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A Novel Technique for Energy Efficiency of UAV-Based Wireless Communication Networks

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ABSTRACT

Unmanned aerial vehicles (UAVs) have evolved rapidly in the past decade and are expected to play a significant role in our daily lives in the future. Although UAVs were initially developed and used by military, the recent development in technology as well as the reduced production cost have made the use of UAVs more attractive for a wide range of civil and industrial applications such as cargo distribution, video streaming, communication networks, etc. As far as wireless communication networks are concerned, UAVs can be utilized to provide reliable and low-cost wireless connectivity for many practical scenarios. More specifically, using UAVs as aerial base stations (BSs) promises several advantages over the conventional BS-based wireless networks. For instance, UAV-based wireless networks not only can allow line-of-sight communications with ground users but can also provide additional capacity, thanks to their flexibility, which can deliver coverage to some hard-to-reach areas. Another attractive feature of UAVs is their ability to act as flying relays allowing the establishment of more reliable communication links over longer distances. The aforementioned advantages, along with others, qualify UAV-aided wireless communications to be a major component in future wireless systems including the forthcoming 5G and beyond. However, a reliable and efficient realisation of such networks faces significant challenges, the most notable of which is perhaps the limited battery capacity of the UAVs. Therefore, energy efficiency of such networks is a detrimental factor which needs to be considered to prevent any potential power depletion and hence link disruption. In this respect, the aim of this project is to develop advanced signal processing algorithms and design new protocols to maximize the energy efficiency of UAV-based wireless communication networks. Different practical scenarios will be investigated. The simulation results shows that the proposed technique provides better throughput of UAV-based wireless communication networks.

INTRODUCTION

Recently, the unmanned aerial vehicles (UAVs) communication has attracted substantial attention by Fifth-generation (5G) and beyond wireless networks researchers due to its salient features to support convenient connectivity with enhanced spectral efficiency. The UAV provides on-demand, cost-effective deployment, on-board communication, and the flexible system recon_guration compared to the base stations (BSs) on the ground. It can support better communication links between air and ground terminals due to less signal blockage and shadowing effects.

The specific system recon_guration provides _exible and reliable connections between the UAV and its users with reduced power consumption. The BS can be excessivelycrowded nowadays while serving the exploding traffic demands. Moreover, the BS may malfunction anytime. Thus, there arises a burning issue to serve the users in the eventof too congested traf_c, the BS hardware limitation, etc. Fortunately, the UAV potentially overcomes this issue owing to its cost-effective and energy-ef_cient features. Moreover,the UAVs offer a better line of sight (LOS) communication links by signi_cantly shortening the UAV to user distance. UAV communication has many potential applications, which
can be categorized as follows:

1) The UAV works as the aerial BS o support the ground users. In any case, the UAV also provides reliable connectivity with low latency. In this scenario, the UAV while it has a quasi-stationary position on the air. This kind of UAV communication can apply in many areas, such as recovering the natural disaster, remote areas, etc.

2) The UAV can also work as a relay to support the distance/remote users. The UAV relay can be mobile/static and is a great choice to support smart cities in the next-generation wireless networks.

3) UAV communication can be used to send/receive real-time information . This also suitable for the periodic sensing applications such that the UAV can over the sensors. This leads to potential network lifetime enhancement.

When the UAV serves like the terrestrial wireless communication infrastructure, it can enlarge the next generation wireless capacity due to its reliable uplink and downlink communication, mobility, swift deployment, and on-demand service, etc. Moreover, the UAV deployment as an aerial BS can also compensate signal blockage due to its LOS channel advantages. Furthermore, the UAV deployment can limit the higher transmit power compared to the BS on the ground because the UAV can easily adjust its mobility and altitude based on the user's location. These features eventually provide a solution of the energy efficient UAV deployment to serve the users on the ground in the event of the malfunctioning of the BS on the ground.

2. SYSTEM MODEL AND KEY DEFINITIONS

Nowadays, the base stations (BSs) are too congested withnext-generation users, which may prevent users from attain-ing the required quality of service (QoS). As an alternative,the unmanned aerial vehicles (UAVs) can support excessiveusers, especially when the BS has the hardware limitationorthe malfunctioning. In that case, the UAV can also serve as aterrestrialwirelessnetworkinfrastructure.

