



PowerStream™ Technology Background

Due to the hostile powerline environment and the difficulties of communicating over it, the design of a powerline communications system must be optimized for the powerline in order to meet 5 Mbps throughput and higher without compromising other requirements.

The characteristics of the hostile powerline that need to be contended with are:

- Impulsive noise from dimmers, ballasts, variable speed motors, etc.
- Distortion: Frequency dependent attenuation of up to 60 dB that varies over time
- Reflections from non-terminated points resulting in nulls and distortion

The powerline as a networking medium is an attractive solution because of the ubiquity of electrical outlets in buildings and the simplicity of the power plug. The challenge is to overcome the hostile powerline environment to deliver a powerline communications system requirements of:

- connectivity for a large number of nodes (up to 65,536 nodes) over an area at minimum distance of 300 feet in a home or building
- 5 Mbps throughput for multimedia including audio, video, telephony as well as others
- support for multicast and broadcast with an aggregate throughput of 5 Mbps or more
- prioritization of the network for quality audio, video and phone transmission with sufficient throughput while other applications run simultaneously and with an aggregate throughput of 5 Mbps or more
- BER of $< 1 \times 10^{-9}$
- latency of 0.01 seconds
- compliance with FCC regulations with throughput of 5 Mbps or more

Meeting these requirements is not a simple task. The solution must be specifically designed for the powerline addressing the inherent noise, distortion and reflections. The design must be optimized for the powerline or else the satisfaction of one requirement will compromise the satisfaction of other requirements.

Product Technology & Solution Approach

The powerline communications system developed by Adaptive Networks contains PowerStream™ technology. PowerStream™ is based on Adaptive's proven lower speed approach to communications on the powerline having successfully served industrial and commercial applications with throughputs of up to 100 kbps since 1988. Using our low speed technology as the foundation, PowerStream™ incorporates patented, breakthrough technology that provides for greater throughput (5 Mbps (20 Mbps raw) with the potential of 50 Mbps or even more in the future) while providing for the multipurpose, multi-node network required. With careful consideration of the network requirements and with a deep understanding of the causes and effects of proper and improper communications on the powerline, Adaptive Networks developed

PowerStream™ technology. PowerStream™ technology differs greatly from other powerline communications approaches. The key components of this technology include:

Patented Wideband Spread Spectrum Modulation: PowerStream™ differs from other powerline approaches. These approaches use a multi-carrier technology that requires the transmitter to train to the receiver. This limits the technology's best performance to point-to-point PC-oriented unicast connections. Multi-carrier technology is not sufficient for applications that require low latency. Also, adopters who seek 5 Mbps throughput and who use non-wideband technology will likely have problems meeting FCC Part 15 regulations due to the high power spectral density of these approaches. By using a wideband approach (5 – 35 Mhz), PowerStream™ supports simultaneous multicast & broadcast streams, with high throughput and wide coverage while having a much lower power spectral density. The result is a technical foundation that easily delivers 5 Mbps throughput with multicast & broadcast support AND which meets FCC Part 15 regulations. In addition, the power emissions headroom and our ability to go beyond simple BPSK modulation provided by our wideband approach allows for future increases in throughput (projected at 50 Mbps and even higher) and greater distances for achieving connectivity. Finally, the wideband approach allows for precise digital notching to prevent interference with other transmissions in similar frequencies such as the Ham Radio band.

Patented & Patent-Pending Digital Adaptive Equalization: Other powerline technology developers have shied away from the wideband approach compromising on multiple carriers (e.g., OFDM) due to the challenge of equalizing the distorted signals inherent on the powerline. Adaptive Networks chose to meet this challenge developing patented digital equalization permitting dynamic, instantaneous adaptation to the inconsistencies of powerlines. Requiring significant innovation and effort, Adaptive's patented frequency domain equalization (FDE) is the core technology that makes high-speed communications possible on the powerline and on other distorted media.

Patented & Patent-Pending Rapid Synchronization: PowerStream™ uses rapid synchronization enabling very short frame sizes to contend with the noise that challenges speed and connectivity.

