Unmanned aerial vehicles: A review

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ARTICLE INFO

ABSTRACT

The lightweight Unmanned Aerial Vehicle (UAV) flight activities are constrained, particularly in the UAV range or activity span and perseverance, by the strategic correspondence link capabilities. This paper tends to the different overlap issue of trading off a set of mission prerequisites, the UAV execution parameters, and strategic credibility; thus compromising between the communication load characterized by a crucial, communication link transmitting power necessities, power accessibility onboard UAV as a weight-restricted parameter, and the UAV security.

1. Introduction

In current years, an outcome of decreased sizes and weights concentrated charges and amplified functionalities of various sensors and devices. The Unmanned Aerial Vehicles are attracting progressively general trendy varied variety of internal submissions (atmosphere monitoring, surveillance, photography, search-and-rescue, etc.) [1]. Through the marketplace develops and the diversity of applications increases, additional necessities are present-day being compulsory in spreading the flight variety and growing adaptability toward complex assignments of UAV structures [2].

UAV stands for Unmanned Aerial Vehicle, which is commonly considered to be a drone or an aircraft with no pilot on board. UAVs can be remote-controlled aircraft [3]. The unmanned aerial vehicle contains cameras, sensors, communication belonging as well as other payload devices [4]. It was created for military usage, and civilian usage to protect the border. UAVs are widely used in the military [5]. Unmanned aircraft system manufacturing was started by the United States department of defense (DOD) in 2005 [6]. Presently, leading UAV manufacturing countries are the USA, Israel, China, Iran, and Russia [7]. Rustom series of Indian UAVs are under development [8]. The Building of a UAV is easier, it is less expensive and it can be created at a reasonable price. UAVs are made of essential components.

There are two categories of UAV.

ü Fixed Wing UAV
ü Rotary wing UAV

Fixed and Rotatory wing UAV consists of their strength and weakness.

1.1. Fixed wing UAV

Fixed-wing UAV drones have gained popularity in military and defense applications, and fixed-wing has high speed and heavy payload [9]. They are not suitable for stationary applications, because fixed-wing UAVs can't do a close inspection. Fixed-wing UAV

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drones use a wing to lift themselves in the sky. Fixed-wing drones only use energy to go in a particular direction rather than remaining in one place in the air. The fixed-wing drone can go on long distances and cover larger areas. And fixed-wing UAV drone can spend up to 16 h time in the sky because a fixed-wing UAV drone uses a gas engine rather than using an electric engine.

1.2. Rotary wing UAV

Rotary-wing UAVs is known as quadcopters, hexacopter, tricopter, and helicopter are the kinds of rotary wing UAV [10]. Rotary wing UAV drone is designed for monitoring the ground situation from the air, for instance, detecting and tracking border state, surveillance of military equipment, and so on [11]. It has been specially created for remote surveillance. Rotary-wing UAV drones have limited speed and payload rather to fixed-wing [12]. They can stay in a stationary position in the sky. This UAV can do a close inspection. The choice of UAV depends on the uses.

UAVs are demonstrated to be a greatly adaptable stage for a variety of applications [13]. With propels in computation, sensor, communication, and organizing advances, the utilization of UAVs for military and civilian regions has gotten to be greatly well-known within the last two decades [14]. It could be a moderately simple errand to utilize UAV in an unmanned aerial framework for expanding communications extend and information conglomeration capability. For occasion, if all communication frameworks are destroyed in a perilous zone, and there is a sudden got to make organize between rescue groups, at that point UAV can effortlessly be utilized as a communication transfer between rescue groups to successfully arrange the rescue.

This paper will address the topic of UAV and the start of the art of UAV. Further, it will explore UAV communication system design, a ground control station (GCS), sensor-based data processing, applications, and security. Limitations of previous work and challenges of future work are also discussed. Further, we discuss open research issues for future research direction and development in the field of UAV systems.

This paper is organized into 8 sections. Section 2 is based on the UAV communication system, and Section 3 provides details of how UAVs are controlled by the ground control system. Section 4 provides data collection from sensors and processing by using UAV, Section 5 presents the detail of applications, and Section 6 is based on security. Section 7 provides an open research issue, and finally, in Section 8 we conclude our work.

2. UAV communication system

UAVs are made out of an assortment of fundamental parts [15]. While all segments agreeably play out a particular reason that adds to operational flight, the most significant segment is the interchanges frameworks. UAV interchange frameworks help rambles and their administrators to accomplish their ideal outcomes. Without these frameworks, not exclusively would unmanned flight be viewed as ridiculous, however, it would likewise make gathering and transmitting flying visuals and correspondence information unimaginable [16].

As UAVs keep on situating themselves as the prevalent airborne information assortment stage over a wide assortment of ventures, their interchanges frameworks develop relatively insignificance. Without exceptionally versatile and solid interchanges frameworks, administrators are left with a distinct weakness in getting flying visuals and information [17]. The way things are, RF correspondences are the most enhanced answer for dependable UAV interchanges frameworks [18]. A mix of their little size, weight, limited force utilization, and strong correspondence interface makes them the most appropriate answer for most non-military personnel UAVs.

Regular citizen UAV correspondences frameworks normally work on frequencies of 2.4 GHz and 5.8 GHz [19]. UAV correspondence frameworks work by utilizing one recurrence to control the elevated vehicle starting from the earliest stage of a remote pilot while the other recurrence is utilized to the bar or hand-off First-Person View (FPV) video. By using high-caliber, solid interchanges join, regular citizen UAVs can hand off airborne visuals and information to those on the ground easily, while as yet staying in flight.

