行政院國家科學委員會專題研究計畫
期末成果報告

具備多封包接收能力的無線網路中的機會式媒體接取控制

計畫類別: 個別型

計畫編號: NSC 97-2221-E-009-189-MY3

執行期間: 97年08月01日至100年07月31日

執行單位: 國立交通大學電機工程學系

計畫主持人: 高榮鴻

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中文摘要:

這個研究計畫的研究成果有三部份。首先，我們利用機率模型與排隊理論解出經典的樹狀分裂樹演算法應用於具備同時多封包接收能力的無線接取網路的 network throughput 和 average packet delay。這部份的研究成果[24]已經於2008年發表於IEEE Transactions on Mobile Computing。其次，我們利用 Poisson 機率模型推導出經典的 Non-persistent CSMA 演算法應用於具備同時多封包接收能力的無線接取網路時的 network throughput。這部份的研究成果[27]已經於 2009 年發表於 IEEE Communications Letters。最後，我們針對多封包接收矩陣並非是對角化矩陣的一般情況，提出新的分裂樹演算法來做媒體接取控制。這部份的研究成果[34]已經於 2011 年被 IEEE Transactions on Wireless Communications 所接受。我們的研究成果可以用來進一步增進無線接取網路的效能。

中文關鍵字: 多封包接收能力、媒體接取控制、無線接取網路。

Abstract:

The achievements of this research project are composed of three parts. First, we have proposed a novel analytical approach for the exact performance evaluation of the classic tree/stack splitting algorithm in an interference-dominating wireless access network with random traffic and finite nodes. The work [24] has been published in the IEEE Transactions on Mobile Computing in 2008. Second, we have derived the network throughput for the non-persistent CSMA algorithm for wireless networks with multipacket reception. The work [27] has been published in the IEEE Communications Letters in 2009. Last, we have proposed and evaluated novel medium access control algorithms based on tree/stack splitting. The proposed algorithms work even when the multipacket reception channel matrix is not a diagonal matrix. The work [34] has been accepted for publication in the IEEE Transactions on Wireless Communications in 2011.

Keywords: medium access control、MPR、wireless access networks。

1. Introduction

In this project, we propose and/or evaluate algorithms for medium access control in wireless networks with multipacket reception [5] [11]. According to the conventional (0,1,e) channel model, when two or more nodes simultaneously send packets to the access point, a collision occurs and the access point does not receive/decode any packets. With multipacket reception capability, when two or more nodes simultaneously send distinct packets to the access point, an access point could successfully receive/decode one or more packets. Therefore, in a wireless network, multipacket reception capability could be used to increase the throughput without requiring more bandwidth, which is usually seen as scarce resource. Multipacket reception can be realized by CDMA multiuser detection techniques [31] or Successive Interference Cancellation [32].

A multipacket reception channel is characterized by a matrix. We [24] analytically derived the network throughput and the average packet delay for the classic tree/stack splitting algorithm when the channel matrix of multipacket reception is a diagonal matrix. The classic tree/stack splitting algorithm is not designed for and therefore does not work in a wireless network with multipacket reception when the channel matrix is not a diagonal matrix. While there are many tree-based medium access control algorithms for the conventional collision channel (and channels with capture effects), to the best of our knowledge, in the literature, there are no distributed medium access control algorithms that are based on tree splitting and work for an arbitrary channel matrix of multipacket reception. In [34], we propose and evaluate novel splitting algorithms, each works for a wireless network with an arbitrary channel matrix of multipacket reception. In addition, for each of the three algorithms, it is unnecessary to know/estimate the value of the channel matrix of multipacket reception. Among the three splitting algorithms, the tree/stack splitting with remainder algorithm has the best performance in terms of network throughput and average packet delay. For the splitting with remainder algorithm, we mathematically derive the exact values of the network throughput and the average packet delay. We show that our analytical results are consistent with packet-based simulation results.

