UNIVERSITY DEPARTMENT, RAJASTHAN TECHNICAL UNIVERSITY, KOTA
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

PRESENTATION ON SEMINAR

AUTONOMOUS UAV NETWORKS : A SURVEY

PRESENTED BY
ANISH SONI (21/189)

SUBMITTED TO
Chandresh Ma'am

Drones

Autonomous UAV Networks: A Survey

Presented by: Anish Soni

21/189 CSE A1

Agenda

Overview

Introduction

AI Bases UAV Networks

Security & Privacy

Network & Design

Localisation & Trajectory

Energy Efficiency

Drones

Conclusion

Goals

Introduction

RESEARCH ON UNMANNED AERIAL VEHICLE (UAV) NETWORKS HAS GENERATED GREAT INTEREST AMONG NETWORK RESEARCHERS RECENTLY.

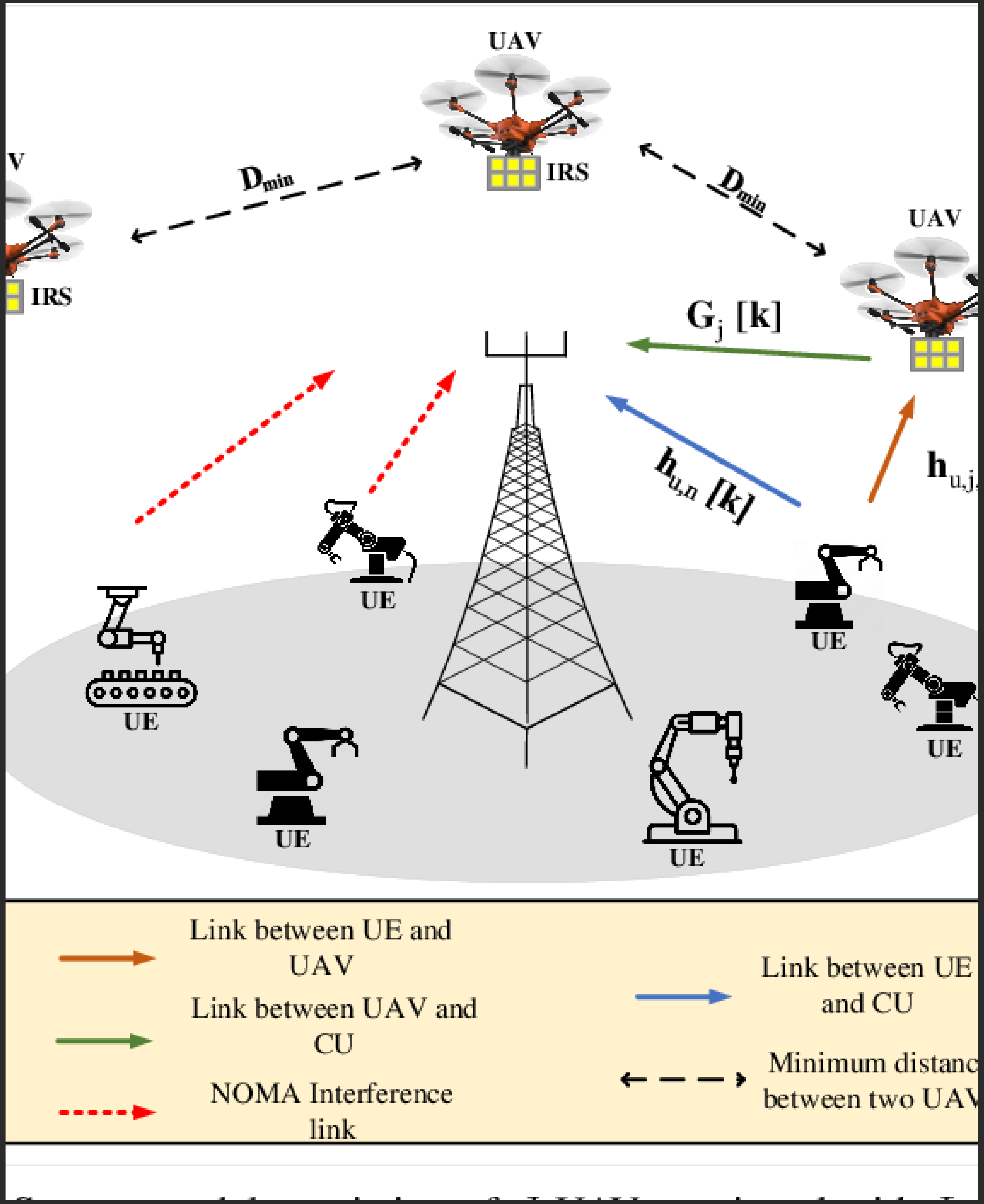
- One of the reasons for using UAV networks is to address the challenging terrains, which are very difficult or impossible to be covered by traditional communications networks. UAV networks are excellent at providing optimal performance based on their topology, spectrum efficiency, and context awareness.

- As human interventions are limited to UAV network operation, network researchers are keen to explore artificial intelligence (AI) techniques to manage these networks effectively. Various applications are being developed using machine learning methods.

- To solve the review question, we have conducted a comprehensive literature survey by selecting more than 100 papers on UAVs focusing on some aspects of autonomous features, network planning, resource management, network access and routing protocols, and energy efficiency.

AI based UAV Networks

- Artificial intelligence (AI) is the science used to develop techniques that can think like humans or even beyond humans’ intelligence.
- While AI-based UAV network design is an ongoing research area, in this section, we focus on four key areas, including security and privacy, network design, localization and trajectory, and general applications of UAVs that are necessary for the efficient design and deployment of next-generation UAV networks.



Security & Privacy

Security and privacy are always a concern when dealing with a wireless network. This concern even gets more robust when the wireless network we are dealing with has an ever- changing topology.

