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Aerial and Under-water Dronal Communication: Potentials, Issues and Vulnerabilities

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Abstract: ***The use of UAVs has been on the rise since the past decade. These UAVs are very versatile and can be applied to several fields ranging from agriculture to military reconnaissance. Due to the immense functionality of the UAVs, it has now become a very popular topic in Research. With the advent of Deep Learning and Machine Learning the autonomous navigation functionalities have been improved but it still poses a challenge as navigating a drone involves the integration of its software and hardware functionalities. This paper reviews both indoor and outdoor navigation. Topics in navigation such as Control, Hardware, Algorithms, Path-Planning, and communication are touched upon in this paper. The paper also presents a discussion on the Navigation of UAVs using vision-based technologies, this technology encompasses the use of various sensors and cameras and integrate it with the navigation system of the UAV to ensure the success of UAV's operation. UAVs play a pivotal role in networking, many applications have been developed which have UAVs as an important component in them. Their applications include Urban computing, Internet of Things, Ubiquitous Computing to name a few. Safely operating a UAV as a network node is not a simple task, these nodes are prone to various types of attacks. A new type of attack introduced in this paper is termed as "Coagulation Attack". This attack gets its name from the coagulation property of fluids wherein fluids clot and their particles settle down. This paper explores the concept, issues, challenges and research aspects of Coagulation attack. This paper also introduces the concept of Underwater Wireless Communication. On a planet where 70% of the surface is covered in water, UWC has a lot of potentials to be exploited. Moreover UWC is critical in many key areas of Maritime research, commerce, and surveillance. UWC is used for experimental observation, data collection and analysis, underwater navigation, disaster prevention and early detection warning of a tsunami. In addition, we summarize emerging technologies in the UWC, future research directions and recommendations using fifth-generation (5G) communication techniques.***

Keywords: Aerial Drone Communication, Under-water Drone communication, Coagulation Attack, Vulnerabilities, Security Aspects

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I. INTRODUCTION

Drones are robots capable of flight which can be operated remotely or autonomously without the need of having a pilot to be present inside it.

When operated remotely they are controlled by pilots from a ground-based control center and when operating autonomously their flight is managed by a navigation and control system which consists of hardware sensors and software methods that integrate seamlessly to generate flight plans and control the position and configuration of the drone. Determining the position of an entity and guiding it along a path is called Navigation. Drone navigation is the study of systems that enable users to ascertain the position of a drone and effectively generate path plans. Developing a state of the art Drone navigation is the bleeding edge technology for deploying next-generation autonomous drones. Drones can assist is exploration of places where it is not viable for humans to reach. They can be used effectively in crucial operations ranging from search and rescue, security reconnaissance, transportation, agriculture, mapping terrains, etc. Drones have been employed at farms where they are used to map out the fields, detect and identify the health of crops and check irrigation systems. Drone Delivery System is being tested out by major companies like Amazon to deliver their products. Aerial cinematic footage is often used in movies. Due to recent innovations in the field of communication, drones are deployed in a swarm where their actions are synchronized with the other drones present in the network and the operations are performed by all the drones in cohesion. Owing to their superior flexibility and mobility, drones are being increasingly deployed for civil applications. Despite all these advancements, drones when deployed in complex environments, behave incorrectly. Hence it is still necessary to develop more sophisticated communication and navigation systems so as to make the operations of a drone more reliable and secure. We can conclude that it is imperative to develop a high-performance independent navigation capability for drones, this is illustrated in Fig.1

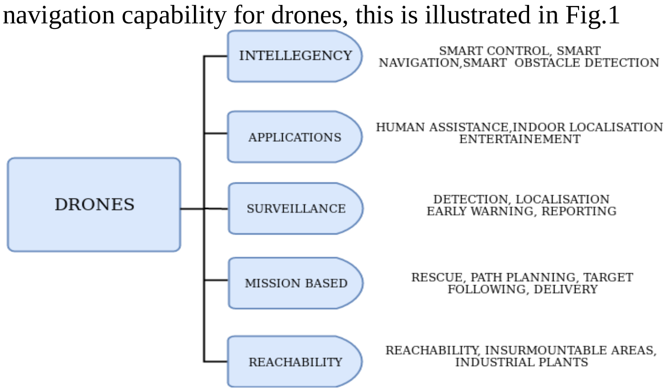

Fig1. Introduction to Drone Communication

The pilot of a drone is responsible for controlling his/her drone, the pilot is aided by the visual tracking system and is also relayed the information about the drone's position and configuration.

