Xilinx at Work in Digital Modems

How Xilinx high-volume programmable devices can be used to implement complex system-level glue logic.

by Robert Bielby, Strategic Applications, Xilinx,
robert.bielby@xilinx.com

Internet users are continuing to demand higher bandwidth access to the net. In the face of this demand analog modem technology has hit the end of the road with the 56K generation of devices. Increasing Internet access bandwidth requires a migration to digital modem technologies.

While there are numerous approaches being proposed, including wireless and satellite technologies, it is generally accepted that the bulk of users will get their high bandwidth Internet access using either cable modem or Digital Subscriber Line (DSL) modem technologies. Cable modems offer data rates up to 10 Mbps. DSL technologies offer a variety of access rates up to 6 Mbps.

Cable Modems

Cable modems use the same coaxial cable that is used to deliver cable TV service to provide a connection to the Internet. Digital data is RF modulated and transmitted on 6-MHz channels reserved for data services.

In spite of the higher bandwidth that cable modems appear to offer over DSL technologies, the multidrop configuration of cable requires that the bandwidth be shared among users in a neighborhood. This means that all of the homes in a neighborhood are effectively wired together and all see the same data. Unless data is encrypted before it is transmitted, it is vulnerable to interception by other users.

DSL

DSL technologies use the same twisted pair copper wiring that is used for voice telephone service to deliver high speed digital data. In fact the same line that is used for DSL service can be used for voice service using a standard analog phone. Due to standardization issues, DSL services have gotten off to a slow start. However, it is expected that DSL services will be rapidly rolled out over the next few years.

DSL Technologies

Driving high-speed data down copper pairs from a central office to a subscriber's home requires sophisticated digital signal processing technology. The problem is compounded by the variances in line length, cross talk, wire gauge and other factors. In response to this the various DSL technologies that have appeared make different tradeoffs between data rate, the distance that data can be driven, and complexity of the line-coding scheme used (Table 1).

Fortunately the key players have agreed on a common ADSL technology described in ANSI Standard T1.413, and based on the Discrete Multi Tone (DMT) coding scheme. G.992.1 is the original full rate, 6.1 Mbps, specification. The problem with this standard is that it requires the installation of a "splitter" at the customer premises to support both voice and data over the same line. The G.992.2 (formerly known as G.Lite) was developed to eliminate the need for a

Table 1 DSL Technology Comparison

Technology	Pairs Required	Upstream Data Rate	Downstream Data Rate	Reach
HDSL	2	2 Mbps	2 Mbps	4 km
HDSL2	1	2 Mbps	2 Mbps	4 km
SDSL	1	768 Kbps	768 kbps	4 km
ADSL	1	up to 768 Kbps	up to 6.1 mbps	4 km
VDSL	1	6 or 13 Mbps	13, 26, 52 Mbps	1.5 km
IDSL	1	144 Kbps	144 Kbps	11 km

splitter at the customer end of the line. The tradeoff for the simplified lower cost installation is a reduced data rate, 1.5 Mbps.

Digital Modems and SOHO Routers

A modem has two interfaces: a Wide Area Network (WAN) interface, connected to the phone line, and the host interface, connected to a computer. The function of the modem is to modulate and demodulate (hence the term modem) data for transmission across the WAN interface.

The explosive growth of Local Area Networking (LAN) has created a class of devices targeted at Small Office/Home Office (SOHO) applications that combine a modem with an Access Router. An access router is used to determine whether traffic on a local LAN segment needs to be forwarded to the WAN. SOHO routers typically look like external modems with an Ethernet connection rather than a host connection.

The advantage of a SOHO router over a standard modem is that it lets multiple users share a single Internet connection. The increasing interest in home LAN technology is expected to increase the demand for this class of product.

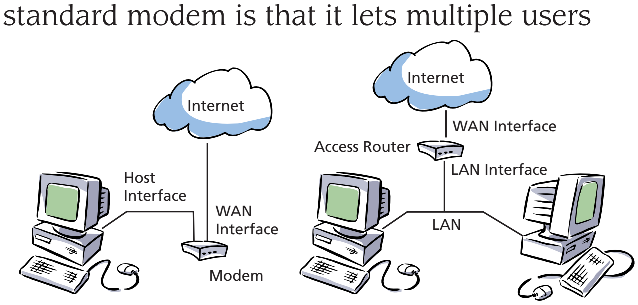

Figure 1 - Digital Modems and SOHO Routers

Digital Modem Architecture

Whether the product is a cable modem, DSL modem, or SOHO router, all of these digital modem products share the common functional blocks shown in Figure 2.

