UAV-Based Smart Environmental Monitoring

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Chapter 16
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ABSTRACT

In the context of digital governance, manmade activities will have the most impact on the environment. The concept of internet of things (IoT) is much more profound, supposedly having an impact on the way environmental sampling of data takes place. The cost benefits of unmanned aerial vehicles (UAVs) as alternate to satellite or high-altitude platform system (HAPS) is established as these are more flexible, mission specific, and versatile. UAV in sensor network context and communication relaying as well as data harvesting application is explored. Proposal to upgrade environmental laws and implementing network infrastructure security and cyber insurance for HetNets involving UAVs and environmental monitoring will be covered as well.

INTRODUCTION

IoT Data Sampling and Smart Environment

The Industrial Revolution 4.0 is revolutionizing our world and its future. The future holds the key for connecting the home, work place, industry and the rest of the concept of a Smart City. In the next few years, an estimated 500 billion devices will be connected to the internet. There is the obvious energy

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usage, but also the impact on natural IoT connects physical world to cyber world or computer world where, objects can have smart capabilities, and can make their own decisions. Design of technology infrastructures using fast and efficient delivery of services and data aims to cover the Digital Divide that is a need of the day. Here the natural consequence of evolution of architectures in the digital landscape requires interactivity and increased efficiency for betterment of the quality of life of residents. Climate change and environmental sustainability has assumed importance in the lives of the digital citizens as it impacts health, work life patterns, city operation, communication and socio-cultural contexts. The most profound effect of man-made activity is on environment.

It is aimed to explore the impact of transportation including man-made activities on environment using fixed sensors spread in an urban environment. Air pollution monitoring systems have low three-dimensional and time-based resolution using only a few measuring sensors with small footprint. This is because of limited resources using lower time resolution hence the huge sampling intervals.

UAVs aid in spatially efficient handling of environmental data from smart sensors. These can also house various sensors as well as collect data from the same. It is proficient as it can be in close proximity to data collection hardware in a variety of terrain. The data can be relayed remotely to a centralized location and processed using power efficient UAV to UAV and UAV to Ground links. The UAV platform and payload are discussed in following two configurations 1) fixed sensor on ground and 2) air borne sensor on board the UAV.

In the former context, the idea of information relaying is explored where data is stored and forwarded or processed and forwarded for various sensor configuration. It is explored with request to the data relaying portion and tests are discussed in detail to enable COTS development in the context of Technology Adoption for developing countries. The most important part is the communication payload because that is where most of the energy is utilized and where most of the operational problems like control, connectivity and application specific issues occur. For communication sensors, information is relayed to neighbor nodes to transfer the data but for transferring data. However, for other nodes it needs to be in the transmission radius referred to as the transmitting range. Finally, the relayed data is transferred to sink node which is the end node in wireless sensor network. Here all the traffic from different nodes gather at a point and from there, it is transmitted to the server.

In the later context, the architecture and present scenario for onboard scientific testing is normally taking place on board the Data Acquisition (DAQ) and Ground Control System (GCS). As in the wireless sensor networks, UAVs can also sense and monitor different parameters such as temperature, pressure, humidity, pollution indexes etc.

A single UAV is good but with limited coverage, it cannot cover the whole area of interest. UAV monitoring is usually associated with UAV swarms because swarms can provide larger coverage area. Hence the idea of multiple aerial platform deployment is considered. However, this concept is still in its infancy. There are issues concerning the autonomous operation and control of devices in 3D space. The tracking and accurate alignment is required for guidance as well as communication. Where the communication system is itself a payload this becomes more crucial.

Finally, the idea of merging risk transfer mechanism for upgradation of the scheme is attractive for future agriculturists and environmentalist is explored in some detail.

ENERGY SCAVENGING AND WIRELESS SENSOR NETWORK

Wireless sensor networks are backbone of any IoT network. Main operations taking place are data sensing, processing the data, transmitting or relaying the data through communication with different nodes. When sensor nodes sense the data, it collects some information which needs to be processed by the processor to convert it to a useful form.

The central part of a network is communication such system which relays information to neighbor nodes within the transmission radius referred to as the transmission range. Finally, the relayed data is transferred to sink node which is the end node in wireless sensor network, where all the traffic from different nodes, it is transmitted to the server.

The main problem in wireless sensor network is limited power source. Currently there are two ways to tackle this issue. First is to minimize the energy consumption of the network by altering some parameters or adjusting duty cycle of the node. Second is to use ambient power source from surroundings referred to as energy harvesting.

