Survey of UAV Communication Network

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Abstract — **People are willing to create things that are unmanned, for instance unmanned space ship or cars, in order to release hands to do more things while commuting or to provide more secure and reliable operations. UAVs, that is Unmanned Aerial Vehicles, is an old topic created in the 1920s. Recently, however, with the help of a specific kind of UAV that is usually called "drones", the concept is getting more and more popular. UAVs can be used in image shooting, video recording and racing. Some further application includes rescuing after disaster, farming, harvesting, fishing or other signal transmission or data communication missions. However, there are many issues that need to be solved for better application or further use. Using Mobile Ad Hoc Networks (MANETs) or Vehicular Ad Hoc Networks (VANETs) cannot tell the unique address of the UAV networks. There are other issues as the UAVs can be vary large scale and can be actively dynamic, the connection stability is a tough question to be solved. In this survey we will talk about the characteristic UAVs, about how blockchain Technology can be used to improve UAV system, routing technology and handover technology, and finally discuss the energy efficiency and provide our opinions or solutions.**

Index Terms — **UAV, Unmanned Aerial Vehicle, ad hoc network, blockchain, software defined network, routing, seamless handover, energy efficiency.**

I. Introduction

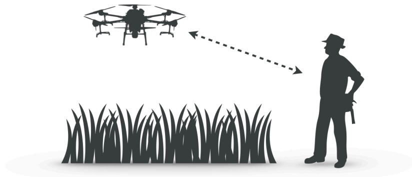
A. Development of UAV

The development of Unmanned Aerial Vehicles (UAVs) have never stop since the first UAV concept being announced in the United Kingdom in the World War I. During that time, UAVs are built to throw bombs and even in nearly a hundred years, UAVs are basically used by the military of countries on the planet. UAVs can be classified by civilian and military use. Since they are unmanned, UAVs are appropriate for remote missions and prevent loss. This is why is is developing fast in military use especially.

In 2016, a video shows that the U.S. Military unleashed a "swarm" of drones in the skies over California. Hundreds of micro UAVs communicated to each other and were able to defense and of course, attack as well. In 2018, China release the drone swarm system aiming to be more powerful than four American Apaches (Boeing AH-64 helicopter gunships).

Thanks to the era of peace, and the development of communication and digital signal processing technology, UAVs, especially so called drones, are getting more and more popular in photo capturing and video recording, or other communication services.

Drones developed by DJI (SZ DJI Technology Co.,Ltd.) can help with agriculture. The model T20 have the ability to sow and water or spray pesticide automatically. The farmer can control T20 using their computers or smartphones, and receive realtime images feed back. Using drones, not too many farmers are needed to manage a large scale of farm, and outputs and efficiency would be greatly increased.



Small UAVs are also used in video recording not only for film makers, but for family members as well. With the development of small size CMOS, cameras became smaller than before and flying cameras can finally be achieved. Film makers can shoot images which they once can only take on a helicopter, and families can take selfies without the help of strangers or a passerby.

UAV networks can help with criminal arresting by sensing and scanning the movements and escaping routes of the criminals. Other than that, UAV networks can improve region communication quality through providing seamless handoff connecting network via 3G, LTE or Wi-Fi, etc. With the help of GPS and 5G network, UAVs can be used in logistics and so that parcels to remote areas can be sent more quickly and more efficiently.

In China, however, consumer-grade drones are under strict management. In Beijing, limited area are forbidden for drones, and the flying height is also limited in different areas. An allowed take-off needs strong GPS connection, battery fully charged and even needs the pilots to be awake but not drunk. Some kind of UAVs need the pilot be well trained and have related documents or certifications. The Civil Aviation Administration of China announced that UAVs weight more than 250 grams need to be registered.

In the U.S., the limits of taking-off is divided into different categories by what the UAV is used for. For example for recreational flyers, you have to register your drone and and fly only for recreational use. In "Class G" airspace, drones shouldn't fly above 400 feet; and for commercial or academic flyers, a test must be passed to get the permission to take-off, according to FAA (Federal Aviation Administration).

B. Current Challenges

UAVs for civil and commercial use is a new topic and actually few researches and applications are about UAV communication networks. It is not hard to understand the difficulties to maintain the UAV network to be stable and reliable for a long time as UAVs can be at a vary large scale and the battery or power supply cannot offer continues working condition in a tough mission. Previous protocol may not fit every situations an UAV will face and the cost may also be large.

The network topology keep changing as the UAVs are moving fast and even if only one command on an UAV doesn't work, the whole communication will need to be rebuilt and reconsidered.

In this paper, we will discuss several problems happen in a UAV communication system, including aspects about characteristic, the using in the help of blockchain, and discuss the routing protocols in UAVs as a UAV system needs to be able to rapidly self-reorganize when operation fails. Besides, in user applications, the ability for a UAV system to seamlessly handover a signal from one node to another is also a challenge we have to consider. Lastly, we will concentrate on energy problems such as power efficiency and protocol efficiency.

C. Ad Hoc Network

Ad Hoc Network is found to be the most suitable network for a UAV system. It is a kind of peer-to-peer (P2P) connection and is usually used on wireless terminal devices. The word "Ad Hoc" comes from Latin means "for this" or "for this purpose only", which points out that the Ad Hoc network is built for a special purpose. There is no center device communication to other nodes, every nodes connects to each other so that when one node fails to work, the whole network maintain usable.

Although there are not many researches and information about the use of Ad Hoc in UAVs, some similar networks are developed to use in mobile or auto-mobile system. Mobile Ad Hoc Network (MANET) is an example. For traditional wireless cellular communication network, static network devices such as cell tower needs to be built, this is not the case for MANET as every node self-organize the network. In this way, UAVs can be used in the construction of remote networks in extreme situation like rescuing. Vehicular Ad Hoc Network (VANET) is also a solution. This is a network that usually used for cars and other transportation on the surface. VANET is a kind of network based on MANET and the difference between them is that the information architecture from vehicles to vehicles and vehicles to roads both exist in the network system in order to provide traffic safety. This sounds to be just what a UAV need but actually a UAV system is far more complicated than a traffic system.

TABLE I
DIFFERENCE BETWEEN THREE NETWORKS

	MANET	VANET	UAV Network
Mobility	slow, 2 m/s	faster, 6-30 m/s	more faster, 0-100 m/s
Topology	Random, Ad-Hoc	Star with Road infrastructure, Ad-Hoc among vehicles	Star with control center, Ad-Hoc/ mesh among UVAs
Energy Source	Battery powered	Car battery powered or own battery powered	Energy constrained
Typical Use	Advertising, events…	Traffic, emergency, police…	Rescue operating, harvesting…

MANETs do not care about movements, in contrast a VANET is limited by the road and traffic conditions. The movement of UAVs are more like random but not like cars, however they are also limited by laws and rules and by the instructions given by the flyer. Besides, UAVs can move at very high speed (0 to 100 m/s) while in VANET the speed of devices should not be lower than 6 and not higher than 30 m/s, and that in MANET is even worse. Another important thing to notice is that UAV network is in 3 dimensions while VANET is usually in 2 dimensions. The hight is also in consideration and the relevant position of each UAV is even more difficult to be decided.

Based on all these information we believe a new kind of topology or network system should be designed, using which UAVs can be connected stably when moving at high speed in 3-dimension and even if some of the drones failed to work the system can still keep complete functioning at full capacity.

D. An Upper-Level Prospective of the Survey

In the rest parts of this survey, we discussed our topic from 5 different views. In section II, we discussed the characteristics of UAV communication networks, including advanced features, network categorization, network self-organization and multi-UAV network. At last of II , we provide a perspective of SDN automating in UAV networks. In section III, a blockchain based UAV swarm communication architecture is introduced, we also provides an upper-level view of how to enhance network security for multi-UAV communication. In section IV, the requirements of the unique routing protocol of UAV network and the requirements of fault-tolerant network are mentioned detailedly. In section V, we discussed about the importance and the implementation difficulties in seamless hand-off of UAV network and what we should do for further development, and in section VI, the per-layer schemes and protocols designed to address the issue of energy efficiency is covered. At last, we sum up our survey and give a brief conclusion.

II. Characterizing the UAV Networks

As the growing importance of UAV Networks that we have introduced in PART I, in this section, we will focus on specific characterize of UAV Communication Networks.

Due to the peculiarity of Unmanned Aerial Vehicle, it is important to characterize the network to understand its nature, constraints and possibilities. For instance, because UAVs move regularly, how fast should the topology change with time to maintain a reliable communication? Furthermore, how to increase the network life span and what type of architecture would be more suitable? Whether the network's performance depends highly on self-organizing and self-healing capabilities? Which protocol could be run at different layers? Does this network support addition and removal of nodes dynamically? What about the quality of service (QoS)?

We will discuss the characteristic of UAV Communication Networks from five aspects. Subsection A introduces different topologies that are commonly used in multi-UAV communication; Subsection B discusses important features that set them apart from each other; Subsection C summaries the UAV networks from an high-level perspective by categorizing their usage; Subsection D introduces the self-organizing behavior of UAV networks; Last but not the least, we provides a glance in Software Defined Network(SDN) to control UAVs.

A. Multi-UAV Network

In the beginning stage of UAV's development, people deploy single UAV for a specific task. In such systems, the communication is fully depends on the connectivity between aerial node and ground control nodes.

