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A Survey of UAV on Wireless Communication: Applications and Challenges

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***Abstract*— A large number of unmanned flight platforms, such as Unmanned aerial vehicles (UAVs), are widely used in wireless networks, and the number and scope are expanding. Due to the properties of the UAVs, such as flexibility, adaptive height, and mobility, the UAVs has important application value in the wireless communication system. On the one hand, the UAVs can be equipped with a base station as a flight base station to assist the wireless network to improve coverage, capacity, reliability, and the like. For example, UAVs can be deployed to complement existing cellular systems by providing additional capacity to hotspots and providing network coverage in emergency and public safety situations. On the other hand, the UAVs perform operations such as monitoring as a flight terminal in a cellular network. In this paper, the application and challenges of UAVs as flight base stations in the field of public safety are introduced.**

***Index Terms*—UAVs Base Station, Public Safety, Recovery Communication, Location Deployment.**

I. INTRODUCTION

Due to its autonomy, flexibility and wide range of applications, UAVs have been the subject of research in various fields over the past few years [1]–[5]. In fact, UAVs have long been recognized as promoters of various applications such as military, surveillance and surveillance, telecommunications, medical supplies, and rescue operations[3], [6]–[10]. However, UAVs communication applications are often ignored or considered part of the control and autonomous components. The unprecedented development of UAVs technology has made the deployment of UAVs widely used, such as the application of UAVs, small aircraft, balloons and airships in the communication platform. [9], [11]–[14].

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Especially through the deployment of UAVs, UAVs can provide reliable, low-cost, high-efficiency wireless communication solutions in real-world scenarios. In particular, if deployed and operated properly, UAVs can provide a reliable and cost-effective wireless communication solution area for a variety of real-world scenarios. On the one hand, UAVs can be used as air user equipment (UE), UAVs called a cellular connection, to coexist with ground users (for example, to deliver or monitor UAVs). On the other hand, UAVs can be used as air base stations (BSs) to provide reliable, cost-effective, on-demand wireless communication to the needs.

In particular, when UAVs are used as flight and air base stations, they can support the connectivity of existing terrestrial wireless networks, such as cellular and broadband networks. Compared to traditional terrestrial base stations, the advantage of using UAVs as flight base stations is their ability to provide real-time communication and establish a line of sight (LOS) communication link. In fact, due to its inherent characteristics, such as mobility, flexibility and adaptability, the UAVs base stations can effectively complement existing cellular systems by providing additional capacity to hotspots and network coverage in hard-to-reach rural areas. Another important application of UAVs is the Internet of Things (IOT) scenario Internet of things scenario auxiliary application [15], [16], where the transmit power of the device is often small and may not be able to communicate over a long range. UAVs can also be used as wireless resources to improve the connectivity and coverage of terrestrial wireless devices, as well as to monitor scenarios, a key use case for the Internet of Things. Last but not least, the cost is reduced when building and deploying UAVs, eliminating the need for expensive towers and infrastructure deployment. Based on these characteristics of the UAVs, in this paper, we describe the application of the UAVs as a UAVs base

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station in the security field.

The rest of this article is shown below. In the second section, we describe the system model of a submarine to build base stations of different heights. In the third section, we explain the application of UAVs base stations in the field of public safety. In the fourth section, we analyze and summarize the problems involved in the public safety of the UAVs base station. It is summarized in the fifth section.

II. UAVS BASE STATION SYSTEM MODEL

A. *UAVs Classification and Characteristics*

The capabilities of the UAVs and its flight altitude are taken into account. In general, UAVs can be divided into high altitude platforms (HAPS) and low altitude platforms (LAPS) according to their height. The HAPS height is above 17 kilometers, typically as in [17], [18]. On the other hand, the LAPS can fly to a few kilometers at a height of tens of meters, can move quickly and flexible [18]. UAVs can also be classified into hot air balloons, fixed wing and rotary wing UAVs according to type. A further comparison of these UAVs is summarized in Table 1.

