Hybrid Li-Fi and Wi-Fi Networks Based Data Access System

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***Abstarct* – Hybrid light fidelity (Li-Fi) and wireless fidelity (Wi-Fi) networks are an emerging technology for future indoor wire-less communications. This hybrid network combines the high-speed data transmission offered by visible light communication (VLC) and the ubiquitous coverage of radio-frequency (RF) techniques. While a hybrid network can improve the system throughput and users' experience, it also challenges the process of access point selection (APS) due to the mixture of heterogeneous access points (APs). In this paper, the differences between homogeneous and heterogeneous networks regarding APS are discussed, and a two-stage APS method is proposed for hybrid Li-Fi/Wi-Fi networks. In the first stage, a fuzzy logic system is developed to determine the users that should be connected to Wi-Fi. In the second stage, the remaining users are assigned in the environment of a homogeneous Li-Fi network. Compared with the optimisation method, the proposed method achieves a close-to-optimal throughput at significantly reduced complexity. Simulation results also show that our method greatly improves the system throughput over the conventional methods such as the signal strength strategy (SSS) and load balancing (LB), at slightly increased complexity.**

I INTRODUCTION

Mobile communication has been technically challenged by exponentially increasing demands for data traffic. The Cisco visual networking index (CVNI) reports that global mobile data traffic reached 2.5 exabytes per month at the end of 2014, which is 69% more than the traffic at the end of 2013. During the same period, the average cellular network connection speed increased by 20% only. One solution to relieve the pressure on existing base stations is offloading traffic to wireless fidelity (Wi-Fi), based on the fact that over 80% of mobile data traffic comes from indoor locations. However, the dense deployment of Wi-Fi hotspots becomes the bottleneck of improving the system capacity. An alternative short-range wireless communication technology is visible light communication (VLC) and its networking variant, light fidelity (Li-Fi) . In Li-Fi, light-emitting diode (LED) lamps act as access points (APs), and light is used as a medium to carry information bits via intensity modulation and direct detection (IM/DD). At the receiver, a photon diode (PD) is employed to collect photons and convert them into electric current. Unlike the radio-frequency (RF) techniques including Wi-Fi, Li-Fi does not experience interference from other sources because it is contained within a specific area, and light is not transferred through opaque objects such walls. In addition, Li-Fi offers a much wider spectrum than RF, and is licence-free. Furthermore, Li-Fi can be used in RF-restricted areas such as hospitals and underwater. Recent research shows that by using a single LED, Li-Fi is capable of offering high-speed data transmission in the Gbps range .A Li-Fi AP has a smaller coverage area than Wi-Fi, of approximately 2-3 m diameter [6]. In order to provide enhanced coverage, a hybrid Li-Fi and Wi-Fi network, which combines the high-speed data transmission of Li-Fi and the relatively large coverage of Wi-Fi, is envisioned for indoor wireless communication . In , it was shown that such a hybrid network can achieve a greater throughput than stand-alone Wi-Fi or Li-Fi networks. In that study, all of the users are first connected to the Li-Fi network, and then those of low achievable data rates are switched to Wi-Fi. This access point selection (APS) method fails to take into account the fact that the required data rates might vary with users. Also, due to the limited Wi-Fi resource, switching a Li-Fi user that achieves a low data rate to Wi-Fi does not necessarily benefit the overall network performance. An apparent example is that user receives a very weak Wi-Fi signal and could drain the Wi-Fi resource to meet its demand for data rate.The APS issue in a hybrid network is more complicated than in a homogeneous network. For homogeneous networks, a straightforward APS method is to select the AP from which the user can receive the strongest signal. This method is called the signal strength strategy (SSS), which is widely used in the current wireless networks when unbalanced load is not considered. In a homogeneous network, APs are deployed in a way with little coverage overlap to avoid inter-cell interference (ICI). In this situation, unbalanced load occurs when the number of users or their required data rates are unequally distributed among the coverage areas of APs. In a hybrid network, however, the coverage areas of different networks overlap each other. Therefore even if the traffic demands are equally distributed in geography, Wi-Fi still faces more traffic load than Li-Fi due to a larger coverage area. Tmakes the infeasible for a hybrid network, and load balancing (LB) is of vital importance.