Energy harvesting is a trending research topic which requires scavenging ambient energy from the environment. This ambient energy can be from sun as solar energy. It can be from vibration using piezoelectric devices, from wind as wind energy, or from waves as tidal energy etc. This ambient energy can be utilized in wireless sensor networks to supplement the power source.

The main problem in harvesting energy from the environment is that it is unpredictable. This ambient energy is variable in nature and thus it is very hard to design conditioning circuits for them. Second, the ambient energy sources also have their disadvantages such as that solar energy cannot be used at night. RF energy fades away at long distances because of the path loss function. Mechanical energy from vibration using piezoelectric devices produces very low output power. Thermal energy only works if there is a huge difference in temperature. Wind energy only works efficiently when there is a good steady wind pressure. Due to the very nature of these ambient energy sources, the application and trends are very specific and hence limited.

Aerial Sampling

Unlike HAPs and satellites, UAVs have the capability of real time monitoring and in close proximity to the detection site. Exploiting their three-dimensional sampling or mobility, the target can be reached in time. A single UAV is good but with limited coverage, the resolution is high. It can be used to control the region of interest in different sorts. UAV monitoring is usually associated with UAV swarms because swarms can provide a large coverage area.

UAV Sampling for Smart Environment

It is inevitable that growing pollution in cities motivates the development of smart environment so that air quality can be monitored and improved (Gu, Q., & Jia, C. 2019). In large cities, many people living in are subjected to bad air quality, which is a basic cause for disease burden. To eliminate these problems causing air pollution, many large cities have initiated to combine smart cities technology to observe air qualities and pollutants within.

Wireless sensor networks are manually calibrated. They can only acquire data in low spatial resolution and thus, cannot trace the change in air pollution within a spatial dimension. Aerial relay network is getting considerable attention for high-spatial-quality and near-to-surface vertical gradation of atmospheric pollution. For effective air quality monitoring, UAV should carry air pollutant sensors and must operate beyond simple platform.

Air Pollution Sampling and Collection of Big Data

The use of UAVs has potential because it is flexible, mobile and is economical. People are now more aware of the hazards caused by air pollution and existing monitoring equipment cannot provide solution to requirement of modern cities UAVs are important assets for collecting data using sensor equipped UAVs embedded with existing Wireless Sensor Networks. It has been proven that air pollution has sudden changes at lesser distances horizontally and vertically.

Air Pollution Substances

Pollution in air is very difficult to detect and analyze. Contamination is commonly caused by human activities, so it is mostly measured in urban areas. There are six common pollutants

Carbon monoxide is produced when fuels for example oil, gas, wood and coal do not burn fully.

Fired up charcoal, fumes emitting cars and people smoking cigarettes also produce carbon monoxide gas.

Wood, oil, Gas and coal are the source of fuel for many commonly used household appliances that may include:

1. Boilers
2. Cookers
3. Water heaters
4. Gas fires
5. Central heating systems
6. Open fires

Management of the above is crucial in terms of digital governance as it indirectly impacts the general public and domestic household

Table 1. Description of six common air pollutants along with their significant characteristics

Symbol of Substance	Component Details and Characteristics
CO	Carbon Monoxide without color is a gas without odor.
NO2	Nitrogen Dioxide is a highly reactive gas.
O3	Ozone found abundantly in upper atmosphere and is a pale blue gas; responsible for GHE.
SO2	Sulphur Dioxide is a gas with irritating smell with no color trace.
PM2.5 / PM10	This matter contains particles which negatively impacts on health when inhaled.

Sensors for Pollution Sampling

Low-cost sensors are installed using readily available drivers and have better prospects for more sampling leading to better accuracy. They can be used in direct contact with air pollution sources. The sensor's data should be analyzed in detail: it can be affected by many parameters like temperature, humidity, wind and contamination of air-based pollutants in the region. As they are not bulky, only low-cost sensors can be mounted on UAVs. Following are the basic components that maybe used to serve the purpose of pollution sampling for UAVs:

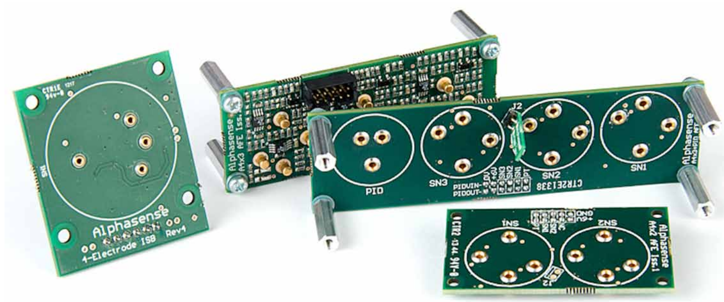
1. A control device as in Raspberry Pi with the latest version i.e. version 3
2. An analogue processing device or Analogue Front End (AFE) from makers as in Alphasense
3. Analogue to digital solution as in by South Coast Science
4. Various reactive gas sensors as in one by Alphasense
5. Specific particulate size including Volatile Organic Compounds (VOCs) sensors by Alphasense

