行政院國家科學委員會專題研究計畫
期中精簡報告

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

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計畫編號: NSC 97-2221-E-110 -052 -MY3

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計畫主持人: 高榮鴻

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中文摘要:

機會式媒體接取控制主要是利用無線通訊管道的時變性(如 fading)，只使用瞬間情況良好的管道傳送封包，以增加無線網路的總體產出(throughput)。傳統的通訊理論把通訊管道的時變性視為必須克服的缺點；而機會式媒體接取控制則將無線通訊管道的時變性視為一種可以利用的資源。目前，大多數關於機會式媒體接取控制的文獻都是假設基地台不能同時接收多個封包。多封包接收能力是指一個基地台可以在同一時間(time slot)、同一頻帶(frequency band)同時成功地接收並解碼來自不同網路節點的多個封包。在傳統的(0,1,e)通道模型中，同時傳送兩個以上的封包只會造成碰撞，對網路 Throughput 並沒有任何貢獻。然而，網路消息理論(Network Information Theory)與先進的通訊技術(如 CDMA+Multi-user Detection 及 Smart Antennas+SIC 等)允許基地台可以同時成功地接收多個封包。以先進的通訊技術為基礎的 medium access control scheme 可以達到傳統的 medium access control schemes 所無法達到的無線網路效能。分散式的媒體接取控制方案可以分為 3 大類：Aloha、Tree Splitting 及 CSMA。我們目前正在針對這 3 大類的 MAC Protocols 各自選擇一個代表來研究如何使之與 Opportunistic Packet Transmission 相結合。目前我們已有一些初步的結果。在此多年期研究計畫結案前，我們會將研究成果投稿到網路通訊領域的 IEEE 期刊。

Abstract:

An opportunistic medium access control scheme takes advantages of the time-varying nature of wireless communications channels. In particular, in order to maximize the network throughput, an opportunistic medium access control scheme uses only channels with good instantaneous qualities to transmit packets. In conventional communications theory, channel fading is seen as a detrimental property. In contrast, from the viewpoint of opportunistic medium access control, channel fading is beneficial to network throughput. Currently, most works on opportunistic medium access control use the conventional (0, 1, e) collision

model.

In a wireless network with multiple packet reception, an access point could simultaneously receive/decode a number of packets from different sources, which use the same frequency band to transmit packets. In the conventional (0, 1, e) channel model, simultaneous packet transmissions to an access point results in packet collisions and leads to a decrease in network throughput. However, network information theory implies that it is possible for the access point to simultaneously receive/decode a number of packets from different sources. The multiple packet reception capability could be realized by advanced communications technologies such as CDMA-based multi-user detection and smart antenna with successive interference cancellation. More important, the capacity region of an information-theoretic medium access control scheme is larger than that of an arbitrary pure TDMA-based medium access control scheme.

Random access control schemes can be classified into three classes: Aloha, Tree Splitting, and CSMA. Currently, for each of the above classes, we have identified one representative MAC protocol. We are working on modifying the classic MAC protocols so that they could benefit from being opportunistic. We have come up with some preliminary but promising results. We will further improve our work and then submit it to related IEEE Transactions before the end of this three-year research project.

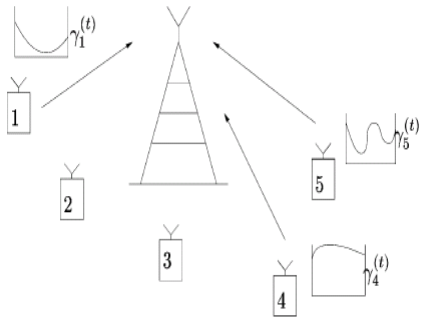

Figure 1: Uplinks with Different Channel States

1 Related Work and Our Approach

Adireddy and Tong [7] proposed a variant of Slotted ALOHA for medium access control, where the transmission probability depends on the CSI (Channel State Information). Qin and Berry [5] proposed an opportunistic medium access control scheme for wireless networks based on tree-splitting. Qin and Berry [14] proposed distributed approaches to exploit multi-user diversity in wireless networks by scheduling users to transmit when their channel conditions are favorable. Yu and Giannakis [17] proposed an opportunistic medium access scheme that adapts to decentralized CSI for wireless networks. Sabharwal, Khoshnevis, and Knightly [20] proposed

a measurement-based opportunistic spectral usage scheme based on CSMA/CA for a multi-band wireless networks.

Liu, Chong, and Shroff [15] studied the problem of opportunistic transmission with resource-sharing constraints mainly for downlink communications in wireless networks. Leung and Sung [18] proposed an opportunistic power control scheme for cellular networks. Sadek, Liu, and Ephremides [16] proposed a cooperative multiple access scheme that takes channel state information into consideration for wireless networks. Ribeiro, Cai, and Giannakis [19] proposed an opportunistic multipath scheme for cooperative multiple access in wireless networks.

Zhao and Tong [17] proposed a multiqueue service room (MQSR) MAC protocol for wireless networks with multipacket reception. For medium access control in wireless networks with multiple packet reception, Gau and Chen [35] proposed the predictive multicast polling scheme that continuously updates the prediction for queue states, which are used to determine the best polling order. Gau and Chen [12] analytically derived the exact values of the network throughput and the average packet delay for the classic tree/stack splitting algorithm in wireless networks with multiple packet reception.

There are three well-known classes of distributed random access control schemes in the literature: Aloha, Tree Splitting, and CSMA. For each of the above three classes, we have identified one representative MAC protocol. We are working on modifying the classic MAC protocols so that they could benefit from being opportunistic. In particular, for a variant of the tree-splitting protocol and a variant of the CSMA protocol, we have worked out some preliminary but promising analytical results. Our analysis is mainly based on discrete stochastic processes and algorithmic queueing theory.

