Powerline Technologies In Home Networking
Agenda

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  – Push for Home Networking
    • Applications
  – Market Acceptance & Penetration
  – Applications
  – Market Direction

• Technology
  – Control Network
  – Power Line Technologies
    • Intellon CEBus
      – CEBus & OSI Model
      – Spread Spectrum Technology
  – Echelon LONWork
    – LONTalk Protocol
    – Architecture
  – Carrier Sense Multiple Access/Collision Detection
  – X 10
  – Plug in
  – Adaptive Networks
    – hybrid token passing media access scheme

• Products
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The Push for Home Networking

- Rapid growth in multiple-PC household penetration (Dataquest)
  - PC penetration exceeds 50% in US households
- Increasing Internet usage (Yankee Group)
  - Nearly 90% of PC households will be online by 2001
  - Online households growth: 20% (in 1997) to 47% (in 2001)
- Broadband Internet access (Forrester Research)
  - Broadband penetration growth: less than 1M (in 1998) to more than 15M (in 2002)
  - % Penetration of online households: increases from 2% (in 1998) to 26% (in 2002)
The Push for Home Networking

• More digital appliances are coming into the home (by IDC)
  – DSS, DVD, Digital TV
  – Web-Top boxes, set-top boxes
  – PDAs, mobile (cellular) phones
  – Digital cameras
  – Installed base of internet appliances will exceed 50M by 2001

• More digital content being shared at homes
  – Published Content
    • CD-ROMs, DVDs, DVRs, digital photography
  – Networked Content
    • DTV, DBS, VoIP, MP3, movies-on-demand, streaming media
Four Aspects to Home Networking

- **Broadband Access**
  - xDSL, Cable, ISDN, Satellite, Powerline, Analog Dial-up, Phoneline

- **Residential Gateway**
  - Set-top Box, Digital Modems, PCs, Gaming Consoles, SOHO Routers

- **Home Networking Technologies**
  - Ethernet, IEEE 1394, USB 2.0, Powerlines, Phonelines, Wireless LANs (HiperLAN2 & IEEE 802.11), HomeRF, Bluetooth

- **Information Appliances**
Applications Driving Home Networking

Phone Line | Power Line | RF | Ethernet | Other
---|---|---|---|---
1999 | 2000 | 2001 | 2002 | 2003

Courtesy: Dataquest
Market Growth Projection

Annual Spending ($M US)

- Home Control
- Multimedia Distribution
- Home PC Networking

Forrester 2/98
Powerline Based Applications In Home Networking

- Home Automation
  - Lighting Control
  - Temperature & Ventilation Control
  - Security
  - Sprinklers
  - Audio/Video Control
  - Sensors
  - Gates & Doors Control
  - Pool & Spa Control
  - Phone Control
  - PC Control
Powerline Based Applications In Home Networking

• Shared Internet Access
  – Extensions of Cable, xDSL, and POTS modems
  – Can be used in powerline-based Residential Gateways, Set Top Boxes, DLS, Cable, and Satellite modems
  – Multiple PC users can share the Internet via single connection

• Remote Peripherals
  – Printers, Scanners, Fax, especially when these peripherals are connected through the USB port

• IP Telephony from 'Fat Pipe'
  – Extensions of IP and other forms of Cable modem telephony from set-top boxes to telephones around the house
Powerline Based Applications In Home Networking

- Power Line Audio Systems
  - Remote deployment of speakers playing PC based music
  - No need to additional wiring for speakers
- Ethernet Powerline Networking Modules
- File Sharing in Multiple PC Homes
  - Music
  - Images
  - Video
  - Games
Worldwide Revenue Forecast

Source: Cahners In-Stat Group
Market Acceptance

![Market Acceptance Chart](chart.png)

- **Phone Line**
- **Power Line**
- **RF**
- **Ethernet**
- **Other**

*Courtesy: Dataquest*
Problem: Islands of Technology
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Powerlines Advantages

• Most Ubiquitous Coverage of any media
• More likely to have a power line connection within reach of any home PC than you are a phone jack
  – Each room has “at least” one or two power outlets
Powerlines Advantages

• Multiple power outlets can be found in each room
• AC outlets are ubiquitous in virtually every existing home
• Powerline networking takes advantage of the unused capacity of the power cable to transmit data over the existing home power cabling
• A low cost solution
  – No additional rewiring
• Capable of distributing data as fast as 10 + Mbps
Powerlines Cons

- Noisy environment
- Security issues
- Data attenuation
- Power line based modems are more costly than phone line based modems
- There are regulation issues in some international markets
- Powerlines can not deliver high quality video data
# Strengths & Weaknesses

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power line</strong></td>
<td>Shared media</td>
</tr>
<tr>
<td>Price/Performance</td>
<td>Regulatory issues in some international markets</td>
</tr>
<tr>
<td>AC outlets everywhere</td>
<td></td>
</tr>
<tr>
<td>Easy connection for non-PC appliances</td>
<td></td>
</tr>
<tr>
<td>Global Market</td>
<td></td>
</tr>
<tr>
<td><strong>Phone line</strong></td>
<td>Limited number of phone jacks in homes in US,</td>
</tr>
<tr>
<td></td>
<td>worse internationally US Market Only</td>
</tr>
<tr>
<td>Availability</td>
<td></td>
</tr>
<tr>
<td>Price/Performance</td>
<td></td>
</tr>
<tr>
<td>PCs near phone jacks</td>
<td></td>
</tr>
<tr>
<td>Strong industry Alliance (HomePNA)</td>
<td></td>
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<tr>
<td><strong>Wireless</strong></td>
<td>Highest cost</td>
</tr>
<tr>
<td>Only solution for portable devices</td>
<td></td>
</tr>
<tr>
<td>Common 2.4 GHz band worldwide industry联盟 (HomeRF WG)</td>
<td>Fractured market</td>
</tr>
<tr>
<td><strong>Ethernet</strong></td>
<td>Requires new wiring</td>
</tr>
<tr>
<td>Lowest cost components</td>
<td></td>
</tr>
<tr>
<td>Dedicated wiring and bandwidth</td>
<td></td>
</tr>
</tbody>
</table>
Noise Sources

- Switching Power Supplies
  - Rich in harmonics
  - Oscillator 20KHz to > 1MHz
  - Conduct oscillator noise onto power line
  - Frequency often varies with load

- Universal series wound motors
  - Vacuum cleaners, kitchen appliances, drills
  - High repetition rate impulses
Noise Sources

• Dimmers
  – Produce large impulses at 100Hz to 120 Hz
  – Large 20V to 50V impulses

• Power line intercoms
  – 3Vpp to 7Vpp from 150KHz to 400KHz
  – Large harmonics
  – About 30KHz bandwidth
Attenuation Sources

