**PHYSICAL LAYER** **REDESIGN FOR UNMANNED AERIAL VEHICLE (UAV) COMMUNICATION IN 5G**

*Research proposal for the Degree Of*

CANDIDATE OF SCIENCE

*submitted to*

**National Research Tomsk Polytechnic University and Sri Lanka Technological Campus**

By

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:

September, 2019

**APPROVAL OF RESEARCH PROPOSAL FOR THE DEGREE OF CANDIDATE OF SCIENCE**

The resesrch proposal titled **PHYSICAL LAYER REDESIGN FOR UNMANNED AERIAL VEHICLE (UAV) COMMUNICATION IN 5G** by **CHATHURANGA MADHUSHAN BASNAYAKA WIJERATHNA BASNAYAKA MUDIYANSELAGE** is approved by Scientific advisors for submission to the School of Postgraduate Studies & Research,Sri Lanka Technological Campus, Sri Lanka and National Research Tomsk Polytechnic University, Russian Federation.

1.Prof. Dushantha Nalin Kumara Jayakody

Date / / /

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**Scientific Advisor**

2. Dr.Udesh Oruthota

Date / / /

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**Scientific Advisor**

The proposal, which is enclosed, was favorably received by the School of Postgraduate Studies & Research, Sri Lanka Technological Campus, and I approved the scientific content and proposed work as being suitable for a PhD degree program.

Prof. Dushantha Nalin Kumara Jayakody

Date / / /

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**ABSTRACT**

Unmanned aerial vehicles (UAVs) are expected to be an important component of the next generation of mobile networks because of its low cost and flexible connectivity. Telecommunication organizations are currently exploring possibilities for serving UAVs with existing and further cellular network and industries beginning to trial early prototypes of the cellular connected UAV while scholars are in full swing introducing mathematical and algorithmic solutions to address interesting new problems arising from the cellular connected UAV communication system.

Compared to the conventional mobile communication system with terrestrial users, cellular-connected UAV communication possesses substantially different characteristics that present new research challenges as well as opportunities. Also, most of the research on cellular -connected UAV are still at initial stages. As a result, there are only a few simulations and experimental results available. Because of that, the objective of this research is a redesign physical layer of unmanned aerial vehicle communication system to align with the fifth generation cellular network technology.

**introduction**

Related Technology Fields: **Unmanned Aerial Vehicles (UAVs), UAV communication, Trajectory Optimization, Ultra-reliable and low-latency communications (URLLC)**

An unmanned aerial vehicle (UAV) is a pilotless aircraft, which is flown without a pilot-in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous [1]. UAVs have great potential to be widely used in both civil and military applications in areas of surveillance and reconnaissance [2]. Just as in other fields of aviation, collisions, faults and failures are present in the operation of the UAV. Specifically, UAV operations are more likely to experience loss of control in-flight, events during take-off and in cruise, and equipment problems [3].

Previous studies related to UAV found that in most cases, broken communications links between the pilot and the UAV were the cause of the incident, leading the researchers to call for the introduction of new methods to govern the communications systems of UAV [3]. Because they suggested that emphasis on technical issues such as the airworthiness of aircraft and the integrity of the communication links may produce greater safety dividends as against a narrowing of focus onto human operator issues. So, integrating the unmanned aerial vehicles (UAVs) into the cellular network is envisioned to be a promising technology to significantly enhance the performance of communications links between the pilot and the UAV.

**problem statement**

The final objective of this research is redesign the physical layer of the UAV communication system in the 5G cellular network. The first step will be to identify already proposed techniques for the cellular connected UAV communication system and provide an overview of these emerging technologies, by first discussing its potential benefits, unique communication and spectrum requirements, as well as new design considerations. This step includes several comprehensive surveys on UAV communication toward exiting and further mobile communication network.

