Convergence in Home Networking: Broadband over Powerline and Other Wireline Technologies

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Disclaimer

- Contents of this presentation do not represent the official position of DS2, UPA, ITU-T, IEEE, HomeGrid Forum or any other organization mentioned in the presentation.
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>
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![Diagram showing network connections and applications](image-url)
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- **Passive Optical Network**
  - Provider’s Central Office (CO)
  - Optical Line Terminal (OLT)
  - Optical Distribution Network (ODN)
  - Optical Network Units (ONU)
  - Splitter
  - Fiber connections

- **FTTC** (Fiber to the Curb)
- **FTTN** (Fiber to the Neighborhood)
- **FTTP/FTTH** (Fiber to the Premises/Home)
### What are the Applications?

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<td><img src="image3.png" alt="Home Network Diagram" /></td>
</tr>
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</table>

**Access Network**
- Residential
- Substation
- Optical Signal
- Fiber optic cable

**Access Extension**
- Passive Optical Network
- Provider's Central Office (CO)
- Optical Distribution Network (ODN)
- Optical Network Units
- FTTC (Fiber to the Curb)
- FTTN (Fiber to the Neighborhood)
- FTPP/FTTH (Fiber to the Premises/Home)

**Home Network**
- Residential
- Optical Device
- Fiber optic cable
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**What are the Applications?**

- **Access Network**
  - Cable/DSL MODEM
  - Wired Gigabit ROUTER
  - Powerline HD ADAPTER

- **Access Extension**
  - Additional Adapter (NOT INCLUDED)
  - Powerline HD ADAPTER

- **Home Network**
  - DIGITAL MEDIA PLAYER
  - DESKTOP PC
# What are the Applications?

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- **FTTC**: Fiber to the Curb
- **FTTN**: Fiber to the Neighborhood
- **FTTP/FTTH**: Fiber to the Premises/Home
Wall-plug is most common form factor today
IPTV is today the main driver for the powerline networking industry.
The problem we are trying to solve

“The average installation time for our IPTV service has dropped from 7.5 hours to 6.5 hours per home.”

Quote from one of the largest Telcos in North America, Oct 2007
What exactly do we need 6.5 hours for?
What exactly do we need 6.5 hours for?
What exactly do we need 6.5 hours for?
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.
Value proposition to Service Providers

- Powerline technology provides:
  - Lower installation costs/times than any other wired solution (including those based on coaxial cable or phone lines).
  - Opens up the possibility for truly self-installed IPTV
  - Provides consumers with a more convenient solution than cable TV: they can install a TV wherever they want.
But coaxial and phonelines are also valuable options

- Coaxial cable and phonelines usually provide a very high-speed connection, if they are available in the desired location.

- Even if powerline connections are available in more locations, next generation networks cannot afford to ignore the vast amount of bandwidth available in coaxial cables and phonelines.

- We need a single standard that can take advantage of all available media.
IPTV is today the main driver for the powerline networking industry.
IPTV Growth

Source: Broadband Forum, July 2008
IPTV is growing faster in Europe....

....where coaxial cable and phone lines are usually not widely available for home networking.
In Europe, Service Providers are deploying millions of powerline home networks for IPTV delivery
Win a weekend in a haunted house
Enter our competition now >>

Set up costs
In order to receive BT Vision in your home you’ll need BT Total Broadband. But don’t worry if you don’t have it already as we can sign you up when you order BT Vision. Our friendly customer services team will advise on what the best package is for you.

V-box™ £ FREE*
(otherwise £199)

You can choose from the following two installation options:

**Engineer Install**
- **Connection fee**: £ 30
- **Installation fee**: £ 60
- **Total**: £ 90

**Self Install**
- **Connection fee**: £ 30
- **Installation fee**: £ FREE
- **Total**: £ 30

Get BT Vision now
How does British Telecom provide a self-install solution?
Self Install Guide
Contents

BT Vision Quick Start Guide .................................. 1
How it all works .................................................. 3
Step 1 – Check your kit ........................................... 5
Step 2 – Connect your Powerline Adapters ............ 9
Step 3 – Connecting your BT Vision ....................... 13
Step 4 – Start up your BT Vision ......................... 17
FAQs ..................................................................... 25
Helpdesk ................................................................ 39
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Step 1 - Check your kit

BT Vision

Check that your kit contains all the items shown on this page. If anything is missing, please call the BT Vision Customer Services on 0800 800 900 (open daily between 8am and 10pm).

