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Survey on UAV Communications: Systems, Communication Technologies, Networks, Application

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Abstract

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. To deploy more stations, an efficient solution must be simple and affordable. Since an unmanned aerial vehicle (UAV) is much more affordable than ground stations and does not require network or cell replanning, it has been suggested as a potential solution to these problems. This would increase network coverage without requiring the existing networks to undergo additional, unnecessary deployment processes. UAVs will be crucial components of 5G and future networks, acting as mobile aggregators, macro base stations, relay stations, and tiny cells. The position or trajectory of UAVs and the resource management of the entire network significantly impact the performance of UAV wireless networks. Still, a lot of problems (like channel modeling, battery capacity, and trajectory optimization) need to be fixed before UAVs can be effectively used to deliver dependable and robust context-specific networks. A significant portion of research in the fields of vehicular ad hoc networks (VANETs) and mobile ad hoc networks (MANETs) ignores the special qualities of UAV networks. UAV networks can be intermittently linked, have a fluid architecture, and range in speed from slow to dynamic. This article intends to provide a comprehensive analysis of UAV communication. In the present survey, we focus on issues concerning the overview of various communication paradigms, the characterization of UAV networks, communication systems, and the integration of UAVs into cellular networks. We present significant scenarios establishing direct communication links among UAVs, examining communication technologies and more information, and thoroughly examining the architectures, networking systems, communication protocols, and applications of UAVs.

Keywords: UAV, wireless communication, 6G, MIMO, U2U, U2GCS.

1. Introduction

In recent years, Unmanned Aerial Vehicles (UAVs) have become increasingly prevalent and have found extensive applications both in military and civilian sectors. Thanks to their compact size and adaptability, UAVs are employed for tasks ranging from battlefield reconnaissance to inspecting power grids and target identification. With the growing demand for social network services and the widespread adoption of 5G networks, there is considerable interest in utilizing UAVs to establish mobile 5G networks. On one hand, UAV-based stations have the potential to support traditional communication networks, facilitating data transmission over a wider area. This relay transmission technology is more efficient and cost-effective than erecting conventional antenna infrastructure. contrasted with, in remote areas, the usage of UAVs can lead to cost savings in network station construction, and these UAV-based stations offer the advantage of easy mobility and reconstruction, thus preventing the wastage of resources. UAVs present an economical deployment option and swift network system reconfiguration when contrasted with terrestrial base stations, all while ensuring dependable connectivity with minimal latency [1].

Nevertheless, there are significant scenarios where establishing direct communication among UAVs and circumventing terrestrial network infrastructure becomes a critical facilitator. These scenarios encompass autonomous coordination of UAV swarms, collision avoidance measures, UAV-to-UAV relay operations, data transfer tasks, and information-gathering processes. In a manner akin to ground-based device-to-device (D2D) communications, UAV-to-UAV (U2U) communications may similarly yield implications concerning spectral and energy efficiencies, the expansion of cellular coverage and the alleviation of backhaul capacity demands [2].

Typically, based on how services are provided, the use of UAV communications in applications can be divided going to two groups: Communication platforms facilitated by UAVs and UAV communications connected to cellular networks. In addition, UAVs able to broadly classified into two categories based on the kind of wing: fixed-wing UAVs and rotary-wing UAVs. By their respective positions or roles. Rotary-wing UAVs possess the capability to maintain a stationary position in the atmosphere and exhibit adaptable flight patterns. The instructions provided typically have a very restricted capacity for carrying loads. On the contrary, fixed UAVs are required to be upheld. A forward flight enables an aircraft to maintain altitude, while also allowing for increased payload capacity and improved energy efficiency [3].

In addition, to guarantee dependable and affordable wireless communication solutions, several obstacles pertaining to UAV-assisted wireless communication must be overcome. Among the difficulties are:

Operational mode: The working mode, changeover management, channel modeling, and relaying protocols are examples of potential difficulties [4].

Battery capacity: One major problem with UAV-assisted wireless networks is the low battery capacity of UAVs. Enhancing UAV networks' energy efficiency is a difficult task.

handover management is Another difficulty in UAV-assisted wireless communication.

Relaying protocols: Another potential issue with UAV-relaying systems is relaying protocols [1].

Channel modeling: One possible area of study for UAV-assisted communications is channel modeling for air-to-ground and air-to-air communication.

Limited energy: Another issue that must be resolved in UAV-assisted wireless communication is limited energy.

