Demo Abstract: Performance of the Latest Generation Powerline Networking for Green Building Applications

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Abstract

Green building applications need to efficiently communicate fine-grained power consumption patterns of a wide variety of consumer-grade appliances for an effective adaptation and percolation of demand response models down to the consumer level appliances. A key inhibitor to the widespread adoption of such demand response policies at the consumer grade appliances level for intelligent building energy management, is the inability of smart plugs/sensors to efficiently communicate and control the power consumption. However since they already connected with the power grid, a natural question arises, whether the power consumption telemetry can be communicated over existing mains wiring. The use of existing wiring produces a simple and cost-effective attractive solution, and avoids many issues observed with wireless mesh networks, such as islands and bottlenecks and helps vacate the increasing congested spectrum. In this paper we explore the feasibility and efficacy of Powerline Communications (PLC) as a backbone of wireless communications in a home environment, both for high-bandwidth and low-bandwidth intensive applications. In this demo we show several state-of-the-art PLC modems' behavior using end-to-end measurements and their performance, throughput and noise characteristics.

Categories and Subject Descriptors

B.4.1 [**Hardware**]: Input/output and Data Communications—*Data Communications Devices*; C.2.5 [**Computer Systems Organization**]: Computer Communication Networks—*Local and Wide-Area Networks*

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General Terms

Measurement, Performance, Experimentation, Reliability, Standardization

1 Demo Description

The proposed demo would be a re-creation of the test environment as described in [1] to evaluate the performance of some newly designed state-of-the-art PLC standard by exploring the capabilities of a high-bandwidth Ethernet PLC [5] and a low-bandwidth Cypress PLC modem [2]. An interface developed for the demo will plot real-time throughput and reliability for both the high-bandwidth and low-bandwidth power line communication modems [2][5]. Additionally, methods of injecting artificial noise to contrast performance under poor conditions will be used if facilities permit.

1.1 Software

Latency, bandwidth and reliability will be plotted side-by-side in an attempt to provide the clearest comparison between the technologies. Vendor APIs [3] will be used when possible to show typical performance of the high-bandwidth Ethernet PLC and a low-bandwidth Cypress PLC modem. If protocol overhead between the two interfaces differs non-negligibly; no attempt will be made to marginalize the difference in an effort to provide realistic views of throughput.

1.2 Hardware

The software described above will run on two off-the-shelf consumer PCs with a low-bandwidth Cypress and a high-bandwidth Netgear modem.

1.2.1 Low-Bandwidth Interface

The low-bandwidth PLC modem is a Cypress CY3272 exposing an I2C interface [2]. The CY3272 will be connected to the PCs via a Diligent USB <–> I2C bridge. The Cypress CY3272 is a reference platform for the Cypress CY8CPLC10, using FSK modulation to transmit at a max rate of 2400 bps [4].

1.2.2 High-bandwidth Interface

The high-bandwidth PLC modem is a Netgear XAVB5602 with an Ethernet interface [5]. The XAVB5602

Figure 1. Cypress CY3272 Evaluation Board

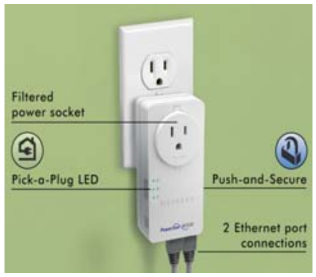

Figure 2. Netgear Powerline 500 Mbps Nano Kit

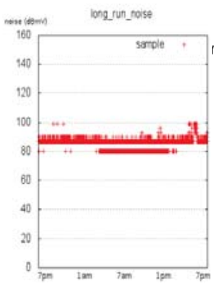

Figure 3. Ambient line noise across 24 hours

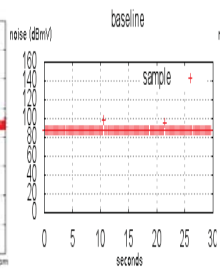

Figure 4. minimal noise baseline

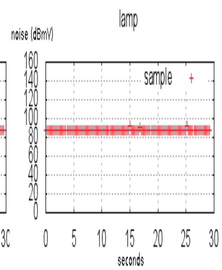

Figure 5. A 40 watt lamp noise in the line

will be connected to the PC via a PCI Ethernet interface. The XAVB5602 implements the Homeplug AV standard, using OFDM modulation and variable sub-carrier modulation that adapts to line conditions to reach a max rate of 500 Mbps under ideal conditions.

2 Cypress Interface: Experimental Setup and Results

The test circuit is a Cypress CY3272 evaluation kit as shown in Fig. 1, which includes the CY8CPLC10 and power line coupler, and pins that expose the CY8CPLC10 I2C interface. Given the limited bandwidth, the overhead of IP was prohibitive in testing. Instead we tested using transmission raw bytes between a pair of modems. In testing range it was found that reception was 100% reliable regardless of where they were attached in the home. Extensive noise testing was done with a variety of devices [1], and then left to run across a 24-hours period as shown in Figure 3.

2.1 Noise Testing

The Cypress IC allows for noise testing in the frequencies used by the transceiver using Cypress's PLC Control Panel software [3]. In the apartment where the range testing was done we tested for impedance of communication and for the noise measured with a small set of household devices in use. Our results showed 100% reliability in reception in all cases, and very little noise on the relevant frequencies. We sampled noise at 200 millisecond intervals, and recorded noise measurements as decibel millivolts. Figure 4 shows the baseline noise over time where only the noise monitoring equipment was operating. Figure 5 represents noise over time for a lamp.

3 HomePlug Interface: Experimental Setup and Results

We have conducted multiple tests in order to quantify the performance characteristics of the latest generation of powerline networking adaptors, HomePlug AV as shown in Fig. 2. Specifically throughput and round trip time (RTT) are the most important metrics to consider, since they indicate the network's capability of transferring large quantities of data with limited latency. Ping tests and iperf software were used to capture these metrics during a distance test and various transfers set up on the extension cord with household appliances operating.

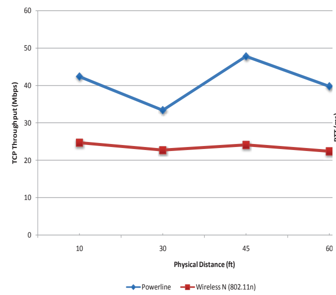

Figure 6. TCP throughput as a function of distance

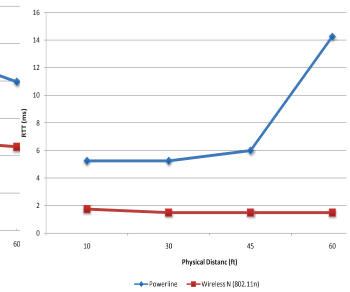

Figure 7. RTT as a function of distance

3.1 Distance and Noise Testing

In this test the adaptors were set up at various outlets within the townhome at increasing distances. These are direct distances between outlets, not electrical cabling distances. Both single floor and multiple floor tests were carried out to demonstrate a wide range of applications. Throughput and RTT were captured at the various outlet positions. At those same positions, an ad hoc wireless network was set up between the two laptops to test the wireless connection for comparison purposes. As shown in Figure 6, the PLC adaptors provide higher throughput than the wireless connection, but the connection seemed less consistent. It was also nowhere near the rated throughput. Figure 7 reinforces the consistency of the wireless connection with respect to RTT, and interestingly the RTT time increases significantly with distance for the PLC adaptors. We also performed extensive experiments to confirm that powerline Ethernet provides rapid but not perfectly reliable transmission of data in presence of noise.

Acknowledgement

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4 References

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