Field Performance Comparison of IEEE 802.11b and HomePlug 1.0

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Abstract

The HomePlug 1.0 standard allows high-speed communication on low-voltage power lines without a requirement for new wires. Effective use of the power line bandwidth requires a robust medium access control (MAC) protocol to mitigate the harsh conditions of the power line channel as well as the capability to support prioritized multimedia traffic. This paper briefly describes the HomePlug 1.0 MAC and PHY protocols, which allow prioritized channel access. It then presents field test results comparing this with the more familiar IEEE 802.11b protocol.

1. Introduction

This paper investigates two cost-effective options for providing in-home networks. One is the wireless LAN based on the IEEE 802.11b standard [1, 3, 5]. The other uses the existing low-voltage (110/220 V.) power lines for communication [7, 9] based on the HomePlug Powerline Alliance's HomePlug 1.0 Standard, which enables one to establish an Ethernet-class network over these lines [6].

Power lines make a poor communication channel due to electrical noise, interference, and channel variability depending on the appliances in use [3, 4, 10]. However, tests of Homeplug powerline devices in some 500 homes show that 80% of outlet pairs will be able to communicate at about 5 Mbps or higher, and 98% support data rates greater than 1 Mbps.

2. HomePlug 1.0 protocol

HomePlug 1.0 uses a Physical Layer (PHY) protocol [6] based on equally spaced, 128-carrier Orthogonal Frequency Division Multiplexing (OFDM) [2, 11] from 0 Hz to 25 MHz, in conjunction with concatenated Viterbi and Reed Solomon coding with interleaving for payload data and turbo product codes for control data. 84 carriers are used to transmit data. BPSK, DBPSK, DQPSK or ROBO (a robust form of DBPSK) modulation is used for data, with a cyclic prefix for synchronization.

A pair of nodes first determines which subcarriers are usable, and what form of modulation and error correction should be applied to the channel. This `tone map' is used for subsequent communication between them. Broadcast packets and frame delimiters use all subcarriers with robust modulation and forward error correction codes so that all nodes can interpret them; the rest of a unicast frame uses the higher speed specified by the tone map.

Large attenuation prevents detection of collisions, so HomePlug 1.0 uses CSMA/CA for its MAC protocol. Powerline modems determine if the medium is idle or not, using virtual carrier sense (VCS). If it has been idle for Extended InterFrame Space (EIFS), the station can send the segment without contention. If it is busy, it waits for CIFS (Contention InterFrame Space) or RIFS (Response InterFrame Space) after the end of the current transmission. The delimiter informs the listening nodes' VCS when the transmission will end and whether a response is expected, for synchronization. The receiver sends ACK, NACK, or FAIL after RIFS when it is needed, taking top priority. ACK indicates successful delivery, while NACK indicates an error detected at the receiving station. FAIL indicates that the receiver was unable to buffer the segment.

Otherwise stations wait until the end of the CIFS period, then use two priority resolution slots to select the highest priority level traffic waiting. Nodes with this traffic contend for the medium during the contention window using a randomly selected delay. Initially, there are eight contention resolution slots, and upon collision, nodes increase this to 16 then 32 according to a backoff schedule [10]. Large contention windows are used to avoid costly collisions. In the case of frame control errors or collision, stations must wait for EIFS.

3. Field tests

Performance tests were conducted at a 2700 SF, 10-year-old home with hollow interior walls, a significant advantage for 802.11b. The tests used two laptop computers, one equipped with a USB bridge and the other with an Ethernet bridge for connection to the power line. Each computer also had a Linksys 802.11b card, to link with a Linksys wireless network access point. Initial tests using an *ad hoc* network were so poor that the remainder used a modified infrastructure mode. These tests used two scenarios: 40 MB file transfer using WSFTP (transmit and receive buffer size of 4096 B.) and TCP performance using WSTTCP (4096 B. buffer length, 5000 buffers sent).

Powerline network performance was always better than that of the wireless network (Table 1). The powerline network also had full connectivity. Furthermore, while the 802.11b cards' transfer rate fluctuated greatly, powerline transfers were always at a near constant rate. A small separation between transmitter and receiver did not give the best throughput, and large distances dropped performance of both systems. In open space, the throughput drop was not severe, but a wall between the transmitter and the receiver created a severe throughput drop for 802.11b. Power line throughputs were not the same for the forward and reverse links.

4. Conclusions

This study compared two technologies for implementing a home or small office network without extra cable installation. Throughput for the powerline network is in general not symmetric for a pair of nodes. The overall results show that the power line network outperforms the wireless network for reliable connection service and throughput performance.

5. References

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Table 1. Field test throughput performance results.

Transmitter Location	Receiver Location	Tx to Rx Distance	802.11b T'put (Mbps)		Powerline T'put (Mbps)	
			WSFTP	TTCP	WSFTP	TTCP
Laptop-1	Laptop-2	2 ft	3.2	4.9	4.2	5.2
Study Room	Dinning Room	23	3.6	4.7	4.5	5.3
Home Office	Kitchen	~35	2.5	4.1	4.0	4.5
Kitchen	Home Office	~35	2.4	1.6	3.1	3.1
Bedroom C	Home Office	~70	No Conn.	No Conn.	1.9	1.8
Home Office	Bedroom C	~70	No Conn.	No Conn.	4.1	3.9
Pool Area	Home Office	~60	No Conn.	No Conn.	2.0	1.6
Home Office	Pool Area	~60	No Conn.	No Conn.	2.4	2.8