# Wireless LAN Solutions

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Wireless LAN that complies with the IEEE802.11 standard has become standard equipment on personal computers in recent years. Further, progress is being made to load these devices into printers and projectors. One could say that they have steadily attained full membership in the SOHO environment. They are also expected to be implemented for home entertainment functions related to applications that transmit audiovisual signals as well as portable-type game machines. Furthermore, their application in the field of voice communications is anticipated, in combination with the Voice over Internet Protocol (VoIP) technology.

In order to develop products in a timely manner for the wireless LAN market, which is rapidly expanding, it is essential to shorten the development period while reducing the risks related to LSI remakes resulting from respins. On the other hand, there is the prospect of utilizing Intellectual Property (IP) for shortening the development of TAT for large-scale system LSIs and a means for improving design productivity. The establishment of IP distribution channels is proceeding at a rapid pace.

This paper will describe the IP for wireless LAN that complies with the IEEE802.11 standard and the evaluation board for the IP of wireless LAN developed in response to these demands by Oki Network LSI Co., Ltd.

## IP for IEEE802.11a/b/g/i compliant wireless LAN

Figure 1 shows an example of a configuration for the wireless LAN transceiver LSI that uses an IP for wireless LAN.

The base band signal processing section of the physical layer is composed of the 802.11a/g PHY BB signal processing IP that processes the Orthogonal Frequency Division Multiplexing (OFDM) signal adopted by the IEEE802.11a/g and the 802.11b PHY BB signal processing IP, which processes the Direct Sequence Spread Spectrum/Complementary Code Keying signal adopted by the IEEE802.11b. The MAC accelerator IP, which performs protocol processing in the Media Access Control (MAC) layer is composed of a hardware section and a firmware section. A configuration that makes a connection via the ARM*2) processor, which is now a de facto standard and the AHB*2) bus, has been adopted for the hardware section. Further, the configuration is such that the hardware accelerator that processes the encryption functions, using the Temporal Key Integrity Protocol (TKIP) added by the IEEE802.11i recommendation and the Counter Mode with Cipher-Block Chaining Message Authentication Code Protocol (CCMP), as well as the firmware that presides over the authentication function with the network, are all operable through the connection with the MAC accelerator IP. The numbers of gates in the hardware sections of their respective IPs recently developed are shown in Table 1.

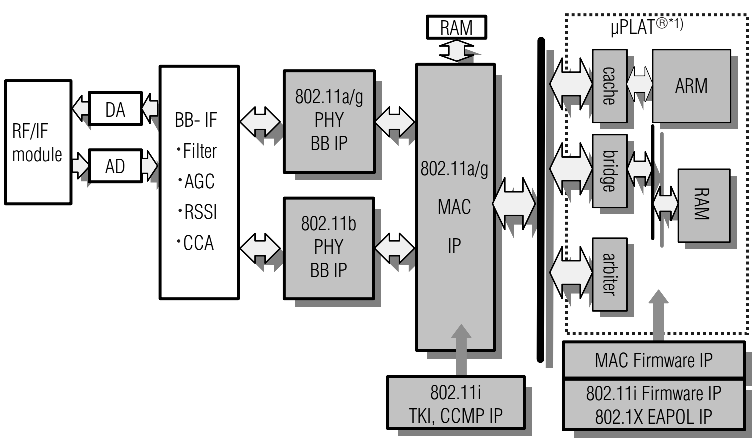


**Fig. 1 Configuration example of a wireless LAN transceiver LSI.**

**Table 1 Number of gates of IPs for wireless LAN.**

| IP name | Number of gates |
|---|---|
| 802.11 a/g PHY BB signal processing IP | 380 k gates |
| 802.11 b PHY BB signal processing IP | 270 k gates |
| 802.11 a/g MAC accelerator IP | 110 k gates |
| 802.11 i security IP | 100 k gates |

*1) μPLAT is a registered trademark of Oki Electric Industry Co., Ltd.
*2) ARM and AHB are registered trademarks of ARM Ltd., in the United Kingdom and other countries.