- Voltage Dividers
  - Wiring series inductance
  - Shunt loads and EMC capacitors
- Phase coupling loss
- Injection loss
  - Transmitter and coupling circuit output impedance
  - Socket load impedance
Powerline Based Applications

• Industrial
  – Utility Telemetering
  – Automated Storage
  – Factory and Machine Automation
  – Shipboard refrigerated Container Monitoring

• Commercial
  – Point-of-Sale Networks
  – Public Transit Vehicles
  – Residential LAN
  – Vending Machines Monitoring
Powerlines Applications
(Power Grids Platform)

- The electric power grid provides a perfect communications platform
  - Most extensive network in the world
  - Extremely robust and modern
  - Long distance signal carriage without regeneration
  - Near light speed propagation, naturally
  - Enormous information carrying capacity
  - No topology limitation
Powerlines Applications (Broadband Access)

• A new revealing technology uses electric power lines for broadband access
• It provides over 1.5 Mbps data access for home users
• The technology uses radio frequencies on top of the mains electricity supply to deliver data
• Access would be gained through electrical outlets, rather than phone lines
Powerlines Applications (Broadband Access)

• This technology uses a signaling scheme to separate data from electrical interference on the power line.
• Allowing users to connect even if power goes out.
• Fiber-optic cabling connected to a central switch carries data between substations and homes.
Powerlines Applications (Broadband Access)

• Media Fusion provides voice, data and video communications over the electrical grid at near light speed

• Media Fusion's Sub-Carrier Modulation process writes data within the electrical magnetic wave surrounding the power line
  – Enables the electrical power grid to carry telephone, radio, video, Internet and satellite data to any destination at near light-speed
  – This magnetic field becomes a wave guide in the same way a LASER output uses materials (optics) to amplify or step frequency levels during or after stimulated emission occurs
Media Fusion Network Overview

Courtesy of Media Fusion, Inc.
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What Is A Control Network?

• A control network is any group of devices working in a peer-to-peer fashion to monitor:
  – Sensors
  – Control actuators
  – Communicate reliably

• A control network can also:
  – Manage network operation
  – Provide complete access to network data
Control Network Platform

• A true end-to-end solution for control networking should offer more than a mere protocol
• A control network platform must address:
  – Interoperability (both at device level and system level)
    • Lower integration
    • Lower installation and maintenance costs
    • Higher system functionality and flexibility
  – Network Operating System
    • A robust, universal platform for installation, configuration, monitoring, and control of networks
    • Software tools interoperability
Control Network Platform

- Seamless integration with IP networks (Internet and Intranet)
  - True end-to-end connectivity between people and devices, using the existing LAN infrastructure
- Easy-to-use application programming environment
  - Programming environment tailored to the needs of control devices and systems as well as the developers
    - more choices in less time
    - Rapid time-to-market
    - Rapid device proliferation
- Infrastructure tools and support
- Routers, Repeaters, PC interface card
- System scalability and flexibility
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Powerline Based Technologies

- **X10**
  - X-10 controllers send signals over existing AC wiring to receiver modules
  - X-10 technology transmits binary data using the Amplitude Modulation (AM) technique

- **Intellon CEBus**
  - An open standard which provides separate physical layer specification documents for communication on power lines and other media
  - Data packets are transmitted by the transceiver at about 10 Kilobits per second (Kbps), employing spread spectrum technology
Powerline Based Technologies

- To avoid data collisions, it uses a Carrier Sense Multiple Access/Collision Detection and Resolution (CSMA/CDCR) protocol
  - Echelon LONWorks
    - Provides a peer-to-peer communication protocol, implementing Carrier Sense Multiple Access (CSMA) techniques
  - Adaptive Networks
    - Utilizes a hybrid token passing media access scheme as opposed to the peer-to-peer CSMA/CDCR schemes
  - Intelogis PLUG-IN
## Powerline Based Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>X-10</th>
<th>CEBus (EIA IS-60)</th>
<th>LONWorks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>X-10 (USA-Corp.)</td>
<td>Electronics Industry Association (EIA). Further developed by CEBus Industry Council (CIC)</td>
<td>Echelon Corp. Testing and certification programs led by LONMark Interoperability Association</td>
</tr>
<tr>
<td>Media Supported</td>
<td>Power lines. X-10 manufactures devices for other media, but there are no standards for them</td>
<td>Power lines Twisted Pair Coaxial Cable RF IR Eventually Fiber Optic</td>
<td>Power line Twisted Pair RF Third party transceivers support</td>
</tr>
<tr>
<td>Max. Data Rate</td>
<td>60 bps</td>
<td>10 kbps, Add'l. support for video, audio, and data</td>
<td>610 bps to 1.25 Mbps</td>
</tr>
<tr>
<td>Licensing Requirements</td>
<td>Proprietary, company does not license others to use it</td>
<td>Public domain, does not require a license. Certification required to use the CEBus logo</td>
<td>License required. Certification required to use the LONMark logo</td>
</tr>
<tr>
<td>Relative Cost</td>
<td>Low</td>
<td>Low to moderate</td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Target Applications</td>
<td>Existing and new homes</td>
<td>Existing and new homes</td>
<td>Existing and new homes, commercial and industrial buildings, industrial automation, automotive</td>
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CEBus

- CEBus is a standard proposed by the Electronic Industries Association
- CEBus is an open architecture which explains how to make products communicate through:
  - Power line wires, Low voltage twisted pairs, Coax, Infrared, RF, and Fiber optics
- CEBus based products consist of two components
  - A transceiver which implements spread spectrum technology
  - A controller to run the protocol
CEBus

- The CEBus standard includes commands such as volume up, fast forward, rewind, pause, skip, and temperature up or down 1 degree
- The CEBus Power line Carrier uses Spread Spectrum technology
- The CEBus Power line Carrier spreads its signal over a range from 100Hz to 400Hz during each bit in the packet transmitted
  - Instead of frequency hopping or direct sequence spreading
CEBus

- Due to the high noise level of power line channels, data should be transmitted via short frames
  - The requirement for short frames is met by a physical layer spread spectrum technology
  - Each frame is transmitted on a raw data rate of 135 Kbps
- Using forward error correction (FEC) and automatic repeat request (ARQ) transfers data with an effective throughput of 19.2 kbps at an error rate of $10^{-9}$
CEBus

• CEBus protocol uses a Carrier Sense Multiple Access/Collision Detection and Resolution (CSMA/CDCR) protocol to avoid data collisions
OSI Model & CEBus

OSI

L7: Application
L6: Presentation
L5: Session
L4: Transport
L3: Network
L2: Data Link
L1: Physical