IILITERATURE REVIEW

On the contrary, few studies have been done with respect to a hybrid Li-Fi and Wi-Fi network, and those few treat heterogeneous APs in the same way as in a homogeneous network. In [11], a distributed load balancing method was proposed based on game theory, which requires quantities of iterations to reach a steady state. With the aim of maximising the overall throughput, [12] reported a centralised optimisation method, which requires extensive computational complexity. Those methods were developed from the APS solutions in a homogeneous network, and they fail to exploit the distin-guishing characteristics between Li-Fi and Wi-Fi. In general, a hybrid Li-Fi and Wi-Fi network challenges the APS in two aspects: i) a Wi-Fi AP dominantly attracts the users close to it, leading to an inefficient use of nearby Li-Fi APs; and ii)a Wi-Fi AP has a larger coverage area but less capacity than a Li-Fi AP, and thus is more susceptible to overload. To the authors' best acknowledge, so far there has been no APS method specially tailored for a hybrid Li-Fi and Wi-Fi network Motivated by this, we propose a novel APS method based on fuzzy logic for a hybrid Li-Fi and Wi-Fi network. Fuzzy logic, which was first introduced by Lotfi A. Zadeh in 1965 [13], is an approach to computing based on "degrees of truth" rather than the usual "true or false" Boolean logic. This approach can readily handle a complicated problem by transforming it into a checklist of rules, and thus has been widely used in control. In [14], fuzzy logic was applied to the APS and resource allocation for wireless networks. The major advantage of this heuristic and near-optimal method is that it can achieve low computational complexity relative to numerically involved optimisation techniques which are often required to solve complex problems such as resource allocation in wireless networks. However, this method was developed in the context of homogeneous networks and does not address the noted APS issues in hybrid networks. The APS method proposed in this paper has two stages. In the first stage, a fuzzy logic system is developed to determine the users that are connected to the Wi-Fi network. Then in the second stage, the remaining users are assigned as if they are in a homogeneous Li-Fi network. The proposed method is a centralized algorithm, and unlike distributed methods it does not need iterations to reach a steady state. In contrast to the centralized optimization method, the proposed method can significantly reduce processing power thanks to the use of fuzzy logic. Unlike most research in this field and our previous work in [1], in this paper a generalized indoor scenario of multiple compartments is considered. Also, the optimality and complexity of the proposed method are analyzed against the optimization method. Results show that the proposed method achieves a near-optimal solution at significantly reduced com-plexity. Comparisons between the proposed method and the conventional APS methods are also carried out.

(1) A Wireless Backhaul Solution Using Visible Light Communication for Indoor Li-Fi Attocell Networks Hossein Kazemi, Majid Safari and Harald Haas

Light-fidelity (Li-Fi) is an emerging technology forwireless optical networking using the principle of visible light communication (VLC). Li-Fi attocells are smaller in size than the radio frequency (RF) femtocells, suitable for deploying ultra-dense cellular networks. In this paper, a novel wireless backhaul solution is proposed for indoor Li-Fi attocell networks using VLC, which is already embedded in the Li-Fi base station (BS) units. Since the backhaul links operate in the visible light spectrum, two methods are proposed for bandwidth allocation between the access and backhaul links, namely, full frequency reuse (FR) and in-band (IB). In order to realize dual-hop transmission over the backhaul and access links, both amplify-and-forward (AF) and decode-and-forward (DF) relaying protocols are analyzed. Considering a direct current optical orthogonal frequency division multiplexing (DCO-OFDM)-based multiple access system, novel signal-to-interference-plus-noise ratio (SINR) and spectral efficiency expressions are then derived for user equipment (UE) randomly distributed in each attocell. Downlink performance of the optical attocell network is assessed in terms of the average spectral efficiency using Monte Carlo simulations. Guidelines are given for the design of the proposed wireless backhaul system.

(2) X. Wu, D. Basnayaka, M. Safari, and H. Haas, "Two-stage access point selection for hybrid VLC and RF networks

This work studies the issue of access point selection (APS) in a hybrid wireless network accommodating visible light communication (VLC) and radio-frequency (RF) technologies. A hybrid network constructs multiple layers of coverage, and thus a user possibly acquires a high level of receiving signal strength (RSS) from more than one access point (AP). This fact undermines the effectiveness of conventional RSS-based APS methods. Another challenging factor is the dissimilarity between heterogeneous APs in terms of coverage area and capacity. In general, RF offers larger coverage area but lower capacity than VLC, and therefore the RF system is susceptible to overload. Although the issue of APS can be formulated as an optimization problem, this approach requires a prohibitive amount of processing power. In this paper a two-stage APS method is proposed on the basis of fuzzy logic, with very low computational complexity. The new method first determines the users that should be connected to the RF system, and then assigns the remaining users as if in a stand-alone VLC network. Results show that when achieving the same amount of throughput, the proposed method can support up to 25% and 56% more users than the load balancing (LB) and signal strength strategy (SSS) methods, respectively.

(3) H. Burchardt, N. Serafimovski, D. Tsonev, S. Videv, and H. Haas, "VLC: Beyond point-to-point communication

Due to the large growth of mobile communications over the past two decades, cellular systems have resorted to fuller and denser reuse of bandwidth to cope with the growing demand. On one hand, this approach raises the achievable system capacity. On the other hand, however, the increased interference caused by the dense spatial reuse inherently limits the achievable network throughput. Therefore, the spectral efficiency gap between users' demand and network capabilities is ever growing. Most recently, visible light communication has been identified as well equipped to provide additional bandwidth and system capacity without aggregating the interference in the mobile network. Furthermore, energy-efficient indoor lighting and the large amount of indoor traffic can be combined inherently. In this article, VLC is examined as a viable and ready complement to RF indoor communications, and advancement toward future communications. Various application scenarios are discussed, presented with supporting simulation results, and the current technologies and challenges pertaining to VLC implementation are investigated. Finally, an overview of recent VLC commercialization is presented.

(4) D. Tsonev, H. Chun, S. Rajbhandari, J. McKendry, S. Videv, E. Gu, M. Haji, S. Watson, A. Kelly, G. Faulkner, M. Dawson, H. Haas, and D. O'Brien, "A 3-Gb/s single-LED OFDM-based wireless VLC link using a gallium nitride LED

This paper presents a visible light communication (VLC) system based on a single 50- µm gallium nitride light emitting diode (LED). A device of this size exhibits a 3-dB modulation bandwidth of at least 60 MHz - significantly higher than commercially available white lighting LEDs. Orthogonal frequency division multiplexing is employed as a modulation scheme. This enables the limited modulation bandwidth of the device to be fully used. Pre- and postequalization techniques, as well as adaptive data loading, are successfully applied to achieve a demonstration of wireless communication at speeds exceeding 3 Gb/s. To date, this is the fastest wireless VLC system using a single LED.