The first type of unmanned platform is a balloon, are widely used in high-altitude platforms (HAPS) over 10 km, and even ultra-high altitude (UHA) applications. For example, Google's Loon project [12] successfully implemented a 20-kilometer balloon network that expanded the Internet connection between rural and remote areas around the world. In October 2017, the Loon project provided an emergency long-term evolution service recovery to Puerto Rico after Hurricane Maria.

The second type of UAVs is the fixed-wing UAVs (FW-UAVs). In general, the FW-UAVs can reach a very wide range of altitudes at the fastest level due to the powerful turbine engine.

The third type of UAVs, known as the rotary wing UAVs (RW-UAVs), has been widely used in the consumer UAVs market. However, the battery significantly limits its flight time and payload. This RW-UAVs offers high flexibility and maneuverability with reliable hovering capability. Due to the limited energy carrying capacity, it is limited in duration and weight in application. How to design an effective solution to solve the energy problem is the focus of future research.

B. *UAVs Base Station Architecture*

In the UAVs-assisted terrestrial network communication, based on the characteristics of different UAVs, there is a distributed multi-layer UAVs (DAMU) network architecture as shown in Figure 1.

Table 1. UAVs classification and characteristics.

Type	Balloon	Fixed - wing UAVs	Rotary wing - UAVs
Speed	Slow	Fast (horizontally), medium (vertically)	Medium (horizontally), fast (vertically)
Altitude (km)	> 20	> 16	< 1
Mobility and hovering	Low mobility, hovering supported	Medium mobility, hovering not supported,	Highest mobility, hovering supported
Endurance	Longest, from weeks to indefinite	Medium, from half day to days,	Low, less than 1 hour
Energy resource	Solar cells, lithium battery petrol	Petrol, solar cells, lithium battery	LiPo, petrol, solar cells
Maximum payload(kg)	Large, > 1000 kg	Medium, < 1000 kg	Low, < 100 kg

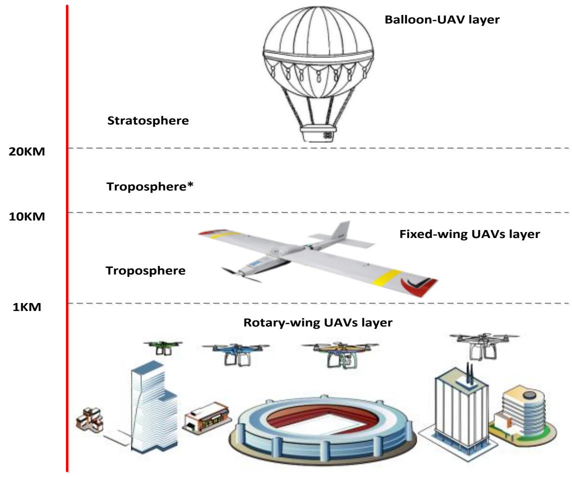

Fig. 1. Multi-layer UAVs (DAMU) base station network architecture

When each layer of the UAVs base station is separately proposed, it can work alone to maintain a fully

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functional network communication. When the three-layer UAVs base stations work together, synchronous active communication can also be realized.

III. APPLICATION OF UAVS BASE STATION IN SECURITY FIELD

To clearly describe how a UAVs is actually used as a flying wireless base station, in this section we outline some of the applications of this wireless-centric UAVs. These applications are extracted from various security scenarios, such as public security scenarios or hotspot coverage, and enhanced network capacity.

Natural disasters such as floods, hurricanes, tornadoes and severe blizzards often have devastating consequences in many countries. In large-scale natural disasters and emergencies, terrestrial communication networks may be destroyed or even completely destroyed [19]. In particular, cellular base stations and terrestrial communications infrastructure are often compromised during natural disasters. In this case, safety communication between first responders and victims of search and rescue operations is essential. Therefore, a robust, fast and capable emergency communication system is needed for rescue activities in public security. Such a reliable communication system not only helps improve connectivity, but also helps save lives.

