FPGAs Enable Wireless LANs

Wireless local area networks (WLANs) provide mobility and portability with high-bandwidth data, voice, and video access – they are the ultimate solution for enterprise, SOHO, and home applications.

by Amit Dhir
Manager, Strategic Applications
amit.dhir@xilinx.com

Wireless local area networks (WLANs) are a rapidly emerging market. They combine data connectivity with user mobility and provide a connectivity alternative for a broad range of consumers and business customers. They have a strong popularity in vertical markets such as telecommuting, SOHOs (small offices, home offices), health care, retail, manufacturing, warehousing, and academia, where productivity gains are realized by using hand-held terminals and notebook PCs to transmit real-time information to centralized hosts for processing.

Spartan™-II FPGAs provide the flexibility needed in the WLAN market, allowing you to easily create products that can adapt to the evolving specifications and standards, and interface with other emerging technologies.

The WLAN Market

Business Research Group, a leading market researcher, predicts that revenues from WLAN products will exceed $2 billion in the year 2002, and show a steady growth of unit shipments and revenue. Demand for computing and telephony mobile devices will be one of the most influential market drivers, along with end users demanding higher data rates and ease of use to sustain growing Internet and data applications.

However, several issues remain unsolved for the industry. Although vendors have made great strides in achieving interoperability, a common wireless standard is far from reality (today, there are seven standards). Interference from competing 2.4 GHz technologies (like Bluetooth™ and HomeRF) threatens the already crowded band. In addition, uncertainties exist with several technologies migrating to the evolving 5 GHz frequency band.

WLAN Technology

WLANs focus on the PHY (physical) layer and the data-link layer – which includes the medium access control (MAC) and logical link control (LLC) sub-layers – of the seven-layer OSI network model. The physical layer defines the electrical, mechanical, and procedural specifications, which provide the transmission of bits over a communication medium or channel.

WLAN PHY layer technologies include narrowband radio, infrared, OFDM, and spread spectrum. The MAC sub-layer ensures error control and synchronization between the physically connected devices communicating over a channel. It is also responsible for determining priority and allocating access to the channel.

PHY Layer (Radio) Technologies

Infrared (IR) – Infrared technology uses very high frequencies, just below visible light in the electromagnetic spectrum to carry data. While popular with other wireless technologies, it is not gaining momentum with WLANs. It is good for inexpensive, directed, very limited range (up to 3 feet) systems, such as personal area networks.

Narrowband Radio – In narrowband radio, the user transmits and receives information on a specific frequency. This radio frequency (RF) bandwidth is kept as low as possible. Any undesirable crosstalk between communication channels is carefully avoided by coordinating the different users on different frequency channels. This technology requires the end user to obtain an FCC license for each site where this technology is to be deployed.

Spread Spectrum (SS) – SS was developed as a wideband RF technology for reliable, secure, and mission-critical military communications while trading off bandwidth. In this modulation technique, the radio transceiver spreads a signal's power over a wider band of frequencies. The spreading process makes the data signal much less susceptible to electrical noise than conventional radio modulation techniques.

The transmitted signal occupies a bandwidth considerably greater than the minimum necessary to send the information. Sacrificing processing gain (bandwidth) to gain signal-to-noise performance contradicts the desire to conserve frequency bandwidth. However, the tradeoff produces much louder and easier to detect signals, if the receiver knows the parameters of the broadcast signal.

Some of the SS modulation advantages include low power spectral density, interference limited operation, privacy, and random access possibilities. SS modulation techniques include:

- **Frequency Hopping Spread Spectrum (FHSS)** – A data signal is modulated with a narrow-band carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies. It relies on frequency diversity to combat interference, which is accomplished by multiple frequencies, code selection, and FSK (Frequency Shift Keying). For example, a frequency hopping radio will hop the carrier frequency over the 2.4 GHz frequency band between 2.4 GHz and 2.483 GHz. If the radio encounters interference on one frequency, the radio will retransmit the signal on a subsequent hop on another frequency.

- **Direct Sequence Spread Spectrum** – DSSS is a more advanced, more recognized, and more used form of SS. The DSSS process is performed by effectively multiplying a 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 (such as BPSK and QPSK). 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.

- **Orthogonal Frequency Division Multiplexing (OFDM)** – OFDM technology is extremely effective in time-dispersive environments. The signals can take several paths to reach their destinations, thus resulting in variable time delays. At high data rates these time delays can reach a significant proportion of the transmitted symbol (a modulated waveform). This results in one symbol interfering with the next, thus making OFDM the only answer to "intersymbol interference" or ISI.

