Designing UAV Surveillance Frameworks for Smart City and Extensive Ocean with Differential Perspectives

Hyunbum Kim, Lynda Mokdad, and Jalel Ben-Othman

The authors design differential frameworks for monitoring smart city and extensive ocean by multiple heterogeneous smart UAVs. Since the requirements and fundamental environments between smart city and extensive ocean are quite different, they consider two differential strategies. For smart city, they introduce a tight plane-based framework. For extensive ocean, they develop a loose hierarchical-based framework.

Abstract

In this article, we design differential frameworks for monitoring smart city and extensive ocean by multiple heterogeneous smart UAVs. Since the requirements and fundamental environments between smart city and extensive ocean are quite different, we consider two differential strategies. For smart city, we introduce a tight plane-based framework that utilizes the existing public transportation including public buses, city trains, and their routes to provide time-sensitive surveillance. For extensive ocean, we develop a loose hierarchical-based framework. To support seamless surveillance over extensive ocean, we use three types of UAVs, which allows replenishment among heterogeneous UAVs at different layers through airborne docking. Moreover, the research challenges and open issues related to the differentiated infrastructures are presented.

Introduction

Thanks to recent advancement of vehicular technology, smart unmanned aerial vehicles (UAVs) or drones have become one of the promising technologies to contribute to people's future daily lives. Basically, it is anticipated that smart UAVs will be operated by public institutions, governments, and industrial companies. Also, UAVs can be exploited in numerous applications including surveillance, patrol, rescue operation, traffic management, delivering items in harsh environment, and so on [1–4]. Although a single large UAV can be utilized in those various applications, multiple small-scale UAVs with heterogeneity have several advantages in terms of cost, scalability, survivability, and speed [5, 6]. However, because those small-scale UAVs intrinsically have limited capabilities, we may deliberate on another type of vehicle to be able to provide replenishment to exhausted UAVs [7]. Hence, we should consider how to construct an infrastructure with efficient recharge strategies for heterogeneous small-scale UAVs.

Since there are different requirements according to types of missions of UAVs, it is essential to deliberate on differential strategies to satisfy various conditions. In particular, it is expected that UAVs will take an important role toward both future smart city and future extensive ocean among enormous applications. However, the smart city has some tight properties such as a high density of population, a high event rate, and the existence of several no-fly zones for privacy. Conversely, the extensive ocean has some loose factors such as a low event occurrence rate and a relatively low risk of UAVs conflicting with people. It follows that the ocean area basically has a low event occurrence rate but requires continuous surveillance for an extensive area. Also, since the ocean is a sparsely populated environment, it has a relatively low risk of UAVs crashing into people compared to the city. Therefore, it is indispensable to create differentiated infrastructures for those different properties and requirements.

Based on the above motivations, we secure a bridgehead for future smart city and extensive ocean development by smart UAVs. Our contributions can be summarized as follows:

- For future smart city and extensive ocean, we introduce differential models: a *tight plane-based framework* and a *loose hierarchical-based framework*.
- For the smart city, a tight plane-based framework (or a dense-horizontal-based framework) is designed with the following sub-contributions:
  – We clarify practical scenarios and objectives that are achievable by multiple UAVs, and define the tight factors and requirements of smart city.
  – The system settings, rules, and components are explained with a consideration of citizen privacy and time-sensitive surveillance. Also, we introduce not only novel strategies, including the use of public transportation and the replenishment of UAVs based on docking technology, but also how to operate those schemes appropriately.
  – Various open research issues related to the proposed smart city model are addressed clearly.
- For the extensive ocean, a loose hierarchical-based framework (or a sparse vertical-based framework) is proposed with the insights below:
  – The loose factors and possible scenarios for future ocean development are specified.
  – We propose novel solutions with hierarchi-

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cal layers and three types of UAVs based on airborne docking to support continuous surveillance.
–Furthermore, we suggest influential research topics related to the extensive ocean operated by heterogeneous UAVs.