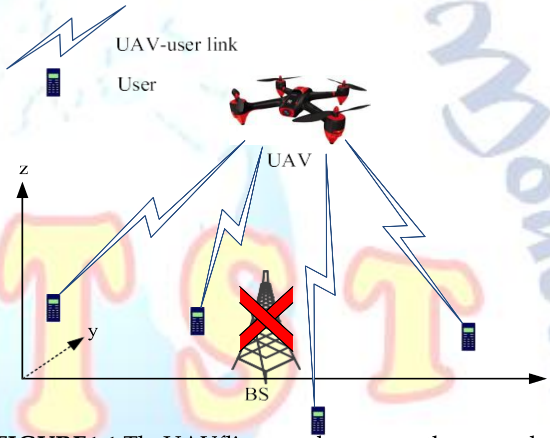

FIGURE1.1. TheUAVfliesovertheusersontheground.Abinarydecisionvariableschedules UAV-to-usercommunicationintheeventoftheBSmalfunctioningorhardwarelimitation,etc.Thus,theUAVworksasterrestrialwirelessnetworkinfrastructure.

InFig.1.1,weconsiderawirelesscommunicationsystemina geographical area, containing a UAV, and a set of multipleusers onthe ground,where 1,2,3,...,$U$where U is Unumber of users. The UAV is dedicated to supportingaset of users. In our investigation, the UAV dynamicallymoves to serve the users. The UAV flight duration to servetheusersonthegroundis0tT.

Thelocationsoftheusersareentirelyknowntothe UAV, whichisusedfordesigningthetrajectory.Thelocationofthestatic user u on the ground is denoted as (x_u, y_u). We investi-gatetheLOSandNLOScommunicationlinks-basedchannelmodel,whichhasnegligibleshadowingandmultipatheffect.Thus, we leave these issues as our future work. We con-siderthetimevaryinglocationoftheUAVis($x(t)$,$y(t)$).

SYSTEM MODELLING METHODS:

a) SYSTEM MODELLING

b) THEUAV-TO-USER SCHEDULING

c) CHANNEL MODELING
d) THROUGHPUT
e) UAV PROPULSION ENERGY CONSUMPTION
f) ENERGY-EFFICIENCY

3. MIMO-OFDM

3.1 MIMO-OFDM Wireless Communications

The key objective of future wireless communication systems is to transmit information streams at a high data rate maintaining its high quality as well like video calling. This is the basis for all the new 3G & 4G wireless communication systems. The drawbacks in narrow band system like GSM (Global system for Mobile Communications) and wide band system like CDMA is that GSM uses Narrowband channels in which frequency reuse is not possible which leads to inefficient use of total bandwidth. Total network is decomposed into high SINR point-to-point links because of which adjacent cells cannot be assigned the same channel. In CDMA the frequency reuse problem of narrowband system is fixed i.e. all users, both within a cell and across different cells, transmit and receive on the entire bandwidth. The signal of each user is modulated onto a pseudo noise sequence so that it appears as white noise to other users. The interference due to universal frequency reuse in CDMA is managed via averaging of the effects of multiple interferences which also allows statistical multiplexing of users and thus increase in the system capacity. The below mentioned two schemes in combination gives a new technology making use of advantages of the above mentioned old technologies.

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique. It splits the transmitted data into several interleaved lower rate data streams and transmits them in parallel by using several narrowband sub-carriers. The advantage of OFDM over Frequency Division Multiplexing (FDM) is that sub-carriers are Orthogonal to each other. Because of Orthogonality, Inter-carrier Interference is avoided, spectral overlap is possible and spectral efficiency is enhanced. OFDM converts frequency selective channel into parallel flat fading channels. OFDM does not require guard bands between sub-carriers.

3.2. MIMO:

MIMO systems are a special class of wireless communication systems which has multiple antennas at transmitter as well at receiver. This system can be employed for diversity gain as it uses multiple antennas in data transmission and reception. MIMO became the key concept for basis of 3G & 4G systems due to its unique SPATIAL MULTIPLEXING feature. Spatial Multiplexing is a process in which we can increase the data rate by transmitting several information streams in parallel and at same transmit power of SISO. This is possible through multidimensional signal processing.