A. UAVs Base Station Enhances Network Capacity

We assume that the flying base station carried by UAVs is an inevitable supplement to the heterogeneous wireless network environment, which will allow us to overcome some of the challenges of the prior art. For example, deploying an ultra-dense residential network in rural and geographically limited areas is a challenge, and UAVs can provide fast, cost-effective flight communications. At the same time, UAVs provides a longer-term sustainable solution in this rural environment. In addition, the deployment unit is used for the sole purpose of serving hotspots and temporary events. For example, in football games or presidential inaugurations, the deployment of fixed ground base stations may be economically and technically impossible because these activities require short wireless access. In contrast, mobile UAVs can provide on-demand connections to these areas with little additional cost. Clearly, the flight base station can provide an important complement to the ultra-dense small cell network.

In addition, UAVs can assist with a variety of terrestrial networks such as D2D and in-vehicle networks. For example, due to the maneuverability and line-of-sight communication capabilities of UAVs, UAVs can facilitate rapid information dissemination and rapid information transfer between ground equipment. For example, after a large vehicle accident occurs on a high-speed bridge, the UAVs network can be used to send an early warning to the vehicles coming from a distant situation, to inform the owner of the accident in advance, and to avoid entering the accident area if the route can be changed. It can reduce the subsequent danger of accidents and greatly improve the mobility of ground vehicles. In addition, UAVs can improve the reliability of wireless links in D2D and in-vehicle communications (V2V) while utilizing transmit diversity. In particular, flying UAVs can help broadcast public information to terrestrial devices, thereby reducing interference with terrestrial networks by reducing the number of transmissions between devices.

B. UAVs Base Stations Replace Damaged Ground Base Stations

In this regard, First Net was established in the United States to establish a nationwide high-speed broadband wireless network for public safety communications. Potential broadband wireless technology public safety solutions include 4G Long Term Evolution (LTE), WIFI, satellite communications, and dedicated public safety systems. However, these technologies may not be able to provide flexible, low-latency services and rapid environmental adaptation services during natural disasters.

The UAVs-based air network is a promising solution for achieving fast, flexible, and reliable wireless communications in a public safety scenario [21]. In fact, the UAVs has the characteristics of strong mobility, flexible deployment, and fast reconstruction speed, which can effectively establish an on-demand public safety communication network. For example, the UAVs can be deployed as a mobile air base station to provide broadband connectivity to areas where ground wireless infrastructure is compromised. In addition, in-flight UAVs can be continuously moved in as short a time as

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possible to provide full coverage of a given area. Therefore, in a public security scenario, a base station installed with UAVs is the most appropriate solution to provide fast and ubiquitous connectivity.

Among them, the UAVs base station in China has been implemented after the actual disaster. In July 2017, the Hunan area was hit by severe heavy rains, and there were many cases where communication base stations were interrupted and damaged. In order to ensure emergency communication requirements, Hunan Mobile urgently dispatched a high-altitude base station system for UAVs. This is the first time that UAVs high-altitude base stations have been put into actual combat in China. The emergency response system established in the disaster area is composed of UAVs + Satellite communication system, including UAVs, ground base, geosynchronous satellite, ground radar main station and data receiving platform. It passes the UAVs data link. Satellite electromagnetic waves and network electromagnetic waves transmit data, which can be transmitted to the command center in a real, accurate and real-time manner, providing signal transmission guarantee for emergency and rescue. In August, the high-altitude base station of the mooring UAVs was once again used in Sichuan Mobile. In August, the high altitude base station of the tethered UAV was once again used in wireless communication. It was deployed in Jiuzhaigou scenic spot in Sichuan quickly got through the mobile communication signals in the disaster area of more than 30 square kilometers to support command and dispatching [31].

C. Smart City

Wireless network technology is rapidly evolving into a huge IOT environment, and it is necessary to integrate various devices, from traditional smart phones to tablets to cars. Sensors, wearable devices and naturally UAVs. Achieving IOT applications, such as smart city infrastructure management, healthcare, transportation, and energy management, requires efficient wireless connectivity between a large number of IOT devices that must reliably transmit data at high data rates or ultra-low latency. .