A Tight Plane-Based Framework for Monitoring Smart City by Multiple Smart UAVs

According to [8, 9], multiple UAVs can be exploited in the future smart city to perform various objectives with different roles of UAVs for public safety, intelligent transportation, and mobile medical systems. We present practical scenarios according to specific objectives as follows.

Rapid emergent disaster detection and report: In the future advanced city, there may be unexpected calamities such as fire, flooding, and collapsing roads and bridges. UAVs can contribute to minimizing the damage of a disaster by sending the recorded information to firefighters after a speedy arrival as well as by warning of the serious event to citizens in neighboring areas or other areas [10]. Besides, UAVs can be utilized for patrol among frequently congested intersections so that areas with traffic jams are controlled promptly by guidance signals or broadcasts of UAVs.

Criminal investigation and tracking a fugitive: Once a criminal is reported to the control center, the closest UAVs among available UAVs fly and arrive at the site of the criminal. Then, if the criminal is verified, a fleet of UAVs can be used for tracking a fugitive and collecting data including criminal identification.

Services of emergent item delivery and disaster recovery: For emergent purposes, it is possible for UAVs to deliver first-aid treatment to accident locations. Also, when cars on land are in temporarily unreachable areas or remote places due to unexpected disasters, UAVs can deliver any necessary goods as well as take a role as temporal equipment to recover communication infrastructure.

Compared to the extensive ocean area, a city has a relatively dense area bound by several tight factors including the existence of private areas and public areas, high population density, high event occurrence rate, numerous obstacles and entities, and so on. Those tight factors are correlated to the applications including rapid detection and report of emergent events, prevention and detection of terror threats, and sustainable surveillance and patrol of areas with high accident rates. Based on this observation, we introduce a dense horizontal-based model allowing both installation of UAV ground stations (UGSs) and applicability of the existing public transportation system. We note that the proposed system can be supported by various public transportation vehicles such as city trains and trams. For convenience, we consider the public bus as the representative of intelligent public transportation and apply it to the system. Also, the tight plane-based model can be operated by installing UGSs at possible public areas as ground units to charge UAVs and to send detected/collected information to UGSs. Also, it is possible to have communications not only between UAVs but also between UGSs. Moreover, the dense horizontal-based model runs the existing public bus system including smart buses equipped with recharging space and regular routes of existing buses to reduce initial installation cost and to overcome the flight limitation of small-scale UAVs. Exploiting public buses may have several advantages: while UAVs are charged on public buses, UAVs with cameras can continuously monitor traffic conditions and collect data from neighboring UGSs with a regular daily bus route. In detail, each UAV is equipped with a standard compliant IEEE 802.11 WiFi card, and UGSs are installed on the ground in an urban area as WiFi access points. Also, it is expected that there is a single link based on a three-state Markov model between a UAV and a UGS. Then multiple UAVs on the public bus and in the air can access available UGSs opportunistically to transmit the monitored traffic information or to collect data from UGSs. Besides, if it is needed, UAVs on public buses freely take off and land with more flexible schedules and locations according to the necessity of the system when a public bus has no movement during a given amount of time at regular bus stops. Furthermore, the buildings in the city can become potential stations of UAVs to take off and land in the framework. If they are buildings with public purposes, UAVs will be allowed to land on specific locations of those buildings all the time. If they are located in private areas, the buildings may give temporary permission to access the buildings when emergent situations occur.

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System Settings and Operating Rules

Now, we describe the system settings and operating rules in the proposed framework. Basically, the system considers three types of areas: public areas, including public roads, temporarily allowed private areas in case of emergency, and permanently prohibited areas (no-fly zones). For UAVs, two types of UAVs are considered. One is public UAVs operated by public institutions for public safety. The other is private UAVs operated by private companies or citizens.

