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A Study of the Communication System of an Unmanned Aerial Vehicles (UAVs)

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ABSTRACT

The aim of the research work was to examine the communication system of an unmanned aerial vehicle (UAV) using the review and explanatory research methods. The work discusses the communication system of UAVs; roles of UAV communication systems, such as data collection, search and rescue operations, and inspection; components of UAV communication systems, such as transceivers, antennas, and amplifiers; UAV communication security, such as secure communication protocols, frequency hopping, and anti-jamming techniques; UAV communication network topologies, such as star topology, mesh topology, and cluster-based topology; and factors affecting UAV communication systems, such as obstacles, distance, and weather conditions, using the review research method and explanatory research method. It was concluded from the results that a communication system is a very vital aspect of a UAV, and without it, it can neither receive nor transmit any data or information from or to the ground control system (GCS).

KEYWORDS: *Data collection, Distance, Frequency, surveillance, Transceiver, Unmanned Aerial Vehicle.*

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1. INTRODUCTION

An unmanned aerial vehicle (UAV) is an aircraft that is guided autonomously, by a remote control, or by both and that carries sensors or electronic transceivers to receive and transmit information. The development of unmanned aerial vehicle (UAV) technology marks a significant chapter in the history of aviation. Originally designed for military reconnaissance and remote operations, these aircraft have evolved beyond their initial wartime purposes and become vital tools in civilian and commercial sectors (Jinghong, 2024). UAVs possess the capability to operate autonomously through integrated microprocessors or can be remotely controlled without the need for human intervention. Due to their adaptability, straightforward installation, cost-effectiveness in terms of maintenance, versatility, and relatively minimal operational expenses, the utilization of UAVs opens up novel avenues for applications across commercial, military, civilian, agricultural, and environmental sectors (Luu, 2024). Unmanned aerial vehicles (UAVs) are being used in a wide range of fields, including business, the military, search and rescue, monitoring, and communications, to mention a few. UAVs are also anticipated to be a component of future air travel. Data exchange between UAVs, along with UAVs and ground stations (GSs), which also heavily rely on aeronautical channels, is necessary to deliver application services. Coverage expansion is a crucial issue to satisfy the demands for improved performance, but it necessitates the nomination of more base or transfer stations (Sara et al., 2023). Although some related works have been done, our work discusses some important aspects of the UAV communication system that are not found in detailed form in other works.

2. Research methodology:

The research was carried out using the review research method and the explanatory research method. This enabled us to critically look at some related works, especially the recent ones, with a view to bringing out needed points to achieve our aim. Given that the review research method was used for the work in addition to the explanatory research method, the materials used for the work were secondary data or sources, which comprise online and library materials.

3. Communication System of an Unmanned Aerial Vehicle

3.1. UAV Communication System

A UAV communication system is the section or the infrastructure of a UAV that enables effective interaction between an unmanned aerial vehicle (UAV) and its Ground Control Station (GCS), as well as other external systems. Without a reliable communication system, a UAV cannot be controlled, monitored, or tasked to perform meaningful operations. This system supports the exchange of control commands, status information, navigation data, and mission-specific payload data. The GCS communicates with the UAVs by implementing the microair vehicle link communication protocol. The most widely used method of communication in commercial UAVs is the radio frequency (RF). Also, a data link is installed on-board the UAV that contains an uplink to carry the control information to the UAV from the operator or command and control (C&C or C2) stations and a downlink to get the video feed and telemetry data from the UAV, such as speed, orientation, direction, altitude and latitude, power or fuel levels, payload information, and many other parameters back to the C2 (Yousef et al., 2021). Typically, based on how services are provided, the use of UAV communications in applications can be divided into two groups: Communication platforms facilitated by UAVs and UAV communications connected to cellular networks (Sara et al., 2023). This makes communication at some points depend on UAV and vice versa.

