ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 12 (2022) No. 2, pp. 315-324
DOI: 10.33168/JSMS.2022.0215

ETE Model and High Precision Positioning for Autonomous Flight in 5G

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Abstract: In a 5G environment, it is possible to provide various services that have not been experienced before based on high-speed infrastructure. In particular, high-precision positioning data with a very low error range is essential information for intelligent convergence technologies that provide high-quality services. For example, high-precision positioning data with a minimized error range will be essential for autonomous flight drones to fly stably in the city. A GPS is basically used for autonomous flight, and in general, factors that reduce the accuracy of GPS location measurement can be divided into three. First, there are errors caused by structural factors such as satellite time errors, satellite position errors, refraction and noise of ionized and convective layers, and multipaths. Second, there is a geometric error according to the satellite's location situation, and finally, there is Selective Availability (SA), which is the cause of the largest error. The errors that these factors produce vary greatly depending on the time and place. Various studies have been conducted to increase the accuracy of GPS positioning, developing from a calibrated satellite navigation system (DGPS) with a few meter-level of position accuracy to a carrier calibrated satellite navigation system (CDGPS) with a few centimeter-level of position accuracy. However, in order to expect a few centimeters of location accuracy, the amount of computation is higher than that of the location calculation using the code, and the integrity of the system is reduced, so the areas used are limited to narrow areas. Therefore, this paper proposes an End to End (ETE) model, an SDN network structure that can overcome the shortcomings of a 5G high-band frequencies and existing SDN structures, have a close relationship with reliability and delay, and prepare for unexpected situations. In addition, system-level analysis was conducted through simulation on the relationship between the layer to which the drone should request information and the information collection cycle and RTD, which are most important in determining this layer according to the cell radius and drone speed. Furthermore, the exact location of the drone was measured through a three-sided survey using the ETE communication network model so that the drone could land at the target point where the error range was minimized.

Keywords: Autonomous flight, drone, 5G, SDN, position, measurement

1. Introduction

Today, mobile communication has continued to develop rapidly for decades, mainly focusing on speed improvement to cope with soaring data demand from 2G to 5G (Bae and Cho 2020). It has recently been used in various private sectors with the development of information and communication technology, demanding not only innovation in drone technology but also various technical problems related to 5G network technologies. A representative example of autonomous flight is the unmanned delivery service of Internet shopping malls that deliver documents, books, and pizza to individuals using GPS technology that photographs places that are difficult for humans to go and shoot, or uses satellites to check their location. In addition, with the recent development of drone taxis, autonomous flight drones equipped with (Taimoor, et al., 2015) flight systems have been developed for commercialization. However, as drones for various purposes are developed, there are obstacles to overcome for commercialization, and the biggest part of them is safe drone landing. In other words, it lands safely despite unexpected situations in the desired location. GPS is basically used for autonomous flight, and in general, factors that reduce the accuracy of GPS location measurement can be divided into three. First, there are errors caused by structural factors such as satellite time errors, satellite position errors, refraction and noise of ionized and convective layers, and multipaths. Second, there is a geometric error in accordance with the positional situation of the satellite, and finally, there is Selective Availability (SA), which is the cause of the largest error (Ju et al., 2019). The errors that these factors produce vary greatly depending on the time and place. Various studies have been conducted to increase the accuracy of GPS positioning, developing from a calibrated satellite navigation system (DGPS) with a few m-level positioning accuracy to a carrier calibrated satellite navigation system (CDGPS) with a few cm-level positioning accuracy (Lee and Mun, 2020). However, in order to expect a few centimeters of location accuracy, the amount of computation is higher than that of the location calculation using the code, and the integrity of the system is reduced, so the areas used are limited to narrow areas. Thus, the drone's autonomous flight causes this GPS error to land a few meters away from the landing target point. This GPS error causes the user to experience the inconvenience of finding a drone. As the use of drones, which are unmanned aerial vehicles, is expanding in various fields, research is needed to increase the accuracy of autonomous drone flight. Therefore, in order to minimize this problem, it is necessary to study the SDN structure, which is strongly considered as a next-generation network structure. In particular, the most suitable scenario for delay and reliability to be considered most important in 5G is an unexpected situation in autonomous flight. Drones pass through small 5G cells at very high speeds, and messages that must be delivered and processed in an unexpected situation are scenarios that must be delivered and processed in a very short time, and can be considered a prime example of delay-sensitive worst conditions. In this scenario, for a small delay, the structure of the network that processes drone information must be considered as a major variable, but it is difficult to satisfy the desired level in SDN, a generally considered centralized structure. It is the scale to which SDN can be separated and processed information such as the position speed of the drone has a major influence on the delay. In practice, the speed and density of the drone, the size of the cell, the data rate, and the message processing speed are factors that influence delay and processing. Therefore, in this paper, we proposed the End to End (ETE) model, an SDN network structure, for safe autonomous flight and accurate landing of drones, to overcome the disadvantages of 5G high-band frequencies and the disadvantages of existing SDN structures and to minimize delays. The relationship between them was derived, and a system-level simulation was performed on the network structure supporting them. In addition, by measuring the exact location of the drone through a three-sided survey using the ETE communication network, the drone was studied so that it could land at the target point where the error range was minimized.

