

Original Article

IoT Advertising System using LED Dynamic Message Sign (DMS) and Mobile Application

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Abstract - LED display boards are an effective tool for disseminating information. The popular LED advertising display boards broadcast only non-modifiable information with static text or animation. This work proposes configurable Dynamic Message Signs (DMS) using an LED matrix to make the advertising display more profitable by taking advantage of IoT technologies. The proposed system is called NS-Connect and is managed from an Android application. The luminescent electronic display of the DMS is made of LEDs with high luminous efficiency. The message processing unit incorporates a Bluetooth module that exchanges messages with the Android device and a microcontroller for text display management. The mobile application is designed with several features concerning text edition and display settings, including scrolling speed, brightness, and font choice. This technological innovation reduces the costs of awareness-raising activities or marketing and communication campaigns on major themes such as COVID-19, climate change, or civic engagement.

Keywords - Dynamic message sign, LED display board, mobile application, Advertising display, IoT advertising system.

1. Introduction

The digital revolution brings sociocultural and economical changes, including how people experience information, media, and advertising. In the past years, Web advertising has become a vital component of the digital ecosystem [1], [2]. Computational or mobile applications-based advertising in the Internet of Things (IoT) is an under-investigated research field despite the advances observed in recent years. IoT advertising would enhance traditional Internet advertising and public place advertising by taking advantage of IoT opportunities [3], [4].

Illuminated electronic signs or LED (Light-Emitting Diode) display boards are electronic devices that disseminate information in real time. LED display boards are designed in alignment with technological and environmental trends. The U.S. Department of Energy recommended LED adoption after evaluating lighting applications of different technologies where LED demonstrated the greatest energy savings impact [5]. One of the interesting results of IoT technology development could be the key role of LED display boards in the shift to smart cities.

Organizing message display through local computer networks or the Internet using 24 hours accessible LED signs opens up new possibilities. The advantages of this type of awareness-raising and advertising are numerous: (i) to access the information displayed by an outdoor LED sign, the target audience does not need to buy a piece of equipment; (ii) LED display boards provide higher brightness and resolution than

the traditional screen, ensuring high visibility of displayed messages even in broad daylight, or deep night; (iii) Outdoor LED advertising is perfect for turning passerby's into customers by captivating their attention with personalized and creative messages.

LED boards in advertising started decades ago, but the remote control of displayed messages in such systems is recent. Most related works are based on GSM technology, for which Bluetooth and Wi-Fi protocols are interesting alternatives [2]. Therefore, in this work, we propose a Bluetooth/Wi-Fi-based system for dynamic display using LED boards and an Android application called NS-connect.

Apart from section 1, this paper is organized as follows. Section 2 presents the research methodology. In Section 3, we describe the modeling process. The results are discussed in Section 4. Section 5 concludes this paper.

2. Methodology

This research work was conducted using the next methodology:

- Data gathering. The needed data for this research was gathered by reviewing existing works on LED display technology, LED matrix wiring, and the new advertising opportunities using the IoT concept.
- Data analysis. The analysis of collected data helped select the right devices and technology to design a system that meets the needs of the end-users requiring few resources without quality loss.



Table 1. Summary of recent works on dynamic display using LED boards

Sign types	Description	Related works	Technologies
Electronic notice board (including LED Advertising screen)	Boards in institutions or organizations and public utility places like airports, bus stations, and railway stations to display and pass information	[8], [9], [10], [11]	GSM technology
		[12]	Web, Ethernet
		[13]	Mobile app and Wi-Fi
Emergency LED Exit Sign	Emergency Exit Signs are used to attract the immediate attention of people needing guidance for exiting.	[14]	Zig Bee network

- IoT design approach. The authors proposed that the 10-step IoT platform design methodology in [6] was used to model the system and integrate devices and components.
- Software development. We applied the advanced V-model of the Software Development Life Cycle [7] to improve the quality of the mobile application. This approach helped conduct software testing and its interactions with electronic components and devices.

