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FPGA Enabled Home Networking Technology Bridges—Connecting Disparate Technologies

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Introduction

The digital age of consumer electronics is here and it is bringing with it faster computing at lower costs. The Internet revolution and distribution of broadband access to different digital consumer electronics and their interoperation introduces a new wave of technology into your home. Home networking involves distribution of audio, video, and data around the home and ensures interoperability between various information appliances in your home. Home networking has four aspects, which include broadband access, residential gateways, a vast range of information appliances, and the technologies that bind them all—interconnectivity or home networking technologies (Table 1).

Table 1: **Aspects to Home Networking**

	Market Requirements	Solutions Available
Broadband Access	High-speed access for data, voice, and video; simultaneous up-link and down-link communication; support simultaneous and multi-user access	xDSL, Cable, ISDN, Powerline, Satellite, Mobile/Wireless
Residential Gateway, Home Gateway, or Services Gateway	Provides access into the home; remote management access platform; bridging between different networks; firewall and security; e-services capabilities	Open-System Gateway Initiative (9OSGI), Jini, UPnP, HAVI
Home Networking Technologies	Low cost; speed; mobility; quality of service; reliability; ubiquity; ease-of-use	No New Wires (Phonelines, Powerlines), New Wires (Ethernet, IEEE 1394/FireWire, USB 2.0); Wireless (HomeRF, Bluetooth, Wireless LANs—IEEE 802.11, HiperLANs)
Information Appliances	Digital electronics with advanced computational capabilities that add more value and convenience when networked	Digital TV/HDTV, set-top boxes, Internet screens, phones, digital VCRs, gaming consoles, MP3 players, cordless phones, security systems, utility meters, PCs, Web pads, Web terminals, PDAs, digital cameras, auto PCs, etc.

Islands of Home Networking Technologies

Home networking represents a collection of multiple (over 20) end-technologies and not representative of one standard or specification. Clearly, no one technology is going to dominate the home networking arena and different technologies will co-exist. This introduces a whole

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new set of variables to the nascent home networking market. Home networking technologies are categorized under three separate islands of technologies.

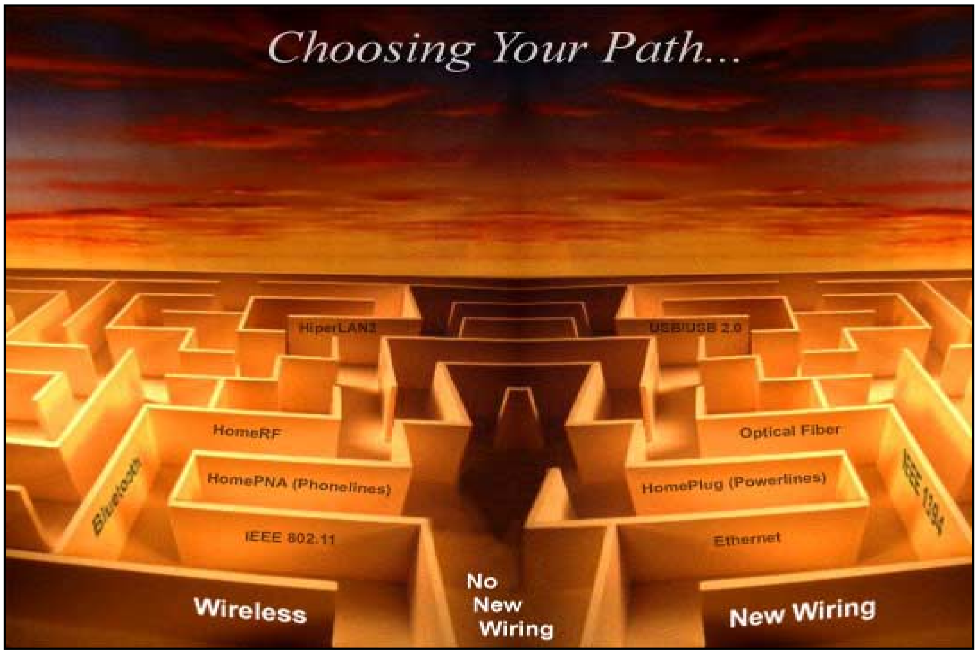

Figure 1: **Disparate Islands of Home Networking Technologies**

No New Wires

No new wires technologies utilize the existing infrastructure available in most homes across the world. These are based on powerlines and phonelines. Advantages of using no new wires are that the consumer does not need to rewire the home and products based on this technology can be cost-effectively deployed immediately. However, the ability to handle high-speed video and other high bandwidth applications under a noisy environment is an issue to overcome.