Smaller inexpensive drones lack GPS capabilities but the expensive models come with GPS receivers which enables the drone to implement some smart routines like Return Home, wherein the drone stores the location from where this drone was launched and when called back the drone can return to the place of launch. Another such smart routine is Hold Current position wherein the drone hovers at a fixed location and altitude. The control of each drone falls on the pilot who uses visual tracking to determine his position and orientation. GPS is not used in starting drones but in more advanced drones GPS receivers play very important role in navigation and control loop which provides some smart features that include, Return to Home that is the drone memorizes its starting position from where it took off and when this function is executed, it will automatically return to this spot; Holding Current Position which allows the drone to remain at a fixed altitude and location. But more importantly the Autonomous flight routine uses GPS to establish GPS waypoints, when the flight trajectory has been determined then it can follow this path autonomously. The goal of this paper is to touch upon all the recent advancements in the various fields associated with drone navigation and communication, this paper is a good starting point for any individual who wants to improve their knowledge in this field. This paper is an earnest attempt to contribute to the state-of-the-art in the field. The motivation to write this paper comes from the extensive use case of drones. [1] presents the use of drones in data collection and patrolling. [2] presents the idea of using Multiple Micro Aerial Vehicles in search and rescue operations in disaster-hit regions. [3] presents the use of drones to assist visually challenged individuals in navigation. [4] presents methods for controlling huge crowds, for example, using mid-air display or navigation of crowds in huge events like concerts or sports. This paper is divided into several different sections each section touches upon a different topic, the topics are ML, AI and Computer Vision Technology, Control Systems, Communication System, Path Planning and Autonomous Navigation. These are discussed below and their details are summarised in the table above. Communications networks are quintessential to data sharing. Over the past decade, there have been many breakthrough developments. The use of nodes has greatly extended limits for data transmissions. The use of UAVs as network nodes to improve connectivity is one such example of data transmission using varied nodes [5]. When multiple UAVs are deployed in a swarm and cooperative mode, they create a network that is more advantageous than traditional networks due to their mobility and flexibility. Many tasks such as Internet Of Things, Ubiquitous Computing make use of the versatility of UAVs [6][7][8]. Despite their rapid use, there are still issues that, when left unchecked can disrupt the network. One of the biggest issues is security. Several network attacks have been presented below along with their countermeasures. Vulnerability assessment is a good tool to identify the potential threats an aerial network might face [9][10][11]. A robust and reliable system is of significant interest in aerial drone systems [12][13][14].

Attacks on UAVs are regarded as a component of the cyber-physical system, hence UAVs are proportional to cyber systems and hence they are studied and evaluated to identify threats and devise countermeasures[15][16]. Cyber-attacks can be fatal and disrupt normal operations of the drone [17]. False data injections are other significant part of cyber-attacks [18]. [19] describes how fatal cyber-attacks can be and how disrupting a drone delivery system can damage the entire business model. This paper touches upon a new sort of attack that can bring down the whole network. This is known as Coagulation Attack. The name has its origins in the property of coagulation, where substances clot and solidify. Using this attack successfully renders the attacker capable of reconfiguring the configuration of drones in the network, this has the possibility of destroying the whole network. This paper discusses coagulation attacks, the major problems in handling these attacks and some robust countermeasures.

The increased carbon footprint and greenhouse emissions have led to a rise in global warming, which has been the focal point of climate change for a few decades now. The sea levels are gradually rising and it is of utmost importance to observe the environmental activities in the ocean and collect the data for analysis. Oceanographic data such as water sampling, salinity level, etc are to be collected, and drones can be effectively deployed to aid in this task. Underwater Wireless Communication (UWC) is a key building block to deploying drones in water. UWC can be used to perform military surveillance, mapping of underwater terrain and also for commercial purposes like detecting underwater resources. UWC also finds a place in experimental observation, data collection and analysis and also disaster prevention and early detection tsunami warning. Optical, acoustic and radio frequency (RF) wireless carriers are key components in UWC applications. The use of UWC methods in underwater is a very arduous task when compared with terrestrial communication [20]. Physical characteristics and chemical features of the water medium greatly affect the quality and reliability of data transmission [21]. An underwater system for communication consists of sensor nodes that are anchored to the seabed, nodes floating on buoys, towers for processing signal and onshore base stations[22]. Ships and submarines can also be used to build the system

II. MAIN COMMUNICATION TECHNOLOGIES IN UWC AND UAV AUTONOMOUS NAVIGATION

Significantly higher data rates and bandwidth was observed when underwater optical wireless communication (UWOC) was employed as compared to acoustic waves. Using acoustic waves provides low latency signals in underwater over the long-distance delay. There have been reviews on signal propagation techniques like UWOC, UWAC, UWRF recently [23]. [24] reviews techniques like high-speed acoustic communication through orthogonal frequency-division multiplexing (OFDM). The existing UWC technologies have future perspectives towards the next generation (5G) to user's requirement. This paper discusses emerging UWC technologies, compares UWC techniques and related issues [25].

A study of generalized frequency division multiplexing technique (GFDM) towards underwater 5G communication system based on a multi-branch filter bank has been conducted in the recent article [26]. An encouraging technique for 5G applications in underwater is Filter Bank Multicarrier (FBMC).

Types of Water

Clearest Water, Intermediate and murkiest water are the different groups' seawater has been classified for UWC [27]. The Mid-Pacific and Atlantic contain clearest water. Northern Pacific ocean contains intermediate water, North Sea and Eastern Atlantic Ocean contain murkiest water. There are four categories [28] into which seawater is classified for optical communication, these categories are pure seawater, clear ocean water, coastal ocean water, turbid harbor and estuary water. Clear ocean water which contains a high concentration of suspended particles leads to losses due to scattering whereas pure seawater leads to absorption and major losses. In coastal waters the high concentration of suspended particles contributes to absorption and scattering, but estuary and turbid harbor water contain the highest concentration of particles.