On the other hand, the tight plane-based framework requires the following settings for successful implementation:

- A UAV has limited ability, including limited battery for a flight, and has its own sensing range to monitor events.
- To avoid any failure, UAVs are allowed to take off and land from/on public buses only at bus stops where public buses stop on a daily route schedule.
- UAVs are able to stay at UGSs to recharge their own resources if they get permission from public institutions or administrators before the use of the UGSs.
- Public UAVs basically include emergency items such as medicines for emergency delivery as well as equipped cameras.
- For collision avoidance, two phases are considered. In the first phase, visual sensors such as equipped cameras are utilized to get information on any obstacles. In the second phase, once UAVs get information on the obstacles, we may apply several detection approaches such as trajectory calculation,

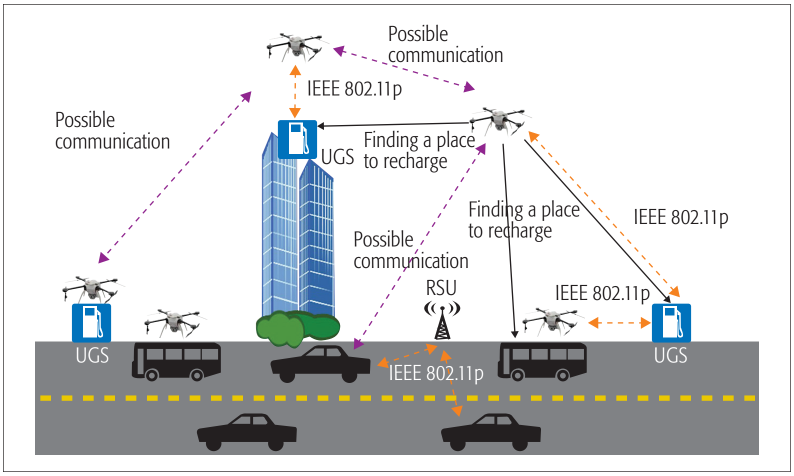

Figure 1. A framework for monitoring smart city with an elevation view.

distance estimation, worst case estimation, and probabilistic estimation to decide if there are any imminent conflicts.

- UAVs are equipped with Global Navigation Satellite System (GNSS), which allows the control center to navigate UAVs. While UAVs recharge own resources on UGSs, the location/navigation information and trajectory history of UAVs can be transmitted to UGSs, and then the UGSs are able to report the information to the control center.
- Using the IEEE 802.11p standard, UAVs can communicate with each other, or Long Term Evolution (LTE) can be utilized among UAVs depending on the city infrastructure.
- For maneuvering UAVs, the proposed framework for smart city deliberates on a combination of autonomous flight and controlled maneuver by authorized users. Then multiple UAVs operate autonomous flights to achieve specific missions, including moving to specific locations, and taking off/landing on UGS and public buses.

Architecture and Operating Steps

The dense horizontal-based framework should support the simultaneous detection of multiple events. To fulfill the goal, the following steps are performed.

Periodic Report and Event Detection: Fundamentally, a control center should check the status of all UAVs for their locations with altitude and battery status through periodic reports from UAVs to UGSs and the control center. When emergency events occur, the events can be detected by patrolling UAVs. In this case, the events are immediately recorded by the UAV, and the information is forwarded to the closest UGS or roadside unit (RSU) and finally sent to the control center over dedicated short-range communications (DSRC). On the other hand, the events can be identified by a citizen's emergency call. The control center with the call should announce the events to UGSs and RSUs. Hence, all possible entities including UAVs, public buses and smart cars can receive the announcement through UGSs and RSUs.

Scheduling Workable UAVs: When events are announced by the control center, the system makes a list of workable UAV candidates based on current information including UAV locations and current UAV battery condition, and map information covering area type, obstacles, and so on. It follows that from the candidates, the system decides which UAVs should go to the specific event locations with efficient trajectory of UAVs using current map information to minimize total delay or minimize a maximum mission completion bound.

Scheduling Returning UAVs: After missions are finished, it is necessary to schedule which UAVs return to which locations among available public buses and UGSs to provide continuous service. In this step, efficient scheduling should be considered carefully in order to minimize the movement distance of UAVs to available public buses or UGSs considering trajectory, which protects the privacy of citizens or provides safety to citizens by avoiding flight over private areas and over crowds.