In resistance applications, various sorts of automatons are executed. Resistance rambles fluctuate extraordinarily from non-military personnel UAVs, as their missions are much of the time longer in length or require striking abilities notwithstanding giving flying visuals of the combat zone underneath. One worry in the utilization of automatons in barrier applications is the event of sign sticking. At the point when sign sticking is utilized, this cuts the remote pilot and activities based on visuals of what the automaton is seeing. While it appears to be an appalling situation, most barrier rambles are built to come back to base after lost correspondence contact. Barrier administrators have discovered another answer for potential sign sticking – repetitive onboard route frameworks that do not depend on GPS [20]. By disposing of accessible GPS information, sticking turns into an inconsistent event, permitting protection automatons to finish their missions and come back to base securely.

2.1. UAV communication design system

The subject of the plan is a lightweight hand-propelled UAV with the most extreme take-off mass of up to 7kgs [21]. The UAV's reason for existing is insight, observation, surveillance, and target following for the help of detachment and friends activities. Back-to-back, the UAV will be outfitted with a balanced camera payload [22]. The knowledge and observation missions can be flown self-sufficiently, along these lines the payload symbolism and flight progress down-joins are the prime capacities (assignments) of a UAV's correspondence framework Stealthiness of a UAV ought to be verified by its shape, shading, and insignificant warm and commotion outflows [22]. Since the lightweight UAV will have just short continuance in the zone of battle tasks because of the weight-limited onboard power accessibility, electromagnetic stealthiness is not envisioned. Counteractive action of disguise assault on UAV, along these lines, UAV control by substances with different expectations, counteractive action of assault on UAV correspondence

streams trustworthiness, for example, counteractive action of information inclusion, change, reordering, answer or deferral, as well as protection of the correspondence classification (listening in) is foreseen with a reasonable lightweight COTS recurrence jumping handsets, and confirmation techniques between the UAV and its UC.

- Parts Used for better UAV communication:
- We want better UAV communication related to the situation, we will have to use the best part for great connectivity to reach the proper signals.

Sensor:
The sensor is better for our UAV communication application because this sensor is very small and lightweight and has less battery consumption [23].

ü **RF communication:**
RF frequency converters and RF filters and RF Bi-directional devices are also essential for UAVs [24,25].

ü **Antennas:**
There should be high-performance antennas for unmanned aerial vehicle platforms.

ü **Propulsion:**
Engines, motors, LiPo batteries, propellers, and so on, these accessories help your project in moving..

ü **Drone frame:**
This frame is composed of nylon and carbon fiber materials [26]. Because of this, it is a stronger and more suitable weight. The most essential component is the communication system. The UAV communication system assists drones and helps the operator to obtain the desired result. If we do not use this communication system in our drone, it will be difficult for us to achieve unmanned flight. We cannot give information about aerial and visual communication without this communication system. And it will be impossible for us to transmit data by making a collection of data either without this system. The civilian UAV communication system operates on frequencies of 2.4 GHz and 5.8 GHz. UAV communication system is work by using frequencies to control the aerial vehicle from the ground.

The author discussed the services of the UAV so that the Aerial communication platform can work on the UAV, and it cannot support the transmission of information in the Internet of Things (IoT) [27]. However, it consumes less power in wireless devices. On the other hand, Orthogonal Frequency Division Multiplexing (OFDM) can be enabled in the network where two subcarriers can be divided into transmission information and energy harvesting. The OFDM can UAV-Enabled network, so the sub-carriers are shared within two groups for transmitting the information and energy reaping. Similarly, Simultaneously Wireless Information and Power Transfer SWIPT technology is being proposed by the UAV trajectory and communication design scheme. Furthermore, the author used the divide and conquers technique to solve the original problem. The first Sub-Problem depends upon the user scheduling, subcarrier, and fixed UAV trajectory is enhanced power allocations. The second problem has a fixed UAV trajectory, which enhanced the user scheduling, subcarriers, and power separation. After that, both problems are solved step by step until the predefined accuracy is achieved. The author worked on the simulation results, so the proposed algorithm is working correctly. However, it does not guarantee the average harvested energy in the proposed scheme, but it also gives the best normal achievable rate compared to other flight modes.

UAV enabled Network Communication for further consideration, where Employing Non-Orthogonal-Multiple-Access (NOMA) for many users [28]. The total power has been taken maximum and minimum ratio related to the total power and bandwidth with UAV height and width ray limitations. To solve the formulated problem, they have created the Path-Following Algorithm. Moreover, the Maximum and Minimum rates have been calculated for the orthogonal multiple access (OMA) and dirty paper coding (DPC), so the developed path following the algorithm has been solved. Furthermore, they have calculated the results, which show the NOMA outclass OMA and achieves results like DPC. After that, all parameters are connected jointly and observed together. When those results are compared with all parameters and make their interest in combined optimization, they have faced such types of issues and tackle them with inner convex. Based on these issues, they have proposed Path-Following-Algorithm for making a better solution. Regarding these solutions, they have collected positive and best results. An essential thing in these solutions they have used UAV-Enabled for physical layer security within the communication. They have focused on most of the things as necessary in communication.

The UAV is driven by solar energy that enables multiple terrain users to use reliable communication services [29]. To enhance the system's total performance within a specific period, they analyzed the 3D aerial trajectories' standard configuration. The wireless resource allocation and initially considered an offline resource allocation method as a performance benchmark, presuming not having a considerable understanding of the channel gains. Algorithms are formulated as a non-convex mixing integer optimization problem that considers an ultimate energy storage capability, aerodynamic power usage, solar power production, and users' quality of service (QoS) demand. Although the optimization problem has not been convex, it can be efficiently resolved using monotonic optimizations to achieve optimum 3-dimensional trajectory and power and subcarrier allocation strategy and then concentrate on designing online algorithms where only real-time and statistical information about the channel gains are needed. The offline scheme drives the optimal online algorithm for allocating resources. It requires a high complexity of computing systems, therefore needed a sub-optimal iterative online scheme with low complexity, and based on successive convex approximation. The simulation outcomes show that both of the online programs provide a similar approach to the performance of the offline benchmark scheme and greatly surpass the two baseline schemes.

