A Low-Cost Chip Set for Broadband Powerline Communications at 200 Mbps

Chano Gómez, DS2

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What is Powerline Communications?

Powerline Communications is a technology that enables transmission of high-speed data over electrical lines.
What are the Applications?

<table>
<thead>
<tr>
<th>Access Network</th>
<th>Access Extension</th>
<th>Home Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Optical</td>
<td>DIGITAL MEDIA PLAYER</td>
<td>ADDITIONAL ADAPTER (NOT INCLUDED)</td>
</tr>
<tr>
<td>DIGITAL MEDIA PLAYER</td>
<td>ADDITIONAL ADAPTER (NOT INCLUDED)</td>
<td>POWERLINE HD ADAPTER</td>
</tr>
<tr>
<td>CABLE/DSL MODEM</td>
<td>WIRED GIGABIT ROUTER</td>
<td>POWERLINE HD ADAPTER</td>
</tr>
</tbody>
</table>
Wall-plug is most common form factor
Why not simply Wireless?

Because Powerline provides connectivity where Wireless 802.11n can’t

Percentage of locations capable of delivering 10, 20 & 30 Mbps UDP streams with 0% PLR.
Test performed in 9 homes in urban areas in Europe. Source: DS2
Powerline Networking is a Challenging Technical Problem

- Electrical wires were never designed for high-speed transmission...
- Uncontrolled and (almost unpredictable) environment
- Impedance mismatch causes Strong multipath effect
- Unknown, non-flat and non-stationary channel frequency response
- Electrical devices connected to the network generate non-gaussian, non-white, non-stationary noise
- Risk of EMC problems because of unshielded wires
## Technical Features of Modern Powerline Communication Systems

<table>
<thead>
<tr>
<th>Feature</th>
<th>Type</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2-32 MHz</td>
<td>Lower Frequencies are too noisy. Higher Frequencies have too much attenuation and FCC limits are too strict</td>
</tr>
<tr>
<td>Modulation</td>
<td>OFDM</td>
<td>OFDM systems can adapt to non-frequency-flat channels well.</td>
</tr>
<tr>
<td>MAC</td>
<td>TDMA</td>
<td>Time-Division Multiple Access provides better QoS than CSMA systems</td>
</tr>
<tr>
<td>PHY Data Rate</td>
<td>200 Mbps</td>
<td>Currently limited by available spectrum and available SNR</td>
</tr>
<tr>
<td>App Data Rate</td>
<td>120 Mbps</td>
<td>MAC, LLC and FEC overhead</td>
</tr>
<tr>
<td>Encryption</td>
<td>AES-256</td>
<td>To avoid eavesdropping by neighbours!</td>
</tr>
</tbody>
</table>
Dealing with the specific characteristics of the power line channel
Multipath Effect:
Channel Response is Frequency Selective

Combination of original signal + echo produce **stronger** signal at frequency $f_x$

Combination of original signal + echo produce **weaker** signal at frequency $f_y$
How do received signals look like?

Spectrum of Transmitted Signal

Spectrum of Received Signal

Spectrum of Received Signal + Noise

Strong signal at $f_x$

Weak signal at $f_y$

Weak SNR at $f_a$

Strong SNR at $f_b$
SNR Determines Optimum Modulation Scheme

Well Defined and away from the decision boundaries

Well Positioned Dots in a Square

Dots are spread out causing errors to occur
Each sub-carrier is modulated according to the SNR in that frequency.

Spectrum of Received Signal + Noise

Spectrum of Signal-to-Noise Ratio (SNR)

Modulation Level used in each sub-carrier
Block diagram of a powerline communications transceiver
Programmable QoS is Key

- Powerline networks are usually deployed in environments where packets may not have QoS tags (802.1p, TOS, DSCP, etc)

- Powerline devices need to figure out how to assign priorities with limited information

- Goal: Allows device manufacturers and service providers to create custom QoS rules that are appropriate for the intended application.

