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Implementation of IR-UWB MAC Development Tools Based on IEEE 802.15.4a

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Abstract

IR-UWB has been developed as a standard of indoor ranging technology because it has robust and good transmission characteristics in indoor environments and it can be operated with low power. In this paper, an IR-UWB MAC packet analyzer and a MAC test suite are designed and implemented based on IEEE 802.15.4a, which are useful in developing IR-UWB real time location systems with a resolution of a few ten centimeters. A sniffer device of the packet analyzer monitors IR-UWB wireless networks, captures MAC packet frames, and transmits packet frames to the packet analyzing computer. The packet analyzing program in a computer analyzes received MAC packet frames and displays parsed packet information for developing engineers. The MAC test suite serves as a role of higher layer for testing IR-UWB MAC functions one by one. Developed MAC development tools are used to analyze IEEE 802.15.4a MAC protocol, and it can also be used in other IEEE 802 series MAC protocol by modifying some functions.

Keywords: *IR-UWB, packet analyzer, MAC test suite, IEEE 802.15.4a*

1. Introduction

Automatic navigation systems using satellite GPS (Global Positioning System) and various LBS (Location Based Services) using mobile communication networks have been developed for wide-area location estimation. But its estimation accuracy is low and it does not operate in indoor or radio shadow area. New indoor location estimation technologies have been developed by using techniques such as IR-UWB (Impulse Radio Ultra Wideband), WLAN, ZigBee and CSS (Chirp Spread Spectrum). Among them, IR-UWB has become a frontier of indoor ranging technology, because it has robust and good transmission characteristics in indoor environments and it can be operated with low power. Impulse technology transmits very short pulses of about 2 nsec, so it can be used not only for data communication, but also for a precise location estimation and tracking with a resolution of a few ten centimeters. The IR-UWB standard defines two layers, made up of a physical layer and a MAC layer. It became a standard of IEEE 802.15.4a WPAN in March 2007 [1, 2].

Packet analyzer consists of a sniffer device and a packet analyzing PC program. A sniffer device of the packet analyzer monitors IR-UWB wireless networks, captures MAC packet frames, and transmits packet frames to the packet analyzing computer. The program analyzes received MAC packet frames following IEEE 802.15.4a standard and displays parsed packet information for developing engineers.

The MAC test suite serves as a role of higher layer for testing IR-UWB MAC primitive functions one by one. MAC layer program and network layer program of IEEE 802.5.4 have been developed widely [3, 4, 5, 6]. However, the commercial product of MAC layer

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program of IEEE 802.15.4a has not been released. Because error checking and debugging are always prerequisite in developing a new communication system, the packet analyzer and the MAC test suite are essential in the early stage of research and development.

In this paper, the packet analyzer to analyze IR-UWB packets based on IEEE 802.15.4a standard and the MAC test suite to test MAC functions by acting the higher layer functions are designed and implemented. The IR-UWB packet analyzer has three key design factors. It satisfies IEEE 802.15.4a standard, uses Ethernet communication lines to meet the data rate of IR-UWB of 1Mbps, and implements packet analyzing functions of packet parsing, packet filtering, saving and loading of packets, and display of parsed information.

The IR-UWB MAC test suite has three key design factors. It satisfies IEEE 802.15.4a standard, uses serial communication lines of RS-232, and implements MAC test functions of MAC primitive generating and transmitting, MAC primitive receiving and parsing, PAN coordinator setting, and data saving.

2. Design of IR-UWB MAC Packet Analyzer

The packet analyzer system checks that air packets follow the rule of standard protocols, and it can be used in error checking and debugging process.

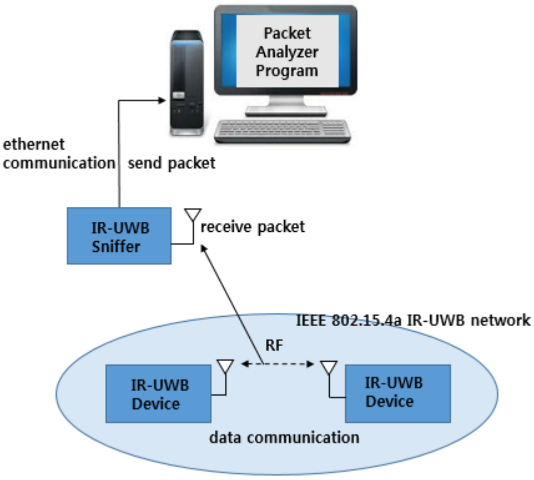

Figure 1. Packet Analyzer System

Figure 1 shows the packet analyzer system which consists of three components. First component is IR-UWB devices performing data communication in the IEEE 802.15.4a network. IR-UWB devices build up a network and generate and receive packets which will be monitored by the packet analyzer. These devices are RFDs (Reduce Function Device) or FFDs (Full Function Device) and they are associated in a PAN (Personal Area Networks).