[29] explores the method of indoor localization with the help of low-cost hardware present, it overlooks other mini drones as well as static obstacles. Collision Disk, a binary structure used for exploring the environment is employed to efficiently select collision-free paths. The drone can identify its current location as well as the location of other mini drones, it can also monitor its height and sideways drift with the help of the additional sensors installed. [30] Presents how the sensor automatically determines the position and orientation using a 3D scene model, in this scene model 2D image structures are geometrically matched with projected component in the 3D model. Efficient flight over urban areas can be achieved using this method. Path following control system for a drone, which is dependent on 3D localization by pictorial marker and its strategy and execution is presented in [31]. There are two components that compose the system of path following, one is responsible for the drone navigation and another is responsible for image analysis and 3D pose estimation. The design is exclusive to indoor drones and experimental verification was done on a real drone and gazebo simulator. An expansive possibility for study of territory and survey has been discovered due to the new technique of observing and understanding the environment, this has been discussed in [32].Mapping, creation of orthophotos, 3D model's generation, data integration into a 3D GIS (Geographic Information System) and authentication through autonomous techniques Were used to measure the abilities of photogrammetric RPAS multi-sensors platform. [33] Describes a technique used for autonomous navigation of small drones called Simultaneous Localization and Mapping (SLAM) which is a vision-based method for a multi-dimensional geometric feature extraction technique for monocular SLAM extraction and comparison of two-dimensional lines is done efficiently is accomplished by the fast line search matching algorithm built on monocular SLAM system. The extraction and comparison of 2D lines are efficiently calculated using the fast line search matching algorithm which is based on monocular SLAM method. The map descriptor's efficiency has been improved by the multiplane features which are generated by a J-Linkage algorithm. Fuzzy/Lyapunov and kinetic controllers are integrated and a 2D motion control for the drone is based on it, this idea is presented in [34]. The drone is capable of being controlled from satellite, air, sea, and ground and also during semi-immersible operation. The logistic problems involved in very shallow water are solved using the SI-Drone system. [35] presents early work on methods for charging drone batteries in an efficient manner. The charging time and queueing time is taken as input and Djikstra's algorithm is used to derive the aforementioned method. A cloud-based management system is known as Traffic Control System (TCC) is used to collect report of a drone's flight information like current position, speed, and destination position. The goal is to reduce the overall travel delay for drones at QCM. [36] explains the VR associated communication session provided to remote user using a multi-view sensing drone network , communication operates in 2 sessions, at the first step a viewpoint-priority-aware scene reconstruction error is formulated as a function of the allocated sampling rates And this used to calculate the optimum value that minimized the aforementioned error for a given drone position and system limitation i second stage and online view sampling policy is designed, it searches for new drone location while taking action to detect the optimal drone configuration for the area.

III. COMMUNICATION

[37] introduces a method which uses good quality images and lives video streaming to detect and access a location, "structure from motion" method is used for the generation of orthomosaic images and 3D scene rebuilding using images collected by drone. Results were obtained after comparison of unsupervised classification methods with direct observation. HOG and SVM algorithms are used to address some issues like covering long flight routes. [38] mentions a method for self-navigation of Micro Aerial Vehicle (MAV) with an inexpensive quadcopter that is fitted with monocular camera. In this method the MAV's trajectory is evaluated in real-time and is based on LSD-SLAM. A self-flying and hindrance handling system built on monocular vision is presented in [39]. A ground station laptop receives navigation data and camera video from the drone wirelessly. The precise location of the surrounding 3D scattered map is derived using ORB-SLAM. A Kalman Filter is used for sensor fusion. The 3D position is controlled using a PID controller. The experimental validation of scientific theories and methodologies by employing an inexpensive MAV is presented in paper [40]. In a nutshell, the MAV's flight capabilities in real-world situations are demonstrated in [40]. Instead of using small datasets or simulations, an interesting approach is presented in [41] wherein the drone learns by crashing itself (12000 times). This dataset consisting of negative and positive flying is very effective for UAV navigation. Ideas pertaining to the control of flying data characteristics and the insertion of high-quality video feed are presented in [42]. Video Piloting (FPV/RPV) along with image processing are methods currently available that can be employed to analyze flight. Sensors like Altimeter, GPS, and IMU integrated with Adruino can provide critical data that can contribute to a stable flight characteristics. [43]

shows how Inertial Measurement Units (IMUs) can be calibrated analytically. The calibration method mentioned involves analysis of errors wherein the IMU is placed at different positions first by moving it using hands and later by employing analytically designed algorithms.

Digitized Intermediate Frequency GPS signal is depicted in the model presented in [44]. First of all, C/A code, navigation data, and the noise data are altered at the same moment. After simulation the GPS IF signal data is collected and is given as input for various algorithms like tracking, generating GPS signal spoofing, etc. An active circularly polarized antenna is used for Global Navigation Satellite System (GNSS) signal reception and this is presented in [45], this works at 2 bands, which are GPS L1 (around 1,575 MHz) and GLONASS L1 (around 1,602 MHz). The antenna is split up into three layers namely patch layer, feed layer, and circuit layer. Wideband Radio makes use of Air-to-Ground/satellite connection to progressively transmit and receive channel information to/from an Aircraft and a Ground Station [46]. The coding and implementation of PWM driver and its development are presented in [47], it also showcases the “Drone Bosco”. The paper also introduces the use of hardware descriptive language to use FPGA

Drones can be employed to review power lines and this idea is presented in paper [51] which provides a notion for constructing a “GPS- non-GPS integrated navigation”. Additionally to address the issue of drone collision the UTM rules are drawn up. [52] Introduces the idea to design and integrate GPR (Ground Penetrating Radar) on autonomous drones to create an aerial system that can be used to detect landmines. A custom-built and lightweight GPR is built based on Software Defined Radio (SDR) and this is used for landmine detection in various scenarios. The position and behavior of the drone are regulated using “backstepping+DAF” which is a control strategy. Paper [53] introduces the idea of using an airborne multisensory system to autonomously detect landmines. The components of this system include two IR sensors, an RGB camera integrated with laser illuminator and a radar.

