On Demand Deployment of UAV Assisted Wireless Communication

A.M.M.H.Ranasinghe
School of Engineering, Sri Lanka Technological Campus
madhushikar@sltc.lk

Abstract

On demand deployment of Unmanned Aerial Vehicle (UAV) assisted wireless communication is an essential topic in wireless communication. The UAVs are developed for many reasons, such as military users, agriculture, delivery, telecommunication systems. From that, the telecommunication systems are got a significant advantage from UAVs, as base stations. On demand deployment, fast response, Low cost for develop, More flexible in reconfiguration and movement, Short-distance line of sight (LoS) communication are the basic advantages of UAV base stations. So, the UAV base stations are going to be an essential component in telecommunication field. Because they can be used for control the traffic overload, monitor the places which are unreachable for people and so on. While developing UAV base stations, there are many challenges to overcome. The positioning method, Interference management, Channel modelling are basically considered through this paper.

Key words

Unmanned aerial vehicles, Interference, channel modeling, positioning

I. Introduction

As shown in the name Unmanned aerial vehicles (UAV) are controlled without the human operation. Most common example is drone.The UAVs are commonly used in many applications such as telecommunication industry, military systems, transportation etc. So, UAVs have built with many different types. According to the altitude it has divided to two types. They are high altitude and low altitude. Up to 15m, high altitude UAVs are used. As well as rotary wings and fixed wings are another classification by considering the type. The rotary wing UAVs have advantages over fixed wing UAV because they can move anywhere easily and can hover. So, in wireless communication, these UAVs are used as base stations. When consider an UAV as a base station, the Fast response, high mobility, easily manage are going to be the advantages. According to these advantages of UAVs which are used for wireless communication, are very useful and essential technology as base stations. But existing UAVs have some problems while getting better output. They are having low reliability, low security, more interference in the channel, limited data rate, line of sight requirement, difficult to monitor and low power efficient. So, to reduce these problems, the new research paths are opened. Through this paper, the main target is to discuss about the challenges of UAV assisted wireless base station.

When consider the challenges of UAV base station, path planning is a major challenge. The UAVs do not have fixed positions. They are moving dynamically. As well as the interference is another issue in UAV base station. Normally, interference is occurred in any wireless communication medium. But, the reliability is decreased of the UAV because of this issue. There are two types of interference which can be occurred in UAV named as Co-channel Interference and Adjacent channel Interference. The channel modelling is an another issue. And also, the low power efficient can be seen from UAV base stations. The UAVs can store low energy. So, the power should be restored frequently. it is hard to do. As this the UAV base station has different paths to develop to be a proper base station.

II. Motivation

While considering the importance of UAV base station and the requirements for UAV base station, the challenges of building UAV base station is popped up. So, this paper is basically written to identify the challenges of placing UAV base station and required solutions for these challenges.

III. Literature Review

In this paper the challenges, applications and the solutions of the UAV are discussed. [1] To enhance the coverage, capacity, reliability, and energy efficiency of wireless networks, the UAVs are used. And also they can operate as flying mobile terminals within a cellular network. According to this paper, when building an UAV base station there are many challenges such as three-dimensional deployment, performance analysis, channel modeling, and energy efficiency are explored along with representative results. Then, open problems and potential research directions pertaining to UAV communications are introduced. Finally, various analytical frameworks and mathematical tools such as optimization theory, machine learning, stochastic geometry, transport theory, and game theory are described. The use of such tools for addressing unique UAV problems is also presented. When consider the UAV positioning, channel modelling and interference management with regarding the UAV base station, those three topics have discussed before with good technologies and algorithms.

A. Positioning

For the better positioning and traffic management of UAV, the following parameters are considered. [2] The operating altitudes, coverage radius, and flying speeds are calculated. And the deployment delay is calculated with the maximum and minimum locations. If n number of diverse UAVs are dispatched from the same initial location to the target area, an optimal deployment algorithm is presented with low computational complexity by balancing UAVs' the coverage speed and radius. And there, have analyzed that optimal deployment delay reduces with the number of UAV and the average of UAVs' flying speeds and coverage radius. The system model designed according to this.