AI-based security solutions are being suggested for various cyber-attacks, including cyber-physical attacks. The authors have proposed using convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to identify and classify high-risk areas and various motion characteristics of UAVs.

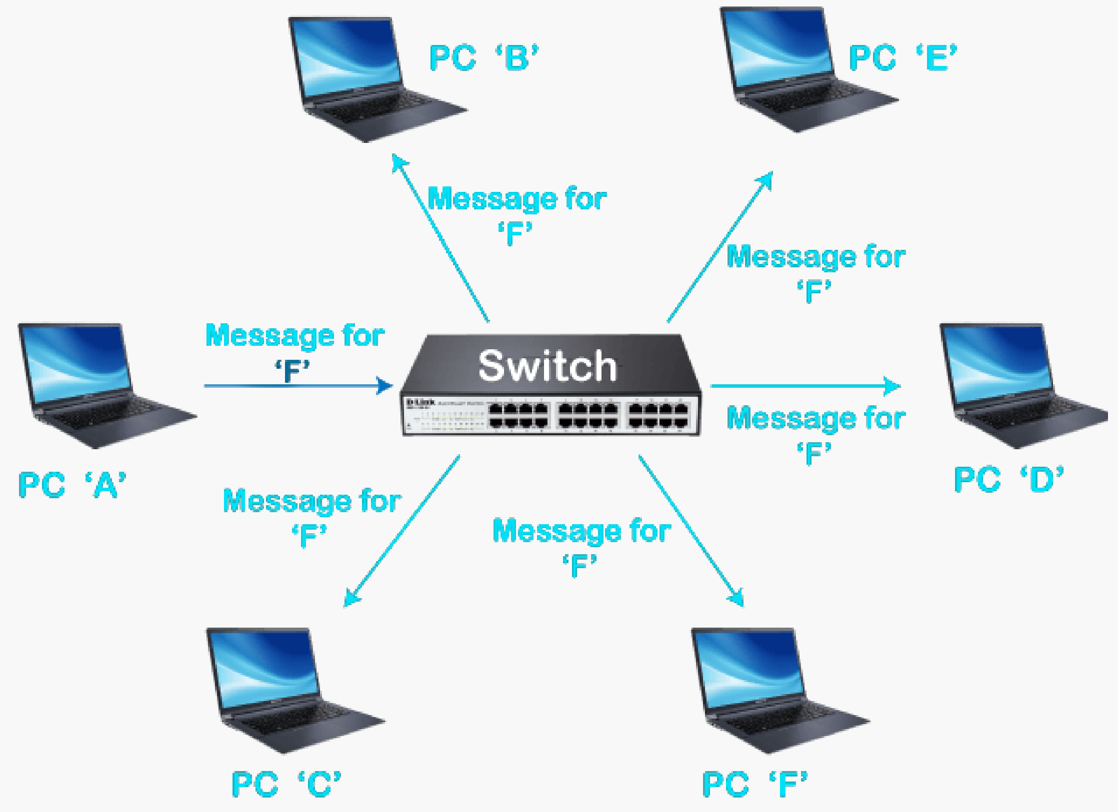
An interesting study is presented based on communicating only local information among the neighboring UAVs in a UAV swamp [5]. The simulation results show that a UAV swamp can effectively blanket terrestrial coverage by using local information and voiding various cyber security threats. The simulation is conducted in OPNET Modeler, considering MANET connectivity for all UAVs.

Federated learning (FL) is a new ML technique proposed for distributed Internet of Things (IoT) devices. FL's critical feature is providing a secure communication channel among IoT devices.

Back to Agenda Page

Network & Design

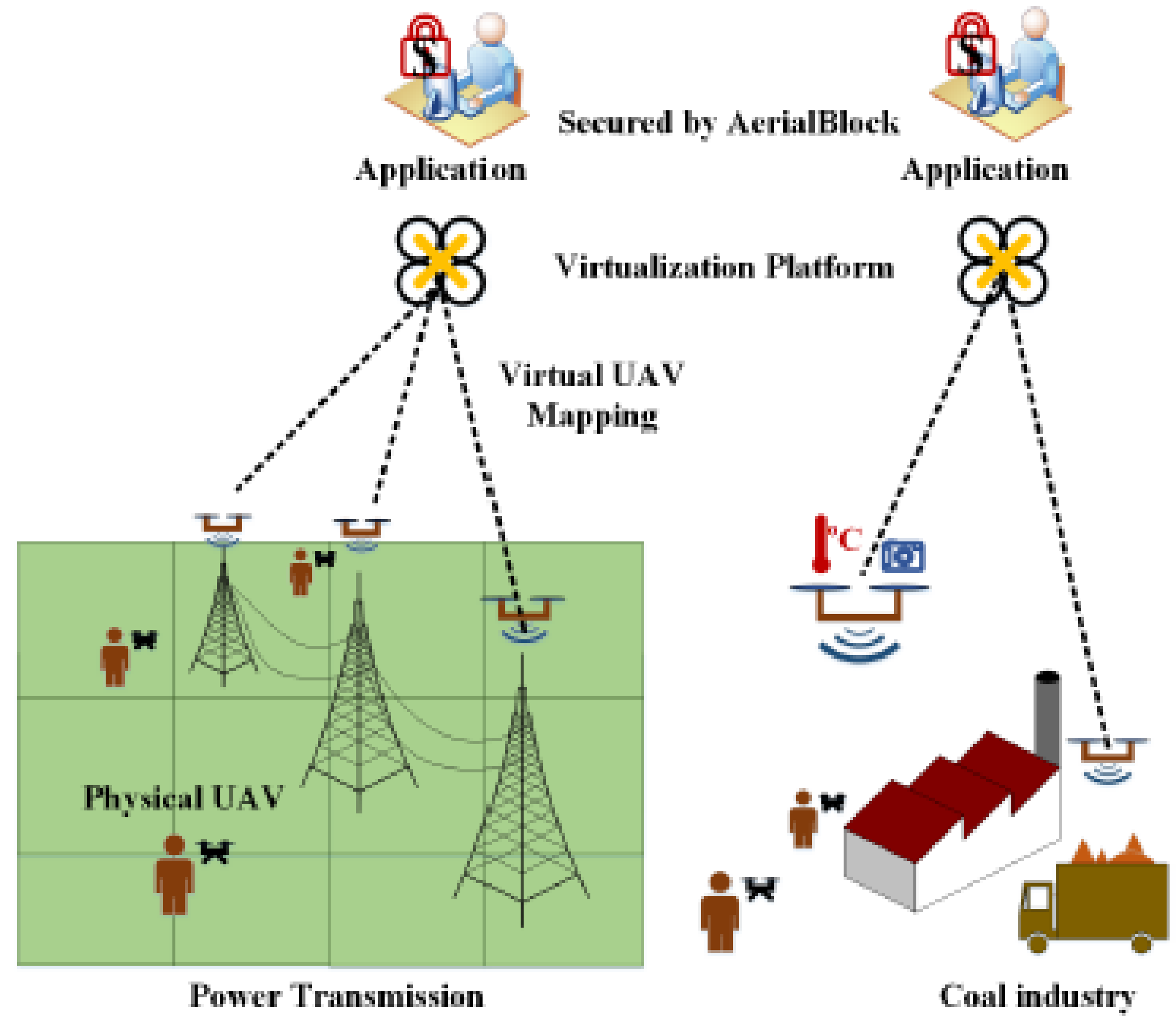
As UAV networks possess unique characteristics, therefore, the solutions developed to address various needs of other wireless networks such as MANETs and VANETs cannot be used for these networks. Therefore, researchers address the network issues faced by UAV networks a bit differently.



