Li-Fi for Secured Access to Wireless Network During Online Examination in Classrooms

Sanket Salvi, Sagar Apune, Vitthal Gutte, Mayuri Gawade and Ranjit Kolkar

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Sanket Salvi[1], Sagar Apune[1], Vitthal Gutte[1], Mayuri Gawade[2] and Ranjit Kolkar[3]

[1]School of Computer Engineering and Technology, MIT-WPU, Kothrud, Pune, 411038, Maharashtra, India.
[2]Department of Computer Engineering , Vishwakarma Institute of Technology, Bibwewadi, Pune, 411037, Maharashtra, India.
[3]Department of Information Technology, National Institute of Technology Karnataka, Surthkal, Mangalore, 575025, Karnataka, India.

Contributing authors: sanket.salvi@mitwpu.edu.in; sagar.apune@mitwpu.edu.in; vitthal.gutte@mitwpu.edu.in; mayuri.gawade@vit.edu; ranjit.kolkar@gmail.com;

Abstract

The traditional conduction of examinations need to use physical copies of question paper and answer sheets, which are then evaluated by the evaluators. However, in a post pandemic era, where the emphasis is more on the minimal usage of physically transferable materials, safe conduction of examinations in the classroom environments becomes challenging. Conduction of examination in complete online mode requires wireless access to the Wi-Fi access points, however, as the range of the Wi-Fi access point goes beyond the classrooms, there is possibility of accessing the network from outside classroom which is not desired. With an aim to address these issues, in this paper a novel approach for providing dynamically changing passwords using visible light communication is designed, implemented and tested for connecting to the wireless network. The setup is useful in the environment where restricted physical access is needed to ensure system and network security.

Keywords: Li-Fi, Visible Light Communication, Optical Camera Communication, Online Exam

1 Introduction

The conduction of examinations is one of the most important factor towards evaluation of a student for attainment of specific learning goals [1]. Traditionally, the exams were conducted using physical copies of question papers and answer booklets under the supervision at an exam centre. The scope of malpractice was limited as carrying physical cheats would pose high risk of getting caught [2]. However, the process of evaluating physical individual copies of students' answer sheets was time consuming and required lot of papers to be used which was not a sustainable solution. During, the recent pandemic situation, educational systems were forced to move towards more technology driven approach for continuing education and conduction of examinations [3, 4]. Various platform provided remote monitoring and proctoring [5] features however, the lack of physical supervision enabled increased possibilities of malpractices [2].

Although, digitization of examination process proved to be a greener and time efficient procedure, the problem of lack of supervision capability is a concerning issue. In a post-pandemic scenario, a hybrid approach [6] is being used at many institutions, wherein, the students are allowed to access mobile phone in the exam hall to attempt questions under the supervision. This approach merges best of both traditional and modern approaches. However, as the mobile requires wireless access, it is often observed that few students connect to Wireless-Fidelity (Wi-Fi) access points from outside the exam halls. This is majorly because Wi-Fi range is upto 45 metres and can even penetrate through walls [7]. Thus, there is need of a solution which would enable Wi-Fi access to the students explicitly when they are inside the exam hall.

Light-Fidelity (Li-Fi) is a field of science where data can be transmitted and received using the unlicensed visible light spectrum [8]. As the visible light cannot penetrate through walls the Li-Fi systems work on line-of-sight communication principles. Li-Fi systems can be categorized into two basic types