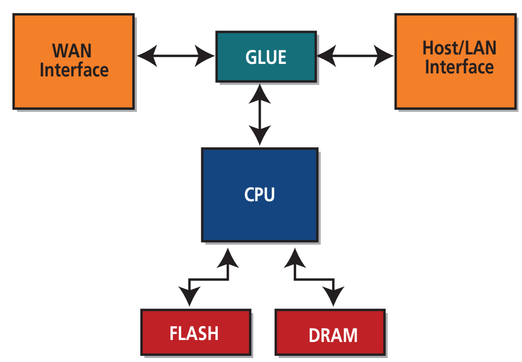

Figure 2 - Digital Modem Architecture

The functional blocks that make up the system are:

- A WAN interface containing the modem functions.
- A CPU complex consisting of the CPU plus RAM and ROM, responsible for configuring and managing the system.
- A Host Interface used to connect a modem to the host computer.

- Or a LAN Interface used to connect a SOHO router to a LAN.

Each of these blocks is typically implemented by a small number of Application Specific Standard Products (ASSPs). In most cases there are mismatches between the ASSPs used to implement each of these blocks. Xilinx FPGAs and CPLDs provide the solution for the system-level glue logic needed to interface these blocks.

Digital Modem WAN Interfaces

WAN interfaces are implemented with specialized signal processing ASSPs, each of which has been targeted at a specific application. Functions that are included in these interfaces include:

- Data encoding and decoding.
- Clock recovery - for encoding and extraction of clock information with the data.
- Adaptive equalization - to deal with line reflections.
- Error Detection and Correction - to deal with data errors.
- Transmission Convergence - to provide framing and ATM cell delineation.

The current price structure for digital modems makes it impractical for these functions to be implemented in current FPGA technology.

LAN Interfaces

LAN interfaces are used on the local side of a SOHO router. This interface gives all users on the LAN access to the WAN connection.

The most popular interface for this application is Ethernet; usually the 10 Mbps twisted pair version (10-BASET). You can also expect to see products being introduced that support the new Phone Networking Alliance (PNA) version of Ethernet. The PNA technology supports 1 or 10 Mbps Ethernet networking over existing phone wiring. Better yet, the technology supports the simultaneous use of the same wiring for phone service.

Another network interface that has been used for first generation DSL modems is 25 Mbps ATM. Ethernet or USB will likely replace this interface in next generation products.

LAN interface ASSPs are targeted at the PC adapter card market. As a result virtually all include a PCI host interface. In addition software support comes in the form of drivers for PC operating systems.

Host Interfaces

Host interfaces are used on the local side of a modem, and connect the modem to a PC, server, or other networking equipment. For an internal modem this interface is the I/O bus of the computer, typically ISA or PCI.

In the past, the most popular interface for external modems has been RS-232. Unfortunately this interface is not fast enough to support the data rates provided by digital modems. As a result manufacturers of DSL and cable modems have had to move to other interfaces.

The most popular choice for new designs has been Universal Serial Bus (USB). A key advantage of this interface is that USB has been incorporated into PC core logic for over a year and as a result is included as a standard feature in all new PCs. The downside to USB is that while the raw data rate is 12 Mbps, most vendors have not been able to get more than 2 to 3 Mbps from existing implementations. While not adequate for full-rate DSL and cable modem applications, this is not a limitation for the 1.5 Mbps supported by G.Lite DSL which is expected to make up the bulk of DSL modem shipments. In addition, USB 2 will support data rates in excess of 120 Mbps.

DSL Modem Add-In Card

An internal modem is still the most cost-effective solution. When using an off-the-shelf ADSL ASSP, such as the Dynamite chipset from Alcatel, there is a need to connect the Utopia interface of the chipset to the PCI bus within the PC. Although the ADSL chipset contains a significant amount of functionality, there is still the need to pack and unpack data into data blocks called cells. This process is commonly referred to as segmentation and reassembly.

In the past this has been accomplished through the use of an ATM device called a segmentation and re-assembly controller (SAR). These devices are relatively expensive. One of the more cost-effective versions available costs $20 in volume and requires a 32-bit wide pool of SRAM to do its job.