Reynolds' Boid model

~ alignment, separation, and cohesion

- The effectiveness of the proposed solution is evaluated by conducting a simulation using the OMNET++ Modeler.
- The highlighted issues include high reliability, low latency, efficient handover, and efficient path planning.



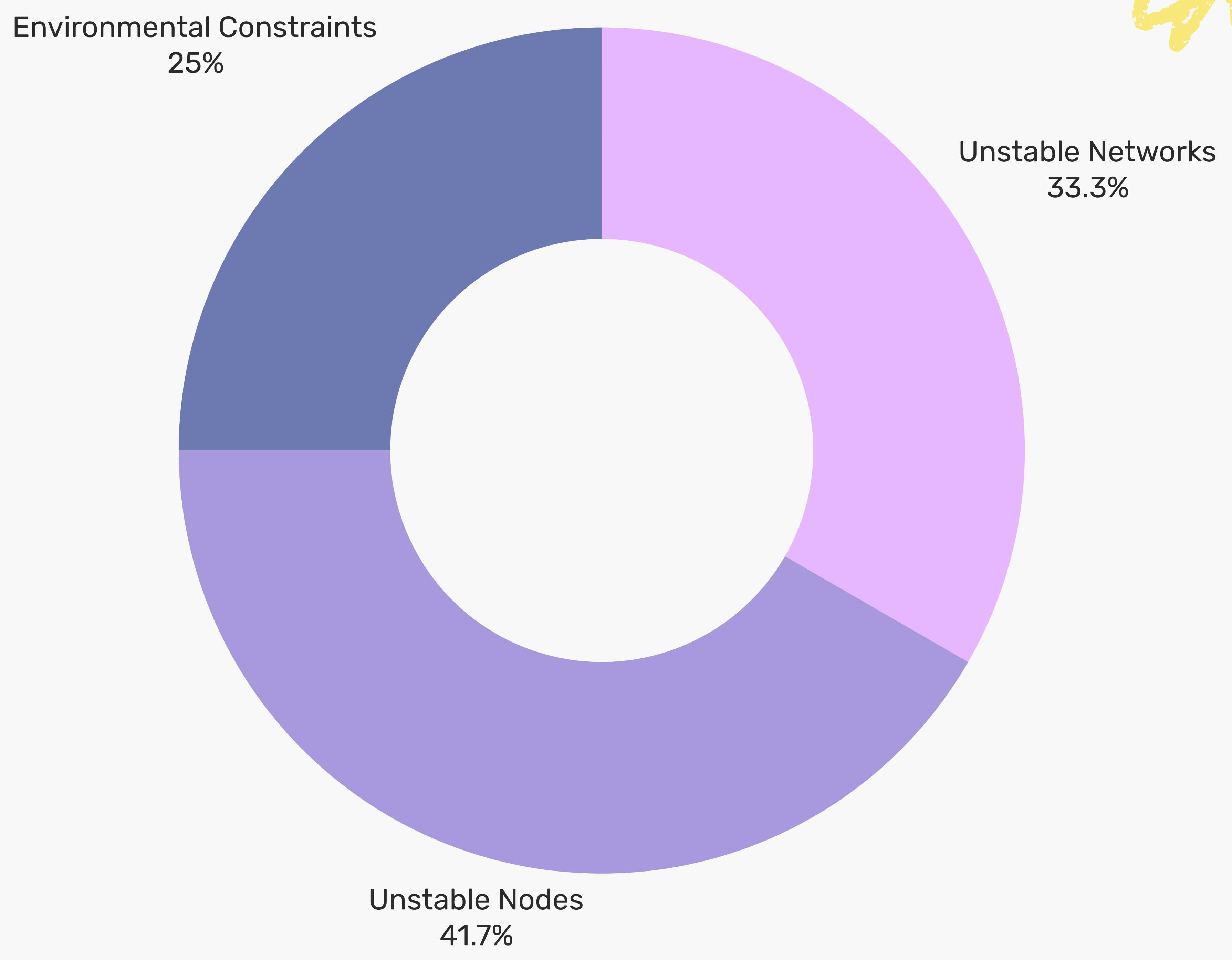
NETWORK ISSUES

Localization & Trajectory

- For Trajectory, the main idea is to use a quantum mechanism to support UAVs from the starting point to their destination place.