Figures 1 and 2 show the tight plane-based framework for smart city. In Fig. 1, from an elevation viewpoint, there are several types of communications. Smart cars and public buses on a public road are able to communicate with an RSU through IEEE 802.11p, and there are possible multihop communications among multiple UAVs; we also have communications between UAVs and smart cars. Also, UAVs are movable to public buses and to UGSs in order to recharge their resources. As can be seen in Fig. 2 with a plan view, there are three areas: public area, prohibited area (no-fly zone), and temporarily accessible private area. Also, the system consists of various entities: UAVs, RSU, UGS, public bus with it own daily route, and smart cars. In Fig. 2, two public buses have different daily routes. UAVs are movable over public area and temporarily accessible area. Also, UAVs can come to stay at UGS and on the roof of public bus as idle mode. Such an idle mode enables to recharge batteries of UAVs but still do communicate with other UAVs, public buses, smart cars.

Research Challenges and Issues

To establish a successful infrastructure, we also address critical research challenges and open issues.

Optimal Number and Deployment of UAVs, UGSs, and RSUs: It is required that each entity, including the UAV, UGS, and RSU, has own role in supporting the dense horizontal-based infrastructure. Given the city area and the number of public buses, finding the optimal number of UAVs, UGSs, and RSUs can be a critical research issue. As a similar research challenge, finding optimal deployment of UGSs and RSUs is an important issue when the number of UAVs, UGSs, RSUs, public buses with daily routes in the same city area are given.

Development of Efficient Algorithms for Workable Returning and Patrolling UAVs with Privacy Protection of Citizens: First of all, the use of patrol UAVs is expected because the system should support continuous monitoring by UAVs for patrol regions with high event occurrence rates. Hence, after those patrol regions are determined based on given information including public/priavate areas and the available number of UAVs, both efficient patrol and selection algorithms should be developed to fulfill the specific goals such as minimizing event detection delay. Second, when emergency events are reported, we need to devise efficient algorithms to choose workable UAVs from current UAV information including their locations, conditions, and so on. Specifically, the issue of preventing privacy threats to citizens in their own private areas should be considered. Depending on mission objectives of UAVs and urgent levels of missions, some group of citizens may selectively allow penetration of UAVs into private areas.

Development of Docking Technology with Policy between UAVs and Public Buses, and UGSs: The proposed infrastructure requires docking technology not only between UAVs and public buses, but also between UAVs and UGSs. Such an autonomous docking technology and mechanism motivate UAVs to stay in a stable space for changing to idle mode and recharging battery for efficient energy management. In particular, when the dockings of UAVs are processed, the solid docking policy should be established for the safety of citizens and efficiency of the docking process between UAVs and public buses or UGSs.

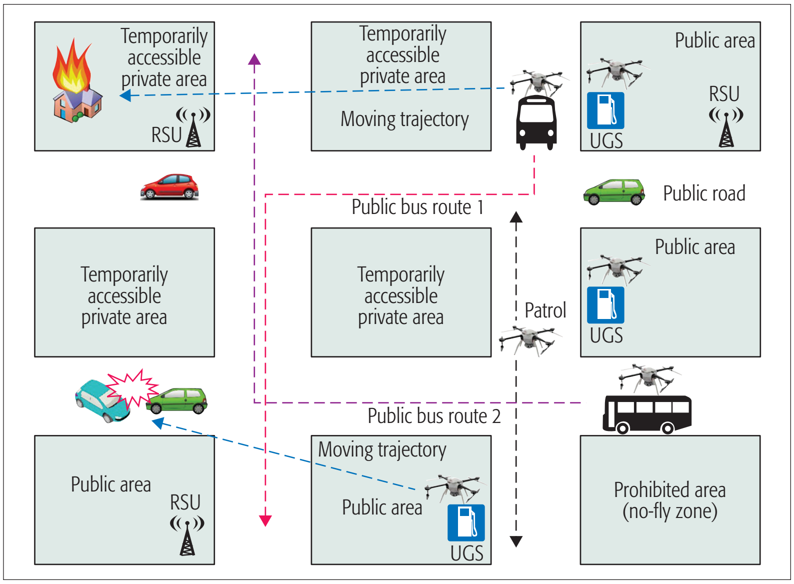

Figure 2. A framework for monitoring smart city with a plan view.

