Regional IP Allocation Techniques Using Drones

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Abstract – Drones, which were initially developed for military applications, have recently been studied and applied to various fields. In this paper, we propose a DANET algorithm that uses a large number of drones to build a wireless communication network infrastructure, and in situations where communication is not possible, such as in disaster areas, we propose a DANET algorithm that uses drones to form a network so that nodes that want to join the network can efficiently acquire IP addresses without collision. In a DANET, a pool of IP addresses is gradually passed to the drones in the next zone in blocks, and the drones in each zone distribute IPs to newly joining nodes, thereby increasing the IP address allocation rate and reducing the IP allocation time to form a temporary but efficient network. Drones assign their own IP addresses through simple Request and Response message exchanges with land-based stations or M-Droin (Mother Droin) in the divided zones that can assign IP addresses. Therefore, DANET can completely eliminate the process of IP collision avoidance (Duplicate Address Detection) and the process of network separation or integration caused by the movement of ships. This paper presents a new possibility for building wireless network infrastructure in unconnected areas such as disaster areas by performing simulations under various conditions to verify the applicability of DANET.

Keywords – Drones, MANET, Ad Hoc Networks, IP Auto-Assignment, Routing Protocols.

I. INTRODUCTION

In the modern world, mobility and portability are becoming increasingly important aspects of network communications due to the proliferation of mobile phones, laptops, and other mobile devices. In particular, 5G environments are further enhancing this mobility and portability by providing ultra-high speed data transmission, ultra-low latency communication, high reliability, and ultra-connectivity [1].

In addition, network communication is increasingly required in situations where certain areas are unavailable. In these environments, it is especially important to dynamically assign IP addresses, which plays a critical role in maintaining network stability and efficiency [2]. A mobile ad hoc network (MANET) is a non-persistent network that exchanges data by autonomously forming ad hoc networks, as opposed to a persistent network that relies on communication between mobile nodes [3]. Mobile nodes can communicate with each other in a multi-hop fashion without the need for a base station or a repeater such as an AP. However, most of the research to date has focused on routing issues. It assumes that nodes participating in mobile ad hoc networks have already been assigned IP addresses and does not consider the problem of assigning IP addresses to nodes [4]. Regarding IP address allocation, on land, nodes can form their own subnets as edges of the backbone network. On the other hand, a mobile in a natural disaster area is unlikely to be assigned a fixed IP address regardless of its current location [5]. Therefore, it is more suitable for a mobile to determine its IP address by requesting an IP address from its neighbours, who can assign it an IP address, such as in a MANET [6]. However, existing address allocation mechanisms in MANETs mostly focus on duplicate address detection (DAD) techniques, which suffer from delays in address allocation and inefficient address space utilization [6]. However, in MANET environments, it is very important to dynamically allocate IP addresses, especially in situations where communication is not possible. For this purpose, regional IP allocation techniques using drones can be presented as an effective solution.

In this paper, we propose a technique for locally assigning IP addresses using drones in situations where communication is not possible. This study considers its usefulness in situations where network communication is

required, especially in situations such as war, disaster relief, and emergency situations. This study is expected to contribute to increasing the stability and reliability of network communication.

This paper is organised as follows in the introduction, we first highlight the importance of solving the IP allocation problem in unreachable situations and introduce the existing related work. The main section describes the IP allocation structure and protocol proposed in this work. Then, we describe the simulation environment and the performance evaluation results of the proposed method. Finally, we conclude with our conclusions.

Related Work The protocol proposed by Perkins [7] is a protocol that floods the MANET with address requests (AREQs), repeatedly tries to find duplicate addresses, and assigns IP addresses based on the results. A new node joining the MANET selects a random address and floods an AREQ to the MANET with the selected address as the destination address to check whether the address is allocated or not. If it does not receive an AREP (Address Reply) for the AREQ within a certain time, it repeats the above process as many times as AREQ RETRIES. If an AREP is not received after all attempts, the node concludes that the selected address is not yet assigned in the MANET and assigns the address to itself. However, since the above protocol is based on flooding, it is not suitable for MANETs with limited bandwidth compared to wired networks. It also does not provide a solution for cases where the MANET is partitioned into multiple partitions, where partitions are merged back together, or where multiple nodes simultaneously select the same random address and flood the AREQ.