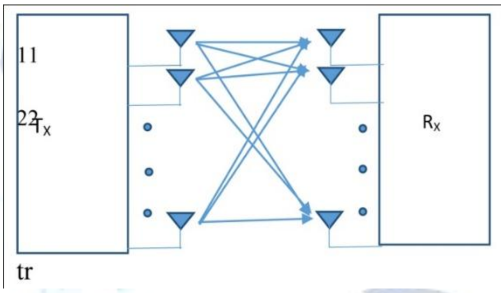

Figure3.1: MIMO Communication system model

Thus the signal that is being transmitted is first divided into sub streams and sent to "t" number of transmitting antennas and it is received at receiver using "r" number of receiving antennas.

4. RESULTS AND DISCUSSIONS

We present simulation results in this section to show theimproved performance of the proposed scheme. We comparethe proposed scheme with a static system and an unconstrainedapproach. The static scheme is defined as the objectivefunction is maximized after achieving the optimal UAV trajectory radius. We evaluate thesystem model performancefor a suburban environment. The UAV has a different hovering path for differentUAV flight time. When the UAV flight time is higher,the hovering path is larger. Thus, for higher UAV flight time,it can support more users on the ground. Weconsider the random distribution of the users in our proposedmodel. Even forshorter UAV flight time, many of the ground users also resideunder the UAV hovering path. Due to the closeness of theusers to the UAV hovering path, we achieve the improvedperformance of both throughput and energy-efficiency maximizationproblem. The UAV trajectory path both for shorterand higher UAV flight time proves the supremacy of theproposed algorithms.

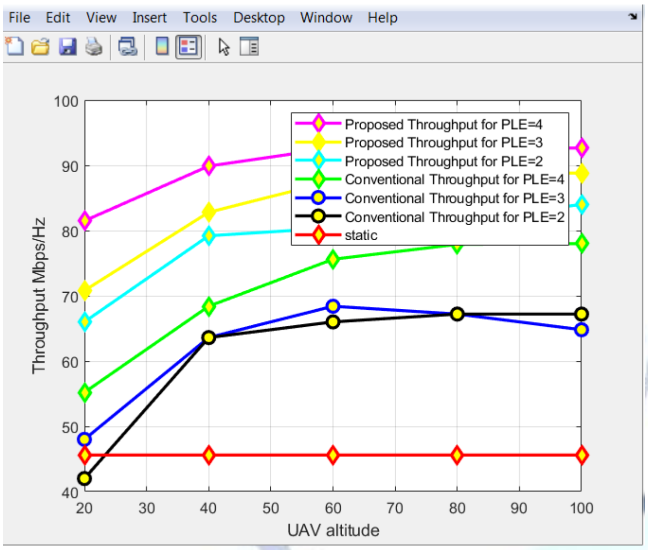

FIGURE 4.1:Comparison of Proposed Throughput and Conventional Throughput with respective PLE's.

Throughput vs. time is shown in Fig. 4.1. As LOS andNLOS communication links are both considered to designthe channel model, various values f path loss exponent D2; 3; 4 have been studied to analyse the bestperformance.We investigate the improved performance of throughput maximizationbased on Algorithm 1 compared to other schemes.Our proposed throughput maximization illustrates the significantimprovement for D 2; 3; 4. Our proposed throughputalmost maintains a constant and higher value though there isthe initial dropup to 10% of our proposed throughput fromD 4 toD 2. That observation proves the superiorityof our proposed throughput and compares it with the unconstraintand static throughput.

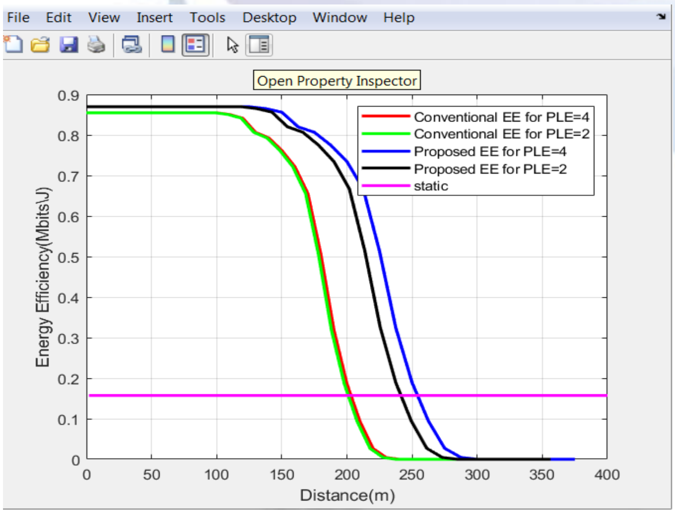

FIGURE4.2:Energy-efficiency maximization versus the UAV-user distance.

