Development of Wireless Connectivity Test Set MT8862A Supporting IEEE 802.11ac WLAN Network Mode

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[Summary] In addition to use in mobile communications terminals, such as smartphones, Wireless LAN (WLAN) technology is being used increasingly in products ranging from consumer electronics to automobiles and the Internet of Things (IoT). RF measurement while connected to a network is one method required for evaluating the quality of WLAN devices. To meet this need, we have developed the Wireless Connectivity Test Set MT8862A supporting IEEE 802.11ac RF measurements using the network mode. This instrument has functions for measuring Tx signals and Rx sensitivity required for evaluating RF performance to help improve the quality of WLAN equipment.

1 Introduction

More mobile devices, such as smartphones, have a built-in wireless LAN (WLAN) communications interface as standard as a consequence of growth of the internet and mobile communications environments. Additionally, adoption of WLAN as short-range wireless infrastructure continues to spread into previously unimagined markets, such as domestic appliances, automobiles, etc. WLAN is also a key communications technology in recently popular Internet of Things (IoT) devices.

Although WLAN specifications are standardized in IEEE 802.11, the procedure for evaluating Radio Frequency (RF) performance has yet to be clarified and the main focus is on evaluations using the direct mode (chip vendors' unique test mode). On the other hand, RF performance of finished products that cannot use direct-mode testing, and Over The Air (OTA) evaluation standardized by the Cellular Telecommunications and Internet Association Converged Wireless Group (CTIA CWG), which is increasingly needed when using a network connection.

The MT8862A has been developed as an RF measurement tester for IEEE 802.11ac WLAN network connections now becoming mainstream. The following materials describe the design concept, design details, and MT8862A features in this development.

Figure 1 Wireless Connectivity Test Set MT8862A

2 System Design

2.1 Design Concept

Network mode measurement implements a very simple measurement system by eliminating the chip-vendor unique control environment. Additionally, since WLAN is not a wireless technology that operators find to be of service value, low-cost devices are in strong demand while lower-priced measuring instruments are a natural requirement. To meet these market demands, the MT8862A design is based on the following concepts.

- Support for IEEE 802.11b/g/a/n/ac

  This targets 2.4 and 5-GHz WLAN standards and a wider bandwidth up to 80 MHz for the IEEE 802.11ac standard used commonly.

- Support for AP mode, STA mode and WLAN security functions

  The MT8862A has built-in communications functions supporting both Access Point (AP) and Non-AP Station (STA) modes as the assumed Device Under Test (DUT). Additionally, it supports DUTs requiring network connections with the Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA)-Personal, and WPA2-Personal security functions.

- RF I/O for OTA Tests

  When using OTA test systems in a large anechoic chamber, it may sometimes be necessary to use a calibrated RF amplifier. To support smooth configuration of the RF path, the MT8862A is designed with both a common shared RF input and output connector as well as separate Rx and Tx connectors that can each be switched independently.