- The localization problem is being solved in a 3D model, in which UAV node localization is being realized by limiting the search space in the initial step. This helps reduce the localization error and increases the network convergence speed.
- Important point is to use the most energy-efficient point.

Localization & Trajectory

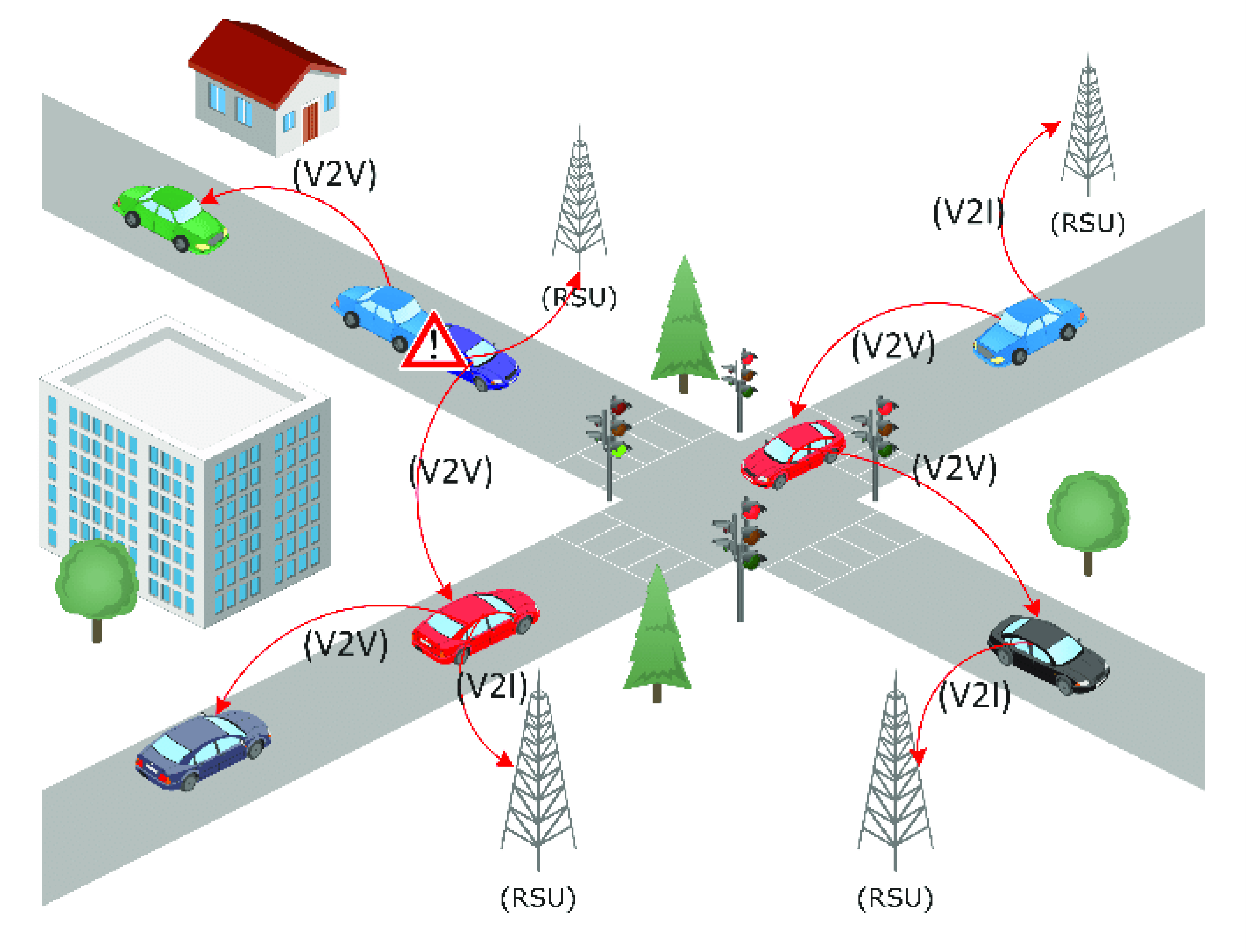


VANETs

Vehicular Ad-hoc Networks (VANETs) are networks of vehicles that can communicate with each other using a wireless connection. VANETs are a subclass of mobile ad hoc networks (MANETs).

VANETs can provide safety and comfort to drivers in vehicular environments. They can also support a variety of applications, including:

- Electronic brake lights
- Platooning
- Traffic information systems
- Road transportation emergency services
- On-the-road services
- Electronic toll collection



Summary of Existing Surveys

Energy Efficiency

2019 : 5G MILLIMETER WAVE SURVEY

- The survey classified the routing protocols in various groups with their performance evaluations.
- Security, performance evaluation, and link performance.

2019 SURVEY

- The survey proposes the use of ML techniques to achieve optimized performance for UAV networks. The authors proposed using a large amount of multi-source data and applying various deep-learning techniques to achieve a highly effective UAV network.

2020 SURVERY

- A survey based on the use of a software-defined network (SDN) and network function virtualization (NFV) in UAV networks was conducted in 2020.
- This study highlights the interoperability issues in UAV networks and explains how SDN and NFV can be considered a natural fit to solve this.

