Chapter 12
UAVs/Drones-Based IoT Services

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Abstract Unmanned aerial vehicles (UAV)/drones are deployed for military applications such as intelligence gathering, Surveillance and Reconnaissance (ISR). But not confined to military missions but drones are integrating into civilian domains rapidly for Internet of Things (IoT) services from delivering pizzas to mapping land resources. Technological innovation and increased diverse applications are the two key drivers of the rapid expansion of the drone technology. Low cost, ease of deployment, use any type of networks, anywhere 24×7, and ubiquitous usability of drones play an important and key enabler in the IoT vision. The main technology components of drones are structural airframe, propulsion, IoT systems such as ground control station (GCS), autopilot system, radio link, payload, launch and recovery system. Drones can offer IoT services when suitable payload is equipped to carry out value-added services.Some of the challenging issues are drone standards, regulations issues, physical collision, privacy issues, etc. The design standards used are any of the FAR 23, MIL-A-87221, DEF STAN 00-970/ STANAG 4671 to build the air vehicle, and airworthiness certificates are obtained from certification authorities. Regulations for operating UAVs in the military airspace are not restricted by aviation authorities, for civilian applications any individual nation's civil aviation authority is free to formulate its own aviation rules, roadmap and regulations for operations within their autonomous airspace. The regulations bodies for the USA-FAR, UK-CAP722, Europe-EASA, Canada-SFOC, Australia-CASR part 101 and India-DGCA are building robust roadmap for operation of drones in civilian airspace. In this paper, current trends of drones, classifications, IoT architecture and IoT services are introduced. Civilian airspace regulations, challenges and requirements are presented.

Keywords Unmanned aerial vehicle · Drone · IoT architecture · Regulations · Standards

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12.1 Introduction

Unmanned aerial vehicles (UAVs)/drones are making significant impact for their continuing technological innovations and their diverse applications in both military and commercial field. In the military, UAVs are used for Net-Centric Operations (NCO) missions as an intelligent sensor grid such as persistence intelligence gathering, Surveillance and Reconnaissance (ISR) and target acquisition (TA), the acquired data will be transferred to command and control (C2) via robust secure data link which may be with in line of sight or beyond line of sight for decision making and action will be taken to attack target using precision weapon shooter grid. In the commercial scenario, small UAVs landscape is emerging steadily IoT services such as border surveillance, disaster response, firefighting, law enforcement, precision agriculture, news coverage, land mapping and personal use to mention a few. Small UAVs or drones are available in the market which is fully equipped with an HD camera controllable with an iPad for about $300.

In future, thousands of drones are deployed in the sky for IoT services such as e-commerce applications, precision agriculture and package delivery operations. From January 2016, the drones registered in the USA exceed 2 lakhs in the beginning 20 days as per Federal Aviation Administration (FAA). In India, government research and development institutions are allowed to deploy the drones for their missions. Where as private operators need to get a permission from DGCA (Directorate General of Civil Aviation) before putting the drones into the sky.

IoT services such as daylight and night surveillance using daylight TV camera/thermal infrared imaging technology, airborne data telemetry and algorithms to successfully track wild animals, disaster management at various places of India, 3D mapping, precision agriculture such as soil quality study are done using Netra developed by DRDO-India forge has successfully carried out.

Tactical UAV Nishant catapult version has been demonstrated as per the requirement by Indian security agency low-intensity conflicts for law and order purposes such as anti-Maoist operations at Jagdalpur, Chhattisgarh during February 2015. A recent study by private defense agency found that India has the fastest growing micro-/mini-UAVs market in the world.

UAVs integrated with high-definition IoT cameras and sensors to monitor sensitive communal situations such as Ramadan Procession in Lucknow, networked UAVs at Kumbh Mela, Uttar Pradesh and Ganesh Chaturthi processions in Maharashtra. The data were archived, disseminated and transmitted to traffic police officers over mobile phones to allow for instant diversions, vehicle and crowd control in real time. UAVs assembled with IoT infrared and high-resolution imaging are being considered by the Indian security agency for border surveillance, coastal and maritime security, oil and natural gas pipeline monitoring, securing offshore assets and urban security. UAV manufactured by China, DJI Phantom is being used in India by several Indian start-ups such as Funaster and Quidich for photography and video services. In India, drones for IoT services are going to stay and one can say the future is unmanned and IoT unlimited.