Layer System Management

EIA-600

L7: Application
L3: Network
L2: Data Link
L1: Physical

Relationship of OSI model and EIA-600 Model

Coax
Fiber Optic
Infrared
RF
Twisted Pair
Power Lines

RF
Infrared
Coax
Fiber Optic
Twisted Pair
Power Lines
CEBus & OSI Model

- **Application Layer**
  - Specifies how service is perceived or experienced by the user
  - Responsible for managing the communication access
- **Presentation Layer (Not used by EIA-600)**
  - Specifies how the appearance of the service is generated at the user terminal from the telecommunications signal received
  - Provides the services that allow the user to interpret the meaning of the information being transferred
CEBus & OSI Model

• Session Layer (Not used by EIA-600)
  – Specifies how a specific interaction is set up between user and computer
  – Supports the dialog between cooperating users, binding and unbinding them into and out of a communicating relationship

• Transport Layer (Not used by EIA-600)
  – Defines protocol of very general applicability; provides flow control and error control
  – Provides end-to-end control and information/status interchange with the level of reliability and quality of service needed by the user
CEBus & OSI Model

• Network Layer
  – Sets basic standards for formatting of information once link is established
  – Provides the switching and routing functions needed to establish, maintain and terminate connections and data transfer between user
• Physical Layer
  – Provides the characteristics to activate, maintain and deactivate the physical links passing the stream of communications symbols
  – Exchanges symbols with the data link layer, encoding and decoding the symbols to and from the medium states
CEBus & OSI Model

• Data Link Layer
  – Makes a transmission channel appear to the Network Layer as an open, and error-free channel
  – Provides the means for establishing and maintaining individual data links
  – Provides for the transfer of information over the physical link with the required synchronization, error control and flow control functions
  – Provides for the encapsulation and de-encapsulation of the messages exchanged between itself and the network layer
  – Exchanges symbols and medium status between itself and the physical layer
CEBus & OSI Model (Data Link)

• Data from the Network Layer is incorporated into a frame within the Data Link Layer
  – The "frame" is the form of data which is generated within the Data Link Layer
• The contents of the frame are relayed to the Physical Layer for transmission across the channel
• Data received from the channel are passed from the Physical Layer to the Data Link Layer to form the received frame
CEBus & OSI Model (Data Link)

- Data link layer is divided into two sublayers of MAC and LLC
- The Medium Access Control (MAC) Sublayer
  - Performs the functions of transmitting and receiving Protocol Data Units
- The Logical Link Control (LLC) Sublayer
  - Provides the interface to the Network Layer
  - Administers the transmission and reception of Protocol Data Units
## OSI Model

<table>
<thead>
<tr>
<th>OSI Layer</th>
<th>Purpose</th>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
</table>
| Physical  | Electrical Interconnection            | • Support for various media                                               | • Installation  
• Performance  
• Reliability  
• Low latency for critical nodes, uniformly democratic access for all other nodes  
• Support for discrete, analog, as well as configuration and diagnostic data without fragmentation and performance impact |
| Link      | Media Access and Framing              | • Democratic media access scheme and priority  
• Large Packet size                                                      |                                                                                                                                                        |
| Network   | Destination Addressing                | • Support for routers                                                    | • Size and interconnectivity – support for large networks  
• Reliability – traffic filtering, segmenting network into functional clusters, while allowing transparent communication across clusters when needed  
• Installation ease and reliability  
• Reliability – creating additional paths between communicating nodes |
| Transport | End-To-End Reliability                | • Unacknowledged service, with and without repeat  
• Acknowledged service  
• Multicast service with and without acknowledgment from each node, and the ability to re-transmit selectively  
• Duplicate detection                                                      | • Optimal communication to a large number of devices, or devices unable to acknowledge. Maintains network reliability in these conditions  
• Reliable delivery  
• Performance and reliability |
| Session   | Remote Actions                        | • Request/Response                                                       | • Reliability – to ensure acknowledgement of action  
• Reliability – to ensure sender legitimacy |
| Presentation | Data Interpretation                   | • Standard Data type                                                     | • Ability to exchange and interpret standard data regardless of applications  
• Representation of any sensor, actuator, or controller interface as aggregations of high level objects  
• Interpretability with standard sensor interface |
| Application | Sensor/Actuator Appellation compatibility | • High level standard object interface definitions  
• Standard configuration properties                                           |                                                                                                                                                        |
Spread Spectrum Technology

- Physical layer function
- Spread spectrum is a modulation technique of transmission where
  - The transmitted signal occupies a bandwidth considerably greater than the minimum necessary to send the information
  - Some function other than the information being sent is employed to determine the resulting modulated bandwidth
Spread Spectrum Modulation

- Spreads a signal’s power over a wider band of frequencies
- Process gain - sacrificing bandwidth to gain signal-to-noise performance
  - Contradicts the desire to conserve frequency bandwidth
  - Spreading process makes the data signal much less susceptible to electrical noise
- Narrow bandwidth transmission & electrical noise
  - Interfere with a small portion of the spread spectrum signal
  - Result in much less interference & fewer errors when the receiver demodulates the signal
Spread Spectrum Modulation

- Frequency spectrum of a data-signal is spread using a code uncorrelated with that signal
  - Codes used for spreading have low cross-correlation values and are unique to every user
  - Sacrifices bandwidth to gain signal-to-noise performance
Spread Spectrum Advantages

• Low power spectral density
  – Spreading the signal over a large frequency-band makes the power spectral density very small
  • However, the Gaussian noise level increases
• Interference limited operation
  – In all situations the whole frequency-spectrum is used
  – Spread spectrum reduces multi-path effects
• Privacy is kept due to unknown random codes
  – Applied codes are unknown to a hostile user
• Random access possibilities
  – Users can start their transmission at any arbitrary time
How Does Spread Spectrum Work?

• Receivers should be assigned different codes
  – It will address them away from other receivers with different codes
• Codes with low cross correlation properties should be chosen to minimize interference between groups of receivers
• Selective addressing and Code Division Multiple Access (CDMA) are implemented via these codings
How Does Spread Spectrum Work?