Direct Sequence (DS)	Frequency Hopping (FH)
Higher throughput	Interference immunity
Wider range	Echo resistant
Upgradeable to higher speeds at 2.4 GHz	Less expensive than DS systems
	Simpler installation
	More expensive product selection, more vendors

Figure 1 - Direct Sequence vs. Frequency Hopping

Data-Link Layer Technologies

LLC – The Logical Link Control sub-layer resides above the MAC sub-layer in the data link layer. It is responsible for the framing (or frame construction). The LLC inserts certain fields in the frame such as source and destination address at the head end of the frame and error handling bits at the end of the frame.

MAC – The MAC provides access control functions for shared medium PHYs in support of the LLC layer. The primary functions of the MAC layer include addressing (accessing the wireless medium), access coordination (joining the network), and frame check sequence generation and checking (providing authentication and privacy). The MAC layer uses access protocols such as carrier sense multiple access (CSMA) and time division multiple access (TDMA).

WLAN Types

The different types of wireless LAN standards are IEEE 802.11b, IEEE 802.11a, and HiperLAN2. IEEE 802.11b was among the first and currently most successful and popular wireless LAN standards to break onto the enterprise and home networking scenes. IEEE 802.11b is a 2.4 GHz standard using DSSS and is based on CSMA/CA. The future for wireless LANs is looking to migrate to 5 GHz OFDM-based PHY layers for both HiperLAN2 and IEEE 802.11a standards.

While having very similar PHYs and data rates (of 54 Mbps) the two will have dissimilar MAC layers, with HiperLAN2 supporting TDMA/TDD, and IEEE 802.11a supporting CSMA/CA. The growing popularity of wireless LANs is primarily because of the leap to high data rates and QoS (Quality of Service). Some industry pundits also believe that the wireless LAN market will pose a significant threat to the cellular (3G) space.

IEEE 802.11

IEEE 802.11 is the IEEE standard addressing the 2.4 GHz and 5 GHz WLAN market. The IEEE 802.11b extension employs a modulation scheme called complementary code keying (CCK) and operates in the 2.4 GHz ISM (industrial, scientific, medical) band. It is designed to enable data rates of 1 Mbps to 2 Mbps for FHSS networks and 1 Mbps to 11 Mbps for DSSS systems and provide interoperability between both DSSS and FHSS networks.

IEEE 802.11a, a recently formalized extension to 802.11, provides higher speeds and compatibility with existing standards. IEEE 802.11a employs the OFDM modulation scheme and uses the 5 GHz band. It provides a maximum optional speed of 40 Mbps and a range of 150 meters.

HiperLAN2

HiperLAN2 is an OFDM-based, variable bit rate PHY layer technology operating at 5 GHz. It has FEC error control, with dynamic sub-channel modulation allowing data transmission at higher rates with a strong SNR at lower throughputs in adverse conditions. HiperLAN2 provides high bandwidth up to 54 Mbps, with a range of over 150 meters. It has a generic architecture and supports Ethernet, IEEE 1394, ATM, PPP, and 3G.

The HiperLAN2 data-link layer/MAC provides QoS via dynamic fixed time slots. The time slotted structure allows simultaneous communication in both downlink and uplink in the same period. It is also a connection-oriented technology that allows negotiation of QoS parameters like bandwidth, bit error rate, latency, jitter, and delay requirements. This assures that other terminals will not interfere with subsequent transmissions. It provides ARQ (Automatic Repeat reQuest), dynamic frequency selection, power control and power save, cellular hand-over and, security (authentication and encryption).

WLAN Products Using Spartan-II FPGAs

WLAN products include network interface cards (or NICs/PC adapters), APs (end-user-to-LAN and LAN-to-LAN) and technology bridges for communications. NICs provide an interface between the end-user device (desktop PC, portable PC, or handheld computing device) and the airwaves via an antenna on the APs. APs act as transmitters/receivers between wired and wireless networks. They connect to the wired network via standard Ethernet cable (token ring is available, but less common) and use airwaves to transmit information to and from "connected" wireless end users.

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

The Spartan-II family is ideal for creating WLAN products. It provides increased densities (up to 200,000 system gates) and system-level features (such as DLLs, BlockRAM, and SelectI/O™) at a much lower cost. 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 controllers, PCI controller, UARTs, and forward error correction (FEC).