Here a comparative history of the development of Rasberry Pi 2 is discussed for context sake. It is proposed that Rasberry Pi be used due to its easy installation features. In February 2016, Raspberry Pi2 Model 2 was replaced by Raspberry pi 3 Model B, which is a third generation of Raspberry Pi. In the range of Raspberry Pi 3 Model B there is another model which is referred to as Raspberry 3 Model B+. This is shown in Figure 1 which is a photograph of a Rasberry Pi3 Module.

The Analog Front End (AFE) group of circuits is intended for use with the Alphasense A4 group of four-electrode gas sensors is as shown in Figure 2 where space is provided, for example, with portable air quality screens. Alternatives incorporate a 2-sensor AFE, 3-sensor AFE and 3-sensor +PID AFE. All circuits incorporate a low commotion bandgap to give 200 mV inclination voltage to NO sensors. Requiring from 3.5 to 6.4 VDC supply, the 3-sensor board for instance just needs 2 mA power.

Figure 1. Rasberry Pi 3 module

Figure 2. Alphasense electrochemical gas sensors
Source: (Alphasense CO-A4 Carbon Monoxide Sensor, 2019)



For software temperature corrections, each board includes a pt1000, provides the signal of 1mv/K. The group of circuits i.e. AFE can measure the both reducing (NO, O3) and oxidizing(CO, H2S,NO, SO2).

South Coast Science can deliver on all of the gasses supported by Alpha sense electrochemical sensors: CO, H2S, NO, O3, and SO2. In addition, an Alpha sense photoionization detector (PID) is available for measurement of volatile organic compounds (VOCs) to part-per- billion resolution. Electrochemical sensors and PIDs can be deployed in almost any combination of two, three or four sensors per device. Measurement of CO2 can be performed by devices with the Alphasense non-dispersive infrared (NDIR) sensor. South Coast Science boards are provided with an interface for the forthcoming Alpha sense digital NDIR product.

Particulates

PM1.5 PM2.5 and PM10 – can be sampled using the Alpha sense optical particle counter OPC N2, and future OPCs. This has implication for monitoring particulate pollution of different sizes. A summary is provided in Table 2.

Table 2. Summary of the range of air pollutant effect

Substance	**Range**	**Data Sheet**
CO	500 ppm	Alphasense CO-A4
NO	20 ppm	Alphasense NO-A4
NO2	20 ppm	Alphasense NO2-A43F
VOCs	50 ppm	Alphasense PID-AH2
PM	0.38 to 17 um spheq size	Alphasense OPC-N2

UAV System Design for Environmental Sampling Delivery

Application and Types of UAVs

In recent years, the UAVs platforms are becoming increasingly popular in a wide range of domestic applications (photography, surveillance, environment monitoring, search-and-rescue, etc.) having reduced weight and size and a wide range of speeds. As the market develops various applications expand, more requirements are then imposed to extend the flight distance and increase the flexibility to adapt to the complex missions (Li, B, Jiang, Y, Sun, J, Cai, L. and Wen, C. 2016).

UAV works like a Wi-Fi hotspot, for example a switch or a router. There are two different sub networks, one for the sensors to the UAV and another for the connection among UAV and destination. Mobile Hotspots program, which aims to transform small UAVs into flying wireless hubs are also very popular.

A novel spatial domain data sampling system has been recently proposed, which can abruptly reduce the quantity of data sampled at sensors and get rid of the bandwidth requirement between cloud and UAV. The principle followed behind this proposed scheme is the temporal and spatial correlation between the sensor data. In complex environment, sensors data correlation is not as simple as linearity as the data is heterogeneous. Therefore, a new approach has been introduced, basically a neural network model; denoising auto encoder is utilized (Yu, T., Wang, X., & Shami, A, 2018), which has the ability of compressing both linear and nonlinear correlated data. The recently proposed sampling scheme basically comprised of three phases; system initialization, model training and data sampling. In the first stage, UAV flies above the target served by the IoT system and the cloud. All the sensor nodes will keep active and upload the data to cloud through UAV. Based on this collected data, sensor nodes will be clustered by bounded-size K-means clustering algorithm. In second phase, various sensor nodes within their clusters are selected as data sampling bodies. In the third phase of data sampling, data is sampled from selected bodies and encoded by UAV before it gets forwarded to the cloud. The final dataset is finally decoded and recreated in the cloud. With the complete support of UAV and cluster formation, the efficiency of data sampling can be improved.