3. UAV ground control station (GCS)

Now missions are search-and-rescue and investigation, systems of UAV are typically obligatory to work in trendy complex environments although still presence able to preserve continuous communication with the ground controller station intended for the resolve of monitoring, reporting, and control [30]. Intended for instance, in high-density or precipitous urban areas, the communication between UAVs and the GCS can be effortlessly interrupted, producing the GCS to misplace real-time statistics feedback after the UAVs, foremost to task failure [31]. Besides assignment requires extended flight variety, the communication capacity also is intermittent by the detachment.

Commercially obtainable up till now economical UAV communique solutions but have several confines that potentially delay their extensive application. Initially, the communication variety of main public UAV communication resolutions is reasonably short. Telemetry modules, for instance, 3DR, XBee, Sik2, and extra Wi-Fi modules, which are mutual options for public UAVs, have communication varieties that are incomplete to insufficient kilometers [32]. Second, this one is problematic to find stable information links as soon as obstacles, for example, tall buildings, trees, or mountains distinct the UAVs & GSC. In circumstances discussed overhead, it can be problematic to broaden the mission through only one UAV organized, though keeping charge and organization intricacy necessities encountered.

To connect the compensations of UAVs in the following circumstances and minimize problems at a similar period, a substitute resolution is to organize a multi-UAV organization, which might utilize inter-connectivity amongst manifold UAVs to preserve continuous statement among each UAV and minced control station. UAV communication transmits a solution that was established, that usages communication and directing to encompass communication variety and avoid problems by low-slung charge [33]. Impartial stood to progress and assessment proof-of-concept two-UAV organization, which established the capability to communicate wireless communication. This structure individually contained dual UAVs, then its strategy might put up adding additional UAVs. The edifice usages unique UAVs by way of statements to communicate a point and permits additional UAVs to function in parts wherever an unswerving message with a broken-up regulator cannot be recognized. This formation permits statements to stand recognized across difficulties or else ended reserve more than the diversity of the on-the-ship wireless transceiver, together that will be established in-ground tests far along. The distinctive application situation of the scheme is revealed. The organization uses a single UAV as a statement to communicate opinions and permits additional UAVs to work in ranges wherever communication through a pulverized regulator cannot be recognized.

UAV stands for an unmanned aerial vehicle, this is a simple-view unmanned aircraft in which aircrew is removed and instead of its computer systems and radio-link are used. In reality, it is more complex than what is shown and this aircraft must be designed properly and perfectly for more efficiency. Although aircraft is the most important part of it.

The main components of a UAV (unmanned aerial vehicle) are discussed below:

- A Control Station (*CS*), which operates the system, actually it is the interface between the operator and the rest of the aircraft system.
- The Aircraft carrying the payload which may be of many types.
- The communication system between the CS (transmits control system input to the aircraft) and resend the data of payload (*which may be of any type*) to the CS (control station) this communication is done by the radio transmission.
- Some extra equipment which may include maintenance and transportation items.

3.1. Development of GCS

GCS is a system that is a human portable and easy-to-use station [34]. It is specially made for controlling the UAV and communication system and antenna. Its usual dimensions are $360 \times 96 \times 96$ inches, triple-axle, A trailer is required which is used for loading and unloading the aircraft, and no other species used this trailer [35]. The trailer is consist of an Uninterrupted Power Supply (UPS), an Environmental Control System (ECS) used for controlling thermal, providing air supply, and cooling, considering the main part of the aircraft, a pilot operator, a payload operator, workstations, synthetic aperture radar (SAR), Data exploitation, communications terminal, radio links, a camera for recording, because of the absence of onboard pilot on the crew, the camera provides the live imagery recording of all the missions. This camera is attached to GCS. Power to the GCS is supplied by either commercially available power or by 35 kW generators.

The Pilot and payload operators (PPO) are the main part of GCS because they are providing a first-hand response to the air vehicle and sensory payload [36]. Data Exploitation Mission Planning and Communication (DEMPC) are used for communication [37]. The DEMPC workstations are used for the exploitation of data, mission planning, monitoring of the payload, and management of the system.

Synthetic Aperture Radar (SAR) works for monitoring and controlling the SAR data like limited exploitation [38], or the region-wise location either in which the region's boundary vehicle is located. For voice/data Ground Control Station used High frequency, Ultra High Frequency, and Very High Frequency (HF/UHF/VHF). For hardware, connectivity stations used the TROJAN SPIRIT II satellite communication terminal.

SATCOM is used for the intelligence connection of the GCS with the vehicle [39]. It has the feature of Automatic Target Recognition (ATR) technology, using Synthetic Aperture Radar (SAR) so that it identifies the target from the aerial platform on the battlefield; it is controlled by the Ground Control System (GCS). It is the requirement of the military for the capability of finding the deep strike objectives.

One GCS controls one predator. The basic plan was to make a GCS that controls the two predators at one time. One for Vehicles and one for Ku Band Link (it is the part of electromagnetic (EM) spectrum in the microwave ranges of frequencies from 12 to 18 gigahertz GHz), but it is not included in now a day's plans.

The development of the Ground Control System is now focusing on the ATR capability so that they are capable of imaging sensors onboard an unmanned aerial vehicle (UAV) platform [40]. This system makes capable of the GCS giving Day/Night all-weather imaging at wide-area coverage to expect the search of the targets/enemies in any weather. It will be made by unique algorithms to automatically work with 99% efficiency.