Backhaul link.: is another issue that must be resolved to guarantee dependable wireless communication solutions.

Mobility and handover: Other issues that must be resolved in UAV-assisted wireless communication include mobility and handover [5].

Privacy and security: When it comes to UAV-assisted wireless communication, there are a number of issues to be aware of, including privacy, security, public safety, and collision avoidance [6].

Trajectory optimization: is an additional problem that must be considered in order to accomplish the best possible UAV deployment [1].

For example, the authors in [7] provided an overview of UAV-enabled communication platforms by outlining three common use cases, each with associated potential and challenges, including ubiquitous coverage augmentation, mobile relaying, and information collection/dissemination. The authors of [8] provided an instruction on UAV communication for 5G and beyond wireless networks. They covered the state-of-the-art outcomes for cellular-connected UAV communications and UAV-enabled communication platforms, as well as the principles of performance analysis, evaluation, and optimization for UAV communications. Additionally, the book [9] looked into a wide range of UAV communications topics, including standardization, control, security, resource management, cooperative communications, physical layer design, trajectory and path planning, performance analysis and optimization, and many access. [6] also provided a detailed comparison of the use of UAVs in aerial base stations versus cellularly connected UAVs, highlighting key issues, tradeoffs, and challenges. Additionally, several studies have reviewed particular UAV uses in civil utilizations [10], [11], ad hoc network [12]–[15], UAV-to-X [16], cellular edge networks [17].

2. UAV Communication Systems

In principle, as shown in Figure 1, Using a UAV communication link, the vehicle may receive commands from the GCS, and information regarding the flight may be received via the downlink. It is possible to build a bidirectional link to enable communication between the drone and GCS. These two parts must be able to maintain a constant and dependable relationship while communicating across a great distance. As a result, creating a channel model that is appropriate for UAV features is crucial to improving the UAV's data link. An unmanned aerial vehicle's microcontroller, frequently referred to as its flight controller, acts as its brain and central processing unit. It controls waypoints, dependable, autonomous, and countless additional autonomous features. This microprocessor receives data beginning with the receiver, GPS module, battery monitor, inertial measurement unit (IMU), whose accelerometer and gyroscope can be used in navigation systems to maintain a reference heading and other onboard sensors. The GCS provides vital vehicle information, including velocity, orientation, altitude, location, yaw, pitch, and roll, as well as alarms and other data. A UAV has two connections, as shown in Figure 2: a data link and a communication link. To be able to transmit data through the UAV and GCS, the frequency range of the vehicle's data interface is between 150 MHz and 1.5 GHz. On the opposite side of the spectrum, 2.4 GHz is used to control the vehicle., thereby establishing a communication link between the transmitter and receiver [18].

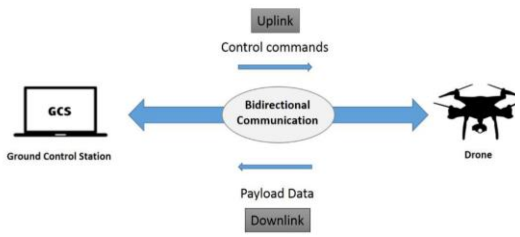

Fig.1 Drone communication link

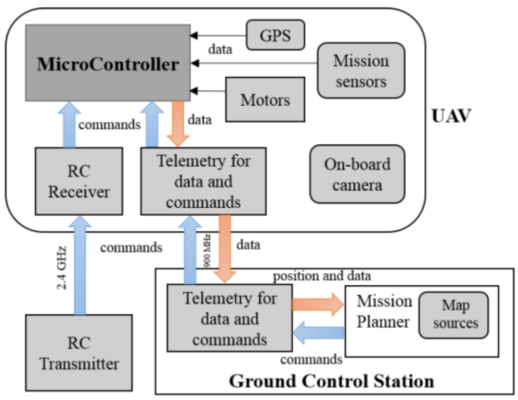

Fig.2 UAV communication system components.

Two separate links—one for data and the other for visual signal—are used for communication between the UAV and GCS (Ground Control Station), and an autopilot connects them all.

Data transmission system: A two-way link is necessary for the transmission of control and telemetry info. The aerial vehicle will provide telemetry data to the GCS, and control data will flow in the opposite direction.

Video transmission system: There will be two distinct links that are both unidirectional, one for each camera. It follows that There will be two separate transmitters on it. control instructions for the data transmission system will transmit cameras.

Autopilot: a component that manages communication and stability of flight [19].

