Multi UAV Path Planning by 6G Non-Terrestrial Network

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***Abstract*— Unmanned Aerial Vehicles (UAVs) are a great way to achieve mobile communication where the communication infrastructure has been damaged by the natural disaster. Even though UAV can be employed in situations where existing mobile communication infrastructure is insufficient to offer their full range of services or not established yet. The development of the emergency communication network greatly benefits from the use of UAV networking communication, which is a component of the 6G air-space-ground integrated network system. Non-Terrestrial Networks (NTN) have been successfully integrated into 3GPP Rel. 17 and are most likely to have an even bigger role in 5G advance (5G-A) (up to Rel. 20) and 6G systems (beyond Rel. 20). We've outlined two path planning strategies for 5G-A and 6G NTN communications to find the shortest or most efficient route for UAVs while consuming the fewest number of resources and energy is the subject of UAV path planning.**

Keywords—UAV, GA, PSO, 6G-NTN, 3GPP, Path Planning

I. Introduction

Telecommunication networks will be extended and updated to satisfy the demands of distant and high mobility services, full coverage space air-ground-sea communications, Cellular Vehicle-to-Everything (C-V2X), and mobile, computing, and sensing scenarios. Path planning plays a fundamental role in the unmanned aircraft system's autonomous flight capability (UAVs). It relates to the Unmanned Aircraft Optimal Path Planning Problem, which is an optimization problem to determine the most direct route between a source and a destination. This paper has multi-UAV distributed path planner with comprehensive coverage of certain operational zones. We summarize two path planning technology where energy consumption, flight risk, path length, and feasibility etc. of the paths were taken into consideration. The rest of paper is organized in the following manner. In section II, UAV Path Planning, Challenges of Path Planning and UAV path planning algorithms, III and IV respectively. Finally, the paper is conclusions, and the Future Work is in V.

II. UAV Path Planning

From the first generation (1G) through the fifth generation (5G), communication standards and technology have been widely employed to provide data exchange among UAVs and other smart objects. Multi UAV path plan for mobile communication has illustrated in Fig. 1. These standards-based methods for communication have been created for the next generation of cellular wireless UAV communications. A multi-band multilayer multi-dimensional (MB-ML-MD) network architecture will be an essential component of future infrastructures to meet the performance needs of 5G-A and 6G systems and to promote connectivity across the physical, digital, and human domains. It will be heavily influenced by low Earth orbit (LEO), medium Earth orbit (MEO), and geosynchronous Earth orbit (GEO).

For orbit satellite, Path planning is essential for carrying out tasks like sensing and computing in the UAVs' communication system. The challenge of path planning is figuring out how to get the UAVs from one place to another. The UAVs' chosen course should be devoid of any collisions with the surrounding objects. Their intended motion complies with the kinematic and physical requirements of the UAV, such as electrical and kinetic energy.

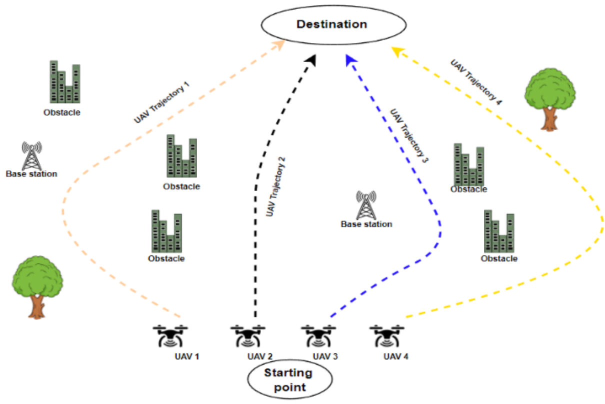

Fig. 1. Multi UAV Path Plan by 6G-NTN

The two phases of UAV path planning are categorize as follows. The pre-processing phase is the initial step. On the workspace "W" with obstacles "O," nodes (points) and edges (lines) are in this phase. The configuration space (c-space) idea is then used to explain U and O on W. The generation of the graph mappings is then done using representation techniques. For UAVs with points and lines, the path is defined differently by each path planning technique. The search and rescue actions are carried out from the path's beginning point to the target point during the second phase, which is known as the inquiry phase. The graph search-based Floyd algorithm, flood-fill algorithm, and ant colony algorithm are employed for the query phase. Numerous path planning techniques, including probabilistic models, mixed integer linear programming, bio-inspired models, and evolutionary models, can be used to plan the best course for UAVs [1].

