A Novel QoS Differentiation Framework for IEEE 802.11 WLANs: A Game-Theoretic Approach Using an Optimal Channel Access Scheme

Barsha Mitra, Debarshi Kumar Sanyal, Matangini Chattopadhyay, and Samiran Chattopadhyay

Jadavpur University, India
{mitra.barsha,debarshisanyal}@gmail.com,
chttpdhy@yahoo.com, samiranc@it.jusl.ac.in

Abstract. The ubiquity of multimedia applications and its sustenance with more traditional data services demand a Quality of Service (QoS) differentiation mechanism in telecommunications networks. This paper takes up a novel access method called Idle Sense developed to provide short-term fair high aggregate throughput to wireless stations in an IEEE 802.11 WLAN. We use a game-theoretic interpretation of the algorithm to determine how to incorporate QoS in the game. We show how the parameters in the algorithm may be tuned in order to achieve proportional throughput differentiation at the Nash equilibrium point of the game. Extensive numerical simulations performed for both IEEE 802.11b and 802.11g indicate that the traffic classes are indeed differentiated in terms of throughput.

Keywords: Quality of service, Nash equilibrium, Wireless networks, Throughput, Performance.

1 Introduction

Multimedia applications are ubiquitous in today's networks. Audio and video coexist with data traffic. While low throughput is tolerable for applications like web access, high throughput is necessary to sustain critical transmissions of data and multimedia. Thus Quality of Service (QoS) is an important requirement in today's network whether it is the Internet or a local area network. The DCF protocol defined in the IEEE 802.11 standard suffers from reduced throughput for large network sizes. Hence the Idle Sense access method [1] was developed. It assures optimal throughput equally distributed among the nodes even for large networks. In this paper, we use a recently developed game theoretic interpretation [3] of Idle Sense to support proportional QoS in WLANs. We show that simple tuning of the parameters used in the control algorithm of Idle Sense can support proportional throughput differentiation and hence QoS. It is noteworthy that our scheme is different from that in [2] where the contention window is directly manipulated.

2 Proposed QoS Differentiation Framework for WLANs

We consider an ad hoc wireless LAN of $\aleph$ nodes where all nodes can hear each other.

V.V. Das and N. Thankachan (Eds.): CIIT 2011, CCIS 250, pp. 500–502, 2011.

Node i accesses the channel with probability p_i which is, in general, time-dependent. We assume all nodes are permanently backlogged. In [1], the authors show that for equally divided high aggregate throughput, the mean number of idle slots between two transmission attempts approaches a constant as the number of nodes becomes arbitrarily large. This constant depends only on protocol parameters and is called the target number of idle slots. The Idle Sense access method uses this observation to formulate an additive-increase-multiplicative-decrease (AIMD) algorithm. If the mean number of idle slots between two transmission attempts is lower than the target, the channel access probability is reduced multiplicatively by b_i. If the mean is higher, the access probability is increased additively by a_i. In [3], the authors recover a non-cooperative game from this access method. The game played by the nodes is termed as the *IdleSense-Game* which is defined as $[\aleph, \times_{i\in\aleph} S_i, \{U_i\}_{i\in\aleph}]$ where $\aleph$ is the set of players (the nodes of the network), $S_i := \{p_i \mid p_i^{\min} \le p_i \le p_i^{\max}\}$ is the strategy set of player i, and $U_i(\mathbf{p})$ is the utility function that node i attempts to maximize. It may be noted that the strategy set of each player is the set of its channel access probabilities and $0 < p_i^{\min} \le p_i \le p_i^{\max} < 1$. In [3], the authors further prove that the game has a Nash Equilibrium (NE) in pure strategies and that under mild restrictions, the non-trivial NE in IdleSense-Game is unique. Here, we observe that at the unique non-trivial NE of the IdleSense-Game where node i has a channel access probability p_i^*, the channel access probabilities of the nodes depend on the AIMD parameters as:

$$\frac{p_i^*}{p_j^*} = \left(\frac{1-b_j}{1-b_i}\right)\frac{a_i}{a_j}$$

Thus if different nodes choose different (a_i, b_i), they enjoy different channel access probabilities and hence different throughputs at the NE. This is our proposed QoS model for proportional throughput differentiation. We validate it through numerical simulations in MAXIMA [4]. Both IEEE 802.11b (basic rate = 1 Mbps, data rate = 11 Mbps) and IEEE 802.11g (basic rate = 24 Mbps, data rate = 54 Mbps) style WLANs are simulated. We assume two traffic classes: I and II. Nodes are equally divided into the two classes. All nodes in each class choose the same (a_i, b_i) values. We plot aggregate throughput of each class against total number of nodes. Two cases are considered: (1) class I nodes choose a_i = 0.002 and class II nodes choose a_i = 0.001 while all nodes have same b_i. Here the throughput divides in 2:1 ratio. (fig. 1a and 1b) (2) class I nodes choose b_i = 0.8 and class II nodes choose b_i = 0.4 while all nodes have same a_i (fig. 2a and 2b). In this case, the throughput divides in 3:1 ratio.

3 Conclusions

We have presented a simple method using a non-cooperative game model to incorporate QoS at the MAC layer of an IEEE 802.11 based wireless LAN. We have shown that at the stable operating point of the protocol, the hosts can divide the aggregate throughput in a proportional manner.

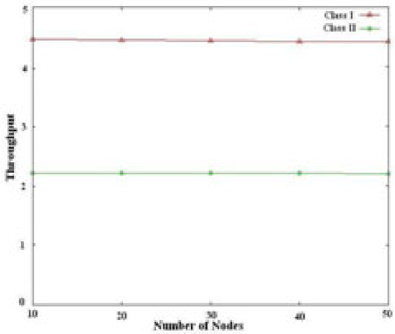

Fig. 1a. Varying a_i: Number of Nodes vs. Throughput for IEEE 802.11b Network

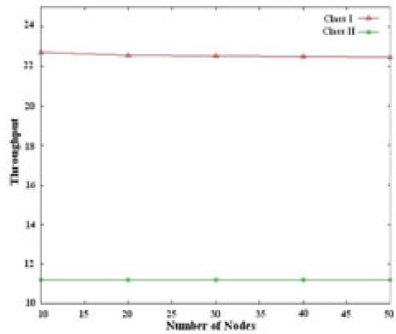

Fig. 1b. Varying a_i: Number of Nodes vs. Throughput for IEEE 802.11g Network

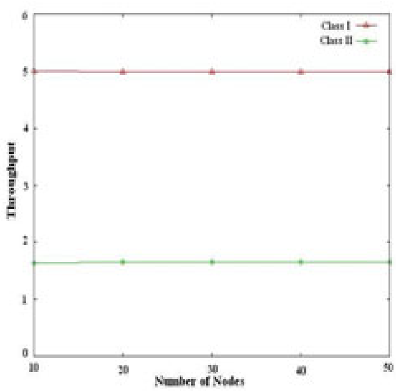

Fig. 2a. Varying b_i: Number of Nodes vs. Throughput for IEEE 802.11b Network

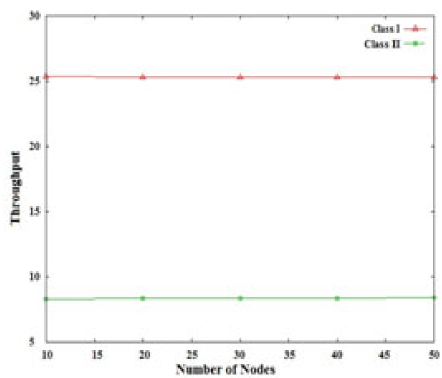

Fig. 2b. Varying b_i: Number of Nodes vs. Throughput for IEEE 802.11g Network

References

1. Heusse, M., Rousseau, F., Guillier, R., Duda, A.: Idle Sense: an Optimal Access Method for High Throughput and Fairness in Rate Diverse Wireless LANs. In: ACM SIGCOMM 2005 (2005)
2. Nassiri, M., Heusse, M., Duda, A.: A Novel Access Method for Supporting Absolute and Proportional Priorities in 802.11 WLANs. In: IEEE INFOCOM 2008 (2008)
3. Sanyal, D.K., Chattopadhyay, M., Chattopadhyay, S.: Recovering a Game Model from an Optimal Channel Access Scheme for WLANs. Telecommunications Systems (2011)
4. Maxima, `http://maxima.sourceforge.net/`