UAV Subsystem

UAV subsystem includes various parts mentioned below:

1. Sensors
2. Communication unit
3. Navigation unit
4. Ground equipment
5. Propulsion

The subsystems can be added or modified based on the type of application:

Sensors

UAV sensors are of wide variety of types. Different sensors are for different types of applications. Below are the list of different types of sensors.

Distance Sensors

A Laser Range Finder (LRF) type of sensor shoots beams of certain intensity in specific intervals. When those beams reflect from objects, the sensor finds out the time taken for the beams to reflect back to the UAV according to the reflected distance hence the range.

Light Detection and Ranging (LiDAR): are best for making 3D constructions and for surveillance activities needed for navigation purposes and aerial surveys.

Thermal Sensors

Thermal sensors senses the heat that radiates from materials and objects as to transform this gathered data into videos and images

Thermal Sensors Cameras can capture a wide variety of organisms and objects, as to almost all source on our planet, as well as in the Universe, basically radiates some thermal energy. These includes, but is not limited to, buildings, living species, electrical sources, planes, land, machinery, rocks, gas, liquid, etc.

Air Pollutant Sensors

Air pollutant sensors are used for smart environment purposes. These sensors monitor the quality of air and pollutants present in it at different altitudes. There are wide variety of sensors for different air pollutants

Orientation Sensors

Accelerometers basically sense movement of the UAV in real time which is highly dependent on type of sensor used for the purpose. Magnetometers detects changes in UAV's direction and translates the data to processor that includes the data for speed, direction and orientation.

Communication Unit

This is the main unit that serves communication purpose. RF unit contains radars, antennas, transmitter and receiver circuits, RF frequency converters, RF filters, RF power amplifiers etc. All the subtypes in communication unit can be added based on the type of application used.

Navigation Unit

The navigation unit consists of inertial navigation unit along with GPS receiver.

Ground Equipment

For remote operations, ground equipment is necessary, where the sensors sometimes directly sends data to ground station, where there video receivers for video processing. Communication unit also communicates with the ground unit about flight control etc.

Propulsion

Engines, motors, batteries and propellers which helps put UAV in motion are all part of propulsion subsystem.

UAV Payload: Wireless Sensor Network

UAV payload designing is an important part in design of any UAV. UAV payload is the amount of load that it can carry during its flight operation. Modern UAV payload consists of three applications; Data collection (using sensors), communication with other UAV'S, base station, and navigation support (Borky, J. M. (n.d.).1997). All these functions; sensors, communication and navigation are centralized using a controller, which is also a part of UAV payload where batteries are crucial. The application of UAV payload is for military purposes such as weapon delivery and warfare.

Communication payload often includes radio frequency equipment such as antennas. These antennas basically include radar and other spectral surveillance functions such as signal monitoring and RF radiometry for accurate estimation for signal of arrival. Behind these payload antennas, are associated transmitting and receive electronics for communication purposes. Typically, fiber optic serves that purpose.

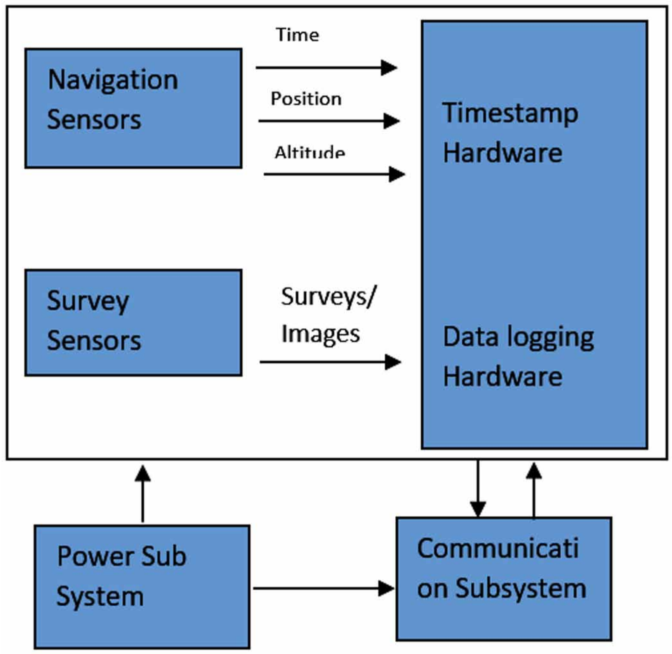
Navigation payload basically consists of inertial navigation unit with a GPS. Automatic landing of UAV will require a differential GPS. UAV position and other data are passed to sensors, processing unit or flight controls.