New Wires

Consumer devices that require high-speed data and video packets are built using Ethernet (IEEE 802.3), IEEE 1394 (FireWire), Optical Fiber, or USB 2.0 (Universal Serial Bus) technologies. However, all of these technologies require additional special wiring around the house, which comes at an additional cost.

Wireless

Wireless technologies such as Bluetooth, HomeRF, IEEE 802.11a, IEEE 802.11b, and HiperLAN2 provide users with mobility, but bandwidth remains an issue. While Bluetooth is a popular personal area network technology, IEEE 802.11, and HiperLAN2L are wireless LAN technologies that provide connectivity to telecommuters, small office/home office (SOHOs) and hospitals. HomeRF remains focussed on cordless transmission of voice and data around the home.

Understanding the Chaos in Home Networking

There is clearly chaos in the home networking market place. There are too many home networking technologies and standards trying to address the same problem. Each standard has its pros and cons and quite a few of them are in conflict with complementary technologies. Each technology has different specification versions and standards, and these keep changing from time to time for the purpose of adding more functionality, bug fixing, and adaptation of new standards. This leads to products with bugs and incompatibilities.

Another implication of this chaos is translation to a steep learning curve. It eventually mandates a “ready, fire, aim” development model. Products should be planed for the longest life cycles and should get to the market as fast as possible. The situation mandates that technology leaders actively participate in multiple consortiums and standards to keep track of the market very closely. Home networking products are being built today and leading technology players are unable to decide a technology of choice and are supporting several if not all possible choices.

The home network created of information appliances will have islands of appliances, supporting varying technologies. Examples of these appliance islands include one that networks mobile devices such as cellular phones, PDAs and notebook PCs with Bluetooth, another island that uses USB/USB 2.0 to network PC-centric devices such as desk-top PCs, printers and scanners, and still another island that networks digital TVs, set-top boxes, gaming consoles, and other bandwidth-heavy entertainment appliances using IEEE 1394.

Critical Need for FPGA-Based Home Networking Bridges

Home networking bridges exist at the periphery of each product and are the most susceptible to constant change and evolution. These products need a flexible, reprogrammable, and low-cost platform to accommodate for time-to-market pressures, specification changes, lack of clear direction, and short product life cycles.

Aggressive process technology adoption has allowed FPGAs to obtain more die per wafer, provide more logic, offer increased performance, and accommodate various ASIC-like features required to allow system integration. This has been fundamentally instrumental in narrowing the wide gap between FPGAs and ASSPs. FPGA vendors, by virtue of the benefits reaped through process technology now have the capability to bring traditional FPGA benefits to the cost-sensitive home networking market.

Conflicting specifications and lack of a clear direction create the need for FPGA-based home networking bridges. It is also quite likely that some of these conflicts may never get resolved. It would be nearly impossible and cost-prohibitive for a supplier of home networking products to cater to all the various specifications and changing needs. At the same time betting on the success of one single product may preclude them from being successful in the marketplace. An example of a wireless LAN to Ethernet technology bridge is shown in Figure 2. An example of a USB to HomePNA and Ethernet technology bridge is shown in Figure 3.

