Handover and Flight Analysis in Hybrid Lifi - Wifi UAV network

Abhimanyu Jha
abhimanyu17126@iiitd.ac.in

Chavisha Arora
chavisha18136@iiitd.ac.in

***Abstract*—In this paper, we investigate a handover in hybrid (Lifi) light fidelity and Wifi (Wireless Fidelity) networks in a Wifi UAV Network. The increasing number of wireless connected devices has greatly increased the demand for a fast and efficient network connectivity. To cater to this increasing demand for connectivity in the age of high speed data requirement, aerial networks (Drones) come to play a very important role. In this paper, we propose an efficient method for the purpose of a proper network connectivity in the presence of movable drones minimising the handover rates between the Access points. We present a comprehensive characterization study of an experimental system to deploy the aerial WiFi network with smart handovers.**

***Index Terms*—Li-Fi, Wi-Fi, Drones, Handover Skipping, UAV, Network Access**

I. Introduction

A good network connectivity has become one of the most important assets of the digital era. There's an increasing number of devices which require a good connection almost 24 hours of the day. From head to toe we're covered with devices (eg. phones, Laptops, Smart Watches , Fitness trackers, other wearables) which require a good connection for constant monitoring , real time data updating etc. With the advent of IOT (Internet of things) which is an ecosystem of internet-enabled devices using embedded systems like processors, sensors to store and process data the devices gather from their environments, the demand for a good connectivity at school , offices, colleges and even recreational places like parks and sports grounds is at an all time high. A very surprising example of this demand comes from the article which highlighted the first question asked by one of the refugees in the camp which was , "Is there Wifi?". In this day and age this question is no longer seen as frivolous demand but is instead seen as a necessity. Therefore this corroborates the claim that the demand has doubled and continues to increase every day with the invention of new technologies for common use.

Wi-fi which stands for Wireless Fidelity and Li-fi which stands for Light fidelity are both used to communicate wirelessly. For Wi-fi routers and radio frequency (RF) waves are used to transmit data however for Li-fi , light signals are used for the same. A Li-fi is capable of transmitting data above 10GBps covering a distance of around 10 metres in radius but since it uses light signals, it's prone to blockages and obstructions due to opaque objects. A Wi-fi on the other hand, can transmit data at a faster rate and covers a distance of about 32 meter in radius. Therefore, a hybrid network of Lifi's and Wifi's which is termed as an HLWNet comes forward as a promising solution for indoor communications. In a dense network, users are bound to have frequent handovers and hence to prevent that we use a Handover skipping technique to avoid excessive handovers using the SINR value of the Access Points at several time instances. The traditionally used strategy called as Signal Strength Strategy (SSS) switches the user to the AP with the highest RSRP (Reference Signal Received Power) value however this gives rise to the ping pong effect where the handover is constantly being done. To eliminate this, we've used Hysteresis with a certain time to trigger (TTT). This proposed solution postpones the handovers to a certain extent maintaining the efficiency and need of the user.

A. Problem Formulation

In this paper, we are focusing on dealing with outdoor communications with the users moving in random directions therefore we combine the concept of HLWNets and the UAV network for the purpose of a seamless data experience.

UAV's (Unmanned Aerial Vehicles) also called as drones have been an increasing sight nowadays because of their versatile performance and efficiency. Drones are increasingly being used in several applications like photography , military strike , environmental monitoring owing to their miniature size , efficiency , speed and low energy requirements. Drones eliminate the need for human involvement to carry out dangerous tasks such as going to dangerous heights and are very easy to maintain and work with.

Another very important use of drones that is being extensively research on lately is the use of Drones in the Telecommunications field. In an indoor environment one can very well work with static Access Points for a full seamless coverage however it becomes increasing difficult to maintain the same in an outdoor environment. For a moving user and a static AP there's bound to be a point of network disruption or a case of excessive handovers which is under the condition that there are multiple Lifi's or Wifi's in the area which isn't really a reasonable assumption. These drones are capable to deploy a wireless communication network acting as network nodes for the system.Therefore we propose the the Handover analysis in a Hybrid Lifi-Wifi UAV network.