In the protocol proposed by Nesargi [8], a new node n joining the MANET sends an address allocation request to the MANET, and one node i among n's neighbours performs the address allocation operation on behalf of n. Every node in the MANET has a list of addresses assigned to each other. i selects a random address that is not in the list and floods the MANET with an Initiator Request to request an address assignment. All nodes in the MANET send an acknowledgement message to i if the address is not on their list. If all nodes approve, then i assigns the address to n. Since this protocol performs address allocation based on flooding, and if an acknowledgement message is not received from even a single node, the address allocation does not take place, it can put a heavy load on the network and the time taken for address allocation can be long.

In [9], a method called MANETconf is proposed to allow a randomly selected address to be used after the address has been checked for duplication by all other network nodes. However, this suffers from an instantaneous spike in traffic for address allocation. It also requires a proportionally longer address allocation time and additional cost for list management due to the failure to obtain consent. In [10], the Prophet method is proposed, which devises a function that has a very low probability of generating the same address, allowing an address to be assigned by communicating with only one node in the network. This method has obvious advantages in terms of address allocation time and communication overhead. However, it is extremely wasteful of available address rape and relies on probability, which means that additional methods are needed for a more robust algorithm. And these additional methods end up negating Prophet's biggest advantage: the ability to assign addresses by only communicating with one node.

In the field of drones, since the initial development of unmanned aerial systems, advances in flight control technology, power technology, and wireless communication technology have led to a variety of applications for drones. A system for detecting fires in mountainous areas using multiple small drones is presented in [11], and the use of drones for road surveillance and traffic measurement is studied in [12]. There is also a study on using multiple drones to perform transport tasks in [13]. On the other hand, a study focusing on the control of multiple drones and swarms of drones was done in [14]. Examples of approaches that use drones to build networks or collaborate with existing networks include Google's LOON Project [15] and Facebook's Aquilla [16]. The LOON Project proposes to bring the Internet to remote areas by launching hot air balloons into the stratosphere, and Facebook's Aquilla Project proposes to collaborate with existing network infrastructure using large drones that can fly for long periods of time using solar power. However, unlike the drone wireless network infrastructure proposed in this paper, these projects are either supplementary to existing networks or provide internet to a randomly wide area. The DANET proposed in this paper is a way to quickly supply network networks to disaster areas through the excellent mobility of drones, and has the advantage of simplifying the deployment and return process of the network compared to [15] and [16], and flexibly coordinating the network network.

II. MATERIALS AND METHODS

This chapter defines the DANET concept, the messages used, and details the procedures involved in assigning IP addresses to ground stations and drones.

The concept of DANET

As shown in **Fig 1**, the density of nodes has an unpredictable distribution. DANET propagates non-overlapping IP addresses from the AP to the nodes. As shown in **Fig 1**, the region is zoned by coordinates.

Nodes that can directly connect to the land base station assign IPs directly and assign a block of IP addresses to M-Drone (Mother Drone) A in the 1-hop zone by zone. Nodes B in the 2-hop area that cannot be directly connected to the base station are assigned IPs by the M-Dron at the first hop, and M-Dron B at the second hop is assigned 1/2 of the IP address block of M-Dron A. In DANET, it consists of a pre-request-post-assignment between nodes that need to be assigned IP addresses and nodes that can assign IP addresses. After the node requests an IP address from the ground

station, it is assigned an IP by the ground station, and M-Drone A receives a block of IP addresses. M-Drone A assigns its assigned IP address to a node that requests an IP address in the next zone, and assigns 1/2 of the remaining IP address block to M-Drone B. Like M-Drone A, M-Drone B distributes IP addresses by assigning its assigned IP address to a node requesting an IP address in the next zone, and then assigning 1/2 of the remaining IP address block to M-Drone C in the next zone.