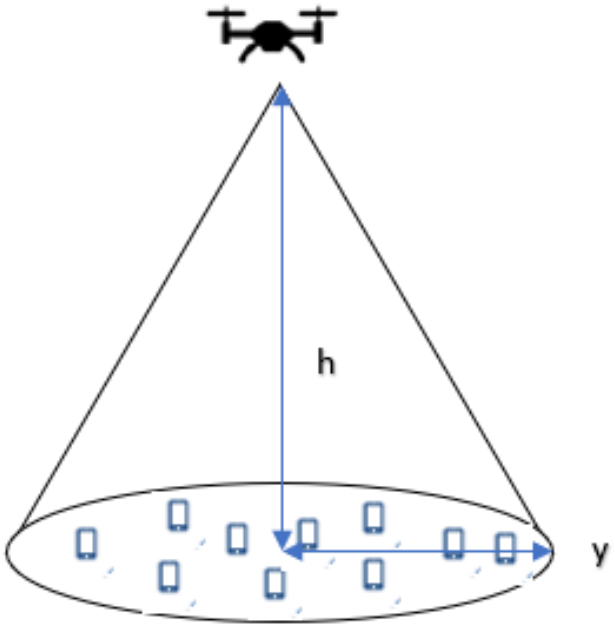

Figure 1: System Model

Then machine learning is used to allocate the UAV with better performance. And also, the main intention of this project is to design a novel approach for predictive deployment of UAV aerial BSs to complement

the ground cellular system in face of the prospective steep surge in cellular traffic. The predicted cellular traffic demand which has given is formulated by the deployment of UAV BSs. To solve this problem a Machine Learning framework is used. According to the simulation results, the proposed predictive deployment method of UAV can improve the utility of base station by $60percent$

Other than that The major challenge of UAV assisted wireless communication is to determine an efficient way to position them in a relatively large 3D search space. [3] For that, consider a discrete set of possible UAV locations distributed in a given 3D space and the problem is formulated as a mixed integer linear program (MILP). Using the complexity of the MILP problem, an effective greedy approach is presented. That mimics the behavior of the MILP for small network scenarios and it can increase the scale efficiently for large network scenarios. After that, a practical approach for multiple UAV deployment in a continuous 3D space is evaluated using an unsupervised learning technique. Using these techniques, the problem of UAV deployment is formulated. The problem is discussed along two methods. 1) the required number of ABSs will be minimized to reduce cost for the network operator 2) The ABSs is deployed with the best positions that can maximize the received power for the served users. For that the downloading bit rate and other performance should be enhanced. According to that Greedy approach for Selection phase is developed. Then another algorithm is developed for Placement of multiple UAVs based on electrostatic forces.. After the simulation of this problem the behavior of the proposed Force3D algorithm as compared to the greedy approach can be analyzed. The achieved average user rate normally starts to increase steadily when the locations of the Aerial Base Stations are adapted from iteration to another. when minimal change is observed over multiple consecutive iterations, equilibrium is achieved. According to the simulation, an unsupervised learning algorithm has the better performance, low complexity, more practical and not restricted to a fixed set of locations. The proposed algorithm is based on the notion of electrostatic forces to position ABSs in a 3D continuous search space. Finally the effectiveness of the proposed algorithm compared to the greedy approach is discovered.

B. Channel Modelling

In wireless communication networks, [4] the propagation channel is the medium between the transmitter and the receiver. It helps to imply performance of wireless networks.The generation of UAV wireless base station, the study of channel modelling is very important technology. Using radio channel characterization and modeling with their architecture, it is difficult to evaluate the achievable network performance. The wireless communication with UAVs do not use these models. When consider the A2G channels, they imply a higher probability of LOS propagation. This can be resulted to a a higher link reliability and low power transmission . Even for NLOS links, power variations are lower than in the terrestrial communication networks due to the fact that only the ground-based side of the link is surrounded by the objects that affect the propagation. The UAV mobility causes high rates of change.So, when Modeling a channel for UAV this is an challenging problem. As well as environment complexity is another problem.In this paper the self interference of the channel, s=antenna characteristics. air-frame shadowing is discussed.

When consider the architecture of wireless communications with UAVs, there are two basic types of communication links. [5]

- The data link
- The Control and Non-Payload Communications Link (CNPC) link

The data link is the link which helps to communicate with the terrestrial base stations (BSs), mobile terminals, gateway nodes, wireless sensors, and so on.It supports to the models such as Direct mobile-UAV communication as for BS offloading or during complete BS malfunction, UAV-BS and UAV-gateway wireless back haul, UAV-UAV wireless back haul.