A Loose Hierarchical-Based Framework for Monitoring Extensive Ocean by Heterogeneous Smart UAVs

Let us consider a future extensive ocean implementation using multiple heterogeneous smart UAVs that accomplish important missions for public safety, scientific research, and ocean development. Then we depict the following possible scenarios.

Detection of disaster and prevention of criminals on coasts and over extensive areas: The UAV network is highly likely to be utilized to give warnings for disasters such as fires, flood tides, tsunamis, accidents involving cargo ships, and so on. With collaboration of underwater sensor networks (USNs) [11], a fleet of UAVs can detect any events and send alarms to people or control centers. Also, since there are various tasks (i.e., loading and unloading items) at harbors from different sizes of ships, a set of UAVs can be exploited to prevent any possible crime by patrolling or constructing barriers, enabling recognition of any penetration into the given area [12].

Scientific research: As described in [13], USNs consist of several entities such as underwater sensors, buoys, and onshore sinks. Through underwater sensors, we can monitor the specific region and collect the sensed information of ocean and underwater conditions for scientific purposes. The collected information can be sent to a buoy, and a group of UAVs can receive the sensed information.

Support ocean construction: For ocean development, several ocean plants or construction projects can be built in extensive ocean areas. Multiple UAVs can record the condition of unseen or severe shadowing in construction. The recorded information can be sent to workers in the construction. Also, when it is necessary to deliver small-sized items among plants, UAVs are used to provide quick delivery of small items.

Compared to an urban environment, an ocean area has a relatively loose area, with factors such as low event occurrence rate and low risk to people of UAV collisions. Hence, we should design a loose framework with multiple UAVs for the ocean area. It is especially challenging to apply UAVs to extensive ocean areas because UAVs have limited movements and it is very difficult to recharge batteries over extensive oceans. Thus, the problem due to energy depletion of UAVs is critically considered, and its solution should be sought. Based on this observation, we introduce a sparse vertical-based model that allows us to recharge UAVs through airborne docking. Since the ocean area has a property of low risk in case of conflicts among UAVs, it is actively applicable to airborne docking [14] to recharge UAVs.

System Settings and Operating Rules

Now, we explain the system setting and operating rules for the proposed framework for extensive oceans.

Note that we think over three types of UAVs: child-UAVs (C-UAVs), mother-UAVs (M-UAVs), and supremacy-UAVs (S-UAVs). Basically, C-UAVs are positioned at the lowest layer (referred to as the C-Layer) at the lowest altitude. C-UAVs have responsibilities to monitor the given extensive area, and they can also collect information from surface buoys and communicate with M-UAVs that are located at the middle layer (M-Layer) whose altitude is higher than that of the C-Layer. We expect that M-UAVs have capabilities to provide replenishment of exhausted C-UAVs through airborne docking. M-UAVs take care of only C-UAVs within own rechargeable area at the lower layer, which is referred to as the shadow area. Lastly, S-UAVs are located at the highest layer (S-Layer). The S-UAVs can communicate with M-UAVs as well as with onshore control centers. Similarly, S-UAVs only take care of M-UAVs within their own shadow areas Then, the loose hierarchical-based model follows the below parts.