Finally, sensors for data collection are major part of any UAV payload. There are wide variety of sensors categorized as per application requirement. IR sensors includes optical or IR cameras for image processing. Pressure sensors, thermal sensors, magnetometers, gyro meters, accelerometers are all part of sensors used as payload for UAV. These sensors collect data which is processed on board.

Finally, the heart of the UAV payload is the controller or processor. A processor controls the operations of the sensors and processed data gathered by the sensors. The UAV payload subsystem description is summarized in *Figure 3* which gives a description of different components.

The problem with free lancing UAVs is that it can fly up to 30 minutes on single fully charged battery. Carrying extra devices does reduce the UAV's flight time, because these additional devices contribute weights to the UAV and these devices themselves consumes electricity. A conventional microcontroller powered by usb consumes power in the range from 1W to 10W.\

Figure 3. UAV payload components



TYPES OF UAVS

UAV are categorized into different types. Most are classified in terms of size, payload, flight range, flight endurance, altitude and its capabilities. The characteristics of these UAV are correlated. Usually, large UAVs carry more payload, move a longer distance, fly at higher altitudes, and thus have good flight timing and capability as compared to mini-ones. Based on the wing types, UAV are classified into five major types.

The first type of UAV's is the rotary-wing, which uses batteries and thus have very shorter flight times (Paneque-Gálvez, J., McCall, M.K., Napoletano, B.M., Wich, S.A.& Koh, L.P. 2014). This particular type of UAV basically includes the helicopter, Quad copter, octocopter and other types of multicomputer. This type of UAV has an advantage over fixed-wing UAV that it needs less space for landing. Second type of UAV is the fixed-wing UAV, which are suited for applications that demands longer flight time. They require very large space for landing and takeoff and as a result, they face problems in areas that are crowded with tall objects like mountains, buildings, trees, wind farms and other infrastructures. Regardless, they have simple structure which does not have maintenance problems (Klimkowska, A., Lee, I., & Choi, K. 2016).

Third type of UAVs are lightweight aerial systems basically called blimps such as airships and balloons, which are very light and thus have longer flight time, flies at low speeds and usually are very large (Gupta, S.G., Ghonge, M.M., & Jawandhiya, P.M. 2013). The fourth type of UAV is the flapping-wing UAV,hich has an advantage of flexibility and have morphing small wings, just like birds and flying insects. Finally, the Vertical takeoff & Landing (VTOL) UAV does not require takeoff and landing run (Watts, A.C., Ambrosia, V.G., & Hinkley, E.A. 2012)

The above shows that there is a vast choice to select an appropriate technology that is best suited for required application so that it conforms to the constantly prevailing environmental settings and purpose.

UAV Characteristic Applications

Characteristics of UAVs in environmental monitoring can be segmented according to the specific applications and time to perform certain mission. These are detailed as follows:

Hefty Operations: Operations that need more time like 30 plus hours in a mission are most suitably carried out by using UAV. Here the time consuming workload with low intensity operations are suited to unmanned air vehicle. These missions can be automated by programming the UAV to navigate autonomously and requires human attention rather than continuous and direct control. Examples may include: change monitoring of life surveillance over fixed locations, acting as a communications relay for example wifi extender or an air-to-air refueling systems.

Self-Trap: Unmanned aerial vehicles are best suited when operation needs to be carried out in harmful environment such as nuclear clouds or radioactive region or highly polluted regions where human being has risk of life. Sensors may be installed for sampling data in such kind of atmosphere. Small UAVs can be used to detect fires in inaccessible areas or where smoke or fire is injurious to human being.

Risk Taking: Missions for example monitoring of enemy activities may put many lives in danger so UAS serve as valuable assets in such scenario. The intensity of risk maybe too high in case of using air support while having high alert for ground to air combat or even more when using ground troops. In this case UAS may be used to suppress such threats. Cheap UAS maybe used intended to be sacrificed so that enemy may expend its arsenal so that their command and control equipment is exposed (Suraj G. Gupta, Mangesh M. Ghonge, Dr. P. M. Jawandhiya 2013)

UAV Environmental Applications

Oil Refinery and UAVS: Just like diesel fuel demand for hydrogen have increased according to United States Energy Information Administration (EIA; Washington, DC United states; www.eia.gov). It is used to lower the sulfur contents in diesel. Diesel price is rising globally and so is the regulation to decrease sulfur contents is becoming strict. A process of steam-methane reforming is conducted in which methane is brought into steam at high temperatures in catalyst pipes. As a result the combination of hydrogen, carbon monoxide and carbon dioxide is obtained. Pressure swing absorption is then used to remove carbon monoxide for purification of hydrogen.