The second component is a sniffer device of IR-UWB to collect packets from the IEEE 802.15.4a network devices. The sniffer device has the same hardware function with common IR-UWB devices. This means that the sniffer device has IR-UWB physical layer as same as IR-UWB devices. However, it does not participate in data communication with network devices. It is a RFD device only receiving data packets from all other devices, and collected packets are transmitted to a personal computer. When the data rate between a sniffer device and a computer is not high, serial data communication such as RS-232 specification is used typically. The maximum data rate of RS-232 is 115.2kbps. However, the maximum data rate of IR-UWB devices are about 1Mbps; it is higher than the data rate of RS-232. Therefore, the connection between a sniffer device and a computer uses

Ethernet communication with data rate of 10Mbps. So, Ethernet can take every packets from the sniffer device.

The third component is a packet analyzer software program on a PC that analyzes packets from the IR-UWB sniffer device and displays parsed packet information on the monitor screen. Analyzer software controls the Ethernet port and makes a connection to a sniffer device of IR-UWB. It also parses received packets by the rule of the IEEE 802.15.4a standard and displays parsed packet information on the screen. When there are packet errors, the analyzer software checks error types. It enables engineers to debug IR-UWB hardware and software.

The three key design factors for the IR-UWB packet analyzer are as follows:

•Satisfying IEEE 802.15.4a standard

•Using Ethernet communication lines to meet the data rate of IR-UWB of 1Mbps

•Implementing packet analyzing functions of packet parsing, packet filtering, saving and loading of packets, and display of parsed information.

Figure 2 shows the software structure of packet analyzer. The program starts at the main dialog, then the packet analyzer gets PSDU (Physical Service Data Unit) data either from a sniffer device or from data memory of the PC. As soon as PSDU data is received, the packet information is saved in the linked-list, the PSDU is parsed, and the parsed result is displayed on the monitor. There are three operation modes. 1st mode has functions of parsing PSDU data and displaying the parsed data on the monitor. 2nd mode saves PSDU data, and 3rd mode searches linked-list according to a query.