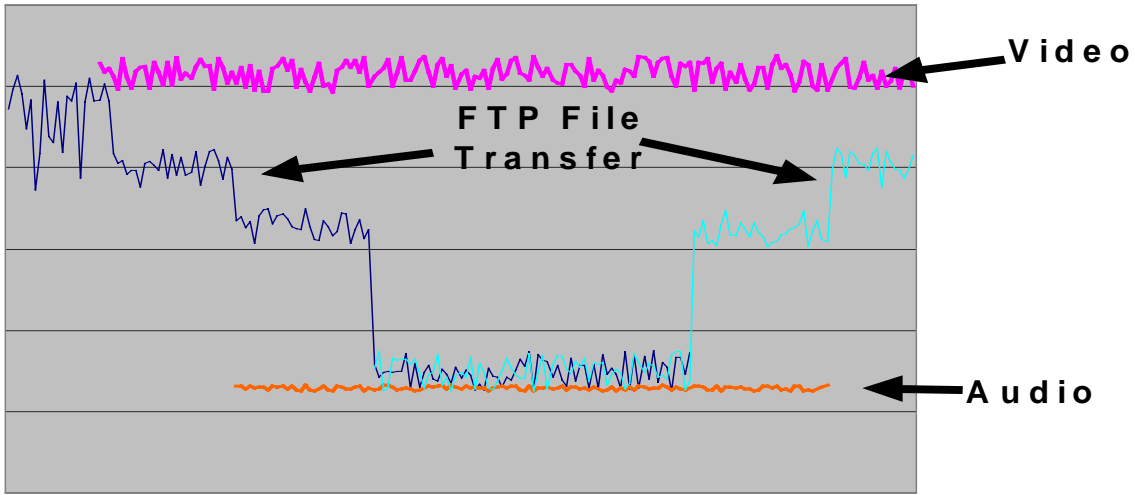
Patented & Patent-Pending Error Control Coding: Powerline communications requires more than a robust Physical Layer. PowerStream™ has a reliable Low Level Link Protocol with rigorous Forward Error Correction & Error Detection and Retransmission. Forward Error Correction offers the advantage of sustaining throughput under extreme conditions.

Patent-Pending Powerline Optimized token passing protocols: Conventional wisdom has led others to a CSMA approach for handling the MAC. This approach works well in static media such as phone lines but is severely compromised in the dynamic powerline environment, especially when communicating over larger distances. Due to these inconsistencies, communication with a CSMA approach cannot be guaranteed to reach all of its intended nodes in a reliable manner and on a timely basis, if at all. PowerStream™ uses a powerline optimized token passing protocol that deterministically insures that each node on the network is communicated to whether near or far and regardless of noise on the network. With a Token Rotation Time (TRT) of 0.01 seconds each node is assured a timely, successful transmission. For demanding multimedia applications this is especially important.

Patent-Pending Integrated Physical Layer QoS: To provide true QoS on the powerline an integrated approach at the PHY, MAC and Link layers is required.

- PHY: Digital Adaptive Equalization on-the-fly allowing for multicast & broadcast and Rapid Synchronization
- MAC: Deterministic access with inherent QoS support via a token passing protocol
- Link : Provides a SAR with multiple priority levels

The result is a system that is able to manage multiple simultaneous streams including multimedia multicast and broadcast streams with consistent throughputs.



PowerStream™ technology demonstrating simultaneous file transfer, video and audio streams over the powerline with provisioning of bandwidth and steady prioritization of multimedia streams using Chariot testing software by NetIQ.

Technology Summary

Physical Environment	Requirements	Adaptive Solution
Network not point-to-point link	All nodes can hear any transmission	<ul style="list-style-type: none"> Wideband Modulation Adaptive Equalization
Severe frequency-dependent attenuation	Wideband signalling	<ul style="list-style-type: none"> Wideband Modulation
Dynamic time-dependent network characteristics	Receiver must adapt on faster time scale	<ul style="list-style-type: none"> Fast Synchronization Adaptive Equalization SAR
Location-dependent network characteristics	<ul style="list-style-type: none"> All Receivers must adapt to current transmitter Deterministic MAC 	<ul style="list-style-type: none"> Adaptive Equalization PL-optimized Token Bus Protocol
Noise	<ul style="list-style-type: none"> Robust synchronization FEC and ARQ Wideband signalling Deterministic MAC 	<ul style="list-style-type: none"> Fast Synchronization FEC ARQ Wideband Modulation PL-optimized Token Bus Protocol
Isochronous communications	<ul style="list-style-type: none"> Short frames Low latency MAC QoS support 	<ul style="list-style-type: none"> SAR PL-optimized Token Bus Protocol Token Rotation Time Token Hold Time Priorities
Multiple homes per transformer	Multi-home MAC	<ul style="list-style-type: none"> Multi-home PL-optimized Token Bus Protocol