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An overlapping communication protocol using improved time-slot leasing for Bluetooth WPANs

Yuh-Shyan Chen[a,*], Yun-Wei Lin[b], Chih-Yung Chang[c]

[a]*Department of Computer Science and Information Engineering, National Taipei University, Taiwan*
[b]*Department of Computer Science and Information Engineering, National Chung Cheng University, Taiwan*
[c]*Department of Computer Science and Information Engineering, Tamkang University, Taiwan*

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Abstract

In this paper, we propose an overlapping communication protocol using improved time-slot leasing in the Bluetooth WPANS. One or many slave–master–slave communications usually exist in a piconet of the Bluetooth network. A fatal communication bottleneck is incurred in the master node if many slave–master–slave communications are required at the same time. To alleviate the problem, an overlapping communication scheme is presented to allow slave node directly and simultaneously communicates with another slave node to replace with the original slave–master–slave communication works in a piconet. This overlapping communication scheme is based on the improved time-slot leasing (TSL) scheme which modified from the original TSL, while the original TSL scheme only provides the slave-to-slave communication capability. The key contribution of our improved TSL scheme is to offer the overlapping communication capability. With the overlapping communication scheme, we developed an overlapping communication protocol in a Bluetooth WPANs. Finally, simulation results demonstrate that our developed communication protocol achieves the performance improvements on bandwidth utilization, transmission delay time, network congestion, and energy consumption.

Keywords: Bluetooth; Time-slot leasing; WPAN; Communication protocol; Wireless communication; Mobile computing

*Corresponding author. Tel.: +886 2 8674 6686; fax: +886 2 2674 4448.
E-mail address: yschen@mail.ntpu.edu.tw (Y.-S. Chen).

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1. Introduction

The advances of computer technology and the population of wireless equipment have promoted the quality of our daily life. The trend of recent communication technology is to make good use of wireless equipment for constructing an ubiquitous communication environment. Bluetooth (The Bluetooth^{TM} wireless technology white paper in white paper; Bluetooth Special Interest Group, 2004; McDermott-Wells, 2005b; Rashid and Yusoff, 2006) is a low cost, low power, and short-range communication technology that operates at 2.4 GHz ISM bands. Those features may applicable for many applications, such as the novel technology, wireless sensor networks (WSNs) (Dai et al., 2005; Cai et al., 2006) and short-range wireless personal area networks (WPANs). Energy consumption is a key issue for WSNs and WPANs. The features of low power, low cost are suitable for the physical layer of WSNs and WPANs. Bluetooth is a possible solution for WSNs and WPANs for the applications with the requirements of the higher data rate.

A Bluetooth scatternet is constructed by many piconets. In a piconet, a master node is responsible to manage at most seven active slave nodes and hundred parked slave nodes (McDermott-Wells, 2005a; Riley and Zhang, 2005). A host can participate two or more piconets simultaneously and alternatively play role of slave node in various piconets. The slave node that participates two or more piconets is defined as relay node. A relay node is used to deliver messages among piconets so that the resources or services will not be restricted due to the maximum number of active members in a piconet. The packet transmission among piconets can be achieved by their common *relay*s (Chang and Yu, 2005; Bray and Sturman, 2001; Proulx et al., 2006; Amin and Bhuyan, 2006). When a master node invites a Bluetooth device as its slave node, it must switch to *inquiry* state and then changes to *paging* state after receiving the 48-bit Bluetooth address and clock of slave node. After paging state, a piconet is constructed. A master node polls slave nodes by sent polling packets to slave nodes using round robin (RR) scheme within the piconet. The master node communicates with one slave node and all other slave nodes must hold and wait the polling packet, so the transmission of other slave nodes is arrested. This condition is called the "transmission holding problem". In addition, the master node has to relay the packets from one slave node to the other slave node (Cordeiro et al., 2006), which is incurred double bandwidth and energy consumption, and the slave–slave communication occupies approximately 75% of all connections (Lee et al., 2007).

To reduce the "transmission holding problem", the efficient scatternet topology formation and establishment schemes are investigated. Law et al. develop a new scatternet formation protocol (Law et al., 2000) by optimizing the number of piconets and minimizing the number of Bluetooth device in each piconet. The transmission holding time is slightly decreased because that piconet polling cycle time is reduced. Amin and Bhuyan (2006) develop a Bluetree scatternet formation scheme to construct a bluetree. It reduces the transmission holding probability by using the bluetree scheduling result. A proximity-awareness and fast connection establishment scheme is proposed by Salonidis et al. (2000) to reduce transmission holding problem. Unfortunately, "transmission holding" problem still exists if utilizing the existing scatternet topology formation and establishment schemes.

Many other novel schemes are concurrently investigated, which aims to completely reduce the "transmission holding" problem. Capone et al. (2001) presented an efficient polling scheme to reduce the master and slave queue lengths. With the smaller length of the master and slave queues, the transmission holding time can be decreased. Kalia et al. (1999) investigated an