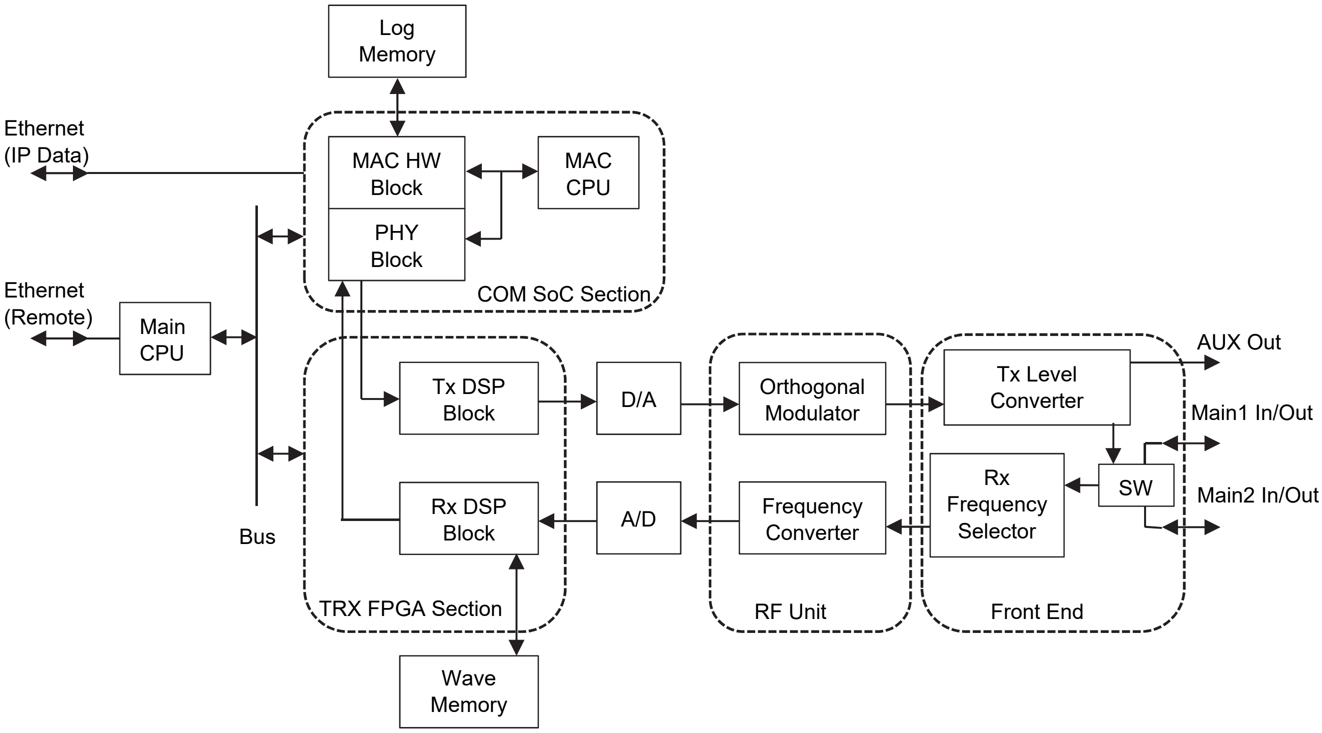


Figure 2 Hardware Block Diagram

- Graphical User Interface (GUI) Operation

  The operation panel has been removed main unit and equipped a built-in web server, control is implemented from a connected external PC, enabling GUI control without a PC platform.

- Effective design process

  The development time has been shortened and design quality was ensured by reusing the design in the Universal Wireless Test Set MT8870A and Signaling Analyzer MS2830A hardware, FPGA, and software.

2.2 Hardware System

Figure 2 shows the MT8862A hardware block diagram. The key function blocks are explained below.

2.2.1 Main CPU Section

The Main CPU section is responsible for controlling the MT8862A internal hardware, performing signal analysis, and supporting the user interface. The embedded Linux operating system was chosen, considering portability of existing software; COM Express is used as the form factor. Remote control and the GUI described later run over a GbE interface.

2.2.2 COM SoC Section

The COM System on a Chip (SoC) section uses a SoC Field-Programmable Gate Array (FPGA) built into the CPU to implement WLAN signaling functions. The Physical (PHY) and Media Access Control (MAC) layers requiring real-time processing are at the FPGA side. Higher-layer functions are implemented in software running at the CPU side. Using this design achieves the optimum hardware structure with good simplicity. A large 2-GB memory is incorporated in the design to save WLAN communication frames log. In addition, there is an Ethernet port (IP Data) linked directly to the CPU, supporting the IP Data transfer function using an external PC.

2.2.3 TRX FPGA Section

The TRX FPGA section is composed of Tx DSP and Rx DSP sections and is mainly responsible for baseband signal processing. The Tx DSP section performs orthogonal compensation on the Tx baseband signal from the COM SoC and outputs it to the D/A conversion section. The Rx DSP section performs in-band amplitude compensation on the digital Intermediate Frequency (IF) signal from the A/D conversion section as well as orthogonal processing to convert the signal to the baseband signal. The Rx baseband signal is saved to the waveform memory simultaneously with output to the COM SoC section. The Rx baseband signal saved in waveform memory is transferred to main memory by Direct Memory Access (DMA) when executing Tx measurement.