In general, UAV Network (UAVNET) is the name of the temporary network that forms when UAV and GCS exchange data. Through a wireless link, a communication protocol manages communication across the UAV and the GCS. a representation of a UAV communication scenario made up of multiple parts and communication links of various kinds. Figure 1 demonstrates how various types of data and information are exchanged over each of these links.

These networks rely on wireless communication channels to exchange information. Additionally, it has three different types of connectivity, including radio communication and satellite link, depending on the sort of information being conveyed. Radio communication links transmit control information, audio, video, and telemetry data. Although the various communication routes appear to be identical, there are significant differences among them in terms of security. Different security criteria apply to different communication links. Although certain threats could affect components like satellite links, the current security procedures may prevent them from being overly vulnerable [20].

3. Usage of Wireless Networks for UAVs

The following are the top three UAV application cases for wireless communication networks: (1) A UAV relay station (RS) for wireless connections to distant sites, and (2) a UAV base station (BS) for wireless service inside a predefined target region. As depicted in Figure 3, UAV aggregators allow users without direct access to the base station or command center to communicate with or collect data from remote sensors or equipment.

3.1 UAV Base Station

User equipment (UE) can connect to UAV BS reliably and seamlessly, which helps the current networks provide more service coverage. The UAV base station can establish a backhaul connection with a satellite, a mega base station (MBS) that is close to Earth, or other unmanned aerial vehicles in proximity. UAV BS can benefit both emergency zones where infrastructures are damaged or destroyed due to human error and densely populated areas where additional connections are needed because of base station unloading such stadiums.

3.2 Relay Station for UAVs

Without compromising network performance, UAV RS offers wireless connectivity to distant users or groups of users that lack a direct communication link to a base station (BS) or transmitter. Thus, the capacity of the networks is expanded. One or more UAVs can be used to build a UAV relay network (URN), Nevertheless, for applications, it is crucial to tailor the quantity of UAVs, network architecture, as well as routing protocol to ensure a dependable transfer link with using a minimal quantity of power.

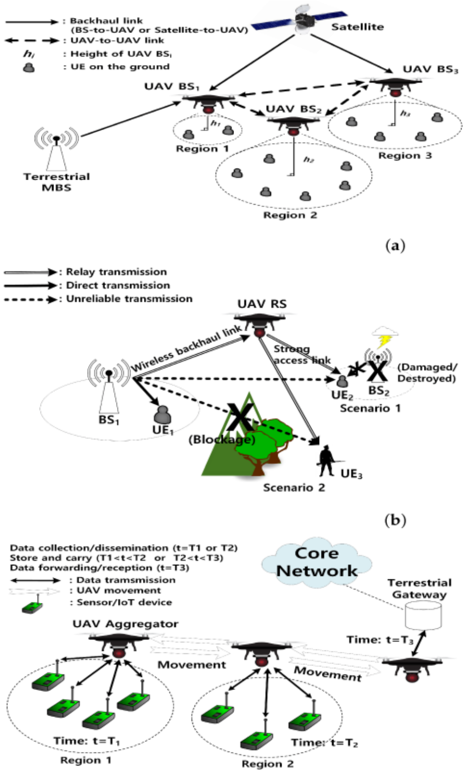

Fig.3 UAV use cases.

3.3. UAV Aggregator

Overhead, a UAV aggregator distributes (collects) data to the dispersed wireless equipment, including sensors, data must tolerate delays and able to flow within a predetermined latency [7]. Wireless sensor networks can be used in risky situations to perceive the environment without the need for terrestrial connection infrastructures. However, gathering information from these places can be expensive or even deadly. In this situation, using UAVs to gather data is a possible answer. Energy-saving solutions for both the UAV and sensor nodes are a big problem because many sensor nodes do not have a fixed power source. Due to its constant speed and trajectory, a circle is one energy-efficient UAV flight path [8].

4. UAVS Types and Characteristics

UAVs have both mechanical and electronic components, and their operations are highly complicated.

Typically, these devices come with an operating system that houses the UAV software. UAVs can be categorized according to several factors, including their flight mechanism, weight, aircraft altitude, and wing type. UAVs are separated into the following groups based on their flight mechanisms.