Paper [49] introduces GNSS 141 reflectometry (GNSS-R) which uses reflected GNSS signals to determine the properties of the object on Earth that reflected these signals. The interaction of these signals extends a few centimeters and soil moisture limits the depth of penetration.An inexpensive prototype of a receiver to be used as payload to detect metal objects is developed using SDR technology. [54] presents the notion of employing UAVs to assist in collecting data and reduce the burden on operators through automatic guidance. An architecture based on the ROS-TMS framework is presented in [55], this architecture renders the drone capable of completing a particular service job on its own in an Informationally Structured Environment (ISE). The architecture involves a navigation system that uses a finite state machine to solve the path planning and flight control system in ISE. The navigation of the drone is carried out by a tracking system based on ROS-TMS framework, this system uses infrared cameras to track optical motion. The role of drones for communication is shown in Figure 2.

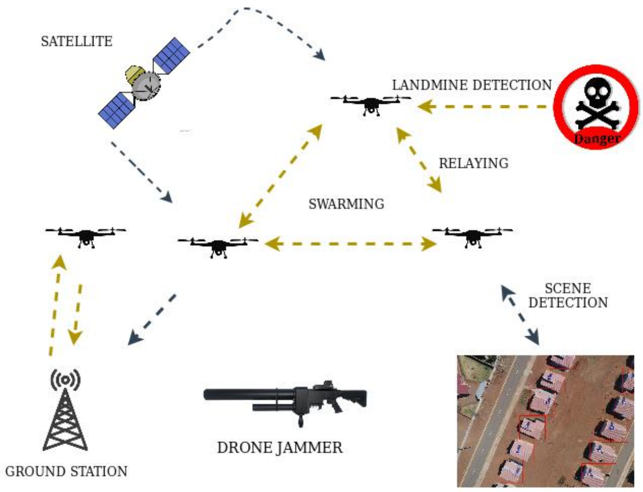

Fig2. Communication in drones

A drone capable of self-navigation indoors is presented by [56]. With the use of only a front camera for sensing this drone has the ability to detect and avoid pedestrians in the indoor environment. Navigation is handled by vanishing point algorithm, detecting walls is done using Hough transform and the detection of walking individuals is done using SVM along with HOG descriptors. The optical navigation device of the drone is an interesting idea and its algorithm design and implementation are the main focus of [57]. It has two functions, the first is to use optical image data to track a particular object and then use drone stabilization to make perfect landing on the target object. The idea of teach-and-replay navigation using Monte Carlo method is described in [107]. The probability of doing a loop detection is generated by MCL in 1D. This control system of MAV constitutes a parallel tracking and mapping system which is described in [48]. Working PTAM on a 5watt computer is a feasible solution using currently available technology. [50] discussed the development of jamming and spoofing circuits/devices which can alter the navigation signal leading to transmission of erroneous navigation signal which can misinform the system. [105] discusses challenges involving communication and the networking of UAVs in future. The safety of UAS is a natural concern since it can directly interfere with the control and non-payload communication (CNPC). The low elevation of flight and wide bandwidth requirements are some of the problems associated with CNPC.

IV. CONTROL

[55] describes a ROS-TMS based control architecture. The architecture involves a navigation system that uses a finite state machine to solve the path planning and flight control system in ISE. [58] presents an autonomous navigation control to track trajectories in the XY plane, this system is intended to be used in Micro Aerial Vehicles (MAVs) and it contains designs for controller,system modeling,planning, and simulation. This involves two models, a linear model for steady-state and a nonlinear model for dynamic transitions. [59] mentions the idea of reactive control, a technique that focuses on properties of control logic and this technique outperforms the time-triggered method.

Reactive control and Navigation sensors are employed to make control decisions. Objectives such as executing more timely and controlled decisions can be achieved by this method, moreover it also enhances the utilization of hardware and reduces the need to over-provision control rates. The use of Inertial Navigation System renders a drone capable of returning back to its base without relying on external communication. [60] presents some improvements to the accuracy of INS and also the onboard video camera, the paper also discusses some computer vision methods. The accuracy of drones with long flight distances is improved with the usage of Google and Yandex satellite maps.

[61] presents a conformal Planar Inverted-F Antenna (PIFA) for mounting antennas, this is the result of efforts made to improve wireless communication hardware. This antenna is inexpensive and easily manufactured and is a good component to be used in communication for UAVs, bicycles, and drones. [62] presents methodology based on gradient descent is used to tune the attributes of Proportional Integral Derivative (PID). Control of leader-follower formation and way-point navigation is used to develop this method. The AR Drone is a good choice for application in research and education in robotics. [63] presents the drone's hardware,software, components, and capabilities to demonstrate various tasks like position stabilization,target tracking, and autonomous navigation. There is also a demonstration for navigating and controlling an ensemble of mobile robots. To help facilitate research in this field some efforts have been undertaken. [64] presents a single-day competition on autonomous visual navigation of a UAV, intended to serve the purpose of tutoring students don't have prior knowledge of this field. Programs to accelerate learning and to guide students are introduced and available as an open-source programming library. [65] presents an exhaustive review of various open-source flight controllers that are available for hardware and software, it also describes the essential components of a UAV system.