We compare the performance between energy-efficiencymaximization, static energy-efficiency, and unconstraintenergy-efficiency problem in Fig. 4.2. For D 4, there is a significant improvement in energy-efficiency for our proposedenergy-efficient Algorithm 2 compared to the benchmarkmethods. When *ru*D 150 m or more substantial, both ourproposed _*eeuav*and unconstraint energy-efficiencyproblemare investigated as impractical due to their low performance.

On the other hand, the static schemehas low performancedue to the optimal static location of the UAV. The UAV isnot expected to cover larger areas when the UAV altitudeis too high. though Thus, proposed energy-efficient UAV isproved useful for the 5G and beyond wireless networks. And Figure 4.3 represents energy efficiency difference between conventional method and DAS.

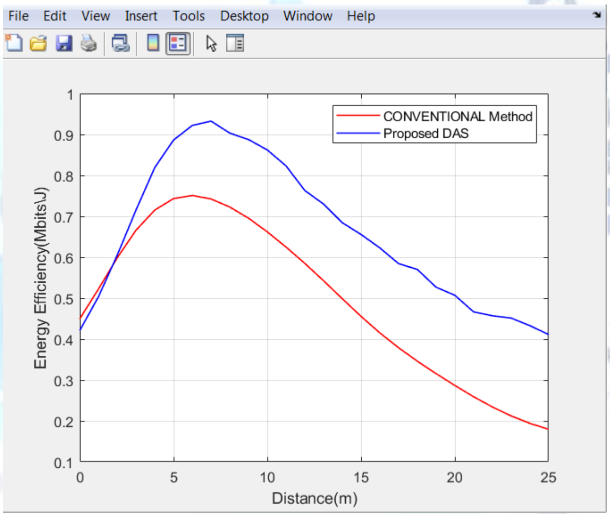

FIGURE 4.3: Conventional Method versus Proposed DAS

5. CONCLUSIONS AND FUTURE SCOPE

CONCLUSION:

The UAV provides a better communication link based on LOS and NLOS, which guaranteesa better QoS. In this paper, an energy efficient UAV serves the users via jointly optimizingthe UAV trajectory path, the UAV to users scheduling, the UAV transmit power, and the UAV mobility. We design the UAV-user channel model based on LOS and NLOS communication links. A binary variable is introduced to schedule the connectivity between UAV to the user. Before formulating the energy efficient problem formulation, we develop a throughput maximization problem and propose an efficient algorithm to solve it optimally.

We also formulate an energy efficiency maximization problem via optimizing throughput and UAV propulsion energy. We also formulate the UAV propulsion energy expression. We

derive the energy efficient maximization problem. The problem is investigated as a non-convex fractional, and MINLP problem. We propose an efficient algorithm based on SCA and Dinkelbach method, non-convexity, fractional, and MINLP problems are tackled by SCA, Dinkelbach, and *cvx*solver*mosek*, respectively. Simulation results prove the supremacy of the algorithm in terms of the energy efficiency and throughput maximization.

We claim our proposed model is an excellent to design the energy efficient UAV communication in 5G and beyond wireless technology due to the consideration of the feasible channel model and the UAV trajectory design.

FUTURE SCOPE:

The rapid development of marine economy, reliable and high-throughput maritimewireless communication has become a more and more important requirement. Conventionally, satellite maritime communication faces the limitations of large propagation delay and high implementation cost, and the marine MF/HF/VHF-based radio communication has insufficient bandwidth. With the aid of UAV relays, the offshore ships and devices can be connected with the ground stations via low latency and high-capacity

communication links. Moreover,46 for far-ocean area, aircrafts and vessels may form air-andsea integrated networks for efficient information exchanging and situation sharing. The mmWave frequency bands have potentials to be exploited for supporting high data rate in maritime communication. Due to the special physical environment over the sea surface, theelectromagnetic characteristics of the air-to-sea channels are different from the conventional A2A and A2G channels. Since the study of air-and-sea integrated communication is still in an initial stage, more research efforts are needed to explore the communication and network design.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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