Achieving a global vision of smart connected communities and cities is a daunting technical challenge. Smart cities will effectively integrate many of the previously mentioned technologies and services, including the IOT environment (with its many services), reliable wireless cellular work, resilience and large amounts of data [22]. To this end, UAVs can be used in several wireless application use cases in smart cities. On the one hand, they can be used as data collection devices that can collect large amounts of data from different geographical areas. And send them to the central cloud unit for big data analysis. On the other hand, UAVs can provide flying wireless base stations that can be used simply to enhance the coverage of urban cellular networks or to respond to specific emergencies [23].

Obviously, the above application is just some of the scenarios that UAVs use as a flight wireless platform in public safety. Once implemented, these applications will have far-reaching technical and social impact. However, to truly deploy such a UAVs-centric application, many technical challenges must be overcome, as described in the next section.

IV. CHALLENGE

In this section, an overview of the key research directions that must be followed to actually deploy a UAVs as a flying wireless device.

A. Air-to-Ground Channel Modeling

Wireless signal propagation is affected by the medium between the transmitter and receiver. The air-to-ground (A2G) channel characteristics are significantly different from traditional terrestrial communications. These channels, in turn, can determine the performance of UAVs-based wireless communications in terms of coverage and capacity [12], [24]-[26]. In addition, A2G channels are more susceptible to blocking than LOS. Clearly, the optimal design and deployment of the UAVs communication system requires the use of an accurate A2G channel model. Accurate A2G channel modeling is very important. In particular, UAVs are used in applications such as coverage-enhanced, cellular-connected UAVs-UEs and Internet of Things communications.

Any movement of the UAVs will affect the channel characteristics. In addition, the height of the A2G channel depends on the height and type of the UAVs, the elevation angle and the type of propagation environment.

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As shown in Figure2. Therefore, finding a universal channel model for air-to-ground communication requires comprehensive simulation and measurement in various environments. In addition, the role of the UAVs for channel modeling must capture the talents caused by the body of the UAVs, Antenna movement and shadows. Obviously, capturing these factors is challenging in A2G channel modeling.

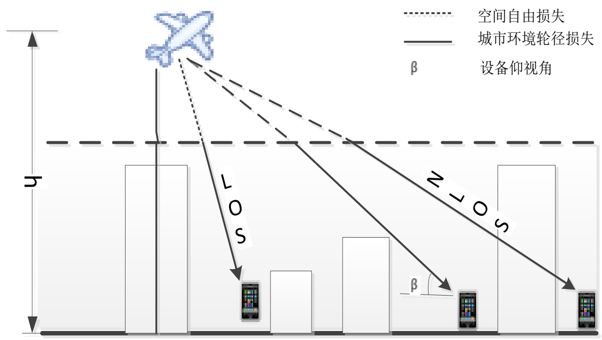

Fig. 2. Link model

Among them, the height of the building can be simulated by Rayleigh distribution as follows: $f(h_B) = \frac{h_B}{\gamma^2}\exp\left(\frac{-h_B}{2\gamma^2}\right)$, (where hB is the height of the building (In meters, and γ is an environmentally relevant parameter [29]. Obviously, due to the randomness of the building height (uncertainty) (from the perspective of the UAVs), the design is based on UAVs the probability LOS model must be considered when communicating with the system. Therefore, using the statistical parameters provided by ITU-R, other work such as [29] and [18] derived the LOS probability expression given by [8] : $P_{LoS} = \frac{1}{1+C\exp(-B[\theta-C])}$,(where C and B are constant values that depend on the environment (rural, urban, dense city, or others), and θ is the elevation angle in degrees. Obviously, $\theta = \frac{180}{\pi} \times \sin^{-1}($ h is the height of the UAVs, and d is the distance between the UAVs and the ground user. We note that the probabilistic path LOS model in (2) is an example of an existing A2G channel model, such as the model proposed by the Third Generation Partnership Project (3 GPP).