IMPORTANT: Depending on the way your service is set up, you might not need all the cables. Just keep them safe in case you need them in the future.

1 x BT Vision V-box™  
1 x BT Vision Remote Control  
1 x Pack of Batteries

1 x BT Vision Welcome Pack & Additional Information Booklet  
1 x Aerial Lead  
1 x Phone Lead (not required for set-up)

1 x Mains Lead  
1 x SCART Lead  
1 x Ethernet Lead

Comtrend Powerline Adapters

You will receive Comtrend Powerline Adapters.

2 x Powerline Adapters  
1 x Ethernet Lead
Step 2 - Connect your Powerline Adapters

1. Open the back of the BT Home Hub and plug one end of an Ethernet Lead into yellow Ethernet Port 1. If you already have another device plugged into Ethernet Port 1, please move it to Ethernet Port 2. Plug the other end of the Ethernet Lead into the Ethernet Socket on the bottom of one of the Powerline Adapters.

2. Plug this Powerline Adapter into a wall power socket near your BT Home Hub.

3. When plugged in and switched on, the Status Light will be red, the AP (Access Point) Light may be orange or off.

4. Plug the other Powerline Adapter into a wall socket near to the BT Vision V-box™.

5. Connect the other supplied Ethernet Lead between the Yellow LAN Socket on your BT Vision V-box™, and the Ethernet Port on the nearby Powerline Adapter. The connectors will click into place when correctly inserted.

Configuration for Powerline Adapters.

BT Home Hub

Ethernet Port 1

Powerline Adapter

Ethernet Lead

House Mains Wiring

Powerline Adapter

BT Vision V-box™
A model to be copied

- The “self-install” model will be replicated by most IPTV Service Providers, as they are pushed to:
  - reduce cost
  - accelerate subscriber growth
  - improve customer satisfaction
Powerline Networking
Technical Challenges
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 multi-path effect
  • Unknown, non-flat and non-stationary channel frequency response
  • Electrical devices connected to the network generate non-gaussian, non-white, non-stationary noise
  • Potential Risk of EMC issues 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>
Performance in Multiphase topologies

Because of the high frequencies used by modern powerline communications systems, capacitive coupling between phases (i.e. “cross-talk”) provides enough performance even for devices connected in different phases.

![Bar chart showing performance in different houses](chart.png)

**Figure 2.** Phase 1 In-Phase vs. Cross-Phase Results

Application Examples
Block Diagram of a Powerline-to-Ethernet Bridge

PHY/MAC/Network Processor (DSS9101)

Analog Front End (DSS7800)

User Interface (Buttons, LEDs, etc)

SPI Bus (AFE Control)

Ethernet PHY

MII

TX/RX path

Flash

SDRAM

GPIOs

Powerline-to-Ethernet Bridge

AC line

Coupling Unit

HPF
Standards in powerline technology
Situation until last year

- Wired networking industry heavily fragmented
- Different technologies for different media:
  - MoCA over coax
  - HomePNA over phoneline and/or coax
  - Three incompatible specification for powerline
    - UPA (single “de-facto” vendor: DS2)
    - HomePlug AV (single “de-facto” vendor: Intellon)
    - HD-PLC (single “de-facto” vendor: Panasonic)
Very complex situation in powerline

- DS2’s UPA products don’t interoperate with...
  - Panasonic’s HD-PLC products, which don’t interoperate with...
    - Intellon’s HomePlug 1.0/Turbo products which don’t interoperate with...
      - Intellon’s HomePlug AV products.
Standards consolidation

- Two efforts being developed almost in parallel:
  - IEEE P1901: 3-PHY/3-MAC specification that works over powerline.
  - ITU G.hn: 1-PHY/1-MAC specification that works over powerline, phonelines and coaxial cable.
IEEE P1901

- Since October 2007, the group has been considering a proposal based on two different PHY and MAC specifications (trade-off between two proposals that the group could not merge).