- Power spectrum spreads out with spreading the intelligence of a signal over several MHz of spectrum
  - It makes the detection of the none-coded signals very difficult
- By increasing the bandwidth Signal/Noise may be decreased without decreased BER performance

\[ C = W \log_2 \left(1 + \frac{S}{N}\right) \]
- \(C\) = Channel capacity in bits
- \(W\) = Bandwidth in Hertz
- \(S\) = Signal Power
- \(N\) = Noise Power
Frequency Hopping SS FHSS

• It works very much like its name implies; Frequency hopping
  – Data signal is modulated with a narrowband carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies
  – Relies on frequency diversity to combat interference
• This is accomplished by multiple frequencies, code selection & FSK
FHSS Technology

• Hopping code determines the frequencies that should be transmitted and in which order
  – Hopping pattern is known to both transmitter & receiver
    • To properly receive the signal the receiver must be set to the same hopping code & listen to the incoming signal at the right time & correct frequency
      – If properly synchronized the net effect is to maintain a single logical channel
  • Unintended receiver sees FHSS to be short-duration impulse noise
FHSS Technology

• FHSS system must hop its whole information signal over a band of frequencies of the ISM band in use
  – Does not interfere with primary user
• Because of the nature of its modulation technique frequency hopping can achieve up to 2Mbps data rates
  – Faster data rates are susceptible to huge number of errors
• Frequency hopping technique reduces interference
  – An interfering signal from a narrowband system will affect the spread spectrum signal only if both are transmitting at the same frequency at the same time
  – Aggregate interference will be very low, resulting in little or no bit errors
FHSS Example for One Channel

- 7 frequency slots exist in the band
  - System send the information signal in frequency slot 24 for the first time slot, then frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on
- Users wishing to receive signals must tune receiver to particular frequency slot
  - To receiver channel number 1 must tune its receiver to frequency slot 24 for first time slot, frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on
Different FH Pattern

• Each channel is a different frequency hopping pattern
  – Channels are distinguished between channel 1 & channel 2 by having a different frequency hopping pattern
  – Receiver of channel 2 must hop his receiver according to the channel 2 FH pattern
  – This is not a different frequency as in Frequency Division Multiplexing - it is a different Frequency Hopping Pattern
Direct Sequence Spread Spectrum (DSSS)

- Most widely recognized form of spread spectrum
- The DSSS process is performed by effectively multiplying an RF carrier and a pseudo-noise (PN) digital signal
  - First, the PN code is modulated onto the information signal using one of several modulation techniques (e.g., BPSK, QPSK, etc.)
  - Then, a doubly balanced mixer is used to multiply the RF carrier and PN modulated information signal
  - This process causes the RF signal to be replaced with a very wide bandwidth signal with the spectral equivalent of a noise signal
DSSS

- The signals generated with this technique appear as noise in the frequency domain
  - The wide bandwidth provided by the PN code allows the signal power to drop below the noise threshold without loss of information
DSSS

Direct Sequence Spread Spectrum

• Combines a data signal at the sending station with a higher data rate bit sequence
  – High processing gain increases the signal’s resistance to interference
• A chipping code is assigned to represent logic 1 and 0 data bits
  – As the data stream is transmitted, the corresponding code is actually sent

<table>
<thead>
<tr>
<th>Chipping Code: $0 = 11101100011$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 = 00010011100$</td>
</tr>
</tbody>
</table>

Data Stream: 101

Transmitted Sequence:

<table>
<thead>
<tr>
<th>00010011100</th>
<th>11101100011</th>
<th>00010011100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Example: DSSS sends a specific string of bits for each data bit sent - The transmission of a data bit equal to 1 would result in the sequence 00010011100 being sent
DSSS Technology

- Generates redundant bit pattern for each bit to be transmitted
  - This bit pattern is called chip/chipping code (processing gain)
  - Longer the chip
    - Greater is the probability that the original data will be recovered
    - More is the bandwidth that is required
  - If one or more bits are damaged during transmission
    - Statistical techniques embedded in the radio can recover the original data without the need for retransmission
- Unintended receivers
  - View DSSS as a low-power wideband noise & is ignored or rejected by most narrowband receivers
DSSS Technology

- "one" data bit
- "zero" data bit

10-chip code word for each "one" data bit

same chip code word but inverted for "zero" data bit
DSSS Operation

- Input data stream
  - Runs at 1Mbps
  - Multiplied by a chip stream running 11 times faster at 11 Mcps
- A chip is exactly like a bit - zero or one
  - Called chip only to be distinguished from a bit
  - More chips exist than do bits
- When the bit stream is multiplied, its frequency spectrum becomes spread out
  - Occupies about 11 times as much bandwidth, spectral energy is 11 times lower
  - Since it is so low it does not interfere with the primary user
DSSS Operation

- With more DSSS systems occupying the band, the overall noise level (interference) rises
  - Causes degradation in performance
  - Causes primary user to increase a bit
    - Increased interference to DSSS users are expected to become a problem long before the primary user notices any interference
- At the receiver
  - Input chip stream is multiplied by the same coded chip stream that was used at the transmitter
  - Two codes are synchronized
    - Original bit stream is correlated
    - Any interference on the air when it goes through the correlator becomes spread out
DSSS vs. FHSS Comparison

- FHSS degrades gradually, DSSS degrades drastically!
- DSSS can achieve much higher data rates than FHSS’s 2Mbps
- FHSS can have up to 10 or 15 channels, while DSSS can have up to 2 or 3 channels
DSSS vs. FHSS Comparison

• Instantaneous data rates of DSSS can be larger than FHSS
  – In FHSS the maximum bandwidth of the signal is specified to 1MHz at the 2.4GHz band
    • Realistic data rates are limited to 1 or 2 Mbps
  – With DSSS, the rule is to spread by at least a factor of 11
    • Theoretically it is possible to use the whole 80 MHz band & provide a data rate in the order of 6 or 7 Mbps
    • Circuitry would be required to run at a very high rate of 66 or 77 Mbps in order to generate the chip stream necessary to support the 6 or 7 Mbps bit rate
    • This high rate would be very expensive & not seen in the industry at this time
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  – Power Line Technologies
    • Intellon CEBus
    • CEBus & OSI Model

• Echelon LONWork
  – LONTalk Protocol
  – Architecture

• Carrier Sense Multiple Access/Collision Detection
  • X 10
  • Plug in
  • Adaptive Networks
    – hybrid token passing media access scheme

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• Summary
LONWorks

- LONWORKS (Local Operation Networks) technology is an important new solution for control networks developed by Echelon® Corporation.
- A control network is any group of devices working in a peer-to-peer fashion to monitor:
  - sensors
  - control actuators
  - communicate reliably
  - manage network operation
  - and provide complete access to network data
- In some ways, a LONWORKS control network resembles LAN
LONWorks

- It can control and link factory conveyor belts, product inventory, and distribution systems for optimum efficiency and flexibility.
- Smart office buildings can turn lights on and off, open and lock doors, start and stop elevators, and connect all functions to a central security system.
- Homeowners can program a vast array of products and conveniences, from sprinkler systems to VCRs, with a touch tone phone from any remote location.
LONWorks

• LONWORKS technology is a solution for implementing distributed control networks
  – These networks consist of nodes that communicate with one another over a variety of communications media using LonTalk® protocol
    • A common message-based communications protocol
  • In a LONWORKS application, nodes sense, monitor, count, measure time, manage switches and relays, and respond to conditions reported by other smart nodes
LONWorks

• The technology of distributed nodes can reduce the amount of wire and number of junctions by one or more orders of magnitude
  – As a result, the network has simpler field installation, increased reliability, and decreased cost
• Since the communications protocol supports different transmission media, such as twisted pair, RF, and power line, the network is extremely flexible
LONWorks Applications