2. Literature review

2.1. 5G

The 2G mobile communication technology, which implemented voice calls and text messages digitally, has evolved into 4G mobile communication technologies and has repeatedly undergone technological innovation. This is because higher performance is required in terms of latency and transmission capacity in various service fields such as games, medical care, transportation, and national defense. To meet these demands of the times, 3GPP3 announced 5G NR (New Radio) standards in June 2018, and from 2019, major developed countries around the world, led by South Korea, began commercializing 5G services in earnest (Soo Jin Cho, 2019). The 5G network technology is an advanced mobile broadband (eMBB) technology capable of high-capacity transmission services over 20Gbps, high-reliability and low-latency communication (ULLC) that guarantees less than one millisecond of latency for remote control and control of autonomous driving. The 5G is included as a core technology (Cho and Bae 2021). Due to these technical characteristics, the 5G network can smoothly implement technologies that require ultra-high-definition image information, such as Virtual Reality (VR) technology, which is being actively researched, and hologram that will become a reality in the future, using ultra-low latency and large-capacity services. One of the technologies for this is network slicing, which separates one physical network into several logical virtual networks, enabling independent services to be implemented for each virtual network (Lee and Shin, 2016). At this time, each network slice is virtualized and acts like an independent network, so even if an error or problem occurs in a specific slice, it does not affect the other slice, so it is possible to implement an independent service for each slice. In the existing 4G network, only voice communication and data communication were provided. At this time, in the case of voice communication, some differentiated services were provided, but in the case of data communication, only the transmission speed was increased in all service areas, and only the same service was provided. However, unlike in 4G networks, 5G networks can provide differential services depending on service characteristics in data areas by applying network slicing technology. For example, in slices implementing autonomous driving services, services can be implemented to minimize latency, and large-capacity transmission can be performed in slices that require high-definition image information to be transmitted using virtual reality (VR) technology. Since network slicing technology can guarantee independence between slices, it is mainly used in the private sector to implement customized services. However, it is currently difficult to commercialize all services because it does not provide the required bandwidth for all users, and 5G has very short reach and objects such as trees and buildings cause serious signal obstruction, requiring numerous base stations to prevent signal path loss (Sulyman et al., 2014).

2.2. SDN

In the telecommunications field, research on network composition is underway for the next 10 years. In fact, there is a demand for various services for 5G, and network operators are changing from special hardware for each function to server farms using data centers. This trend is preparing for a transformation into a cloud form different from traditional IT. This virtualization gives operators an opportunity to enable various services, and furthermore, operators contemplate how to evolve the current network structure in consideration of various customer needs and competition. Against this background, software defined networking (SDN) was born in a new form in the field of computer networks. However, to date, these SDN networks have been used only in limited wired environments due to efficiency aspects (Bernardos et al., 2014). The SDN is divided into a control plane and a data plane in the network equipment (Kim and Kwon 2020). The separated control part is integrated into one controller, and the controller controls each equipment with only a transmission function excluding the control part. The next generation data center using SDN and Cloud will be the SDN implemented as a network fabric. <Figure 1> expresses the logical structure of a typical SDN.