Today, more and more public and civil applications can be carried out more efficiently with multi-UAV systems. For example, after an earthquake, UAV swarm are able to hove over the disaster area and provide a global view for rescue groups, such that trapped people are more likely to be found quickly. On the other hand, UAV swarm are also widely used in forest and agriculture surveillance, monitoring a large area in cooperation.

The main advantages of multi-UAV systems are reliability and survivability and these two features are based on the redundancy of the system. In a multi-UAV system, the network should be able to recover after failure of single node, this including reorganize and maintain communication through other valid nodes, such that the links can automatically reconfigure themselves. By contrast, it is not possible for a single UAV system to do so. However, to benefit from such features, the deployed protocols need to take care of the issues such as changing of the topology, mobility and energy constraints. Another benefit of multi-UAV system reflect in energy efficiency, the reason is only one or two UAV in the swarm may need connect to the control center or server and feed the other UAVs. This kind of system saves lots of energy when comparing with single UAV system. The reason is single UAV system would have to maintain links with the servers, control centers, base stations, and also provide access functionality, consequently, a heavy constraint has been put on the limited power and bandwidth. On the other hand, in a multi-UAV communication network, most of the UAVs in the swarm only need to maintain a mesh structure, then they can easily offer access functions for data, voice or video. Last but not the least, it has been turned out that multi-UAV systems are less expensive to construct, maintain and control than their larger counterparts. A comparison between single UAV system and multi-UAV system has been shown in *Table II*.

An important issue in multi-UAV systems is about the effective algorithm of coordination and tasks planning among robots. A routing planning algorithm has been raised in [1], the author of this paper introduced a learning algorithm named '*Opportunistic Cooperative Learning*'. This is a decentralized learning algorithm which is different from centralized algorithms that people normally used. Meanwhile, the author also illustrates why decentralized algorithm is suitable for UAV networks from algorithm complexity, energy efficiency and robustness. The interesting point of this algorithm is that, each UAV will try to approach other UAVs physically as a stochastic process, they compare their learning model with others. Then less successful UAVs adopt the models of more successful ones by copying, such that UAVs can 'evolute' with time.

TABLE II
COMPARISON BETWEEN SINGLE UAV SYSTEM & MULTI-UAV SYSTEM

FEATURE	SINGLE UAV SYSTEM	MULTI UAV SYSTEM
Impact of failure	High, mission fails	Low, system reconfigures
Scalability	Limited	High
Survivability	Poor	High
Speed of mission	Slow	Fast
Cost	Medium	Low
Bandwidth required	High	Medium
Antenna	Omni-directional (expensive)	Directional
Complexity of control	Low	High
Feature to coordinate	Low	Present

B. Self-Organization in UAV Communication Networks

Self-Organization is an important feature in network engineering since it influences the performance of the whole system. It means the network can recover from failures and reconfigure to work properly, this is why self-organization and its related features are considered seriously in most of the UAV communication networks. This means once the nodes have been configured and activated, the network can resist and recover from node failures with predefined rules.

The procedure of self-organization in an UAV network system can be described by the following steps:

1) Failure Detection & Available Nodes Finding: When the system detects a node A failed, their neighbors first find out potential nodes in the system to replace node A in order to maintain or reduce the affection in network coverage and connectivity.

2) Re-Organize & Collision Handling: After finding the available substitution node for node A, the network changes its structure by removal or addition of devices. This process is very likely to cause collisions because accessing the medium may influence performance of the network. Normally these collisions are handled by Medium access control (MAC) layer, such that the errors due to collisions are minimized.

3) Connectivity & Path Establishment: The network first focus on establishing connectivity, once connectivity has been established, the service revery management process handle network disruption avoidance and recovery from local failures.

4) Energy Management: Last but not the least, energy management process takes over the tasks for load balancing in data forwarding. It also operate in scheduling algorithms to reduce energy consumption of the whole network.The final goal of recovery is to ensure connectivity among all active nodes so the topology of the network is maintained[2].

Autonomous reconfiguration requires high complexity in computation and message transmission, therefore, bandwidth of the network is considered important in realizing self-organization. However, the benefits of self-organization are huge and therefore are encouraged. This exciting research problem raises challenges in more than this paper discussed[3].

C. SDN-Automating in UAV Communication Networks

UAV communications are limited to many factors, atmospheric conditions can affect fading such as rainfall. Moreover, UAV communication networks are in mobile environment, that is to say, antennas is moving relative to each other, the relative location of various obstacles changes over time. Consequently, this creates complex transmission effects. For example, vehicular communication networks use IEEE 802.11p Wireless Access Vehicular Environment (WAVE) to support the application of Intelligent Transportation Systems (ITS); whereas in wireless mesh networks, the IEEE 802.11s revision has been standardized for self-configuring multi-hop technology. However, people have not yet reached a consensus on which routing protocols should be used in above situations. As a result, nodes using a particular access technology in a network may not not be able to operate in another network with the same access but with different higher layer protocols.

TABLE III
UAV REQUIREMENTS AND SDN CAPABILITIES

FEATURE REQUIRED IN UAV	SDN CAPABILITIES
Node mobility	Reconfiguration by orchestration mechanism
Flexible switching and routing	Flexible definition of rules based on header or payload for routing data
Dealing with unreliable wireless links	Selection of paths and channels
Greening of network	Support switching off devices when not in use. Supports data aggregation in the network
Reduce interference	Can be done through path/ channel selection

Software defined protocol stack provides the possibility to solve such problems in UAV communication networks. On top of this, UAVs are able to work flexible with programmed stack. However, this is not the biggest advantage of Software Defined Network (SDN). Since networks has speciality needs in UAV and VANET as we discussed in section A, the networks should be able to adjust to frequently changes and support dynamic nodes configuration. For example, in UAV networks, it is common to see nodes failure since the battery of single UAV is very limited. Therefore, new nodes should be added and tasks from from previous drones should be handover. SDN provides ways[4][5] to control network with programming, this simplify the deployment and management of services, network policy and performance.

SDN is well know in fixing infrastructure-based networks, but such applications are more likely to see in data centers. The reason is that SDN was believed more suitable to apply in centralized network like star topology. However, as discussed previously, UAV communication networks are decentralized for convenient message passing. Meanwhile, concerns for flexibility, control balance and security reasons have been raised for separate forwarding devices from the network. In VANET, SDN is used to help multi-path selection and to improve the channel utilization and multi-hop routing. Although people have increasing interest about SDN, there is no clear and comprehensive understanding of how the concept of SDN should be expanded to suit the characteristic of mobile and wireless communications [6].

OpenFlow is one of the most widely used protocols to implement SDN in wireless mesh networks. It claims to have crucial advantages for wireless and mobile networks, as well as for UAV communication networks. OpenFlow provides a method to automate operations, such that global policies can be implemented easier and this leads to a faster initialization of new services [7]. To be specific, functions like forwarding and control are separated by OpenFlow protocol and therefore switches are programmable. In additional, flow tables and communication protocols are also contained in such implementation. A summarization of requirements in UAV and SDN capabilities are listed in *Table III*.

Researchers have demonstrated that it is feasible to integrate OpenFlow into WMN with appropriate testbed [8]. Under the simulations of SDN based routing protocol in wireless networks, researchers have proved that SDN-based routing performs better than traditional Ad hoc routing protocols in the aspects of packet delivery ratio at different speeds. This is because controllers in SDN are able to obtain more aggregated knowledge than in Ad hoc. As a result, SDN offers better performance in configuration and. Although there is still some fundamental issues have not been fully solved, SDN technology still shows obvious advantages in WMN communication.

III. Blockchain Technology for Networked Swarm of UAVs

Based on research[8] from Dr Shakhatreh, the predicted value of UAVs in market is almost 127 billion dollars. Meanwhile, UAV technology is expected to create approximately one hundred thousand job positions by 2025. As we discussed in previous sections, UAV's application can be various, there is no doubt that UAV will be used in more areas and larger scales in the near future. Such applications requires the communication between UAVs to be robust and secure enough, therefore the data stored in UAVs can be well protected.

Blockchain is a hot topic these two years, many conferences paper have mentioned this technology and its combination with other modern network technology. For example, blockchain in IoT, blockchain in 5G optical networks, etc. In this section, we will discover the possibility to combine this technology with UAV communication network to pursue a better network performance. First of all, a brief introduction of blockchain will be given. Next, we will focus more on how blockchain can be applied in UAV communication networks. Finally, we will discuss some existing challenges of this combination.

A. Introduction to Blockchain and its Advantages

As its name suggests, blockchain regards a distributed system as different blocks. Each block maintains hash value to their next block and hash value of their previous block. Meanwhile, each block carries a list of transactions. With blockchains, applications are able to operate in a decentralized structure, such that there is no need for a central authority. Therefore, we say that the blockchain enables *trustless* networks because transactions can be executed between nodes even they do not trust each other.