- Appliance Control
- Asset Tracking
- Automated Supermarket Pricing
- Automated Work Environments
- Avionics Instrument Integration
- Circuit Board Diagnostics
- Consumer Electronic Controls
- Discrete and Process Control
- Electronic locks

- Intelligent Industrial I/O Irrigation
- Management, lighting Control
- Liquor Dispensing
- Livestock Management
- Medical Instrumentation
- Office Machine Automation Patient Monitoring
- Power Supply Management
- Research Experiment monitoring
LONWorks Applications

- Vending Machines
- Whole House Automation
- Wire Harness Replacement
- Restaurant Automation
- Security Systems
- Slot Machines
- Traffic Lights
- Utility Meter Reading
- Fire Protection
- HVAC (Heating Ventilation Air Conditioning) Control
- Highway Toll Collection
- Identification Systems
- Elevator Control
- Energy Management
- Environmental Monitoring
- Vehicle Wiring Systems
LONWorks Network

PC

Security Camera

Motion Sensor

Dimmer/Switch

HVAC

Light Control

Building Security

Remote Client

LONWorks Control Network
LONTalk Protocol

• It is a common message-based communications protocol
• The LonTalk protocol implements all seven layers of the OSI model
  – Using a mixture of hardware and firmware on a silicon chip
    • thus precluding any possibility of accidental (or intentional!) modification
• The protocol can be run as fast as 20 MHz
LONTalk Protocol

- Features include:
  - Media Access
  - Transaction Acknowledgement
  - Peer-to-peer Communication
  - Authentication
  - Priority transmissions
  - Duplicate Message Detection
  - Collision Avoidance
  - Automatic Retries
  - Mixed Data Rates

- Client-server Support
- Foreign Frame Transmission
- Data Type Standardization and Identification
- Unicast/Multicast/Broadcast Addressing
- Mixed Media Support
- Error Detection & Recovery
LONWorks Network Service (LNS) Architecture

- Services are provided using:
  - Network Service Server (NSS)
  - Network Service Interface (NSI)
- The NSS
  - Process standard network services
  - Maintains the network database
  - Enables and coordinates multiple points of access to its services and data
(LNS) Architecture

- The NSI
  - Provides the physical connection to the network
  - Manages transactions with the NSS and application servers
  - Provides transparent remote access to the NSS and application servers
- Each host is attached to the network using an NSI
  - The host can be any microcontroller, Microprocessor, or PC running any operation system
Carrier Sense Multiple Access with Collision Detect (CSMA/CD)

- When a station has data to send, it first listens to the channel to see if anyone else is transmitting
- If the channel is busy, the station waits until it becomes idle
- A Collision occurs when two stations listen for traffic, hear none, and then transmit simultaneously
  - In this situation, both transmissions are damaged
  - Stations must retransmit at some later time
- Back-off algorithm determines when the colliding stations should retransmit
Variations of CSMA Protocol

• 1- persistent CSMA
  – When a station has frames to transmit, it first listens to the channel, if the channel is idle, the frame is sent
  – If the channel is busy, the station waits and transmit its frame as soon as the channel is idle
  – If a collision occurs, the stations waits a random amount of time and starts all over again
  – The station transmits with a probability of 1 whenever it finds the channel idle
Variations of CSMA Protocol

- Non-persistent CSMA
  - When the channel is busy, the station simply gives up and tries at a later time
- p-persistent CSMA
  - When the channel is busy, the station will keep listening until the channel becomes idle (like 1-p persistent)
  - Then the station transmits the frame with a probability of p. The station backs off with the probability of q = 1 - p.
What is a Neuron?

• The Neuron is actually three 8-bit inline processors in one
  – Two are optimized for executing the protocol
  – One is for the node's application
• It is both a network communications processor and an application processor
• Up until recently, all devices on a LONWORKS network required a Neuron
Component Of A LONWorks Device

- Transceiver
- Comm Port
- Optical External Memory
- I/O Conditioning
- I/O (Counters Resources, Drivers)
- Application CPU
- Media Access CPU
- Network CPU
- Protocol Firmware (Layers 3-6)
- (Layer 1-2)
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X-10

- Is a powerline carrier protocol
- It allows compatible devices to communicate with each other via the existing 110V wiring in the house
- Transmits binary data using Amplitude Modulation (AM) technique
- X10 is trying to innovate it into higher speed with regard to establish the communication between home PCs and controlled home appliances
X-10

- To differentiate the data symbols, the carrier uses the zero-voltage crossing point of the 60 Hz AC sine wave on the cycle’s positive or negative transition
- Synchronized receivers accept the carrier at each zero-crossing point
  - X-10 uses two zero crossings to transmit a binary digit so as to reduce errors
X-10

• Every bit requires a full 60 Hertz cycle and thus the X-10 transmission rate is limited to only 60 bps

• Usually a complete X-10 command consists of two packets with a 3 cycle gap between each packet
  – Each packet contains two identical messages of 11 bits (or 11 cycles) each
  – A complete X-10 command consumes 47 cycles that yields a transmission time of about 0.8
X-10 Applications

- Telephone Control
- Pool & Spa
- Security
- Ventilation Control
- Temperature Control
- Computer Control
- Voice Control
- Lighting
- Doors & Gates
- Sensors
- Audio/Video Control
- Sprinklers
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PLUG-IN

- Is a control networking protocol developed by Intelogis
- It is closely related to the Open System Interconnection (OSI) model
  - All OSI layers but the presentation and session layers are defined in the PLUG-IN protocol stack
    - Network Layer - PLUG-IN Power Line Exchange (PLX) Protocol
    - Transport Layer - PLUG-IN PLX Protocol
    - Data-Link Layer - PLUG-IN PLX Protocol
    - Physical Layer - PLUG-IN Digital Power Line (DPL)
PLUG-IN

• PLUG-IN uses the CEBus Generic Common Application Language as its Application Layer protocol
  – But Intelogis uses a client/server topology instead of the peer-to-peer model
  – Using a client/server topology allows more of the intelligence of each PLUG-IN node’s application to be placed in a centralized Application Server

• PLX defines the MAC portion of the data link layer
  – Uses a MAC protocol consisting of two separate access mechanisms
    • Datagram sensing multiple access (DSMA)
    • Centralized Token Passing (CTP)
PLUG-IN

• PLX protocol also defines rules of operation for the Data Link, Network, and Transport layers

• At the physical layer, DPL protocol uses a modulation methodology called Frequency Shift Keying (FSK) to send digital signals over the power line
  – FSK modulation sends digital signals over the power line by using two or more separate frequencies that are in a fairly narrow band

• PLUG-IN DPL single channel solution boasts line speeds of up to 350 Kilobits (Kbps) per second
PLUG-IN