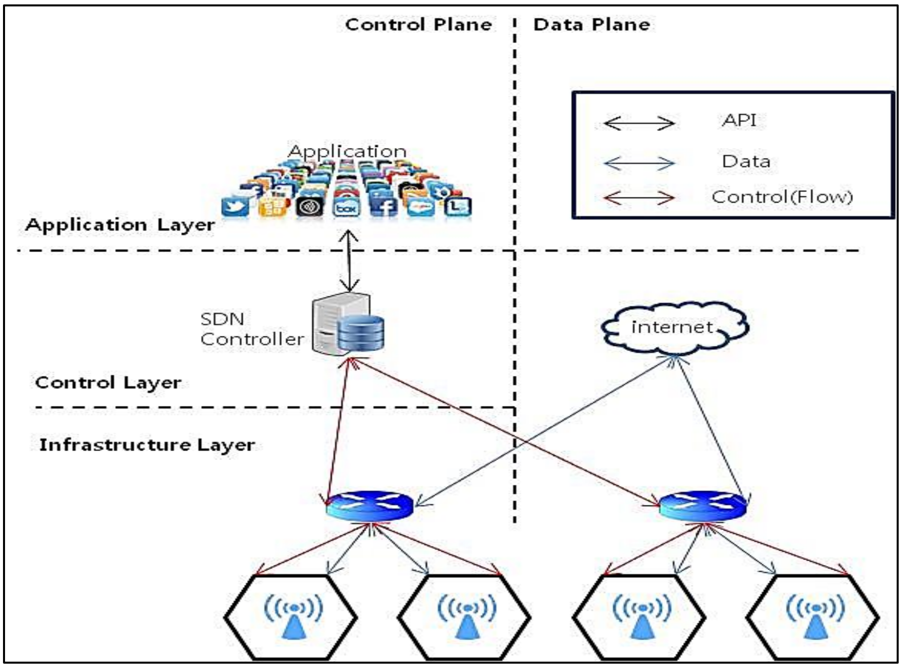

Fig. 1: Structure of SDN(Bae, K. Y., Lee, H.W., 2016)

As shown in <Figure 1>, SDN basically has a structure in which all control functions are concentrated in the SDN Controller. That is, all intelligence is concentrated on the SDN Controller, and this SDN Controller performs an adjustment function for the entire network. However, this centralized structure can be considered unfavorable to delay-sensitive services. Therefore, assuming an emergency of V2X communication, control and data processing are possible within the required delay only when the related control function exists in the form of some substructure of the tree.

3. Simulation

3.1. Simulation overview

The existing centralized SDN is a structure in which server dependence on computational processing gradually increases as the computational load for big data processing increases, and even if the computational load is moved to another server, it is difficult to obtain actual effects without fast support from the network. Therefore, it overcomes the shortcomings of 5G high-band frequencies and the shortcomings of existing SDN structures and presents the End to End (ETE) model, which is an SDN network structure for minimum delay. The simulation assumed that the 5G mobile network had a small cell with a radius of 50 to 100 m, and the drone's maximum speed was 30 to 130 km/hour, and the 5G speed was sufficiently high, providing sufficient transmission speed to receive information about surrounding drones without errors.