(5) D. Basnayaka and H. Haas, "Hybrid RF and VLC systems: Improving user data rate performance of VLC Systems

A hybrid radio frequency (RF) and visible light communication (VLC) system is considered. A hybrid system with multiple VLC access points (APs) and RF APs is designed and compared. In indoor environments, VLC APs can provide very high data rates whilst satisfying illumination requirements, and RF APs can offer ubiquitous coverage. Even though very high throughput is supported by VLC APs, such coverage area may be spatially limited. This gives an opportunity to introduce a new small cell layer to current heterogeneous wireless networks, and it is referred as optical attocellular layer. However since VLC piggy-backs on the existing lighting infrastructure, it may not be possible to achieve full coverage. Hence in practical deployments, the spatial throughput distribution of standalone VLC systems should be augmented. In this context, RF APs can be used to improve the overall rate performance of the heterogeneous wireless system. In this study, the focus is on improving the per user average and outage throughput. It is assumed that the VLC system resources are fixed, and the study quantifies the spectrum and power requirements for a RF system, which after introduction to the VLC system, achieves better per user rate performance

III EXISTING SYSTEM

We describe the overview of the three existing VLC data transmission schemes, based on the ANSI E1.45, in the lighting control network. In addition, the timer-based schemes are classified into the two schemes: packet-based and FRVSs. In the packet-based scheme, a whole VLC data (with one or more fragments-) will be retransmitted for error recovery, whereas in the FRVS only the fragment which has experienced a loss will be recovered.

CHAPTER IV
PROPOSED METHOD

SYSTEM MODEL

Hybrid Li-Fi and Wi-Fi Network

Consider a generalised hybrid Li-Fi and Wi-Fi network for indoor downlink communications, where a number of rooms or compartments are taken into account, as shown in Fig. 1. Each room has a number of ceiling LED lamps, and each lamp is enabled as a Li-Fi AP covering a confined area. Also, a Wi-Fi AP is fitted in each room, providing coverage for the entire room. Though the APs might be irregularly placed in practice, we assume Li-Fi APs to be arranged in a rectangular shape and Wi-Fi APs in the room centre for the purpose of simplicity. Carrier sense multiple access with collision avoidance (CSMA/CA) is used in the Wi-Fi system [15], and therefore no interference occurs among Wi-Fi APs. Regarding the Li-Fi system, all of the Li-Fi APs reuse the same bandwidth. Since light does not penetrate walls, interference only exists between those Li-Fi APs in the same room. At each Li-Fi AP, time-division multiple access (TDMA) is adopted to serve multiple users.

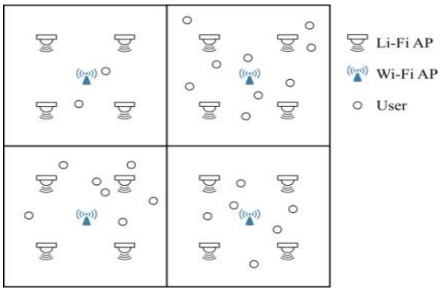

Fig4.1:Schematic diagram of an indoor hybrid Li-Fi and Wi-Fi network.

PROPOSED BLOCK DIAGRAM

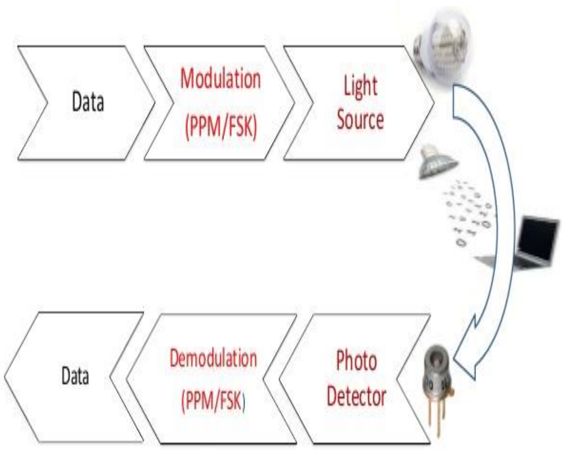

Fig.4.2: Block diagram of Li-Fi

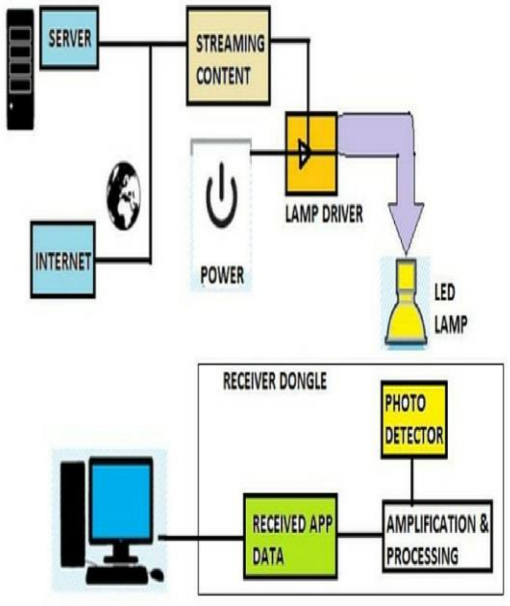

Fig.4.3: Overview of Li-fi and Wi-fi

B. Li-Fi Channel Model

A VLC channel is comprised of the line of sight (LOS) and non line of sight (NLOS) paths. The geometry of indoor VLC propagation is presented in Fig. 2. It is assumed that each user device is fitted with a PD vertically facing upwards. The LOS path of Li-Fi AP i and user u is the straight line between them, and the corresponding Euclidean distance is denoted by $d_{i;u}$. The angles of irradiance and incidence related to the LOS path are denoted by ${}_{i;u}$ and ${}_{i;u}$, respectively.