• The future versions of PLUG-IN DPL will be capable of speeds up to 1 Mbps and beyond
  – Using multiple channels
  – Using carrier signals

• The PLUG-IN FSK modulation scheme delivers bit error rates in the range of 10^-9 with 80 dB of dynamic range
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Adaptive Networks Technology

• Utilizes a hybrid token passing media access scheme
  – As opposed to the peer-to-peer CSMA/CDCR schemes
• A token-passing MAC provides:
  – Reliable transfer of control in a noisy medium
  – Support for multimedia
• It addresses:
  – False synchronization
  – Missed transmissions
  – Near-far problems
Token-Passing MAC

- It ensures only one token holder at any time even in a noisy environment
- Each node receives a transmission subject to different distortion and noise
  - There is the possibility that some nodes will miss a transmission that other nodes hear
- In token passing, nodes cannot transmit unless they hold the token
  - There is no possibility that nodes will transmit during another node's transmission
Token-Passing MAC

- It includes the use of a Token Rotation Time (TRT)
  - The TRT is a fixed value that sets the maximum amount of time a station must wait for the token
  - This value is chosen to balance the worst-case access latency against network bandwidth being consumed for nonproductive token-passing overhead

- When nodes gain access to the network they are limited to their allotted Token Hold Time
  - The THT is the amount of time a station allowed to transmit before it must pass the token to the next station
  - Enforcing THT ensures that all nodes receive their fair allocation of network bandwidth
Token-Passing MAC

• Segmentation and Reassembly (SAR) is integral to the architecture
  – Short power lines frames are derived from segmentation of the typical packet
  – Segmentation into short frames ensures that high-priority traffic is not delayed by maximum-size Ethernet packets
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Example Of Powerline Products Enikia

- Enikia has adapted the powerline to comply with IEEE 802.3
- The Enikia 10Mbps Powerline Ethernet Transceiver is a chipset that adapts standard, off-the-shelf Ethernet controllers (MACs) to the home's powerline network
- This device supports the following MACs:
  - the Motorola QUICC family, AMD AM7990, Intel 82596, Fujitsu MB86950, Fujitsu MB86960, Seeq 8005, National Semiconductor 8390, and the Texas Instruments TMS380C26
Example Of Powerline Products Echelon

• Echelon products and services enable you to develop, manufacture, install, operate, and maintain LONWorks networks

• LONWorks Transceivers
  – Provide a physical communication interface between a Neuron Chip and a LONWorks network

• LONWorks Control Modules
  – Include a Neuron Chip, Echelon transceiver, memory and clock oscillator in one compact module
Example Of Powerline Products Echelon

- **LONWorks Routers**
  - Allow you mix multiple media types on a single network

- **SMX Transceivers**
  - Provide a modular, flexible solution for interfacing a variety of LONWorks devices to different LONWorks communication media

- **The LONPoint System**
  - Integrates new and legacy sensors and actuators, as well as LONMARK devices into an interoperable control systems
Example Of Powerline Products Intellon

- **SSC P300 PL Network Interface Controller**
  - Is a powerline transceiver and channel access interface for implementing CEBus Standard compatible products
  - Provides the Data Link Layer (DLL) control logic for CEBus (EIA-600) channel access and communication services
  - A Spread Spectrum Carrier (SSC) powerline transceiver
  - Signal conditioning circuitry
  - An SPI compatible host interface

- **Other products are:**
  - SSC P200 PL Network Interface IC
  - SSC P485 PL Transceiver IC
  - SSC P111 PL Media Interface IC
Example Of Powerline Products Inari

• IPL0201 – 2 Mbps Powerline Network Controller
  – Is a MAC/PHY 2 Mbps Powerline Network Controller
  – Features:
    • Microcontroller (803x/5x compatible processor core)
    • USB Peripheral Core
    • Generic Host Application Interface
    • Security and Error Detection
    • Inari’s Digital Powerline (DPL™) Transceiver
    • Inari’s Powerline Exchange™ (PLX™) Embedded Protocol
Example Of Powerline Products
Itran Communications

- IT800 7 Kbit/s highly reliable DCSK/CEBUS Power Line Communications modem ASIC
- IT5000 50 Kbit/s DCSK/CEBus Power Line Communications modem ASIC
- ITM1 2.5 Mbit/s Power Line Modem ASIC
- ITM10 12 Mbit/s Power Line Modem ASIC
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Introduction to Xilinx
Where Does Xilinx Fit In the Electronics Industry

Key components of an electronics system:

- Processor
- Memory
- Logic

Xilinx is the Leading Innovator of Complete Programmable Logic Solutions
Strategic Business Model Ensures Focus

• “Fabless” strategy
  – Leading edge IC process technology
  – Wafer capacity at competitive prices
  – Fastest, lowest cost, densest parts
• Independent sales organization (Reps & Distributors)
  – Sales is a variable cost
  – Permits greater reach—over 20,000 Customers
  – Over 10,000 “Feet On The Street”
• Focus on key strengths
  – Product design
  – Marketing
  – Applications & Technical Support
Xilinx Product Portfolio

- **Advanced Products Group**
  - High Performance
  - High Density
  - Virtex

- **General Products Division**
  - High Volume
  - Low Cost
  - Spartan-III

- **CPLD Division**
  - Low Power
  - Low Cost
  - CoolRunner

- **Software Solutions**
  - Foundation
  - Alliance
  - WebPACK
  - WebFitter
  - IP Center
  - Alliance Xpert
  - Xilinx Online
Xilinx - Leader in Core Solutions

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Introducing the Spartan-II FPGA
Spartan-II: Extending the Spartan Series

- More Gates
  - 2X gates/$
  - 3X gates per I/O
  - 2X I/O Performance
  - 3X number of gates

- More Performance

- Feature Rich
  - DLLs
  - Select I/O
  - Block RAM
  - Distributed RAM

- Time to Market
  - Cores
  - Easy Design Flow
  - Re-programmable
  - Fast, Predictable Routing

- Programmable ASIC/ASSP Replacement!