Now successfully Unmanned Aerial Vehicle (UAV) is made that can detect and identify and locates six (6) high-value mobile targets at a time using a real-time strip map fine resolution Synthetic Aperture Radar (SAR) with onboard Automatic Target Recognition (ATR).

The author has developed an android application named Ground Control Station, which displays an easy graphical interface for controlling the Unnamed Aerial Vehicle (UAV) [41]. In this application, the author has enhanced the quality of function so that the user can easily monitor GCS media. One of the most exciting things in GCS is to provide navigation information to easily find out the UAV device's location on the map. After that, it can be configured as a flight controller like PID. For sending and receiving the data of both devices in half-duplex, the application can connect to the Multiwii-Flight-Controller. The author has tested the GCS, where he gets 96.12% data accuracy with a precision level of 0.7%. So the android application of GCS works accurately. Moreover, the GCS application's detailed functionality is to navigate by showing the location based on one longitude and latitude data. After that, the GCS application has the IP Camera which can be connected through any local Wi-Fi connection. The author has measured the coverage of that Wi-Fi signal, so it found the low coverage where he has pointed some range like 0–100 m.

The internet of things (IoT) has usually been a massive load of data and a broad range of coverage. Mobile-Edge-Computing (MEC) and UAV-Base Stations have recently appeared as exciting IoT technologies [42]. MEC-Based data processing network has been recommended. On the bottom layer, distributed sensors with local information produce raw data. UAV-BSs are used to gather data and execute initial data processing phases when moving as MEC servers. A central cloud obtains analyzed findings and carries out further assessments. The edge nodes can help stabilize delays to ensure data freshness for online processing requirements. Besides, restricted onboard energy also imposes limitations on the capacity to manipulate the edges. In low data rates, the amount of edge processing for energy efficiency is limited. With high data rates, bandwidth would be intelligently reserved for edge data deposition. Although hovering UAV-BSs has provided a broad and versatile range of services, this leads to a route planning dilemma. This issue is acknowledged, and comprehensive enhanced learning is applied in this article to design an algorithm for online route planning. Taking environmental measurements as inputs, a CNN network is equipped to forecast incentives for behavior. Its usefulness is confirmed in the enhancement of service coverage through simulations. The outcome would assist with the analysis of big data in future IoT [118,119].

4. UAV sensors based data processing

Within the UAV based information collection, there are three sorts of information are collected such as video stream, telemetry, and ancillary information [43]. Since the collected video is MPEG based encoding stream, to begin with, It should be encoded [44]. For the telemetry information which is recorded by GPS or INS (Inertial Navigation Framework) sensor, they are portrayed with a distinctive reference outline and require hence formally dressed [45]. Moreover, to pick up well-symbolized GCPs for move UAV framework or precision estimation of made orthoimage, the USGS DEM (Digital Height Show) and USGS DOQQ (Digital Orthophoto Quarter Quadrangle) reference picture, These are diverse in both outline venture and determination ought to be co-registered so that the intelligent estimation of 3D GCPS (Global Climate Points of view Framework) can be executed.

Basically UAV is based on five sensors;

4.1. RGB sensor or camera

Unmanned Aerial Vehicle (UAVs) is inaccessible controlling plane models and RGB cameras installed on the UAV, the cameras alongside the route sensors, Such as GPS or IMU constitute vital components of the UAV surveying system [46,47]. There are numerous ranges of RGB cameras accessible within the advertisement and are utilized for diverse applications. Selecting fitting RGB cameras for the installation on UAVs can be a key to victory. There are some common parameters for selecting RGB cameras. This incorporates the focal point of the camera (better focal point with less geometric mutilations), determination of the camera, and quality of Charged Couple Device (CCD)/Complementary Metal Oxide Semiconductor (CMOS) chips (pixel measure and clamor level).

4.2. Multispectral sensor or camera

Multispectral cameras are lightweight [48]. They are one of the vital commonly utilized sensors in expansion to RGB cameras within the UAV sensors family. The work of this sensor is for experts on vegetation and agribusiness [49]. This camera is utilized to see the water level in farms such as leaf-level disease assessment [50]. An incredibly good thing about the multispectral sensor is to pick up information with tall determination (way better than 30 cm Ground Testing Separate (GCD)) that is regularly not feasible in conventional multispectral [51]. It is distinctive from RGB cameras, as a rule, multispectral cameras come with higher fetches due to extra equipment required for wiring extra groups to the RGB groups.

4.3. Hyperspectral sensor

Hyperspectral sensors are utilized to capture pictures with hundreds of limit groups (5–10 nm transmission capacity) [52,53]. Most of the hyperspectral sensors are direct cluster cameras [54]. Hyperspectral sensors capture tall volumes of data which are greatly valuable for numerous applications [55]. More often than not, lightweight hyperspectral cameras come with half unearthly ranges (400 nm to 1100 nm or 1100 nm to 2500 nm) as compared to aerial hyperspectral cameras. It is not troublesome for UAV based Hyperspectral sensors as with a few exertions in the flight plan and at the cost of the restricted ground scope. The determination of procured pictures can reach up to 2 cm to 5 cm levels or lower.

4.4. Thermal infrared sensor

The sensor is additionally lightweight [56,57]. These are of the mid-range inactive sensors whose wavelength is between (3um to 35um). They are majorly utilized within the measurement of surface temperature and thermal outflows estimation. The fundamental issue of motor temperature and emissivity assurance is through the concentration and its conveyance. The utilization of thermal sensors is regularly utilized for real-time with an earlier choice of the qualified capture rate [58]. Thermal information can be utilized for numerous agrarian and natural applications and others utilize the thermal camera.