$$H_{\mathrm{LOS}}^{i,u} = \frac{(m+1)A_{\mathrm{pd}}}{2\pi d_{i,u}^2}\cos^m(\phi_{i,u})g_f g_c(\psi_{i,u})\cos(\psi_{i,u}), \quad (1)$$

where $m = -\ln 2/\ln(\cos\Phi_{1/2})$ is the Lambertian emission order, and $\Phi_{1/2}$ is the radiation angle at which the intensity is half of the intensity at the main-beam direction; A_{pd} denotes the physical area of PD; g_f is the gain of the optical filter; and $g_c(\psi_{i,u})$ is the optical concentrator gain, which is given by:

$$g_c(\psi_{i,u}) = \begin{cases} \frac{n^2}{\sin^2(\Psi_{\max})}, & 0 \le \psi_{i,u} \le \Psi_{\max} \\ 0, & \psi_{i,u} > \Psi_{\max} \end{cases}, \quad (2)$$

where n denotes the refractive index, and $\Psi_{\max}$ is the semi-angle of the field of view (FOV) of the PD.

where n denotes the refractive index, and ${}_{max}$ is the semi-angle of the field of view (FOV) of the PD.

For the NLOS path, only first-order reflections are taken into account for the purpose of simplicity. A first-order reflection consists of two segments:

i) from the AP to a small area w on the wall; and ii) from w to the user.

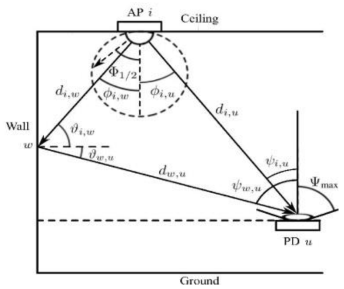

Fig.4.4: Geometry of indoor VLC downlink propagation.

Combining and (1) and (3), the channel from Li-Fi AP i to user u is given by:

$$H_{\text{Li-Fi}}^{i,u} = H_{\mathrm{LOS}}^{i,u} + H_{\mathrm{NLOS}}^{i,u}. \quad (4)$$

At the receiver, photons are gathered by a PD, and then converted into an electric current. The current value is measured by:

$$I_{\mathrm{elec}} = R_{\mathrm{pd}} H_{\text{Li-Fi}}^{i,u} P_{\mathrm{opt}}/\kappa, \quad (5)$$

The coefficient Popt/k is equivalent to the optical signal power. The signal-to-interference-plus-noise ratio (SINR) of the desired signal received by user u is written as:

$$\mathrm{SINR}_{\text{Li-Fi}}^{i,u} = \frac{(R_{\mathrm{pd}} H_{\text{Li-Fi}}^{i,u} P_{\mathrm{opt}}/\kappa)^2}{N_{\text{Li-Fi}} B_{\text{Li-Fi}} + \sum_{j \neq i}(R_{\mathrm{pd}} H_{\text{Li-Fi}}^{j,u} P_{\mathrm{opt}}/\kappa)^2}, \quad (6)$$

where N Li-Fi is the power spectral density (PSD) of noise at the PD, and B Li-Fi is the system bandwidth of a C. Wi-Fi Channel Model The path loss model used for indoor RF propagation consists of the free space loss (slope of 2) up to a breakpoint distance, and a slope of 3.5 after the breakpoint distance [17]. Let L_{FS}( ), X and d_{BP} denote the free space loss, the shadow fading and the breakpoint distance, respectively.

TABLE II
WI-FI CHANNEL PARAMETERS

Parameter	Value
Breakpoint distance, d_{BP}	5 m
Shadow fading standard deviation, σ (before d_{BP})	3 dB
Shadow fading standard deviation, σ (after d_{BP})	5 dB
Central carrier frequency, f_c	2.4 GHz
The angle of arrival/departure of LOS, ϕ	45°
Transmit power, $P_{Wi\text{-}Fi}$	20 dBm
Bandwidth per Wi-Fi channel, $B_{Wi\text{-}Fi}$	20 MHz
PSD of noise, $N_{Wi\text{-}Fi}$	-174 dBm/Hz

TABLE III
MODULATION AND CODING SCHEME [18]

min. SINR [dB]	Modulation	Code rate	Spectrum efficiency [bit/s/Hz]
-	-	-	0
2	BPSK	1/2	0.5
4	BPSK	3/4	0.75
5	QPSK	1/2	1
9	QPSK	3/4	1.5
11	16QAM	1/2	2
15	16QAM	3/4	3
18	64QAM	2/3	4
20	64QAM	5/6	5

Li-Fi vs Wi-Fi - Basic difference between Li-Fi and Wi-Fi

This page on Li-Fi vs Wi-Fi describes basic difference between Li-Fi and Wi-Fi technologies.Following table mentions feature comparison between both.

devices operate in one of the three topologies mentioned below.