- A proposal needs to get 75% positive votes to become a baseline. Then it would take 2-3 years to become a standard.


- In Dec 2008, P1901 added a 3rd PHY/MAC to the proposal. This 3PHY/3MAC proposal got enough support to become “baseline”.

- The 3rd PHY/MAC is called GC (“G.hn compatible”)
P1901 block diagram

Common Convergence Layer (Ethernet interface)

- **OFDM MAC**
  - OFDM PHY
  - Inter-PHY Protocol

- **Wavelet MAC**
  - Wavelet PHY
  - Inter-PHY Protocol

- **G.hn compatible MAC**
  - G.hn compatible PHY
  - Inter-PHY Protocol

DS2
Powerline is the technology of choice for IPTV in Europe, but the US market for wired solutions is still fragmented, with significant presence of coax and phoneline solutions.
Nobody is completely happy in a fragmented market

“Silicon Vendors”
“We’d like to have the chance to address additional markets without increasing our NREs”

“Equipment Vendors”
“We’d like to simplify our product design, be able to serve more markets with fewer products, and get more choices when choosing silicon vendors”

“Service Providers”
“We’d like to deploy solutions that can work in 99.999% of situation, no matter how our customers’ networks look like”
How do we go from a fragmented market...?
... to a unified market?
ITU-T G.hn - Unifying the wired home networking market

• G.hn has developed a standard that specifies a single-PHY/single-MAC that works over any kind of home wiring (power lines, phone lines and coaxial cable)

• Depending on how vendors implement the different options included in the standard, G.hn networks will provide “real life” speeds 2x to 5x time faster than today’s wired technologies.
Unifying the industry

<table>
<thead>
<tr>
<th>Power lines</th>
<th>Coaxial cable</th>
<th>Phone lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPLC</td>
<td>MoCA</td>
<td>HPNA over Phonelines</td>
</tr>
<tr>
<td>HomePlug</td>
<td>HPNA over Coax</td>
<td></td>
</tr>
<tr>
<td>UPA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ITU-T G.hn over power lines, phone lines and coaxial cable

Today

Tomorrow
Seamless migration path

- Today’s wired technologies provide a good solution for today’s problems.

- G.hn will provide solutions for tomorrow’s problems.

- By the time G.hn products are in the market, we’ll have millions of “legacy devices” based on today’s technologies.

- Although interoperability with today’s technologies is “out of scope” for G.hn, most silicon vendors are expected to provide implementations that allow today’s network to migrate to G.hn in the future.
Dual-mode chips will provide migration path

- DS2 UPA-compatible 100 Mbps
- DS2 UPA-compatible 200 Mbps
- DS2 G.hn/UPA-compatible 400+ Mbps
- Other G.hn vendors
Timeline

- Recommendation G.hn (now known as G.9960) was “consented” in Dec 12th 2008.
- G.9960 includes PHY layer and system architecture
- G.9960 allows silicon vendors to start designing chips
- The rest of the G.hn recommendation (MAC and security) is expected to be consented between May and Sept 2009.
- First chips expected to be sampling in 4Q2009, first products in 2Q2010
Support for G.hn from multiple silicon vendors
Support for G.hn from multiple silicon vendors

Aware Applauds the ITU’s Consent of a Revolutionary New Home Networking Technology

Semiconductor vendors plan development of G.hn chipsets as wired home networking shifts to a global mass-market.

BEDFORD, MASS – December 15, 2008 – Aware, Inc. (NASDAQ: AWARE), a leading supplier of wireline communications technology to semiconductor companies, applauds the International Telecommunications Union’s (ITU) remarkable success in achieving the on-schedule consent of the new G.hn standard (G.9960) last week in Geneva, Switzerland. G.hn is a next generation home networking technology that enables users to share all varieties of digital content over any of the three most common wire-types found in homes worldwide: coaxial cables, electrical wires, and telephone lines. G.hn’s three-wire capability and performance exceeds existing wired and wireless home networking technologies, making G.hn ideal for distributing all varieties of digital content, including multiple channels of high definition television (HDTV), throughout an entire home.