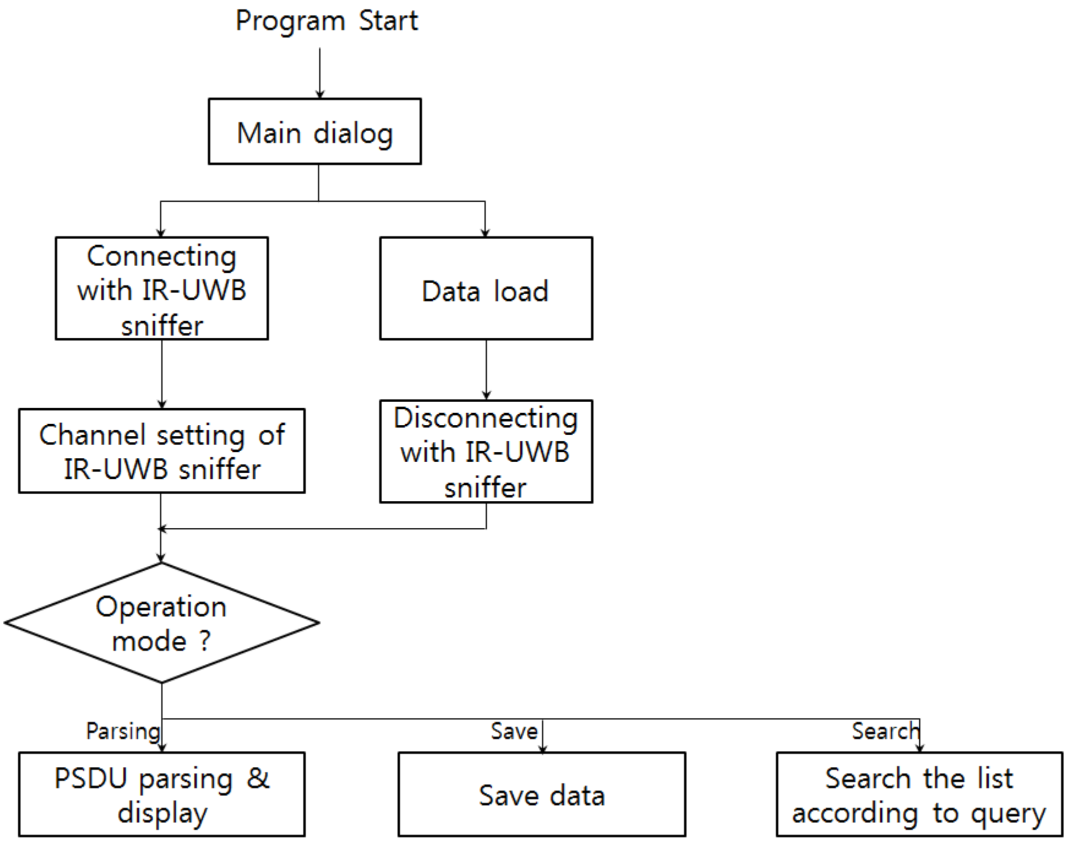

Figure 2. The Software Structure of a Packet Analyzer

3. Development of IR-UWB MAC Packet Analyzer

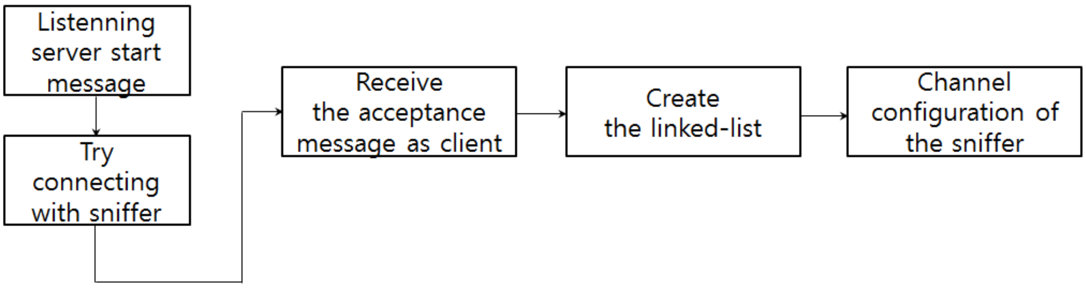

Figure 3. Connecting and Channel Setting Block

Main dialog is a first interface which makes a user select a sub-block among many program functions. Figure 3 is a detail block diagram which performs communication functions with IR-UWB sniffer device. Ethernet connection is used as a communication link between a packet analyzing PC and an IR-UWB sniffer device. The packet analyzing program acts as a client, and the sniffer device acts as a server. So, the packet analyzing program waits until a start message comes from the sniffer server device. After the packet analyzing program receives the start message, it tries to connect the sniffer device and receives a permission message from the server. Then it generates a linked-list for reception of MAC packets and sets a monitoring channel.

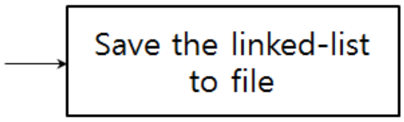

Figure 4. Data Save Function

Figure 4 is a block diagram whose function is writing a file by using PSDU data from saved linked-list. The function writes parameters of PD-DATA.indication primitive from saved linked-list, i.e., length of PSDU, PSDU, UWB PRF, UWB PSR, DataRate, Ranging, CounterStart, CounterStop, TrackingInterval, and Offset.