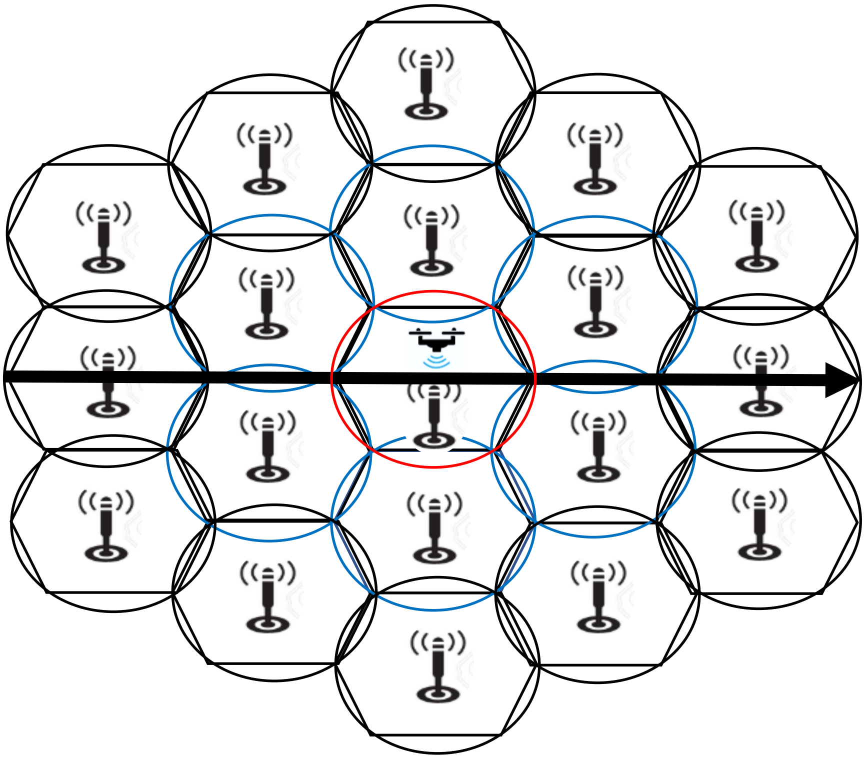

Fig. 2: 5G Cell Layer and Drone

In <Figure 2>, a cell with a drone is assumed to be a red cell. The first layer represents a blue cell, and the second layer represents a black cell. Each cell has a hexagonal coverage so that there is no shaded area of the signal. Assuming that a drone passes through a 5G cell at a speed of V, the surrounding information to be provided to the drone increases as the cell size increases, so the number of cells required decreases, and the smaller the cell size, the more information required. In addition, the longer the reporting cycle and round-trip delay (RTD) of each drone, the greater the number of cells and drones required for information. Finally, as the speed of the drone increases, the probability of leaving the cell increases, so various information within multiple layers of cells is required. However, the demand for information on drones in many cells increases the likelihood of delays. Therefore, the equation representing the number of layers of cells to receive information from the drone is as follows.

$L = (D+RTD/2)*V/(2R)$

L : The necessary layer of 5G cells that you need to know through the 5G network.

D: Changing the information of drones

RTD : Round Trip Delay to SDN Controller
V: The maximum speed of a drone.
R: Cell radius

3.2. Conditions and tesults

The conditions of the simulation were to assume that the radius of the cells of the 5G mobile communication network was 50m to 100m, and that the maximum speed of the drone was 30 to 130km/hour per hour. In Figure 3, the result of the simulation represents the required cell layer when the sum of D and RTD/2, one of the important factors, is one second. In conclusion, in all of these cases, it shows that it is possible to prepare for emergencies by collecting only the information of drones in the first layer cell.