Hypothetically, the geometric demonstration of a thermal camera is entirely proportionate to that of a standard point-of-view camera [59]. On the inverse hand, the warm film commonly goes beside a parcel of fewer textures than the RGB pictures and modern photogrammetry or structure from the movement strategy can come up short since of the deficiency of interest points. Subsequently, once the geometric perspectives of the camera square measure concerned, it's counseled to claim an RGB camera stamp and stuck relative to the thermal camera and take pictures at the same time for the utilization of default the postures of the thermal camera.

4.5. LIDAR

LIDAR (Light Detection and Ranging) Sensors are moreover known as one of the foremost exact ways for geometric information picking up [60]. These sensors are broadly utilized in ranger service, Social legacy, and Building Data Modeling (BIM). The portable, the scholarly world, and earthly LIDAR these days have been made in both the industry and the scholarly community. The GPS or IMU (Inertial Measurement Unit) sensors in UAVs are frequently wrong concerning the sensor determination, so that's why the stage is additionally more unstable when flying. In this way, indeed with well-calibrated light-weight LIDAR sensors, the gotten reason clouds' precision is generally low. It is detailed that profoundly exact UAV-borne LIDAR frameworks are as a rule coming with differential GPS stations [61]. Where the tall exactness GPS estimations are gain able. The fetching of LIDAR sensors is generally low.

It is illustrated that UAVs are commonly used in several fields, and formation flights for UAVs are also steadily introduced [62]. However, several commonly-used UAVs are still hard to handle with the distributed theory of formation control. These models and control laws have been checked and validated in MATLAB/Simulink and exported to C++ code and implemented in the Qt-based simulation framework and Ground Control System (GCS) with the manual disruption of the communication. The simulation framework offers UAV state data, and the GCS depicts it as Human-Machine-Interface (HMI) for presenting state data and implementing control laws for formation flights. Any UAV can perform formation flights unchanged under centralized GCS control. The formation control algorithm is strongly correlated with the network topology, and a virtual-leader-based consensus formation control algorithm is implemented with a centralized structure. The GCS was responsible for the formation control algorithm and the surveillance of the UAV's status to prevent collisions and act as an HMI to offer adequate user-friendly graphical user interface (GUI) information of UAV and minimize pilot workload. The UAV model and control algorithm was then translated to C++ code and implemented in the Qt-based simulation platform and GCS after validation on MATLAB/ Simulink. The GCS offers a user-friendly GUI and powerful management of UAVs. The isolation of GCS from the simulation framework enables it to be extended in the future to semi-physical or physical simulations.

4.6. UAV LiDAR sensor for forensic evidence detection

UAVs are used for data collection using the LiDAR approach with high accuracy [113]. LiDAR systems in UAVs assist to improve the understanding and planning for urban infrastructure management and allow geometrical extraction and spectral detection. Photogrammetry is the study of science that measures photographs and provides information about the drawing, maps, and 3D models for objects of real-world scenarios. UAVs use LiDAR technology which uses Ultraviolet-rays, visible light, and IR light for close objects. The UAVs that used IR light for imaging are more suitable for forensic applications. UAVs having LiDAR systems are capable to collect high-quality photographs of the scene, and searching the evidence through videotaping for mapping and reconstruction of crime scene investigation. The conventional procedure of crime investigation is consuming time extensively, However, introducing the novel technique and application of UAV is a powerful tool for forensic investigations. The UAV can be used as a multipurpose tool for crime investigation through videotaping, photography, and searching evidence by examining the sites, and assessments where it is hard to reach, however, it is a tremendous technique to deploy the UAVs for forensic investigations [114].
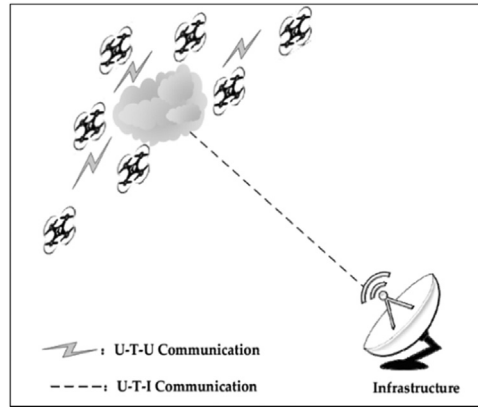
Fig. 1. Single group UAV swarm [116].

4.7. UAV swarm concept

The UAV swarm concept presents a group of unmanned aerial vehicle UAV carries out robust operation in a self-organized way to complete the mission [115]. The current inclination of the development of UAVs and UAVs technology indicates that the swarm of UAVs spontaneously establishes communication, which is decentralized in nature.

Several routing protocols and networking techniques were developed and studied to improve the performance of the network. To make ensure the stability, and dependability of unmanned aerial vehicles, numerous researchers provided different concepts, architectures, and topologies that have made significant progress for autonomous communication for the specific scenario. In addition, the strategies of UAV swarm collaboration play an important role in reliable communication. the decentralized approach to communication provides the platform for UAVs to communicate intelligently.

Under the umbrella of decentralized architecture, the swarm of UAVs performs real-time communication in Adhoc mode by eliminating the restriction of communication range and infrastructure dependence. The decentralized architectures of a swarm of UAVs are single-group swarm ad-hoc networks (SGSAN), multi-group swarm Adhoc networks (MGSAN), and multilayer swarm Adhoc networks (MLSAN) [116].