Kleinrock and Tobagi [35] analyzed the performance of CSMA protocols based on the conventional (0,1,e) channel model. Chan and Berger [36] investigated the impact of multiple packet reception on CSMA, when each node always has packets to be transmitted. In contrast, in [27], we use the Poisson random traffic model. Chan, Berger, and Tong [37] used drift analysis techniques to evaluate the performance of the slotted nonpersistent CSMA protocol in wireless networks with multiple packet reception. While they focused on the value of the maximum stable throughput, we derive the complete throughput function, which is a mapping from the network traffic load to the network throughput. Our work is the first in the literature that extends and applies the analytical techniques developed in [35] to CSMA protocols in wireless networks with MPR.

2. Related Works

Medium access control protocols can be classified into distributed protocols and polling-based protocols. There are three well-known classes of distributed medium access control protocols. They are Splitting, Aloha, and CSMA. Gallager [3] proposed the FCFS splitting algorithm. Garces and Garcia-Luna-Aceves [9] proposed using a deterministic tree-splitting algorithm for nodes in a wireless network to compete for the right to acquire the floor of a particular receiver's channel. Houdt and Blondia [7] proposed combining polling and a variant of the splitting algorithm for contention resolution in a wireless access network. The above works used the conventional (0,1,e) channel model. Sidi and Cidon [6] analyzed the performance of the FCFS splitting algorithm in channels with capture. Qin and Berry [12] proposed using opportunistic splitting algorithms that exploit channel state information. Yu and Giannakis [19] developed a medium access control protocol that exploits successive interference cancellation over multiple time slots in a tree splitting algorithm. Wang, Yu, and Giannakis [23] proposed combining the binary exponential backoff algorithm with a tree algorithm that relies on successive interference cancellation. In the above two papers, it is assumed that the access point knows the identities of all competing nodes in every time slot. In contrast, we do not make the assumption. Gore and Karandikar [29] proposed a FCFS splitting algorithm that adjusts the transmission power based on quaternary channel feedback. They focused on the capture effect rather than the general multipacket reception capability. Yim, Mehta, Molisch, and Zhang [26] proposed the DPMA (Dual Power Multiple Access) scheme, which is based on FCFS splitting and uses transmission power control to limit the reception power levels to two values that facilitate successive interference cancellation. They studied the case in which the buffer size is infinity and derived the stable throughput. In contrast, we study the case in which the multiple access channel is fully characterized by a matrix and the buffer size is finite.

Chlamtac and Farago [8] studied the multipacket reception capability provided by multiple independent collision channels. Adireddy and Tong [14] studied the use of distributed channel state information for random access in wireless networks with multipacket reception. In particular, they proposed a variant of slotted Aloha in which the transmission probability changes with the channel state. Naware, Mergen, and Tong [15] studied the effect of multipacket reception on stability and delay of slotted Aloha. Luo and Ephremides [16] studied the impacts of transmission power control on the performance of random multiple access with multipacket reception. Gau [17][21] analytically derived the saturation throughput and the non-saturation throughput for slotted Aloha in wireless networks with multipacket reception. Dua [22] proposed a user-centric approach for evaluating the performance of slotted Aloha with multipacket reception in a wireless network in which the total number of nodes is finite but the buffer size at each node is infinity. Lotfinezhad, Liang, and Sousa [20] derived the optimal retransmission probabilities for slotted Aloha in wireless sensor networks with multipacket reception. Celik, Zussman, Khan, and Modiano [28] proposed alternative backoff mechanisms for medium access control in wireless networks with multipacket reception capability and spatially distributed nodes. An introduction on CSMA protocols for wireless networks with multipacket reception can be found in [27] [28] and reference therein. Choudhury, Yang, and Vaidya [4] proposed a multi-hop RTS protocol for medium access control in wireless ad hoc networks with directional antennas. Guo, Wang, and Wu [25] studied the capacity of wireless ad hoc networks with multiple packet reception.