We feel that in an outdoor setting, APs with the ability to move their position offer a lot of new possibilities.With these new possibilities, it is important to that we are able to utilise the most out of an aerial network with utilizing the least amount of energy and do so in an optimised manner. Moving APs can cause multiple handovers for a user if the UAVs are not controlled and monitored properly. Using the Objective

Function defined by (Xiping Wu et al, 2019) in their paper Smart Handover for Hybrid LiFi and WiFi Networks, we hypothesize that the same function can be used to minimize handover rates for multiple users in such a network setting too.

II. Proposed Approach

A. System Setup

A huge number of devices have led to multiple APs placed across buildings and campuses to provide users with uninterrupted connectivity. Although, In outdoor scenarios , devices often still lack proper connectivity due to lack of infrastructure in open places where setting up static APs is not possible. Hence we're using movable drones for the purpose of connectivity. For the proposed scheme, our initial setup consists of a square area with a few Wifi and Lifi on Drones and a couples of users. The system starts from a symmetrical setup where all the APs are placed uniformly over the simulation space. This is done to ensure the optimal starting position, APs can anyhow be moved to a new better position as soon as there are users which have SINR values less than some threshold value.

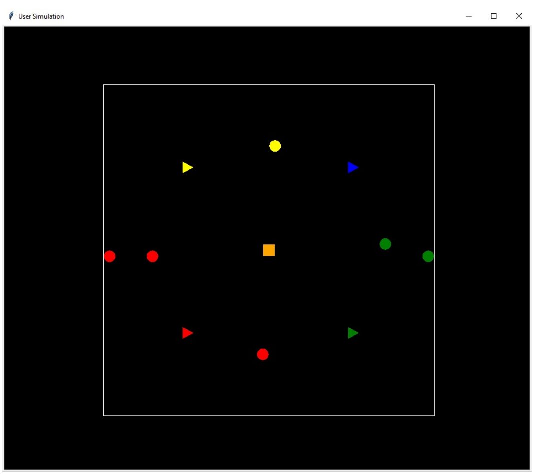

Fig. 1. Initial Setup of the Simulation

Here the Triangles represent the Li-fi APs , Squares represent the Wi-fi APs and Circles represent the Users. The color scheme depicts the user and the APs they are connected to at the present moment.

B. Objective

Given the initial position of the users and the Drones our task is to continuously re-evaluate whether to initiate handover when some other AP provides a better SINR value than the current AP or move the Drone closer to the user to avoid handovers. We need to examine a few cases before talking about the proposed methodology for each of them.

Case 1 : When the number of UAVs is greater than the Number of static/moving Users

In this case, the drones simple hover over a every user leading to a full connectivity at all times and causing no handovers. For the purpose of this paper, we neglect this case.

Case 2 : When the number of UAVs is lesser than the Number of static Users

For this scenario, there will be an optimum position for which every user receives a good signal threshold and the drones will arrange themselves in that optimal position and stay like that unless any user moves.

Case 3 : When the number of UAVs is lesser than the Number of Moving Users

This is the real world scenario we aim to propose a novel method for. Before the simulation is started, the drones arrange themselves in an optimal position as described in the second case. Once the timer starts and the users start moving, we run our algorithm to decide between optimal drone positions for that time instant and make handover decisions.

```python
def getOptimalPoint(center, radius, existing_users, currPos, d_max=600,
wifi=True, radius_step_size=5, angle_step_size=10, min_SINR=0.2):
    # existing_users is a list of users connected to that AP which we are
    considering to move
    coords = []        You, 5 hours ago • optimal position algo
    for r in np.arange(0, radius + radius_step_size/2, radius_step_size):
        for theta in np.arange(0, 360 + angle_step_size/2,
        angle_step_size):
            x = center[0] + r * np.cos(np.radians(theta))
            y = center[1] + r * np.sin(np.radians(theta))
            if euclidieanDistance([x, y], currPos) <= d_max:
                coords.append((x, y))

    optimalPoint = None
    optimalSumSINR = None
    for (x, y) in coords:
        sumSINR = 0
        flag = True
        for user in existing_users:
            new_SINR = hypothetical_SINR(
                [x, y], user.hostAP.index, user.turtle.pos())
            if new_SINR < min_SINR:
                flag = False
                break
            else:
                sumSINR += new_SINR

        if flag:
            if (optimalSumSINR is None) or (sumSINR > optimalSumSINR):
                optimalPoint = [x, y]
                optimalSumSINR = sumSINR

    return optimalPoint
```