“Broadband access to the home has seen major advancements in the last few years,” said Mario Finocchiaro.
Support for G.hn from multiple silicon vendors

CopperGate Communications Commits to G.hn
12.15.08, 09:47 AM EST

CopperGate Communications, the Everywire Home Networking Company(TM), has announced full support for G.hn, the next generation home entertainment network standard, which was just approved by the International Telecommunication Union (ITU) in Geneva, Switzerland on December 12, 2008.

G.hn represents the first global standard to support all three wire types that already exist in consumers’ homes: phone lines, coax cables and AC power lines. The new standard (Recommendation ITU-T G.9960) is designed to deliver up to 20 times the throughput of existing wireless technologies and more than three times the performance of existing wire solutions. On December 12, the G.hn working group consented on a "foundation specification" that will allow silicon manufacturers to begin designing solutions. Ratification of the
Support for G.hn from multiple silicon vendors
How hard is it to design a single-PHY/single-MAC standard for 3 different wires?

- Not so hard...
- Power lines are the most “hostile” environment for communications (noise, interference, changing channel conditions, etc)
- If a system works over power lines, it can work over anything
How does ITU-T G.hn look like?

Data Link Layer

- Application Protocol Convergence
- Logical Link Control
- Medium Access Control
- Physical Coding
- Physical Medium Attachment
- Physical Medium Dependent

Physical Layer

- Ethernet encapsulation
- AES128 Encryption CCM mode
- Selective Retransmission
- Master/Slave MAC
- TDMA+CSMA
- FEC: QC-LDPC-BC
- Frequency + Time Redundancy
- OFDM+QAM modulation
How does ITU-T G.hn look like?

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Only this part is “medium dependent”
PHY layers

Figure 7-1/G.hn – Functional model of the PHY

Note: diagram cited from G.hn draft (Nov 2008) - subject to change
(Simplified) Frequency Bands

- **Powerline**
  - 0-50 MHz
  - 0-100 MHz
  - 100-200 MHz

- **Phoneline**
  - 0-50 MHz
  - 0-100 MHz

- **Coaxial (baseband)**
  - 0-50 MHz
  - 0-100 MHz

- **Coaxial (RF)** - [between 300 and 2000 MHz]
  - 50 MHz wide
  - 100 MHz wide
  - 200 MHz wide (Japan only)

Coax RF is compatible with cable modem, cable TV and satellite TV.
PSD mask for each medium

Figure 7-24/G.9960 – Limit PSD mask for transmission over phone lines (Amateur radio-band notches are not shown)

Figure 7-25/G.9960 – Limit PSD mask for baseband transmission over power lines (Amateur radio-band notches are not shown)

Figure 7-27/G.9960 – Limit PSD mask of a single channel for RF transmission over coax

Figure 7-28/G.9960 – Limit PSD mask of baseband coax

Note: diagrams cited from G.hn draft (Dec 2008) - subject to change
G.hn Scales OFDM parameters to adapt to the medium

Carrier spacing in coaxial cable:
- Carrier Spacing: 195.31 kHz

Carrier spacing in phoneline:
- Carrier Spacing: 48.82 kHz

Carrier spacing in powerline:
- Carrier Spacing: 24.41 kHz
Notches for ham bands

Table D-1/G.hn – International HAM bands in the frequency range 0-30 MHz

<table>
<thead>
<tr>
<th>Band start (kHz)</th>
<th>Band stop (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 800</td>
<td>2 000</td>
</tr>
<tr>
<td>3 500</td>
<td>4 000</td>
</tr>
<tr>
<td>7 000</td>
<td>7 300</td>
</tr>
<tr>
<td>10 100</td>
<td>10 150</td>
</tr>
<tr>
<td>14 000</td>
<td>14 350</td>
</tr>
<tr>
<td>18 068</td>
<td>18 168</td>
</tr>
<tr>
<td>21 000</td>
<td>21 450</td>
</tr>
<tr>
<td>24 890</td>
<td>24 990</td>
</tr>
<tr>
<td>28 000</td>
<td>29 700</td>
</tr>
</tbody>
</table>