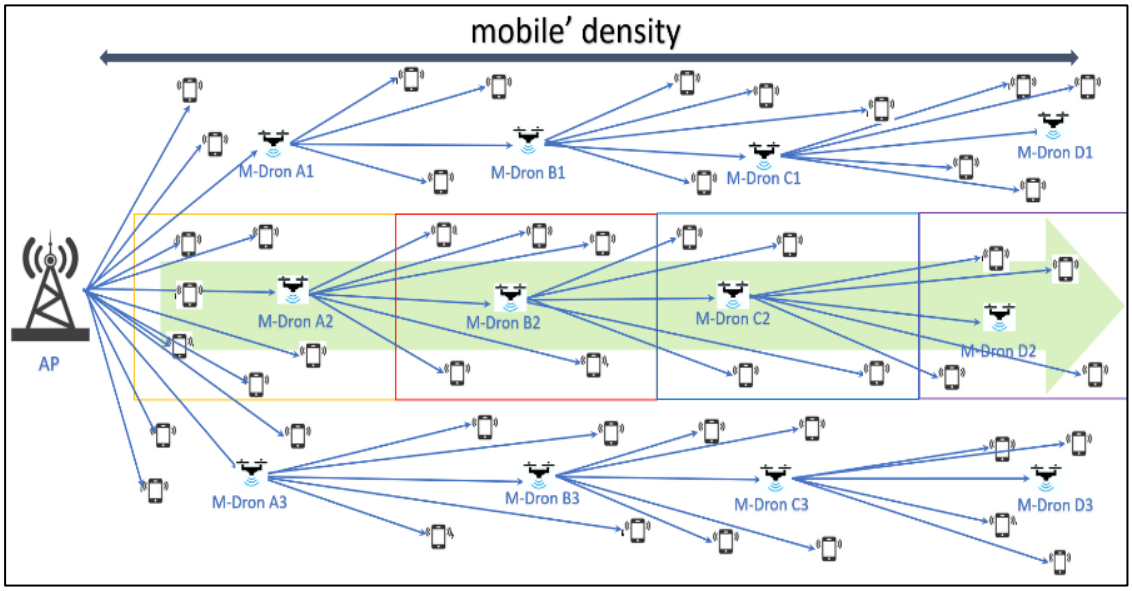

Fig 1. DANET Structure

In this way, DANETs allow most nodes to determine their IP addresses without IP collisions by distributing IP addresses in a tree topology (a tree-structured network that uses multipoint media to connect each node in the network). DANETs can also reduce the load on terrestrial base stations and avoid frequent IP address changes caused by network merging and partitioning management due to IP conflicts or node mobility. Therefore, the message overhead incurred to obtain a new IP address is expected to decrease, and non-DANET messages for routing or data transfer are also expected to decrease because M-Drones act as nodes.

DANET Messages

Three types of messages are used in DANET, including Beacon, Address REquest (AREQ), and Address REsPonse (AREP). These messages are included in the payload of the MAC frame and are generated and processed at the data link layer. This is to maintain compatibility regardless of the medium access control protocol. Beacons are messages sent periodically by the provider to communicate to other stations the current IP address holdings of the provider.

Beacon

A Beacon is a message sent periodically by a provider to inform other stations of its current IP address holdings. It consists of the following five headers

- Location of the provider: This header is used by the node to check the possibility of reaching the provider sending the beacon. To check this, the node uses its current location to calculate the distance to the provider.
- Provider's Zone: This header tells the requester the zone in which the provider is located. A one-hop requestor will be assigned an IP address by the land base station, while a multi-hop requestor will choose a provider in the previous zone among the providers and be assigned an IP address.
- Subnet information of the terrestrial base station: This header is used when connecting to the IP's backbone network. This information is generated by the terrestrial base station and propagated by the providers throughout the network.
- Number of IP addresses available for allocation (NIABR): This header informs the requestor of the number of IP addresses available from the provider.
- IP Address: This is used by the requester to select a provider.

AREQ

A Beacon is a message sent periodically by a provider to inform other stations of its current IP address holdings. It consists of the following five headers

- Location of the provider: This header is used by the node to check the possibility of reaching the provider sending the beacon. To check this, the node uses its current location to calculate the distance to the provider.