V. PATH PLANNING

[66] presents a system that uses a 433MHz nRF905 wireless communication module to capture motion by laying out 3D coordinates for the drone. The real-time current location can be viewed in a user interface designed in visual C#. In an indoor flight three multi propeller flying robots were controlled at the same time using Human-Machine Interaction (HMI). The Parrot AAr 2.0 drone is capable of following a predefined route, this is demonstrated in [67]. Optimized path planning algorithm and Simulated Annealing (SA) optimization algorithm are employed to secure an obstacle-free path. The position and location of the drone are found using IMU and to control the copter a Simulink model is used. [68] presents some algorithms for tracking and generation of trajectory.Flight paths are generated using cubic polynomials and bezier curves. The drone is driven using a PID controller, the navigation techniques involve the application of artificial repulsive and attractive potential field.Extended Kalman filter and visual landmarks were applied to get the global location of the drone. [69] presents a navigation system to control a non-holonomic mobile robot. The scanning laser finder which is a component of the robot's external stimuli perception system is used to get environmental data with high precision. The data gives the drone terrain traversal ability by modeling a tessellated environmental model.Point-to-point traversal is accomplished using a kinodynamic path planning algorithm that employs Rapidly-exploring Random Tree (RTT) approach to the model. [70] addresses the problem of higher energy and time consumption associated with a drone by proposing a solution where a rover is used to plan the trajectory. An optimized path or the drone is computed by a system of a physically controlled drone attached to a rover, this system searches and identifies interferences using stereo imaging, this reduces time and power consumption. [71] presents a study on the use of drones for mapping purposes. With an average ground sampling distance of 6.93cms about 1.28 square kilometers of area was imaged. Orthoimages and a digital surface model (DSM) of the area were obtained by processing the images using Pix4D software. The accuracy of the products was assessed using Global Navigation Satellite System. The paper showed that an armature camera coupled with a GPS is an inexpensive device that can be used for mapping. [72] addresses the issue of real-time collision-free path planning for an AR Drone 2.0. This solution solves the unreachable goal problem by using a modified potential field method. There are three components that constitute this solution, they are: localization using pattern-based grounds, path planning using potential field method and steering commands using PID controllers. Highly precise locating and control methods are required to give drone indoor flight capabilities. [73] tackles this problem and gives an algorithm that integrates monocular vision and Micro Inertial Measurement Unit (MIMU). The location is updated using measurements of MIMU while the monocular detection algorithm gives the detection outcome of the element of reference lines. [76] demonstrates the use of AscTec Firefly hardware for indoor navigation, the Firefly hardware is equipped with an RGB-D camera. Collision free paths are generated using sensor output to construct a map of the environment. [74] presents a method to automatically extract skyline extraction in digital images. The user's interest is maintained as a priority and the steps involved in this method are: Usage of canny filter to get the edges, a graph is made from the upper part of the edge map, shortest distance algorithms are employed to connect the breaks. A method for UAV visual serving is presented in [75], this method uses the controller's feedback of the 3D pose of the drone. A remote monocular camera is employed to observe the tracked UAV and the pose is obtained using a cuboidal model-based 3D tracking.

VI. MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE TECHNOLOGIES

[77] presents a method to observe the forward velocity of a mini drone, this is based on raw data from radar and using it to approximate the deviation in velocity.The doppler rate variation caused due to the flight deviation of the drone is calculated using sub-aperture map-drift d (MD) method, an adaptive filter is used to extract the forward velocity and radial acceleration. [78] presents a platform based on smartphone developed by researchers at the Air Force Research Laboratory's (AFRL)

TechEdge Labs under SATE(Summer at the Edge) and YATE(Year at the Edge) student research programs and is used in detection and tracking of unidentified hostile drones. It consists of a Smartphone application that uses data from onboard sensors to capture a drone's characteristics and real-time ability to collaborate and a processing unit to forecast the possible flight path of an unknown drone. [108] presents the method of image stitching to map an unknown environment for search and rescue operations, where it is severely crucial to perform a quick scan of the disaster area, localize the wounded people and send aid. Computer vision techniques are applied to this map to detect humans. UAV swarms use algorithms to guide the formation of safe and collision-free navigation. Reconstruction accuracy of a swarm of drones patrolling in a 3D environment and its effect on formations is presented in [79]. The ineffectual configuration is overcome by making use of the camera-in-view side information. Monocular cameras and sensors can be integrated to be used in SLAM for MAVs in indoor environments. A better inference of the 6DOF (Degrees of Freedom) pose of the MAV and a map (3D map for LSD-SLAM) of the local environment can be obtained by integration of visual data and data from the IMU and using an Extended Kalman filter to estimate the pose.