Fig. 2. Algorithm to find Optimal Position for Access Points to avoid Handovers

1) Proposed Standard Handover Scheme for Moving Access Points: The novel algorithm provides an new optimal position for the host AP(say AP-x) for user that provides at least the same or better SINR values as a new target AP that is a handover candidate. This position is found within a circle with the user as center and the distance between the target AP and the user as its radius. To find the optimal position, we then check which position would allow us sufficient SINR for other users connected to this particular host AP-x. (The minimum SINR value can be found in the outdoor setting experimentally and fed into the UAV Network system.) We can also limit the movement of the drones by not letting them fly beyond a certain threshold to preserve drone battery.

We do this by checking that the optimal position on the perimeter of this circle, where the position provides an SINR above a threshold value for all users. If there are no such points available, we allow the user to handover using the handover algorithm (Xiping Wu et. al, 2019). If there are multiple such points available, we decrease the radius progressively until we find the perfect position where we can move the host AP without compromising the SINR of other connected users.

C. Assumption

For the purpose of simulation we've considered the following assumptions.
1. Moving all drones requires the same amount(some cost C) of energy(Drone Battery).
2. Drones are set up at the optimal position at the beginning of the simulation.
3. No two users will reach the point of controversy at the same point in time or within the Time-to-trigger of one user.
4. Moving drones cost more energy than static drones

III. Results

The full code has been uploaded at the GitHub repository.

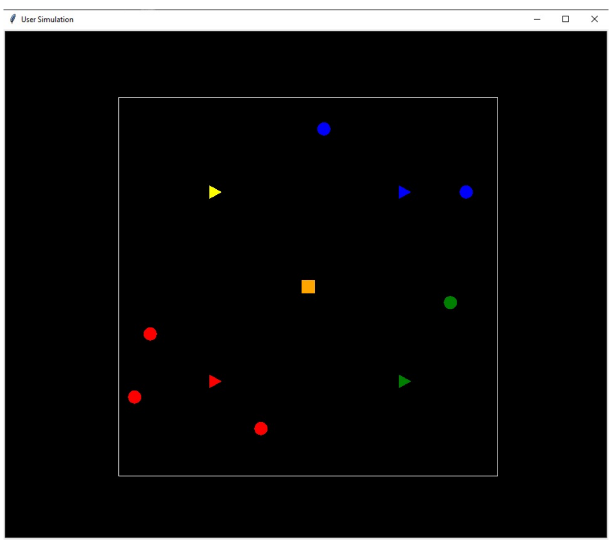

Fig. 3. A snapshot of simulation with static APs and handovers

Through the simulations, we can see that when APs are static, there are definite handovers which are needed to keep the SINR for users above a certain threshold. We are able to realise that when APs are made mobile, they are able to reduce the handovers by moving the host AP in an optimal position which offer same or even better SINR than the target AP.

For the particular random simulation in the code, we are able to see up to 4 handovers in the stipulated random simulation time for the static APs scenario. Making the APs mobile allows us to reduce the handovers, which is 0-2 in the stipulated random simulation for our code.

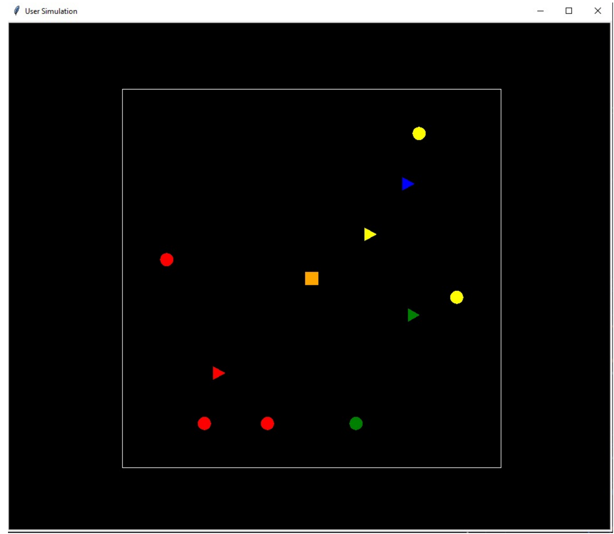

Fig. 4. A snapshot of simulation with mobile APs and lesser handovers for same simulation duration

IV. Novel Contributions

The novel contribution of our research and proposed method is three folds :
1. Proposing the Handover skipping method for Lifi and Wifi in an ultra dense network with more than one user.
2. Extending the indoor HLWNets to an outdoor environment with the introduction of UAVs to facilitate the concept of movable APs as opposed to the traditionally used static AP methods.
3. Finding optimal positions for mobile access points to avoid Handovers.