NIC/PC Cards

Figure 3 shows the WLAN card, which consists of the antenna, radio/PHY, baseband controller and the MAC. The role of FPGAs is highlighted in red. The block diagram of the PC card shows that the Spartan-II FPGA provides functionality of a WLAN MAC (radio control, packet header generator, MAC protocol engine,

Characteristic	IEEE 802.11b	IEEE 802.11a	HiperLAN2
Spectrum	2.4 GHz	5 GHz	5 GHz
Maximum physical rate (approx.)	11 Mbps	40 Mbps	54 Mbps
Maximum data rate, layer 3 (approx.)	5 Mbps	28 Mbps	32 Mbps
Medium access control/Media sharing	CSMA/CA		Central resource control/TDMA/TDD
Connectivity	Connection-less	Connection-less	Connection-oriented
Multicast	Yes	Yes	Yes
QoS support	PCF	PCF	ATM/802.1p/RSVP/DiffServ (full control)
Frequency selection	DSSS	Single carrier	Single carrier with Dynamic Frequency Selection
Authentication	No	No	NAI/IEEE address/X.509
Encryption	40-bit RC4	40-bit RC4	DES, Triple-DES
Handover support	No	No	No
Fixed network support	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, FireWire, PPP
Management	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No	Link adaptation

Figure 2 - IEEE 802.11 vs. HiperLAN2

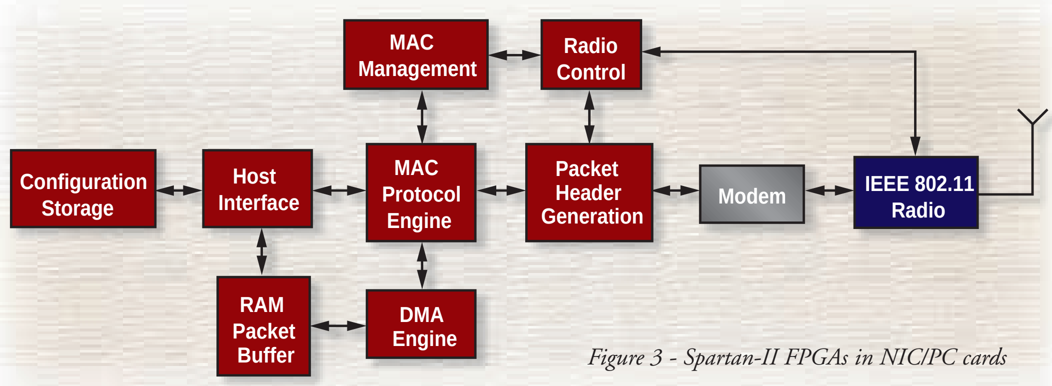

Figure 3 - Spartan-II FPGAs in NIC/PC cards

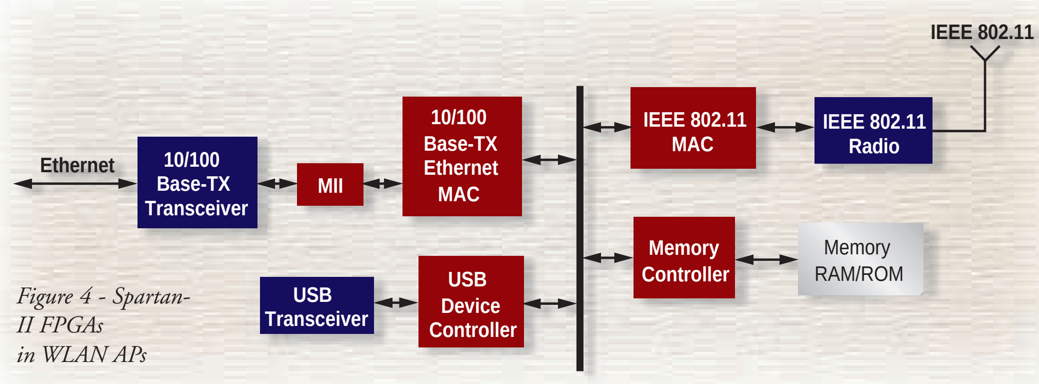

Figure 4 - Spartan-II FPGAs in WLAN APs

DMA engine, RAM packet buffer, host interface, configuration storage and MAC management), memory controller and as an interface to the PC.

Access Points

The APs are devices that provide a wireless hub or a gateway for non-wireless networks to wireless networks. They also act as the network police and perform network management. They receive, buffer, and transmit data between WLAN and the wired network infrastructure. APs function within a range of 100 to several hundred feet. They also connect WLANs to other technologies such as USB and Ethernet. In Figure 4, Spartan-II FPGAs provide solutions in APs such as memory controller, Ethernet MAC, USB device controller, and IEEE 802.11 MAC.