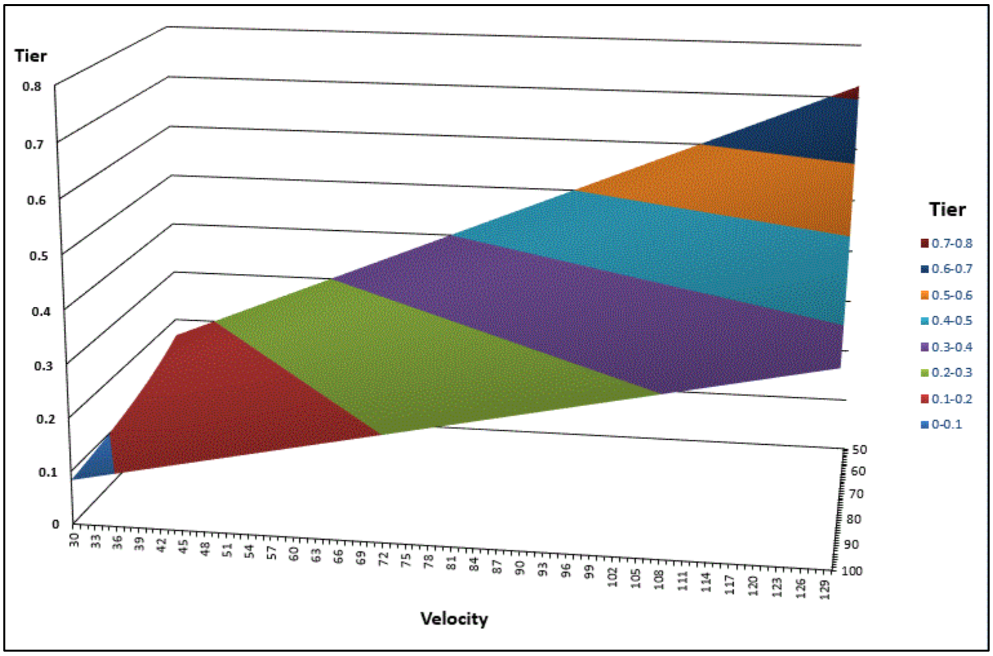

Fig. 3: Relationship between Radius of Cell and Vehicle Velocity

However, as the value of D+RTD/2 increases, the slope of the surface of <Figure 3> increases. Therefore, when the value of D+RTD/2 exceeds about 1.4 seconds, information from the first layer to the second layer is required. <Figure 4> shows the results of the simulation by fixing the maximum speed V to 130 km/hour and the radius of the cell to 50 m to find the relationship between D and RTD/2+T, which is the number of layers required.

<Figure 4> indicates an increase in the required layer as D+RTD/2 increases. It can be seen that as the period of posting drone information to the server and the RTD are prolonged, the number of required layers increases. The required layer can be seen as the minimum scale to collect information from SDN of 5G mobile communication,

and it is thought that a more precise network structure can be improved in design by additionally considering the distribution of drones and the data speed according to the required amount of information.

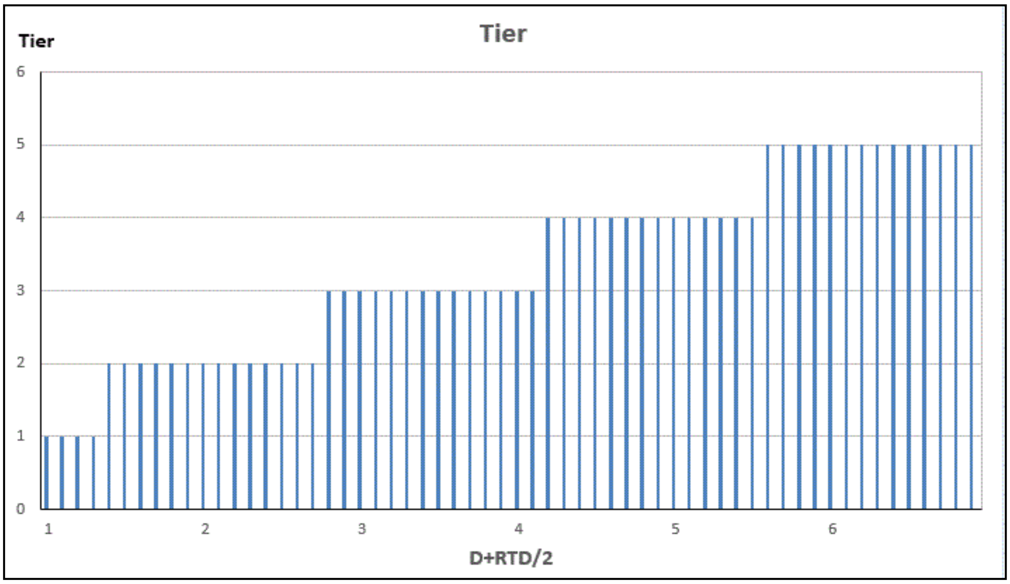

Fig. 4: Tier vs (D+RTD/2)