In addition, the C2 performs critical functions of the UAV communication system, such as transmitting instructions from the GCS to the UAV, such as take-off and landing commands, waypoint navigation, altitude changes, and speed adjustments. A UAV C2 link ensures that the UAV operates safely, responds promptly to operator inputs, and adheres to mission objectives, as loss or degradation of this link can lead to mission failure or even UAV crashes. The UAV communication system is exclusively reliant on communication between UAVs and the infrastructure. This is because the ground node is centrally located, and it facilitates direct communication between the UAVs and the ground node (Luu, 2024). In the views of Feng et al. (2006), Daniel et al. (2010), and Manoranjan & Mkarti (2022), UAV communication systems are significantly different from conventional communication systems because of the fact that UAVs have extremely dynamic communication channels between air-to-ground (AG) and air-to-air (AA). This feature is because of changing velocities of UAVs. This tells how important a communication system is to a UAV, as without it, the exchange of information, including the telemetry, cannot be carried out. UAV communication systems typically operate using duplex communication. Duplex communication is the type in which data or signals can flow in both directions. In a UAV, it is implemented using separate channels called uplink and downlink. The uplink channel is used to send command and control instructions from the GCS to the UAV, while the downlink channel is used to send telemetry, payload data, and system status updates from the UAV to the GCS. In both the uplink and the downlink, most UAV communication links rely on Line-of-Sight (LOS) communication, where there will be a clear and unobstructed path between the UAV and the GCS. UAV can communicate with the satellite in space and makes use of the cellular network as well as radio frequency in order to receive and/or transmit the needed information or data. This is shown in fig. 1.0.

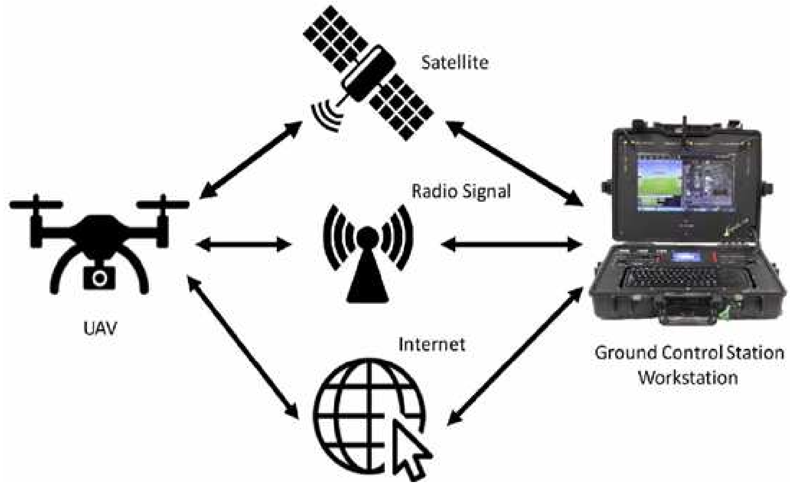

Fig. 1.0: UAV communication system with ground control (Source: Bismark et al…2015)

3.2. Roles of UAV Communication System

The UAV communication system plays a vital role across a wide range of civilian, commercial, and military applications. Their ability to provide real-time data exchange makes UAVs highly versatile and effective tools.

3.2.1. **Data collection**: UAV communication systems help in the transmission of the data from the sensor or payload used in environmental monitoring, land surveying, weather observation, and geographic mapping. This collected data can be processed in real time or stored for later analysis. UAVs are used in applications such as scientific data collection as well as military reconnaissance (Luu, 2024). In addition, UAVs are employed in many applications, such as public safety, search and rescue, emergency communications, unexpected events, transportation management, remote sensing, scientific data collection, industrial inspections, delivery of goods, and precision agriculture (Ahmad and Noor, 2021). No matter how effective the payload is on a UAV, without a reliable communication system, the data collection at any end cannot be done.

