Novel Wireless Lighting-Control System with a Wireless DMX Link for Large-Scale Light Shows

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ABSTRACT

Systems for large-scale light shows require a large amount of electrical wire, leading to problems with the mobility of the control unit and the maintenance of the lighting system. A wireless DMX link between the main controller and the light controllers (e.g., dimmers) would be instrumental in overcoming these constraints. Previously developed wireless DMX links are typically limited to small-scale shows with small audiences. Because the audience uses wireless devices, data transmission by wireless DMX link cannot be guaranteed in real-time. Hence, in this work, a novel wireless lighting-control system with a wireless DMX link for large-scale light shows is proposed. The proposed wireless DMX link can transmit data in real time, and store data beforehand, which can called upon during the light show with simple wireless commands.

KEYWORDS

Wireless DMX, DMX512 protocol, LED, Light Show, IEEE 802.

1 INTRODUCTION

Recently, LED lights have been used in various fields and especially in the arts, lights festivals, theme parks, and outdoor facilities, in which the scenery is colored with LED lights. The availability of these devices, along with their low-energy consumption, long life span, and ease of use, have helped LED lights to emerge as the next generation of lighting devices, replacing existing halogen and fluorescent lighting [1]. Therefore, the demand for LED lights in large-scale light festivals and performances is on the rise, and research is actively being conducted into such applications. A lighting system controls multiple lights by establishing communication through tools such as Power Line Communication (PLC), Digital Addressable Lighting Interface (DALI), Digital MultipleX 512 (DMX512), and CAN [2]. Among these tools, the DMX512 communication protocol is a popular choice to manage effects and lighting in theaters, on stage, and at concerts. Various stage effects can be created with the device beyond merely controlling the lights, such as manipulation, programing, pan/tilt, shutter, and timer, and this breadth explains why the device has become widely used in these fields. It is simple to move, and easy to install and use. Moreover, the control features are reliable, and the wireless DMX512 system has made substantial developments towards the technology required in large-scale performances, gradually increasing the system's effectiveness.

Although there are benefits to wire-based lighting-control methods, such as accurate data delivery and the ability to supply power, the structure of the stage, along with the installation and maintenance of additional equipment, is constrained in such a system. By comparison, lighting-control methods that use wireless technology have considerable advantages over wire-based methods insofar as they overcome the biggest drawbacks of such systems: installation and maintenance. However, the disadvantage to a wireless-based method is that wireless communication is inherently unstable compared with wired technology. Nonetheless, in practice, lights are being directed on a large

scale with wireless technology, despite these stability issues, and this signifies a need to develop a wireless-based DMX512 system that can provide stability.

Existing wireless-based DMX (WDMX) controllers are generally developed either as a WiFi-based WDMX or a ZigBee-based WDMX, but recently, a dual method WDMX device has been developed that utilizes two or more communication methods for increased reliability [3][4]. However, for WDMX devices that transfer lighting-control data in real-time, the interference from surrounding wireless devices hinders the stability of the communication. In particular, the interference between the wireless devices and the data delays cannot guarantee real-time control over the transfer of data. This problem is especially acute at venues such as concerts, where a large crowd has a variety of wireless devices with them. In such environments, real-time control of data transfers is even more difficult to guarantee. Therefore, this study has developed a novel concept: a WDMX device featuring the ability to load data that has been stored in advance and transmit it to the lighting device in real-time. The proposed device saves pre-designed light-production data and various effects in the receiving WDMX device before the performance, using real-time lighting-control data transmissions. Thus, it sends only simple command signals during the actual performance

2 DMX512 PROTOCOL

DMX is a communication method for transmitting digital control signals using a twisted pair cable. The US Institute for Theatre Technology (USITT) developed the DMX protocol in 1986 to control dimmers. The DMX512 protocol is an improved version of DMX, developed in 1990, and has gradually been formally adopted by manufacturers. DMX512-based control devices have been used to create lighting effects and for dimming,

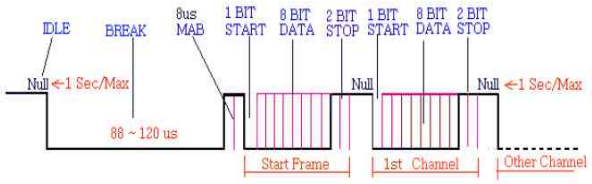

Figure 1. A DMX512 Frame Format.

along with special lighting fixtures for stages and theaters [5].

Figure 1 shows the DMX512 frame format according to which a DMX512 frame is transmitted based on RS-485. The DMX512 protocol is an 8-bit asynchronous serial-communication method that operates at a rate of 250 kbps and has a pulse period of 4 us. A single data slot is 11 bits in size, and uses 8 bits for the data, 1 bit for the start bit, and 2 bits for the stop bit.

A DMX512 controller has 512 channels (or slots) for one connection path, and sends a value represented by 1 byte to the individual channels. In other words, up to 512 channels can be controlled and individual devices are managed with a resolution of 8 bits.