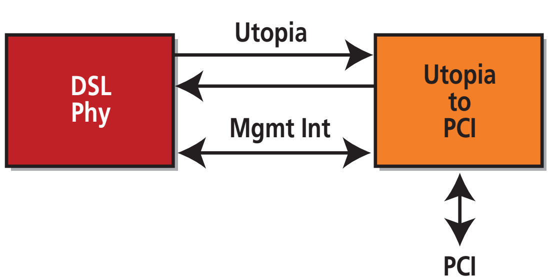

Figure 3 - DSL Modem PCI Card

A significant amount of the complexity and resulting cost of this interface can be eliminated by transferring the SAR functions to the host's CPU and implementing only bus interface and DMA functions in the Utopia to PCI interface. Offloading the SAR function to the CPU allows the interface to be implemented in a Spartan device for less than $10.

DSL Modem with USB

A DSL modem that provides a USB interface is attractive since it not only eliminates the need for users to open their systems but also provides a means of supporting non-PC systems such as the popular iMac.

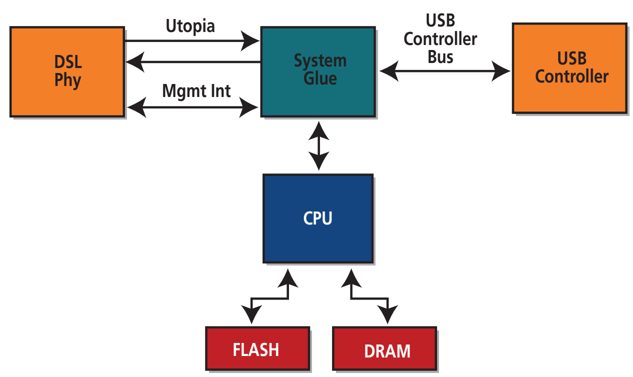

Figure 4 - DSL Modem with USB Host Interface

The problem for the designer of such a product is that it means gluing together several ASSPs that were not designed to interconnect directly. The system glue must interface the Utopia bus that transfers ATM cells to and from the DSL chipset, the proprietary micro controller interface that is provided by the USB controller and the micro controller itself. In addition to just connecting the pins the glue logic, it also needs to implement DMA functionality so that the micro controller is not overwhelmed with transferring the data via software.

There is also this issue: the protocol between the modem and the host system across USB has not been standardized. This means that each modem will require driver support from the manufacturer. This is not the case with most analog modems, which can use a driver that comes with Windows. Therefore the ability to update the design in the field to be compatible with emerging standards is a valuable feature to vendors trying to get products to market quickly.

Both the glue logic complexity and the lack of standardization make this type product an ideal candidate for FPGA-based glue logic. The cost sensitive nature of this high volume market makes Spartan FPGAs the ideal solution.

DSL SOHO Router

Designers of DSL SOHO routers also face the task of gluing together a system from ASSPs with differing interfaces. One of the features that differentiates a router from a modem, the interaction of the CPU with each packet that passes through it, also means that a higher performance CPU is needed and the interface between the CPU and the network interfaces must be more efficient.

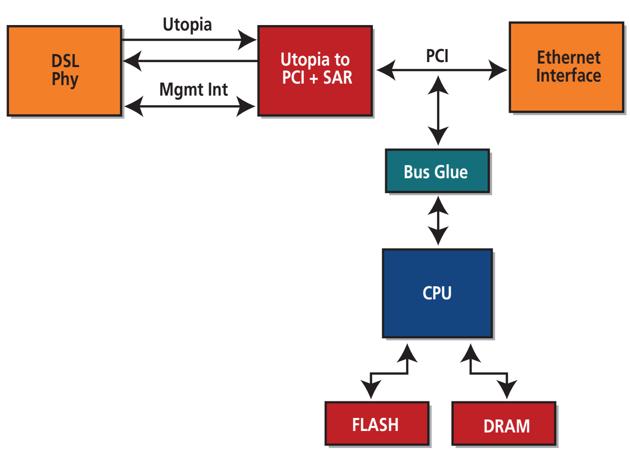

Figure 5 - DSL SOHO Router

Because the LAN interface usually includes an Ethernet interface, a natural approach is to glue the other two blocks to PCI. In the case of the DSL chipset this usually means interfacing Utopia to PCI, and as in our DSL add-in card example, a Spartan device provides a very low cost means of accomplishing this.

Many embedded RISC controllers now come with PCI interfaces built in. If you have chosen a CPU that doesn't, then the same Spartan device can implement a CPU host bridge at a lower cost than off-the-shelf devices designed for that purpose. The Spartan FPGA can also be used to implement routing-specific functions such as header parsing, IP checksum calculation, and buffer management to leverage CPU MIPs more effectively.

Conclusion

Designers of digital modem products are faced with the task of interfacing a variety of devices with incompatible interfaces. Xilinx high volume FPGA and CPLD technologies provide you with cost effective solutions that retain the traditional PLD time to market advantage.