

# Optimization in Handover Frequency with MOHAN Protocol during Access Point Selection in Hybrid Network

**Prajakta A. Satarkar**

Research Scholar, SRTMU, Nanded, MH, India.

Assistant Professor, SVERI's College of Engineering, Pandharpur, MH, India.

**Dr. Girish V. Chowdhary**

Professor and Director, School of Computational Science, SRTMU, Nanded, MH

## Abstract

**Introduction:** Visible light communication (VLC) which uses the light wave for communication is referred as Light Fidelity (Li-Fi). It works similar to that of Wireless Fidelity (Wi-Fi). Both communication systems have their own advantages and disadvantages but to improve indoor wireless communication, recently the hybrid Li-Fi and Wi-Fi networks (HLWNets) have received significant attention which provides high data rate and omnipresent network coverage. In hybrid network, access point (AP) selection, load balancing issues become critical due to overlapping regions of Wi-Fi and Li-Fi. The conventional methods focus on higher handover frequency at the cost of network throughput.

**Objectives:** To Design efficient handover policies we need to focus on many challenges such as reduction in handover frequency, justifying the light path blockage, reducing delay in communication, issues with interference, and reduction in data loss.

**Methods:** A novel multi objective handover (MOHAN) protocol is proposed which performs specific type of handover based on integrated score of mobility speed and Received Signal Power (RSP).

**Results:** Results show that novel MOHAN when compared with previous methods improves average throughput by 12%.

**Conclusions:** The proposed method achieves 0.72 times reduction in average handover frequency, delay and computational complexity when compared with earlier methods.

**Keywords:** Access point selection, Handover frequency, Hybrid network, Li-Fi, Optical wireless communication.

## 1. Introduction

In 2021, the global economic value of Wi-Fi was around \$3.3 trillion and in 2025, it is expected to reach \$4.9 trillion [1]. Wi-Fi should be recognized as dominant economic engine of digital economy. It is required to assign sufficient spectrum to tackle congestion, promoting start ups that rely on Wi-Fi to create new applications. But this may lead to increase burden on available Wi-Fi spectrum. Hence we should think of alternate solution, Light Fidelity (Li-Fi) which is using light waves from available lighting infrastructure [2]. Li-Fi has multiple advantages over Wi-Fi, such as access to a vast and uncontrolled bandwidth resource, portability, security etc. Using wavelength division multiplexing Li-Fi can achieve 14 Gb/s data speeds [3] but Li-Fi signal can traverse only few meters due to path loss and reflections. Hence multiple light sources are required for indoor applications.

To improve the data rate, we can implement hybrid network consisting of Wi-Fi and Li-Fi to tackle interference and blockages [4] and improve system capacity of indoor communications [5]. Traffic congestion and resource allocation are done through load balancing in HLWNets [6]. AP selection method outlined in [7] gets close to optimal results with significantly lower processing complexity. The authors of [8] proposed an iterative approach to handle load balancing and power allocation concurrently. However, the approaches mentioned earlier fail to consider the expenses associated with user mobility-induced handovers. In ultra-dense networks, the selection of access points is notably influenced by the movements of users, as highlighted in [9]. In a hybrid network, if handovers happen within one wireless access technology domain then it is Horizontal Hand Over(HHO), while VHOs take

place between different domains of wireless access technologies. VHOs typically require more time to process compared to HHOs because of variations in media access control (MAC) protocols, as noted in [10]. Employing load balancing techniques can lead to frequent and unnecessary vertical handovers (VHOs), causing a decrease in throughput. Additionally, Li-Fi access points (APs) typically have a limited coverage area, typically around 2-3 meters in diameter [11]. Consequently, even at low speeds, mobile users connected via Li-Fi may experience frequent horizontal handovers (HHOs). Hence, when devising load balancing strategies for High-Luminosity Wireless Networks (HLWNets), it's crucial to integrate mobility management [12].

During the handover initialization phase, there's a deficiency in mechanisms for determining vertical handover (VHO) and horizontal handover (HHO). This deficiency results in inefficient resource utilization within HLWNets and leads to interference issues. Also there is lack of experimental validation for mobility management in earlier studies. As far as we're aware, this paper introduces the first dedicated design and evaluation study for HLWNets. The MOHAN protocol comprises essential phases including handover initialization, target AP selection (for either vertical or horizontal handover), and handover execution. The handover initialization phase aims to determine the timing and type of handover (VHO or HHO) by integrating user mobility and Received Signal Power (RSP) of Li-Fi AP. Based on the handover type, the target AP selection algorithm is executed, prioritizing Quality of Service (QoS) enhancement.

The rest of the paper is organized as in the following sections: A background study of related work is presented in section 2. The design and methodology of proposed MOHAN protocol is presented in section 3. The theoretical analysis of handover frequency is done in section 4. Section 5 presents system model followed by the simulation results and related discussions in section 6. The conclusion with future work suggestions is described in section 7.