100,000 Gates for $10
FPGA Application Trends

Programmable ASIC/ASSP Replacement!
Spartan-II - Architecture Overview

Clock Management:
- Multiply clock
- Divide clock
- De-skew clock

Delay Locked Loop (DLL)

Configurable Logic Blocks (CLB)
- Configurable Logic Block Array and Distributed RAM

Select I/O™ Technology
- Chip to Backplane
  - PCI 33MHz 3.3V
  - PCI 33MHz 5.0V
  - PCI 66MHz 3.3V
  - GTL, GTL+, AGP
- Chip to Memory
  - HSTL-I, HSTL-II
  - HSTL-IV
  - SSTL3-I, SSTL3-II
  - SSTL2-I, SSTL2-II
  - CTT
- Chip to Chip
  - LVTTL, LVC MOS

Block Memory
- True Dual-Port™
  - 4K bit RAM
  - 4Kx1
  - 2Kx2
  - 1Kx4
  - 512x8
  - 256x16

“The Spartan-II family, in our opinion, may be the closest that any FPGA has come to being at a low-enough price to compete against an ASIC”
--Dan Niles, Industry Analyst
Spartan-II - System Integration
Spartan-II Core Support

- On-chip memory & storage
  - Distributed, BlockRAM, FIFOs
- Bus products
  - PCI (64- & 32-bit, 33/66MHz), Arbiter, CAN bus interface
- DSP Functions (FIR filter)
- Error correction
  - Reed-Solomon, Viterbi
- Encryption (DES & triple DES)
- Microprocessor
  - ARC 32-bit configurable RISC, 8-bit 8051 microcontroller
- Memory controllers (10+)
  - SDRAM, QDR SRAM
- Communications
  - ATM (IMA, UTOPIA), Fast Ethernet (MAC)
- Telecom
  - CDMA matched filter, HDLC, DVB satellite, ADPCM speech codec
- Video & image processing
  - JPEG codec, DCT/IDCT, color space converter
- UARTs
Xilinx CPLD Families

Xilinx CPLDs

- High Speed
- Low Cost

XC9500 Family

- 5 Volt
- 3 Volt
- 2.5 Volt

CoolRunner

- Lowest Power
- Highest Density

XPLA (Original & Enhanced)

XPLA2 SRAM Based

XPLA3 (Released)

PAL (Simple PLD-22V10)
Spartan-II End Applications

• Consumer
  – Set Top Boxes/Digital VCRs
  – DTV/HDTV
  – Digital Modems
    • xDSL, Cable, Satellite
  – Home Networking products
  – Bluetooth appliances
  – LCD/Flat-Panel Displays

• Networking
  – Telecom linecards
  – DSLAMs
  – LAN Hubs/Switches
  – SOHO Routers
  – Cellular base stations

• Computer/Storage
  – Printer/Scanner
  – Multi-function office equipment
  – Storage devices
  – Home servers
  – Audio/Video add-in cards

• Industrial/Medical
  – Medical Imaging
  – Industrial automation/control
  – Data acquisition
  – Video capture/editing
  – Automated test equipment
  – Automotive Info-tainment systems
CoolRunner Technology

- Full density range 32 to 960 macrocells
- World’s only TotalCMOS CPLD
  - Bipolar style sense amps eliminated
  - Virtually no static power dissipation
- Advanced PLA Architecture
  - Product term sharing (no redundant logic)
  - No wasted product terms
- 3.3v and 5.0v devices
- ISP/JTAG compatible & full software support
The CoolRunner Advantage

- Industry’s lowest power CPLDs
  - Standby current < 100uA
  - High speed  TPD = 6 ns
  - Revolutionary XPLA architecture
    - Exceptional routability & pin-locking
    - Fast, predictable timing
  - Small form factor packaging
    - New 0.5mm 56-pin MicroBGA
- No Speed / Power tradeoffs in scaling
  - Can build very large / very fast devices
  - 960 macrocell device @ 7.5 nsec $t_{PD}$
XC9500XL Key Features

- High performance
  - $t_{PD} = 5\text{ns}$, $f_{SYS} = 178\text{MHz}$
- 36 to 288 macrocell densities
- Lowest price, best value CPLD
- Highest programming reliability
- Most complete IEEE 1149.1 JTAG
- Space-efficient packaging, including chip scale pkg.

Lowest Price Per Macrocell
XC9500XL/XV System Features

- I/O Flexibility
  - XL: 5V tolerant; direct interface to 3.3V & 2.5V
  - XV: 5V tolerant; direct interface to 3.3V, 2.5V & 1.8V
- Input hysteresis on all pins
- User programmable grounds
- Bus hold circuitry for simple bus interface
- Easy ATE integration for ISP & JTAG
  - Fast, concurrent programming times
System Block Diagrams for Powerline Solutions
Block Diagram Template / Index

Xilinx Solution

Peripheral Components

Memory

Mixed Signal / RF / Analog Component

µP/ µC

Embedded Chip/ ASSP
Residential Gateway (STB)
Home Security

[Diagram showing various components and their connections]

- Home Network Controller
- Microcontroller
- Bus Switch
- Audio DAC
- FIFO
- MPEG Decoder
- Microphone
- Keypad
- Power Management
- Memory Controller
- LCD Controller
- SDRAM
- FLASH
- Camera
- CCD Imager
- CCD AFE
Cable Modem Residential Gateway
Web Tablet Block Diagram

- Powerline Network Controller
- SDRAM
- Compact Flash
- Battery
- LEDs
- Buttons
- SMBus
- LED IF
- Keypad IF
- Power Management
- CPU
- Bus Interface
- Register File
- LCD
- Touch screen
- System ADC
- Analog
- SPI
- PWM
- EEPROM & Tablet ID
- Analog
DSL CPE
(Customer Premise Equipment)

- Line Driver/Receiver
- Analog Front End
- A-to-D & D-to-A Converters, Filters, Amplifiers
- Equalizer, Reed-Solomon FEC Encoder/Decoder, Interleaver, Modulator, Demodulator, Packet Format Logic
- HDLC Framer
- System Controller
- Digital Signal Processor
- Memory
- USB Transceiver
- USB Controller
- Powerline Network Controller
- Clock Generator & DLLs
- PCI Backplane Interface
- Interface
- To line & POTS splitter
- DSL Transceiver
USB to HomePlug Bridge

- 10/100 Base-TX Transceiver
- Powerline Network Controller
- MII
- 10/100 Base-TX Ethernet MAC
- UART
- Ethernet
- Timers, Watchdog Timer
- Processor
- RAM
- SRAM
- Flash
- Memory Controller
- Clock Generator & DLLs
- USB Device Controller
- USB Transceiver
- USB I/F
- USB to HomePlug Bridge
- Powerline Network
- Ethernet MAC
- MII
- UART
- Timers
- Watchdog Timer
- Processor
- Memory Controller
- Clock Generator & DLLs
- USB Device Controller
- USB Transceiver
- USB I/F
HomePlug to 1394 Bridge
Generic PLC

- Hybrid & Protection Circuit
- SDRAM
- Memory Controller
- Processor
- Power Management
- I/O Controller
- PCI Bridge
- XDSL Codec
- Powerline
- Home Network
- PCI Bus
RF Metering

- Docking Station
- RS232 Port
- Remote Device Being Read
- 2.4 GHz IEEE 802.11
- IEEE 802.11 Radio
- IEEE 802.11 MAC
- Main Controller
- UART
- SPI
- EEPROM
- Keypad
- LCD Controller
- LCD Display
- IEEE 802.11 MAC
- IEEE 802.11 Radio
- RS232 Port
- Docking Station
Spartan-II IP Solutions for Powerline Enabled Devices