An introduction on polling-based protocols of medium access control with multipacket reception can be found in [11][18] and reference therein. Shad, Todd, Kezys, and Litva [10] introduced dynamic slot allocation for cellular systems with antenna arrays to utilize the multipacket reception capability. Zhao and Tong [11] proposed the MQSR (Multi-Queue Service Room) protocol for medium access control in wireless networks with multipacket reception. In addition, they proposed a dynamic queue protocol [13] that achieves a performance comparable to that of MQSR with a much lower computational complexity. Gau and Chen [18] proposed and analytically evaluated the predictive multicast polling scheme which is a queue-aware medium access control scheme for wireless networks with multipacket reception.

3. Numerical and Simulation Results

In this section, we show numerical results and corresponding simulation results. Details for related analytical results can be found in our papers [24][27][34]. We first evaluate the performance of the classic tree/stack splitting algorithm when the channel matrix of multipacket reception is a diagonal matrix. In Figure 1, we show that for the network throughput the numerical results are almost identical to the simulation results, when the buffer size at a node equals one. In Figure 2, we show that for the average packet delay the numerical results are almost identical to the simulation results, when the buffer size at a node equals one. In Figure 3 and Figure 4, we show that when the buffer size at a node is two, for the network throughput and the average packet delay our numerical results are consistent with simulation results.

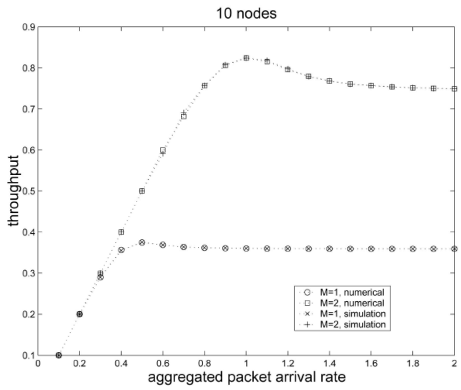

Figure 1: network throughput for the classic tree/stack splitting algorithm, 10 nodes, and buffer size equals one

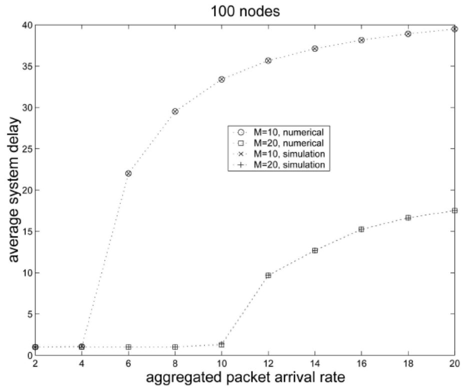

Figure 2: the average packet delay for the classic tree/stack splitting algorithm, 100 nodes, and buffer size equals one

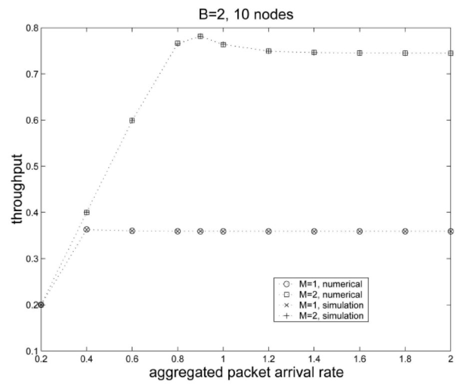

Figure 3: the network throughput for the classic tree/stack splitting algorithm, 10 nodes, and buffer size equals two

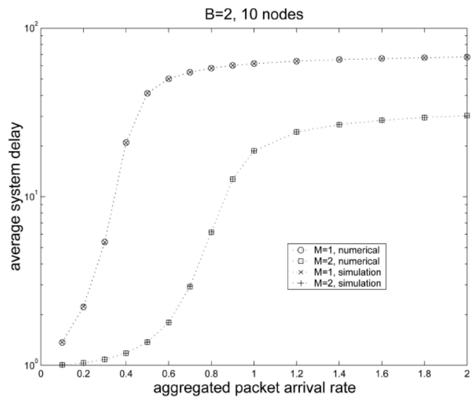

Figure 4: the average packet delay for the classic tree/stack splitting algorithm, 10 nodes, and buffer size equals two