2.2.4 RF Unit

The RF Unit is composed of orthogonal modulation and frequency-conversion sections. The orthogonal modulation section orthogonally modulates the baseband signal from the D/A conversion section to output 2.4-GHz and 5-GHz band WLAN signals. The frequency-conversion section converts the RF modulation signal from the Front End to an IF signal which is output to the A/D conversion section. The 160-MHz bandwidth is secured to support measurement of IEEE 802.11ac wideband signals. In addition, the RF Unit design supports a wide RF band from 10 MHz to 6000 MHz for both Tx and Rx in anticipation of expansion into new frequency bands.

2.2.5 Front End

The Front End is composed of a Tx level converter and a Rx frequency selector. The Tx level converter increases and decreases the level of the modulation wave from the RF Unit for output at the connector. The Rx frequency selector receives the WLAN signals for output to the RF Unit. In consideration of use for OTA test systems, the RF input/output has both a shared connector as well as separate Tx and Rx connectors that can be switched independently. At Co-existence tests (test for degraded sensitivity due to interference when using both WLAN and cellular systems simultaneously), the main unit Rx section has band-limiting filters for both 2.4 GHz and 5 GHz to minimize the impact on the MT8862A Rx section.

2.3 Software System

The MT8862A software system is split mainly into a Main CPU section responsible for key functions, and a WLAN Signaling section responsible for WLAN signaling. Moreover, the Main CPU section software is composed of Platform and Application sections. Figure 3 shows the Main CPU software structure and the function of each section is explained below.

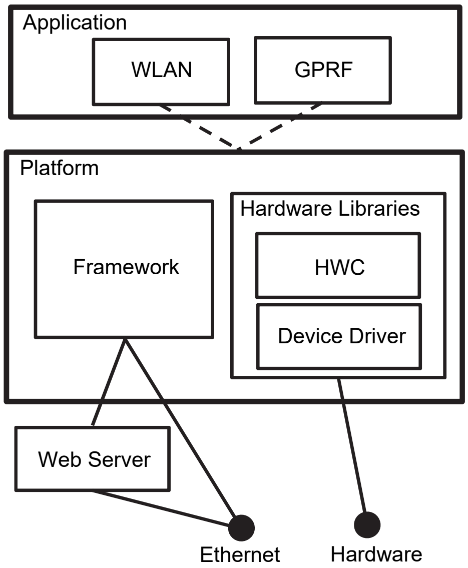


Figure 3 Main CPU Software Structure

2.3.1 Platform Section

The Platform section is composed of Framework and Hardware Libraries. The Framework Libraries process remote commands, manage main-unit data, manage applications, etc. The Hardware Libraries are composed of HWC and Device Driver sections for controlling the MT8862A hardware as well as data delivery between the hardware and Application section. APIs are also provided for controlling hardware corresponding to the Application section. When the Application section sets data such as the RF ports, frequency, level, and triggers, the HWC section performs conversion to the hardware register settings and sets the hardware via the Device Driver section.

2.3.2 Application Section

The Application section executes signal output, measurement, and analysis in accordance with the remote commands. The execution function is defined in measurement application units ("app" hereafter) and each app operates exclusively. The MT8862A has two types of built-in app: WLAN app, and General Purpose RF (GPRF) app. The WLAN app handles the WLAN Tx and Rx measurement functions, as well as control of the WLAN signaling system. The GPRF app outputs a CW signal for adjusting external loss and performs power measurements.

2.3.3 WLAN Signaling Section

The WLAN Signaling section incorporates IEEE 802.11 functions in a single SoC for signaling, packet generation and data transfer between the external PC and DUT. Figure 4 shows the function blocks.

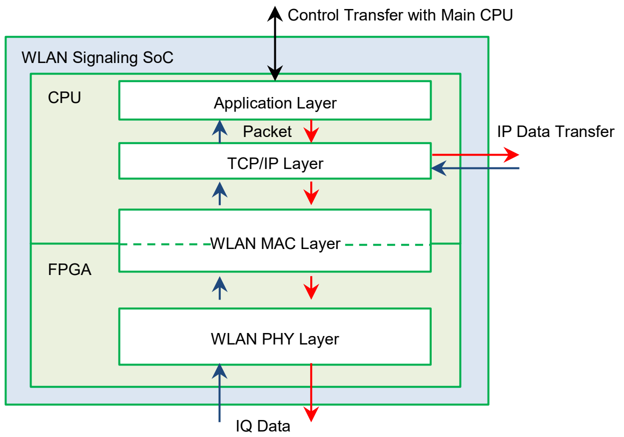


Figure 4 WLAN Signaling SoC Function Blocks

As shown in Figure 5, at data transfer, frames are generated while assigning a header at each layer, and analysis is performed by referencing and removing headers at each layer when the data are received.