The different device has different coverage range, data rate and other requirements.

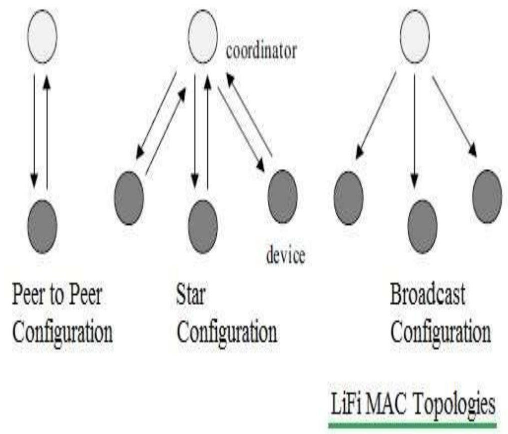

Fig.4.6: Li-Fi network topologies

It works in three modes as mentioned above in figure. In star topology, communication is established between central controller (i.e. coordin ator) and devices. In peer to peer topology, one of the device should become coordinator at the time of establishing association.
Each device or coordinator has unique 64 bit address. Device can use 16 bit address also upon request at the time of establishing association with coordinator.

Li-Fi Protocol Stack

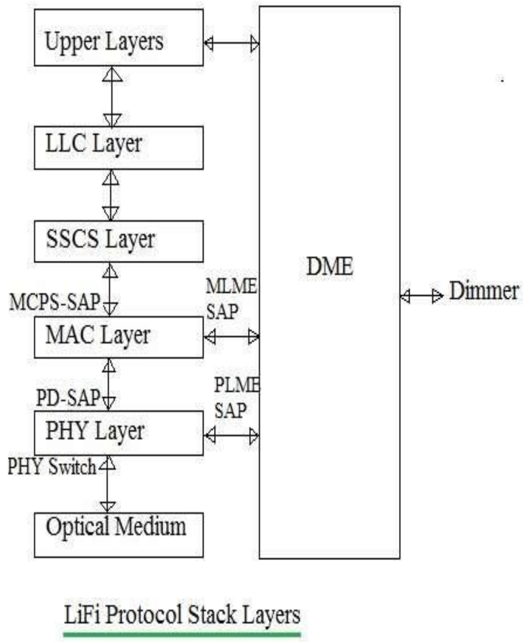

Fig.4.7: Li-Fi Protocol Stack

The figure-2 depicts protocol stack used in a typical VPAN device. As shown protocol stack consists of PHY, MAC and upper layers. Physical layer houses light transceiver. PHY switch housed in PHY layer interfaces with optical SAP which connects it to the optical medium. The optical medium composed of one or multiple optical sources or optical detectors (e.g. laser diodes or photodiodes).

MAC layer provides channel access for all types of data and control message transmissions.

Upper layer consists of network layer and application layer. Network layer takes care of providing network configuration, network manipulation, message routing etc. Application layer takes care of providing intended functionality as needed by the VPAN

Li-Fi device. DME (Device Management Entity) is also supported by Li-Fi or VPAN network architecture. It makes interfacing between dimmer and PHY/MAC a reality.

Li-Fi PHY.
There are three types of physical layer configurations supported in VLC or LiFi System Viz. PHY-I, PHY-II, PHY-III. Different rates can be achieved in different configurations. They can be used indoor or outdoor.

Li-Fi MAC.
MAC layer takes care of resource management i.e. allocation of channels, IDs as well as entire network management.

Li-Fi Modulation Types-OOK, VPPM, CSK
There are different modulation schemes used in different physical layer modes. OOK stands for On Off Keying, VPPM stands for Variable Pulse Position Modulation and CSK stands for Color Shift Keying.

Applications of Li-Fi or VLC system.

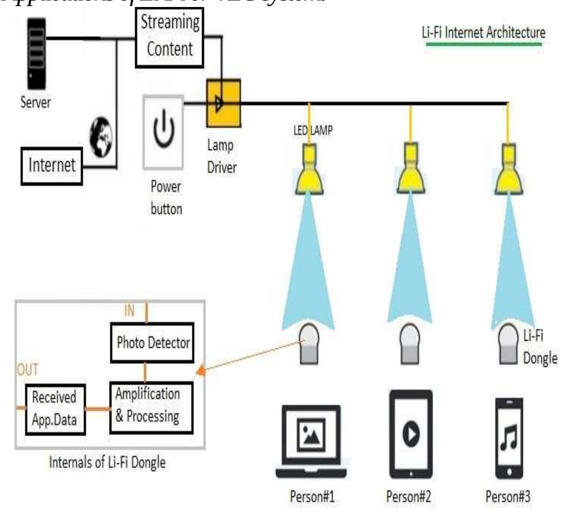

Fig.4.8: VLC System

There are many applications of Li-Fi or VLC system as lighting and data communications. Typical among them are lighting, signboards, street lights, vehicles and traffic signals or lights. The figure mentions emerging application of Li-Fi for internet data communication. It has also become popular due to wide adoption of IOT based technologies.

Benefits of Li-Fi System
Following are the benefits of Li-Fi system:
1.It transfers data very rapidly.
2.It transfers data securely as it can be used in Line of Sight mode of optical signal.
3.It does not pierce through the walls and hence it can not be easily intruded by hackers.
4.It uses much low power for transmission compare to other systems such as Wi-Fi.