The second step will be introduced a novel mobile relaying technique, where the relay system is mounted on unmanned aerial vehicles (UAVs) and hence are capable of moving at high speed. The proposed mechanisms will be simulated using engineering simulation tools. Many challenging problems must be addressed. One problem is how to determine optimal power allocation at each transmitting node along with the relay trajectory, optimal bandwidth allocation for each transmission, beamforming techniques to limit data collision and optimal UAV altitude. Another problem is to mitigate the interference in the cellular connected UAV communication system. The study of this problem can also lead to the definition of efficient mechanisms for cellular connected UAV communication system.

**OBJECTIVES AND AIMS**

The primary goal of the research is to develop a novel communication system for the unmanned aerial vehicle (UAV) through integrating UAV communication system into the existing and future cellular networks. Basically, it is based on a new mobile relaying technique and the main aspects of this work are:

1. To investigate the current state of UAV-assisted wireless communication technologies and the feasibility of integrating UAV into the cellular network using these technologies.
2. To investigate how to guarantee the Quality of service (QoS) and the network availability for Ultra-reliable and low-latency communications (URLLC) with the UAV.
3. To introduce a novel mobile relaying technique where the relay nodes are mounted on unmanned aerial vehicles (UAVs) and to develop accurate engineering models for high-mobility relays using simulation tools.
4. To introduce a novel mobile relaying technique where the relay nodes are mounted on unmanned aerial vehicles (UAVs) and to develop accurate engineering models for high-mobility relays using simulation tools.
5. To improve currently available 5G communication techniques using Simultaneous Wireless Information and Power Transfer (SWIPT) and WPT assisted technologies for the UAV communication system.
6. To develop optimization schemes for relay trajectory, power allocation, the altitude of UAV and bandwidth allocation and proposed a new algorithm to jointly optimize the power allocation and relay trajectory.

**BACKGROUND AND SIGNIFICANCE**

Existing UAV communication technologies based on the simple point-to-point communication over the unlicensed band such as ISM, which is of low data rate unreliable, insecure, vulnerable to interference. In general, communications equipment operating in unlicensed bands must tolerate any interference generated by other ISM applications, and users have no regulatory protection from ISM device operation.

The basic communication requirements of the UAV can be classified into two categories as control and non-payload communication (CNPC) and payload communication. Here, CNPC refers to the two-way communications between unmanned aircraft and ground control station (or remote pilot) and it must operate over the protected aviation spectrum. Also, the loss of CNPC link will be caused by catastrophic consequences. However, most existing CNPC of UAV with the simple direct UAV-to-ground communication over unlicensed spectrum. Also, due to the severe distance attenuation and shadowing, a single wireless link between user and control station cannot maintain reliability. As solutions for aforementioned problems, many studies are proposed to combine the UAV communication system with existing cellular networks. As a result, there has been significant interest in integrating the UAV communication system into the existing and future cellular networks [4-5]. Also, many attempts have been made in the past to integrate UAV with the cellular network and it may be traced back to the early 2000s. Wzorek and others were able to present a prototype network that was created between two UAVs and a ground operator using GPRS technology in 2006 [7]. However, due to technology limitation, the idea has not been widely further developed and commercialized. In 2016, China Mobile Research Institute and Ericsson presented field trial results collected in a prototype LTE -UAV integrated network. In this trail prototype, they elaborate on how the drone ecosystem can benefit from mobile technologies, summarize key capabilities required by drone applications, and analyze the service requirements on mobile networks. [8-10]. Researchers further investigated this scheme and the 3rd generation partnership project (3GPP) released several proposals which were investigated the ability for aerial vehicles to be served using LTE network. [11]. These series of studies were completed at the end of 2017 and the outcomes are documented in the 3GPP technical report [11] including comprehensive analysis, evaluation, and field measurement result. Specially, field trials were performed by various telecommunication companies to analyze the performance of a cellular-connected UAV in a commercial cellular network and to compare handover and link reliability between the ground and airborne UEs. Overall, these studies provided insights into various aspects and shortcoming when UAVs are integrated with the existing cellular network.

More specifically, these studies identified the following potential issues to cater to aerial vehicles using the existing LTE network.