- Provider's Zone: This header tells the requester the zone in which the provider is located. A one-hop requestor will be assigned an IP address by the land base station, while a multi-hop requestor will choose a provider in the previous zone among the providers and be assigned an IP address.
- Subnet information of the terrestrial base station: This header is used when connecting to the IP's backbone network. This information is generated by the terrestrial base station and propagated by the providers throughout the network.
- Number of IP addresses available for allocation (NIABR): This header informs the requestor of the number of IP addresses available from the provider.
- IP Address: This is used by the requester to select a provider.

AREP

The AREP is a response message sent by the provider to the requestor with the result of IP address allocation. The AREP consists of four headers, including the location of the provider, the provider's zone, the subnet information of the terrestrial base station, and the IP address allocation information. The IP address allocation information is as follows

- The MAC address of the requestor
- IP address allocation result (ACK/NACK)
- IP address
- M-Drone IP address available for IP assignment

Procedure when the land base station is the provider

A land base station performs two tasks as a provider. First, it periodically sends out beacon signals to let nodes know its location and subnet information. Second, it assigns an IP address to a one-hop drone when it receives an IP address assignment request. Then, the size of the IP address block is determined and assigned by considering the number of M-Drones in the 1-hop area to be assigned an IP address block. Therefore, the size of the IP address block to be assigned to the M-Drones at the first hop is NIABM = (K -Nd1) / (NMD +1). Nd1 is the number of drones located at one hop, and NMD is the total number of M-Drones in each zone of one hop. We also add the number of land-based stations because land-based stations must have a certain amount of IP to respond to additional allocation requests. K is the number of IP addresses. After determining the value of NIABM, refer to the IP address allocation table to complete the IP address allocation information. The ground station then sends the AREP request to the M-Drone. The ground station updates the IP address allocation table by marking the allocated IP address and IP address block as used.

Procedure when you are the drone (provider)

M-Drones that have been assigned an IP block like the ground base station also broadcast Beacon periodically as a provider. It waits for a certain period of time and periodically processes IP address allocation requests received from multiple requesters. When assigning an IP address, M-Drone checks the queue that stores the received AREQs, calculates the number of AREQs received from nodes in the next zone, and assigns the IP address to the node with the highest number of attempts. If there are more requests than it has IP addresses, it can ask the previous provider to reallocate the block of IP addresses, meaning that it can always assign IP addresses to requesters, just like a land-based base station. However, if there is no M-Drone in the previous zone of the zone where the requestor is located, the IP address allocation rules are different from those of a terrestrial base station, as follows

- If the number of IP addresses in reserve is equal to or greater than the number of requesters, IP addresses are assigned to all requesters.
- If the number of IP addresses in reserve is less than the number of requesters, only some of the requesters are prioritised for one IP address and request the provider in the previous zone to reallocate the IP address block. The criteria for selecting the requesters to be allocated IP addresses in priority is determined by looking at the IP address allocation attempt count header in the received AREQ message.
- The requesters are selected in the order of the largest value of Ntry.
- If there are multiple requesters with the same Ntry, a random selection is made among them.
- If the current zone of the requestor is not the next zone of the provider, but the number of IP address assignment attempts is more than 100, it is recognised that there is no M-Drone in the previous zone of the zone where the requestor is located, and an IP address is assigned.

Complete the IP address assignment information in the same way as the ground base station. If you have exhausted all of your IP addresses, follow the procedure to request an IP address again.

Simulation

Simulation Conditions

The number of nodes, transmission distance, IP allocation latency, and number of IPs used in the simulation are as follows.

- The DANET consists of one land base station and N nodes. Where N is the number of nodes in the network. The number of nodes is measured as 400 by default.

- The initial location of the nodes is randomly selected in a (60x120) kilometre area. The initial location can be changed and if it is changed, the location of the land base station can also be changed. The reason for setting the initial location to (60x120) kilometres is that the minimum stable transmission distance of a drone is 20km to 30km, so it is set to a total of 60km, 30km left and right from the ground base station, and this value can be changed to the left and right if you consider the installation of a ground repeater. Then, we set the distance from the base station to 120km and deploy the drone only up to 90km. The maximum transmission distance of the drone is 50Km.
- The initial location of the drone is randomly located in zones 1 to 9, and the drone is excluded from zones 10 to 12 to check the process of assigning IP to nodes outside the zone.
- In DANET, the time after requesting IP (TAREP) is a simulation variable, and the values of 50 milli second (0.05 second) and 100 milli second (0.1 second) are given. TAREP was predicted to be a factor that affects the IP allocation rate with TAREP set as a variable, and there is little deviation in the IP allocation rate when the latency is over 100ms, so 50ms and 100ms were set as variables.
- The number of IPs K is a variable in the simulation, and its values are K= 15000, 30000, 60000. Since we use the subnet of the land base station, the number of IPs is a resource that can be used indefinitely, but we used it as a variable to check the correlation between the number of IPs and the IP allocation ratio.
- The simulation is run 10 times to get an average for each condition. The reason for setting the simulation to 10 simulations is that the average value of more than 100 simulation runs showed little deviation from the average value of 10 simulations, and the deviation was up to 10% for less than 10 simulation runs.