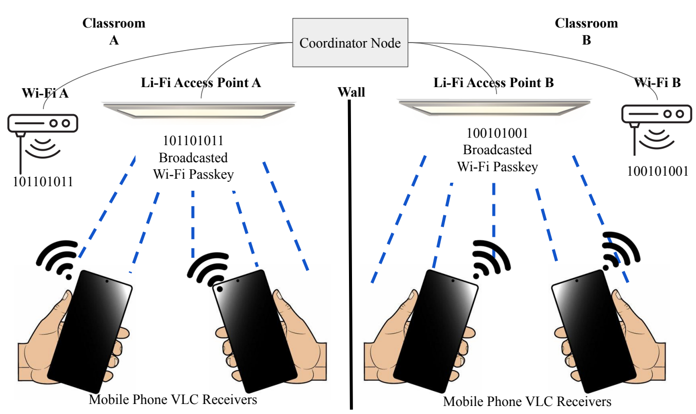


Fig. 1: Generic Hybrid Li-Fi Wi-Fi System

based on the sensor used at the receiver side [11]. As the light signals in Li-Fi are modulated by varying the brightness of light, the receiver sensors are generally photo-diodes or cameras. Photo-diodes provide high sensitivity and faster response time, thus providing larger bandwith as compared to slower frame-rate camera based Li-Fi systems. However, integration of additional hardware in existing mobile phones restricts the adoption of photodiode based Li-Fi systems. Meanwhile, since cameras are pre-integrated in mobile phones, camera based Li-Fi systems can be easily adopted [9]. With a motivation to include advantages of camera based Li-Fi system with existing hybrid online-offline examination system, this paper proposes a framework to integrate Li-Fi and Wi-Fi in a classroom based examination scenario as shown in Fig.1.

The remainder of the paper highlights the proposed framework in section 2, while section 3 provides details of requirements and implementation. Section 4, discusses experimental setup and results followed by conclusion.

2 Proposed Framework

The proposed framework is sub-divided into 4 modules namely as Coordinator node, Li-Fi access point, Wi-Fi access point and mobile phone as shown in the Fig. 2.

- **Coordinator Node**: The basic functionality of the coordinator node will be to generate passkey and share it with Li-Fi access point as well as Wi-Fi access point. It can be any programmable device with computational capability such as Raspberry Pi, a laptop or a desktop and that could connect with Arduino and Wi-Fi router. It will be responsible for managing various passkeys across various rooms. It will be also be responsible for maintaining a log of previous and current passkeys as well as share the same passkey for Li-Fi and Wi-Fi access points located in same classroom.

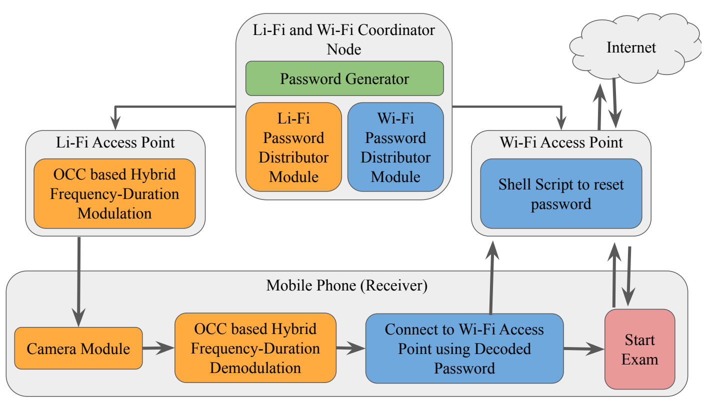


Fig. 2: Proposed Li-Fi based online exam framework

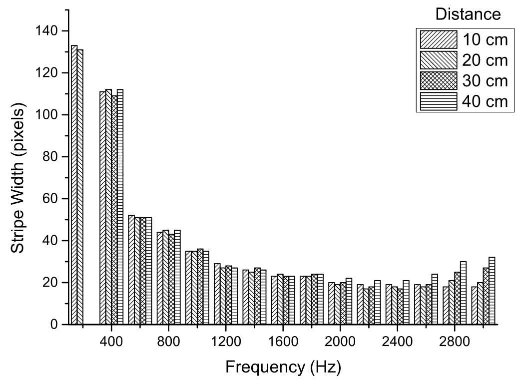


Fig. 3: LED Flickering Frequency vs. Stripe Width.