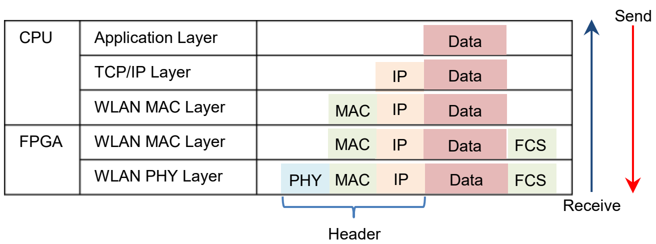


Figure 5 Processing for Each Layer

In addition, there is a suitable retransmission system for test and maintain the connection. Frames used for measurement are sent according to the user-specified data rate and Tx count without retransmission. When using a frame to establish and maintain the link, resending is performed at the lowest rate determined by Association with the DUT to confirm the frame has been delivered successfully.

3 WLAN Measurement Functions

3.1 RF Measurements in Network Mode

The MT8862A uses a WLAN connection using the previously described WLAN signaling system and a packet generation function to execute Tx and Rx tests while connected to a network. Figures 6 and 7 show each of the measurement screens and each measurement function is explained below.

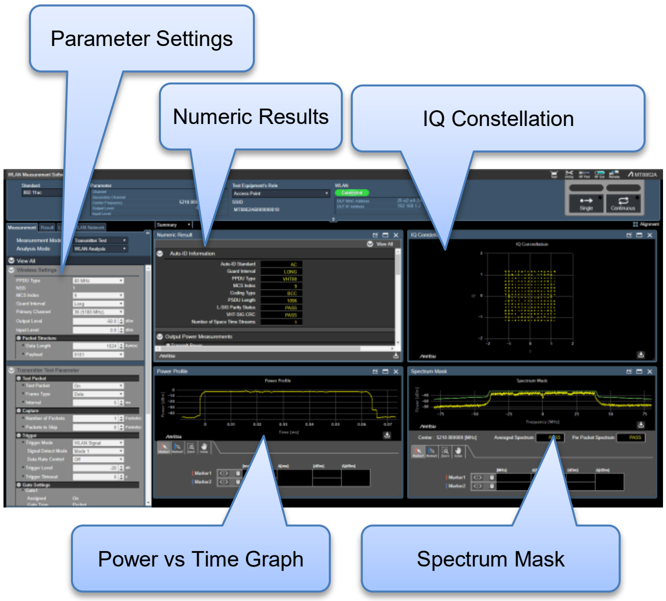


Figure 6 WLAN Tx Measurement Window

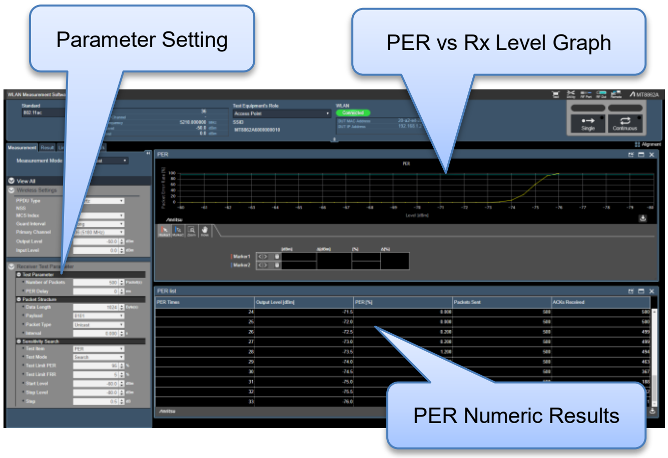


Figure 7 WLAN Rx Measurement Window

3.2 Tx Measurement Functions

Since the standard test mode and loopback function for RF measurement are undefined for WLAN, the MT8862A sends a signal for measurement to the DUT using the following methods.

(1) Data Frame Measurement

Measurement is performed by sending an Internet Control Message Protocol (ICMP) Echo Request (Ping Request) from the MT8862A, and receiving the ICMP Echo Reply (Ping Reply) returned from the DUT.

