless network. Cooperative wireless protocols achieve such efficiency by enabling cooperation among nodes to exploit spatial diversity. CoopMAC is a Medium Access Control (MAC) protocol that enables cooperation by using an intermediate node as a helper to a direct communication under poor channel conditions. In this paper we focus on designing a new CoopMAC including analyzing its performance by deriving expressions for the throughput and validating it by means of simulations using NS-2.

1 Introduction

As wireless networks become more and more popular the increase of the users that demand high quality services by such networks is tremendous. However, wireless links have always had orders of magnitude less bandwidth than their wireline counterparts. Interference and signal loss due to distance and fading severely impairs system performance. In most implementations, transmissions received by stations other than the intended receiver will be discarded. While newer technologies such as multiple-input multiple-output systems(MIMO) increase the number of bits per hertz of bandwidth, it is not possible to integrate several antennas on handheld mobile devices because of their size and weight limitations. To exploit the broadcast nature of wireless channels, a significant amount of research on cooperative communication techniques is being developed to allow stations to cooperate in their transmissions in order to improve the overall performance of the network.

Inspired by this work, it is natural to introduce the notion of cooperation into the medium access control(MAC)layer. A new MAC protocol, which is called CoopMAC, illustrates how the legacy IEEE 802.11 distributed coordination function(DCF)can be enhanced with minimal modifications to maximize the benefit of cooperative diversity.

In this paper, we propose and study a cooperative MAC protocol...

2 Warm Up

2.1 The Definition of MAC

The MAC (Media Access Control),is a sub-layer of the Data Link Layer specified in the seven-layer OSI (Open System Interconnection) model, which acts as an interface between the Logical Link Control (LLC) sub-layer and the network's physical layer. It provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multipoint network, typically a local area network (LAN) or metropolitan area network (MAN). When transmitting data, the MAC sub-layer can estimate the validity of the transmission in advance. After the confirmation it will append some control data to the original data and transfer them to the physical layer in certain formats. When receiving data, the MAC sub-layer firstly checks the transmission errors in the input data. If the data is inerrant it will eliminate the control signal and transfer it to the LLC layer.

3 Background,The IEEE 802.11 Standard MAC

3.1 Introduction

The 802.11 standard specifies a common medium access control (MAC) Layer, which provides a variety of functions that support the operation of 802.11-based wireless LANs. As the wireless LANs advance rapidly ,the bandwidth ,flexibility and security are the main problems concerning us. Bandwidth is restricted by the radio link ,since there are problems like multi-path fading and noise,etc. Flexibility is realized by using multi-channel allocation, which brings problems like synchronization and multi-channel hidden terminal. A sender-receiver pair must be synchronized to a common idle channel before attempting data transmission ,while a transceiver cannot be tuned to more than one channel simultaneously .The multi-channel hidden terminal problem happens when two nodes attempt to send data in the same channel at one time.However,the MAC protocol has some mechanism to avoid these problems.

3.2 The MAC Protocol

In general, the MAC Layer manages and maintains communications between 802.11 stations by coordinating access to a shared radio channel and utilizing protocols that enhance communications over a wireless medium .The 802.11 MAC Layer uses an 802.11 Physical (PHY) Layer, such as 802.11b or 802.11a, to perform the tasks of carrier sensing, transmission, and receiving of 802.11 frames .IEEE 802.11b was introduced later in 1999. It provides four physical layer rates 1, 2, 5.5, and 11 Mbps at the 2.4 GHz band. The basis of the IEEE 802.11b WLAN MAC protocol is Distributed Coordination Function (DCF), which is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with binary exponential back-off scheme .The carrier sensing is mainly targeted to detect if the channel is available .The work is divided by two ,first it uses the virtual carrier-sensing ,then the physical carrier-sensing. Only if both of them declare the media is free can the stations use the them.