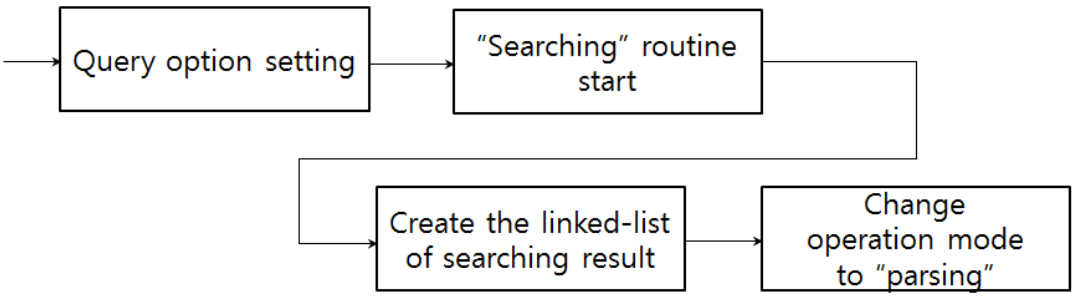

Figure 5. Searching Function

Figure 5 is a block diagram of searching function. Inputs of searching engines are linked-lists, search option, and search language. Searched results are saved as a new linked-list. Options of the search language are Type, Source PAN ID, Source Address Mode, Destination PAN ID, and Destination Address Mode, and multiple options can be used. The saved information is PD-DATA.Indication primitive itself, and later it can be parsed to display on the monitor.

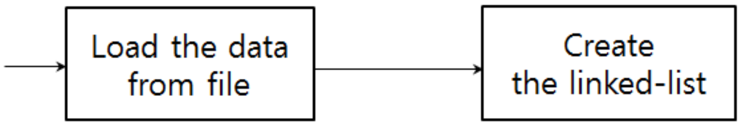

Figure 6. Data Load Function

Figure 6 is a block diagram of data loading function from saved data file. The saved data is parameters of PD-DATA.Indication primitives and many MAC primitives. Files are classified by filename extension; we can load data file with corresponding filename extension. Loaded data is saved in linked-lists, and later it can be parsed to display on the monitor.

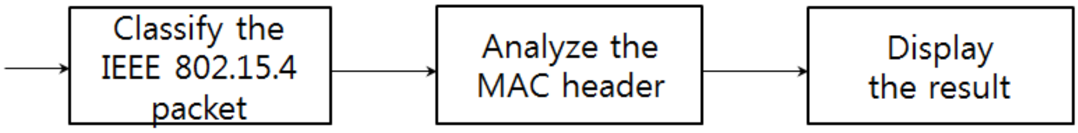

Figure 7. PSDU Parsing and Display Function

Figure 7 is a parsing block which performs interpretation of PSDU data coming from PD-DATA.Indication parameters. PSDU parsing function parses PSDU in the linked-list by the rule of IEEE 802.15.4 MAC standard. The result is displayed on the monitor for engineering.