3. Related Works

Research has been carried out to design remote control systems for LED signs in recent years. Table 1 summarizes reviewed recent works with the used technologies description.

Conventional LED signs do not offer the possibility of changing the displayed message dynamically. Therefore different approaches are used to control the display.

The design principle is the same for GSM-based systems [8], [9], [10], [11]. SMS messages from a mobile phone using a registered user number are received by a GSM module interfaced with a microcontroller's ports. Then, suppose the newly received message is validated (correct sender and format). In that case, the displayed message is updated by the microcontroller, which is interfaced with the display unit of the LED board. The limitations of the SMS-driven approach are not negligible, starting with the message's predefined size and limited display settings. The use of GSM facilitates the remote control of the system. Still,

when the system is experiencing connection troubles, the displayed message can no longer be modified, even if the user is nearby the display system. Also, the use of the GSM SIM is subject to a subscription, which can be cut off for non-renewal reasons and compromise the system's functioning.

Another work proposed using a LED dot matrix board managed by the microcontroller Arduino Mega to display academic information [12]. The displayed message is stored on an S.D. card mounted on the Ethernet shield. This system requires an Ethernet and lacks a remote controller.

A speech-to-text conversion approach has also been applied to manage dynamic content displayed on a LED board [13]. Here, speech content is sent by an Android application from a mobile device using Wi-Fi technology to a receiver for speech-to-text signal conversion. The receiver is interfaced with an 8051 microcontroller which triggers the text display on the LED matrix. The message is stored only for the display time in this system, and no display setting options are developed.

A specific IoT enables emergency LED exit signs to be developed to make the display of the existing system dynamic and more effective in guiding people [14]. The proposed system uses a sensor network (temperature, humidity, sensors) to provide income to the Arduino microcontroller for display decision-making. Using the combination of fire, glass breaking, humidity, and temperature detection, the system demonstrated a good performance in terms of time for exit route decisions compared with other static display LED signs.

4. System Modelling

This work aims to design a cost-effective LED board with a changeable display to broadcast dynamically 24 hours information using a mobile application with setting options.

This section presents the analysis and modeling specifications of the display system.

4.1. Requirements Specifications

Functional and non-functional requirements of the system are addressed in this subsection.

4.1.1. Functional Requirements Resource Discovery

The mobile application can manage only discovered display devices. Bluetooth or Wi-Fi device discovery service shall be used to identify the available display device or system.

Data Management

The created messages shall be stored locally in the mobile application. The local storage approach should allow the system to operate independently of an internet connection. The application shall offer the possibility to modify or delete an already stored message.

Event Management

The system should enable the user to effectively change the display to reach the targeted audience.

Power Supply Management

The energy efficiency requires a 5v regulated power supply for all devices and electronic components. This range of voltages should offer better compatibility between different equipment.

4.1.2. Non-Functional Requirements

Scalability

The mobile application shall be able to control more than one display device. The system shall support the addition of sensors to collect data for further functions.

Availability

The system should be available 24 hours a day for continuous display except for the scheduled maintenance period. The system availability should be achieved by ensuring some levels of fault tolerance and display delay tolerance.

Security

The system shall be protected from power variances and the mobile application against non-authorized access.

Usability

The mobile application shall be developed focusing on user-centred design principles. The usability should be achieved by ensuring ease of use (learning and manipulation).

Interoperability

The system shall support interoperability and interworking at the application service layer.

Ease of Deployment

The ease of a deployment-driven approach should guide the design of the system.

4.2. The Information Model and Service Specifications

The main virtual entities of the display system with changeable attributes are LED boards and Messages. The key information being managed in the system is the displayed message. Therefore, many options are available for the text to display. The attributes of the virtual entities and their relations are presented in fig. 1

Basic services provided by the system are:

- User authentication: access to the application core is secured by a user password. The password is set when the application runs the first time.
- Message editing: the user can create, delete or edit a message in the mobile app.
- Text display: the system supports the text display with special characters, such as letters with accents.