2. Summary of Recent Research Achievement (2008/08/01~2009/05/31)

We published a paper [12] in the prestigious IEEE Transactions on Mobile Computing in December 2008. In the paper, we propose novel probability models to derive the exact values of the network throughput and the average packet delay for the classic tree/stack splitting algorithm in wireless networks with multiple packet reception. Our work can also be applied to the conventional collision channel, which is just a special case of the general multiple packet reception channel.

Reference

[1] Dimitri Bertsekas and Robert

Gallager, *Data Networks*, Second Edition, 1992, Prentice Hall Publication, Upper Saddle River, NJ 07458, USA.

[2] Sylvie Ghez, Sergio Verdu, and Stuart C. Schwartz, ``Stability properties of slotted ALOHA with multipacket reception capability," IEEE Transactions on Automatic Control, Vol. 33, July 1988, p. 640-649.

[3] F. Shad, T. D. Todd, V. Kezys, and J. Litva, ``Dynamic Slot Allocation (DSA) in Indoor SDMA/TDMA Using a Smart Antenna Base station," IEEE/ACM Transactions on Networking, Vol. 9, No. 1, February 2001, p. 69-81.

[4] Qing Zhao and Lang Tong, "A Multiqueue Service Room MAC Protocol for Wireless Networks With Multipacket Reception," IEEE/ACM Transactions on Networking, Vol. 11, No. 1, February 2003, p. 125-137.

[5] Xiangping Qin and Randall Berry, "Opportunistic Splitting Algorithms for Wireless Networks," IEEE INFOCOM 2004, Vol. 3, pp. 1662-1672.

[6] Qing Zhao and Lang Tong, "A Dynamic Queue Protocol for Multiaccess Wireless Networks with Multipacket Reception," IEEE Transactions on Wireless Communications, Vol. 3, No. 6, November 2004, pp. 2221-2231.

[7] S. Adireddy and Lang Tong, "Exploiting Decentralized Channel State Information for Random Access," IEEE Transactions on Information Theory, Vol. 51, No. 2, February 2005, pp. 537-561.

[8] Vidyut Naware, Gokhan Mergen, and Lang Tong, "Stability and Delay of Finite-User Slotted ALOHA With Multipacket Reception," IEEE Transactions on Information Theory, Vol. 51, No. 7, July 2005, pp. 2636-2656.

[9] Rung-Hung Gau, "Performance Analysis of Slotted Aloha in Interference-Dominating Wireless Ad-Hoc Networks," IEEE Communications Letters, Vol. 10, No. 5, May 2006, pp. 402-404.

[10] Rung-Hung Gau and Kuan-Mei Chen, "Predictive Multicast Polling for Wireless Networks with Multipacket Reception and Queueing," IEEE Transactions on Mobile Computing, Vol. 5, No. 6, June 2006, pp. 725-737.

[11] David Tse and Pramod Viswanath, *Fundamentals of Wireless Communications*, 2005, Cambridge University Press, USA.

[12] Rung-Hung Gau and Kuan-Mei Chen, “Probability Models for The Splitting Algorithm in Wireless Access Networks with Multi-Packet Reception and Finite Nodes,” IEEE Transactions on Mobile Computing, Vol. 7, No. 12, December 2008, pp. 1519-1535.

[13] Rung-Hung Gau, “Performance Analysis of Finite-User Slotted Aloha in Wireless Networks with Multipacket Reception and Random Traffic,” IEEE Communications Letters, Vol. 12, No. 2, February 2008, pp. 140-142.

[14] Xiangping Qin and Randall A. Berry, “Distributed Approaches for Exploiting Multiuser Diversity in Wireless Networks,” IEEE Transactions

on Information Theory, Vol. 52, No. 2, February 2006, pp. 392-413.
[15] Xin Liu, Edwin K. P. Chong, and Ness B. Shroff, "Opportunistic Transmission Scheduling With Resource-Sharing Constraints in Wireless Networks," IEEE Journal on Selected Areas in Communications, Vol. 19, No. 10, October 2001, pp. 2053-2064.
[16] Ahmed K. Sadek, K. J. Ray Liu, and Anthony Ephremides, "Cognitive Multiple Access Via Cooperation: Protocol Design and Performance Analysis," IEEE Transactions on Information Theory, Vol. 53, No. 10, October 2007, pp. 3677-3696.
[17] Yingqun Yu and Georgios B. Giannakis, "Opportunistic Medium Access for Wireless Networking Adapted to Decentralized CSI," IEEE Transactions on Wireless Communications, Vol. 5, No. 6, June 2006, pp. 1445-1455.
[18] Kin-Kwong Leung and Chi Wan Sung, "An Opportunistic Power Control Algorithm for Cellular Networks," IEEE/ACM Transactions on Networking, Vol. 14, No. 3, June 2006, pp. 470-478.
[19] Alejandro Ribeiro, Xiaodong Cai, and Georgios B. Giannakis, "Opportunistic Multipath for Bandwidth-Efficient Cooperative Multiple Access," IEEE Transactions on Wireless Communications, Vol. 5, No. 9, September 2006, pp. 2321-2327.
[20] Ashutosh Sabharwal, Ahmad Khoshnevis, and Edward Knightly, "Opportunistic Spectral Usage: Bounds and a Multi-Band CSMA/CA Protocol," IEEE/ACM Transactions on Networking, Vol. 15, No. 3, June 2007, pp. 533-545.