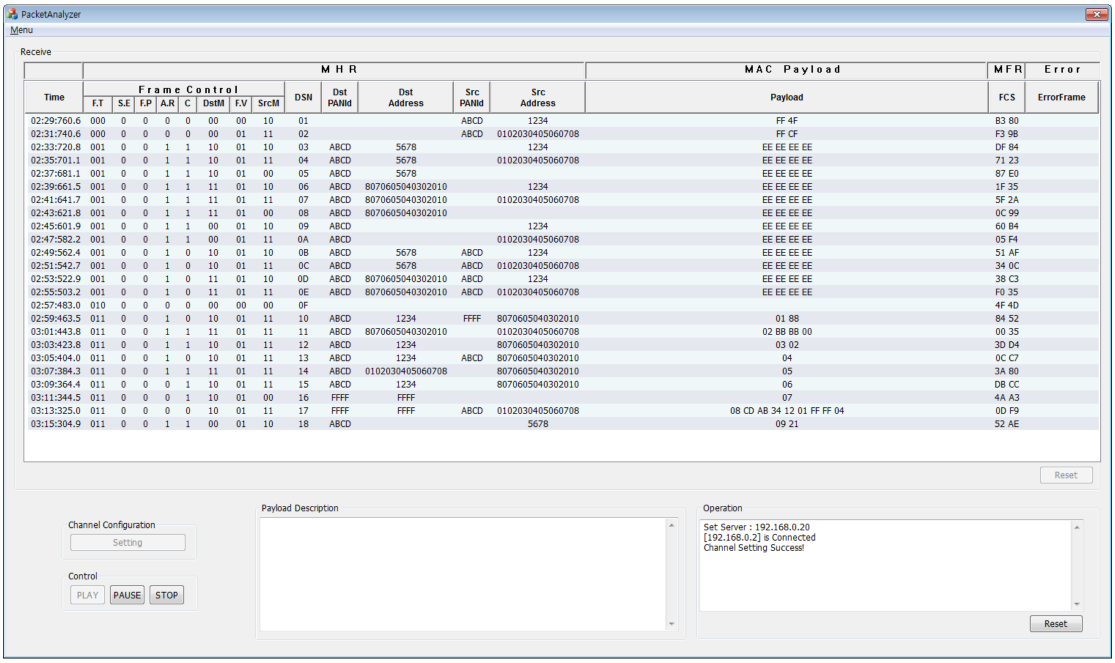

Figure 8. User Interface of Packet Analyzer Software

Finally, Figure 8 shows the user interface of a packet analyzer. It shows parsed data such as packet arrival time to the sniffer, MAC header, MAC payload, MAC footer, and error.

4. Design of IR-UWB MAC Test Suite

IEEE 802.15.4a defines PHY layer and MAC layer of IR-UWB. The MAC layer handles all access to the physical radio channel and is responsible for the following tasks: [7]

- Generating network beacons if the device is a coordinator
- Synchronizing to network beacons
- Supporting PAN association and disassociation
- Supporting device security
- Employing the CSMA-CA mechanism for channel access
- Handling and maintaining the GTS mechanism
- Providing a reliable link between two peer MAC entities

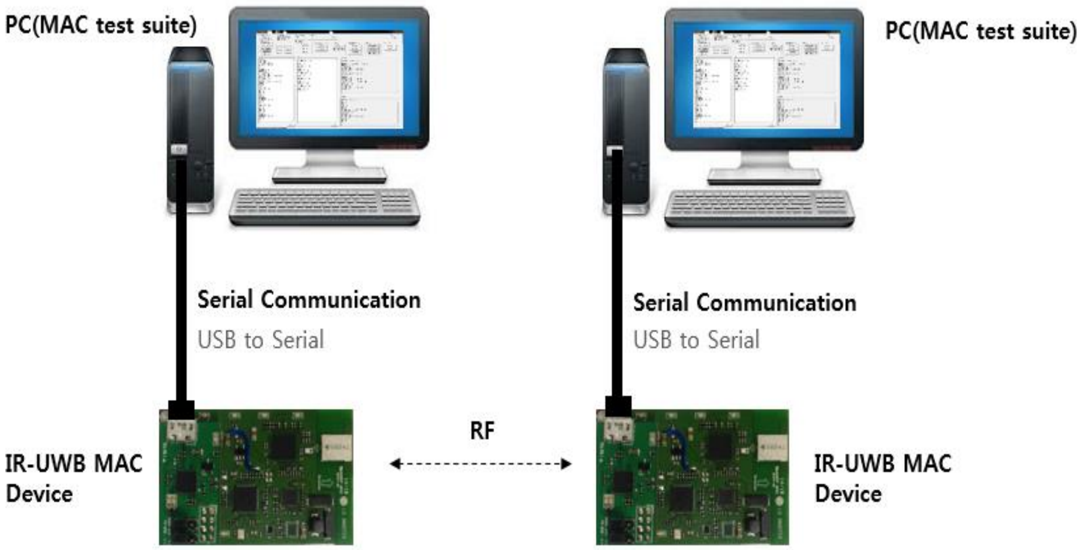

Figure 9. Concept of MAC Test Suite Program

The MAC test suite serves as a role of higher layer for testing IR-UWB MAC primitive functions one by one. Figure 9 shows the MAC test suite system. The connection between the MAC test suite software on a PC and the MAC software on a target device uses a serial communication of RS-232. MAC test suites do the role of higher layer which sends MAC primitives to a target device or receives MAC primitives from a target device.

When a test suite generates a primitive, it makes a primitive and sends it to an IR-UWB device via a serial communication line. Then, the target device sends it to other UWB devices on a network by using RF channel. When the MAC test suite receives a primitive, it takes packets from a target device via a serial communication line, and it parses packets to display on the monitor. The MAC test suite transmits request primitives and response primitives to a target device, and receives indication primitives and confirms primitives from the target device.