The advantage of blockchain can be various. On top of this, since there is no need for a trusted agency, blockchain allow s faster reconciliation between transacting parties. This feature is even more significant when blockchain is combined with IoT technology. Imagine a company introduces blockchain to store the hash value of their latest firmware. Users can either ship with the smart contract's address baked into their blockchain client, or they find out about it via a discovery service[9]. Then users of this company can query the contract through blockchain and find out the latest firmware. Finally they request to download by verify the hash value, downloaded via distributed peer-to-peer filesystem like IPFS[10][11]. Once the binary codes has propagated to enough nodes[12], there is no need for the manufacture node. An important characteristic of blockchain in this example is devices are configured to share the binary they got with each other. As a result, other device that joins the network long after the manufacturer has stopped serving can still retrieve the updated file and be assured that it is correct. Such process happens automatically, without any external interaction.

From the above example we have seen that even a simple application of blockchain in distributed system can be beneficial. In the sub-section B, we will show the survey result that we found about how blockchain can be applied in multi-UAV communication networks. Lastly, we will discuss challenges of such applications in sub-section C.

B. Introduction to Blockchain Technology in UAVs

Back to our topic, applications of drones tend to become larger, that is to say, the number of drones in the network grows. In centralized system, this requires UAVs to maintain close communication with each other. On the other hand, as the number of UAVs increases in the network, both design complication and control cost (such as latency) of the centralized system increased. As a result, people started to think about the possibilities to develop a decentralized UAV control system.

The Ethereum blockchain network[14] breaks the deadlock. The author proposed a protocol named the Autonomous Intelligent Robot Agent protocol (AIRA)[14], this protocol utilizes blockchain to manage the "economic activity" between actors in a multi-agent system. What does this mean? Generally speaking, each robot has to run an operating system, Robot Operating System (ROS) is the most widely used OS currently. AIRA protocol utilizes ROS as agent to perform operations like request for service, create smart contract, service acceptance by UAV agent, etc., stores data on the InterPlanetary File System. Transactions of the system can be executed using both tokens from the Ethereum network and their own custom tokens[14]. Finally, the system establish and approve "air corridors" by "agent-dispatchers" [14].

A simpler blockchain-based structure[15] that can increase security of UAV networks was also raised. The author claimed a concept where UAVs act as different nodes in the blockchain network. They have also explore a new consensus mechanism called "Proof of Graph" [15] which enable to find the shortest path in the blockchain network.

The most famous blockchain application in UAV networks is packet delivery system, which is possible to make the delivery quicker and cheaper. Chronicled company has developed "prototype solution" for packet delivering[16]. The basic idea of their solution is to integrate cryptographic chips into drones for identification. The signature is checked with a blockchain network, packet delivering permissions will be granted if and only if the hash value is verified through the blockchain. This process is described in *Fig 1*.

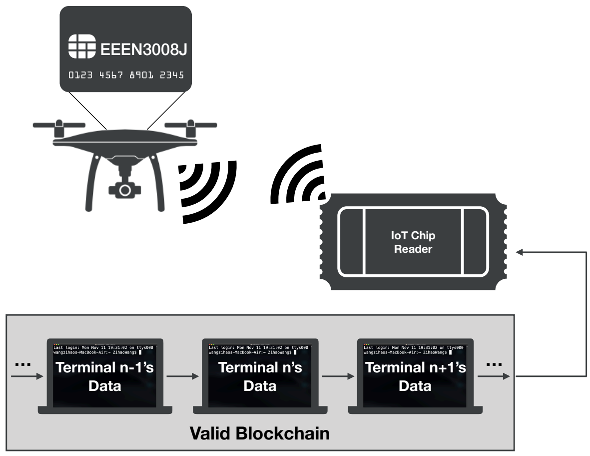


Fig 1. Description of Blockchain Solution in UAV Networks

C. Possibility to Apply Blockchain in Robot Swarm

As we discussed in Section IIA, multi-robot has a huge potential and a wide prospect in both public and civil applications. However, the first question we have to face in order to maintain such large number of UAV swarm is: How to keep the system secure? Different with other controlling systems, distributed system requires robust and collaborative control strategy to keep data transmitted safety and efficiently. Due to the decentralized structure and security transaction of blockchain, such problems is expected to be solved with blockchain.

One researcher proposed a solution in [17], utilizing unique keys to manage UAVs. Under this scheme, each UAV in the swarm must register a key before they submit data to the cloud database. Without the key, any attempt to transmit data into server will be treated and marked as threat by the coordinator. Blockchain will be used as safety storing such that the keys can be protected and well managed. Moreover, for each transaction, devices in the blockchain network can eventually

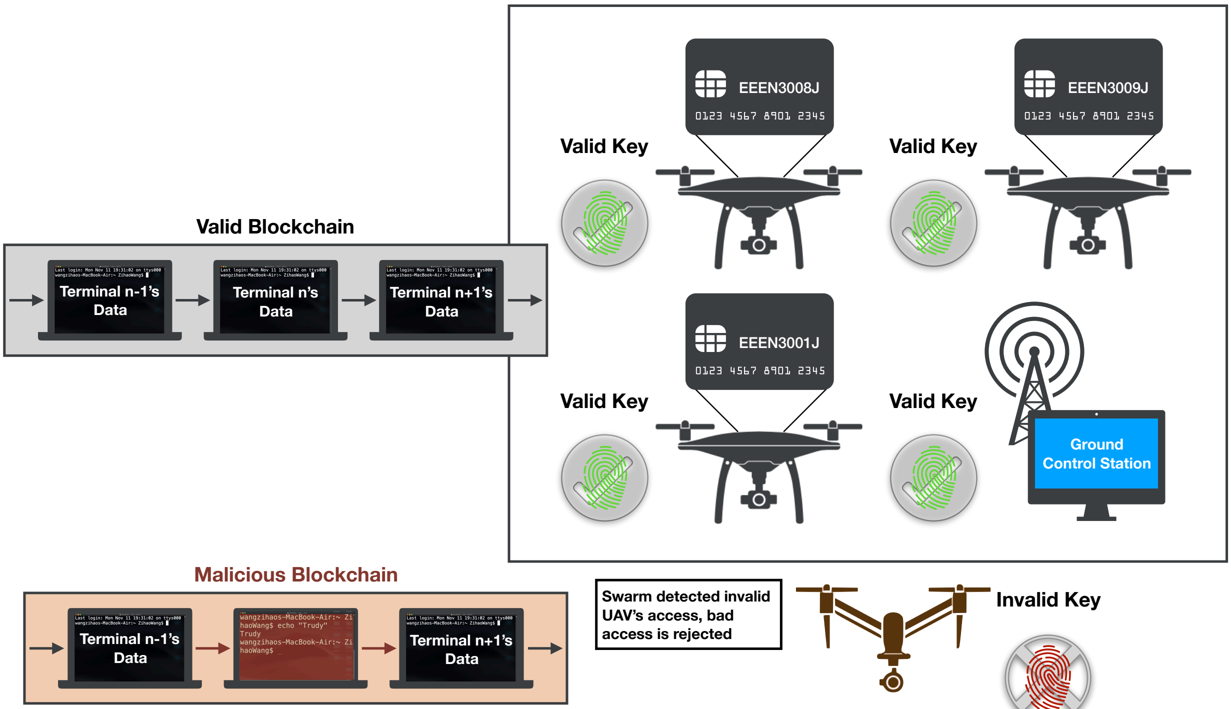


Fig 2. Description of Blockchain Solution in UAV Networks

reach a consensus. This ensures that once a drone submit its data, the data is able to be considered safe and cannot be edited (because the hash value has been calculated and spread among blocks within the blockchain). This process is illustrated in *Fig 2*.

In a nutshell, the combination of blockchain and UAV swarm can effectively protect the system from epidemic — dissemination of malicious information.

IV. Routing

Various application ranging from ones fly slowly to ones at a considerable speed are constituted in the UAV networks. The failures are common for nodes out of service or power constraints. Meanwhile, the reliability requirements from the UAV networks are diverse. For example, while sending pictures and video of the earthquake may be done with lower reliability but stricter delay and jitter requirements, sending earthquake data may require a 100% reliable transport protocol. Therefore, the UAV networks need more than all requirement for mobile wireless networks—Node mobility, network partitioning, intermittent links, limited resources and varying QoS requirements. While many protocols attempt to replace the previous ones, we can find it promising in this field.

A. Routing Problems to fixed

Routing in air networks requires location awareness, energy awareness, and enhanced robustness to intermittent links and changing topologies. Designing network layer for UAV network is still one of the most challenging tasks [18].

Some papers have studied the use of existing routing protocols for possible use in airborne networks. Although conventional self-organizing routing protocols are designed for mobile nodes, they are not necessarily suitable for airborne nodes due to the changing requirements of dynamic and link interruption. Therefore, a routing protocol suitable for the special needs of airborne network is still needed to adapt to high mobility, dynamic topology and different routing functions [21]. Routing protocol tries to improve the transmission rate and reduce the delay and resource consumption. In addition, problems related to scalability, degree of freedom of circulation, energy conservation and effective utilization of resources must be considered, which also need to be solved [22].

B. Applicability of Existing Routing Protocols

Many routing protocols that have been proposed for MANET attempt to adapt table based active protocols in the era of interconnection to ad hoc wireless networks with nodes. Many protocols in routing and response protocols can use update protocol to reduce the overhead, but location management is still a problem in dynamic networks such as UAV networks. Some protocols that introduce the concept of cluster head introduce performance problems and single point of failure [23]. On WMN fixed or mobile nodes, it is pointed out that the available Mac and routing protocols do not have enough performance, and the throughput decreases with the increase of nodes or hops. It is further added that the improvement of single layer protocol can not solve all problems, so it is necessary to enhance all existing protocols or replace them with new ones of UAV network [24].