- **Li-Fi Access Point**: The Li-Fi access point will work as a beacon that transmits a message repeatedly. The passkey provided by the coordinator node will be continuously transmitted using Hybrid Frequency Shift Pulse Duration Modulation (HFSPDM) [10] modulation technique, where each character of the passkey will be converted into its corresponding binary and the binary will be transmitted as frequencies of Light Emitting Diode (LED) 'on-off' cycles.
  The LED flickering at high rate frequency will not be visible to the naked eyes however, due to the rolling shutter effect the receiver camera will be able to capture the frames with visible stripes. As the width of the stripes is directly related to flickering frequency as shown in Fig. 3, by identifying the stripe width using image processing and reverse mapping to flickering frequency one can estimated the transmitted frequency. The duration of detected frequency will then be used to deduce the received bit pair.
- **Wi-Fi Access Point**: The Wi-Fi access point will work as a network connection enabling device, which will have a preset Service Set Identifier (SSID) and would require a passkey to connect. Any device connected to Wi-Fi access point will be able to access network connected server and the hosted data. A shell script will be used to reset the password.
- **Mobile Phone**: The an app installed on the user mobile will serve as the receiver. The working of the app will be divided into three modules. Wherein the first module will be responsible for receiving beacon data from Li-Fi access point, second module will be responsible for connecting to Wi-Fi access point, and the final module will be responsible for the test conduction. The app will use the video input from the front camera to perform demodulation and reconstruct passkey. The received passkey will then be set as password to connect with a Wi-Fi router with preset SSID. Once the connection is successful, the app will load exam from local network.

3 Requirement Analysis and Implementation

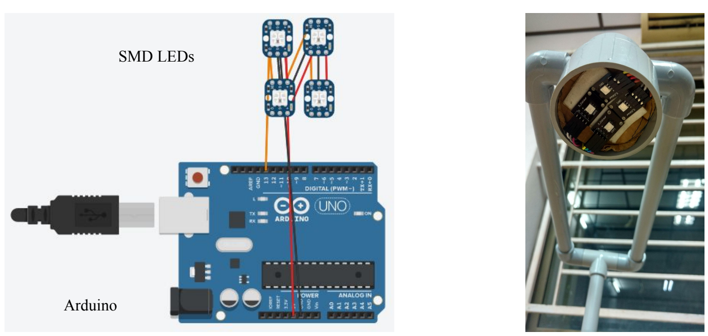
The hardware and software requirements for implementing the proposed framework and implementation details are discussed in this section.

Four bright surface mounted device SMD LEDs connected to an Arduino Uno is used to implement the proposed Li-Fi transmitter. The circuit diagram is as shown in Fig. 4a. The implemented transmitter is then housed in a PVC pipe based low-cost lamp like setup as shown in Fig. 4b. The LEDs connected to Arduino is controlled by programming the board. The LEDs are turned on and off in a fast succession such that the flickering is invisible to human eyes. The coordinator node is a desktop system connected to Wi-Fi router and Arduino.

Algorithm 1 Passkey Generator

```
import random
passkey=""
for x in range(6):
  passkey+=chr(random.randint(55,120))
print("Password is :",passkey)
```

The coordinator node generates a six letter passkey using a random character sequence generator as shown in Alg. 1. The generated passkey is passed as a parameter to the Arduino sketch while uploading the code using a shell script. The same passkey is also set as a new passkey to the Wi-Fi router. The passkey received by Arduino at Li-Fi transmitter side is modulated using HFSPDM. At the receiver side, the mobile front camera is used to capture the transmitter access point and perform demodulation as shown in Fig. 5. The input video is processed frame by frame. Each frame undergoes image pre-processing and extracts the region-of-interest (RoI). The frequency of On-Off