CHAPTER V
CONVENTIONAL SELECTIONMETHODS

For simulation benchmarks we introduce three conventional APS methods: the signal strength strategy (SSS), the load balancing (LB), and the optimisation method.

A. Signal Strength Stratergy

The SSS is a straightforward method that always selects the AP offering the highest spectrum efficiency. In a homogeneous network, the receiver experiences the same level of noise power when collecting the signals emitted from different APs. Therefore for the user of interest, the SSS method simply selects the AP that delivers the highest received signal power. In a hybrid network, however, different mechanisms are needed to receive light and radio signals, leading to different noise
power per bandwidth between the Li-Fi and Wi-Fi systems. Also, those two systems could use different bandwidths. Thus we adopt signal-to-noise ratio (SNR) instead of signal strength to perform the SSS method in a hybrid network. With AP i ,sending out the desired signal, the received SNR at user u is

denoted by $\gamma_{i,u}$:

$$\gamma_{i,u} = \begin{cases} \dfrac{(R_{\mathrm{pd}} H_{\text{Li-Fi}}^{i,u} P_{\mathrm{opt}}/\kappa)^2}{N_{\text{Li-Fi}} B_{\text{Li-Fi}}}, & \text{if } i \text{ is a Li-Fi AP} \\ \dfrac{G_{\text{Wi-Fi}}^{i,u} P_{\text{Wi-Fi}}}{N_{\text{Wi-Fi}} B_{\text{Wi-Fi}}}, & \text{if } i \text{ is a Wi-Fi AP} \end{cases}.$$

Load Balancing.
The LB methods, which consider resource availability as well as channel quality, can be classified into two categories: channel borrowing and traffic transfer. Since Li-Fi and Wi-Fi operate at different spectrum, channel borrowing is infeasible
in a hybrid Li-Fi/Wi-Fi network. Here we consider a straightforward traffic- transfer method, while the optimisation-based LB is deemed as an optimisation method.

PROPOSED ACCESS POINT SELECTION METHOD.

In this section, based on the different characteristics between Li-Fi and Wi-Fi in terms of coverage and capacity, we propose a tailor-made APS method for the hybrid network. The main contribution of this section is three-fold: i) analyse the key issues when conducting the conventional APS methods in a hybrid network; ii) formulate the APS process as a two-stage problem, which firstly determines the users that need service from Wi-Fi and then performs APS for the remaining users as if in a homogeneous Li-Fi network; and iii) apply fuzzy logic to the first stage to rank the user's priority of accessing Wi-Fi. Regarding the second stage, a conventional APS method, such as the SSS and LB, is applicable.

Discussion about the APS in a Hybrid Network
With respect to APS, a hybrid network differs from a homogeneous network in two aspects: i) the coverage areas of different systems overlay one another; and ii) the coverage range varies with the AP types. The first point widens the scale of possible options for APS, leading to an exponential increase in the computational complexity required by the optimisation method. Regarding the second point, a Wi-Fi AP has a larger coverage area but less capacity than a Li-Fi AP. In Fig. 3, the Wi-Fi SNR is stronger than the Li-Fi SNR in the green area, which covers 32% of the room, while otherwise in the red area. Considering

Uniformly distributed users, this means the Wi-Fi AP has to serve 32% users if the SSS is adopted. Meanwhile, in average, each Li-Fi AP serves less than 6% users. Therefore in this situation the Wi-Fi system is prone to be overloaded, i.e. it cannot meet the data rate demands of all served users. Also, it is worth noting the users nearby a Wi-Fi AP are attracted to Wi-Fi, even if they are right beneath a Li-Fi AP (e.g. user 1). As a result, the Li-Fi APs close to a Wi-Fi AP are underused. The LB method can relieve the congestion of Wi-Fi by diverting new users to Li-Fi. However, because of not affecting the AP assignment of existing users. The LB method does not necessarily improve the usage of those underused Li- Fi APs.

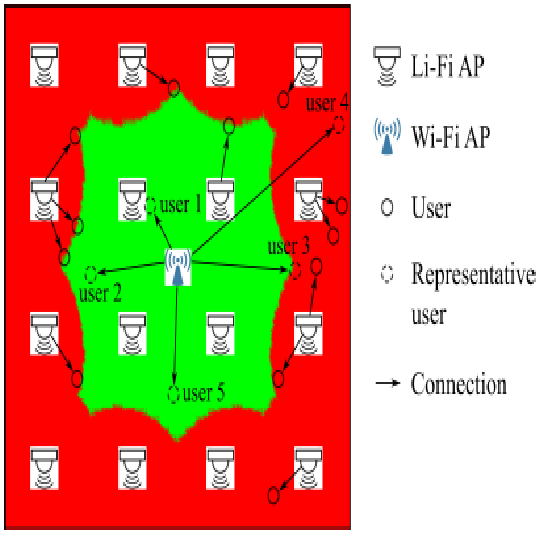

Fig.5.1: Representative users for APS in a hybrid Li-Fi and Wi-Fi network.