- It is proper to combine with USNs where underwater sensors are deployed under the water. Then those sensors can report sensing information to surface buoys.
- A UAV has a limited capability including limited battery for a flight, and has its own sens-

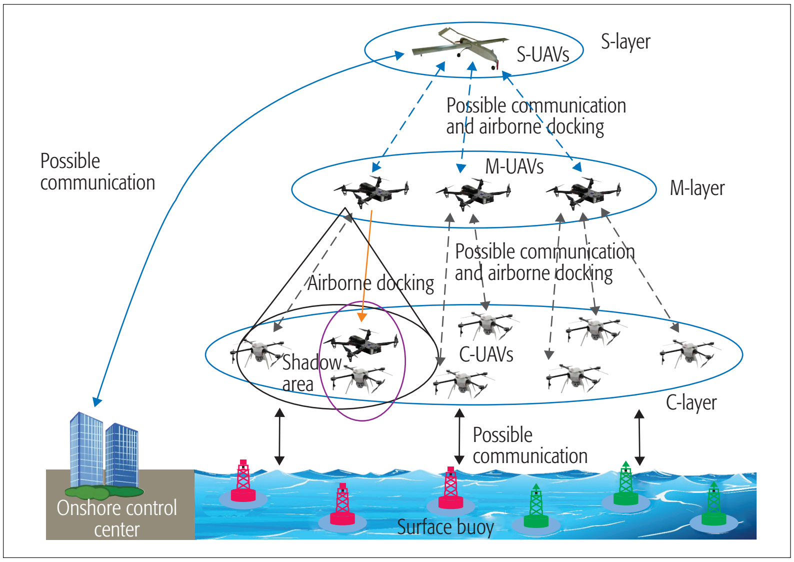

Figure 3. A framework for monitoring an extensive ocean: elevation view.

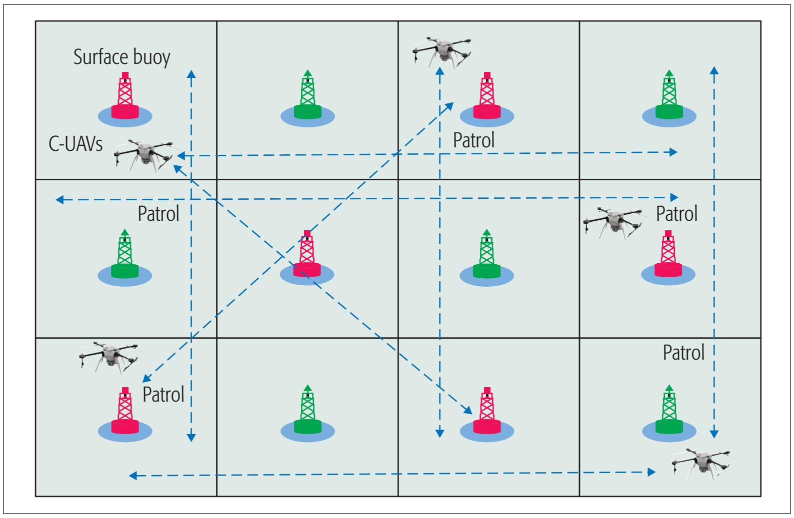

Figure 4. A framework for monitoring an extensive ocean: plan view.

ing range to monitor events.

- If M-UAVs verify the depleted C-UAVs within their own shadow area, M-UAVs move toward the exhausted C-UAVs at the C-Layer. C-UAVs communicate with buoys during tamping in order to support seamless monitoring.
- Although M-UAVs have better energy resources compared to C-UAVs, the resource of M-UAVs is still limited.
- Similarly, S-UAVs may move to the depleted M-UAVs at the M-Layer. And M-UAVs simultaneously communicate with C-UAVs within their own shadow areas during replenishment.

Table 1 covers a description of the key components in the proposed frameworks of both ocean and smart city. We note that smart UAVs in smart city can be selected from three types of UAVs in Table 1.

Architecture and Operating Steps

Fundamentally, the sparse vertical-based system should carry out seamless, autonomous monitoring for extensive oceans by a given number of UAVs. To satisfy those properties, we execute the following steps.