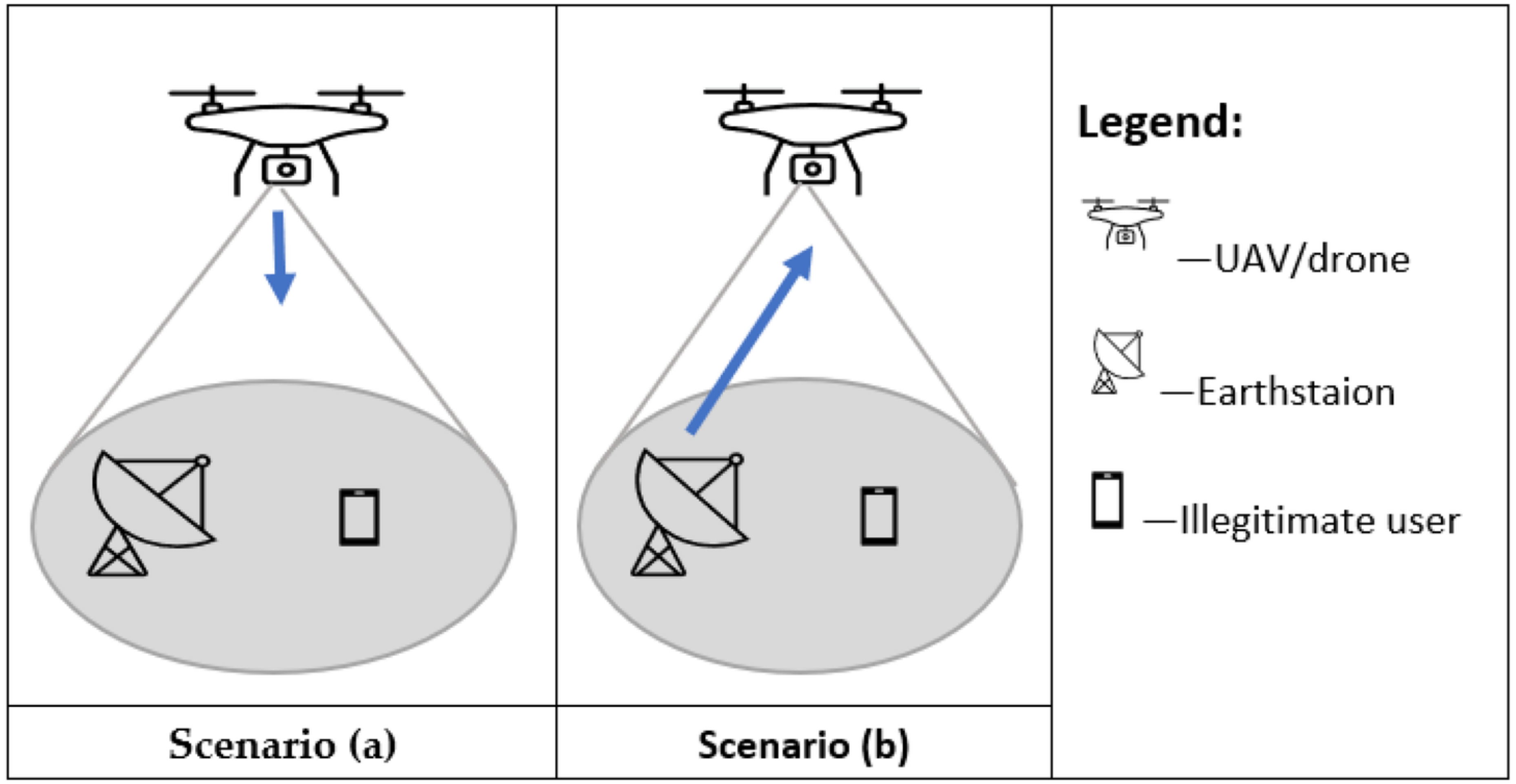
Summary of Related Surveys

Survey Scope	AI-Inspired?	UAV Features Addressed	Limitations	Reference
Cooperative UAVs, system deployment	Yes	Coverage, deployment, and nodes used	Obstacles in coverage are not considered	[12]
Various UAV networks, routing	Yes	Topology, mobility, reliability, and energy efficiency	System optimization has not been explored	[13]
UAV channel modeling, low altitude	Yes	Channel measurement and characteristics, fading	UAVs in dense urban areas are not explored	[14]
UAV-assisted and 5G mm wave communications	No	UAV as aerial access, relay, and backhaul	Antenna design, channel modeling, and performance assessment	[15]
Routing protocols for UAV networks	No	Topology, position, and cluster-based routings	UAV routing such as link disconnection has not been explored	[10]
Integration of UAV and cellular networks	Yes	UAV categorization, standardization, aerial channel modeling, and security	UAV antenna design has not been explored	[17]
UAV software-defined network (SDN) and network function virtualization (NFV)	Yes	SDN, NFV, cellular communication, routing, and monitoring	Wireless power transfer has not been addressed	[18]
Applications of multiple UAV systems	Yes	Coordination, cooperation, system autonomy	Multiple UAV systems have not been explored	[19]
Safety, privacy, and security issues of UAVs	No	Sensor-based attacks, GPS jamming, spoofing, and multi-UAV-based security	UAV privacy and security have not been addressed well	[20]
Machine learning for UAV communications	Yes	Channel modeling, positioning, resource management	UAVs for vehicular networks not addressed	[21]
UAV-centric machine learning	Yes	Cooperation trajectory planning, channel modeling, mobile-edge computing	Traffic dynamics and channel conditions not explored	[22]
UAV prototyping and experiments	No	Cellular UAVs, interference mitigation	Path planning optimization not explored	[23]
UAV Channel modeling, link budget	No	Two-ray fast fading, Rician fading, Rayleigh fading	UAV with satellite not explored	[24]

Autonomous Features of UAV Networks

It is mainly divided into:

- Resources Management and Network Planning
- Multiple Access and Routing Protocol
- Power Control and Energy Efficiency



Resources Management and Network Planning

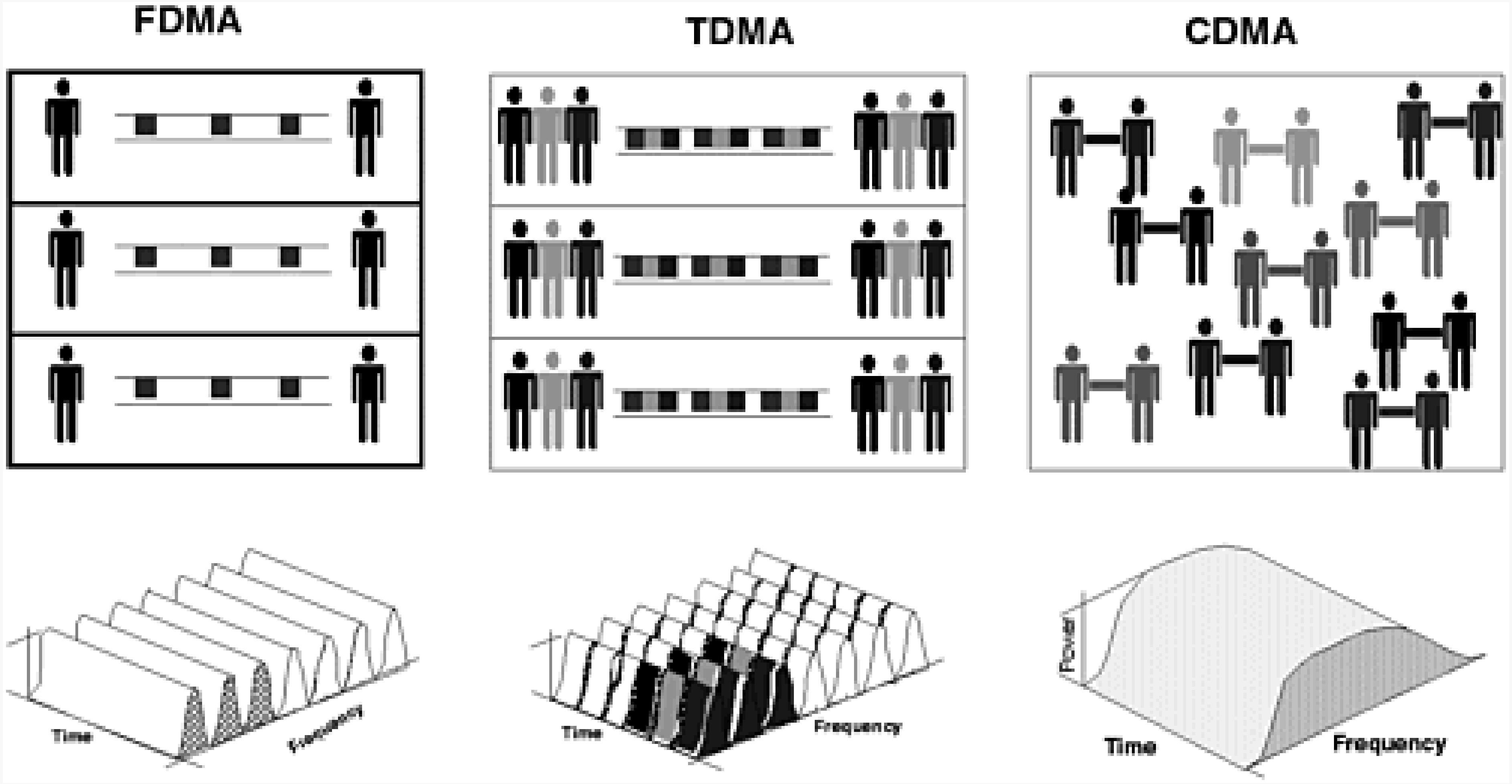
- Optimal management and planning of network resources are very crucial for the success of any network. This is particularly true when it comes to networks where human intervention is minimal.

- We have used the concept of game theory and highlighted various game models that may be used for optimal resource management among UAVs. Specifically, five game theory models were discussed, including coalition, potential, graphical, mean-field, and Stackelberg. Each model is explained based on its goals, design of utility function, and strategies, which implies their application areas.

Multiple Access and Routing Protocol

- Multiple access and routing protocols are another challenging domain for UAV networks. As UAVs are supposed to be co-located with other networks, the natural choice for multiple access for UAVs was initially space division multiple access techniques.
- Most of these include orthogonal, non-orthogonal, or rate-splitting techniques.

- In orthogonal multiple access techniques, the interference is reduced by ensuring that the simultaneous communications are orthogonal to one another. Some studies propose to use time division multiple access (TDMA) and frequency division multiple access (FDMA) in their system models. Another group of researchers focused on using code division multiple access (CDMA). On the other hand, orthogonal frequency division multiple access (OFDMA) is explored by some researchers, while some other research studies are conducted exploring space division multiple access (SDMA).