3.2.2. **Surveillance and monitoring**: UAV communication systems enable the transmission of live video and imagery for security operations, agricultural monitoring, border patrol, and disaster management. Real-time communication allows users to observe situations remotely and respond accordingly when there is a need. Based on its operation, UAVs are simple to integrate into wireless communication networks because they can function as flying base stations or relay nodes to create self-organizing networks and provide network services. That is why UAVs are used for various duties such as video surveillance, data collection, and cargo transportation, thanks to their many sensors (Zeng, 2016; Sara et al., 2023). However, even though the UAV can fly automatically when given a flight route, certain drone operations, such as surveillance and military patrol, may not have a predetermined flight route, so one may not plan a flight route ahead of the mission (Bismark et al**., 2015**); hence, continuous communication with the UAV from the ground station is needed.

3.2.3. **Search and rescue operations**: UAV communication systems help in rapid deployment, real-time situational awareness, and coordination with rescue teams. Live video and sensor data help locate victims and assess disaster zones efficiently. UAV wireless communication systems have shown great potential for applications in various fields such as aerial photography, disaster monitoring, and search and rescue operations (Xinyue, 2023). In this, secure and reliable communication is essential to prevent interception and ensure mission success.

3.2.4. **Inspection**: UAVs make use of robust communication links to inspect projects or infrastructure such as bridges, power lines, pipelines, and towers. High-quality data transmission reduces the need for human involvement in hazardous environments, thereby improving safety and efficiency. UAVs can also be used for power transmission lines, construction sites, and remote cellular site inspections, and all these are possible through the use of a communication system along with the payload.

3.2.5. **Cargo delivery and logistics**: With the aid of a communication system, UAVs can follow predefined routes, avoid obstacles, and report their status continuously. Reliable communication ensures accurate navigation, timely delivery, and effective fleet management. As of today, Unmanned Aerial Vehicles (UAVs) are currently used in the cargo delivery system, where the delivery of emergency medical supplies is essential, especially in rural areas (Eichleay et al., 2019). The use of drones will help to achieve the objectives of operational logistics, in accordance with the requirements of combat forces, supporting appropriate factors. Just-in-time logistics such as speed and efficiency, accessibility, lower costs, and reducing risks to personnel (Lucic, 2023).

3.3. Components of UAV Communication System

A typical UAV communication system is composed of several interconnected hardware and software components, each serving a specific function. The major UAV communication systems are as follows.

3.3.1. Transceiver: The transceiver (transmitter/receiver) is the component of a UAV communication system that is responsible for sending and receiving radio signals between the UAV and the GCS. It forms the core of wireless communication and determines operating frequency, modulation type, and transmission power. UAV transceivers commonly operate in the Industrial, Scientific, and Medical (ISM) bands, including 2.4 GHz and 5.8 GHz. For long-range and professional UAV operations, licensed or semi-licensed bands such as 900 MHz, 1.3 GHz, or L-band (1–2 GHz) are also used to achieve better propagation and reduced path loss. The modern UAV transceivers support digital modulation schemes such as Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (16 QAM) to improve the efficiency.

3.3.2. Antenna: An antenna is defined as an electrical device used for radiating transmitted RF signals and receiving incoming signals. Antenna characteristics such as type, gain, polarization, radiation pattern, and orientation significantly affect the communication range, signal quality, and link reliability. UAV platforms typically make use of omnidirectional antennas, such as monopole and dipole antennas, for short- to medium-range communication. These antennas provide uniform coverage in all horizontal directions in order to maintain the connectivity during UAV maneuvers. For long-range communication, directional antennas such as parabolic, Yagi-Uda, patch, or helical antennas are commonly used at the GCS. These antennas offer higher gains, thereby allowing extended communication distances when combined with appropriate transmission power and line-of-sight conditions.

3.3.3. Modem: A modem is used to modulate digital data into radio signals for transmission and demodulate received signals back into usable data. That is, the modem (modulator–demodulator) is responsible for converting digital data into RF signals suitable for wireless transmission and recovering digital data from received RF signals. It performs key signal processing functions such as modulation, demodulation, channel coding, interleaving, and symbol synchronization. In UAV communication systems, modems support various modulation schemes, including QPSK and QAM, depending on the required data rate and channel conditions. It is also important to note that some modems today also incorporate forward error correction (FEC) techniques such as Reed–Solomon, Turbo codes, or Low-Density Parity-Check (LDPC) codes to improve reliability in noisy and fading environments.