Deployment of UAVs at Layers: Note that the proposed system may collaborate with USNs including surface buoys. Before minimizing the delay for event detections, we first should develop how to locate three types of UAVs at layers to maximize system lifetime. That is, given a number of UAVs with initial locations and a surface buoy, it is suitable to consider efficient deployment strategies so as to monitor an extensive area including a coastal area. After finding proper positions for C-UAVs, M-UAVs, and S-UAVs, each UAV recognizes its own role and area. Then S-UAVs verify M-UAVs within their own shadow areas to provide prompt recharge. M-UAVs also check C-UAVs within their own shadow areas. Also, C-UAVs confirm deployed surface buoy and the region to be monitored.

Scheduling Patrol by UAVs: After the successful deployment and verification of UAVs, each type of UAV patrols at its own layer to cover an extensive area and to take care of UAVs within its own shadow area. According to the scheduling algorithm, C-UAVs at C-Layer monitor the extensive area by visiting a group of surface buoys or by flying over an ocean area. By movement of C-UAVs within their own shadow areas, M-UAVs may move around at the M-Layer instead of stopping. Similarly, S-UAVs may also move around at the S-Layer depending on movement of M-UAVs within their own shadow areas. Those reasonable movements of M-UAVs and S-UAVs supply rapid replenishments when some UAVs are depleted due to excessive flight.

Scheduling Airborne Docking: With a combination of patrol schedules, the scheduling of airborne docking should be investigated. When M-UAVs receive recharge requests from multiple C-UAVs within their own shadow areas, the M-UAVs decide how to handle multiple requests and where the rendezvous points are for airborne docking at the C-Layer. After the airborne docking is done, M-UAVs should return to the M-Layer to support continuous management of the system. Similar to M-UAVS, S-UAVs also follow the same process to decide the rendezvous points with M-UAVs at the M-Layer and to consider successful return locations at the S-Layer.

Figure 3 represents the sparse vertical-based framework with an elevation view including three types of UAVs: C-UAVs, M-UAVs, and S-UAVs. Each type of UAV is located and flies at its own layer except in an emergency case of energy depletion of UAVs. At the highest layer, S-UAVs can communicate with an onshore control center as well as M-UAVs within its own current shadow area. S-UAVs sometimes may move to depleted M-UAVs to provide replenishment using airborne docking. As can be seen in Fig. 3, M-UAVs not only can communicate with C-UAVs but also support recharging of the exhausted C-UAVs within their own shadow areas. At the lowest layer, C-UAVs can monitor extensive areas and collect information from surface buoys. On the other hand, Fig. 4 depicts the sparse vertical-based framework from the plan view. Given an extensive area, it is adequate that we divide the extensive area into several zones. Each zone is assigned to each buoy. Then a buoy can collect

Component	Standards and equipment	Activities and roles
UGS	–IEEE 802.11 standards –IEEE 1609 standards –IPv6 standards –IPv4 standards –Security policies –Docking bay –Power source to recharge power module of UAVs	–Receive recent reported information from UAVs –Advertise the information including status and locations of UAVs –Recharge UAVs staying on UGSs –Generate public/private key pairs –Forward signed and encrypted data to other UGSs, UAVs, control center
RSU	–IEEE 802.11 standards –IEEE 1609 standards –IPv6 standards –IPv4 standards –Power over Ethernet (802.3at-2009 PoE Plus 25.5W) –Health and monitor standards	–Announce available services to vehicles and other RSUs over DSRC –Forward service information to other RSUs, remote network hosts, control center –Support IPv6 network access –Receive updated health information and status from requested users in vehicles and send them to necessary remote network hosts
Public bus	–IEEE 802.11 standards –IEEE 1609 standards –IPv6 standards –IPv4 standards –Docking bay –Power source to recharge power module of UAVs	–Monitor traffic information according to scheduled regular route –Recharge UAVs landing on public transportation –Forward the recorded traffic information to RSUs
C-UAVs	–IEEE 802.11 standards –IEEE 1609 standards –Visual camera –GNSS navigation –Power battery –Hook for airborne docking	–Monitor a scheduled ocean and onshore area –Receive a detected event or data from a surface buoy –Regularly transmit the updated information to M-UAVs
M-UAVs	–IEEE 802.11 standards –IEEE 1609 standards –Visual camera –Sensor to check weather and atmospheric condition –GNSS navigation –Hook for airborne docking –Docking bay and power source to recharge C-UAVs	–Record an atmospheric and weather condition in sky area –Receive information detected by C-UAVs –Regularly send the updated information to S-UAVs –Verify resource status of C-UAVs within own shadow area –Recharge depleted C-UAVs through docking
S-UAVs	–IEEE 802.11 standards –LTE standards – visual camera –Sensor to check weather and atmospheric condition –GNSS navigation –Docking bay and power source to recharge M-UAVs –Integrated hybrid self-replenishment system using solar energy and hydrogen fuel cell	–Advertise requests and system status to every type of UAVs –Receive the sensed information from M-UAVs –Regularly report the updated data to onshore control centers –Check resource status of M-UAVs within own shadow areas –Replenish exhausted M-UAVs through docking

