An Efficient and Optimized Bluetooth Scheduling Algorithm for Piconets

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Abstract. Bluetooth is an emerging standard in short range, low cost and low power wireless networks. MAC is a generic polling based protocol, where a central Bluetooth unit (master) determines channel access to all other nodes (slaves) in the network (piconet). An important problem in Bluetooth is the design of efficient scheduling protocols. This paper proposes a polling policy that aims to achieve increased system throughput and reduced packet delays while providing reasonably good fairness among all traffic flows in a Bluetooth Piconet. We present an extensive set of simulation results and performance comparisons with two important existing algorithms. Our results indicate that our proposed scheduling algorithm outperforms the Round Robin scheduling algorithm by more than 40% in all cases tried. Our study also confirms that our proposed policy achieves higher throughput and lower packet delays with reasonable fairness among all the connections.

1 Introduction

Bluetooth (BT) is a wireless technology that has been developed with the original aim to eliminate cables between devices. BT is built on a fast frequency hopping (1600 hops/sec) physical layer operating in the 2.4 GHz frequency ISM band. The immense potential in this technology opened a wide range of applications; the three most popular usage scenarios being replacement for cables that are used to connect devices, universal bridging to connect data networks, and ad-hoc networking to provide a mechanism to form small personal area networks (PANs).

The smallest network unit formed among BT devices is called a piconet, which comprises of a master node and one or more slave nodes. During the process of piconet establishment, the device that initiates a link connection with another device within its range takes the role of the master while the latter takes the role of a slave. Eventually, other slave devices may join the master and thus increase the size of the piconet. Exchange of information takes place only between the master and a slave (i.e., there is no direct slave-slave communication).

The limitation of the BT polling scheme is that once a master polls a slave, the next slot is reserved for the slave irrespective of whether it has data to transmit or not, resulting in a pairwise scheduling of slots between the master
and the individual slave nodes. For such a system, the default Round Robin scheduler, suggested in the BT specification, is not suitable for the BT Piconet as it does not perform well in the presence of asymmetric and heterogeneous traffic conditions.

Thus one requires a scheme that employs an efficient scheduling mechanism which can predict the availability of data at the master and slaves, thereby preventing wastage of slots, and an adaptive packet selection scheme that can adapt (by not allocating slots to slaves that are predicted not to have data packets for transmission) the data transmission according to channel conditions, by choosing the correct packet types. We focus here on scheduling Asynchronous Connection-Less (ACL) data traffic in the presence of asymmetric and heterogeneous traffic.

The rest of the paper is organized as follows: Section 2 gives an overview of the BT technology and polling mechanism. Section 3 introduces our proposed piconet scheduling scheme and its features. Section 4 describes the simulation model and results. Finally, Section 5 concludes the paper.

2 Bluetooth Overview

[1] describes BT architecture and its working in detail. A BT system consists of a radio unit, a link control unit and a support unit for link management and host terminal interface functions. It provides both a point-to-point or point-to-multi-point connection. In the latter case, the channel is shared among several Bluetooth units. Two or more peer units sharing the same channel form a piconet. One of the units in the piconet forms the master node (or simply the master), while the remaining units act as slave nodes (or simply the slaves). All the units in a piconet follow an identical frequency-hopping scheme as determined by the master. Upto a maximum of seven slaves and a master can be active in a piconet. Multiple piconets with overlapping coverage areas form a scatternet. A master in a piconet can be a slave in another piconet. The bridging units which are connected to two piconets use a time division multiplex system for switching between the hopping schemes of the two piconets at regular intervals.

A Time Division Duplex (TDD) scheme is used for transmission of packets where each slot is of 625\(\mu\)s. The master transmits packets in even numbered slots and the slave being polled may transmit in the following odd slot. The packets transmitted by master or slave may cover 1, 3 or 5 time slots.

Two types of links may be established between master and slave(s): Synchronous Connection Oriented (SCO), and Asynchronous Connection-Less (ACL), respectively. The SCO link is a point-to-point link between the master and the specific slave. The SCO link reserves slots and can be viewed as a circuit-switched connection. The ACL link, on the other hand, provides a packet switched connection between the master and slave(s). Data packets are of two types, DM and DH. DM1 (Data Medium rate) may cover up to 1 time slot, DM3 up to 3 time slots, and DM5 up to 5 time slots respectively. DH (Data High rate) packets are similar to DM packets except for the encoding techniques they use. Hence a DH packet contains more data.