- I/O Control
  - Multiple front end interfaces
  - Multiple back end interfaces
- Hard disk drive interface
- Clock distribution
  - DLLs
- MPEG decoder
- Ethernet MAC
- Error Correction
  - Reed-Solomon, Viterbi
- Memory solutions
  - Distributed memory, BlockRAM
  - Memory controllers
- CPU
- HDLC controller
- PCI
- Glue Logic
  - LCD controllers
  - UARTs
  - DMA controllers
Programmable Solutions Advantages
Xilinx Programmable Solutions Provide Several Benefits

- Time to market
  - Consumer devices require fast time-to-market
  - ASICs & ASSPs take 12-18 months to spin out
- Flexibility
  - Product customization to meet customer needs
  - Accommodate multiple standards & spec updates/changes
  - Feature upgrades
- Testing and verification
  - Re-programmable allows risk aversion
  - Your solutions are built on a proven FPGA technology with pre-verified silicon and IP that guarantees performance
Xilinx Programmable Solutions Provide Several Advantages

• Xilinx On-line - field upgradability
  – Remote update of software and hardware
  – Results in increased lifetime for a product (time-in-market) and allows new, interesting applications
  – Enable product features per end-user needs
• Issues in creating a stand-alone ASIC/ASSP
  – Choosing the right solution
  – Product customization
  – Development cost and amortization
• Low Cost
Lifecycle Component Logistics

• Xilinx is an assured source of supply
  – Spartan FPGAs are high volume standard parts
  – Xilinx is a Strategic customer to our fab partners
  – If a device is retired, designs are quickly portable
• Xilinx’s solutions reduce exposure to component supply issues
  – Designs can be quickly adapted to efficiently address component supply problems
    • NAND to NOR type Flash support for example
  – Gives latitude in maintaining a cost effective BOM in dealing with the allocation, end of life & generational migration realities of today’s component market
Speciation Changes

- Emerging markets are exposed to multiple standards and specification changes
  - DSL Modem market
    - 6 different variations
  - DTV market
    - 18 different formats

U.S. Networks Select Digital Broadcasting Format

- ABC: 720-Progressive. For non-HDTV broadcasts, ABC will use 480-line progressive format.
- CBS: 1,080-Interlaced. Wants to be compatible with HDTV sets as well as normal quality formats on regular analog television sets. Digital broadcasting will begin at select CBS-owned stations in the fall of 1998. By November 1999, CBS plans to be broadcasting digitally into 43% of U.S. households. For other broadcasts, CBS will use the 480-line Interlaced format.
- NBC: 1,080-Interlaced. NBC is leaning toward 480-line progressive for non-HDTV broadcasts.
- FOX: 720-Progressive. For non-HDTV broadcasts, Fox will use the 480-line progressive format.
- PBS: For HDTV, PBS is undecided. For non-HDTV broadcasts, PBS will use the 480-line Interlaced format.

Local Stations
Will have to conform to their network’s format for national programming but can select any format for local programming.

Source: IC Insights

A Programmable Solution Future Proof’s Success
New Flexibility from FPGAs

Driving down the cost of consumer products with low cost reprogrammable products

Enabling a whole new breed of consumer products

Reprogrammable nature allows
- Field upgrades
- Field fixes
  - Mars probe repair from earth
- Support for numerous standards

Xilinx & Replay TV
- Revolutionizing consumer TV
FPGAs, the Unsung Hero
Driving the Consumer Digital Logic Revolution

• The digital consumer world is here
  – Imperatives driving market success
    • Time to market and time-in-market
    • Flexibility
    • Custom digital logic
• Xilinx - The answer for consumer digital applications
  – Introducing the low cost Spartan-II programmable family
    • Cost reduced for the consumer market
    • Fully programmable at the desktop, in the field or in the application
    • Future proofed for changing standards
Xilinx Digital Consumer Logic

A Natural Fit for Home Networking

- Xilinx solutions enable you to thrive in chaos
  - Fastest time-to-market
    - First to market, gains market share and revenue advantage
  - Xilinx Online provides reconfigurability in the field
    - Allows shipped product to support revisions to the spec
    - Enables unique opportunities to add Value
    - Increases life-cycle revenue yield & hence time-in-market
  - Enables rapid product proliferation
    - New designs can be quickly turned into derivatives
  - Feature superior lifecycle component logistics
  - Testing and Verification
    - Proven FPGA technology, software, test benches
- Cost Effective!!!
Agenda

- Introduction
  - Push for Home Networking
    - Applications
  - Market Acceptance & Penetration
  - Market Direction
- Technology
  - Powerlines Facts & App.
  - Control Network
  - Power Line Technologies
    - Intellon CEBus
      - CEBus & OSI Model
      - Spread Spectrum Technology
- Echelon LONWork
  - LONTalk Protocol
  - Architecture
- Carrier Sense Multiple Access/Collision Detection
- X 10
- Plug in
- Adaptive Networks
  - hybrid token passing media access scheme
- Products
- Xilinx Solutions
- Alliances
- Summary
HomePlug

• Is a non-profit corporation established to provide a forum for:
  – The creation of specifications for worldwide home powerline networking products and services
  – Accelerating the demand for these products and services through the sponsorship of market and user education programs

• HomePlug has chosen the Intellon's high-speed powerline networking technology as the baseline upon which to build the alliance's first-generation specification
HomePlug Members

Xilinx is an adopter member of the HomePlug
LonMarks

- The Association's mission is to enable the easy integration of multi-vendor systems based on LONWorks networks.
- Today over 3,500 companies are using LONWorks control networks.
- The Association has three major functions:
  - Promote benefits of interoperable LonMark products.
  - Provide collaborative marketing programs for companies developing LonMark products.
  - Provide a forum to define application-specific design requirements.
LONMarks

- Xilinx has joined the LONMarks as a participant
- There are more than 100 system integration companies on the member’s list
Agenda

• Introduction
  – Push for Home Networking
    • Applications
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• Technology
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      – CEBus & OSI Model
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• Summary
Summary

• No need for additional new wiring
  – Existing wires can be used as a medium
  – An inexpensive solution

• Multiple availability of power outlets in each room and across homes
  – There are more power outlets than phone jacks in each room
  – In every 6 feet there is a power outlet

• A mature and proven technology for home automation
  – X-10, CEBus, LONWork, Plug-in, and Adoptive Network technologies have been used for many years
Summary

- New powerline controller products promising a faster, more reliable, and more secure delivery of data, voice, and even video applications
  - Some products have the data rate of 10 Mbps and higher
  - New product developments to reach 25 Mbps and higher
  - New technologies have reduced the noise, data attenuation, and security issues
- Spartan-II FPGAs, CoolRunner & 9500 CPLDs provide system interconnectivity in Ethernet based products