Flying variety of huge number of drones in the civil aviation is going to be really a challenging one. First and foremost is Sense, Avoid and Detect (SAD) system, secondly public property safety and privacy. Therefore, an effective SAD system would be very important, assuring for the rule-making or task committee authorities a continuous insertion of drones into sky the present existing Air Traffic Management (ATM) procedures and maintenance of safe flying levels. Public's perception and acceptance are another important factors that may constrain the range of utilization of drones in the airspace. This issue is reasonable as UAVs may hamper the privacy of individuals by passing above them and covertly keep an eye on their daily happenings. Confirmation, safety measures and confidence are again a very vital parameters for the public approval and acceptance of UAV-based IoT services.

IoT vision allows drones to turn into essential integral part of IoT infrastructure. As IoT's objectives are to connect the things together for 24$\times$7, anywhere ideally using unique private network and providing number of IoT services. Drones possess exceptional characteristics in being versatile, easy of deployment, cheaper, ease of re-navigating during mission-time, ability to measure area, distance between two points, and able to fly in any part of airspace. Drones encompass different technology components such as aviation packages, IoT instruments or packages, customized software, and data link equipment line replacement units (LRU) that provide radio links to the ground support system (GCS). The drone and GCS are two elements integral units, called UAV/drone-IoT thing.

12.2 Navigable Airspace and Drone Classifications

As per ICAO (International Civil Aviation Organization), navigable airspace can be generally categorized into segregated airspace and unsegregated airspace. Segregated or controlled airspace will use IFR and VFR are used in the controlled airspace within ATC and prior permission is required to enter the controlled airspace. Classes A to E exist in this category. In the uncontrolled airspace, ATC permission is not required. Under this category, F and G classes exist. Instrumental flight rules and visual flight rules are two important rules in the segregated airspace.

Drones classification is based on the type of function or mission, range, altitude, endurance and all up-weight factors. Based on the functionality, drone can be categorized as target drone/ISR drone/package delivery/e-commerce drone, combat, research and development. Based on the range, altitude, endurance and all up-weight drones can be classified as nano or micro, mini or small, MALE and HALE drones. The maximum altitude of nano-/micro-drones is below 300 m, mini/medium up to 5000 m while it exceeds 5000 m for MALE UAVs. Regarding the range line-of-sight (LoS) communication, it is not greater than 3 km for micro-/small drones and up to 250 km for the medium drones. However, the long range, high altitude and long endurance HALE drones work beyond LoS (BLoS). Hence, the IoT-based services basically executed by the small UAVs.

12.3 Existing Regulations and Standards

Drones provide highly potential market which will definitely yield many possible benefits for users, service providers and manufactures, many challenges are required to be tackled. Paramount issue is regarding the privacy factor: Drones can easily violate this issue. Reliability and safety are another important factor. Drones carry supplies and objects that could be lighter in mass, but they become very unsafe if drone falls from high altitude due to malfunction. Apart from this, drones could be used for life-threatening activities such as illegitimate drug transport, spying, or simply loitering over sensitive or strategic areas, viz. government-owned institutions, R&D establishments, river dams and power stations. For these reasons and more, there is a need of regulations, policy, norms in the market of drones. In the USA, Canada and European countries, this regulation already exists. Seven-point draft regulation activities have been released in India very recently by DGCA.

Any operator who wishes drone-IoT services need to get Unique Identification Number from DGCA above 200 ft. Drone operation below 200 ft requires permission from local police commissioner. The design standards for UAVs available for military missions are Defense standard 00-970 part 9, STANAG 4671, Aerospace Recommended Practices ARP 4761, FAR 23, MIL-A-87221. They provide the guidelines for general requirements, climatic conditions, flight performance, structural strength requirements, airframe, power plant, avionics, flight termination, payload, etc. Provided that all the requirements and procedures listed in SOP are satisfactorily carried out and supported by successful test results in the development phase, a Design Certificate will be issued to the system by the appropriate authority. This certifies that the system meets the performance quoted and is a safe system to operate. Similarly for civilian applications, UAVs employed should safeguard the safety of the airspace and air infrastructures.

The three important advisory organizations playing a role in the evolving and implementing of unmanned aviation standards are the Society of Automotive Engineers (SAE)—the engineering society for advancing mobility—land, sea, air, space. The Radio Technical Commission for Aeronautics (RTCA)-US society for production of consensus-based standards, and ASTM International society—American Standards for testing of Materials. Industry regulations for military UAVs are through "file and fly," i.e., mission plan can be filed at ATC and obtain clearance and fly the UAV. For civilian UAVs, any country's civil aviation authority is free to make and disseminate its specific or unique rules and standards regulations for design/operations in their airspaces.

12.3.1 India

Presently in India, all drone/UAV flying is done with permission from Directorate General of Civil Aviation (DGCA) and Ministry of Defence (MoD). DGCA has formulated seven-point comprehensive regulations policies to operate UAVs/drones in Indian civilian airspace. The regulation-making, standards development and roadmap processes are under progress.