The three key design factors for the IR-UWB MAC test suite are as follows:

•Satisfying IEEE 802.15.4a standard

•Using serial communication lines of RS-232

•Implementing MAC test functions of MAC primitive generating and transmitting, MAC primitive receiving and parsing , PAN coordinator setting, and data saving

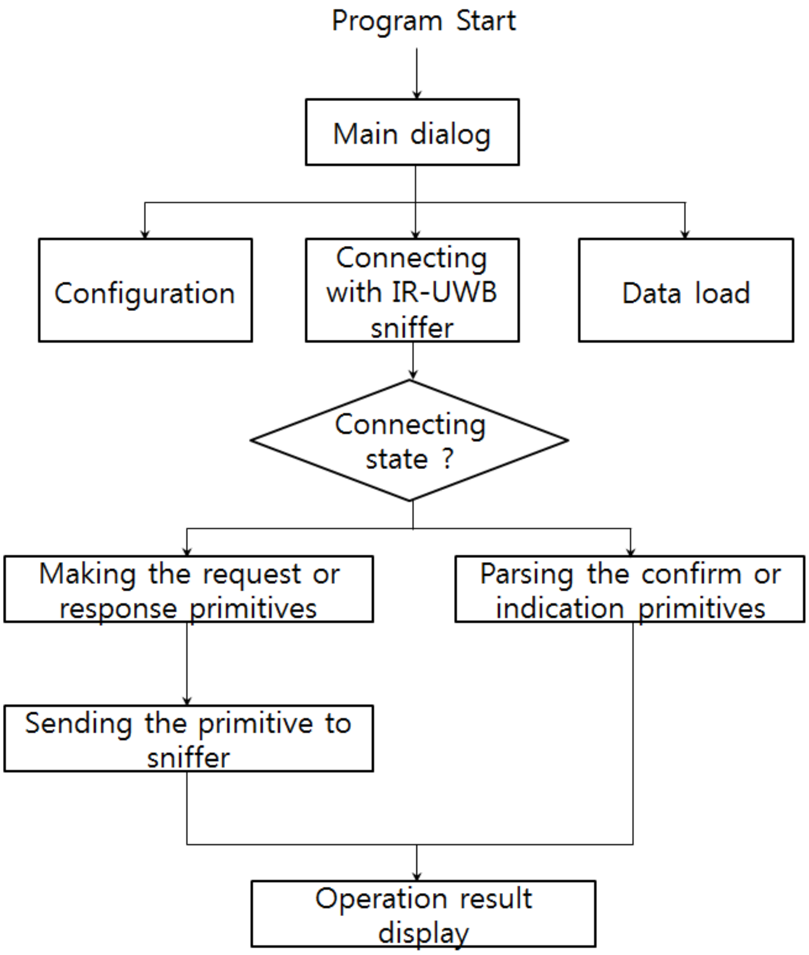

Figure 10. The Software Structure of the MAC Test Suite

Figure 10 shows the software structure of a MAC test suite. This program starts at the main dialog, then performs a connection via a serial communication line, configures a PAN coordinator, and sets a MAC address for testing. When a user makes a primitive, he can type new parameters in a dialog window. Then these parameters are formatted in packets, and packets are transmitted to a target device via a serial communication line. Also the transmitted packets are displayed on a monitor. The receiving block parses received primitive packets and the parsed information is displayed on the monitor.

5. Development of IR-UWB MAC Test Suite

Main dialog is a first interface which makes a user select a sub-block among many program functions. Figure 11 is a block diagram of connecting MAC program of IR-UWB MAC device. The connection is done by using serial communication lines of RS-232 and by setting baud rate, data bit, stop bit, and parity bit. After setting RS-232 serial communication, the port number is assigned to connect a MAC device. As soon as MAC test suite connects to a MAC device, it enters a wait state.

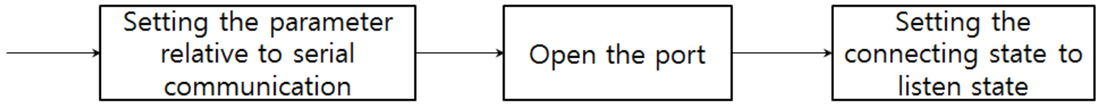

Figure 11. Function of Connecting to MAC

Figure 12 is a block diagram which makes request primitives or response primitives. There are many request primitives such as associate, disassociate, get, GTS, orphan, reset, RX-enable, scan, set, start, sync, poll, DPS, sounding, and calibrate, and primitive type tells which primitive should be made. Also, there are two response primitives such as associate and orphan, and primitive type again tells which primitive should be made. After making primitives, a header for serial communication is added and frames are generated for transmission.