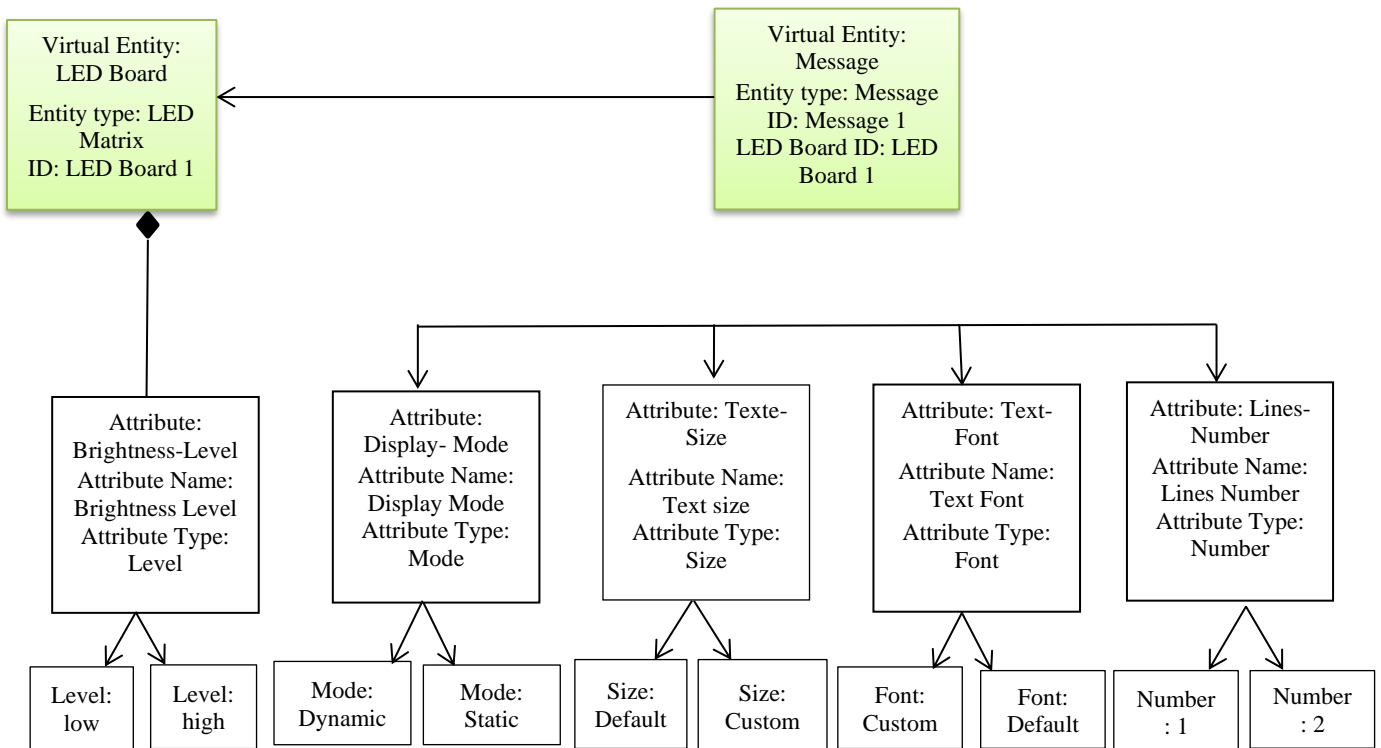


Fig. 1 The display system information model

Different display setting options are available:

- Display mode: the user can decide to scroll the message or make it static. When the scroll mode is used, the scrolling speed can be set.
- Font and text size: default or custom values are available.
- Lines number: the text can be displayed on the LED board using one or two lines.