Control and Non-Payload Communications Links help to ensure the safe operation of all UAV systems. They are Highly reliable,usually with low data rate

requirements low-latency, and secure two-way communications The main CNPC information flow can be broadly categorized into three types:

- Command and control from GCS to UAVs
- Aircraft status report from UAVs to ground
- Sense and-avoid information among UAVs

Then the UAV channel characteristics can be shown by 2 types.

- UAV-ground channels
- UAV-UAV channels

UAV-ground channels are more complicated in the operation environment. While LoS links are essential for more scenarios. But in most scenarios, there are many obstacles such as terrain, buildings, or the air frame itself and so on. So, in addition to the path loss, the shadowing and multi-path effect can be occurred. For 5this the main target is the modelling the Air to Ground Channel. So, The AG channel for UAVs has not studied much. So there are many research path according to this. The available AG propagation channel models are used for higher altitude aeronautical communications. And often they do not use in low altitude UAV communication. in this paper [6] the A-G channel modelling for low altitude communication is discussed and the characteristics and enhancements are also discussed.When selecting the channel modelling there are many factors to be cosidered. They are the used frequency, the environment type, path loss, Doppler spread, fading type etc. So, there are different types of channel models such as path loss model, Rician fading model, Rayleigh fading model, Nakagami etc. So, the channel model can be chosen for the propagation, after designing the proper system model.

In this paper [7] In this paper the channel modelling is done for develop accurate and validate A-G channel model for transmission in UAV systems..And also, the channel modelling, transmission design and the system performance are also discussed. According to this paper, the dispersion should be the important parameter while selecting channel model. But this is not a full requirement for this. then the system model should be designed with considering the parameters such as frequency, environment, capacity, data rates and so on.

C. Interference Management

When consider the UAV base station it is basically affected by the interference. [8] the interference is known as, when transmitting signal from transmitter to receiver,the process of disruptive modification of a communication signal. Interference is occurred resulting various reasons such as the noise of the signal, multiple channel usage with same frequency and so on. There are some different types of interference.

- Co-Channel Interference
- Adjacent Channel Interference

The Co-Channel Interference is occurred while transmission the signal in the same frequency. In the small geographical areas, The frequency is reuse for efficient use of spectrum. When the reuse increases the interference also increases. Then the usable capacity and the service quality for the customers decrease. As well as the core- channel interference is occurred because of the poor frequency panning, Overly crowded radio spectrum or adverse weather conditions. From this, although the poor weather condition cannot control, Other two can reduce with proper interference management.

When the data signals are transmit on close frequencies, Adjacent channel Interference happens. This occurs when the imperfect receiver filters allow to nearby spectrum leak into the pass band. This is occurred frequently in between multiple UAVs and overloaded base stations. When using the wide range of spectrum, this adjacent channel interference can be reduced. But it is not cost effective and inefficient.

IV. Technical Background

Table 1: The suitable channel models acccording to the different environments

Statistic	Environment	Channel model
Large Scale Fading	open field and suburban scenario	zero–mean Gaussian distribution and analyzed with PDF
Large Scale Fading	single–hop UAV system	log–distance model
Large Scale Fading	open field and campus environment	Free space Path loss model
Large Scale Fading	low coverage zones in the cellular–connected UAV network	combinational model
Small Sacle Fading	land mobile satellite system	Rician Fading Log–normal compositional models
	time varying effects in the AG propagation channel	Rician Fading
Fading	A-G Propergation	Rayleigh Fading Model and Nakagami model

According to the literature, the methods and the challenges are identified due to the UAV base station. From that the UAV base station should have better positioning by selecting proper channel model and mitigating the interference that can be occurred in the channel. According to my studies the channel models that can be used in UAV base stations can be explained like Table 1. As well as for interference management is another important challenge which should mitigate. For that there are different types of methods use. When use the directional antenna, the co-channel interference can be reduced.