3.3.4. Amplifier: An amplifier is a device used to increase signal power. In this case, it is used to increase the signal power so that the communication range will be extended, particularly in long-distance or high-interference environments. The power amplifier boosts the RF signal to a level sufficient for long-distance transmission. It also plays a critical role in determining communication range and link margin, particularly in high-interference or beyond-visual-line-of-sight (BVLOS) operations. Typical UAV communication systems use power amplifiers with output levels ranging from 20 dBm (100 mW) to 33 dBm (2 W).

3.3.5. Frequency converter: A frequency converter enables signal translation between baseband, intermediate frequency (IF), and RF bands. It shifts signals to and from the assigned operational frequency band, enabling compatibility with communication standards and minimizing interference. It typically consists of mixers, local oscillators, and filters that upconvert transmitted signals to the assigned carrier frequency and down-convert received signals for baseband processing. In UAV systems, frequency conversion allows flexible operation across multiple frequency bands, such as 900 MHz, 2.4 GHz, and 5.8 GHz, using a common baseband architecture. The use of GHz frequencies in UAV communication systems is driven by several technical and practical advantages, such as antenna size, given that higher frequencies correspond to shorter wavelengths, which allow the use of smaller antennas. Another important factor is data rate capability, as GHz frequency bands offer wider bandwidths, which enable higher data transmission rates. This is essential for applications requiring real-time video streaming, high-resolution imaging, etc.

3.3.6. Controller: The controller is the component of a UAV communication system that serves as the central management unit of the UAV communication system. The UAV communication system handles communication protocols, packet routing, synchronization, encryption, and error handling across all subsystems. It manages multiple data streams, including command and control (C2) data, telemetry, navigation signals, and payload data such as real-time video or sensor measurements.

3.4. UAV Communication Security

Communication security is a vital aspect of UAV systems, as unsecured links can expose UAVs to hijacking, spoofing, data interception, or denial-of-service attacks. Effective UAV Communication Security measures are as follows:

3.4.1. Encryption: Encryption is defined as a process of converting plaintext data into unreadable ciphertext to protect it from unauthorized access, using algorithms and keys. It is commonly employed to protect command signals, telemetry data, and payload information. Advanced Encryption Standard (AES) and similar cryptographic algorithms are used to prevent unauthorized parties from understanding intercepted data.

3.4.2. Authentication mechanism: An Authentication mechanism is defined as a process that verifies the identity of users, devices, or systems, ensuring only authorized entities access resources or data. It verifies the identity of both the UAV and the Ground Control Station before communication is established. This prevents unauthorized entities from issuing commands or accessing UAV data. Authentication may involve digital certificates, cryptographic keys, or secure passwords.

3.4.3. Frequency hopping: Frequency hopping is defined as a technique that rapidly switches a signal between multiple frequency channels, reducing interference and increasing security. It is a security measure in which the communication system rapidly switches between different frequencies according to a predefined pattern. This makes it difficult for attackers to disrupt or intercept the communication link.

3.4.4. Secure communication protocols: They are defined as the standardized rules, such as HTTPS, SSH, and TLS, that ensure data confidentiality, integrity, and authenticity during transmission. The use of secure communication protocols, such as encrypted versions of MAVLink, ensures reliable data exchange while incorporating error detection and correction mechanisms. Additionally, physical security measures protect UAV and GCS hardware from tampering, theft, or unauthorized modification.

3.4.5. Anti-jamming techniques: These are the processes or methods used to prevent intentional interference or disruption of wireless communications. Some of these methods are spread spectrum and frequency hopping. These techniques enable the communication system to detect and resist signal jamming or spoofing attempts, thereby maintaining link stability in hostile environments.

3.5. UAV Communication Network Topologies

UAV **communication** network topology refers to the structural arrangement of communication links between UAVs and control stations. It is the physical arrangement of the network architecture components that is called the topology. The major ones are shown below.