(2) ACK Frame Measurement

Measurement is performed by sending a test packet from the MT8862A and receiving the ACK frame-received response.

Various WLAN frames are exchanged when connected to a network and sometimes it is impossible to distinguish frames to be measured by amplitude alone. Consequently, the MT8862A has a WLAN signal trigger function supported by WLAN signaling system demodulator. This is used to distinguish Data and ACK frames as well as to perform Tx measurement of DUT frames at the specified data rate.

3.2.1 Tx Power Measurement

The average power, peak power, and crest factor of received DUT frames are measured. A graph of the power vs time for the measured burst is displayed simultaneously (Figure 8).

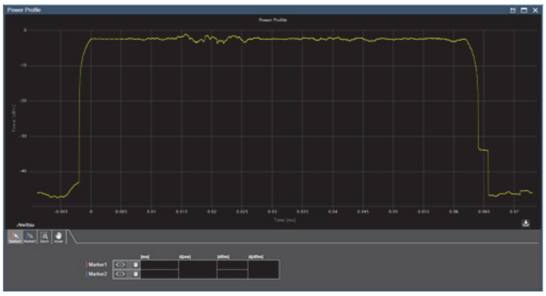


Figure 8 Power vs Time Graph Window

3.2.2 Modulation Accuracy Measurement

Modulation accuracy, such as the EVM, carrier frequency error, etc., are measured for received DUT frames. The WLAN signal analysis section auto-detects the various modulation schemes, executes the corresponding demodulation processing, and measures the modulation accuracy. The IQ constellation for analyzed frames is also displayed (Figure 9).

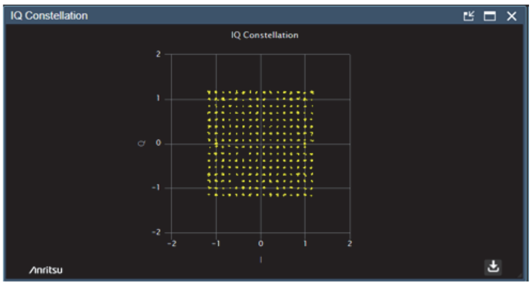


Figure 9 IQ Constellation Window (256QAM)

3.2.3 Spectrum Measurement

The MT8862A has a signal analysis bandwidth of 160 MHz for spectrum measurement using FFT. The created signal spectrum is pass/fail evaluated using the IEEE 802.11-specified spectrum mask (up to ±80 MHz for IEEE 802.11ac 80-MHz bandwidth). The signal spectrum can be displayed as a graph with the previously described spectrum mask (Figure 10).

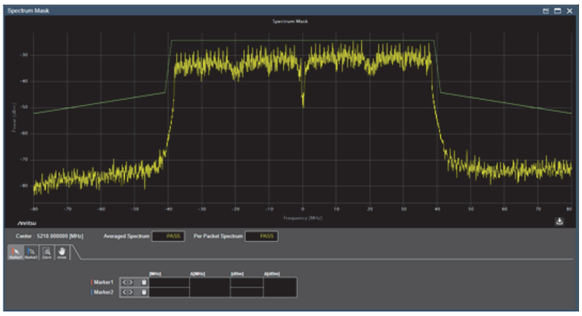


Figure 10 Spectrum Mask Results Window

3.3 Rx Measurement Functions

3.3.1 PER Measurement

When a self-addressed frame (packet) on the WLAN is received, an ACK frame is returned as a confirmation response and the Packet Error Rate (PER) is measured to evaluate the Rx performance. In concrete terms, the MT8862A sends a specified number of frames for measurement and then counts the number of ACK frames returned from the DUT. The ratio of unreceived frames is calculated as the PER using the number of sent frames as the denominator and the number of ACK frames returned from the DUT as the numerator.

At PER measurement while connected to a network, sometimes there can be issues over measurement accuracy while the DUT is operating in the Power Save mode. This mode sets the WLAN device receiver circuits to off periodically to save power. Since test packets are not received at the time, the apparent PER seems degraded unrelated to sensitivity. To prevent this, the MT8862A monitors Power Save/Active notifications from the DUT and saves PER measurement while the DUT is in the Power Save period. This enables the user to evaluate Rx sensitivity while ignoring the DUT Power Save function. Figure 11 shows an image of PER measurement at Power Save operation.