Due to the similarity between UAV network and Manet and VANET, researchers have studied the protocols used in these environments. Due to many unique problems of UAV network, although the modification of MANET protocol has been proposed, it is still necessary to develop a new routing algorithm for reliable communication between UAVs and from UAV to control center [19]. We will use the following well-known classifications to discuss many network protocols with a view to seeing their usefulness for the UAV network: 1) static protocols 2) active protocols 3) on demand or response protocols, and 4) hybrid protocols.

static routing protocol: the static protocol has static routing tables, which are calculated and loaded when the task is started. These tables cannot be updated during the operation. Because of this limitation, these systems are not fault-tolerant and are not suitable for dynamic environment.

Active routing protocol: active routing protocol (PRP) uses tables in its nodes to store all routing information of other nodes or nodes in a specific area of the network. The table needs to be updated when the topology changes. The main advantage of active routing is that it contains the latest routing information. However, in order to keep the table up-to-date, many messages need to be exchanged between nodes. Due to the bandwidth limitation, it is not suitable for UAV network. Another problem that makes them unsuitable for UAV networks is their slow response to topology changes, resulting in delays [19].

Responsive routing protocol: responsive routing protocol (RRP) is an on-demand routing protocol. When there is communication between a pair of nodes, the routes between a pair of nodes will be stored in it RRP aims to overcome the overhead of active routing protocol. Due to the on-demand nature, there is no periodic messaging that makes RRP bandwidth efficient. On the other hand, the process of finding a route can take a long time. Therefore, high latency may occur during route lookup. There are two types of response protocols: source routing and hop by hop routing. In the source routing, each packet will carry a complete source to destination address, so the intermediate node can forward the packet according to this information. There is no need for regular beacon maintenance connections. Because the probability of routing failure increases with the increase of network size, and the increase of header size also increases the overhead, so the scalability is not good. In hop by hop routing, each packet carries only the destination address and the next hop address. Intermediate nodes maintain routing tables to forward data. The advantage of this strategy is that the route can adapt to the dynamic environment. The disadvantage of this strategy is that each intermediate node must store and maintain the routing information of each active route, and each node may need to know its neighbors by using beacon messages [20], [23]. Two commonly used RRPS are dynamic source routing (DSR) and AODV.

Hybrid routing protocol: by using hybrid routing protocol (HRP), we can reduce the large delay of initial route discovery process in reactive routing protocol, and reduce the overhead of control messages in active routing protocol. It is especially suitable for large-scale networks, and the network is divided into multiple regions, in which the active method is used to perform intra region routing, while the passive method is used to perform inter region routing. Hybrid routing is very useful for MANET because it adjusts policy according to network characteristics. However, in MANET and UAV networks, dynamic node and link behavior make it difficult to obtain and maintain information. This makes it difficult to adjust the routing strategy.

Geographic 2-Dimension and 3-Dimension Protocols: For two-dimensional networks, many routing schemes have been proposed, which can use plane geometry modeling. Many outstanding aspects are described in this survey, and some good performances in delivery, delay and throughput are shown in the simulation. The geographical scheme assumes that the geographical location of the nodes is known. Greedy forwarding is the most commonly used technology in geographic routing in which each node only forwards messages to the node closest to the destination based on local information. The recovery mechanism usually faces the route, which finds the path to another node, in which greedy forwarding can be recovered [40].

In many applications, it is more suitable to model UAV network in 3D. Some protocols have been proposed, such as their two-dimensional protocols, which use greedy routing to try to deliver packets to the node closest to the destination. But it is more challenging to recover from local minima because the faces around the network holes are now expanding in two dimensions and difficult to capture. When packets are stuck in the local minimum, their main difference is the recovery method [41].

The greedy hull greedy (GHG) protocol proposed in [42] involves routing on the hull to avoid local minima. For the two-dimensional protocol, this is a three-dimensional equivalent for routing on the surface.

In [43], the author proposes a greedy random greedy (GRG) protocol, through which messages are greedily forwarded until a local minimum is encountered. In order to get rid of the local minimum, a random recovery algorithm is used, such as random walk with limited area or random walk on the surface. The simulation results of the following five recovery algorithms are introduced: dual random walk, surface random walk, graph random walk, bounded DFS on spanning tree and bounded flooding. DFS on spanning tree has good performance for sparse network, while random walk has good performance for dense network.

GDSTR (greedy distributed spanning tree routing)—3D, the routing scheme was described in [44] uses 2-hop neighbor information to reduce the possibility of local minima during greedy forwarding, and researchers used two 2D convex packets to aggregate 3D node coordinates. Their simulation and test platform experiments show that GDSTR-3D can ensure the transmission of data packets and realize the hop expansion close to 1.

MDT (multi hop Delaunay triangulation) protocol is proposed in this paper. This protocol can provide guaranteed transmission for 3-D general connectivity graph, effectively forwarding packets from local minimum and low routing range. The simulation results show that MDT provides a better routing range than many 2-D and 3-D protocols. They also show its applicability to dynamic topology as the number of nodes and links changes.

C. *Routing in Network Prone to Delays and Distributions*

According to the delay tolerance network research group, the term "delay tolerance network" refers to extreme environments and performance challenged environments in which continuous end-to-end connections cannot be assumed. Originally defined for interplanetary communication, it now involves interconnection of highly heterogeneous networks. When disaster strikes and normal communication is interrupted, the lack of information flow may cause delay of rescue and recovery operations.

In many bad cases, the connection is intermittent and the network is partitioned for a long time. This will cause the transmission delay to exceed the threshold limit described by the TCP protocol, and usually discard the packets that can not reach the destination, thus making TCP inefficient.

UDP does not provide reliable services and cannot "keep and forward.". Traditional routing protocols such as AODV and OLSR can not work normally during the interruption. In these cases, when the packet arrives and there is no end-to-end path to the destination, the packet will be simply discarded [25]. Although traditional solutions can not guarantee connectivity, the protocols used in UAV network should allow buffering and forwarding of packets in some way. Existing protocols developed for infrastructure based Internet cannot handle data transfer in networks and new algorithms.

TABLE VI
APPLICABILITY OF PROTOCOLS TO UAV NETWORKS

Protocol type	Problems in application to UAV networks
Static	Fixed tables, not suitable for dynamic topology, does not handle changes well, not scalable, higher possibility of human errors
LCAD	Delivery delays
MLHR	CH becomes single point of failure, capacity issues at CH
Data Centric	Network overload due to query-response. Problems as in cluster based.
Proactive	Large overhead for maintaining tables up-to-date, bandwidth constrained networks cannot use them, slow reaction to topology changes results in delays
OLSR, GSR, FSR	Higher overheads, routing loops
DSDV	Consumes large network bandwidth, higher overheads, periodic updates
BABEL	Higher overheads and more bandwidth requirement due to periodic updates
B.A.T.M.A.N	Depends on packet loss, does not perform well if network is reliable
On-demands or reactive	High latency in rout finding. Source routing does not scale well, for large network overhead may increase because of larger header size. For hop-by-hop intermediate node must have the routing table
DSR	Complete route address from source to destination, scaling is a problem, dynamic network is a problem
AODV	Lower overhead at the cost of delays during route construction. Link failure may trigger route discovery more delays and higher bandwidth as the size of the network increases.
Hybrid	Hard to implement for dynamic networks
ZRP	Inter zone traffic may congest. Radius is an important factor may be difficult to maintain in UAV networks. Complexity higher
TORA	May produce temporarily inna; id results
Geographic 3D	
GHG	Requires location information which may become unrealistic in many applications
GRG	Uses random walk recovery which in inefficient and does not guarantee delivery of messages
GDSTR-3D	Assumes static topology
MDT	None documented

For UAV networks that tend to be intermittently linked and zoned, we need to establish tolerance for delay and interference. Because of the long delays and disconnections in these networks, end-to-end reliability methods such as multi-step request response, acknowledgment, and timeout transmission will not work. To achieve delay and interrupt tolerance, the architecture must be based on the store and forward (SCF) protocol, in which nodes store and carry data (usually for extended periods of time) until it can be replicated once or more. Nearby nodes. In this case, the node must have enough buffer capacity to store the data until it has the opportunity to forward it. In order to effectively deliver messages to destinations, the best node and time to forward data should be known for each message. If the message cannot be delivered immediately because of a network partition, select the node that hosts the message

Mail is the most likely to be delivered successfully. In SCF routing, messages move from source to destination one hop at a time. The choice of path from source to destination depends on whether the topology evolves with time is deterministic or probabilistic. If the nodes know nothing about the network state, the best they can do is to randomly forward the packets to their neighbors [26], [28].

Because the end-to-end path is not available in the UAV network, the traditional routing protocol using the above method cannot be delivered before communication begins. Therefore, many researchers have proposed advanced new routing algorithms, such as direct delivery [45], which provides a single copy method for intermittent networks. The authors claim that less bandwidth is required than a popular method that basically contains multiple copies. Epidemic routing involves multiple copies to be sent [46]. In [47], a controlled replication algorithm called "spray and wait" is proposed.