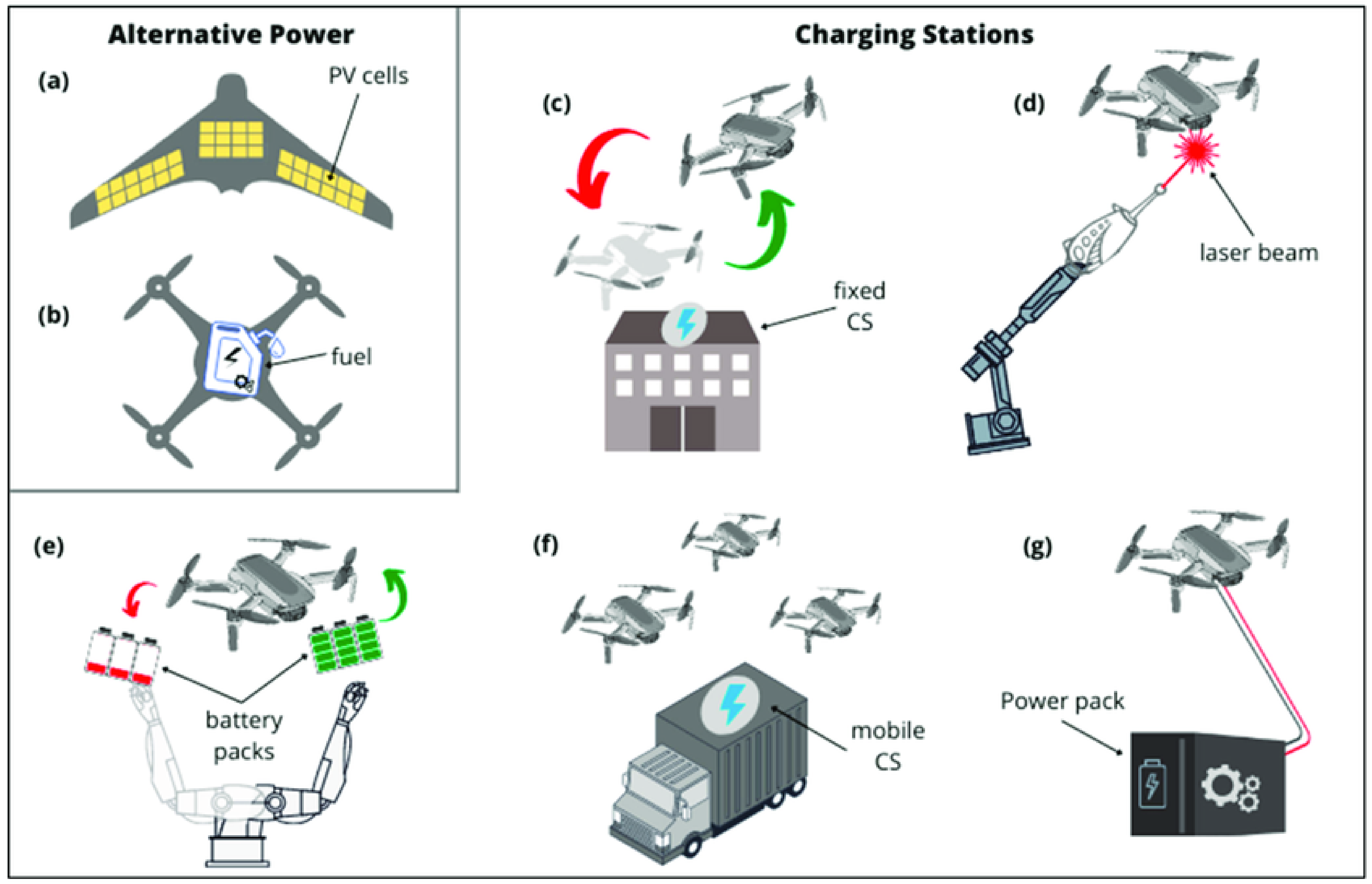


Power Control & Energy Efficiency

For drones and unmanned aerial vehicles (UAVs), power control and energy efficiency are other very critical realms. As these network nodes are not on the ground, an uninterrupted supply of power and efficient utilization of energy become very crucial. Many research studies have addressed this area and proposed several solutions, some targeting multiple power sources, including:

- battery,
- hydrogen fuel,
- solar,
- hybrid, etc.

that can be utilized by the UAVs. While others focus on how efficiently energy can be consumed. Energy efficiency affects all the operations of a UAV. Many studies have been conducted to explore UAV placement for optimal energy efficiency.