III. RESULTS AND DISCUSSION

To check the applicability to DANET, we analyse the results of the IP address allocation ratio simulation. First, the results of the IP address allocation ratio can be analysed as follows.

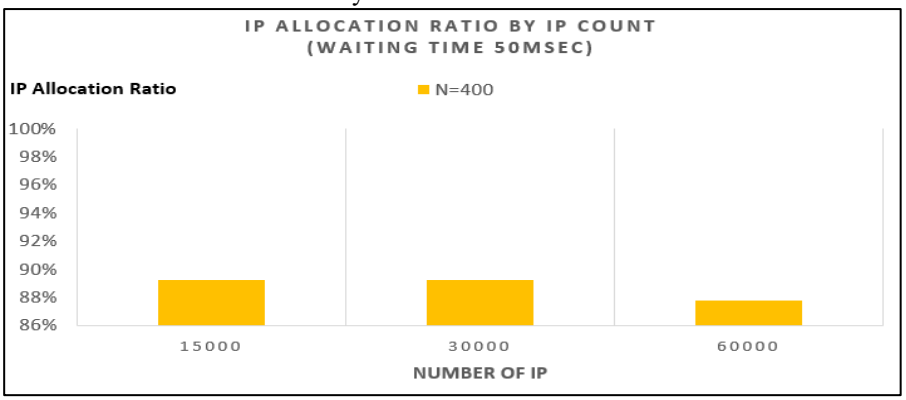

Fig 2. IP Allocation Ratio by IP Count (Waiting time 50ms)

Fig 2, which shows the percentage of IP assignments with a 50ms post-IP request latency, shows that on average, about 89% of nodes are assigned an IP address in every simulation, regardless of the number of IPs, and the average assignment time is about 11.5 seconds.

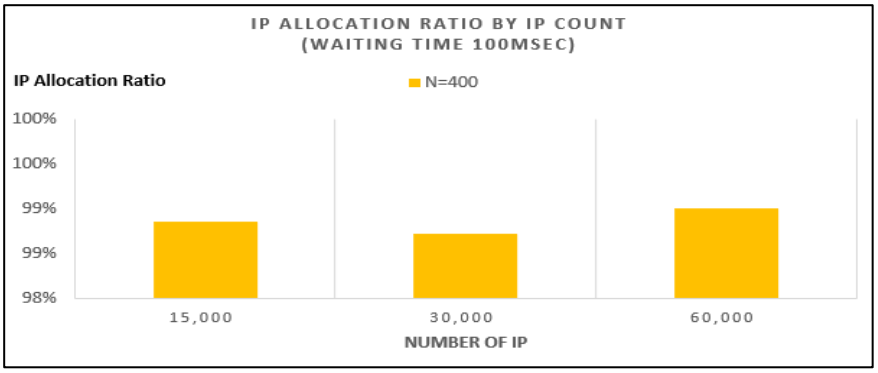

Fig 3. IP Allocation Ratio by IP Count (Waiting time 100ms)

Fig 3, which shows the IP assignment rate at 100ms latency after IP request, shows that on average, about 98% of the ships are assigned an IP address in each simulation, regardless of the number of IPs, and the average assignment time is about 13 seconds. As the latency increased, the overall IP assignment time increased, but compared to the 50ms result, we can see that the IP assignment rate improved by about 9%. This means that the wait time after an IP request is

affecting the IP allocation rate. As a result, the number of nodes should be taken into account to set an appropriate post-IP request latency, because the increase in post-IP request latency is a contributing factor to the increase in IP allocation completion time.