3 PROPOSED WDMX SYSTEM

The WDMX proposed in this study is not designed to send control or effect data in real-time, during the performance. Rather, it is designed to send the data to the receiver-side of the WDMX before the performance, where it can be stored. Therefore, when the pre-stored show number or effect number is sent wirelessly to the WDMX receiver through the WDMX transmitter from the main controller during the performance at the time the effect is needed, the WDMX receiver loads the pre-stored production data and sends that data to the stage controller (e.g., to the dimmer). For instance, for a set of ten songs, the director might create ten light performances that are synchronized with the songs. With the proposed method, these can be designed in advance using the stage lighting and equipment. With the proposed system, the production data from the pre-produced light performances is stored

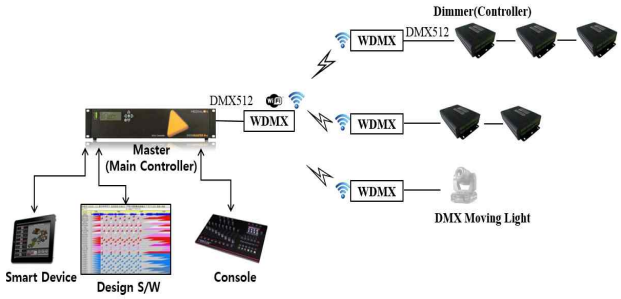

Figure 2. A Proposed Wireless Lighting Control System.

wirelessly in the WDMX receivers that are using the WDMX transmitter on the main controller before the start of the performance attached to each stage controller (e.g., dimmers). Consequently, it is easier to apply changes to the performance production, even when all the equipment is installed before the start of the show. During the actual performance, the pre-produced light show is managed by wirelessly sending simple command data (including the number and play-time information for each song) to the DMX receiver from the main controller at the beginning of each song in accordance with the performance. Thus, when the play signal for pre-stored effects with various external inputs is wirelessly sent from the main controller to the DMX receiver, the stored effects are sent from the DMX receiver to the stage-production controller, triggering the appropriate effect for the external input to perform in real-time, and thus, creating an interactive performance.

The WDMX proposed in this study was also configured to operate in real-time data-transfer mode in order to be compatible with existing systems. The data-recording mode and the data-playback mode were added to minimize the uncertainty caused by interference with external wireless equipment during a performance.

3.1 System Design

Figure 3 shows the transmitter and receiver system for the proposed WDMX. The WizFi250 module by Wiznet was used for

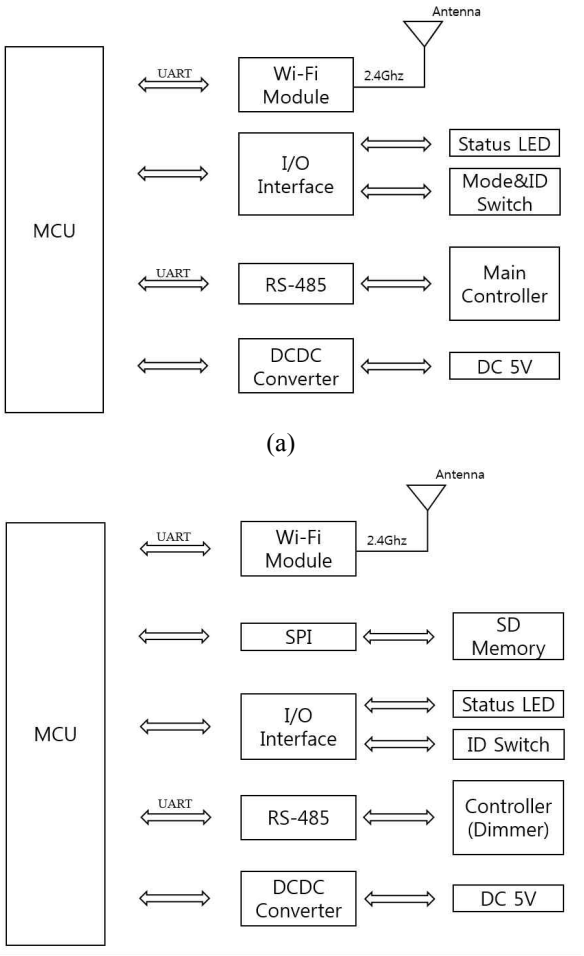

Figure 3. A Schematic Diagram of Proposed WDMX: a) is transmitter and b) is receiver.

wireless communications. The operating mode can be selected externally using hardware, which is a switch on the side of the transmitter that toggles the operating mode. Furthermore, an external switch was placed on the receiver-side in order to set the ID for the receiver module, along with a configuration that can save the production data via external memory. RS-485 was used as the hardware interface for both the transmitting and receiving units for compatibility with existing wire-based controllers.