(a) Tx Circuit Diagram

(a) Implement Li-Fi Access Point

Fig. 4: Li-Fi Transmitter

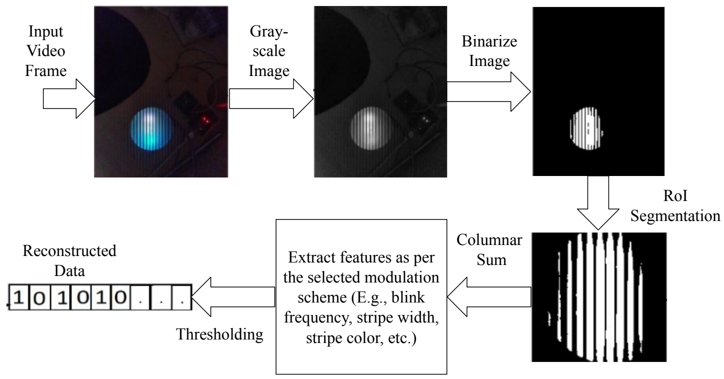


Fig. 5: HFSPDM Demodualtion Steps [10]

cycles is determined from the extracted RoI and corresponding data is reconstructed. The reconstructed data is set as a passkey for the pre-set Wi-Fi SSID and the mobile app gets connected to the Wi-Fi access point. The objective based exam questions and respective options are then loaded using the local server.

At the end of the online objective text, the participants are provided with a google form link to evaluate to user experience.

4 Experimental Setup and Results

This section highlights the experimental setup and results of the conducted experiment and user feedback.

A network hosted SQL database of questions and options was used to fetch the questions for demo online exam. The camera based image processing technique for demodulation of transmitted Li-Fi signals was integrated into a mobile application. To evaluate the experience of the proposed system, a minimilistic questionaire was built based on standard human computer interaction guidelines and a user survey was conducted. The questions were as shown in Table. 1. Sample size of 30 participants was used with diverse age groups with minimum educational qualification being 4th grade. A separate survey was conducted to study the learning curve for using the app and its ease of use. Three goals were defined as shown in Table. 2 and participants were asked to achieve the goals without any prior instructions.

The screenshots of the implemented application is as shown in the Fig. 6. From left to right, the figure shows various screens of the app such as Splash Screen, Li-Fi Access Point Detection Screen, Login Screen and Demo Test Screen respectively. Splash screen shows the name of the app and a progress bar. Once the app is loaded it lands to Li-Fi access point detection screen, which turns on the front camera and on press of 'Connect' button the Li-Fi signal demodulation process is initiated. On successful detection of access point and reconstruction of passkey string, the mobile phone connects to predefined

Table 1: User Experience Questionnaire

Q. No.	Question
Q1	Please rate your experience with the mobile application on a scale of 1 to 5.
Q2	On a scale of 1 to 5, assess the interface of the mobile application.
Q3	Rate the intuitiveness of the icons on a scale of 1 to 5.
Q4	How would you rate the loading speed of the mobile application on a scale of 1 to 5?
Q5	Evaluate the navigation of the mobile application on a scale of 1 to 5.

Table 2: Goals for evaluating ease of use

No.	Goals
G1	User should be able to open the app connect to Li-Fi Access Point
G2	User should be able to connect to Wi-Fi and submit login details.
G3	User should be able to start and end the test without disconnecting from Wi-Fi.

SSID with received passkey. As the process is synchronous, after successful connection to Wi-Fi access point, the next screen is loaded which fetches the test questions and corresponding option from internal network database and populates the content on the screen. Finally, once the test is completed all results will be stored on local network data server.

The Fig. 7, shows the collective responses of 30 participant with respect to questions and their corresponding rating with 1 being bad and 5 being the good. It can be observed that maximum participants have given good response to Q1 and Q4, indicating the experience and navigation of the app was appealing. Whereas, Q4 had received least good rating mainly due to the time taken for Li-Fi demodulation and Wi-Fi passkey reconstruction.