**Table 2 IEEE802.11a/g main specifications.**

| Functions | Specifications |
|---|---|
| Modulating method | Primary modulation: BPSK, QPSK, 16QAM and 64QAM.<br>Secondary modulation: OFDM method. |
| Number of sub-carriers | 52 sub-carriers<br>(including four pilot signals) |
| Error correction methods | Convolution coding<br>(Constraint length = 7; Coding rate = 1/2, 2/3 and 3/4).<br>Viterbi decoding method<br>Symbol internal interleave |
| Transmission rates | 6Mbit/s (BPSK, R=1/2)<br>9Mbit/s (BPSK, R=3/4)<br>12Mbit/s (QPSK, R=1/2)<br>18Mbit/s (QPSK, R=3/4)<br>24Mbit/s (16QAM, R=1/2)<br>36Mbit/s (16QAM, R=3/4)<br>48Mbit/s (64QAM, R=1/2)<br>54Mbit/s (64QAM, R=3/4) |
| Symbol length | 4.0µs (guard interval: 0.8µs) |
| Occupied frequency bandwidth | 16.6MHz |

**Table 3 Main Specifications of the IEEE802.11b.**

| Functions | Specifications |
|---|---|
| Modulating method | Primary modulation: DBPSK and DQPSK.<br>Secondary modulation: DSSS method. |
| Diffusion codes | Barker coding: 11 chips/symbol.<br>CCK coding: 8chips/symbol. |
| Transmission rates | 1Mbit/s (DBPSK and Barker coding).<br>2Mbit/s (DQPSK and Barker coding).<br>5.5Mbit/s (DQPSK and CCK coding).<br>11Mbit/s (DQPSK and CCK coding). |
| Symbol length | 1Mbit/s and 2Mbit/s: 1.0µs.<br>5.5Mbit/s and 11Mbit/s: 0.73µs. |
| Occupied frequency bandwidth | 11.0MHz |

**(1) 802.11a/g PHY BB signal processing IP**

In general the OFDM modulation and demodulation method, adopted by the IEEE802.11a standard and the IEEE802.11g standard, very efficiently uses frequencies and is suitable for high-speed transmissions, aside from the fact that it is the method being adopted by various digital transmission systems that are not limited to wireless LAN, as with the insertion of guard intervals it is a robust modulating and demodulating method even with Signal degradation which can occur due to multipath, etc. The main specifications of the IEEE802.11a standard and the IEEE802.11g standard are listed in Table 2.

A block diagram of the 802.11a/g PHY BB signal processing IP is shown in Figure 2. The OFDM modulation and demodulation, which is a multiple carrier transmission method, is loaded by using the Fast Fourier Transform (FFT)/Inverse FFT (IFFT) circuit. With this IP a gate level reduction is realized with the adoption of the configuration wherein the FFT/IFFT circuit is shared for transmission and reception. The reception performance is improved by loading the automatic frequency compensation circuit, which compensates for carrier frequency errors and the channel estimation circuit that compensates for the selective phasing of frequencies, along with the channel compensation circuit. Further, the Viterbi demodulation circuit of the soft decision-making method has been adopted as the error correction circuit.

**(2) 802.11b PHY BB signal processing IP**

The IEEE802.11b standard established in 1999 adopted CCK that realizes an acceleration of speed by assigning information to complimentary codes, which are diffusion codes, in order to further accelerate the speed using a spectrum mask the same as that of the DSSS modulation method of the IEEE802.11 standard. The maximum transmission speed was extended from 2Mbit/s to 11Mbit/s. Main specifications of the IEEE802.11b standard are shown in Table 3.

A block diagram of the 802.11b PHY BB signal processing IP is shown in Figure 3. A Rake reception circuit, which synthesizes delayed waves with a multipath for the purpose of improving the reception SNR, is loaded in this IP. The CCK demodulation is realized by loading the Fast Walsh Transfer (FWT) circuit. Further, the adopted