Fig.5.1 demonstrates some representative users. Due to the presence of ICI in the Li-Fi network, cell-centre users (e.g. user 1) obtain a much higher SINR and thus a much higher spectrum efficiency than cell-edge users (e.g. user 2). Note that both user 1 and 2 would be connected to Wi-Fi if the SSS is applied. To reach the same data rate, user 2 requires more resource than user 1 if they are both switched to Li-Fi. Hence assigning user 2 to Wi-Fi is better than assigning user 1, though user 1 receives a stronger Wi-Fi signal than user 2 does.
User 3 is in a situation similar to user 2, but locates in the field where the Wi-Fi SNR is lower than the Li-Fi SNR. In other words, user 3 is connected to Li-Fi when using the SSS method. Because of receiving a lower Wi-Fi SNR, user 3 has a lower priority than user 2 to use the Wi-Fi resource. However, not all of the Li-Fi cell-edge users should be switched to Wi-Fi. When a user experiences a very weak Wi- Fi signal (e.g. user 4), it would consume a substantial quantity of Wi-Fi resource. Therefore this user is better to stay in the Li-Fi network in order to avoid draining the Wi-Fi resource. Another case is when the Li-Fi APs adjacent to a user are not in service (e.g. user 5). In this case, the user receives slight interference from distant Li-Fi APs, and thus is better to be served by Li-Fi so as to offload traffic from Wi-Fi.

Proposed APS Method

The APS for a hybrid Li-Fi and Wi-Fi network is formulated as a two-stage problem: i) determine the users that need to be served by Wi-Fi; and ii) conduct APS for the remaining users as if they are in a stand-alone Li-Fi network. We apply fuzzy logic (FL) to fulfill the task of the first stage, while the SSS or LB can be used in the second stage. Correspondingly, the formed methods are referred to as the FL-SSS and FL-LB. In the following context, a FL system is developed to measure how well a user should be assigned to Wi-Fi. Fig. 4 presents the block diagram of the

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FL system, which is comprised of three steps: fuzzification, rule evaluation and defuzzification.

In general, based on some information of a user, the FL system outputs an accessibility score, which indicates the priority of connecting that user to Wi-Fi. Here four parameters are considered as input: the required data rate, the Wi-Fi SNR, the SNR variance of adjacent Li-Fi APs, and the activity of adjacent Li-Fi APs. Taking the network

deployment in Fig. 3 as an example, the Li-Fi APs adjacent to a certain user are the four closest ones.
The SNR variance of adjacent APs reflects how deeply a user might be affected by interference. A zero variance means the user receives equal signal power from the adjacent APs.
Consequently, this user will experience severe interference if those APs are transmitting signals. The activity of an AP is defined as the percentage of time during which the AP is active for data transmission. The average activity of adjacent APs reflects how likely a user is affected by interference. 1) Fuzzification: The first step of FL is fuzzification, which converts a single-valued input into the values of a fuzzy set comprised of a number of membership functions (MFs). The only condition an MF must satisfy is that it must vary between 0 and 1, and there is a very wide selection of MFs.

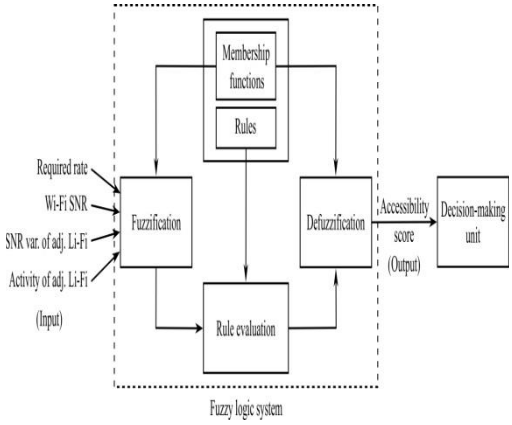

Fig.5.2: Block diagram of the fuzzy logic system.

Defuzzification:
This step obtains a single-valued score for each user. This score signifies the priority of a user accessing Wi-Fi, and thus is termed accessibility score. Similar to the step of fuzzification, MFs are used to describe the relation between the aforementioned states and the score.

Decision-making:
A central unit is employed to store and process the accessibility scores of all users. When a new user requests access to the network, its score is compared with the Scores of the existing users. The users are assigned to Wi-Fi in a descending order of their accessibility scores, until the Wi-Fi resource is depleted. Those users that fail to access Wi-Fi are then connected to Li-Fi. Note that whenever a Li-Fi AP connects or disconnects a user, the activity status of that AP needs to be updated. Consequently, the accessibility score has to be remeasured for the users adjacent to that AP.

TABLE IV
FUZZY RULES OF ASSIGNING USERS TO WI-FI.

Rule No.	Operator	Required rate	Wi-Fi SNR	SNR var. of adj. Li-Fi APs	Activity of adj. Li-Fi APs	Assigned to Wi-Fi
1	AND	-	High	Low	High	Positive
2	AND	Low	*not* Low	Low	High	Positive
3	AND	-	High	Low	Med	Neutral
4	AND	Med	*not* Low	Med	High	Neutral
5	OR	-	-	High	Low	Negative
6	AND	High	Low	-	-	Negative

VISIMULATION RESULTS

In this section, Proteus simulations are conducted to validate the performance of the proposed method in comparison with the conventional methods. Consider an indoor scenario with 4 rooms as shown in Fig. 1, and each room is square with a side length of 10 m. On the ceiling of each room, 16 Li-Fi APs are placed in a layout of a square matrix, with a separation of 2.5 m between the closest two. The users are randomly distributed with a uniform probability distribution. In addition, the number of available Wi-Fi channels is assumed equal to the number of Wi-Fi APs, except when analysing its effects on the network performance.