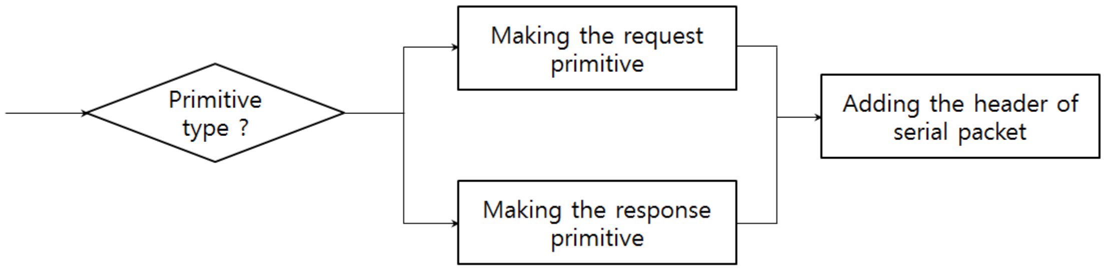

Figure 12. Function of Making Request and Response Primitives

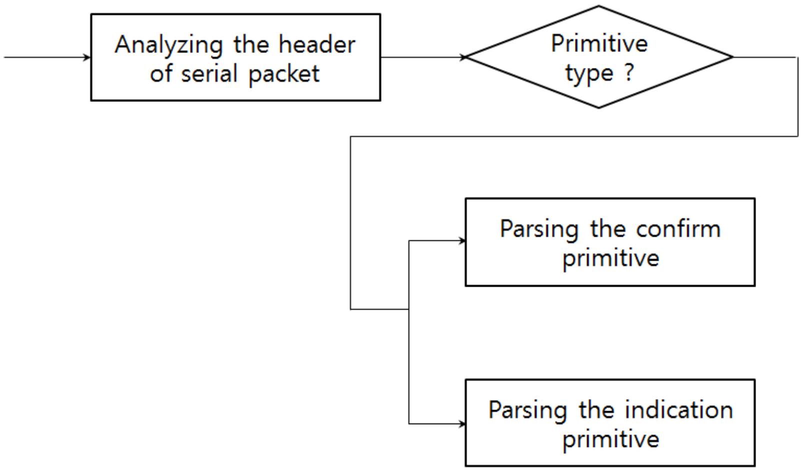

Figure 13. Function of Making the Parsing Confirm and Indication Primitives

Figure 13 is a block diagram of parsing confirm primitives or indication primitives which are received from a MAC device. Firstly, MAC test suite analyzes serial data frames coming from the serial communication link. If a confirm primitive is received, the test suite displays confirmed detail information. If an indication primitive is received, the test suite displays indicated detail information and informs that a response primitive should be returned.

Configuration performs loading the previous information or saving the displayed information, as shown in figure 14.

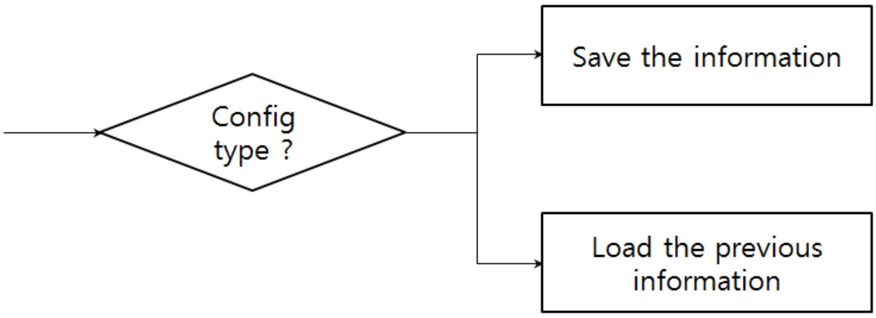

Figure 14. Function of Configuration

Figure 15 shows the user interface of a MAC test suite software. Left request window displays the request primitive information which will be sent to a target device. The right confirm window displays the confirm primitive information which is received from the target device.