3.3. High precision positioning

In the ETE communication network model, the location of the drone can be accurately measured through communication with the drone. By checking the location of the drone in real time, it is possible to avoid obstacles, and in particular, errors such as the inconvenience of landing at another location can be minimized, especially in this landing. First, in order to measure the distance and direction between the repeater and the drone to know the current location of the drone, the distance to each repeater calculated using the departure time and arrival time of radio waves is measured using a three-sided position recognition technique. This is expressed by the figure and equation as follows.

<Figure 5> shows a three-sided position recognition technique. The three-sided position recognition technique, which measures the position based on the measured distance information between each repeater and drone, calculates the position of the drone using the individual measurement distance between the three repeaters and the drone that wants to know their position. The triangulation is based on simple mathematical calculations.

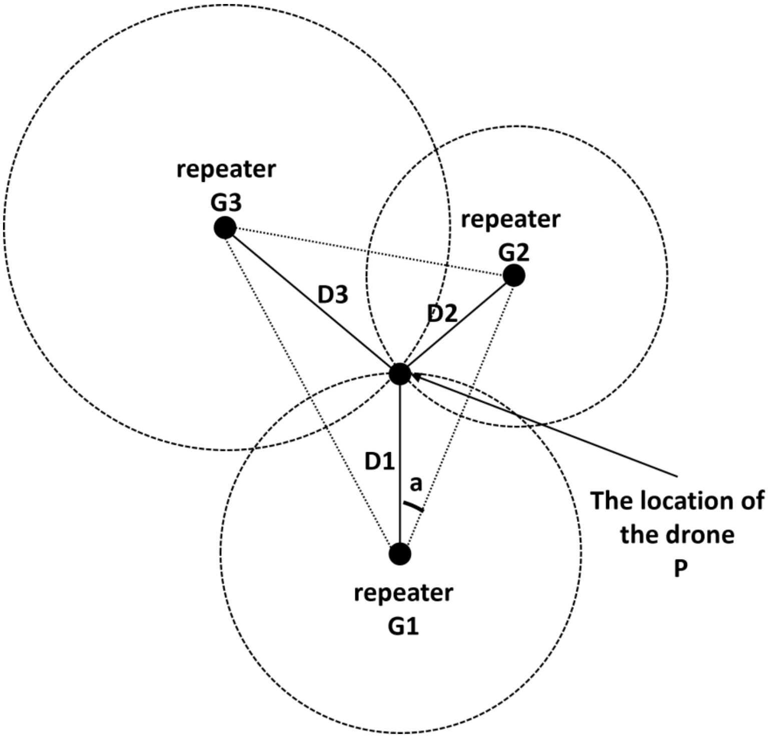

Fig. 5: Trilateration localization

4. Conclusion

In this paper, we proposed an ETE model reflecting the SDN structure in 5G autonomous flight and examined the layer at which drones should request information according to changes in cell radius and drone speed and the relationship between RTD. This model can be used as a minimum criterion for network design for supporting intelligent autonomous flight systems and services, and applying these requirements to 5G SDNs will be able to be used for a variety of intelligent services that are more relaxed than the worst conditions for delays. In fact, in the intelligent autonomous flight system service, the design of RTD, including the period and procedure of data uploaded from each drone to the network, determines the layer to share the network information, which will be affected by the drone's distribution and quantity, required information level, and processing time. Therefore, in the future, research should be conducted through actual implementation in light of the above variables, and research should also be conducted on environmental factors that affect the size of small cells when establishing a 5G network.

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