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ScienceDirect

IERI Procedia 10 (2014) 153 – 159

Procedia IERI

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2014 International Conference on Future Information Engineering

Achieve Significant Throughput Gains in Wireless Networks with Large Delay-Bandwidth Product

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Abstract

Traditionally, Bandwidth-Delay Product can be used to measure the capacity of network "pipe" between two nodes. However, in multi-hop wireless networks, Bandwidth-Delay Product cannot reveal the network condition accurately. In this paper, we define a new metric called Delay-Bandwidth Product (DBP) for wireless networks, which measures the capacity of a one-hop pipe in wireless networks. Wireless networks with a large DBP can have a throughput larger than the one based on traditional understanding. We propose a scheduling algorithm aims for making use of the large DBP in wireless networks. We then design simulations to figure out how much throughput gains can be achieved in wireless networks, with small DBPs and large DBPs respectively. The simulation result demonstrates that we can achieve significant throughput gains in wireless networks with large DBP.

Selection and peer review under responsibility of Information Engineering Research Institute

Keywords: wireless networks; wireless sensor networks; throughput; delay-bandwidth product

1. Introduction

Traditionally, Bandwidth-Delay Product (BDP) is used to measure the capacity of an end-to-end network pipe [1]. It is defined as the product of a data link's capacity and its end-to-end delay. BDP is a key factor for the performance of traditional networks; for instance, in networks with a large BDP, the standard TCP needs

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Selection and peer review under responsibility of Information Engineering Research Institute
doi:10.1016/j.ieri.2014.09.070

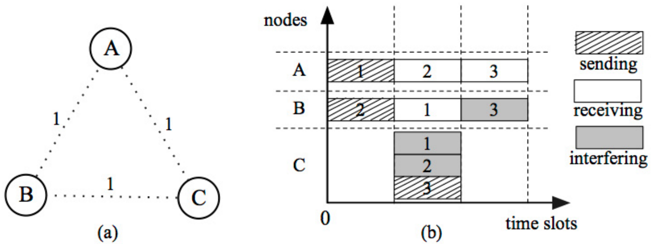

Fig. 1. Three nodes in a broadcast domain (a) and the transmission schedule (b). It can be verified that all the packets can be successfully transmitted and received without any collision.

to be modified to fully utilize the underlying available bandwidth [2].

However, some wireless networks employ "hop-by-hop" transmitting scheme instead of "end-to-end" scheme, such as wireless sensor networks. As a result, traditional Bandwidth-Delay Product cannot reveal the performance of wireless network accurately. In this paper, we define a new concept called *Delay-Bandwidth Product* (DBP) for wireless networks, which is defined as the product of the average delay of one-hop propagation and bandwidth in the wireless network. It measures the capacity of a *one-hop* pipe in wireless networks. In wireless networks with a large DBP, even a one-hop pipe may contain more than one packet propagating simultaneously. What's more, since most wireless sensor networks employ hop-by-hop transmitting schemes, DBP may be a key factor to the performance of those networks.

Traditionally, we believe nodes within a single broadcast domain in wireless networks can transmit and receive at most one packet per packet transmission time (PTT) [3]. In this work, we find wireless networks with a large DBP can have a throughput larger than the one based on traditional understanding. Since even a one-hop pipe is able to contain more than one packet propagating simultaneously, we can make use of it.

The example in Fig. 1(a) presents the findings intuitively. Three nodes *A*, *B* and *C* are in the same broadcast domain. The propagation delay between every two nodes is one PTT. After dividing time into continuous time slots in units of PTT, consider three transmissions: packet #1 from *A* to *B* in slot 0, #2 from *B* to *A* in slot 0, and #3 from *C* to *A* in slot 1. It is easy to verify all the packets can be successfully transmitted and received without any collision, as shown in Fig. 1(b).

This example implies that we may achieve throughput gains by making use of large DBP. However, the example is too ideal to apply in practical circumstances for two reasons. First, the nodes must be placed carefully; second, even if the nodes are placed carefully, a small shift of location will ruin the transmission. Fortunately, we propose a novel transmitting scheduling algorithm in Section 3, which not only adapts to arbitrary node locations, but also is tolerant to location shifting.

We now discuss wireless networks which can have a throughput larger than the one based on traditional understanding. Let η denote the Delay-Bandwidth Product. For simplicity, we consider η in units of packets rather than bits, and we assume each packet has the same length of 200 bytes. Clearly, the scenario in Fig. 1 can happen if and only if $\eta \geq 1$.

We begin with the IEEE 802.11b/g networks, which has a propagation speed of $3*10^8$ m/s, an average bandwidth of usually less than 50Mbps and an average distance between two neighbor nodes being less than 100m. The DBP is less than 0.01 packets. Due to the very small η, the scenario in Fig. 1 cannot be constructed.

We move on to find other wireless networks with $\eta \geq 1$. Generally, a large DBP can be caused by a large propagation delay or a large bandwidth. A large propagation delay can be further caused by a long distance or a low propagation speed. We can give several examples.

Spacecraft networks. In spacecraft networks [4] or Interplanetary Internet, with a propagation speed of $3*10^8$ m/s, an average bandwidth of 200kbps and an average distance between two neighbor nodes larger than