4.1 Flying Mechanism

Drones can be classified as three classifications according to how they fly:

i. rotating-wing or multirotor UAVs: These UAVs can linger over a specific area and can launch and vertical landing. However, compared to other UAV kinds, these ones have comparatively less mobility.
Additionally, because these UAVs must defy gravity, they need more energy.

ii. Fixed wing UAVs: These UAV types can glide through the air like passenger planes and can also transport large payloads. They may move faster than other UAV kinds of thanks to this flying style, but it also means that they must take off and land on a runway. Additionally, they are often more expensive in comparison to multi-rotor UAVs and are unable to hover over a specific area like other devices do.

iii. Hybrid fixed/rotary-wing UAVs: These UAVs combine the two aforementioned systems and have the ability to flip between them [21].

4.2 payload

UAVs are often categorized by civil aviation authorities according to their gross weight. According to their total mass, UAV systems are categorized by the Australian Civil Aviation Safety Authority (CASA) in the ways listed below.

i. Micro: Weighing under 100 g.
ii. Extremely tiny: Greater than or equal to 100 grams but less than or equivalent to 2 kilograms.
ii. Little: refers to a weight greater than 2 kg but less than or equal to 25 kg.
iv. Medium: Weighing between 25 and 150 kilograms but less than 300 kilograms.
v. Large: Weighing 150 kg or more [9].

4.3 Altitude and Range

The geographical location at which point a drone can be controlled remotely is referred to as its range (one hop). For small drones, the range can be anywhere between a few meters and hundreds of kilometers. In this context, "altitude" is related to the highest point a drone can fly, despite national laws. According to their altitude, airborne platforms can be broadly divided into two types:

low-altitude platforms (LAPs) are frequently used to support cellular communications due to their affordability and rapid deployment. Additionally, LAPs frequently offer short-range LOS linkages that can considerably improve communication performance.

High-altitude platforms (HAPs) Cellular connectivity can also be offered by objects like balloons. HAPs have a larger coverage area and a significantly longer flight time than LAPs. Although HAP deployment is more difficult, it is primarily thought of as a way to connect vast portions of the world's population to the Internet who are not currently covered by cellular networks.

4.4 Speed and Flight Time

While big drones are able to attain an astounding speed of 100 m/s, small drones normally cruise at speeds below 15 m/s. A UAV BS/relay's speed must be carefully evaluated if the trajectory necessitates numerous twists in order to optimize energy and spectral efficacy.
Table 1 lists typical drones and their characteristics to exemplify the weight-based classification used by the Australian Civil Aviation Safety Authority (CASA) [22].

Table 1 Features of various UAV types

	Micro (the weight≤100g)	**Very Small (100g<the weight<2kg)**	**Small (2kg≤the weight<25kg)**	**Medium (25kg≤the weight≤150kg)**	**Large (the weight>150kg)**
Prototype	Kogan Nano	Parrot Disco	DJI Spreading Wings S900	Scout B-330 UAV helicopter	Predator B
Weight	16g	750g	3.3Kg	90kg	2223kg
Payload	N/A	N/A	4.9kg	50kg	1700kg
Machine for Flying	Multi-rotor	Fix-wing	Multi-rotor	Multi-rotor	Fix-wing
Range	50-80m	3km	N/A	N/A	1851km
Altitude	N/A	N/A	N/A	3km	15km
Flight Time	6-8 min	45 min	18 min	180 min	1800 min
Speed	N/A	80 km/h	57.6 km/h	100 km/h(horizontal)	482 km/h
Power Source	Li-battery 160mAh /3.7V	LiPo Battery 25A 3-cell /2700mAh	LiPo Battery (6S, 10000mAh~15000mAh, 15C(Min))	Gasoline (Heavy fuel availability is discretionary)	Turboprop Engine with 950 shaft horsepower
consumption of power	N/A	N/A	Hover: 1kW. Maximum: 3kW	power generator for payload: 1.5kW	The engine: 712kW

				the engine: 21kW; Onboard	

5. OVERVIEW OF DIFFERENT COMMUNICATION PARADIGMS

UAV communications, also known as UAV-2-X communication, can occur between a UAV and another end point. While in flight, a UAV communicates with multiple entities. Figure 4 illustrates how we categorize four UAV-2-X communication endpoints:

i. Satellite-to-UAV communication: The operator must ascertain the position of the UAV in order to ensure safe navigation during Beyond Line-of-Sight (BLOS) missions. So, UAVs can create a satellite communication link, obtain their real-time GPS location, and then use the satellite to send it back to the GCS. Additionally, satellite communications offer dependable communication with large transmission bandwidth over great distances without established infrastructure.