B. 3D UAVs Location Deployment

In fact, deployment is a key design consideration when using UAVs for coverage and capacity maximization, public safety, smart city, caching, and IOT applications. Therefore, the optimal deployment of unmanned aerial vehicles has received great attention [7],[8],[29],[32]-[38]. The deployment of UAVs is a challenging task because it depends on many factors, such as the deployment environment (such as the geographic area), the location of the ground users, and the characteristics of the UAVs-to-ground channel. It is itself a function of the height of the UAVs. The deployment of UAVs is more challenging than the deployment of terrestrial base stations, as is done in traditional cellular network planning. Unlike terrestrial base stations, UAVs need to be performed in a continuous 3D space while considering the impact of altitude on A2G channel characteristics. In addition, when deploying UAVs, flight energy limitations also need to be considered because they directly affect network performance.

The result of 3D location deployment can be to solve the problems of maximum coverage area, cover the most users, minimize communication energy consumption, rationalize the relay location as information transmission, reduce path LOSs, minimize the number of UAVs in the same coverage area, and rationally deploy more. UAVs, reducing interference between UAVs and so on. Other key open issues in deployment include: 1) jointly optimizing deployment and bandwidth allocation for low latency communications, 2) jointly optimized 3D layout and cell association to minimize flight time, and (3) maximizing the use of wireless coverage, Deploy obstacle-aware deployments of unmanned aerial vehicles (UAVs).

C. Energy Efficiency Problem

When operating UAVs in key scenarios such as public safety and UAVs-assisted cellular wireless networks, resource management and energy efficiency need to be highly valued. At the same time, resource management is the main challenge of cellular networks [18], [30], and UAVs pose unique challenges because: 1) the interaction between flight time, energy, path planning and spectral efficiency of UAVs, 2) Strict energy and flight

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Volume 9, Issue 9, March 2020

restrictions for UAVs, 3) LOS interference caused by aerial-to-ground and air-to-air connections, 4) unique mobility of UAVs. Therefore, it is necessary to optimize and manage. In a complex wireless UAVs-assisted wireless network, resources are distributed across heterogeneous spectrum bands and coexist with terrestrial networks.

Naturally, UAVs have limited onboard energy and must be used for transmission, movement, control, data processing, and payload . Therefore, the flight time of UAVs is usually very short and is not sufficient to provide long-term, continuous wireless coverage. The energy consumption of the UAVs also depends on the role and mission of the UAVs, weather conditions and navigation paths. This energy limitation in turn leads to limited flight and hover time. Therefore, when designing a UAVs communication system, the energy and flight limitations of the UAVs must be explicitly considered. In fact. The limited carrying capacity of UAVs is a key factor that limits the deployment and movement of UAVs in a variety of applications.

In summary, UAVs communication systems are significantly affected by UAVs resource allocation strategies and energy constraints, to effectively use UAVs for wireless network applications, must effectively manage the use of available resources, such as energy, bandwidth, and time.

IV. CONCLUSION

In this paper, we analyze the application of UAVs base stations in the field of public safety. The UAVs base station is analyzed in different secure communication scenarios. Introduce the basic development issues and challenges of the application. In the future research on UAVs base stations, we will focus on the deployment of UAVs base stations in the field of public safety, and research on the location deployment and energy consumption of UAVs.

REFERENCES

[1] K.P. Valavanis, G.J. Vachtsevanos, "Handbook of Unmanned Aerial Vehicles," Springer Netherlands, 2015.

[2] R. Austin, "Unmanned aircraft systems: UAVs design, development, and deployment," Journal.publications.chestnet.org, vol. 79, no.50, pp.31-36, 2010.

[3] R.W. Beard, T.W. McLain, "Small Unmanned Aircraft: Theory and Practice," Princeton University Press 2012.