In order to save bandwidth and use routing algorithms in energy constrained systems, the feasibility of beacon free geographic routing in opportunistic intermittent connection mobile networks is explored. Beacons are special messages that are transmitted periodically. Many routing algorithms use them to determine the neighbors of nodes. They consume bandwidth and energy, and information may be inaccurate.

In order to apply it to the UAV network, it must be remembered that the resources (such as storage, power and bandwidth) on the UAV nodes are limited. Transmission speed is affected by transmission distance, number of encounters, network condition and node movement. Delivery times are also important, and in this regard, it may be noted that this architecture is not suitable for real-time content, as delays can be extended to hours or days. In addition, the current suitable route may not be stable for a long time. How long it will remain stable depends on the speed of topology change. If it is determined that some routes are stable, route caching can be used to avoid unnecessary routing protocol switching [29]. Some schemes use node location knowledge, others may flood the network with packets, while others may use "operator" nodes to carry data. Let's briefly consider three routing methods that can be used in UAV network:

1) Deterministic routing
2) Random routing
    a) method based on epidemiological route
    b) estimation based method
    c) method based on node movement control
    d) method based on coding
3) Methods based on social network

You need to overlap shapes at different points in time to find an end-to-end path. In a UAV network, the contacts of nodes change with time, because the duration of their communication is limited. In view of this, let's take a look at the applicability of various types of protocols to UAV networks.

Deterministic routing: in the deterministic routing method, we assume that future mobility and links are completely known. In the environment of UAV network, this may be realized in the application of UAV flying in controlled form or the application of hovering the mouse in a certain area. If all hosts have global knowledge of the availability and movement of other hosts, you can use the tree method to select paths. The tree is built with the source node as the root and the child nodes added and the time associated with those nodes. If the hosts do not initially know the feature profiles, they can learn them by exchanging the available profiles with their neighbors. The deterministic algorithm assumes the global knowledge of nodes and links in time and space Handorean et al. A global algorithm [31] is proposed, in which the host fully understands the feature profiles of all hosts The authors in [32] investigated such agreements. Therefore, these methods are not suitable for frequent changes of network topology or uncertain availability of nodes and links. The mobility of nodes does mean that the network topology will be constantly changing, and the nodes will constantly contact with new nodes and leave the communication range of other nodes. If the node can estimate the possible meeting time or frequency, our network will have predicted contacts [48].

Random routing: This is the case when the network behavior is random and unknown. In this case, it becomes important to decide where and when to forward packets. In this case, one possible way to route a message is to forward it to any contact in the scope. The decision can also be based on historical data, liquidity patterns and other information. This kind of protocol maintains the network topology that changes with time. Whenever a node is encountered, the network topology will be updated. Moreover, it is not suitable for networks with delay tolerance and high node mobility [33]. A routing protocol, named rapid, has been proposed, which considers network resources, such as bandwidth and storage, when optimizing a given routing metric. This is particularly important when nodes have resource constraints [34].

In UAV networks with intermittent links and opportunistic connections, routing is challenging because of the time at which nodes start to contact and the unknown time. When a contact does occur, it needs to be determined whether the contacted peer is likely to bring the packet closer to the destination. The decision to hand over the packet to the contact also depends on the contact's possibility of bringing the packet closer to its destination, the buffer space available in both nodes, and the relative priority of forwarding the packet compared to other packets held by the node. In addition, if a node has information about its location, the information can be used to gain benefits. According to [48], in the above case, the main purpose of routing is to maximize the probability of delivery at the destination while minimizing end-to-end delay. Next we will discuss some random protocols. Epidemic routing, spray and wait, node mobile control and coding.

Epidemic based routing method: this method is used in most mobile nodes' networks that are not connected [48]. This is a random flooding protocol. Nodes copy a large number of messages and forward them to other nodes called relays. When a message contacts another node, the relay transmits the message to the other node. There is no prediction of link or path forwarding probability. In this way, messages can be quickly distributed through the connection part of the network. However, when contacting each other, nodes exchange only data that they do not have in their storage buffers.

Epidemic routing uses node mobility to propagate messages during contact. Using large buffer, long contact or low network load, epidemic routing is very effective when messages arrive at destinations on multiple paths, and provides minimum delay and high success rate. If there is no information about the node's movement, the packets received by the node will be forwarded to all or some neighbors of the node, rather than from its neighbors.

When a source or relay node with more than one replica contacts another node without a replica, it may transmit all n replicas in normal mode, or N / 2 replicas in binary mode (spray phase). Therefore, after contacting, both nodes have n / 2 replicas. A copy requires direct contact with the destination (waiting stage). Even if the transmission may actually involve multiple copies, the message is physically stored and sent only once.

Using indiscriminate or controlled flooding will use different amounts of buffer space, bandwidth, and power. There are variations such as prophet and maxprop protocols, where data is prioritized based on certain criteria. Priority is based on path possibilities to peers [35], [36]. However, our airborne network topology may change without any known patterns. Similarly, even the random walk model may not be able to describe the node movement caused by horizontal and vertical movements. In this case, the three-dimensional architecture can better define random and drastic topological changes, and can generate available paths at unpredictable times.

Estimation based method: the intermediate node does not forward messages to neighbors indiscriminately, but estimates the possibility of each output link finally arriving at the destination. Based on this estimation, the intermediate node decides whether to store the packet and wait for a better opportunity, or to decide when and to which node to forward it. This change can be a decision based on the next hop forwarding probability estimation, or a decision based on an average end-to-end metric (such as shortest path or delay) [32]. The author believes that nodes in DTN tend to visit some locations more frequently than others, and nodes that have repeatedly contacted in the past are more likely to contact in the future.

Method based on node movement control: the node can passively wait for the opportunity of reconnection with another node, or actively find another node. For some applications, the transmission delay is too long. In the case of proactive, many methods have been proposed to control node mobility to reduce latency. In one class of methods, the trajectory of some nodes is changed to improve some system performance indicators, such as delay [37]. In the message delivery method, a special ferry node carries data on a pre planned route, or other nodes approach the ferry and communicate with it, or the ferry node moves randomly, and other nodes send service requests as the response to select the ferry node to approach the request node [38]. Using datamules, randomly moving nodes with large storage capacity and renewable energy is another approach in this category.

Coding based method: the concept of network coding comes from information theory, which can be applied to routing to further improve system throughput. The intermediate node does not simply forward packets, but merges some packets received so far, and sends them as a new single packet to maximize the information flow [32]. Erasure coding involves more processing and therefore requires more power, but improves the worst-case delay [49]. In [50], the author has shown that the performance of network coding is better than that of probability forwarding. Erasure coding includes redundant data and is very useful when retransmission is not possible. One aspect to keep in mind is that in UAV, retransmission will be a different path with possibly different node sets, and the storage required for redundant information is also limited.

TABLE VII
DELAY/DISRUPTION PRONE UAV NETWORKS

DTN Routing Algorithms	MANET
Deterministic	Useful when future availability and location of the nodes is known. In some UAV networks topology may change frequently and availability of nodes and links may not be certain.
Stochastic	
Epidemic based	Requirements large buffer space per node, bandwidth and power. For UAV networks it must be noted that message delivery time depends on the buffer size. Comparatively delay is lower with high-energy expenditure.
Estimation/ Probability/ Statistical	Random methods work well for small networks but for large networks estimation result in large overheads. Maintains encounter but no location information. Changes in topology, like in UAV networks, affect convergence time. Delays are moderate at moderate. Changes in topology affect convergence time.
Node movement based	UAVs can be made to follow a given trajectory that will connect source and destination nodes in partitioned networks.
Message ferrying	Location information is maintained. Large storage space required in ferries. Delays are high but energy expenditure is low. Can work with heterogeneous nodes.
Coding-based	Builds in redundant information so that retransmission is avoided. This aspect may be exploited in UAV networks. In UAV's retransmission would require finding a new path as disruptions are the norm. However, maintaining redundancy and aggressive forwarding takes additional bandwidth and buffer space. May provide better delivery rates than probabilistic in some settings but is inefficient if connectivity is good.
Social Networks	Applicable when some UAV nodes have 'more likely' locations. Such nodes must have higher buffer size and higher bandwidth links to avoid contention delays and losses.

Hybrid erasure coding combines erasure coding and active forwarding mechanism, which can send all data packets in sequence during node contact. If a node's battery is exhausted or its mobility is lost due to failure, it cannot transmit data to its destination, which results in the loss of "black hole" information HEC solves the black hole problem by using the contact time of nodes effectively.

Routing based on social network: when the mobility of nodes is not completely random, and nodes may appear in some known places with a greater probability, the random mobility model used in a large number of protocols is not realistic. Nodes that visit these places have the potential to connect and will be more successful in distributing bundles. The concept of popularity of groups, communities and nodes can also be used [22]. However, due to the limited capacity of these nodes, the protocol may overuse popular nodes, and performance may decline. The expected delay is likely to increase due to contention. Some degree of randomness integration may improve performance. This is a relatively new area, and more work needs to be done to make proper use of it [39]. Some applications of UAV network.

V. Seamless Handover

A. *Introduction and motivation*

An UAV mesh network could be set up at places where no signal or man can reach, such as ruins after a disaster, hurricane or tornado, or remote districts like mountains and islands, in order to offer cellular networks or other communication condition. In another situation, for instance in harvest or pelagic fishing, UVAs must move at needed speed and keep stable connection.