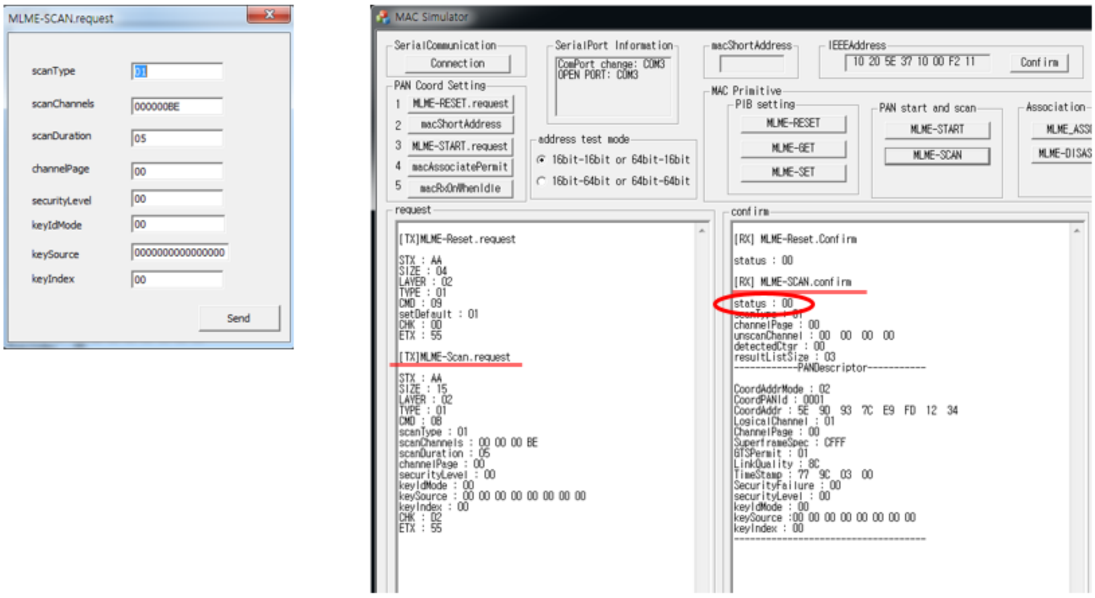

Figure 15. User Interface of MAC test Suite

6. Conclusion

IR-UWB has been developed as a standard of indoor ranging technology because it has robust and good transmission characteristics in indoor environments and it can be operated with low power. In this paper, the packet analyzer to analyze IR-UWB packets based on IEEE 802.15.4a standard and the MAC test suite to test MAC functions by acting higher layer functions, are designed and implemented.

The packet analyzer controls the Ethernet port and makes a connection to a sniffer device of IR-UWB. Also, it parses received packets by the rule of the IEEE 802.15.4a standard and displays parsed packet information on the screen. When there are packet errors, the analyzer software checks error types. It enables engineers to debug IR-UWB hardware and software. MAC test suite does the role of higher layer functions, which sends MAC primitives to a target device or receives MAC primitives from a target device.

IR-UWB technology will likely be used for indoor location-aware service. In the early stages of development of IR-UWB, the packet analyzer and the MAC test suite based IEEE 802.15.4a would be very useful.

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References

[1] IEEE 802.15.4a TG4a, "Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Network (LRWPAN)", IEEE Computer Society, New York **(2007)**.
[2] M. K. Oh and J. Y. Kim, "Ranging Implementation for IEEE 802.15.4a IR-UWB Systems", Vehicular Technology Conference (VTC), **(2008)**; Singapore.
[3] Ubisys, "IEEE 802.15.4 USB Stick with Wireshark Firmware Reference^{TM} Manual", Ubisys Technologies, DÜSSELDORF, **(2012)**.
[4] Texas Instruments, "SmartRF^{TM} Packet Sniffer User's Manual", Texas Instruments, **(2010)**.
[5] Daintree Networks, "Product Data Sheet Sensor Network Analyzer", Daintree Networks, Inc., Fremont, **(2009)**.
[6] P. Baronti, P. Pillai, V. W. C. Chook, S. Chessa, A. Gotta and Y. F. Hu, "Wireless Sensor Networks: A Survey on the State of the Art and the 802.15.4 and ZigBee Standards", Computer Communications vol. 7, no. 30, **(2007)**.
[7] IEEE 802.15.4, "Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)", IEEE Computer Society, **(2011)**.

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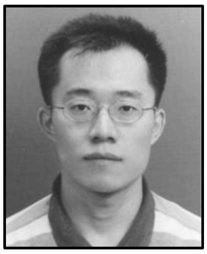

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