[4] M. Asadpour, B. V. D. Bergh, D. Giustiniano, K. Hummel, S. Pollin & B. Plattner, "Micro aerial vehicle networks: an experimental analysis of challenges and opportunities," IEEE Communications Magazine vol. 52, no. 7, 141-149, 2014.

[5] R.S. Stansbury, M.A. Vyas, T.A. Wilson, "A Survey of UAS Technologies for Command, Control, and Communication (C3)," Journal of Intelligent & Robotic Systems. Vol. 54, 61-78, 2009.

[6] A. Puri," A Survey of Unmanned Aerial Vehicles (UAVss) for Traffic Surveillance," Department of Computer Science & Engineering , 2005.

[7] M. Mozaffari, W. Saad, M. Bennis, and M. Debbah, "Mobile unmanned aerial vehicles (UAVss) for energy-efficient Internet of Things communications," IEEE Transactions on Wireless Communications, vol. 16, no. 11, pp. 7574—7589, 2017.

[8] R.I.B. Yaliniz, A. Elkeyi," Yanikomeroglu, H.: Efficient 3-D Placement of an Aerial Base Station in Next Generation Cellular Networks," IEEE international conference on communications (ICC). IEEE, pp. 1-5, 2016.

[9] I. Bucaille, S. Hethuin, T. Rasheed, A. Munari, R. Hermenier, & S. Allsopp," Rapidly Deployable Network for Tactical Applications: Aerial Base Station with Opportunistic Links for Unattended and Temporary Events ABSOLUTE Example," Military Communications Conference, pp. 1116—1120, 2013.

[10] M. Mozaffari, W. Saad, M. Bennis, and M. Debbah," Unmanned Aerial Vehicle With Underlaid Device-to-Device Communications: Performance and Tradeoffs," IEEE Transactions on Wireless Communications, pp. 3949—3963, 2016.

[11] K. Kamnani, and C. Suratkar, "A review paper on Google Loon technique," International Journal of Research In Science & Engineering, vol. 1, no. 1, pp. 167—171, 2015.

[12] Q. Wu, J. Xu, R. Zhang," UAVs-Enabled Aerial Base Station (BS) III/III: Capacity Characterization of UAVs-Enabled Two-User Broadcast Channel," IEEE Journal on Selected Areas in Communications, pp. 1955-1971, 2018.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 9, Issue 9, March 2020

[13] Q. Wu, R. Zhang, " Common throughput maximization in UAV-enabled OFDMA systems with delay consideration," IEEE Transactions on Communications,vol. 66, no. 12, pp. 6614-6627, 2018.

[14] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, & M. Ayyash," Internet of things: a survey on enabling technologies, protocols, and applications," IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347-2376, 2015.

[15] T. Park, N. Abuzainab, W. Saad, "Learning How to Communicate in the Internet of Things: Finite Resources and Heterogeneity," IEEE Access, vol. 4, no. 99, 7063-7073, 2016.

[16] Y. Zeng, R. Zhang, J.L. Teng," Wireless communications with unmanned aerial vehicles: opportunities and challenges," IEEE Communications Magazine, vol. 54, no. 5, pp. 36-42, 2016.

[17] A. Al-Hourani, S. Kandeepan, A. Jamalipour, "Modeling air-to-ground path LOSs for low altitude platforms in urban environments," Global Communications Conference.IEEE, pp. 2898-2904, 2015.

[18] K. Gomez, A. Hourani, L. Goratti, R. Riggio, S. Kandeepan, & I. Bucaille, " Capacity evaluation of Aerial LTE base-stations for public safety communications," European Conference on Networks and Communications, pp. 133-138, 2015.

[19] AT&T detail network testing of UAVs in football stadiums,https://www.androidheadlines.com/2016/09/att-detail-networktesting-of-UAVss-in-football-stadiums.html.

[20] A. Merwaday, I. Guvenc," UAVs assisted heterogeneous networks for public safety communications," Wireless Communications and NETWORKING Conference Workshops, pp. 329-334, 2015.