The swarm of UAV communication made the progress towards cloud-based and satellite-based communication and triggers the information. The current trends of research focused on the security area of a swarm of UAV communication Fig. 2, Fig. 3, Fig. 4.
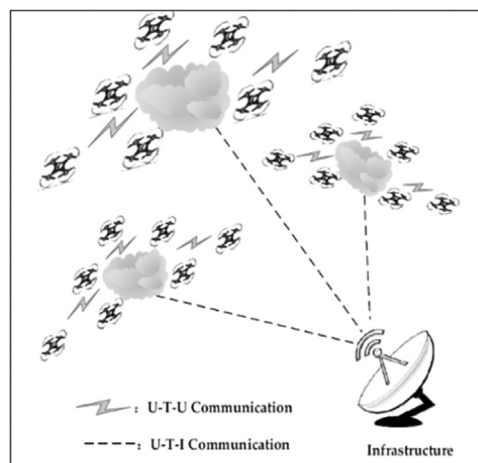

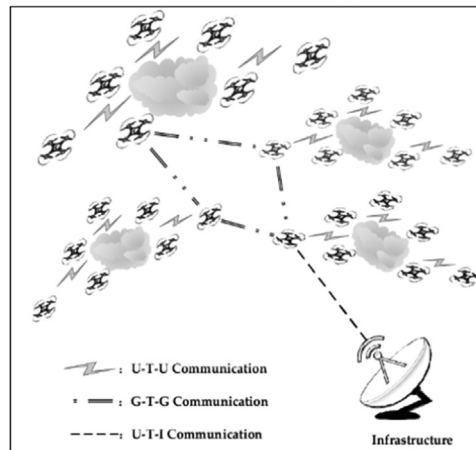**Fig. 2.** Multi-group UAV swarm [116].

Fig. 3. Multilayer UAV swarm [116].

Fig. 4. UAV Swarm Concept [116].

5. UAV applications

After the invention of UAVs or drones, there is a dramatic change in some industries and businesses and this made so many works, procedures, and difficult things too easy. If we say that now drones can make your business, and your daily life work and some rescue organizations are widely used in the military for monitoring and some other purposes.

5.1. Aerial photography

Drones are now widely used for capturing footage that can do the same work, which was done by highly expensive helicopters and cranes [63]. Fast and 4k cameras, action cameras, and sci-fi scenes are filmed by aerial drones, making all this capturing and all other cinematography easier. This UAV or Drone flying device is also widely used for real estate and sports photography purposes. Journalists are now also taking this under consideration the usage of drones for capturing footage and videos in live telecasts.

5.2. Shipping & delivery

Big E-Commerce giants like Amazon, Alibaba, DHL, and some other big eCommerce and delivery companies are in favor of drone delivery [64]. UAVs can save a lot of time can deliver on time in a short period, and will not be affected by any traffic conditions. Besides, they can also be used for small distances to deliver small parcels, meals, and some other orders which must be delivered [65].

5.3. Natural scenery

The interesting application of the UAV is to capture the natural scenery and locations, which we cannot reach there or cannot climb over this like coastlines and beaches, tops of the mountain, and islands in the sea. UAVs are used to map large and huge crowded places [66,67].

5.4. Management of disaster

UAV provides real-time quick response, whenever there is a natural or man-made incident like something or any disaster, to monitor that place from an aerial view and can navigate for the injured persons [68,69]. The equipment and devices used in these conditions are at high definitions and are less with high definitions of cameras, sensors, and radars to give exact information or view

to rescue teams. Since the large vehicles or devices are like a helicopter cannot reach in narrow or cannot get an analyzed closeup view of any place.

5.5. Agriculture purposes

UAV technologies are now also enabling farmers and are dramatically changing the industry of agriculture by Lessing Agriculture with modern technology farmers [70,71]. Agriculturalists are now using drones and UAV devices to monitor their large widespread corps in a very cheap and very effective way and can also react to the health of any corps by getting alarmed to the farmers with the sensors, which are attached to the drones. According to some reports now 80 percent of agriculture will be monitored by drones and UAV devices.

5.6. Weather forecast

Drones are also developed to use for the monitoring of dangerous and sometimes unpredictable weather situations [72,73]. As these devices are cheap, so they can be sent into tornadoes and hurricanes so that specialists and weather forecasters got some new insights into the behavior of weather. Sensors used in drones are helping to detail weather parameters and check the situation and monitor the weather.

5.7. Wildlife monitoring

Wildlife monitoring was a headache to monitor a whole park or any forest to prevent animals to be hunted or any unpredictable situation, but UAVs made it easy to monitor a whole area within seconds or minutes [74].

5.8. Law enforcement

Nowadays UAVs are also widely used for maintaining the law and enforcing the situation in the city [75,76]. It helps the organization, which has the responsibility to maintain law and order to enforce the situation in the city with the surveillance of large crowds and to make sure the safety of the public. They also help them to assist in the monitoring of the very criminal and illegal activities and things in the city.

5.9. Entertainment

UAVs are being used to develop and provide entertainment for users and people so that they can also be used in nightclubs and for some entertainment purposes [77,78]. More than those artificial intelligence-based drones are used in several ways to capture your videos and photographs from a distance and can also be moved as you will step forward or backward.