4.3. Devices and Components Integration

The proposed dynamic message display system integrates an electronic bloc and a mobile (user) application using an LED board. A LED display board and a message processing unit are integrated into the electronic bloc. Fig. 2 presents the architecture of the proposed system.

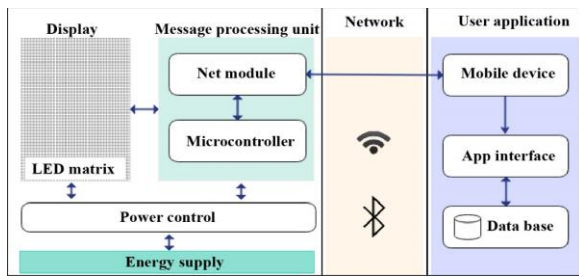


Fig. 2 Architecture of the display system

4.3.1. The Message Processing Unit

The Message processing unit combines a network module and an Arduino Nano microcontroller. The Arduino Nano card allows the remote control of the LED board, and the Bluetooth or Wi-Fi module is used for data exchange with the mobile application.

The mobile device acts as a signal transmitter through the Bluetooth/Wi-Fi network using the mobile app in the proposed system. The messages are received in the processing unit by the Bluetooth/Wi-Fi module, which acts as a receiver. Received messages are transmitted to the microcontroller (Arduino Nano). The microcontroller is an intermediate receiver with embedded intelligence that sends messages to the LED display board.

4.3.2. The LED Display Board

A multiple LED matrix is wired to build the display board. The LED matrix is an intelligent display board where the received message is instantly displayed in static mode or is scrolled with the brightness and speed values chosen by the mobile app user. A Max7219 circuit is used to select the current LEDs, which must light up to display the received text from the Arduino board. A terminal block is used for secure matrix patching. Fig. 3 illustrates the circuit diagram of the system.

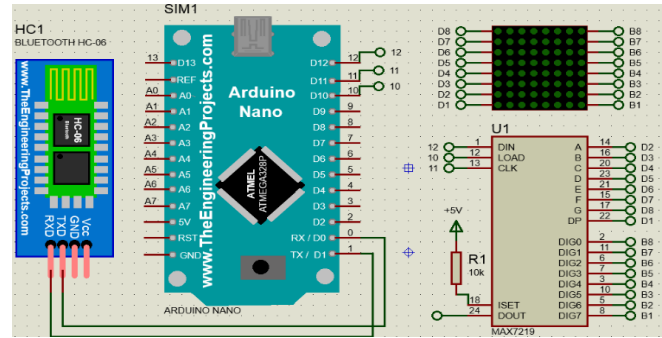


Fig. 3 Circuit diagram of the system

4.4. Application Development

The requirements specifications and the system modeling helped create the first layouts of the mobile app. Afterward, the layouts were improved through usability testing. The proposed mobile app is developed using the Android Software Development Kit in the Java programming language. Created messages are stored in a local database in the mobile app.

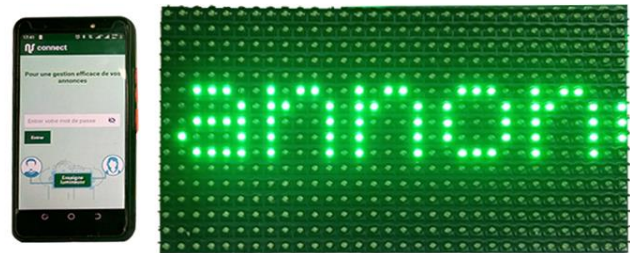


Fig. 4 The mobile app and display board

5. Results and Discussions

A Wi-Fi-based prototype of the system was developed, but due to the Wi-Fi security vulnerabilities, some additional tests are required to validate this prototype [15]. Therefore, this section presents the obtained results for the Bluetooth protocol.

5.1. Performance Analysis

Different tests were performed to detect possible anomalies and verify if the system meets the specified requirements. The next tests were carried out:

- Unit testing was performed during the mobile app development to check the implemented functions, such as user authentication, device detection, and message transmission;
- Integration testing was performed to check the communication interfaces' data exchange between different devices and components.