PROPOSED SYSTEM

To improve the performance of VLC transmission using ANSI E1.45, in this proposed system, we propose the two retransmission schemes.
For error detection and recovery, the proposed schemes use the three fields of existing VLC packet: Sequence number, Fragmentation and CRC

HARDWARE REQUIREMENTS

- PIC16F877A
- GAS SENSOR
- TEMPERATURE SESOR
- ZIGBEE
- LCD
- STEPDOWN TRANSFORMER
- VISIBLELIGHT COMMUNICATION

SOFTWARE REQUIREMENTS:

- MP LAB IDE
- EMBEDDED C

SIMULATION RESULT:

Simulation Circuit diagram:

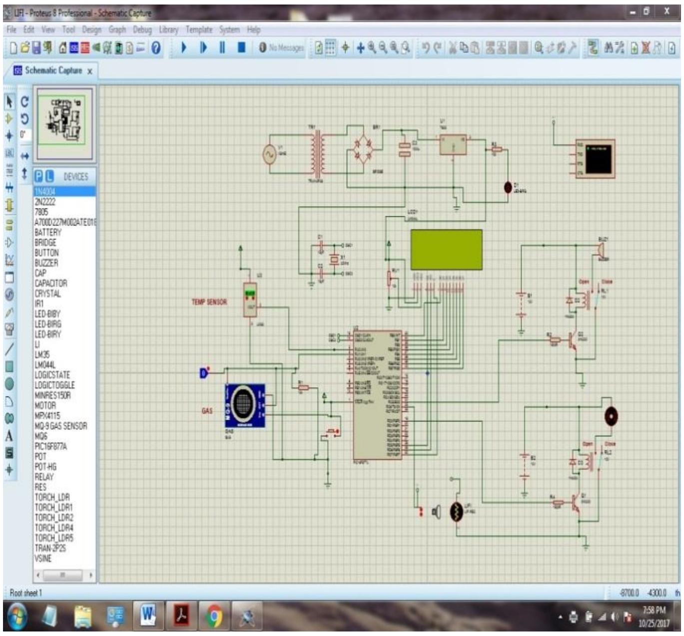

Fig.6.1: Simulation circuit diagram

This simulation done by the proteus software, above the figure is circuit diagram of the overall control unit of the systems.

Simulation Output:

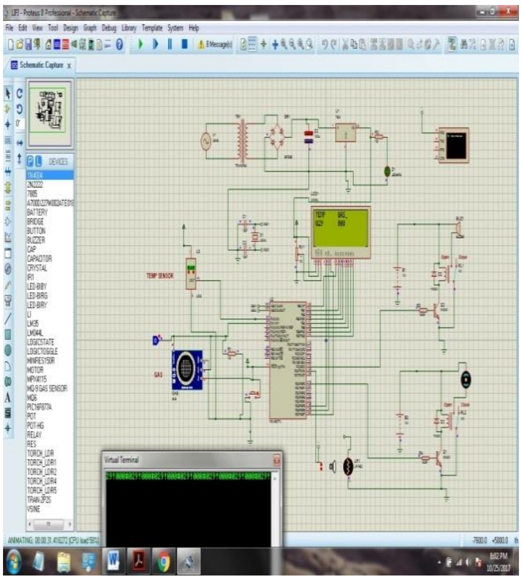

Fig.6.2: Simulation output diagram

Output Display Using LCD:

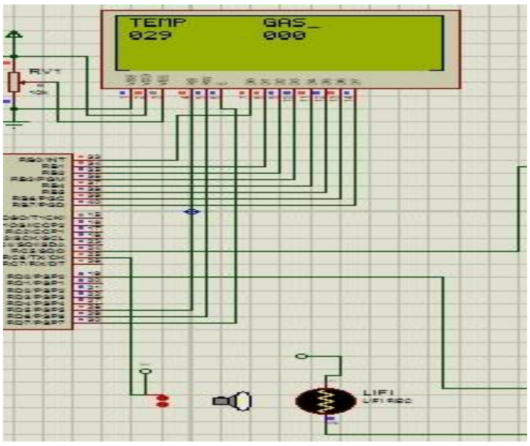

Fig.6.3: LCD Output Display

Above the figures showing all the control unit and simulation result, We are taking the data from sensor unit , that data will send through the Li-Fi unit and we receive the same data in other end using Li-Fi and Wi-Fi devices.

VII CONCLUSION

In this project, a two-stage APS method was proposed for hybrid Li-Fi and Wi-Fi networks, by exploiting the distinguishing characteristics between those two networks. The proposed method at first determines the users that need service from Wi-Fi, and then assigns the remaining users as if in a homogeneous Li-Fi network. The concept of fuzzy logic is applied in the first stage to rank the user's priority of accessing Wi-Fi. In the second stage the SSS or LB can be employed, and the proposed method is named the FLSSS or FL-LB correspondingly. Based on experimental results and complexity analysis, it is shown that compared to the optimisation method, the proposed method achieves a near optimal throughput at significantly reduced complexity. In addition, the FL-LB marginally outperforms the FL-SSS with a slight increase in complexity. Compared with the SSS and LB, results show that FL-LB can improve the network throughput by 24% and 11%, respectively. Future research will involve cellular network in the context of a hybrid network.

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