The predefined position of an indoor location is examined and the orientation and position of UAV approximated by processing the data from an RGB-D sensor and an IMU. The UAV is positioned with predetermined orientations by employing a PD (Proportional Differential)

[80] mentions a method that renders the quadrotor drone capable of autonomously landing around the finishing point of its planned path, it is done through the reference points attained by identification of a landing area and this method uses artificial vision techniques coupled with Artificial Neural Networks (ANN). Markers are identified and located using two cascaded ANNs that are fed images from a mounted camera. A Lucas Kanade optical flow interpreter is used to keep track of the marker-based on its characteristics. An autonomous navigation method for UAV in forest environments is presented in [81] , this method is used to detect and evade trees. Transfer learning from an Alexnet is used for obstacle detection. With all these recent developments, autonomous navigation is now a much more realistic goal

VII. VISION-BASED TECHNOLOGIES

[82] solves the issue of indoor autonomy by using visual markings, this method involves a vision based multi-robot quadrotor which employs an IMU. It provides an architecture level solution for navigation and evasion of obstacles. The software architecture is composed of many modules like mission scheduler, supervisor, trajectory planner and controller, obstacle detector, localization pose estimator, visual marker detector. [83] presents a method to visually steer a UAV in an unknown environment. This is accomplished using a single perspective onboard camera and by the estimation of all possible 3D motion parameters that the UAV can undergo.Using the parameters obtained from estimation, a steering algorithm has been developed along with reconstructing visuals with scene depth to avoid obstacles during navigation. [84] describes the usage of select next viewpoint(s) technique for robust autonomous navigation. This strategy enables the robot to make better exploration decisions based on previously seen environments. The approach in which the robot comes back to its starting location even on mapping system failure is also incorporated into the aforementioned strategy. This improves the quality of image and the exploration ability. [85] shows the usage of Surround Stereo Vision in Automatic Sense and Avoid (SAA) algorithms for sensing and avoiding obstacles. Using the disparity information from multiple stereo cameras an instantaneous 3D occupancy grid(OG) map at each time instance is constructed then spatial information and probabilistic approach based on temporal information is used to filter the noise

[86] mentions an embedded vision system for autonomous navigation drones for environments with a uniform pattern of the canopy , this system can drive the vehicle and take decisions in new environments with non-standard canopy patterns simultaneously. The approach involves two steps. Firstly, non-relevant features are suppressed based on wavelet, so that the canopies with uniform patterns are eliminated. Secondly Scale Invariant Feature Transform (SIFT) algorithm is used to extract key points that can find new landmarks or track available ones.[87] describes a method to estimate the position of a target on a 3D cartesian plane in a small indoor environment, this method uses an Unscented Kalman Filter (UKF).A small UAV mounted with a single board computer and a frontal camera is used which moves in an oval trajectory at a fixed height. Processing the image along with the position and orientation of the drone produces the azimuth and elevation

Azimuth and elevation are obtained by processing the image along with the drone position and orientation. Opti-track Motion system and the Robot Operating System (ROS) retrieves the position of the drone. A framework for direct vision-based control of drones for autonomous flying in indoor environments is presented in [88]. Its velocity is measured through an optical flow sensor and precision navigation is done through a sequence of obstacles using data from a mounted stereo camera. This framework is implemented on a quadrotor carrying an onboard vision-processing computer. A UAV based aid for accidents is mentioned in [89].

VIII. COAGULATION ATTACK: CONCEPT

In coagulation attack the maneuvers and the physical configurations of the UAV are affected due to changes in the UAVs operation states. This type of attack is very difficult to detect and the way to counter this type of attack is through proper capture of vulnerabilities. Coagulations attacks can be classified ,based on the factors causing attack,into four broad categories.These are UAV freezing, Waypoint alteration,Enforced collision and UAV hijacking. Fig. 3 presents a coagulation attack on a single node.The major coagulation attack types are discussed below

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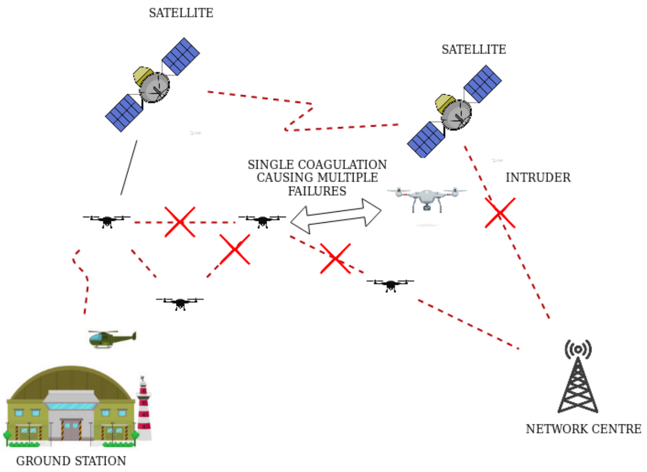

Fig.3 Coagulation Attack on a single node

UAV Freezing: In this type of attack the physical configurations of the UAV are altered which affects the maneuvers, leading to node failure. UAV freezing results in network failure due to mobility loss. Intrusion, signal jamming, and session hijacking are some of the most used methods for UAV freezing.

Waypoint Alteration: This attack is difficult to predict, even though the UAVs may seem to be working normally, they might be in danger of waypoint alteration. This attack causes enforced collision by overlapping mobility patterns which result in fatal disasters.

Enforced Clustering: This type of attack leads to the formation of sub-clusters among the UAVs in the swarm, these subclusters form their own subnetwork and their operation then becomes independent of the main network. The subclusters are used to extract configuration and pattern data.

UAV Hijacking: In this type of attack a third party remotely connects to the UAVs, even though the UAVs operate normally, their operation can be overridden by the third party.