Dangerous Environment in Oil Refineries: Environment in Oil refineries is very dangerous for example the hydrogen production is also known as the radiant box as temperature of furnace is uptill 4000 degree F containing high contents of chromium designed to withstand high temperature. Even a minor error in the radiant box is not accepted. It consists of burners that heat 143, 40 ft tubes which then heat the steam-methane mix. These tubes are kept 1 ft apart for uniform heat delivery.

If a minor error is even detected in manufacturing all 143 pipes are inspected that require scaffolds that have to be taken inside piece by piece as there is not much space in such areas.

Use of UAVs for Inspection Instead of Scaffoldings: The solution to this problem is UAVs. Industrial Skyworks proposed to use UAVs having 1920x1080, 30 fps camera. As a result, instead of using scaffolds for inspection UAVs can capture video of all pipes safely. They may even stream pictures at low resolution. Both video and pictures can be recorded in an SD card and may be transmitted from UAV to its controller. The UAVs can be equipped with carbon fiver structure to avoid damage to both pipes and UAV itself in case of collision. Additional software can then be used to analyze the pictures and videos for detailed inspection.

UAVs and Wildlife Management: In order to detect sea turtles Eric Becker of the world wild Fund (WWF; Woking, Surrey, UK; www.wwf.org.uk) has used a UAV that has 4k color, 336 x 256 micro bolometer based thermal image detector. Pictures were taken from the UAV week before hatching of their nests and then data was analyzed with thermal images finding temperature difference between hatching and non-hatching days. Water resources can also be mapped. UAVs are used to track species of algaes or marine animals using a relay station on an in-situ boat. The linear paths are scanned and fed back to a central hub where real time environmental monitoring of species can be implemented as in for tracking humpback whales, Indus River Dolphins of South Asia or other endangered species.

UAV Relaying of Environmental Sensor Data

The UAV pollutant sensors vary significantly in their mechanisms. Each UAV sensor is for one type of air pollutant, like nitrogen dioxide or particles, and emitted different forms of signals. These signals are in response to the concentration of the pollutants and therefore, should be calibrated before flight (Yu, T., Wang, X., &Shami, A. 2018). Therefore, an individual data acquisition system is usually attached to each sensor to acquire the signal from sensor and gives sensor-type data to process in the data fusion system later. Each type of data acquisition system run its own source program designed for each sensor. In modular approach design, the sensors do not send data directly to the decision making entity but rather, make use of the data fusion system to aggregate the data gathered from the sensors. The aggregated data can be send to the base or ground station.

The data fusion system is the core and most important element in modular design approach. It is basically responsible for processing UAV location data, sensor data and time data. The UAV's flight controller basically provides this location data to the data fusion system. The location data is usually gathered from a GPS that the flight controller is connected to but, because GPS data also carries time information, the flight controller gives time data as well. Moreover, the flight controller can also provide the UAV attitude data, such as its velocity, orientation, acceleration to the data fusion system. This information, accompanies the air pollutant data from air pollutant sensors and thus, can show that how the data was collected by the UAV and this helps in understanding the context of the data measurements. All sensors, including the flight controller provides data in many formats having different rates, so the data fusion system can put on these heterogeneous data types. Moreover, multiple sensors can also be added or removed from the system.

Many researchers have reviewed UAV platform performance. Gupta (Gupta, Jain, & Vaszkun, 2016)] detailed issues regarding wireless transmission in UAV communication networks and emphasized on providing stable and reliable communication. Hayat (Hayat, Yanmaz, & Muzaffar, 2016) studied the civil applications of unmanned aerial vehicle from a perspective of communication. Author also reviewed their characteristics and showed experimental results from different projects. Author Motlagh (Motlagh, Taleb, & Arouk, 2016) presented a detailed survey and discussed the potentials of UAV for low-altitude delivery services from the sky. Cybersecurity related issues were reviewed in (Krishna & Murphy, 2017) where simulated and actual attacks were discussed. J. jiang (Jiang & Han, 2018) discussed most relevant routing protocols for unmanned aerial vehicle and compared different major routing protocols. Khawaja (Khawaja, Guvenc, Matolak, Feibig, & Schneckenberger, 2019) merely focused on air-to-ground channel modelling and measurement along with channel characterization for UAV propagation. Lu (Lu, Bagheri, James, & Phung, 2018) introduces various wireless charging techniques designed for UAV flight time improvement. Author classified wireless charging techniques based on electromagnetic and non-electromagnetic methods. Cao (Cao, et al., 2018) was concerned with protocols and mechanisms for designing of air-borne networks by merely focusing on HAP-based networks, LAP-based networks and integrated networks for air-borne communication. The above literature is outlined in table-1 which help reader to grasp the main study from the literature.