In addition, we evaluate the performance of the splitting with remainder algorithm when the buffer size at a node equals one but the channel matrix of multipacket reception is not a diagonal matrix. In Figure 5, we show that for the network throughput the numerical results are almost identical to the simulation results. In Figure 6, we show that for the average system size the numerical results are almost identical to the simulation results. In Figure 7, we show that for the average packet delay the numerical results are almost identical to the simulation results. Among the three variants of the tree/stack splitting algorithm, the splitting with remainder algorithms has the optimal performance in terms of the network throughput.

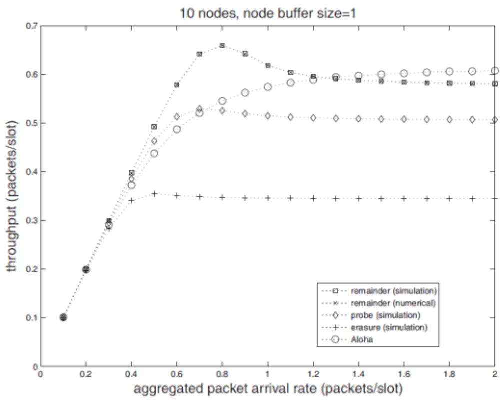

Figure 5: the throughput for the splitting with remainder algorithm, 10 nodes, and buffer size equals one

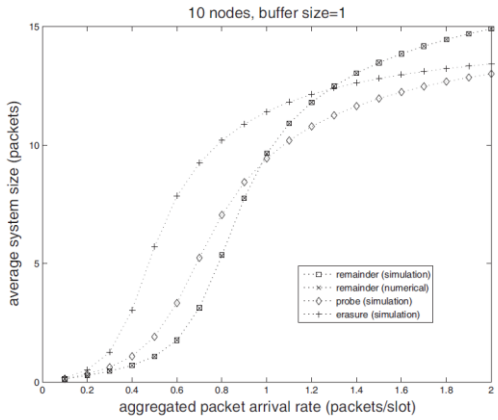

Figure 6: the average system size for the splitting with remainder algorithm, 10 nodes, and buffer size equals one

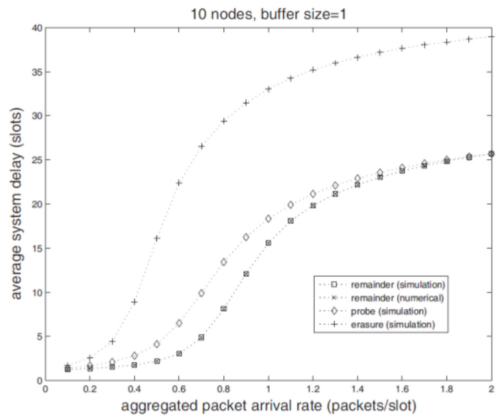

Figure 7: the average packet delay for the splitting with remainder algorithm, 10 nodes, and buffer size equals one

4. Conclusions

The achievements of this research project are composed of three parts. First, we have proposed a novel analytical approach for the exact performance evaluation of the classic tree/stack splitting algorithm when the channel matrix of multipacket reception is a diagonal matrix and the packet arrival times are random. The work [24] has been published in the IEEE Transactions on Mobile Computing in 2008. Second, we have derived the network throughput for the non-persistent CSMA algorithm for wireless networks with multipacket reception. The work [27] has been published in IEEE Communications Letters in 2009. Last, we have proposed and evaluated novel medium access control algorithms based on tree/stack splitting. The proposed algorithms work even when the multipacket reception channel matrix is not a diagonal matrix. We have analytically derived the exact values for the network throughput and the average packet delay, which includes the average queueing delay. The work [34] has been accepted for publication in the IEEE Transactions on Wireless Communications in 2011.

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