The Fig. 8, shows the goal attainment by participants of various age groups. It was observed that maximum participant of age group 20-30 were able to achieve all three defined goals. However it was difficult to achieve in older age

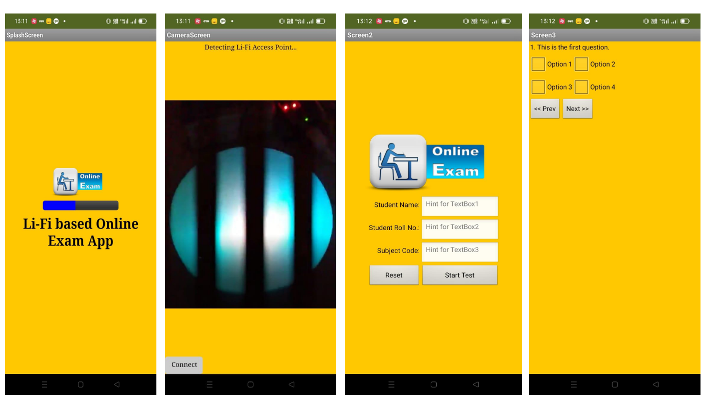


Fig. 6: Li-Fi based Online Exam App

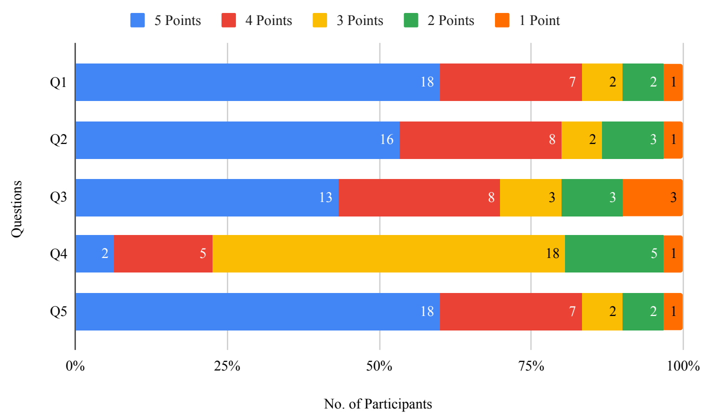


Fig. 7: User feedback

group of 40-50 years and younger age group of <10 years. This is majorly doubted to be due to less experience of using mobile phones and exposure to online exam platforms.

5 Conclusion

In this paper a novel solution to mitigate the challenge of lack of access control mechanism in online exams is proposed, implemented and evaluated. The system uses a camera based Li-Fi communication mechanism using HFSPDM modulation technique to transmit the Wi-Fi passkeys only to the devices which are under the line-of-sight of the Li-Fi access point. A prototype Li-Fi access point was implemented. A coordinator node was used to generate passkey and

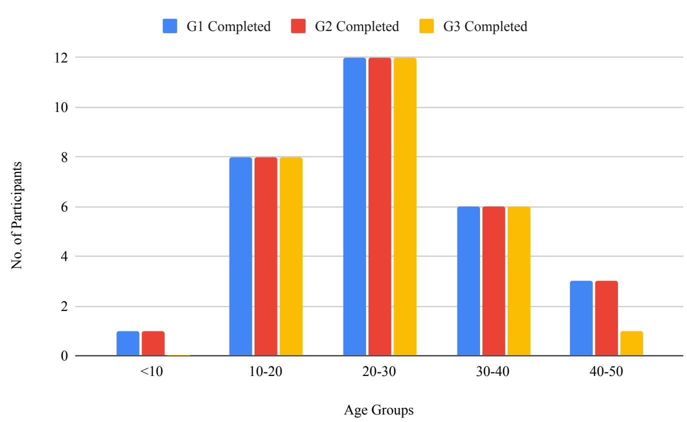


Fig. 8: Goal Attainment

share it via Li-Fi access point while same passkey was assigned to the Wi-Fi access point. A prototype app was implemented to decode the passkey and connect to Wi-Fi. A demo test was loaded in the app the test working of overall proposed system. Finally, user feedback and goal attainment was evaluated to test the performance of the proposed framework. It was observed that the proposed framework provided higher level of security, with easy to use interface. It was also observed that majority of the users were successfully able to navigate across all the screens of the app and attain the set goals. A South African patent with registration number 2023/02929 is filed based on the implemented work.

6 Declarations

Compliance with Ethical Standards:

- **Funding:** This study was not funded by any agency or institute.
- **Conflict of Interest:** All authors declare no conflict of interest.

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