Risk Transfer Mechanism for Climate Change Resilience using UAV based Digital Governance

Places which are hit by calamity for example by causes relate to Climate Change are to be governed by Paris Climate Change Conference of Parties (COP 21, December 2015). This amongst others call for a comprehensive risk transfer mechanism strategy in the context of climate risk management.

For this purpose, various micro level financial insurances have been promoted to support small farmers and local dwellers in dealing with environmental degradations. Here small premiums are used to not only insure life death but also insure personal assets both tangible and livestock, agriculture and fisheries related equipment.

HetNets are heterogeneous networks of varying cell size and coverage overlap. As crops fishers and various man-made environmental artefacts are assessed, the importance of HetNets cannot be overemphasized. Addressing malicious attacks in HetNets, the following difficulties are encountered:

1. Pinpointing attack sources, because traces can be disguised easily
2. Finding attackers' identities due to anonymity of some Internet protocols
3. Avoiding attacks due to the open accessibility of the wireless medium

Table 3. Summary of UAV Application case studies and literature review

Publication	Summary
Gupta (Gupta, Jain, & Vaszkun, 2016)	Issues regarding wireless transmission in UAVs
Hayat (Hayat, Yanmaz, & Muzaffar, 2016)	Civil applications of UAVs from a communication perspective
Motlagh (Motlagh, Taleb, & Arouk, 2016)	Potentials for Low-altitude delivery services in UAVs
Krishna (Krishna & Murphy, 2017)	Cybersecurity issues in UAVs
J. Jiang (Jiang & Han, 2018)	Routing protocols comparison for UAVs
Khawaja (Khawaja, Guvenc, Matolak, Feibig, & Schneckenberger, 2019)	Air-to-ground measurement and channel modeling for propagation of UAVs
Lu (Lu, Bagheri, James, & Phung, 2018)	Wireless charging techniques for improving UAV flight time
Cao (Cao, et al., 2018)	Mechanisms and protocols for the design of air-borne networks for UAVs

To deal with cyber risk damage, the global expenditure on cyber security is expected to reach US$1 trillion from 2017 to 2021. This potentially opens up a vast market for developing anti-risk. Nowadays, the mainstream of security research in HetNets focuses on developing system-based risk mitigation solutions in various enabling wireless technologies, such as massive multiple-input multiple-output (MIMO) technology, cloud radio access networks (C-RANs), and wireless caching. Most of these technologies are compatible with the concept of Internet of Mobile Things (IoMT) of which UAVs form an integral part.

By adding UAVs the MFIs (Micro financial Institutes) can further reduce the risk loss by determining in real time the impact of damage on personal assets as well as commonly used infrastructure reducing the different in actual loss and index as defined by various financial instruments including weather derivatives, catastrophic bonds and climate bonds.

Recommendation for Enhancing Digital Governance in UAV aided Environmental Monitoring

It is advisable to pursue a policy of enhancing outreach using environmental data sampling. The philosophy differs if one has an agrarian base or industrial base. The risk assessment of the sector needs to be carried out. MFIs need to be involved in determining the environmental monitoring format- sampling interval as well as whether it is air borne or terrestrial. Also this can give a better outlook on the updated situation for a community's economic situation. The data gathered reflects the community's GDP and in turn reflects on the level of investment for the future. UAVs will see if the growth is variable. The Environmental variables will be defined.

Here Catastrophic bonds need to handle extreme effects of climate like hurricane and earth quake. These can be considered for capital market as UAV and Smart Sensor Technology fusion. Similarly, derivatives can be introduced based on weather indices as identified through temperature, humidity soil conditions Such a network connects GSM to LoRaWAN and intern to affixed wing UAV based relay network.

Such a work will help protect the most vulnerable people whose livelihood is dependent on variables linked to the environmental variables.

FUTURE RESEARCH

The following summarizes the different trends happening in the field of UAV and its applications:

1. **Relaying Multiple Aerial Platforms**

Unmanned aerial vehicles come in different shapes and sizes with each having advantage and disadvantages. A large aerial vehicle has long range of connectivity as compared to small aerial vehicle because of the fact that the large aerial vehicle can carry big transceivers while small aerial vehicle carries Wi-Fi radios for communication. Small UAV'S although cheap, are constrained in their short flight time and lesser payload capacity. Flight time and payload are inversely related to each other. However, these problems can be countered by reliable communication network formation. For example, a single UAV that is taking images of an area, will do many trips for a complete coverage task and thus consuming battery. In order to avoid this back-and-forth activity, a chain of nodes can be placed for relaying between the UAV and ground-base station for transferring of data in a real-time scenario.