3.5.1. Star topology: In a **star topology**, each UAV communicates directly with a central Ground Control Station. This is the most common configuration for single-UAV operations and provides simple management and low latency. Though simple, its range is limited by the direct communication link.

3.5.2. Mesh topology: This is the type of topology in which multiple UAVs communicate with one another and relay data across the network. This topology is particularly suitable for UAV swarms and extended-range missions, as it enhances coverage, redundancy, and fault tolerance.

3.5.3. Point-to-point topology: This is the type of topology in which a dedicated communication link is established between a UAV and the GCS. This setup offers high reliability and is often used for specialized or mission-critical operations.

3.5.4. Satellite relay topology: For long-distance or global missions, satellite relay topology is employed, where communication occurs via satellites between the UAV and the GCS. This approach enables worldwide coverage but introduces higher latency and operational costs.

3.5.5. Cluster-based topology: This is the type of topology in an Unmanned Aerial Vehicle (UAV) communication system that is a hierarchical network structure designed to manage large-scale drone operations by dividing them into smaller, manageable groups or "clusters." Figure 2.0 shows the type of UAV communication topologies.

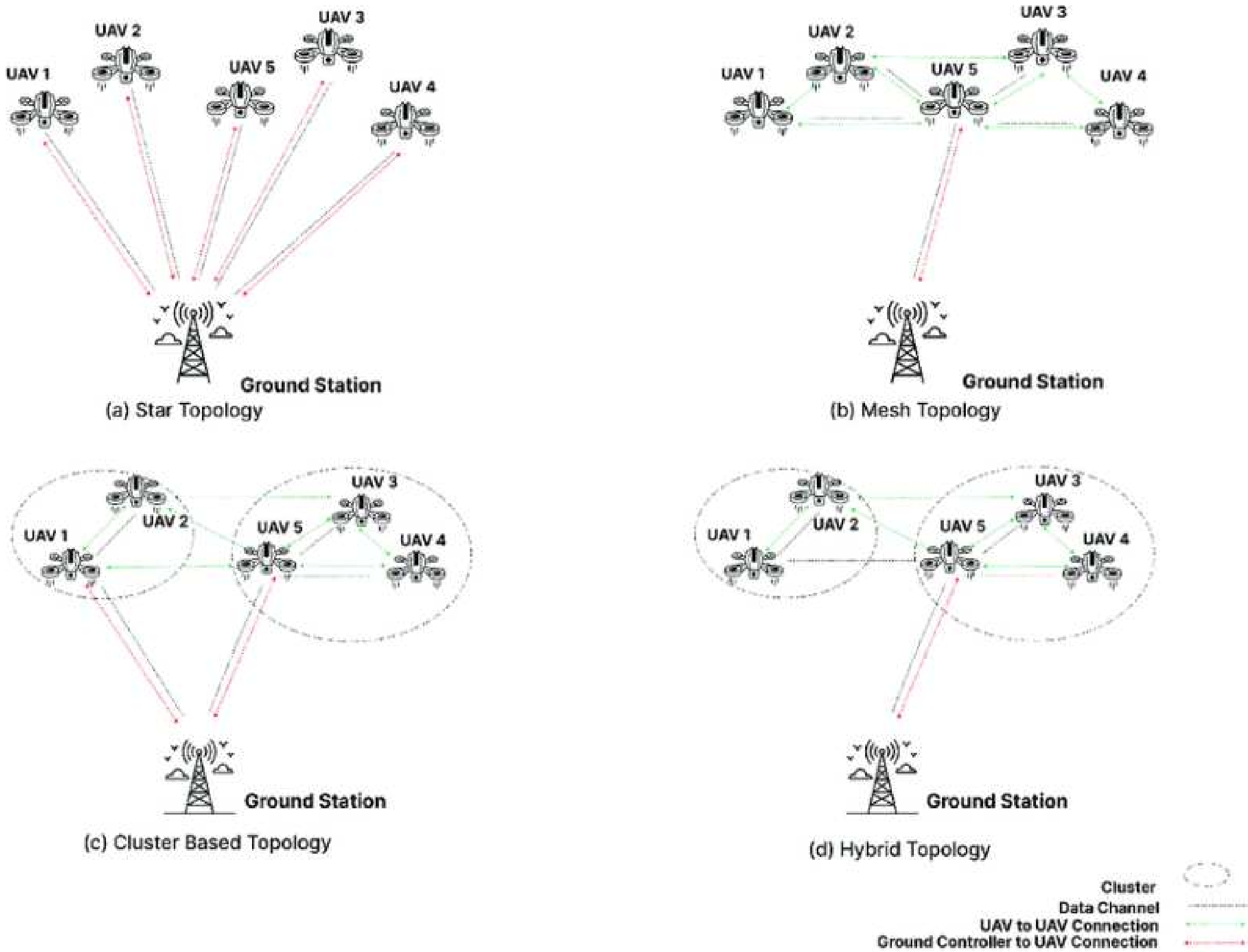

Fig. 2.0: UAV communication topologies (Sources: NAFEES et al, 2023).

3.6. Factors Affecting UAV Communication Systems

Several environmental and technical factors influence the efficiency and performance of UAV communication systems. Some of these factors are shown below.

3.6.1. Distance: Distance between the UAV and the Ground Control Station (GCS) is one of the most significant factors affecting communication performance. As distance increases, the transmitted signal experiences free-space path loss, resulting in reduced received signal strength. This attenuation can result in a lower signal-to-noise ratio (SNR), increased bit error rates, or even link failure if the communication threshold is not maintained. That is why long-range UAV operations must make use of higher transmission power, high-gain antennas, or the use of relay nodes and satellite links to sustain reliable communication over extended distances.