- Example in pseudocode:
  ```
  if ethernet.type == IPv4 then
    if ip.dst_address == 192.168.4.3 then
      powerline.priority = 6
    else
      powerline.priority = 1
    else if ethernet.vlan == 5 then
      powerline.priority = 2
  else
    powerline.priority = 1
  ```

- Note: in practice this is done configuring registers (see next slide...)
Programming Prioritization Rules

Offset 0

Bit-mask 0 =

Pattern 0

Bit-mask 1 =

Pattern 1 =

Pattern 2 =

Pattern 3 =

Pattern 8 =

Other

Priority 1

Priority 2

Priority 3

Priority 8

Default Priority

Trigger

Ethernet Packet
AITANA™ Chipset
Block Diagram of a Powerline-to-Ethernet Bridge

[Diagram showing the TX and RX paths, User Interface, GPIOs, SPI Bus, PHY/MAC/Network Processor (DSS9101), Analog Front End (DSS7800), Coupling Unit, and AC line.]
<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>• PHY, MAC &amp; Network Processor</td>
</tr>
<tr>
<td>Standard</td>
<td>• UPA (Universal Powerline Association)</td>
</tr>
</tbody>
</table>
| Electrical information | • LQFP176  
                       | • Power consumption: 1.2W                                                  |
|                    | • I/O Voltage: 3.3V                                                         |
| PHY                | • OFDM Modulation (1536 carriers)                                          |
|                    | • 2-32 MHz                                                                  |
|                    | • Programmable Carrier Notching                                             |
|                    | • Reed-Solomon + 4D-Trellis FEC                                             |
|                    | • Up to 16 remote devices                                                   |
| Data Rate          | • 200 Mbps (PHY layer)                                                     |
|                    | • 120 Mbps (Ethernet layer)                                                 |
|                    | • 128k packets/sec                                                          |
| Ethernet Switch    | • 802.1d compliant, supports STP                                            |
|                    | • 802.1Q compliant                                                          |
|                    | • 32 MAC addresses                                                          |
|                    | • Packet Snooping (IGMP, etc)                                                |
|                    | • Supports automatic repeating                                              |
| Security           | • AES-256, AES-128, 3DES & DES Encryption                                   |
|                    | • Support for “One-Button Security”                                         |
| QoS                | • 8 priorities                                                              |
|                    | • Programmable prioritization rules                                        |
| Embedded Processor | • Tensilica Xtensa (160 MHz)                                               |
|                    | • SDK available                                                             |
| Interfaces         | • MII, 2 x SPI, I2S/TDM, 8 x GPIO, JTAG, UART                              |
| Technology         | • Toshiba SoC                                                               |
|                    | • ADC, DAC, PLL provided by Toshiba                                         |
DSS9191 Block Diagram
Packet Flow inside the DSS9101
Example of Supported Modes
### DSS7800

<table>
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</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>• AFE (Filter + Line Driver)</td>
</tr>
</tbody>
</table>
| **Electrical information** | • QFN48 7x7mm RoHS  
• 5V Power Supply  
• Power consumption:  
  • Tx mode: 1700 mW  
  • Rx mode: 685 mW  
  • Idle mode: 15 mW |
| **Features**       | • Integrated Line Driver  
• Integrated Low Pass Filter (Anti-aliasing & Smoothing)  
• Power-down Control for each path  
• Programmable Low Noise Amplifier  
• Fully Differential  
• SPI Interface |
| **Manufacturing**  | • Austria Micro Systems |
Transmission & Reception Mode
Test set-up: Two powerline adapters connected through flat channel attenuators in isolated network. Test software: Chariot (bidirectional data transfer). Equipment: DS2's DW21P reference design (DSS9101 chip) and Devolo AV Easy (INT6300 chip). AC cycle: 60Hz.
What next?

- 200 Mbps specification over power lines
  - 2006-2008

- 400 Mbps specification over power lines (PowerMAX)
  - 2008-2009

- 1 Gbps specification over power lines, phone lines and coaxial cable
  - >2010
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