In long-term using upon the situation above, UAVs may go out of service in turns to get charged as the power may run out or some errors may occur unintentionally. To save power, the communication interface may be shut down or some of the drones may be shut down as lighter network condition is needed.

In all the conditions above, the UAV network system needs to reset or reconnect to provide seamless connection or information transmission with very low latency. This will make live videos, audios or data sessions be unconsciously handover.

in the section below we will discuss handover in detail, and talk about what modern technology have achieved and what challenges to be faced. Then we will give our opinion and basic solution to these problems.

B. *Concepts and Details*

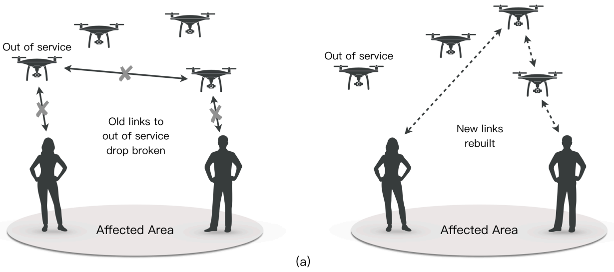
Thanks to the use of wireless mesh network, self-management in UAV connection and handover become greatly usable for customers. Handover, or some call handoff, is never an unfamiliar concept as in our daily life, we benefit from cellular networks as we move around different cell towers. Another example is a function just called "Handoff" designed by Apple inc. in order to make users do their tasks when switching seamlessly between different devices such as iPads or Macs. This is the explanation and brief introduction to handover and its concept.

There are two types of handover: Hard Handover and Soft Handover. Soft Handover is more like what we called seamless handover.

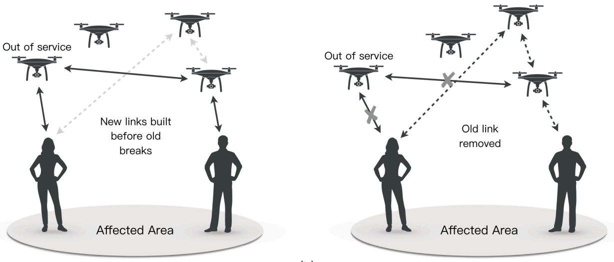
In a Hard Handover (Fig. a), only after a connection truly breaks, the new link will be then reconstructed and bring the system back to work again. This means an interruption of all users using the previous link.

Soft Handover, on the other hand (Fig. b), made new links before old ones being broken. The broken data transmission will be seamlessly move to the new connection which has been built already and provide senseless switching between UAVs.

There is another classification method that is to divide the technology into horizontal and vertical handovers. This is to classify handovers by if the handover process is happening in the same system or not.



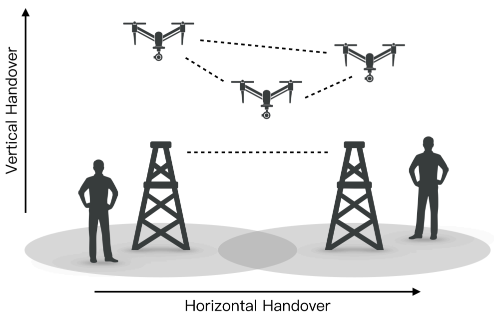
(a)



(b)

Horizontal Handover is when the signal access moves from one node to another, which uses the same technology and is in the same system as the previous one. For example, when a man walk from one block to the next one when calling to someone, the signal access will smoothly switch from one cell tower to another.

Vertical Handover happens when the access switches from one kind of system to another, for example from signal tower to drones or satellites (Fig. c).



(c)

The third category of classification is by if it is the accessing device that lead or guide the handover. If both device and network participate in the the process, then it is called a Hybrid Handover. However, not much is available in UAV communications.

C. Applications and Present Solution

There are few applications and solution for UAV to achieve seamlessly handover.

To honor the 50th anniversary of incredible achievement of the Apollo 11 moon landing, Intel create a display showing changing images composed by hundreds of illuminating drones which is known as Intel® Shooting Star™[48]. Moving images of the launching of the rocket and waving astronauts brought great impression to the audience and to the world. To achieve this, drones are acquired to move flexible and fast enough and the connection needs to have high tolerance and should have very low latency. The communication system technology used might be IEEE 802.5 Token-ring network. Using this method, not all the drones are communicating with the center controller at the same moment. If this is fast enough, the show will seem to be seamless.

Better solutions might be using MANETs and VANETs technology. VANET is a special kind of MANET and it is good for its low latency of nodes and high mobility. Routing protocols and IEEE standards used in MANET is also considered in VANET environment.

Models are used in studies of VANETs. For example the random waypoint (RWP) model. In this model mobile node movement is considered random. Because of the characteristic of VANET, network splits and combines frequently and could cause unwanted and unstable circumstances. This, however, would cause decreasing handover quality for the high latency and packet loss. This shows that the RWP model is a very rough estimation of mobility.

There are other models for example Street Random Waypoint (STRAW) and Manhattan. These are more accurate mobility models and take into account the temporal and spatial dependence of the nodes as well as geographical constraints. Next, the amount of UVAs may increase and the size of the network may increase in the future, and more applications may be needed which leads to further study in UVA communication in order to decrease the time latency and instabilities.

These mentioned above apply to mobile UAV as well, but the study about seamless handover is limited even in IEEE 802.11-based WAMs or VANETs [49]. Here, we introduce some traditional protocols such as Mobile IP version 4 (MIPv4) and Mobile IP version 6 (MIPv6). These protocols are used for handover on UAVs and tries to improve the ability of the technology.

MIPv4 broadcast or multicast a message so-called Agent Broad cast periodically, home agent and foreign agent states their connections. The mobile node receive the broadcast and decided if it is connected to the home agent or not. If so, the mobile node can then work as a stable node.

MIPv6 nodes decided its position through ICMP and Router Discovery. The difference is when the mobile node inform home agent, if security is assurable, mobile node send the address to other few communication partners. The problem in handover is the time latency. The time for a mobile node to prepare for sending or receiving a message takes long time.

A protocol called Network Mobility (NEMO) was created in 2005 in order to solve the problem of mobile connection latency or instability. It is an internet standards track protocol and allows continuous connection for every node in a mobile network when moving [50]. NEMO protocol used the normal nodes in the lowest layer, during multicast, these nodes can support leader nodes and lower the forwarding burden, in order to improve the transmission efficiency and decrease the time latency. The improvements are even more obvious in vary large scale network [51].

D. IEEE 802.21 Media Independent Handover

IEEE 802 basically do not support handover. However, the Media Independent Handover (MIH) service is standardized by IEEE 802.21. 802.21 reduce power consumption by avoiding unnecessary scanning and using information and by using backend (core) network. It can reduce handover time by passing security/QoS information to next point of service and Allow service providers to enforce their policies and roaming agreements. It allows user to select between 802.3, 802.11, 802.16, 3GPP, 3GPP2 networks so that handover across different technologies might be possible. It allows reconnections before break handovers, which makes the handover seamlessly.

The goal of IEEE 802.21 is to enable low-latency handover across multiple technology access networks and help in handover disunion making.

Using MIH service, in situations like disaster rescuing, fishing or harvesting, UAV network can provide video live images sending fluently in conjunction of Wi-Fi, LTE, etc. However, this is a newborn technology and has not been widely used in recent circumstances. So we can see that the thought of seamlessly handoff is a question and can be solve by different ways which is however lack of real examples supporting.

E. Possible Attempts and Ideas

IEEE 802.21 might be possible. Are there any solutions that are even better? Our group think about software based connection.

Each UAV device combine many different protocols. Sensors are used to detect the actual situation of each drone and a center processor collect all the data, which might be the connection quality, the distance between each UAV, the weather condition, etc. Then use big data statistics method to automatically choose the best protocol to use.

This might be hard to implement, but is a kind of machine learning solution which is appropriate for even any condition.

VI. Energy Efficiency

There are two cases in UAV networks. One is where the energy used for communication equipment and for powering the UAV comes from the same source, the other is where the energy for that two purposes comes from different sources. Whichever the case is, the energy consumption of communication equipment is always large and can directly affect the flying time and the working time of the network. Things become even worse because there will still be a large amount of power consumed by the communication equipment when there is no any transmission or reception. A Wifi 802.11n interface consumes 1280mA/940mA/820mA/100mA in Transmission/Reception/idle /sleep modes, respectively. As for a small drone with 5200mAh, 11.1V battery capacity, when its current is around 12.5A (because the transmission and reception processes will be continuous active), it can fly for 25 minutes. However, when it comes to a real case of UAV with the same battery capacity specified above, the flying time will decrease approximately by 16% of the rated value above. If we take GPS and other devices into consider, the flying time will decrease by 20% or more. However, in the real-world application, the battery voltage will drop below 11.1V before the battery is run out, so the useful flying time is even shorter than the values specified above.

If the communication devices have their independent battery, the payload of the UAV should be taken into consider when determining the weight of the battery. The author uses 8 separate AAA batteries to supply the router, which will allow the router to work for 9 hours. However, when the voltage decreases, the router cannot work as usual, which means that it needs to be take down and charged. As for the weight of the battery, the battery will typically take up 30% of the payload of the UAV, which means that the high efficiency can increase the lifetime of the UAV or increase the payload of the UAV.