ii. UAV-2-Cellular communication: Urban or rural locations, UAVs ensure a wide coverage area at high altitude and include cellular networks with allowing ground users to coexist to create a trustworthy communicating wirelessly. When integrating this, the UAVs can be used as ground or aerial User Equipment’s (UEs). alternatively, as airborne Base Stations (BSs). In their actions as consumer electronics, also referred to as cellular-connected They establish UAV-2-Cellular communication using UAVs. the ground pilot can communicate with the terrestrial base station UAVs can be directly controlled via cellular networks [23].

iii. UAV to ground control station (U2GCS) Communication: In this model, big UAVs can be connected to terrestrial or satellite cellular networks to provide network access for ground users. U2GCS communications, when UAVs are incorporated into the cellular network, are also frequently referred to as "network-connected UAV communications" depending on the role that UAVs perform. For instance, in UAVs with their own tasks, such as cargo delivery, video surveillance, streaming videos, and additional services, behave as novice users of aerial and connect to the cellular network via the already-existing ground base stations when they use cellular-enabled UAV communications. Aerial relays, which act as gateways for direct U2GCS communications and the opposite in UAV-assisted cellular communications, are used to connect UAVs to cellular networks in contrast [12]. Consequently, it is common to discover UAVs-to-ground communication connections for transmitting data from Aerial vehicle networks (AANET) nodes to ground stations and vice versa [13].

iv. UAV-2-UAV Communication: In the intra-swarm aerial wireless network, UAV-to-UAV communications can be extensively employed for data transfer, relaying, autonomous flying, collection, and other purposes. As a result, it will increase aerial coverage and improve spectrum efficiency and energy efficiency. Additionally, the weight of Lower transmission delay can be achieved by relieving the backhaul link [24]. Low-altitude platforms (LAP) or high-altitude platforms (HAP) are used to connect UAVs to other UAVs, whilst air traffic control (ATC), LOS, GPS, or beyond LOS (BLOS) are used to connect UAVs to the ground and to satellites.[25].

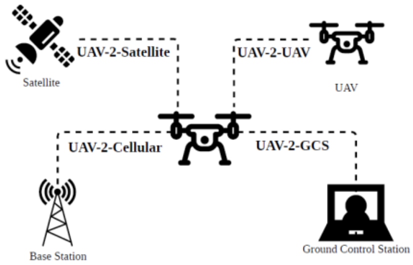

Fig.4 UAV-2-X communication

6. Wireless Networks Taxonomy

Regulations from the Institute of Electrical and Electronics Engineers (IEEE) classify wireless network taxonomy into two domains: The terms "adhoc networks" and "infrastructure-less networks" (ILN) are interchangeable with "infrastructure-based networks" (IBN). There are three varieties of infrastructure-free ad hoc networks: wireless sensor network (WSN), wireless mesh network (WMN), and mobile ad hoc network (MANET). The mobile ad hoc network is divided into the VANET and UAVCN subgroups [26]. The Internet of Drones (IoD) is a network architecture that gives drones in controlled airspaces access to navigational services. IoD consists of node-to-node and end-to-end services and applications. Inspections of industrial or infrastructure facilities, fleet monitoring, search-and-rescue operations, and system administration for delivering commodities are a few examples of the services that IoD can offer. Within the IoD, FANET zones can be utilized to build a multiple UAV system that connects independently and offers coordination for each drone. This generates better scalability, versatility, and permits drone self-organization as compared to a system with a single drone. Without a central controller, FANET allows for communication amongst UAVs. As both heterogeneous and homogeneous UAVs work together to provide a flexible network environment, The structure of the network is unaffected by UAVs entering or leaving the network. With similarities to both the mobile ad-hoc network (MANET) and the vehicular ad-hoc network (VANET), FANET is a subset of those networks. VANET is a subset of MANET in which the nodes are vehicles in motion. MANET is a network structure composed of mobile or static elements. Some FANET features differ from those of MANETs and VANETs because UAVs frequently fly at high altitudes and speeds of over 100 mph [27]-[28]- [29]. Wi-Fi (IEEE 802.11), ZigBee (IEEE 802.15.4), Bluetooth (IEEE 802.15.1), and other widely adopted short-range wireless networking technologies can be seamlessly integrated into a FANET system. These technologies provide spectrum-free frequencies and wireless networking in the immediate vicinity [30].