## 2. Background study

In [13], Fuzzy Logic (FL) and Artificial Neural Network (ANN) handover decision algorithms were

introduced for HLWNets. The FL-based algorithm considers parameters such as Signal-to-Interference-plus-Noise Ratio (SINR), average SINR, mobility speed, and received signal strength (RSS). ANN is utilized to streamline FL rules and reduce computational complexity. In [14], a smart handover mechanism for HLWNets is proposed, leveraging Received Signal Received Power (RSRP) and its rate of change. Dynamic network preferences are adopted without additional signaling between Access Points (APs) and User Equipment (UE). [15] addresses light path blockages, data rate requirements, and random orientation of Li-Fi receivers in HLWNets, introducing Evolutionary Game Theory-based Load Balancing (EGTLB) to tackle handovers. [16] introduces Load Balancing Hybrid Wi-Fi/Li-Fi (LBHWF) networks focusing on handover mechanisms, addressing UE mobility and light path blockage issues in HLWNets through joint optimization challenges, employing FL to reduce computational complexity. Finally, [17] presents the Handover Mechanism for Hybrid Wi-Fi-Li-Fi (HMHWF) in NS3 framework, addressing mobility management and handover capabilities in HLWNets.

## 3. Protocol Design

The proposed MOHAN protocol works with 3 steps: initialization phase, access point selection phase, and the actual handover phase. Integrated score of mobility speed and received signal power determines the type of handover HHO or VHO as described in process below: The function  $t1 \leftarrow getMobility(ue^i)$  finds the moving speed of the  $ue^i$ . Given the frequent movement of highly mobile nodes, our objective is to calculate the mobility trust parameter for each User Equipment (UE), which serves as a factor to check requirement of handover. The mobility of  $ue^i$  is calculated as:

$$t1 = 1 - \left( \frac{speed(ue^i)}{\Delta} \right)$$

(1)

Where,  $speed(ue^j)$  function estimates the current moving speed of the  $ue^i$ . The maximum velocity of UE is represented with  $\Delta$ . The  $t1$  and the velocity of the UE are inversely proportional hence triggers the handover. The function  $t2 \leftarrow getRSP(ue^i)$  is responsible for finding RSP value

of concerned Li-Fi AP. The recent research outlined in [40-43] demonstrates methodologies for calculating the Received Signal Power (RSP) value for Li-Fi Access Points (APs). We adopted a similar approach to compute the current association with the Li-Fi AP  $l^i$ .

$$t2 = \frac{l^i \rightarrow RSP}{\nabla} \quad (2)$$

Where,  $l^i \rightarrow RSP$  returns the current RSP value of the  $l^i$  and  $\nabla$  represents the default initially assigned the RSP to each Li-Fi APs in the network. The value of  $t2$  ranges between 0 to 1. When RSP is closer to 0, then there is need for handover. Then joint trust score  $t \leftarrow jointscore(t1, t2)$  is calculated using the Eq. (3) given below:

$$t = a1 \times t1 + a2 \times t2 \quad (3)$$

Where,  $a1$  and  $a2$  are the dynamic weight parameters and are set to 0.5 for weight management approach. Once the type of handover is known then we need to determine the target access point with highest trust score (TS). To select the best Li-Fi AP,  $LS(i) \leftarrow getLAPscore(l^i)$  function is used with two parameters RSP and channel occupancy (CO). The LS for  $i^{th}$  Li-Fi AP is calculated as:

$$LS = a1 \times CO + a2 \times t2 \quad (4)$$

Where, CO represents the current channel occupancy. The CO of  $l^i$  is computed by:

$$d = getChannels(l^i)$$

This function returns the number of channels allocated to  $l^i$ . Accordingly, we formulate this equation as:

$$CO = 1 - \left(\frac{1}{d}\right)$$

Here the value of CO and the channel occupancy are in inverse ratio. The execution of handover focuses on load balancing and QoS improvement.

#### 4. Theoretical analysis of handover frequency

In this section handover frequency in Random Way Point model is mathematically derived in order to verify it with the simulation results. The handover frequency is defined as the average number of handovers executed in the network throughout the entire simulation duration. To estimate the handover frequency over  $q$  periodic intervals, it is calculated as:

$$HF = \frac{\sum_{i=1}^q h^i}{q} \quad (7)$$

Where,  $h^i$  is number of handovers occurred during the  $i^{th}$  simulation interval. In [16] the average cell dwell time (ACDT) i.e. the time for which user is connected to same AP, is calculated. In this paper we are using novel approach to derive handover frequency (HF) in mathematical way. It is counted as number of times user is assigned to a new AP. We also include mathematical derivation for HF in light path blockage. As in [16] we consider user enters in coverage area and moves along straight line and leaves coverage area without turning. As per equation (26) in [16]

$$T_{ACDT} = \frac{2D}{\pi v} \quad (8)$$

Where D is diameter of AP's coverage area and  $v$  is the velocity at which the user is moving. The  $T_{ACDT}$  is inversely proportional to HF so we can write,

$$HF = \frac{\pi v}{2D}$$

Two cases are considered in this section a) User mobility scenario b) Light path blockage scenario. For first scenario, varying mobility speed from 1m/s to 5m/s is considered during mathematical analysis and simulation and for second case we consider a constant speed of 3m/s. Then calculation for HF in hybrid model is done and we get following outcomes:

The indoor scenario is of 1000\*1000 sq. ft. with 16 Li-Fi and 4 Wi-Fi APs as shown in fig.1. The distance between 2 adjacent Li-Fi AP is 250 ft and for Wi-Fi it is 500 ft. The Euclidian distance ( $\tau$ ) from start point to end point for coverage area can be calculated as [16],

$$\tau = \frac{2}{\pi} \int_0^{\pi/2} D \sin \theta d\theta \quad (10)$$

Assuming  $\theta_{1/2} = 60^\circ$  each Li-Fi AP is covering an area with 430 ft diameter (D) which is around 47% of overlap with nearest Li-Fi AP. Mathematical calculations for average HF for 50 users for a period of 200 s over speed variation from 1 m/s to 5 m/s in mobility scenario and 3 m/s for light path blockage scenario is compared with simulation results as shown in the table 1:

Table.1. Comparison of mathematical and simulation values of HF in 2 scenarios

Average HF value	For Mobility scenario	Light path blockage
Mathematically	2.25	1.75
Through Simulation	2.38	1.86

### 5. System Model

We consider an indoor hybrid network with 4 Wi-Fi APs and 16 Li-Fi APs as shown in the Fig. 1. The indoor area is 1000 \* 1000 sq. feet with approx. height of 13 feet. 50 mobile users with random waypoint mobility model with 200 s simulation time.

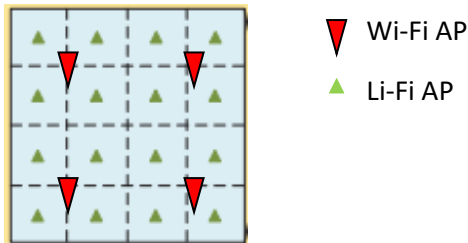


Fig.1. Deployment of hybrid access points in network

### 6. Simulation results

In this section NS2 simulations are implemented to examine the performance of proposed method. Here we have used three base line earlier methods EGTLB [15], LBHWF [16], HMHWF [17] with proposed MOHAN protocol. We have examined performance with throughput, packet delivery ratio and handover frequency and the results are as shown below:

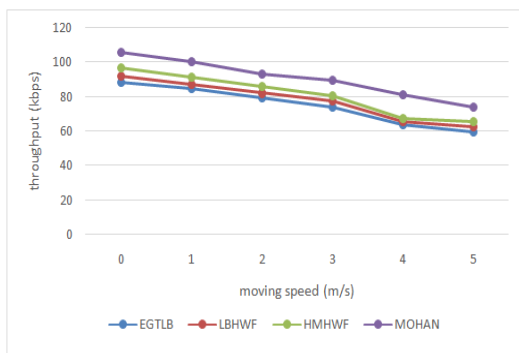


Fig. 2. Throughput over changing mobility speed

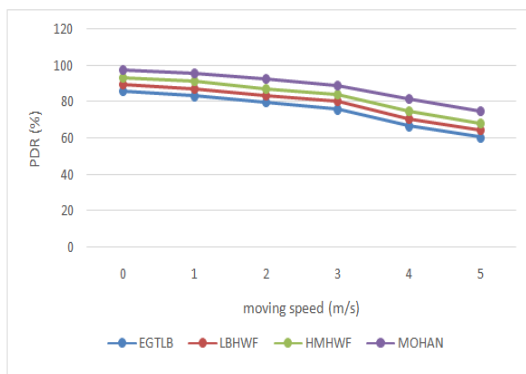


Fig. 3. PDR over changing mobility speed

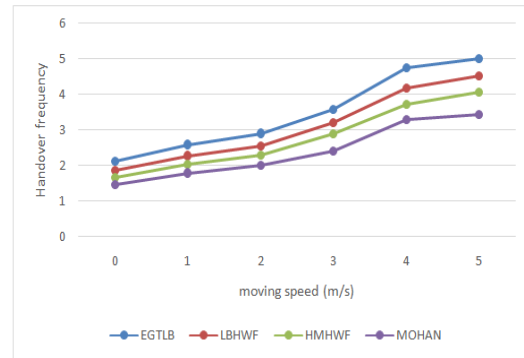


Fig.4. Average HF over changing mobility speed  
Computational complexity

Computational complexity is based on the number of handovers required to achieve a certain packet delivery ratio (PDR). The results shows less number of handovers are required with MOHAN protocol hence computational complexity is much lower.

### 7. Conclusion

This paper introduces a new protocol called MOHAN for managing handovers in HLWNets, which are hybrid wireless networks. The MOHAN protocol addresses challenges like managing user equipment movement, dealing with signal blockage, handling signal interference, and balancing network loads. It does this by effectively organizing the handover process in HLWNet. We have tested the MOHAN protocol by simulating it alongside three other methods by varying the frequencies of mobility and light path blockage parameters during these simulations. The results showed that the MOHAN protocol enhanced throughput by 12% compared to the other methods. Also handover frequency is reduced by 13%. The security aspects of hybrid network can be future problem for study and another future direction can be prevention of data loss occurred due to the fluctuation in LED.

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