For the nodes that are not in use, we can control the transmitting power of the node or make them into sleep state, which can help to reduce the power consumption of the network. The nodes that are active can suffer the traffic. Because some nodes that does not carry the traffic still has its power consumption, so we can close the network elements that are not in use to avoid that waste of power. We have a lot of methods to achieve that goal. In physical layer, we can use the PSM mode of the device. In data link layer, avoiding conflicts and increasing the sleeping time is very important. In network layer, we can use the minimum power consumption as the routing standard. We always use the layer that the method affects to categories the methods. In each category, we also use the power saving strategy to categories them further.

Section A discusses the energy-saving network layer protocol that can be used in UAV network.

Section B discusses the energy-saving data link layer protocol that can be used in UAV network. Section C discusses the energy-saving physical layer mechanism that can be used in UAV network.

A. Energy Conservation in the Network Layer

1. Path Selection Based

The goal of these protocols is to minimize the total energy requirement from source to destination. There are four protocols in total.

a. *EMM-DSR (Extended Max-Min Dynamic Source Routing) protocol:* This mechanism can improve energy efficiency. It can find the path with the least energy demand, which can have good end-to-end delay and throughput performance. It minimizes throughput and improves energy efficiency through a minimax algorithm.

b. *FAR (Flow augmentation routing):* FAR protocol can improve transmission power. It will find the optimal route from the source to the target, so that the sum of the link costs on the path is the minimum. Its cost includes the cost of unit stream transmission through the link, the initial energy of the transmission node and the remaining energy. It needs frequent calculation and conversion, then selects the route with the lowest cost each time.

c. *The minimum-energy routing:* the minimum energy route saves energy by selecting the path of the multi-hop self-organizing network, thus minimizing the total transmission energy. In this protocol, the node adjusts its transmission power level and selects routing to optimize performance. The topology can be selected by adjusting the power supply so that only neighbor communication can be done. this function can be set in a UAV network, but neighbors may change more frequently.

d. *The pulse protocol:* It is sent periodically from infrastructure access nodes and propagates between components in the network. The pulse updates each node relative to the nearest pulse source, and each node tracks the best path of the nearest pulse source according to some measurements. Diffusion flood forms an uncovered routing tree based on pulse source. If the node needs to send a packet, the packet is used. This Agreement may be affected by flood overlap delays, which may result in significant energy consumption. This is in the case of fixed multi hop infrastructure wireless networks. Therefore, it can test the type of infrastructure used for UAV applications.

2. Node Selection Based: They will protect every node's battery life and close node with low battery.

a. *Power-aware routing:* These protocols minimize or maintain battery life in end-to-end communication at each node. MTPR and MBCR are based on these principles. In MTPR, the adaptive transmission of power leads to the concealment of terminal problems. If this happens, more conflicts will lead to more traffic and higher energy consumption. MMBCR only considers cost functions, including low-energy nodes and high-energy nodes. One drawback is that you can choose a longer path, which can lead to excessive delays and attempts to minimize total energy. An improved wireless network scheme is proposed.

b. *Localized energy-aware routing (LEAR):* Use DSR, but allow nodes to decide whether to forward RREQ. According to whether the remaining battery power exceeds a certain threshold (if the remaining battery power is below the threshold), the node removes the message and does not participate in the relay packet. The target node receives a message only if all intermediate nodes on the route have good battery power. If the source node does not receive a reply, resend the message. Intermediate nodes lower threshold to allow further forwarding.

c. *Distributed energy-efficient ad hoc routing (DEAR) protocol:* Traditional power-aware routing algorithms require additional control packets to collect network topology and residual power information. Although it is easy to get this information in active routing, a separate control package may be required in the case of an on-demand protocol. Honey, use the available RREQ packages to get the necessary information without the need for additional packages. Honey, all you need is the average remaining power of the entire network. Node RREQ packets with relatively large battery energy are broadcast in advance. The on-demand routing protocol abandons duplicate rreq without rebroadcasting them. Honey, you can set a relatively high battery. The simulation results show that ADE extends the survival and passage of the network and chooses a more reliable path.

3. Cluster Head or Coordinator Based: They select a cluster head or a coordinator that will remain awake, however, others can sleep to lower power consumption.

a. *Cluster based routing protocol (CBRP):* The node is divided into two hop nodes with a diameter of 2 hops. Each cluster has a cluster as the focus cluster to communicate with other clusters. The team gathers parts by coordinating the equipment. The protocol effectively reduces flooding and path discovery, and speeds up the process of energy saving and consumption reduction.

b. *Distributed gateway selection:* In this way, some of the high-level nodes in the drone network are selected as the gateway, while other nodes connected to the command center pass through the gate. For the selection of the cluster head, the selection of the gateway takes into account the movement of the node. They proposed a basic dynamic network partition. The selection process passes a number of iterations. The selection is a neighbor based on two-hop stability.

c. *Geographic adaptive fidelity (GAF) protocol:* In GAF, the whole network topology is divided into a fixed size Chinese grid. The nodes in two adjacent squares can be each other. In each grid, the node with the maximum residual energy is selected as the coordinator or the primary node. Each grid only needs to know the other nodes in the area, and the node can become the coordinator. The coordinator is constantly changing in this field. In addition to the coordinator, nodes can sleep without affecting routing loyalty. This protocol increases the lifetime of the network. It is a location-based hierarchical protocol in which the coordinator does not aggregate. In UAV networks, nodes are unstable in the grid. The UAV in each grid cannot be maintained when the node is in and out of the high energy connection device. Due to the frequent changes of candidate lattice sets, there are low energy nodes in some squares, which leads to the division of networks.

d. *Span protocol:* The energy consumption is reduced and the connection or capacity is not reduced. It is located at the network layer and the mac layer and utilizes the energy-saving properties of the mac layer, i. e. without data transmission. Each node makes a local decision to coordinate when to wake up or to sleep. The coordinator is always awake and presents a mode in which other nodes can save energy. Each node acquires the ability to select a neighbor and to help change the network topology. The number of links and nodes is reduced and a good qos link can still be used on other nodes. The change in the UAV network backbone coordinator will depend on the position of the unmanned aerial vehicle (UAV). If some of the UAVs are trying to be a coordinator, all of them have to take a step aside from one person. In the process of the withdrawal, their status may change, and some may not be medium-strength. The energy saved depends on the node density. The system life SPAN mode of the 802.11 network is twice the SPAN mode.

4. Sleep Based: They make a lot of nodes in sleep state as long as possible.

a. *Connected dominating set (CDS) protocol:* The connected primary node is a set of nodes, and the nodes in each node network are the neighbors of one of the nodes. If you connect to a member of the CDS set and then connect to all other nodes, you receive a packet. When the dominant set is always active, other nodes can save energy by sleeping. With the help of CDS, the route is simple and can adapt to the change of network topology. In this protocol, CDS nodes and energy-saving non-CDS nodes are also allowed to be selected.

b. *Clustering and decision-tree based (CaDet) protocol:* The protocol uses data mining technology and real wireless data based on probabilistic location estimation a method based on multi-decision tree. These will help identify information about the user defined location at the most commonly used access points. These decisions help select the minimum number of access points to use, so it reduces the number of customers. Shi and Luo propose a cluster-based UAV formation routing protocol. One of the selected cluster heads is residual energy. The protocol format is based on the stable group structure of UAV formation and uses the position of UAV.

c. *Energy aware routing (EAR) protocol:* At the very least, the jump method, regardless of energy, the shortest path is always, and the nodes on that path will exhaust the lead to divide the network. Internal routing and traffic engineering decisions take into account the energy consumption of the equipment, even in a suboptimal cost path. It will actually lead to the defects of multiple suboptimal paths. Energy costs can be used as a unique goal or in conjunction with other constraints, such as QoS. The goal is to completely shut down components that help reduce energy network consumption [90], that is, to achieve this goal, to synchronize the send and receive time on the node, or to minimize routing. In this case, there are more jumps, but shorter routes, it can be more energy-efficient. In many UAV networks, it is not difficult for nodes to send, receive and synchronize continuously.

B. Energy Conservation in the Data Link Layer

1. Duty Cycle With Single Radio

a. *Sensor-medium access control (S-MAC):* This is a simple protocol proposed in this category. Nodes follow a fixed sleep cycle and activity time. This will consume less energy if the node has been listening to your free time. Nodes make their own plans and broadcast them to neighbors. Understand the cluster plans of each other's nodes to keep them synchronized. Low energy processing traffic, resulting in low throughput.

b. *T-MAC (Timeout-mac):* Compared with fixed S-MAC scheduling, this protocol uses adjustable scheduling to improve the efficiency of S-MAC based on any activity that does not hear a certain amount of time.

c. *ECR-MAC (Efficient cognitive radio):* This protocol uses multiple transponders for each node so that multiple paths reach their destination. The first available node is usually used to reduce the waiting time required to leave a particular node idle.

d. *SOFA (A sleep-optimal fair-attention scheduler):* The protocol in a wireless LAN called sofa can help PSM customers save money and let them sleep more, thus reducing energy consumption. If the customer is still from the lighthouse cycle, but AP is serving other customers, the customer must remain awake until the last package is scheduled to be delivered during the lighthouse. Therefore, part of the customer's energy consumption comes from the point of sending other client packets before completion, sending the last packet of the client to it. sofas are trying to reduce these energy costs by maximizing the total sleep time of all customers.

e. *MT-MAC (Multi-hop TDMA energy-efficient sleeping MAC) protocol:* Multi-hop TDMA saves the sleep MAC protocol: to improve the energy performance, throughput, and latency of the WMSN multi-hop TDMA, an energy efficient sleep MAC (MT-MAC) protocol can be used. The main idea of MT-MAC is to divide the frame into two parts, the multi-time slot node (mainly the sensor) to forward the data packet, and adopt the TDMA scheduling method. Due to the conflict and concealment, the scheduling algorithm takes into account the terminal problem, so that the collision probability in the network is reduced and the throughput is increased.