In a MANET, nodes and devices can freely and independently move in all directions. In MANET, there is no infrastructure (base station) that enables every network node to serve as a router. The routers have complete freedom to move at will and arrange themselves. The main application of a wireless ad hoc network is MANET. In MANET, additional collaborating nodes in the generated wireless ad hoc network move at random. It is highly challenging to build a MANET for networked devices to migrate dynamically since the communication link between the two devices fluctuates. However, the fundamental conflict of establishing a MANET is suspended to control the content modification traffic on the road.

Vehicular Ad-Hoc Networks (VANET) the networks that enable wireless intravehicular connection between electronic devices and automobiles in most current autos. However, many contemporary cars have communications devices and vehicles. The communications network for the vehicle is not yet operational, though. Technology for vehicle ad hoc networks is developing to enable vehicular transmission. VANET is considered a subset of MANET, with the exceptions listed below. Here, the accessible nodes are automobiles. As a result, there are limitations on how nodes, or the vehicle, can travel. VANET, however, is compatible with some fixed infrastructure. This architecture can handle some VANET services and offers fixed network connectivity due to its constraints. To create a wireless communication network with a hybrid design, Communication operators, content service providers, or governmental entities may all install the VANET network. The European Car Communication Consortium (C2C-CC) has expanded the VANET architecture, which presently consists of three domains: vehicle-to-road communication (the infrastructure domain), in-vehicle communication (the in-vehicle domain), and workshop communication (the ad hoc domain). During in-vehicle communication, the On-Board Unit (OBU) and the user terminal exchange information.

The user terminal may consist of a specialized device, or a virtual module contained within the OBU. You can communicate using either a wired or wireless connection. The workshop communication (ad hoc domain) incorporates both OBU-to-OBU and OBU-to-RSU-to-RSU communication. Both single-hop and multi-hop modes of communication are conceivable. Dedicated Short-Range Communication (DSRC) enables the OBU to communicate with infrastructure, such as satellites, hot spots, 3G and 4G networks, etc., in order to obtain Internet access [31]. Node mobility, node density, topology changes, radio propagation model, power consumption, network lifetime, computational power, and finally localization are the primary factors that must be considered when working on or studying these categories. All of these factors are compared in the table 2 [32].

7. Integrating UAVs into cellular networks

Unmanned aerial vehicles (UAVs) have become more widespread in both military and non-military uses in recent years. where UAVs are incorporated into the cellular network as new aerial users that access it from the air [8], [33]–[35]. Remote control of UAVs with beyond-LoS connectivity is achievable for pilots or operators due to the nearly universal availability of terrestrial cellular networks. Furthermore, because cellular-connected UAVs may make use of already-existing terrestrial cellular base stations rather than constructing brand-new infrastructure specifically to enable UAV communications, they offer a financially advantageous solution. In order to incorporate UAVs as aerial cellular users, cellular networks must be able to reliably and low latency facilitate command and control message exchanges between ground pilots and UAVs, while also meeting the diverse payload communication needs of individual applications. Nonetheless, several significant obstacles need to be overcome before the present networks of cells can be fully utilized to aid users of UAVs.

Specifically, since the primary purpose of present cellular networks is to support users on the ground, whose movement, operating altitude, and channel characteristics differ greatly from those of UAV users, it is not possible for current cellular networks to ensure an even 3D layer in the sky. Furthermore, Extensive research and modeling have demonstrated that notable aerial-ground interference is an important problem for UAV with cellular connection [36]–[40].

For 5G communications, they can be fitted with multiple-inputs multiple-outputs (MIMO) systems, Whose planning and assessment of performance demand the evolution of a realistic channel model[41]. The massive multiple input multiple output (MIMO) system is a new technology that has the potential to scale up to meet the high throughput demands of the cellular systems of the future. Multiple single-antenna terminals are simultaneously served by base stations with a relatively a great deal of antennas in a massive MIMO cellular system (see Fig. 5). Coherent closed-loop beamforming concentrates energy into a restricted area of space, minimizing interference. Additionally, it significantly increases energy efficiency and decreases latency. Utilizing channel reciprocity, Massive MIMO employs time division multiplexing (TDD) to prevent channel state information feedback [42].

(FD-MIMO) Full Dimension MIMO The full-dimension multiple-inputs multiple-outputs (FD-MIMO) technology is one of the key ones being researched right now in mobile communication. The method has the capacity to deliver

Table 2 Three different forms of ad-hoc networks are compared.