V. Related Work

A. Handover Rate

HLWNets are defined as the hybrid of Lifi and Wifi networks. Working with such a network, we're introduced to the process of Handovers. A handover is essentially a client disconnecting with one device and connecting to another. The handover rate in an HLWNet is found out by multiplying the handover rate of Signal Strength Strategy (SSS) with the probability of an AP not being skipped. The simulation setup for such a network is assumed to be a square area with the user entering from one side at a random angle. The angle "theta" and the distance between the point where the user enters to the the target point (at the end of the simulation) is called "d". Another variable called "pathdistance" tracks the length of the region the user moves within the simulations time in the square setup. Therefore the handover rate for SSS is found by dividing "pathdistance" with the speed of the user. After this we consider the scenario where the AP is not skipped by the user, whose probability is defined as P(X). The handover rate for this system is therefore defined as the result of speed over "pathdistance" multiplied to P(X).

B. Wifi Networks on Drones

Drones have become the weapons for the present times used for their high efficiency and precision. Extending the applications of drones in the telecom sector as well,several researches have been devoted to achieve the same minimising the losses. They run on ISM, IEEE-L and IEEE-S bands. To solve the spectrum scarcity issue, the author in (Y. Saleem et al.2015) proposed using Cognitive Radio Technology in UAVs.Routing in UAVs faces its own challenges owing to their high mobility and the fact that most studies have been carried out in 2-D simulations instead of 3-D real life scenarios (Antonio et al. 2016). UAVs have advanced and gotten rid of the issues regarding Delay Tolerant Networks.

C. Standard Handover Scheme and Hysteresis

An HLWNet is susceptible to multiple handovers leading to a ping pong effect, therefore an efficient handover scheme as proposed uses two parameters, Time to Trigger (TTT) and Handover Margin (HOM). In the outdoor scenario with the including of moving Aps on Drones we also consider the range in terms of circular radius for an Ap. This method is called as standard handover scheme which uses the concept of hysteresis. The handover is decided on the basis of the SINR (Signal to Inference Noise Ratio) values instead of conventionally used RSRP values because in an HLWNet the noise levels vary greatly between LiFi and Wifi. This scheme starts the time when the SINR for target AP is greater than the sum of SINR values for Host AP and a handover margin value. Whenever the condition is met, a handover is proposed. Now to avoid unnecessary and excessive handovers, the concept of Hysteresis is applied. For this a certain time to trigger is used which means that the algorithm will wait for the time to trigger to pass and then again check if the condition is met before doing a handover. This efficiently manages excessive handovers.

References

[1] Y. Saleem et al., "Intregation of Cognitive Radio Technology with unmanned aerial vehicles: issues, opportunities, and future research challenges," J. Netw. Comput. Appl., vol. 50, pp. 15–31, 2015.

[2] Wang, Yunlu, et al. "Dynamic Load Balancing with Handover in Hybrid Li-Fi and Wi-Fi Networks." 2014 IEEE 25th Annual International Symposium on Personal, Indoor, and Mobile Radio Communication (PIMRC), 2014, https://doi.org/10.1109/pimrc.2014.7136231.

[3] Sanusi, Jaafaru, et al. "Handover in Hybrid Lifi and WIFI Networks." 2019 15th International Conference on Electronics, Computer and Computation (ICECCO), 2019, https://doi.org/10.1109/icecco48375.2019.9043251.

[4] "WIFI Networks on Drones." IEEE Xplore, https://ieeexplore.ieee.org/document/7805730.

[5] "An Enhanced Handover Scheme for Cellular-Connected Uavs." IEEE Xplore, https://ieeexplore.ieee.org/abstract/document/9238986.