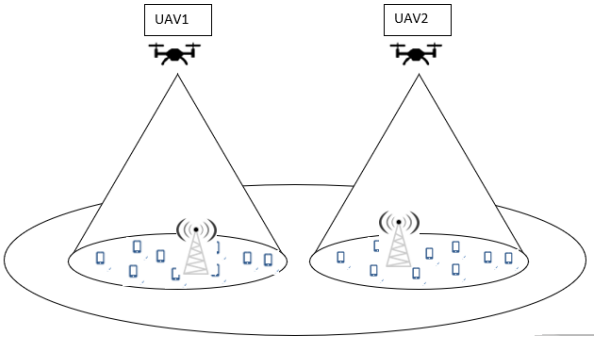

Figure 2: Directional antenna for UAV

A.

The Figure 2 shows the basic behaviour while using the directional antenna. When the UAV antenna is placed for a particular area, the UAV serves only for this area. Then the frequency channels do not intersect with each others. So, the interference does not occur. But in practically, this is not much easy. But good method to reduce the interference. But normally, UAVs are not static elements. They are moving dynamically. Then the UAV can not serve well for the subscribers.

Then the research direction directs to another path. It is tried to reduce the interference by increasing the Signal to Noise plus Interference Ratio (SINR).It seems a good method to reduce the interference.

V. Future Direction of the Area

The Unmanned Aerial Vehicle has given a many research ares as UAV base stations.The new UAV-ground channel models can be found while analyzing the UAV communication. The aerial base stations can store less power in their own. So, the power and energy storage methods should be discovered. The UAV positioning can be planned for different environments separately like Urban area, sub Urban area stadiums and similar large public area and so on.When consider the A-A and A-G channels, A-A is single hop and A-G is multi hop. About these two should be studied further. For that Ray-Tracing and CAD tools can

be used.The main challenge in Air-to-ground (A2G) channel modeling is the complexity of 3D environments. Because large scale fading, small scale fading, transmitter and receiver heights, elevation angles, interference and many things should be considered. For that millimeter wave and Massive MIMO (Multiple input multiple output) may be used in future. These technologies should study to improve channel model performance.Another issue is the stationary distance and its altitude performance analysing. Mobility management and Trajectory optimization are another research ares of UAV based communication.

VI. Conclusion

In this paper, the basic Challenges and the requirements for UAV base station are discussed. When consider UAV base station development, it has faced many challenges and problems. The UAV is moving dynamically while placing on the air. As well as this may occur interference among the multiple UAVs and this is caused for poor coverage for the area. As well as choosing a suitable channel and channel modelling are the problems. While modelling the channel, there are some parameters to consider. the path loss, fading which has two ways like large scale fading and small scale fading and multi-path effect. The channel should be chosen by minimizing these parameters. As well as interference management is another issue in UAV based wireless communication systems.The interference management methods are discussed above. And finally, the future research ares are also discussed.

VII. Acknowledgement

The author would like to acknowledge Professor Dushantha Nalin K. Jayakodi who is the module owner, project mentor Mr. Hassan Hydher and the module coordinator Mr. Chathuranga Basnayake for their guidance and supervision of this paper.

References

[1] M. Mohammad, S. Walid, B. Mehdi, N. Young-Han, and D. M´erouane, "A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems," *IEEE Communications Surveys and Tutorials*.

[2] Z. Xiao and D. Lingjie, "Optimal Deployment of UAV Networks for Delivering Emergency Wireless Coverage," *ResearchGate*, October 2017.

[3] S. Sanaa and I. Rania, "On-demand deployment of multiple aerial base stations for traffic offloading and network recovery," *www.elsevier.com/locate/comnet*, March 2019.

[4] E. Vinogradov, H. Sallouha, S. D. Bast, M. M. Azari, and S. Pollin, "Tutorial on UAVs: A Blue Sky View on Wireless Communication," January 2019.

[5] Z. Yong and J. L. Rui, Zhang.and Teng, "Wireless Communications with Unmanned Aerial Vehicles: Opportunities and Challenges," *IEEE Communications Magazine*, May . 2016.

[6] W. Khawaja, I. Guvenc, D. W. Matolaky, U.-C. Fiebigz, and N. Schneckenbergerz, "A Survey of Air-to-Ground Propagation Channel Modeling for Unmanned Aerial Vehicles," *IEEE Communications Surveys and Tutorials*, 2018.

[7] D. W. Matolak, "Air-Ground Channels and Models: Comprehensive Review and Considerations for Unmanned Aircraft Systems," *IEEE*, 2012.

[8] G. K, "Channel Interference in Cellular Communication and its types," *Free engineering courses for all your technical skills*, May 2020.