Note: diagram cited from G.hn draft (Nov 2008) - subject to change
G.hn’s LDPC code provides better performance at low Block Error Rate than alternative CTC codes.
G.hn encapsulation

Figure 8-4/G.hn – Assembling of an MPDU

Note: diagram cited from G.hn draft (Nov 2008) - subject to change
TXOPS (Transmission Opportunities)

CFTXOP: Contention-Free TXOP
CBTXOP: Contention-bases TXOP
STXOP: Shared TXOP (includes both CF and CB TXOPs)

Figure 8-9/G.hn – Example of a MAC cycle structure

Note: diagram cited from G.hn draft (Nov 2008) - subject to change
Per-flow bandwidth reservation

Figure 8-16/G.hn – MSC showing establishment of a flow to carry unicast data

Note: diagram cited from G.hn draft (Nov 2008) - subject to change
New capabilities enabled by G.hn standard (I)

- Multi-port devices that can select the best communication path between several locations

![Diagram showing G.hn-enabled devices connected via power lines, phone lines, and coaxial cables.]

- G.hn-enabled gateway
- G.hn-enabled STB
- G.hn-enabled STB

Power lines
Phone lines
Coaxial
New capabilities enabled by G.hn standard (I)

- Multi-port devices that can select the best communication path between several locations
New capabilities enabled by G.hn standard (II)

- Multi-transceiver devices can transmit data over several networks simultaneously
About HomeGrid Forum

• HomeGrid Forum has been created as a companion to ITU-T G.hn, with the goals of:

  • Accelerate the technical development of the G.hn standard
  
  • Promote the adoption of G.hn technology in the market
  
  • Ensure G.hn compliance and interoperability, by means of a HomeGrid logo program
HomeGrid Forum Overview and Status

- Announced on April 29, 2008 to promote adoption of G.hn
- >300 press articles, overwhelmingly positive in support of unifying wired networking market
- Analyst community briefed and supportive
- HomeGrid members making substantial contributions to ITU-T G.hn
- Liaison agreements in process with key industry groups

Founding Promoter
Board of Directors

Founding Promoters

Founding Contributors
G.hn Companion Support

ITU-T G.hn
- Creating the specification
- Long-term path for a single PHY/MAC technology that can run over coax, phoneline, powerline
- Broadly supported, with ~35 companies participating, including numerous service providers

HomeGrid
- NOT creating a specification
- Focused on promoting G.hn to the market
- Companion SIG to to ITU-T G.hn, similar to how Wi-Fi Alliance™ and WiMax Forum™ support IEEE 802.11 and IEEE 802.16
Key Takeaways

- One standard for any wire in the home
- Next-generation performance, at 2 to 5 times today’s speeds
- All interested industries participate, so everyone’s represented
- Internationally accepted standards body
- Technology and know-how exists
- Industry is unifying around HomeGrid
Summary

- IPTV delivery is the main driver for wired home networks today.

- Different networking options available in different geographic areas.

- Powerline is most popular option in Europe, which is the major market for IPTV today.

- IPTV Market in North-america is fragmented between coaxial, phoneline and (to a lesser degree) powerline technologies.

- Silicon vendors, equipment manufacturers and Service Providers are interested in unifying all these technologies into a single global standard that can increase total market size, increase competition, reduce product development costs and lower prices.

- ITU-T G.hn is the best candidate for unifying the industry around a single-PHY/single-MAC standard

- HomeGrid Forum is working towards accelerating G.hn, promote its adoption and certify interoperable products.

- DS2, as an active member of UPA, G.hn and HomeGrid Forum, is working to ensure the industry rallies around a single standard.
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