3.3 DCF Description

Following the two carrier-sensing functions ,we may focus on the virtual one, which is a four-way handshaking technique.The method is to use Request-To-Send (RTS) and Clear- To-Send (CTS) frames. The two control frames RTS/CTS are used to set the Network Allocation Vector (NAV), where the reservation information of the channel is stored. After successfully exchanging the control packets, a data packet will be sent and the destination will send back positive acknowledgment (ACK) if the packet has been received correctly. The entire process will not be interrupted due to NAV . To interpret why, we may owe it to priority .In fact, frames of 802.11 usually contains a section called duration, reserving a period to use the media .NAV is essentially a timer to declare the period. For the operating station ,the period usually indicates its lifetime in the media, while for other stations ,they will count the NAV to 0 before visiting the media, which is called virtual carrier-sensing. To hold the integrity of transmission ,we have to distinct the interframe spacing(IF)to be four,including short interframe space(SIFS),PCF interframe space(PIFS),DCF interframe space(DIFS) and extended interframe space(EIFS).SIFS is used for high priority transmissions ,PIFS is used for contention-free transmissions,DIFS is used for contention transmission and EIFS has no fixed IF,it is used just when there is error in the transmission. Before atomic operation(namely one station begins to transmit a frame),it usually should wait for an interval named by DIFS,while the following intervals are SIFS.As SIFS is shorter than other interframe spacings ,the operation of CTS,data frame,and ACK for the current atomic operation are granted high priority .That is,for one,any station attempting to visit the station after RTS is finished should wait for DIFS interval while CTS just need a SIFS interval.Most of the transmission operation adopts DCF mechanism which allows lots of independent stations to interact with each other without a central charging department.There are two basic rules in DCF: 1. if the media is free for a time longer than DIFS,the transmission can be immediate. 2. if the media is busy,the stations must wait for another period called access deferral.As long as there is access deferral,the station will be silent for a DIFS interval as well as preparing exponential backoff procedure. There are also other rules: 1. error recovery is the duty of the sender ,if there is no ACK for the sent frame,it should retransmit the frame after some time. 2. multi-frame can update NAV in every step of the transmission.when the reserving time received by the media is longer than NAV,the station should update NAV immediately.3. if the packet is too large ,it has to be divided to several packets.

3.4 The Description of a CoopMAC

We first study a CoopMAC from [11]. The basic operation of the CoopMAC, which is based upon the IEEE 802.11 distributed coordination function(DCF)mode, is outlined and depicted below.

1. When a source station has a new MAC protocol data unit (MPDU) to send, it can either transmit directly to the destination, or use an intermediate helper for relaying, whichever consumes less total air time. The air time is compared using cached information on the feasible data rates between the three nodes.

2. Beyond its normal function, a request to send (RTS) message is also used by CoopMAC to notify the station that has been selected for cooperation. Moreover, CoopMAC introduces a new message called helper-ready to send (HTS), which is used by the helper to indicate its availability after it receives the RTS message from the source. If the destination hears the HTS message, it issues a clear to send (CTS) message to reserve the channel time for a two-hop transmission. Otherwise, it still sends out the CTS, but only reserves the channel time for a direct transmission.

3. If both HTS and CTS are received at the source, the data packet should be transmitted to the helper first, and then forwarded to the destination by the helper. If the source does not receive HTS, it should then initiate a direct transmission to the destination.

4. A normal ACK is used to acknowledge a correct reception, regardless of whether the packet is forwarded by the helper, or is directly transmitted from the source. If necessary, retransmission is attempted, again in a cooperative fashion.

It is crucial that each station obtains and constantly updates its information about the availability of potential helpers. The CoopMAC protocol deals with this issue mainly hrough maintaining a table called the CoopTable in its management plane. Each entry in the CoopTable corresponds to a potential helper, and contains such information as the ID (e.g, 48-bit MAC address) of the potential helper, and the the latest time at which a packet from that potential helper is overheard, the data rate used for direct transmission between the potential helper and destination, and between the current station and the potential helper. A set of protocols have been defined in CoopMAC to properly establish, manage and update the table in a timely manner.

4 Future Work

We will first further study several CoopMAC protocols[1]-[11]. Then try to design a new CoopMAC protocol combining the advantages of the previous protocols and then analyze the performance by deriving expressions for the throughput. We will also validate the protocol by means of simulations using NS-2.

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