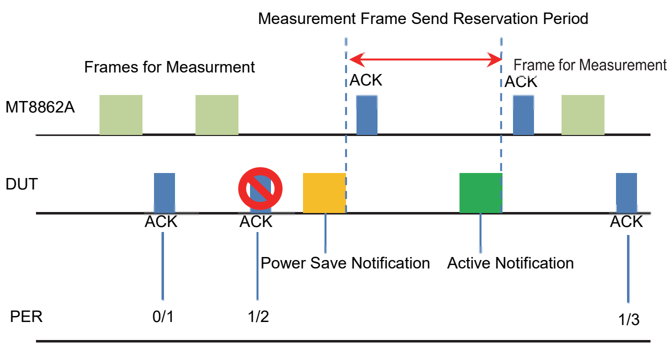
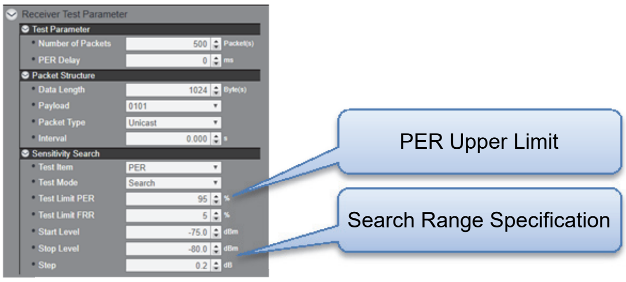


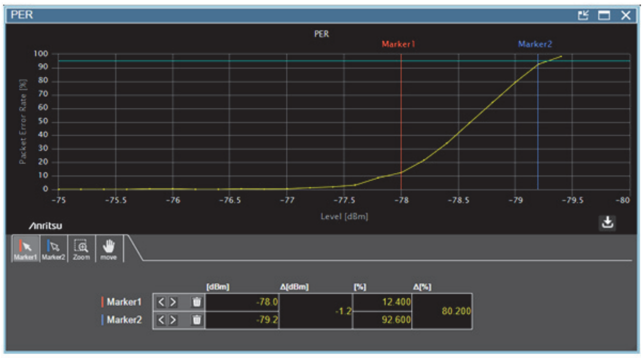
Figure 11 PER Measurement

3.3.2 Rx Sensitivity Search Function

The previous section described the PER measurement function but rather than being interested in PER, users are more concerned about Rx signal level (sensitivity point) at a specific PER value. To help with this, the MT8862A has a built-in GUI function for measuring PER while lowering the DUT receive level (MT8862A send level), helping find the sensitivity point easily. The DUT Rx levels for the measurement start and end are set along with the PER upper limit and measurement stops automatically when the determined sensitivity point is reached.



(a) Rx Sensitivity Search Parameters



(b) Rx Sensitivity Search Results Window

Figure 12 Rx Sensitivity Search

3.4 Measurement Calibration Functions

3.4.1 Frame Capture

A function for capturing TRx fames is built into the MT8862A for monitoring signaling between it and the DUT. Captured frames are saved in pcap format for analysis by applications supporting pcap files, such as the Wireshark network protocol analyzer software (Figure 13).

This function is useful for troubleshooting abnormal connections with the DUT; WLAN frames can be checked when a problem occurs for a quick check of DUT setting errors, etc.

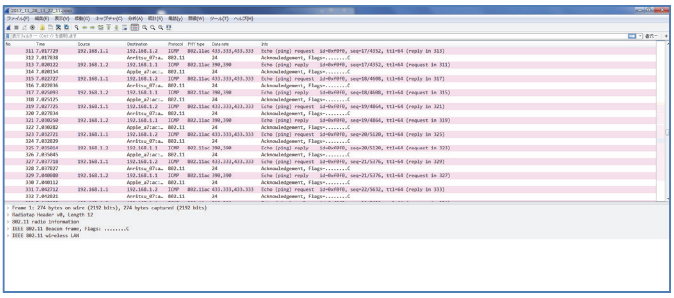


Figure 13 Frame Capture Display (Wireshark)

3.4.2 Tx Data Rate Control

There are various Tx data rate selection logics depending on the WLAN device but only some are defined in the WLAN specifications. As a method for receiving at any data rate from the DUT, Anritsu's previous WLAN Test Set MT8860C had a function for notifying the DUT about control data indicating the receivable data rate to limit it to just the target data rate. However, this method has the following two issues:

(1) At STA Mode Connection Failures

Many WLAN devices operating as Access Points (AP) specify data controlling the minimum supported data rate required by the STA mode. If the STA-mode send control data conditions are not met, the AP rejects the connection. As a result, sometimes a connection cannot be made to an AP in the STA mode when the measuring instrument limits the receivable data rate.