2. **Device autonomy**

Device autonomy is related to the control of UAVs and it specifies that whether the UAV can operate autonomously or need remote-controlled assistance. Whatever, the scenario, it is desirable for aerial vehicles to stay in range of a remote controller so, that in case of an emergency it can be controlled. For autonomous flights, UAV can fly based on adaptive and pre-computed waypoints. These waypoints are decided by the central processing unit such as a base station and sent over a link to the UAV. Moreover, the UAVs can also decide the path of flying by using information collected by the sensors.

3. **Connectivity**

It is the most important aspect in any UAV communication network. For simplicity, it can be divided into three categories. Firstly, connectivity with the decision-making entity such as a base station. It is necessary for the UAV to be connected with DME all the time so that its path can be tracked for security and safety. Secondly, UAVs connectivity with ground-personnel is necessary in case any disaster happens. Thirdly, the connectivity between different devices is an essential part of UAV communication networks.

4. **Traffic demands**

Understanding the network demands in UAV communication plays an important role in designing of the network protocols and system. Traffic demands can be sub-categorized into types of sensors for different type of data traffic, type of traffic that is being exchanged in the network, and the frequency of the traffic.

5. **Adaptability**

Robustness in UAV communication networks demands adaptability of such network. For aerial communication networks, the adaptability includes network adaptability and adaptability of different mission demands. A robust network must be adaptable to different nodes leaving and joining the network and thus, topology changes. These topology changes are more frequent in networks having high devices mobility. In large networks, covering a large area may cause variant terrains and channel conditions and thus, adaptability to this topology changes due to the mobility of devices, will be a basic requirement in UAV communication networks. The dynamism is not only caused by high mobility, channel conditions, terrain changes or node failure but due to the network mission demands as well. In simpler words, the objectives of UAV mission may change and therefore, the tasks assigned by DME to UAVs will also change for successful completion of the mission

6. **Synchronization**

UAV communication requires time synchronization and legitimate time-stamping for the traffic. It is important for the devices to be synchronized with each other. For example, if multiple UAVs are collecting data from different points using different sensors, the data collected from all devices will need to be synchronized in time and space and it basically refers to synchronous activity of the devices performing a joined coordinated task. Coordinating UAVs or multiple UAVs synchronizes with each other so that they do not perform the duplicate task at the same location and time.

FUTURE RESEARCH DOMAIN WITHIN UAV NETWORKS

1. mmWave UAV networks

It is of no doubt that UAV communication requires high bandwidth because it has to deal with different types of data such as video, voice, huge data files. This spectrum crowding and growth encourages transferring to modern frequency allocations. In our context, Mm or millimeter wave communication are emerging as a new candidate that can make use of a huge amount of spectral resource at millimeter wave frequency band so that high bandwidth requirements can be dealt. A basic concern for millimeter wave communication is the high propagation loss as Friis law states that free space path loss grows at the rate of the square of the frequency. Fortunately, short wavelengths of millimeter-wave signals allow multiple rectennas to be wrapped in small UAV. This has application in smart agriculture and in urban cities and short distance channel measurements.

2. UAV NOMA (Non-Orthogonal Multiple Access) transmission

NOMA has drawn much attention as key enabling technology for 5G communications. NOMA basically integrates super position code at the transmitter along with successive interference cancellation at the receiver's side. In comparison to orthogonal schemes, NOMA serves variety of users with varied traffic patterns in non-orthogonal pattern by focusing on power domain. The large variety of wildlife and environmental groups can be connected using this technology.

3. Energy harvesting UAV networks

UAV's have limited power supply as it is powered with capacity-limited battery. UAV has to perform multiple operations such as flight control, data sensing, transmission of data and running applications. All of these operations consume battery, which creates energy deletion problem in UAV communication networks. Energy harvesting is a trending research in the field of communication networks. The idea is to scavenge energy from the environment such as solar energy, wind energy, vibrational energy, thermal energy etc.

SUMMARY

The recent advances in the field of UAV payload development has lead to a vast variety of applications which were not considered for aerial remote sensing and communication due to the large cost associated with deployment logistics and legal issues with respect to HAPS, Satellites and LAPs. The concept of small and localized deployment of sensors conducting data collection and processing in situ and transmitting to a central server is evaluated. It has been suggested that such a method has its own benefits and advantages and can be readily deployed especially in developing countries where there is a lack of appropriate infrastructure and /or geographical restrictions in place which can only be circumvented with use of appropriate technology. The trends are expected to extrapolate with variety of users (NOMA), energy efficiency (UAV based Energy scavenging) and mmWave networks (varied connectivity).

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