12.3.2 Canada

Small drones' operations in Canada are allowed after obtaining a Special Flight Operations Certificate (SFOC). Once SFOC granted, the drone will be subjected to the rules and regulations set by Transport Canada. Depending upon one's situation and intended use of the system, different rules will apply. Restrictions may include flying zones/locations, time and other operating safety parameters.

12.3.3 The USA

To operate small drones in the USA, flier must obtain a Certificate of Authorization (COA) through the Federal Aviation Administration (FAA). Currently, these certificates are only to local government agencies and limit flying to specified areas.

12.3.4 The UK

Before a drone is allowed to operate in the UK, one has to follow Flight Operations Policy (FOP) guidance issued by the Civil Aviation Authority FOP department to ensure required standards and practices to assure safety and airworthiness.

12.3.5 Australia

Part 101 of CASR guidelines allows UAV operations in Australian civil airspace. It provides regulations of UAVs and firework displays, balloons, rockets and model aircrafts.

12.4 Drone—IoT Architecture

Figure below shows a heterogeneous network of drones, each carrying out a assigned task with specific payload. Some cluster of drones is on the assigned task while other clusters of drones are waiting for the command to be initiated to take-off.

IoT sensors and packages are fitted to all clusters of drones for execution of different mission objectives. Drones are usually preprogrammed to execute the tasks through waypoint navigation. Drones will be either fully autonomous or semi-autonomous depending on the technology availability and autonomy level so that the threats of air collisions due to traffic with other drones, or any unpredicted impediments such as, flying natures, trees and highly erected mobile towers. This is accomplished by planning their waypoint navigation. IoT sensors should be remotely controllable when they are in the mission. As illustrated in figure, drones are clustered and dispersed in a vast aerial zone and may be arranged in different drone clusters. Each cluster has different mission objectives and specific jobs to accomplish, and every drone uses different specific radio frequency communications. The cluster system can be classified as clustered cellular system or Wi-fi enabled or satellite based (Fig. 12.1).

As depicted in the figure, the radio communication established between airborne system to ground support equipment, airborne to airborne, viz. UAV-to-GCS, UAV-to-satellite, UAV-to-cellular infrastructure and UAV-to-UAV. In a particular airspace zones, there may exist some communication or connectivity difficulties and range problem to drone systems. These problems can be mitigated by using flying a relay or ad hoc networks among drones. Whenever there are intermittent communications persists alternate technology called delay-tolerant networking (DTN) can be one of the solutions to ensure end-to-end connectivity between drones and GCS, but delay time increases. In every drone cluster, a individual specific drone could be selected as a cluster head (CH) serving as summing point to disseminate or transmit the raw data collected from other drones to the system orchestrator (SO). Data dissemination from drone to the head of its cluster happens using a appropriate protocol procedure for FANET. The core set of connections internally connects drones, while the SO enables data exchange among different components of the network in a more coded and decoded way. The SO, as the key in-charge UAV of the whole system, employs a set of preprogrammed instructions for gathering real-time and updated information about the current status of the drones, drone navigation paths, drone power backup conditions and their systems. SO is head of handling requests and disseminating information for IoT services as per the users' requirements.

After receipt of a request from an IoT device, e.g., weather monitoring agency would like to know the air pressure or moisture in a selected area, SO initially and foremost classifies the most satisfactory drones. This classification is based on different standards or protocols like: (1) navigation ways, (2) geospatial area of interest, (3) equipped IoT device (e.g., pressure/hygrometer sensor) and (4) their battery backup level. The selected quantity of drones for a definite mission task depends on the mathematical computation capability of the IoT service, the versatility of required IoT devices, or the size of the observed zone.

Once the fulfilled requirements and required drones are selected, one or multiple drones will be instructed to carry out the IoT service by actuating their particular IoT sensors only when they are moving over the region of interest. Once the sensing is completed, SO instructs the drones on how to perform, where to navigate, and which