3.6.2. Obstacles: Obstacles such as buildings, trees, hills, and other terrain features can obstruct the direct line-of-sight path between the UAV and the GCS. These obstructions may cause signal blockage, diffraction, or reflection, resulting in signal degradation or complete communication loss. In addition, urban and mountainous environments have a negative impact on UAV communication signals due to dense infrastructure and uneven terrain.

3.6.3. Interference and Spectrum Congestion: Interference is a disturbance. It can be from other wireless systems operating in the same frequency band and can significantly affect UAV communication quality. Common sources of interference include Wi-Fi networks, Bluetooth devices, wireless equipment, and other UAVs operating nearby. Effective channel selection, frequency hopping, can help to mitigate interference effects.

3.6.4. Antenna orientation: Antenna orientation is defined as the positioning of the antenna in a specific direction to align with the target for effective signal transmission or reception. It plays a crucial role, especially when directional antennas are used. Improper alignment between the UAV antenna and the

GCS antenna can result in polarization mismatch and reduced antenna gain, significantly weakening the received signal.

3.6.5. Weather conditions: Weather conditions can influence UAV communication performance, especially at higher operating frequencies. Weather elements such as relative humidity, rain, fog, and atmospheric turbulence can cause signal attenuation, scattering, and absorption. These effects are more pronounced at GHz frequencies, where rain fade and atmospheric losses become significant. Although most short-range UAV systems are relatively tolerant of mild weather conditions, adverse weather can still reduce link reliability and must be considered during mission planning.

3.6.6. Multipath effects: Multipath is when the transmitted signal takes many directions at the same time due to obstacles or other factors**.** Multipath effects occur when a UAV-transmitted signal reflects off surfaces such as buildings, the ground, or water bodies, causing multiple delayed versions of the signal to arrive at the receiver. This phenomenon can lead to constructive or destructive interference, resulting in signal fading, distortion, and fluctuating received power levels.

3.6.7. UAV altitude: UAV altitude has a direct impact on communication performance by influencing line-of-sight availability and propagation conditions. Higher altitudes generally improve communication range by reducing obstacle-induced blockage and multipath interference. However, increased altitude may also expose the UAV to greater interference from other transmitters.