2. Duty Cycle With Dual Radio

a. *STEM (Sparse topology and energy management):* STEM is one of the early MAC protocols based on CSMA for scheduling sleep and active sensor network cycles. One of the radios is used to wake up neighbor nodes. This radio has a working cycle. Use the second radio to send the data to the forwarding node and stay dormant until you wake up. Because it takes some time to wake up there, the more efficient, the more efficient the delay.

b. *PTW (Pipeline tone wakeup) scheme:* The purpose of the agreement is to improve energy efficiency and delay. It uses technology to shorten the time it takes to wake up nodes for data transmission.

c. *LEEM (The latency minimized energy efficient MAC) protocol:* The agreement is also aimed at reducing time delay. The node destination along the path is synchronized so that they can be woken up.

d. *PAMAS (Power-aware multi access protocol with signaling):* The protocol uses a separate radio signal to obtain good data throughput and delay. It hears the signal for other nodes and can hold it on the media that is not available to the signaling interface so that the node listens for the signal exchange and can quickly respond to traffic to it.

3. Topology/Power Control Based

a. *XTC (eXtreme topology control):* neighbors are link quality, ranking the maximum broadcast quantity of each node, and each power node sends its sorting results to its neighbor nodes. Finally, the node selection should be directly connected to. This protocol does not need location information.

b. *LFTC (Location free topology control):* LFTC protocol constructs an efficient network topology. It also avoids any potential conflicts because of hidden terminal problems. Each of the initial nodes broadcast hello messages with adjacent tables. Then, the node adjusts its transmission power to communicate the nearest neighbor. Data control is carried out by selecting the appropriate power supply. This protocol improves XTC, because it has smaller hops and better reliability.

c. *PEM (Power-efficient MAC) protocol:* PEM enhances network utilization and energy reduction. The station estimates the distance between them and the sender, and obtains the interference relationship between the transmission pairs by three handshakes. Transmission based on interference relationship.

d. *Virtualization of NICs:* the most obvious energy saving method is off-peak periods. Of course, some places do not include interest. These functions can be connected through network coverage extension / relay functions. Not only by shutting down nodes to save energy, NIC virtualization can also reduce energy consumption.

4. Cluster based MAC Protocols

a. *LEACH (Low-energy adaptive clustering hierarchy) protocol:* LEACH is a cluster scheduling MAC protocol topology. It is a layered routing algorithm that combines power consumption with media access quality. It divides the network topology into clusters and cluster heads for each cluster. All the nodes in the cluster header cluster and provide better performance in a lifetime. The independent decision not to be a cluster head may cause the energy to accelerate the drainage of some of the nodes in the network. The leaching-C centralized solution can improve some of the problems that must be carried out with the extraction.

b. *PEGASIS (Power-efficient gathering in sensor information systems):* The different methods of using this protocol for leaching are to improve it. Instead of each cluster head in communication with the destination, a cluster head chain is formed. The chain is configured to start at a node furthest from the target and then the last closest to the destination. The cluster head then selects one that will perform the data aggregation. One thousand failed in all nodes, and the chain was reconstructed. The new leader is randomly selected during each round of data acquisition.

C. Energy Conservation in the Physical Layer

1. Dynamic Voltage Control

a. *Dynamic voltage scaling (DVS):* DVS to achieve this energy-quality tradeoff at the circuit level using the variability of processor workload and delay constraints. Low flow load can reduce bias ratio secondary energy saving.

2. Node Level Power Scheduling

a. *LM-SPT (Local minimum shortest path-tree):* this method improves power efficiency by locally distributed effective topology control algorithm. The main idea of this method is to make the topology have the required functions by changing the transmission power of each node in the wireless cell, so as to improve the throughput, increase the network lifetime and maintain the link. In wireless networks, Mesh network does not lose its connection with this energy efficiency and throughput balancing algorithm. This method is based on local neighborhood information, and the calculation of minimum power is limited to one-hop transmission.

b. *Minimum-energy topology:* using this method to generate minimum energy topology G = (V, E), where V represents node and E represents link. It has a locally distributed topology control, it calculates the optimal transmission power to maintain the connection, and only covers the nearest neighbor. Energy saving and life-saving networks have also increased.

c. *CPLD (Complex programmable logic devices):* It is used with commonly used application chipsets to reduce backup power and minimize critical processor time to detect system events. In order to minimize the power consumption of the network, CPLD can be used in the grid node network, which can be cut off when the processor of the workstation is idle for a certain period of time. It can detect anything from the base station and immediately turn on the processor that does not waste time. In the implementation of CPLD, it is a part of wireless Mesh network. It can greatly reduce power consumption without single chip microcomputer and intelligent electronic switch.

3. Choosing Minimum Subset

(A) CNN (critical neighbor number); (B) virtual WLAN; (C) environment; 4) buffer sleep: these protocols are designed to be passive by buffering in nodes. Here is an example of: (A) SRA (sleep and rate adaptation):

a. *CNN (Critical number of neighbors):* CNN refers to the minimum number of neighbors of each node asymptotically connected in the network. This method of maintaining connectivity only needs to know the size of the network to determine the CNN. This information can be easily obtained from active routing protocols such as OLSR.

b. *Virtual WLAN:* It is controlled by single node maximum power saving and interference control. A switching scheme is proposed, which aims to open a minimum number of devices or a combination of devices that use the least energy, so that sufficient coverage and sufficient capacity can be provided at the same time. Through the integration of hardware, some of the hardware can be put into low power consumption, so as to reduce the mode and energy consumption. Depending on the type of device that can store different numbers of devices, the energy saving of wireless Mesh network in time-varying.

c. *Energy savings in wireless mesh networks in a time-variable context:* this is a method of minimizing energy by dynamic selection of mesh BSs in time-varying environment, which takes into account service area coverage, service routing, access segment and wireless return link. In order to achieve the desired goal, the algorithm takes into account the traffic requirements and manages the energy consumption in a set of time intervals, so that it has a load.

4. Sleeping Schedules With Buffering

a. *SRA (Sleeping and rate-adaptation):* there are two forms of energy reduction, online power management solutions. First, place the network interface sleep in a short period of time. A lot of caches are introduced for dormant clients that store packets to create long enough sleep intervals and save energy for clients. The potential problem is that buffering adds too much delay to the entire network and can lead to bursts, which will aggravate the loss. The algorithm arranges routers and switches to hibernate to ensure that buffer delays-paid only once (not per link)-router cleanup does not significantly amplify the loss explosion.

D. Energy Conservation Through Cross-Layer Protocols

1. MTEC (Minimum Transmission Energy Consumption): In order to design the energy efficient protocol, many factors, such as the proportion of successful data transmission, need to be considered, and the node and service conditions on the node need to be considered. The cross-layer design can reduce the energy consumption of data transmission, and also can prolong the network time. The MTEC routing protocol works at the network layer and uses the percentage of a given successful data transfer, the node traffic load, and the number of competing nodes for the channel, and find the appropriate path. Which reduces energy consumption and prolongs the life of the network. To this end, it finds that the node has sufficient residual energy to successfully transmit all of the energy packets. The acw operates on the mac layer to reduce energy consumption and throughput. Based on the proportion of successful data transmission, the node dynamically adjusts the reverse time between the different nodes using the ACW. It reduces the use of a more successful transmission of the channel.

2. CLEEP (Cross Layer Energy Efficient Protocol): The CLEEP protocol can work across the physical, MAC, and network layers by allowing higher proportions. At the physical layer, the protocol first obtains the transmission power required to hold two adjacent node connections. It maintains a neighbor table for each node in the network. The network layer can use this information to select a better routing path for the data. The protocol then makes use of the nodes in the routing information MAC layer that determine the sleep activity pattern for maximum sleep time.

3. CLEERR (Cross-Layer Energy-Efficient and Reliable Routing Protocol): this is to find efficient and reliable routing of energy from the source to the destination. And the retransmission cost of the wireless self-organizing network can be reduced. For each node, if the node is on a route, the cost of relay data from the source to the destination is calculated. This also includes a retransmission cost based on energy consumption. The node receiving the RREQ also estimates the channel quality based on the received signal strength. The node also accepts its mode of interference. All of these calculations can find a high reliability of the route using less energy.

VII. Conclusion

The application UAVs in industry will only continue to increase, as the research about UAV communication network will be more detailed and wide covered. Therefore, it is important to realize the characteristic of UAV communication network and challenges we currently faced. UAV communication networks have many similarities with existing technologies such like VANET. Development of 5G network in wireless communication is also very possible to be applied in UAV networks. Through EEEN3008J survey project, we foresee UAV communication networks will play a critical role in peoples urban life in the near future.

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