The pattern changes as the number of IPs increases, and the IP allocation ratio remains within a certain range. This means that changes in this pattern have little effect on the IP allocation rate. However, the number of IPs does affect the structure of the DANET.

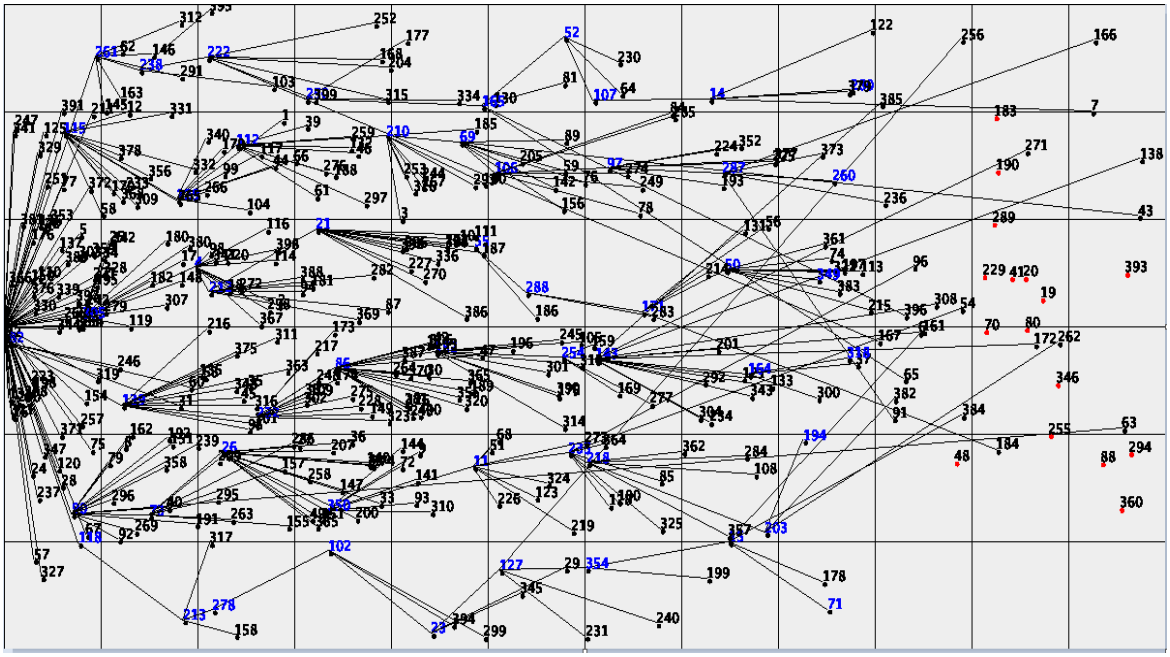

Fig 4. 400_60000_100 Simulation

Fig 4 shows the results of the assignment with 60000 IPs. If the zone's provider maintains the tree structure by assigning IPs, it is assigning IPs. And even if there is no provider in the zone, you can see that the IP is being assigned by the provider as long as it is in range. This structure ensures that IPs are allocated efficiently even when new drones are added or nodes are reconnected. As a result, we can conclude that the number of IPs does not affect the rate of IP allocation, but rather the tree structure of the network.

IV. CONCLUSION

In this paper, we proposed a solution to use drones in the field of communication by constructing a temporary communication network through DANET. In order to solve the problems of delay and inefficient address space utilisation due to address allocation, we simulated the efficient allocation of IPs by propagating non-overlapping IP address blocks in a tree structure from AP to mobile through a simple message exchange between requesters and providers. As a result, we found that regardless of the number of nodes, the most efficient IP allocation ratio can be maintained in a tree-structured propagation format when the latency after an IP request is 100ms and the number of IPs is more than 30000.

In addition, the DANET-based network infrastructure can be highly utilised in various fields such as rescue missions in disaster situations, surveillance, and information gathering, and the system has the potential for further development. In conclusion, it can be concluded that efficiently building a wireless network infrastructure through drones is feasible and can be effectively utilised in various fields.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests

There are no competing interests.

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