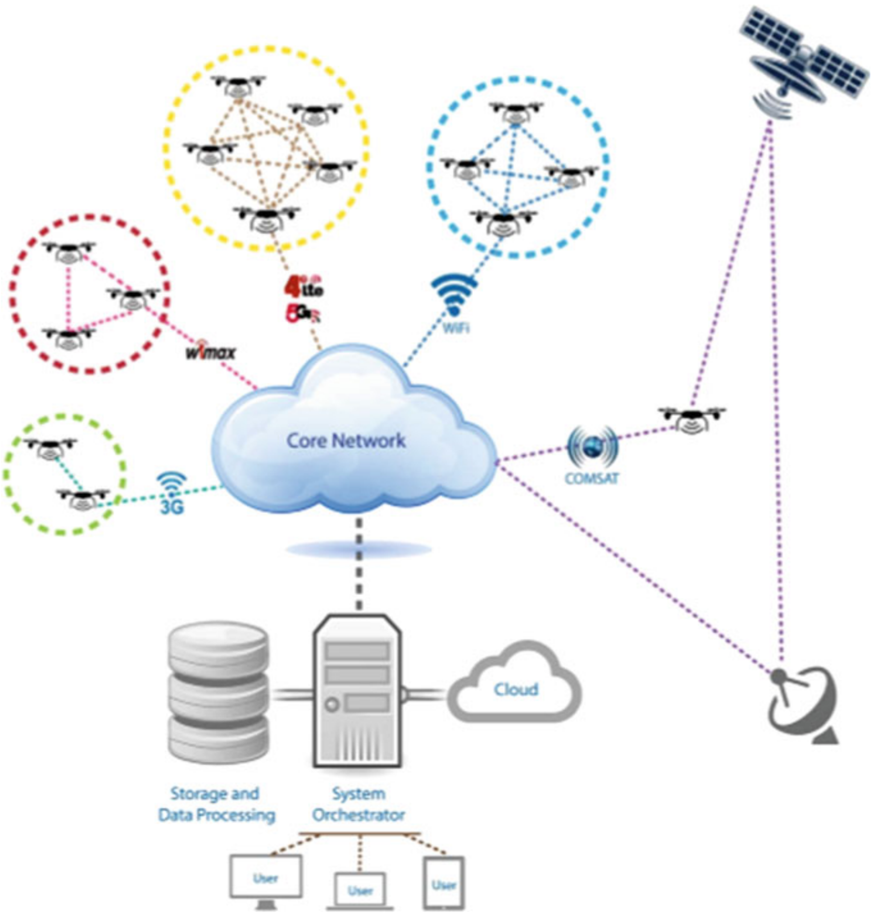

Fig. 12.1 High level view of the envisioned UAV-based integrative IoT platform

particular technology to use for disseminating or relay the required information via interoperable systems.

12.5 Major Challenges in Integrating Drones to Airspace

There are number of challenges in integrating drones to civilian airspace for IoT commercial use. According to Indian Director General of Civil Aviation in association with CUVSI (Consortium of Unmanned Vehicle Systems in India) has prepared a draft to discuss the regulations of drones for civilian use in India. Access to airspace needs a detail master plan to control the air traffic. However, many aspects such as safety and privacy of people need a paramount importance while framing the regulations. Assimilating drones into non-segregated airspace could pose a serious hazard and technological challenges, such as accident, traffic congestion and failure in links. The links between drone and drone need a robust technology features with reliable topology to establish a seamless connection between the drones. There has been a standard shift from centralized to decentralized system build on varying notions of enhanced access. Wireless private communication remotely between drone and ground support systems is an important challenge. There are also multiple challenges to establish seamless connection between flying drones. Another important challenge is interference management and the selection of relevant wireless technology such as cellular network, WiMAX and Wi-fi for the drone's seamless communication.

12.6 Upcoming Research Areas

From the past few years, drones have become essential to the functions of numerous business and governmental organizations and have achieved to solve the problem of productivity. The constant advancement in UAV technology has led to the rapid growth of drones. It is already creating an impact in the areas of precision agriculture methodology, rescue and search operations, reconnaissance and traffic sensing and monitoring, cinematography and many other areas. Moreover, it will open new avenues in the services sector in the market. However, safe and efficient deployment of the technology is paramount importance for the safety and security of the people, property and infrastructure.

In addition, there is a wide range of scope for future research in the areas of management and control, regulations, power consumption, developing navigation system that do not rely on GPS, security and privacy. There is a need to study further in the integration of IoT in UAV/drones for the efficient civilian use. In this manner, processes and methods to control and manage the IoT devices as well as the communication to the network are vital for the effective use of UAVs.

12.7 Conclusion

This study logically highlights the current potential scenario of small drones-IoT vision. It also highlights the importance of IoT in UAVs for integration and formulation of UAV policies for civilian use. In addition, it also draws the picture of IoT in the present context. Hence, such study is necessary for the researchers all over the world and aviation authorities of government to formulate policies and regulations for the mass use of UAVs in India as well as other parts of the world.

Active involvement by the production and manufacturing industry and the user fraternity in the process of IoT-drone is not only encouraged, but is absolutely essential for the industry to grow and progress in an orderly fashion. The opportunities for technological maturity and advancement for drone systems, many of which will have a positive impetus upon the rest of the world aviation from a safety and efficiency perspective, are virtually unlimited.

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