(2) When Unable to Use IEEE 802.11ac Control

The IEEE 802.11ac standard is different from the earlier IEEE 802.11n standard and is unable to use control data for the measurement target receivable data rate. The receivable MCS is expressed as three patterns of 0 to 7, 0 to 8, and 0 to 9 but it is not possible to set so that only MCS0 is supported.

Although the MT8862A also supports the same control method as the MT8860C, in addition, it also has a new built-in method for receiving any data rate by intentionally generating a resend at the DUT.

Many WLAN devices increase the data rate to the maximum when receiving the ACK frame corresponding to the send frame. However, if the ACK frame cannot be received, there is a tendency to resend at a lower data rate to increase the successful delivery rate. As shown in Figure 14, using this method, the MT8862A intentionally restrains sending of the ACK frame for higher data rate so the DUT sends at the measurement target data rate.

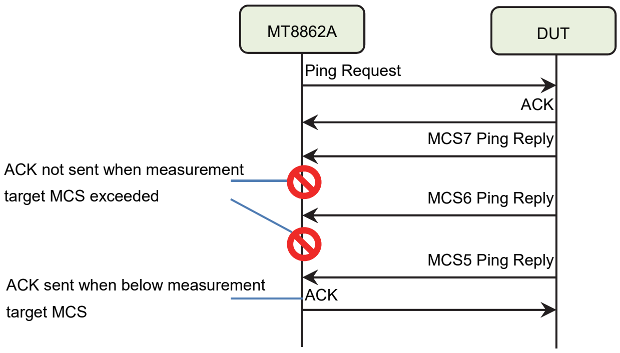


Figure 14 Tx Data Rate Control

4 Graphical User Interface

4.1 Web GUI

The MT8862A does not have a front-panel display; at manual operation, it is operated from an external PC and does not require installation of any dedicated software because the operation screen is displayed on a web browser by accessing the built-in web server at the MT8862A IP address.

User operation can be switched to remote control at the web browser GUI; commands are sent via HTTP to the MT8862A web server to notify applications in the MT8862A and execute operations from the external PC.

The web GUI sets WLAN and GPRF appli parameters, executes measurements, displays measurement results, as well as reads MT8862A data, makes settings, updates firmware, and installs licenses for options, etc.

The structure of the web GUI is based on pages for each usage objective with an easy-to-understand layout for each function. The GUI windows are accessed first from the top page; the WLAN measurement software window executes WLAN measurements, the GPRF measurement window executes GRF measurements, and the system information window executes system settings, such as firmware updates.

4.2 CSV Output of Measurement Results

The WLAN window has a function for outputting send and receive measurement results as Comma-Separated Values (csv) files. Both numeric results displayed on the Numeric Result window at Tx measurement, as well as the PER measurement results displayed as a List at Rx measurement can be downloaded via the web browser for saving on the PC.

4.3 Saving Graphs

The MT8862A has a function for outputting the WLAN and GPRF windows as graphics images supported by web browsers. Graphs of send and receive measurements can be downloaded via the web browser for display as graphics images on the PC.

5 Conclusions

We have developed the MT8862A as an RF measuring instrument supporting IEEE 802.11b/g/a/n and IEEE 802.11ac network connections. It provides functions for evaluating WLAN performance of finished products, which is difficult using the prior direct mode, as well as for performing RF measurements on the assumption of having a network connection. Network connection set-up is simple and operation is easy via the web GUI. A WLAN device evaluation environment can be configured easily to help improve the quality of WLAN devices including IoT technologies which are expected to see widespread future adoption.

References

1) IEEE Standard 802.11-2016
"Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications"

2) CTIA / Wi-Fi Alliance
"Test Plan for RF Performance Evaluation of Wi-Fi Mobile Converged Devices" Version 2.0.3

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