1. High line of sight propagation: In the Downlink, the percentage of cellular-connected UAVs experiencing cell-edge like radio conditions (i.e. Poor DL SINR) and is much higher as compared to terrestrial UEs. This is because cellular-connected UAV, due to their high line-of-sight propagation probability, receive downlink interference from a larger number of cells than a typical terrestrial user does. Also, there is a higher probability that the number of neighboring cells, causing a high level of downlink interference at the cellular-connected UAV is higher than in the case of terrestrial users.
2. High Altitude: Normally, compared to conventional terrestrial users, UAVs typically have much higher altitude. If the Base transceiver station (BTS) ’s antennas are tilted downwards, either mechanically or electronically, a cellular-connected UAV whose height is above BTS antenna boresight is likely to be served by side lobes of the antennas. Due to the presence of possible nulls in the sidelobes, a cellular connection may possibly see a stronger signal from a faraway BTS than the one that is geographically closest. Hence, a cellular-connected UAV may be served by a faraway base station instead of the closest one.
3. Measurement and Reporting mechanism: The RSRP (Reference Signal Received Power) and RSSI (Reference Signal Received Quality) measurement of a cellular-connected UAV in the air are different from those associated with terrestrial users.
4. High mobility: The high mobility of UAVs generally results in more frequent handovers and time-varying wireless backhaul links with ground stations. Hence, the mobility performance of cellular-connected UAV is worse compared to a Terrestrial user.

Most of the current researches in the field of cellular-connected UAV focus on finding potential solutions for the aforementioned issues. In this section, we discuss several solutions and promising technologies to efficiently enable cellular connected communication system for UAVs. Mainly, these solutions and technologies can be categorized into two categories as network-based solutions or user equipment-based solution.

**Full dimension MIMO (FD-MIMO)**: Full dimension MIMO (FD-MIMO) is one of the key technologies currently studying mobile communication field and characterized by its scalability and potential to deliver very high and stable throughputs [12]. Massive MIMO cellular system will be used multiple antennas at the base station to mitigate the interference in the uplink of UAV communication system. In FD-MIMO transmission, the number of antennas has been increased beyond what is supported in conventional cellular communication systems and antennas are no longer placed in a linear one-dimension (1D) array but in a two dimensions (2D) plan array [13].

**Directional antenna at cellular-connected UAV**: In this solution, the UAVs are assumed to be equipped with a directional antenna instead of an omnidirectional antenna. The directional antenna is used to mitigate the interference in the downlink to aerial UEs by decreasing the interference power coming from a broad range of angles. Even with a high density of UAVs, directional antennas at UAVs was found to be beneficial in limiting the impact on downlink Terrestrial users’ throughputs. Since the use of directional antennas is up to implementation at UAVs, specification enhancements may not be needed The direction of Travel, LOS capabilities are considered when tracking the LOS direction between a UAV and the serving cell. Depending on the capability of tracking the LOS direction between the UAV and the serving cell, UAV can align the antenna direction with the LOS direction and amplify the power of the useful signal.

**Beamforming** **for Cellular Connected UAVs:** Beamforming is a powerful technique which has been widely used in signal processing, radar, sonar, navigation and particularly in wireless communications. In cellular mobile communication, beamforming is used to control the transmitted and/or received signal amplitude and phase, according to the desired application and channel environment [14].

Based on the previous studies, it is concluded that cellular networks will be capable of serving UAVs, but there may be challenges related to interference as well as mobility. Both implementation-based solutions and solutions requiring specification enhancements will be identified to address these issues.

**research design and methods**

## Timeframes

The overall schedule of the research is quite simple. The first six months will be dedicated to an exhaustive state-of-the-art not only on cellular-connected UAV communication, but also on fifth-generation cellular network technologies and on optimization techniques. Next one and a half years will focus on building the framework of theoretical studies and the associated simulation tool.

Final year of the research will be devoted to extensive theoretical and simulation investigations and will see the production of scientific results via the thesis and publications of the most significant works, extensive experimentations with feedback on theoretical and simulation studies . Of course, large dissemination of the proposed works will be ensured in national and international conferences, high-quality journals.

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