Other applications of commercial UAVs are parcel delivery or mapping and rescue. The analysis report provided by Tractica that the usage of multicopters and drones will increase in the future in the cooperate sector. For the current year, they estimate the market volume to be 392,000 drones worth US$1.6 billion. Sales and revenue are set to multiply by 2025. North America is by far the largest market for commercial drones, followed by Asia and Europe. Fig. 1 shows the sale of UAVs past and future [79] , Fig. 5.
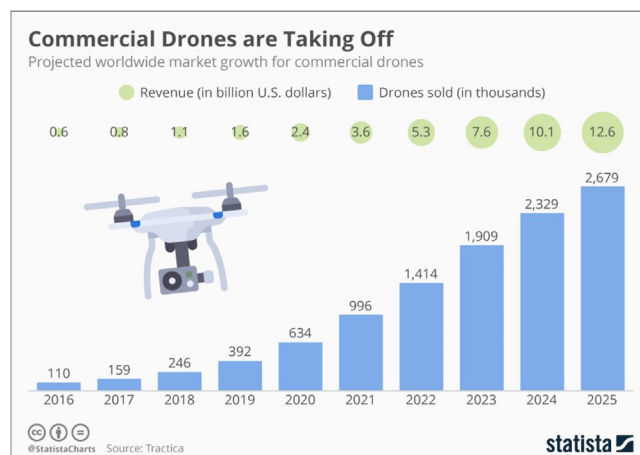

Fig. 5. Sale of UAV according to Tractica [79].

5.10. Military purpose

UAVs' military applications are specific for different operations, which provide intelligence about combat. It is used the concept of a swarm of UAVs to collect information about military operations. Slight unmanned aerial vehicles are used for bomb recognition. These UAVs were developed by the US to alert the military to save human beings. It can be used for reconnaissance of foes' activity. UAVs are very important to perform surveillance of the larger geographical area. The swarm of UAVs can be deployed in unsafe areas for provisioning information about the security. UAV technology is the economical solution for these military applications in modern times [117].

The author has investigated the performance of their Small-Sized and Mid-Sized UAVs, which tends to improve the automatic process with a higher degree of self-independence [80]. On the other side, it improves system issues and closed system solutions. Significantly, the survey shows the machine's performances from the sensor data, which assesses the limited inheritance of the algorithm, we're changing the environmental conditions with different types of function variations. They have collected the results, which show not much better reliability. The author has investigated the performance, so they have mentioned some critical parameters for collecting results. They have made predefined parameters that can improve the results, and it is expected maximum performance. These results' essential objectives are to enhance the quality of flight routes for the UAV and agree to permit efficient using the sensor system. The author has used the Pareto optimization method to improve the flight route and Pareto's actual method, which has been set for the current flight.

The author has discussed the development of a decision-making multi-UAV architecture in conjunction with real UAVs and WSN experiments developed as part of the AWARE Project [81]. Various tasks have also been mentioned in this document, including multiple UAV surveillance, sensor deployment, and confirmation of fire threats. To avoid redundancies, only discrete features have been emphasized, rather than defining the complete architecture's operation for each task. The objectives' execution addresses core problems in multi-UAV systems, including the distributed allocation of the task, dispute resolution, and plan refining. A collaborative framework has also been introduced for multi-UAV coordination in challenging situations like disaster management and national security. The trials show that its enhanced architecture enables us to carry out a broad range of activities: tracking, deployment of sensors, fire recognition, and extinction. The incorporation phase of autonomous vehicles from several manufacturers and study groups was one of the architecture's main features, which allowed various types of UAVs to be integrated with the least development efforts during the AWARE project. However, various tasks implementation and shutting and restarting of the HMI framework have not impacted the platform output because of the distributed decision-making system. Due to any communication layer constraints' unavailability, collaboration between the UAVs could be achieved through a distributed approach.

6. UAV security

The UAVs use network of a service provider for data transmits to the organization and from the ground station [82]. These UAVs use different types of communication technologies such as GPS, Infrared, Bluetooth, Wi-Fi, and ZigBee, but these network technologies are open to security attacks from hackers [83,84]. Recent reports are proof that security attacks were launched on a UAV to control its interface by "channel hop" attack.

The WiFi and GPS Jammers are also used to launch attacks to destroy communication of UAVs, such attach are GPS spoofing 6, which is used to fool the receiver of data by sending fraudulent signals [85,86]. It makes data distorted for the program, which is running the UAV or devices or terminal, which is associated to open Wi-Fi systems in airplane terminals, cafes, and preparation stations.

It extricates client data such as usernames, and passwords. The level of attack will proceed to rise, and manufacturers, as well as governments, should make a collective endeavor to defend these frameworks against attacks. Besides, regulations on transportation ought to be executed to give security rules and preparation ought to be given to clients of UAVs. The security officers should be conveyed to maintain the security of these devices and civilians utilizing them. Better regulation and limitations on utilization ought to be upheld by UAV manufacturers on their items. Privacy of individual information should be kept up, and security should be regarded to maintain a strategic distance from interruptions.

6.1. Hacking methods

The term hacking is referred to controlling another system or network to copy or destroy data or use it for its benefit. Hacking attacks are mostly applied on wireless networks, and different hacking procedures are used to control the UAVs of a legitimate user [87]. Few hacking methods and attacks are given.

6.2. Trojan horse virus

It is another type of attack on UAV, it could be malicious software or code monitor activity on the network and have negative impacts by destroying hard drives and records of a system [88]. This attack has a high impact not limited to one system but increased rapidly and creates more destruction. It provides facilities for the hacker to control systems from a remote location. The most efficient way to avoid these hazardous attacks is by using malware software within the system.

6.3. Distributed denial of service

A DDoS attack could be a large-scale interruption strategy performed by a have source that causes negative impacts to legitimate clients by withholding services once the attacker picks up get to the system, modern instruments can be utilized to pick up control of the have [89]. Infected systems proceed to search for other vulnerable systems and attack them.

6.4. Password theft

Password theft is another way of breaching of security of UAVs. Passwords are based on the 8 to 16 characters of the keyboard and, they may consist of words, special characters, lowercase letters, and numbers to ensure security [90]. This major problem is that complex passwords are difficult to remember. However, complex passwords are also difficult to crack. Dictionary attacks check for open ports and utilize a list of common words from the dictionary to perform the attack.