Technology Bridges

Conflicting specifications and lack of a clear direction create the need for FPGA-based technology bridges. It would be nearly impossible and cost-prohibitive for a supplier of home networking and WLAN products to meet 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.

Figure 5 shows an example of a WLAN to Ethernet technology bridge. In this example, Xilinx Spartan-II FPGAs are at the heart of the technology bridges, which usually connect unlike technologies – such as WLANs to Ethernet. While the Ethernet MAC has been around for a long time, the IEEE 802.11 specification that defines the MAC and PHY layers continue to evolve. With IEEE 802.11a and HiperLAN2 specifications still not defined, it seems ideal for the MAC and MII (media independent interface) to be programmed in an FPGA. Similarly, the HomePNA, HomeRF, FireWire™, USB, HiperLAN2, and Bluetooth are all technologies with evolving specifications.

WLAN products will extend beyond NICs, APs, and technology bridges, and will enable every device in the home, SOHO, and enterprise with WLAN capabilities. This includes such devices as digital TV, residential gateways, set-top boxes, digital modems, PC peripherals, gaming consoles, and other appliances.

Conclusion

The WLAN market is growing fast with a promise to penetrate homes, SOHOs, and enterprises in large volumes. Being a cost sensitive and evolving market, WLAN products require low-cost programmable logic solutions that allow customers to realize time-to-market and time-in-market advantages. Spartan-II FPGAs – with increased densities, system-level features, an extensive IP portfolio, and low costs – provide an ideal solution for WLAN products such as NICs, APs, technology bridges, and other products. Spartan-II FPGAs provide interoperability between different technologies, which is essential for success in this market.

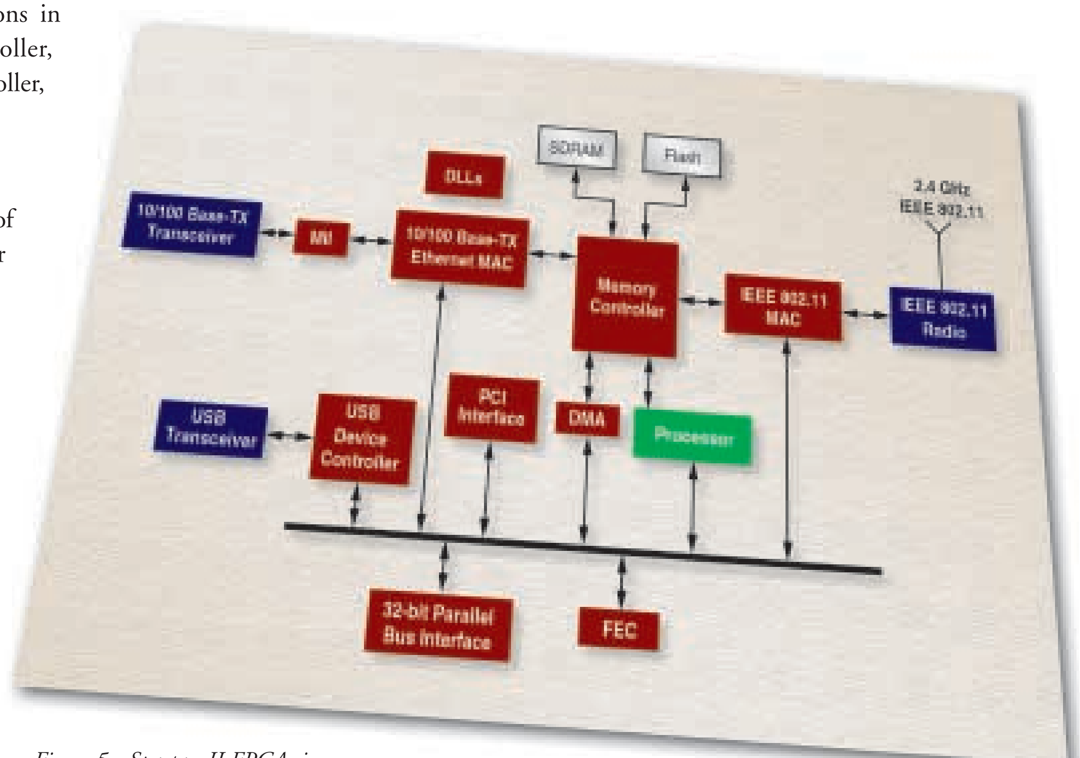

Figure 5 - Spartan-II FPGAs in (WLAN to Ethernet) technology bridges