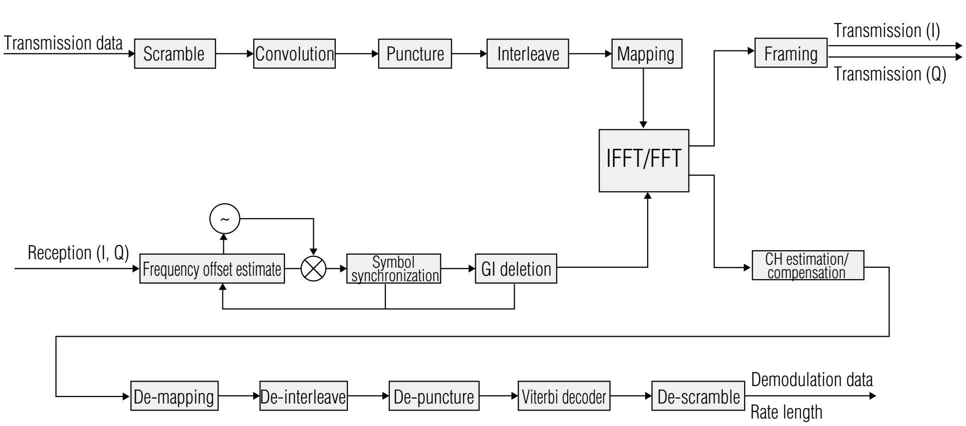


**FIg. 2 Block diagram of the 802.11a/g PHY BB signal processing IP.**

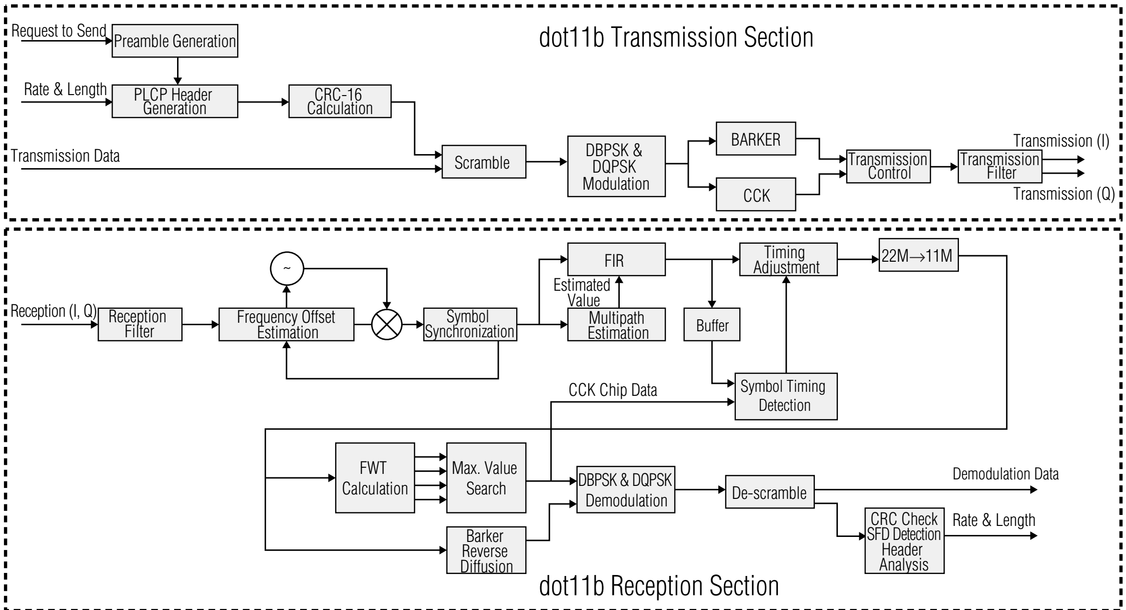


**Fig. 3 Block diagram of the 802.11b PHY BB signal processing IP.**

configuration makes it possible to convert the operating clock of the IP to 40MHz, just like the 802.11a/g PHY BB signal processing IP by applying the interpolation filter, which converts the 40MHz sampling signal of the AD converter into a 22MHz sampling signal as a reception filter. This configuration makes it possible to realize a simple configuration for clock systems while seeking to share the AD converter, making it easier to realize a reduction in the LSI chip's size and to lower the power consumption.

**(3) 802.11a/g MAC Accelerator IP**

The Distributed Coordination Function (DCF) control feature that distributes the access rights to wireless media evenly by using the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and the Point Coordination Function (PCF) control feature, which controls access to all wireless media from a base station, can be mentioned as the basic functions of the MAC section as defined by the IEEE802.11 standard.

The equalization control of access authorization to wireless media, which is implemented by the DCF control, is realized through a randomization of access using the backoff function. The access control provided by the PCF control, on the other hand, is realized by controlling the polling of mobile stations from a base station.

The competition control by CSMA/CA with the 802.11a/g MAC accelerator IP and the sending of response packets by Request to Send/Clear to Send (RTS/CTS) are processes performed in units of microseconds and are installed as hardware in the transmission data control circuit and reception data control circuit. Further, the encryption process that involves a lot of calculation processes will be loaded as a hardware accelerator for an encryption process that is optimized for each encryption method.

The distribution of functions between the hardware and the firmware is considered to be favorable for reducing the power consumption in general, even though logic circuits increase as a result of loading functions as hardware, it becomes possible to lower the operating frequency of the processor. Further, as it would be possible to use processors with lower processing capacities, a reduction in LSI costs can be anticipated. Particular emphasis was placed on reducing the power consumption for this IP. While securing a maximum throughput at 54Mbit/s, complying with the IEEE802.11a and IEEE802.11g standards, functional distribution that make it possible to execute MAC protocol processes complying with the IEEE802.11 standard at approximately 20MIPS, were also implemented in consideration for the flexibility to expand functions as new standards to be established in the future.