Drones

MULTI-ROTOR DRONES

Chief Executive Officer

FIXED-WING DRONES

Chief Executive Officer

SINGLE ROTOR HELICOPTER

Director

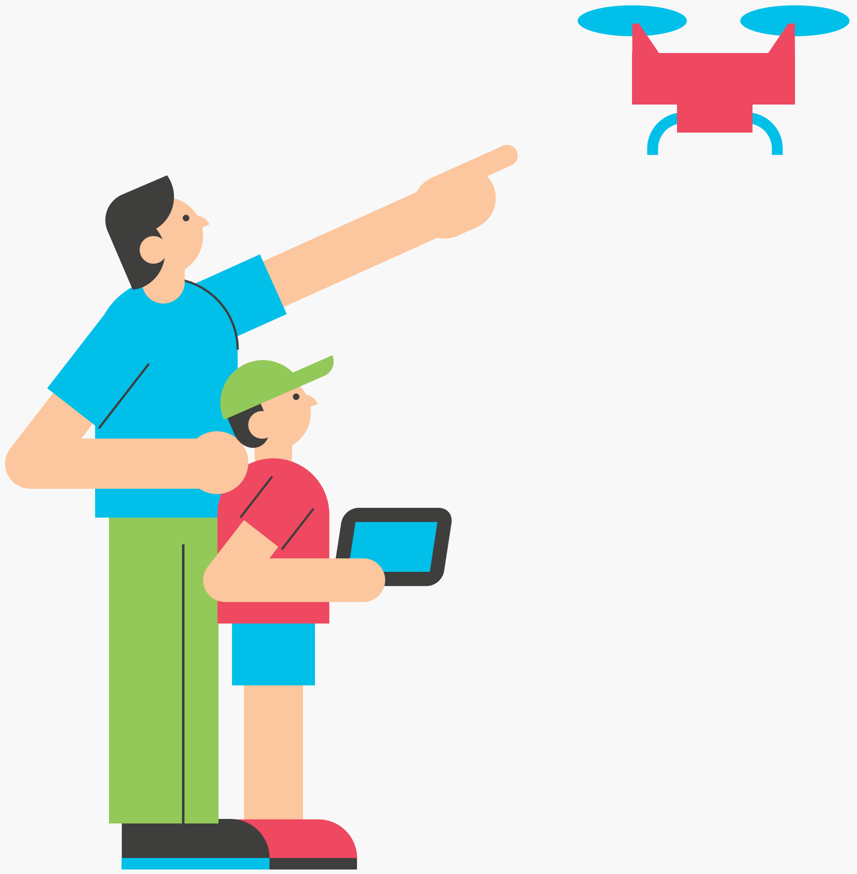
FIXED-WING HYBRID VTOL DRONES

Accountant

Back to Roadmap Page

Types of Drones according to their

Sizes



Size	Length	Propeller diameter	Weight	Use
Very small drones	150mm (15cm, 6 inches) or less	51mm (2 inches) or less	200 grams (0.2kg, 0.44lbs) or less	Military surveillance
Small drones	Up to 300mm (12 inches)	76-152mm (3-6 inches)	200-1000 grams (0.44-2.2lbs)	• Indoor equipment inspections • Recreation and photography
Medium drones	300-1200mm (12 inches – 4 feet)	150-640 mm (6-25 inches)	1-20kg (2.2-44 pounds)	• Professional applications • Amateur photography
Large drones	120cm (4 feet) and up	64 cm (25 inches) and up	20kg (44 pounds) and up	• Enemy detection and combat capabilities • Civil applications such as drone deliveries or filmmaking

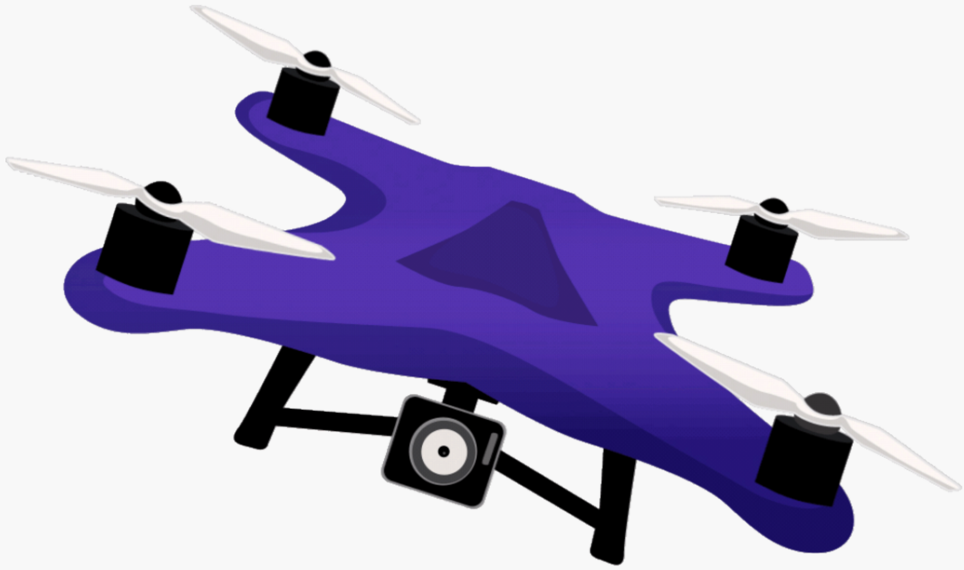
Types of Drones according to their

Payload

Drone type	Weight	Payload capacity	Use
Featherweight drones	Less than 11 grams (0.011 kg)	4 grams to 100 grams (0.004 to 0.1 kg)	Military surveillance
Lightweight drones	200-1000 g (0.2-1 kg)	150-270 g (0.15-0.27 kg)	Recreation and photography
Middleweight drones	1-600 kg (2.20-1323 lb)	400-1460 grams (0.4-1.46 kg)	• Professional applications • Aerial photography
Heavy-lift drones	More than 160 kg	More than 1,000 kg	• Enemy detection and combat capabilities • Civil applications such as drone deliveries or filmmaking

Types of Drones according to their

Range



Drone range	Flight distance	Flight time	Use
Very close-range drones	5 km	1 hour	Recreation
Close-range drones	up to 50 km	1-6 hours	• Military surveillance • Aerial photography
Short-range drones	up to 150 km	8-12 hours	• Large-scale surveillance • Mapping and surveying • Utility inspection
Mid-range drones	644 km	24 hours	Military combat and surveillance
Long-range drones	More than 644 km	More than 24 hours	• Military surveillance and espionage • Weather tracking • Geographic mapping

Challenges and Open Research Areas

NETWORK COVERAGE

- A significant reduction in network coverage can be seen when UAVs and drones are moving in low speeds.
- Furthermore, to provide network coverage to disaster-affected areas right after earthquakes and tsunamis, potentially emerging technologies such as 5G and UAVs can be used.

MAC PROTOCOL DESIGN

- To achieve high-efficiency requirements for the UAV networks.
- The cognitive radio approach can be used as a potential partner in designing MAC protocols for UAVs-assisted networks.

AI ALGORITHM DESIGN

- Various deep-learning techniques can be applied to some specific application areas for UAVs to achieve optimal system performance.

PRIVACY & SECURITY

- LiDAR and other sensors to move around and blockchain technology can also be used in tandem with other security features.

Conclusion

- Finally, we identified and discussed promising future research areas, including network coverage, access protocols, AI algorithms, and the security and privacy of UAV networks.
- New research programs are required to create efficient UAV network architecture and protocols for addressing issues and design challenges of AI-inspired autonomous UAV communication networks. The integration of AI algorithms for a sub-optimal low- low-complexity solution is suggested for future work.


Thank You