The proposed system was deployed in our institute's Electrical Engineering and Informatics Department. The deployment process demonstrated good results. All special characters are displayed correctly.

5.1.1. Energy Consumption

We ran the mobile app on different smartphones during the system integration and deployment phases. The energy consumption of the mobile app is less than 1% in all use cases.

The latest advances in LED technology help to minimize also the energy consumption of the system.

5.1.2. Display Delay-Tolerance

The implemented Max7219 circuit uses a master to reset the system and clear the board register. This resetting process allows the new messages to be displayed on the LED board within 100 milliseconds.

5.1.3. Display Duration

We analyzed the display duration of various texts with different numbers of characters during the system deployment. Results are presented in fig.5 for two texts.

- The first displayed text is "STOP COVID_19 STOP COVID_19," with 27 characters.
- The second displayed text is "STOP COVID_19 STOP COVID_19 STOP COVID_19" with 41 characters.

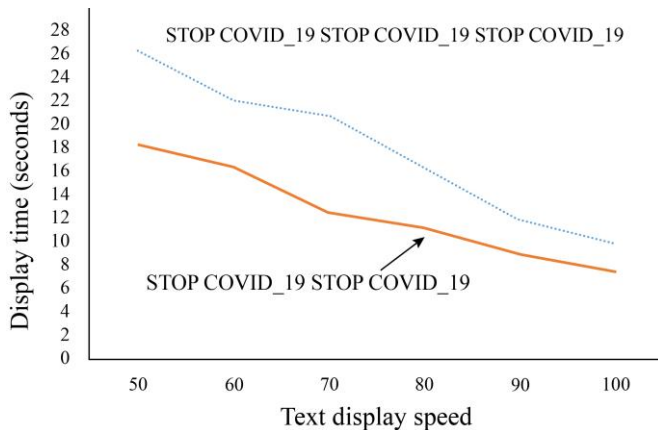


Fig. 5 Text scrolling duration as a function of scrolling speed

The experiment demonstrated that the text reading becomes difficult (too rapid) when the scrolling speed exceeds 100. One of the interesting results is that the display duration of texts with short or medium sizes gets closer when the scrolling speed is high. This outcome can help to set the adapted scrolling speed when disseminating information.

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5.2. Security Mechanisms

In the electronic bloc, the Max7219 circuit is used to multiplex digital inputs of the LED matrix and maintain low power dissipation. This protection circuit prevents the destruction of the LED signs due to mismatched input voltages.

The mobile application is protected from all unauthorized access by a user authentication process using a password. An email-based password reset procedure is proposed in the application.

A developer code is used to protect the installation of the mobile application. This code is used for maintenance tasks.

5.3. System Relevance

The proposed IoT-oriented CDMS offers real-time flexibility to display flash news or advertising messages. The system can be used for many purposes without affecting the surrounding environment, such as:

- Outdoor Notice boards at public places like municipalities, schools, hospitals, shops, bus stations, railway stations, gardens, etc.
- Traffic diversion signs on roads under construction. The system is particularly useful by night to limit road accidents.
- Indoor Emergency LED Exit Signs, especially in big buildings, to guide visitors.

6. Conclusion

This paper presents the design and implementation of a smart, configurable dynamic message sign system based on remote control from an Android mobile application. The displayed messages are transmitted to a LED board through a microcontroller using Bluetooth protocol. One of the system's new features is the possibility of a dynamic display setting from the mobile application. The main Advantages of this innovation are time-saving, cost-effectiveness, and the 24 hours possibility of reaching the target audience. The LED technology is robust and guarantees the sustainability of the proposed system.

Aware of Bluetooth's range limits in perspective, we plan to conduct more research on Wi-Fi protocol to satisfy the security requirements for long-distance control.

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