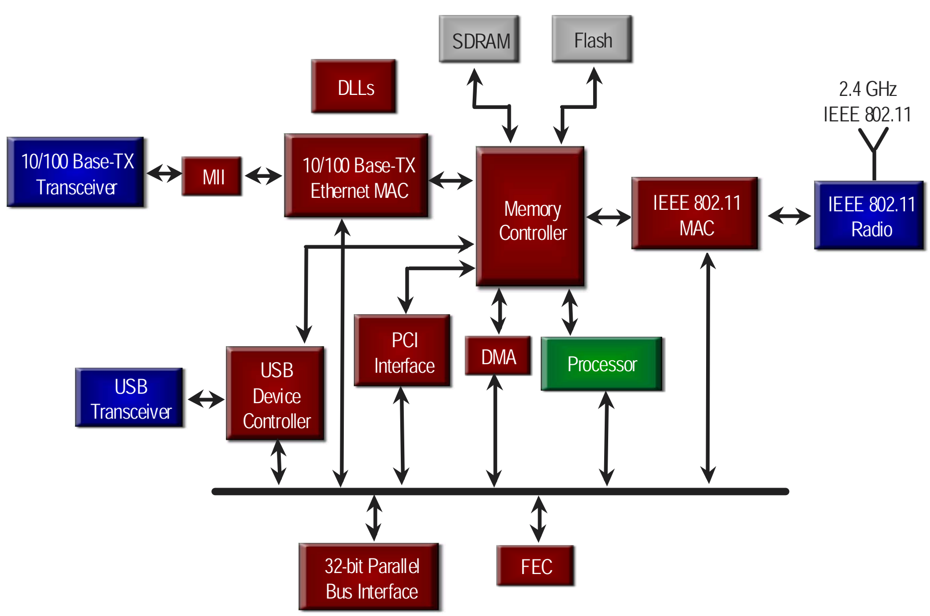

Figure 2: **Wireless-LAN to Ethernet Home Networking Bridge**

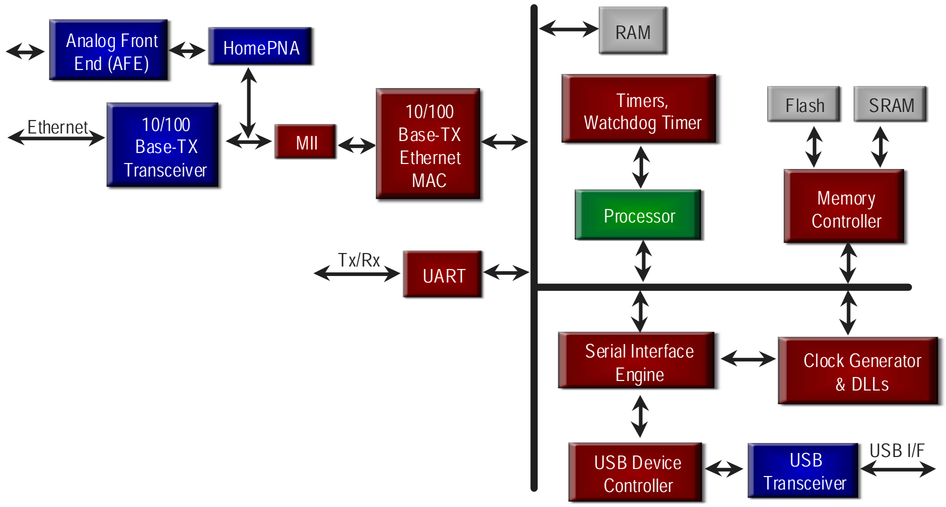

Figure 3: **USB (USB 2.0) to HomePNA (and Ethernet) Technology Bridge**

The functionality of the physical (PHY) and media access control (MAC) layers are defined as part of the OSI network model. The physical layer defines the electrical, mechanical and procedural specifications which provides the transmission of bits over a communication medium or channel. The MAC layer, which is part of the data link layer, ensures error control, and synchronization between the two engaged devices. It is also responsible for determining priority and allocation to access the channel.

In both examples, Xilinx Spartan-II FPGAs are at the heart of the technology bridges, which usually connect unlike technologies—such as wireless LANs to Ethernet or USB/USB 2.0 to HomePNA and Ethernet. While the Ethernet MAC has been around for a long time, the HomePNA specification that defines the MAC and PHY layers are quickly evolving. With the HomePNA 2.0 specification already defined and works on way for a faster, higher bandwidth phonelines specification, it seems ideal for the MAC and MII (media independent interface) to be programmed in an FPGA. Similarly, the IEEE 802.11, HomeRF, FireWire, USB, HiperLAN2, and Bluetooth are all technologies with evolving specifications.

While Spartan-II FPGAs provide critical parts of the technology bridges at low costs, they also have system-level features such as DLLs, block RAM, and SelectI/O to provide additional savings. FPGA gates left over from programming the MAC may be used to customize the end products, and be used for additional functionality such as memory (SRAM, DRAM, and flash) controllers, PCI controller, UARTs, and forward error correction.

Xilinx FPGAs are based on SRAM technology and can be reprogrammed an unlimited number of times. Field upgradability provides the ability to update functionality of the FPGA requiring a simple update to the FPGA configuration bitstream. FPGAs allow designers to gain market share by bringing them to market sooner than a standalone ASSP. Designers can also take advantage of the fact that the solution now allows them to upgrade their hardware and stay in the market-place longer, adapt to specification changes and thus, maximize profitability.

Interoperability is key for market success and products have to be interoperable between different technologies. Technology bridges based on FPGAs address some of the issues facing home networking today, connect different information appliance home networks, and ensure interoperability.

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
03/21/01	1.0	Initial Xilinx release.