4. Conclusion

This research work has been able to look at the communication system of UAVs; roles of UAV communication systems, such as data collection, search and rescue operations, and inspection; components of UAV communication systems, such as transceivers, antennas, and amplifiers; UAV communication security, such as secure communication protocols, frequency hopping, and anti-jamming techniques; UAV communication network topologies, such as star topology, mesh topology, and cluster-based topology**;** and factors affecting UAV communication systems, such as obstacles, distance, and weather conditions, using the review research method and explanatory research method. From the result, it can be concluded that a communication system is a very vital aspect of a UAV, and without it, it can neither receive nor transmit any data or information from it to the ground control system (GCS).

References

[1] AhmadH. Sawalmeh, Noor Shamsiah Othman (2021): An overview of collision avoidance approaches and network architecture of unmanned aerial vehicles. arXiv:2103.14497v1 [cs.NI]. pp 1 – 24

[2] Bismark Owusu, Obed Frimpong and David Kofi Oppong (2015): Unmanned Aerial Vehicles. https://curriculumresources.edu.gh

[3] Daniel, K., Putzke, M, Dusza B, and Wietfeld C (2010): Three-dimensional channel characterization for low altitude aerial vehicles. Proceedings of the7th International Symposium on Wireless Communication System, New York, UK, pp.756–760

[4] Eichleay, M., Evens, E., Stankevitz, K., and Parker, C. (2019). Using the unmanned aerial vehicle delivery decision tool to consider transporting medical supplies via drone. Global Health: Science and Practice, 7(4), 500-506.

[5] Feng Q, McGeehan J, Tameh E K, (2006): Path loss models for air-to-ground radio channels in urban environments. In: Proceedings of the IEEE Vehicular Technology Conference (VTC-Spring), Melbourne, VIC, Australia, pp.2901–2905

[6] Jinghong Chen (2024): Design and Performance Analysis of UAV Communication Networks. Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024), Advances in Engineering Research 240.

[7] Lucic, M.C., Bouhamed, O., Ghazzai, H., Khanfor, A., & Massoud, Y. (2023). Leveraging UAVs to Enable Dynamic and Smart Aerial Infrastructure for ITS and Smart Cities: An Overview. Drones, 7(2), 79. Available at: https://doi.org/10.3390/drones7020079.

[8] Luu Thi Hiep (2024): Several challenges associated with UAV communication networks. Thu Dau Mot University Journal of Science. DOI:10.37550/tdmu.EJS/2024.02.545. pp 193 – 201

[9] Manoranjan Kumar, and Mkarti (2022): A simple characterization of UAV communication systems. Indian Academy of Sciences. Pp 1 – 9.

https://doi.org/10.1007/s12046-022-01983-3 6789.

[10] Nafees Mansoor, MD. Iqbal Hossain, Anatte Rozario, Mahdi Zareei and Alberto Rodríguez Arreola (2023): A Fresh Look at Routing Protocols in Unmanned Aerial Vehicular Networks: A Survey. IEEE Access. Vol 11. Pp 66289 – 66308

[11] Sara A. Owaid, Abbas H. Miry and Tariq M. Salman (2023): Survey on UAV Communications: Systems, Communication Technologies, Networks, Application. University of Thi -Qar Journal for Engineering Sciences. Vol 13.1. doi.org/10.31663/tqujes13.1.471. pp 136 – 145

[12] Xinyue Bai (2023): Design of UAV wireless communication system. Journal of Physics: Conference Series. doi:10.1088/1742-6596/2649/1/012061. Pp 1 - 8

[13] Yousef Alghamdi, Arslan Munir, Hung ManhLa (2021): Architecture, Classification, and Applications of Contemporary Unmanned Aerial Vehicles. IEEE Consumer Technology Society. Digital Object Identifier 10.1109/MCE.2021.3063945. pp 9 - 20

[14] Zeng, Y, Zhang, R, and Lim T. J. (2016): “Wireless communications with unmanned aerial vehicles: opportunities and challenges,” IEEE Communications Magazine. vol. 54, no.5, pp. 36-42.