**(4) 802.11i Security IP**

The IEEE802.11 standard, which was established in 1997, stipulates Wired Equivalent Privacy (WEP) that uses RC4 as the encryption method. In recent years, however, vulnerabilities in this method have been pointed out. The newly instituted IEEE802.11i standard adopts the CCMP, which uses the TKIP and AES coding as the encryption method. Further, as for the authentication method, expansion of the standard has been made to accommodate authentication methods that use authentication servers stipulated by the IEEE802.1X standard along with conventional authentication methods for wireless LAN, which also had in the past been stipulated.

The encryption section is loaded internally in the 802.11a/g MAC accelerator IP as the hardware accelerator for encryption processing that has been optimized for each encryption method. Further, a configuration that allows it to be loaded onto a host CPU, such as an application processor, is adopted for the

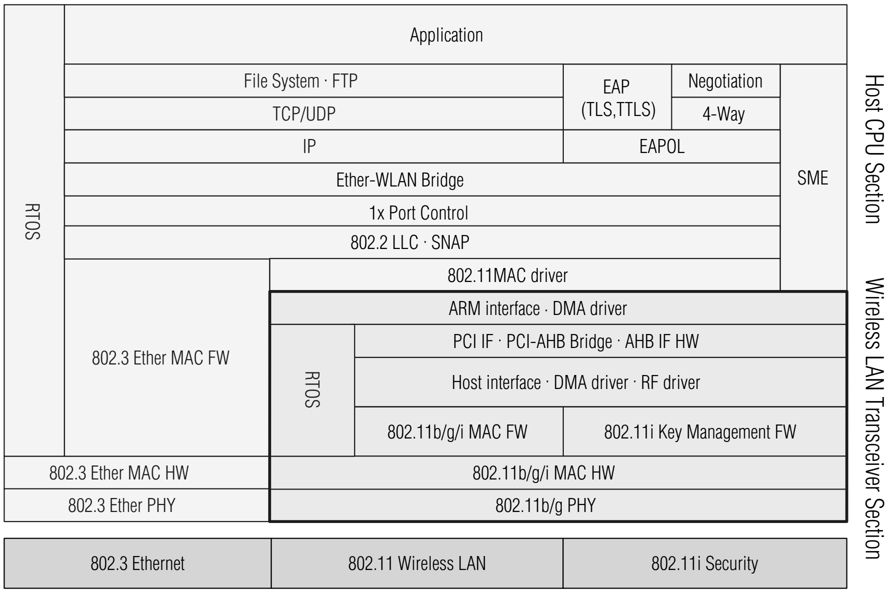


**FIg. 4 Protocol Implementation Example for Wireless LAN and Wired LAN.**

firmware for authentication. An implementation example of the protocol to the bridging equipment of wireless LAN and wired LAN is shown in Figure 4.

## Evaluation Board for IP of Wireless LAN

Building an actual device evaluation environment using a prototyping board is an effective method[1),2)] that can be used to shorten the design TAT for the development of system LSIs. An external view of an evaluation board for the IP of wireless LAN is shown in Photo 1. This evaluation board was developed based on the µPLAT® prototyping board that uses ARM946. It is possible to evaluate an IP for wireless LAN by using it as a simplified bridging device for wired LAN by itself. Further, by connecting it to a host CPU board or a personal computer via a PCI bus it is possible to quickly place this evaluation board into a system development environment already being used by our customers.

**Phot. 1 Evaluation board for IP of wireless LAN.**

This evaluation board makes it possible to perform system evaluations using the IP for wireless LAN in an environment that is as close as possible to the actual LSI environment without causing deterioration of the operating capacity, which can occur due to the configuration of a prototype board, by mounting the FPGA loaded with the IP for wireless LAN on the same board as the ARM processor is mounted.

## Future Developments

Elemental technologies necessary to realize wireless LAN compliant with the IEEE standards, as well as a description on the IP for wireless LAN and its evaluation board developed by ONW, were provided as a wireless LAN solution in this paper. We are planning to concentrate our efforts on the field of streaming transfers of image data in particular in the future. We plan to take on tasks related to realizing the Quality of Service (QoS) functions stipulated by the IEEE802.11e standard as well as the conversion of the physical layer to broader bandwidths by adopting the Multi Input Multi Output (MIMO) method stipulated by the IEEE802.11n.

We at Oki Network LSI will continue developing the wireless LAN technology targeting integrated uses to offer IP solutions of the highest quality based on leading-edge communication technologies.

## References

1) Mori and Saito: “LSI Design Solution - Function Evaluation Solution”, Oki Technical Review, Issue 198, Volume 71, No. 2, pp. 52 to 57, 2003.
2) Inaba: “Prototyping Technology of µPLAT”, Oki Technical Review, Issue 196, Volume 70, No. 4, pp. 52 to 55, 2003.

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