III. Challenges of Path Planning

The trajectories are dispersed across the swarm rather than calculated in a single location. As a result, the communication between the UAVs in the swarm is limited to sharing position and location. To determine the most effective strategy to design a trajectory, we consider three different types of functions, including fitness, goal, and constraint functions. Design a model for these optimum functions are following.

A. Architecture for Fitness

The diagram shows a multi-objective fitness function comprised of eight optimization indexes for evaluating trajectory generated by multi-UAVs path planning algorithm. Optimization indexes are divided into two categories, each with a different priority level. This is to emphasize the varying

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importance of optimization indices throughout the optimization process. 1. The optimization objectives that must be maximized to generate an optimal trajectory 2. the limitations that UAVs must meet owing to their physical limitations. The formulation of fitness function is as:

$$F_{itness} = F_{obj} + F_{const} \quad (1)$$

where F_{obj} is the objective function. F_{const} is the physical and environmental limitations.

B. *Objective Function Design*

The objective function as an optimization criterion to enhance path planning quality [2]. Energy consumption, Flight Risk Estimation like Environmental Risk, High Altitude Risk in addition Surveillance Area Important we have to consider. Objective function can be written as:

$$F_{obj} = -w_1 F_{EC} - w_2 F_{FRE} + w_3 F_{SAI} \quad (2)$$

where, Energy Consumption (EC), Flight Risk Estimation (FRE) and Surveillance Area Important (SAI). w_i (i = 1, 2, 3) were used

for expressing the weight of the objective component.

C. *Constraint Function Design*

A constraint function is to evaluate the feasibility of generated path. When they meet the conditions, each restriction is set to 0, otherwise a negative penalty value P is assigned. This is due to the external environment regulations that the UAV must observe. Constraint function can be as:

$$F_{constraint} = AC + RAC + TAC + OAC + CRC + CA \quad (3)$$

where, Aerial Constraint (AC), Restricted Area Constraint (RAC), Operational Area Constraint (OAC), Coverage Range Constraints (CRC) and Collision Avoidance (CA).

IV. UAV PATH PLANNING ALGORITHMS

There are numerous ways to plan a route and determine the shortest route between starting and ending point. We summarize two most popular way like genetic algorithm (GA) and Particle Swarm Optimization (PSO).

A. *Genetic Algorithm (GA)*

Nowadays, the GA is somewhat well-known for optimal trajectory planning. Multi-objective bio-inspired algorithms, using the joint genetic algorithm and ant colony optimization from possible ideal UAV flying path is chosen based on sensing, energy, time, and risk utilities [3]. Traveling Salesman Problem (TSP) an algorithmic challenge to determine the shortest path between a set of required points and places, solved by GA a strategy based on natural selection, the process that drives biological evolution, to solve both constrained and unconstrained optimization issues [4] GA (Genetic Algorithm) for path planning to reduce the UAV flight distance, which introduces the Teaching–Learning-based Optimization (TLBO) and local search optimization algorithms to improve convergence rate and the path solution [5].

B. *Particle Swarm Optimization (PSO)*

Swarm optimization also popular for path planning. There is Ant Colony Optimization (ACO) and PSO Model as Swarm Intelligence. Swarm based some other models are Artificial Bee Colony, Bacterial Foraging, Cat Swarm Optimization, Artificial Immune System, Glowworm Swarm Optimization [6]. PSO and optimization approach that offers a search outcome based on evolution for both quantitative and qualitative issues. It takes its cues from natural group activities including fish schooling, ant colonies, honeybee hives, and bird flocks. The main steps of PSO algorithm are depict on figure 2.

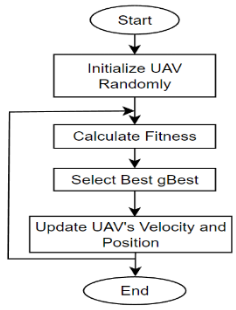

Fig. 2. UAV-PSO Algorithm Flowchart

V. CONCLUSIONS AND FUTUREWORK

In this paper we summarize, why we need UAV path planning for 6G mobile communication, the challenges and how to consider them when to plan a path. Furthermore, we sum up path planning algorithms like GA and PSO. We also outlined multi-dynamic fitness function with optimization indices including energy consumption, surveillance area importance (SAI), flight risk, and UAV maneuverability. With the knowledge gained from this research, we can create more advanced path planning algorithm like A* algorithm in the future. We can also speed up path planning algorithm to find the shortest or most efficient path.

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