Points of comparison	MANET	VANET	FANET
Nodes mobility	Low	High	Very high
Mobilities model	arbitrary	Regularity	Regularity for predetermine paths, But special mobility

			model for Autonomous multi-UAVs system
Nodes density	Low	High	Very low
Topologies change	Slowly	swift	swift
Powers consumption and networks lifetime	Energy efficiently protocol	No required	Energy efficiency for mini UAV; however not require for tiny UAV
Computationally power	Limiting	High	High
Localizations	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU

extremely high and Stable throughput. a large MIMO mobile base station's many antennas may be used by the system to reduce a UAV communication system's interference. For a UAV communication system with a cellular connection, a multiple access technique is a crucial component. Now, researchers have proposed a number of access techniques, Beams Division Multiples Access (BDMA), the Non-Orthogonally Multiples Access (NOMA), Time Divisions Multiples Access (TDMA), and Orthogonally Multiples Access (OMA) are all examples. But both academics and industry have paid exceptional attention to NOMA [43].

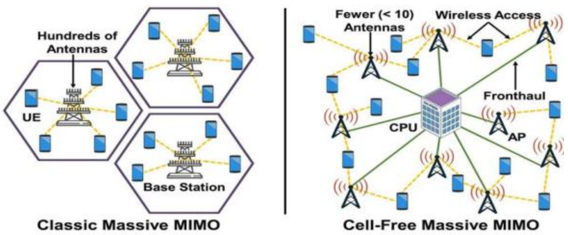

Fig. 5 Massive MIMO cellular system

8. Applications of UAV Application

Future wireless networks will not limit mobile users to terrestrial mobile stations as UAVs become more widely available. There are a variety of uses for UAVs in wireless networks, including surveillance and Internet-of-Things (IoT) networks, vehicle-to-everything (V2X) communications, smart cities enabled by UAVs, traffic unloading in hotspots, and UAV swarm networks in disasters. Typically, unlicensed bandwidth, such as the 2.4 GHz and 5.8 GHz ISM bands, is used for UAV communications. Depending on the throughput and range requirements for small- and medium-range UAV applications, multi-hop 802.11 or Zigbee technologies are taken into consideration. Additional wireless technologies and spectrum need to be taken into account for high throughput applications [44].

Natural disasters occur frequently and have a significant impact on human life and progress around the planet. Understanding a disaster's nature, stages, and components is crucial for responding to various natural disasters and creating workable disaster management approaches and methods. Preserving human lives during a crisis is the most crucial problem that needs to be resolved. The first 72 hours following the accident are the most crucial in this situation, so Search and Rescue (SAR) efforts must be carried out quickly and effectively. The International Search and Rescue Advisory Group (INSARAG) publishes a set of guidelines1 and offers an international SAR protocol and methodology, stating that the SAR procedure must be carried out by teams. A team leader oversees assigning tasks and making local decisions, and an incident commander oversees the coordination of all team activities. There are four basic steps in the execution of a standard SAR mission: The commander creates the search area and divides the first responders into scouts and rescuers. Communication problems amongst rescuers are reduced by a more focused search area. The second step is to set up a command post in the search area. Third, the command post receives the findings from the scout teams. Fourth, rescuers gather data from the command station to determine how to proceed [45].

Currently, drones are used to deliver commodities for consumption, fast food, groceries, medications, and other supplies. Currently being utilized for delivery, drones carry a payload that is up to 2.5 kg, which is roughly the same weight as 83% of Amazon's products. Fedex's typical delivery package weighs less than 5kg as well. This technological paradigm will undoubtedly enable heavier packages to be delivered in the upcoming years. While this drone delivery concept is still in its infancy, major market players including Amazon, DHL, Matternet, and Google have already begun testing a prototype drone for package delivery. When compared to alternative ground-based networks, this technology offers on-demand distribution and is affordable.

Examining a building's structural damage after Engineers may now rapidly and correctly get the raw data, they need with drones equipped with cameras and other communication devices, which once required a risky and time-consuming operation to gather after a military attack or a natural disaster. Unmanned aircraft may maneuver through unforeseen, hazardously small areas for people. Assessing the extent of infrastructure damage can be done by locals [46].