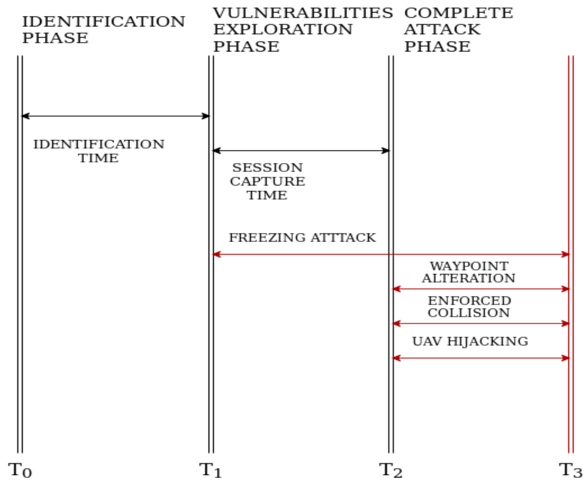

Fig.4 Coagulation Attack Phases

A.Coagulation attack phases

UAVs operating in a swarm are vulnerable to a lot of attacks, and coagulation attacks are a relatively new threat These attacks can either damage a single UAV or bring the whole swarm down. The attack procedure is categorized into three steps which are identification phase, session break/vulnerabilities and attack phase as illustrated in Figure 4.
The categories are discussed below:

Identification Phase: In this initial phase the person trying to hack into the network, collects data about this network and uses some existing techniques like session hijacking to compromise the network security and identifies any loopholes to cause the aforementioned attacks.

Session Breaking/Creating Vulnerabilities: If a loophole was observed in the initial phase then the attacker uses it and initiates an attack by acquiring a session that enables him to use a new set of codes to launch a coagulation attack. This phase is very important for both attack and defense

Attack Phase: Called the 'State of Coagulation' because it is extremely difficult to recover from this state. The whole network is compromised when the attacker initiates this phase and the only option for the network controller is to prevent this state from being initiated.

IX. UAV CHALLENGES AND MAIN ISSUES IN UNDERWATER WIRELESS SENSOR NETWORKS

The loss of a UAV is a very critical issue, a network or even a node failure has serious implications in terms of the expense and the diplomacy and damage to life involved. There are a lot of challenges a network of UAVs can face and some of them are discussed below. In case of an attack, the recovery or the countermeasure should not come at the cost of performance of the network.When a network is compromised the error should be identified swiftly and network be restored to a safe state. In regard to error identification, Dynamic topology is disadvantageous since the rapid topology change makes it difficult to identify errors.Selecting the right bands for exchange of data and reducing the battery consumed by the program trying to reduce attacks are some key challenges. The UAV proximity is altered by a coagulation attack and decreases coordination among them, and programs running to counter these attacks increase the load on the system causing the network to crash and become unresponsive, this makes recovering from such attacks a daunting task.Such an attack also increases the possibility of an attack on the ground station which controls the network and communication with the UAVs.

X. DISCUSSIONS AND OPEN ISSUES

Cyber attacks on UAV is a well-researched topic and a lot of literature is present. This paper presents the Coagulation Attack which is also a cyber attack. The simulation study in this paper discusses the consequences of this attack and also provide solution for its elimination. Apart from the analysis in this paper, there are a number of open issues we need to cover before understanding the impact of such attacks.

The medium of communication used in a network of drones and to transmit data between control system and drone heavily influence the possibility of a coagulation attack, the communication system needs to be deeply analyzed and inspected to uncover vulnerabilities. There is a need to assess the impact of coagulation attacks in presence of other attacks, for example Sybil attack, impersonation attack, node capturing, etc. Along with the study of the impact of coagulation attacks, there is a need to develop methods to counter the security issues raised by these attacks. The impact of these attacks should be formally evaluated and analyzed over a network of UAVs and its effect be studied. The existing approaches to security need to be scrutinized and improved upon to prevent a possible coagulation attack.

A. Most Common Issues in underwater acoustic communication

Acoustic communication is the use of sound propagation for communication underwater. In underwater sensor networks, a group of sensors and drones are placed in an area to collectively do tasks such as surveillance and collection of data. Underwater sensor networks can be deployed in an array of scenarios ranging from scientific study to military warfare. Despite innovations and research into this field there exist some challenges in using UWS. The data collected needs to be localized since the nodes in a UWS network are not static, along with this need for localization, the mobility of nodes also causes the problem of increased power consumption and there is the problem of the land-based routing protocols being inefficient in case of UWS, again due to the mobility of the nodes. This results in the need to develop energy conservative routing protocols to be used in UWS. Using UWS has a direct effect on marine life, the sound waves used in communication can cause hearing loss in animals or injure them which may result in their death.Due to the variation of temperature with the depth from the surface, the velocity of sound is also affected, and factors like salinity also affect the propagation of sound underwater and cause a hindrance to UWSMan made noises, multi-path losses,Doppler spread, high and variable propagation delay are some major factors that influence UWAC. The communication range, bandwidth, and frequency are affected by the factors mentioned below because they alter the temporal and spatial variability of the acoustic channel. The communication channel suffers from low bitrate, this is because the bandwidth requires either a few kHz for short-range or hundreds of kHz for long-range communication. The use of Acoustic nodes is inefficient due to its huge power consumption and the high cost of usage [90]. The use of Underwater Sensor Networks (UWSNs) is a viable method that can improve communication probability. [91]

B. Applicability and Applications

[92] presents a method to design a guidance and navigation system for an autonomous drone which consists of a navigation and control layer and a human-robot communication layer. The system consists of inexpensive sensors and the velocity, position and altitude are computed in the navigation system using nonlinear complementary filters. The performance of this system exceeds traditional methods due to the use of Human-Robot Interface which is used to define way-point navigation. As suggested in [63] the AR-Drone is an excellent platform for research and education. It has been tested with simple tasks like position stabilization and autonomous navigation etc. The drone has also been used for a localization system and autonomous navigation. [93] presents a novel sensor package and its implementation.