6.5. Man-In-The-Middle attacks

This type of attack is launched to gain control of two parties' communication middle networks for a copy or modification of sensitive data [91]. The client does not know about data manipulation, which is performed by the attacker. Typically MITM attacks are based on the scam email to misguide the client or emails which misguide the client to a fake site [92]. Other forms of MITM attacks are URL manipulation, the rogue domain name server (DNS) and address resolution protocol (ARP) poisoning, and duplication of media access control (MAC).

6.6. Intrusion detection systems

This is another way of attack to enter the system without the permission of the owner and utilize the resources or block the resources [93]. The system will be cheated due to attacks and give access permission to an intruder [94]. Intrusion detection is the act of supervising and identifying indications of abnormal activity. Mostly firewalls, encryption techniques, and authentication methods are used as the first barrier to a secure system.

6.7. Defense against hacking

Many techniques are available to secure the UAVs from threats or access to information from a hacker, and prevention or action can be taken suitable actions when found attacks [95]. There are few solutions are given in this section that will be used for enhancing the security of UAVs.

a) Encryption
b) Defense against DDoS
c) Intrusion detection systems (IDSs).

6.8. Encryption

Encryption techniques are used to change the actual text into an unreadable form to secure information on the network [96]. Encryption encoded data that only can be read by the actual user. It is used as an obstacle against unauthorised activities by hiding information about resources such as card data, social security numbers, and debit cards.

6.9. Defense against DDoS attacks

There are many methods are available to avoid DDoS such as preventive and reactive methods [97]. The reactive methods are used to recognize the attack and then prevent the damage. They are also called "Early Warning Systems" A database of well-known attacks is used to compare and identify incoming attacks.

Similarly, the author has presented a protocol that is based on a stochastic game-based model [98]. So in this system, security is a significant problem where it cannot be aware of the attacker's information, so it was the author's challenge. He has used false data injection attacks through the operator, but still, it was a challenge. Therefore, he has built the model as a Delayed-Action-Game (DAG), which can easily use off-the-shelf tools and overcome the security-aware H-UAV model. On the other hand, he has worked on UAV's hidden information range. After that, he implemented that protocol on real human activity that can easily find the operator's geolocation. Moreover, the author has implemented the machine learning technique inside his model, where it has collected experimental data, which receives the geolocation task and process it with their geographical features. The author has represented his unique H-UAV protocol through the case study. So, in this case, study, experimental results have been tested and operated by humans. Such type of experimental results has been evaluated with subjective feedback. The DAG has performed parallel computation so it can reduce the time of processing.

7. Open research issues

UAV networking is an important part of the system, which must be able to provide QoS services but still, no efficient routing protocol is available for better path communication [13]. The energy efficiency-based multicast routing protocols must be developed for communication because a high amount of energy is consumed during the data transmission and reception, and during UAV hovering. QoS service delivery is a big issue in UAV communication, so future research must design and develop new algorithms to avoid delay and reroute [99,100]. Link constancy is also a major issue in UAV communication because of the hovering of the UAV system, it causes problems connecting every time with the base station further research work is required in the area to improve link stability [101].

Nowadays, UAV systems are used in real-time video streaming in sports broadcasting, and service delivery with quality of experience (QoE) to end-users is an issue for service providers [102,103]. The QoE domain is based on the user's satisfaction, so every organization adds this feature to get feedback from the user to improve services for them, they will remain a permanent customer but adding a QoE domain in the UAV system is also a major issue [104,105,120]. In this regard Laghari et al. Proposed a QoE model for a UAV environment for QoS service delivery, however, the proposed model is not implemented in a real-time environment [106].

UAV systems use the battery for hovering and energy purposes, with the battery they have a short time for the flight and also power consumption in communication and video recording cameras [107]. Limited energy of UAV is also a problem for real-time streaming and monitoring so the solar-based body of UAV system will be a better idea to implement to recharge in hovering time so it will also increase the time of operations in agriculture field where work is held in the day time [108].

Ground station control Checks again and again the reliability of the network's architecture and simulates the controlling of vehicles [109]. Control of better UAV systems required the development of more efficient algorithms currently available did not sufficient for this operation [110]. The GCS must notify if vehicles are in collision with each other or any other substance and guide for an alternative path to avoid a collision, this also required more power GCS which controls all information with the improved user interface [111,112].

8. Conclusion

In this paper, we reviewed UAV systems and communication design, and methods used to connect and send data to the ground station. Further, we discussed data processing via sensors and applications with security. We provide key definitions and concepts of UAV systems and details of the development of communication systems and GCS. We provide reviews and analyses of the security of UAVs and the types of attacks that are launched to disturb the communication of the UAV system. Finally, open research areas are given for further development of the UAV system and communication, which leads to better UAV technology for the industry.

Authors' contributions in relation with your submission

(This is "Applicable"—Who made your manuscript and did the research?). Kindly provide complete list of all authors (names or initials) and each contribution in your "Authors' contributions" section.

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5 Funding (Information that Explains whether and by Whom the Research was Supported) The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Code or data availability (Software application or custom code)

Not applicable.

Declarations

Ethics approval

(Include Appropriate Approvals or Waivers) Not applicable – No animals, including humans, were studied in any way during the writing of this paper.

Consent to participate (Include appropriate statements)

This study did not involve any 3rd party participation. All authors consent to participation.

Consent for publication

(Include Appropriate Statements) This study did not involve any 3rd party participation. All authors consent to publication.

Declaration of Competing Interest

(Include Appropriate Disclosures) The authors have no relevant fnancial or non-fnancial interests to disclose.

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