[21] A. Ferdowsi, W. Saad, N.B. Mandayam, "Colonel Blotto Game for Secure State Estimation in Interdependent Critical Infrastructure," 2017.

[22] J. Chen, U. Yatnalli, D. Gesbert, "Learning radio maps for UAVs-aided wireless networks: A segmented regression approach," ICC 2017 - 2017 IEEE International Conference on Communications, IEEE, pp. 1-6, 2017.

[23] A. Zajic," Mobile-to-Mobile Wireless Channels. Artech House 2013.

[24] Y. Zheng, Y. Wang, F. Meng, "Modeling and Simulation of PathLOSs and Fading for Air-Ground Link of HAPs within a Network Simulator," International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery. IEEE Computer Society, pp. 421-426. (2013).

[25] J. Holis, P. Pechac," Elevation Dependent Shadowing Model for Mobile Communications via High Altitude Platforms in Built-Up Areas," IEEE Transactions on Antennas & Propagation, vol. 56, no. 4, pp. 1078-1084, 2008.

[26] S. Mumtaz, K.M. Saidul Huq, A. Radwan, J. Rodriguez, and R.L. Aguiar," Energy efficient interference-aware resource allocation in LTE-D2D communication," IEEE International Conference on Communications. IEEE, pp. 282-287, 2014.

[27] K.A.T. Zadeh, W. Saad, M. Debbah," Brain-aware wireless networks: Learning and resource management," Asilomar Conference on Signals, Systems, and Computers, pp. 1784-1788, 2017.

[28] A. Al-Hourani, S. Kandeepan, S. Lardner," Optimal LAP Altitude for Maximum Coverage," Wireless Communications Letters IEEE, vol. 3, no. 6, pp. 569-572, 2014.

[29] A.T.Z. Kasgari, W. Saad," Stochastic Optimization and Control Framework for 5G Network Slicing with Effective Isolation," 2018 52nd Annual Conference on Information Sciences and Systems (CISS), pp. 1-6, 2018.

[30] M. Mozaffari, W. Saad, M. Bennis, and M. Debbah, "Efficient Deployment of Multiple Unmanned Aerial Vehicles for Optimal Wireless Coverage," IEEE Communications Letters, vol. 20, no. 8, pp. 1647-1650, 2016.

[31] M. Alzenad, A. El-Keyi, F. Lagum, and H. Yanikomeroglu," 3D Placement of an Unmanned Aerial Vehicle Base Station (UAVs-BS) for Energy-Efficient Maximal Coverage," IEEE Wireless Communications Letters, vol. 99, pp.1-1, 2017.

[32] M. Alzenad, A. El-Keyi, H. Yanikomeroglu," 3D Placement of an Unmanned Aerial Vehicle Base Station for Maximum Coverage of Users with Different QoS Requirements," IEEE Wireless Communications Letters, vol. 99, pp. 1-1, 2017.

[33] A.M. Hayajneh, S.A.R. Zaidi, D.C. Mclernon, and M. Ghogho," Drone Empowered Small Cellular Disaster Recovery Networks for Resilient Smart Cities," IEEE

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 9, Issue 9, March 2020

International Conference on Sensing, Communication and networking, 2016.

[34] E. Kalantari, H. Yanikomeroglu, A. Yongacoglu, "On the Number and 3D Placement of UAVs Base Stations in Wireless Cellular Networks," Vehicular Technology Conference. IEEE, pp. 1-6, 2016.

[35] J. Kosmerl, A. Vilhar, "Base stations placement optimization in wireless networks for emergency communications," IEEE International Conference on Communications Workshops. IEEE, pp. 200-205, 2014.

[36] E. Kalantari, M.Z. Shakir, H. Yanikomeroglu, and A. Yongacoglu, "Backhaul-aware Robust 3D UAVs Placement in 5G+ Wireless Networks," IEEE international conference on communications workshops (ICC workshops), pp. 109-114, 2017.

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