It can be used to map huge outdoor structures or for the 3D measurement of landscape purposes. There are several configurations contained in the package, including cooperation with other drones. [94] presents the use of the Sensor Aided Video Coding method using SFM 3D reconstruction for Aerial Motion Imagery. [95] presents a system built by INSPEX for spatial exploration and obstacle detection which can be installed in portable devices. Stationary and moving obstacles can be detected and localized using this device. The possible use cases for this system include navigation for humans in low visibility, navigation for visually challenged people. [106] describes techniques for autonomous drone navigation and it is implemented in an inexpensive quadcopter. The camera’s movement is tracked and LSD SLAM is used to perform 3D reconstruction. A Parrot Bebop MAV is used to implement the aforementioned autonomous search and navigation methods. [96] presents a customized navigation system for non-stationary users. This system is composed of an ad-hoc network between cars, GPS and RFID from urban structures. A network of drones is very efficient when deployed for search and rescue operations and [97] discusses this fact. The use of drones to study the environment from aerial imagery using a drone is presented in [98]. [99] presents the use of modular design for drone delivery system wherein dynamic programming management strategies are used to optimize task management of a network of drones. [100] discusses a possible vulnerability to attacks wherein a drone’s control could be lost if its sensor value and navigation are altered. The solution to counter the ROP attacks is to use MAVR, which substantially increases the computation needed to brute force attack the MAVR. The use of a human’s sensing capability along with their smartphone can be used for drone surveillance, this is presented in [78]. In this system, the users can document the activities of unidentified drones with the help of smartphones so as to get some information about the drone’s flight path.

C. Applications based on Machine Learning

[81] presents a sense sense-and-avoid system based on AlexNet for a drone which enables it to autonomously navigate through forests. The autonomous drone is guided by three states during its flight, these states are - free-space, obstacle-close, and obstacle-very-close, these states are estimated using a state machine. [101] presents a method for the generation of Digital Elevation Model(DEM) using Digital Surface Model[DSM], this method is extremely effective in reducing risks of disasters, especially floods. Vision-based algorithms are used to process this DEM. [102] presents a study of the exploit risk of information from navigation system of drones.Using this method we can predict the probability of system failure. The aforementioned method has been implemented with suitable mathematical model along with the development of an algorithm based on the ideas mentioned.

[103] evaluates the security of an AR Drone 2.0 using DoS attacks tools. LOIC, Netwox, and Hping3 are some DoS attacks utilized by the attacker. [104] presents a system called WI Drone, it is used to regulate the wi-Fi fingerprint which is used in validating a location. It is an anti-hijacking method and it illustrates the adequacy of the authentication algorithm. The use of drones in Search and Rescue for localization and vital sign data transmission is described in [97]. [56] presents a system that renders a UAV capable of autonomously navigating in an indoor environment. The pedestrians are detected with the aid of HOG descriptors and SVM classifiers and walls are sensed using Hough transform.

XI. CONCLUSION AND FUTURE WORK

This paper reviews the basics of a UAV and its components including different sensors, this paper also discusses the various applications of UAV and their advantages. The paper begins with the review of Autonomous navigation technologies which are employed to operate the drone in indoor and outdoor. Then the communication aspect of the drone is discussed, about how LSD-SLAM, HOG and other such algorithms are used for communication. The paper then dives into path planning, on how the UAV plans its path after surveying the environment and using 3D images it rendered with its sensors, Machine Learning is extensively used for this purpose of finding an optimal path. Finally safety and security issues like information security, system failure are explored, these are a few issues that need to be measured to ensure robust flight operation. Further research into Path Planning and SLAM (Simultaneous Localisation and mapping) can further enhance the application of UAVs. Research into areas that specifically deal with UAV's flight control like take-off and hover stabilization will improve the practical operations of UAVs. The return to home feature, where the UAV can automatically return to the point from where it took off from is very beneficial.

The paper then explores Coagulation attacks. These attacks alter the mobility of the node, different variants of coagulation attack can bring down a whole network and are a serious threat to the deployment of drones. Efficient solutions are required to counter these attacks, solutions include developing Protocols and Architecture which have properties that deter coagulation attacks. Improvising the encoding scheme of the physical layer can help to deter the attack. Further research is required to analyze all the factors that form vulnerabilities which can potentially lead to a coagulation attack.

UWC technology is the transmission of data for communication in an underwater medium. This allows communication between underwater devices and land-based stations. The aim of this paper is to briefly discuss the challenges posed by UWC. The varying properties of different water channels drastically affect communication. The paper compares underwater wireless acoustic communication (UWAC) and underwater wireless electromagnetic communication (UWRF) along with underwater optical wireless communication (UWOC). The comparison is done on the lines of acquiring data and approachable range. Further research is being conducted in UWC to achieve higher data rates and reduce noise and signal errors.

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