The Internet of Thing (IoT) is a system of different sensors and terminal devices connected by the internet, with the targets of connecting everything and advancing the industry. The Internet of Thing (IoT) is now widely used in many industries that improve and develop people's lives, including telemedicine, industrial manufacturing, environmental monitoring, and more. It is expected that by 2050, more than a billion devices will be connected to the Internet worldwide. Due to the tremendous amount of data that these countless numbers of gadgets will produce and need to exchange across wireless networks, existing networks will be under a great deal of strain. In addition, the inability to transmit and interpret data produced by sensors and IoTs device in a timely manner is a major hindrance to the progression of IoTs. Due to their versatility, unmanned aerials vehicles (UAV) may be easily positioned to offer extra network materials in regions with a high communication congestion or inadequate interaction. UAV is 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. UAVs can carry out a wide range of duties, including video surveillance, data collection, and cargo transportation, thanks to their many sensors. In addition, they are resistant to most calamities due to their capacity to fly, which allows them to adapt to a variety of situations. Due to their high mobility and adaptability, UAVs can be quickly deployed in response to service demand [47].

9. Discussion

In recent years, unmanned aerial vehicles, or UAVs, have become more common in both the military and the civilian sector. Unmanned aerial vehicles, or UAVs, are used for many different things, including target identification, power grid inspection, and battlefield surveillance. There is a great deal of interest in using UAVs to create mobile 5G networks because of the expanding demand for social network services and the widespread use of 5G networks. Data transfer across a larger region could be made possible by UAV-based stations supporting conventional communication networks. Building conventional antenna infrastructure is more expensive and less efficient than using this relay transmission technology. Using UAVs to build network stations in remote places can save money since these UAV-based stations are easy to move and reconfigure, which reduces resource waste. When compared to terrestrial base stations, UAVs offer a more affordable deployment alternative and a faster reconfiguration of the network system, all while guaranteeing dependable connectivity with low latency.

But in some important cases, having direct connection between UAVs and avoiding terrestrial network infrastructure turns into a vital enabler. These scenarios include UAV swarm autonomous coordination, collision avoidance strategies, UAV-to-UAV transfer operations, data transfer duties, and information collecting procedures. Like terrestrial device-to-device (D2D) communications, UAV-to-UAV (U2U) communications could also have an impact on energy and spectrum efficiency, increase cellular coverage, and reduce backhaul capacity requirements.

Communication platforms facilitated by UAVs and UAV communications connected to cellular networks are the two categories into which UAV communications applications fall based on the services they offer. Furthermore, UAVs can be roughly divided into two groups according to the kind of wing they have: rotary-wing and fixed-wing UAVs.

Numerous assessments have been carried out to investigate the newest UAV communication technology as well as the problems associated with UAV communication networks. These surveys shed light on the most recent developments in UAV communication technology as well as the difficulties UAV communication networks confront. The surveys cover topics including unmanned aerial vehicle communication networks, routing protocols, quality of service, power concerns, UAVCN applications, design issues, and untapped research areas in the future that might be investigated further to further examine this technology.

Conclusions

In this survey, our main concerns are communication systems, UAV network characterization, UAV integration into cellular networks, and an overview of several communication paradigms. The main conclusions and insights from the paper's core findings are summarized as follows:

1. UAV communication systems facilitate control commands and flight data exchange. They necessitate a long-distance, reliable, bidirectional link and demand a UAV-specific channel model. The primary UAV component is the microcontroller, managing various functions, while sensors and GCS provide vital data.

2. Use Cases of UAV Wireless Networks: UAV Base Station (BS) creates backhaul linkages from satellites, terrestrial base stations, or nearby UAVs to provide seamless connectivity and expand service coverage in congested or emergency locations. UAV Relay Station (RS) Serves faraway users without direct communication links, increasing network capacity without degrading performance. UAV aggregator gathers and disseminates data from scattered wireless devices, such as sensors, in applications that can tolerate delays.

3. UAVs encompass both mechanical and electronic components, and they rely on complex operations. UAVs can be divided into groups according to a number of criteria, such as wing type, weight, flying height, and flight mechanism.

4. UAV communications, known as UAV-2-X communication, involve interactions between UAVs and various endpoints.

5. Infrastructures-Base Network (IBN) and Infrastructures-Less Network (ILN), commonly referred to as ad-hoc networks, are two domains for wireless networks.
WSN, WMN, and MANET are examples of ad hoc networks without infrastructure. Subgroups of MANET called VANET and UAVCN are further divided.

6. UAVs are increasingly utilized in military and civilian applications and can incorporate multiples-input multiples-output (MIMO) for 5G communications, requiring realistic channel models.

7. UAVs anticipate playing a significant part in wireless networks of the future, expanding beyond terrestrial mobile stations to serve various purposes.

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