Table 1. Description of key components.

information from underwater sensors within its own zone. Also, C-UAVs gather information by vising the surface buoy. Definitely, C-UAVs monitor the given area by following patrol scheduling. Figure 4 shows several patrol trajectories. Hence, it is necessary to develop efficient patrol strategies with simultaneous consideration of airborne docking scheduling with other M-UAVs and S-UAVs at upper layers.

Research Challenges and Issues

Next, we envision several research challenges and open issues related to the proposed infrastructure.

Construction of Virtual Layers and Optimal Number and Deployment of C-UAVs, M-UAVs, and S-UAVs: To monitor extensive ocean areas, deciding the size of each layer and the distance between layers should be evolved. Also, given the area and number of surface buoys, finding an optimal number of each type of UAVs should be an important issue in the proposed system. As a trade-off, given a number of UAVs, an efficient deployment strategy can be obtained to maximize the performance of the proposed system.

Development of Scheduling Algorithms for Patrolling and Recharging UAVs: Another issue is energy-efficient movement and patrol strategies from initial or current locations of UAVs. With a given number of C-UAVs, it is essential to devise a reasonable patrol algorithm such that each buoy or region is monitored by at least one C-UAV within a given time bound. On the other hand,

With a given number of C-UAVs, it is essential to devise reasonable patrol algorithm such that each buoy or region is monitored by at least one C-UAV within a given time bound. On the other hand, efficient and secure airborne docking schemes should be studied with a simultaneous collaboration with patrol strategies.

The proposed architecture uses the airborne docking technology practically since such a smooth and an autonomous airborne docking technology allows the system to support seamless and continuous surveillance of extensive ocean. Hence, the advancement of recharging technology through airborne docking is an urgent need.

efficient and secure airborne docking schemes should be studied with simultaneous collaboration with patrol strategies. To minimize recharge delay, we may apply a Voronoi diagram [15] so that the locations of C-UAVs within an M-UAV's shadow area can generate a Voronoi cell (e.g., a form of convex hull).

Development of Airborne Docking Technology among C-UAVs, M-UAVs, and S-UAVs: As can be seen in Fig. 3, the proposed architecture uses the airborne docking technology practically since such a smooth and autonomous airborne docking technology allows the system to support seamless and continuous surveillance of extensive ocean. Hence, the advancement of recharging technology through airborne docking is urgently needed to accelerate successful future ocean development by UAVs.

Concluding Remarks

In this article, we introduce differential frameworks with heterogeneous smart UAVs for future smart city and extensive ocean because smart city and extensive ocean have different environments, properties, requirements, and types of applications. For the proposed frameworks, we describe possible various applications and scenarios, and suggest their settings and operating rules as well as operating steps. Furthermore, we present research challenges and issues for both frameworks in order to reach the next advancement stage of the promising technology of UAVs.

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Biographies

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