For the WDMX transmitter, the signal for the RS-485 level that is sent from the main controller goes through the RS-485 drive and is converted to a transistor-transistor logic (TTL)

level-signal that is then sent to the microprocessor. The transmitted data is analyzed in the microprocessor, which uses the First In First Out (FIFO) method. This data comprises the internal SRAM, and is then sent to the WiFi module through a Universal Asynchronous Receiver/Transmitter (UART).
For the WDMX receiver, the signals that come in through the wireless module are processed and, depending on the operating mode, they are either saved on an SD card or used to call saved data from SD card as a DMX512 signal and then outputted via the 485 drive.
The WDMX transmitter/receiver uses the User Datagram Protocol (UDP) by default, and is designed for a single transmitter to send data to multiple receivers for real-time transmissions and commands. When a command signal or the external switch trigger recording mode, the transmitter and specified receiver use a TCP/IP socket for sending and receiving data that is then stored.

3.2 WDMX Protocol

As explained above, the WDMX device proposed in this study aims to secure the versatility of a WDMX device by replacing existing wired transmissions with wireless transmission (real-time relay) and by initiating play in actual performances through command signals using production data sent and saved in advance. To this end, a WDMX protocol was developed for saving and playing performance data. This protocol is distinct from the existing DMX512 protocol. The existing DMX512 protocol was nevertheless retained for real-time sending in order to ensure the system's versatility. The DMX512 protocol was modified, however, for save-and-play mode, as shown in Figure 4. The start frame of the W-DMX signal was modified in order to distinguish it from an existing DMX512 signal. In recording mode, the IDLE signal from the W-DMX signal was set to a minimum of 3 ms to allow sufficient time for the WiFi wireless module to transmit the data at a rate of

Start frame 0x00: Streaming mode (DMX512 protocol)

Break	MAB	0	Ch1 Data	Ch2 Data	Ch3 Data	···

Start frame 0xaa: Recording mode

Break	MAB	0xaa	Ch1 Data	Ch2 Data	Ch3 Data	···

Start frame 0x55: Commend mode

Break	MAB	0x55	Type	Address	Track	Track

Type - 0x00: Recording stop
0x01 : Recording start
0x02 : Recording pause
0x30 : Play stop
0x31 : Play start
0x32 : Play pause
Address : The address of target receiver
Track Number

Figure 4. A Proposed W-DMX Protocol.

250 kbps while the packet is being received. This was done in order to prevent the data from overflowing in the transmission unit.
Figure 4 illustrates the W-DMX protocol proposed in this study. The W-DMX protocol sets the mode for the trans-receiver with the start frame. When the start frame is 0x00, it is in streaming mode and uses the same protocol as the existing DMX512. A UDP socket is used to send data for real-time data transmissions. When the start frame is 0xaa, it is in recording mode and the production data that is to be saved after the start frame is sent through TCP/IP socket, ensuring high reliability. Finally, when the start frame is 0x55, it is in command mode, allowing for the construction of data in channels 1-4, with data sent using a UDP socket.

4 EXPERIMENTS and RESULTS

In order to verify the WDMX system proposed in this study, Arduino—an open-source platform for designing interactive projects—was used for testing. An oscilloscope was used to confirm that the DMX512 data coming in from the console is being transmitted correctly in each mode through the WiFi module and Wizfi250. Furthermore, a dimmer from Feelux was connected to the WDMX transmitter to check the operation of the W-DMX protocol as shown in Figure 5.

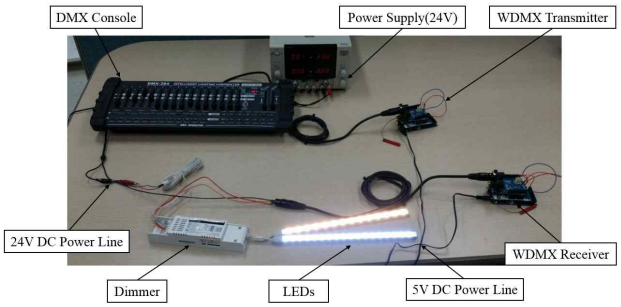

Figure 5. A WDMX Test Environments.

5 CONCLUSIONS

In this study, we proposed a novel WDMX lighting-control system that is distinct from existing wired/wireless DMX devices used for large-scale LED light production. The WDMX proposed in this study is a wireless DMX trans-receiver that uses WLAN, and improves upon the shortcomings of existing wired transmissions, especially with regard to installation and maintenance at large-scale venues. In particular, in order to strengthen the security during real-time data transmissions, which is rather weak in conventional WDMX trans-receivers, the proposed WDMX offers a save-and-play feature designed to be compatible with existing DMX systems. Furthermore, by presenting a WDMX protocol that is compatible with the existing DMX512, the versatility of the proposed WDMX was ensured.

The feasibility of the proposed WDMX system was verified in a laboratory environment, and further testing in a large-scale performance environment is expected to follow.

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