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Saving Lives at Sea with UAV-assisted Wireless Networks

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***Abstract*—In this paper, we investigate traits and trade-offs of a system combining Unmanned Aerial Vehicle (UAV)s with Base Station (BS) or Cloud Radio Access Networks (C-RAN) for extending the terrestrial wireless coverage over the sea in emergency situations. Results for an over the sea deployment link budget show the trade-off between power consumption and throughput to meet the Search and Rescue targets.**

I. Introduction

One of the greatest crisis in Europe today is the rising number of casualties among the immigrates through the Mediterranean sea. Since 2014, more than 14,500 people have lost their lives in their attempt to reach Europe's shores [1]. Emergency rescue operations are deadly needed in the Mediterranean area. However, due to lack of proper communication infrastructures, the rescue and recovery operations in such environment are limited. The existing communications are mainly relying on the satellite service which has disadvantages such as high cost and long latency. Moreover, not all the smaller vessels and passengers own a satellite phone. For these reasons, new technologies are being investigated to provide a reliable communication over the sea for enhancing timely rescue and recovery operations. One of the interesting solutions is to extend the coverage of the conventional terrestrial wireless networks to the sea to provide wireless connections to the people in needs via UAV-assisted networks.

II. Related Work

UAVs will be used in next generation wireless networks. In the simplest form, UAVs are used as flying User Equipment (UE) or receive and forward relay for enhancing the connectivity of ground wireless devices [2].

In addition to that UAVs are able to deploy or carry aerial BSs to deliver wireless connectivity to desired areas. In particular, they can complement existing cellular systems in need of additional capacity, e.g. Long Term Evolution (LTE), or expand the cellular coverage and deliver internet services to remote and dedicated regions where infrastructure is not available or expensive to deploy [3]. Another attractive solution is UAVs acting as Remote Radio Head (RRH) [4].

In emergency networks applications UAVs, due to their properties, are a promising solution to satisfy the robustness, efficiency and rapidity requirements of Search and Rescue tasks. In [5] low cost UAVs are used in mountain terrain to survey and locate individuals who may be in distress. To the best of our knowledge, not enough attention has been given to UAV as communication provider for Search and Rescue operations in the sea.

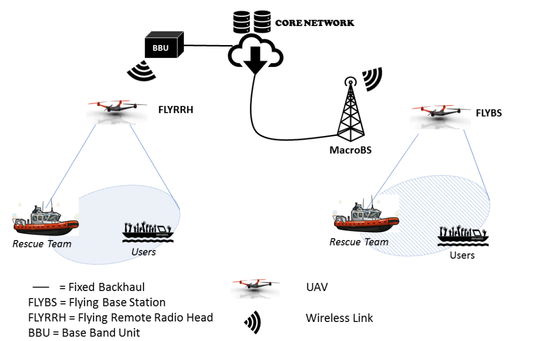

Fig. 1. Graphical illustration of the architecture for extending the cellular coverage over the sea using flying BS and RRH

III. System Description

In case of an emergency, an airborne network can be used to provide coverage for mobile users and rescue operators in areas not covered by terrestrial network [3]. In a sea scenario UAVs could be deployed to act as flying BS or flying RRH to serve the users. In this way, UAVs would ensure access to the core network through a wireless backhaul from the flying BS, or via wireless fronthaul link between the ground Base Band Unit (BBU) and the UAV-RRH (see Figure 1). Moreover, the altitude of UAVs allows a direct connection to the users. As a first consequence, we consider for the UAV-users and UAV-cloud links Line of Sight (LOS) connections. As second, we can operate at millimeter Wave (mmWave) band. At these frequencies, taking into consideration an extra attenuation due to dry air and water vapor, the free space path loss model is the most accurate representation of the path loss occurring over the sea [6].

IV. UAV as RRH or BS

The deployment of UAV-assisted cellular networks struggle with issues at different levels. In particular, mechanical and power limitations affect the choice on

TABLE I
CHALLENGES COMPARISON

Challenge	*FLY-BS*	*FLY-RRH*
Power dissipation	Transmission Power, Computation Power	Transmission Power
Computation Power	at BBU	cloud/caching computation functions
Load	more than 2kg	1 kg
Limitation	Backhaul Capacity	Fronthaul Capacity
Processing	UAV	Cloud
Cooling	Passive	Passive

the communication technology to be mounted on the aerial platform [7]. Thus, a trade-off between throughput, complexity, weight and power consumption of the access solution must be investigated.

Flying cellular BS can potentially provide high data rate wireless services to several users. High throughput communication would enable applications like video streaming, but it would contribute also to an increase in the consumed power for data processing at the BS. UAVs have a limited amount of on-board energy which must be used for all its tasks. An increase in the volume of traffic reduces the energy available for hover and flight time, key resources for Search and Rescue operations over the sea. The other side of the coin is that a limited transmission power restricts the mobility of the UAV, that may need to assist rescue team and users in distress and reach the core network also at long distances from the land. The deployment of antenna arrays on the UAV can provide a useful gain to reduce the required transmission power at the front end, but the effect on the total consumed power must be investigated. Hence, the trade off between power consumption and system throughput requires careful consideration as it can significantly impact the performance of the UAV communication over the sea.

C-RAN has been proposed to enhance resource management and reduce power consumption at the edge by centralising the baseband processing. The implementation of RRH on UAV within a C-RAN system can represent a promising approach that combines the benefits of an aerial communication with the ones given by a cloud architecture [4]. Due to their compact size and lighter weight, RRH platforms are more suitable for energy limited UAVs. In addition, all digital signal processing will be performed at BBU, requiring the UAVs lower computation power. Moreover, the power efficient design of RRH would not require an active cooling system on the UAV, leading to lower energy consumption. All these advantages allow UAVs to save power in exchange of a longer activity without affecting the quality of the transmission. Though this approach seems to encourage the deployment of UAV-assisted networks for Search and Rescue operating over the sea, challenges remain. A main challenge is the limited capacity of the wireless fronthaul, that leads to a trade off between number of UAVs for hovering, data rate and energy consumption.

V. RESULTS

We have simulated the target Equivalent Isotropic Radiated Power (EIRP) required to overcome the path loss over the sea at mmWave frequencies delivering an uplink throughput of 1 Gbps. For increasing path loss values, we have computed the array gain to be introduced on the UAV to mantain the EIRP and the resulting consumed power [1] (see Fig 2). This work shows for the proposed approaches the trade off between the targets of mobility and data rate given a limited average output power and power consumption.

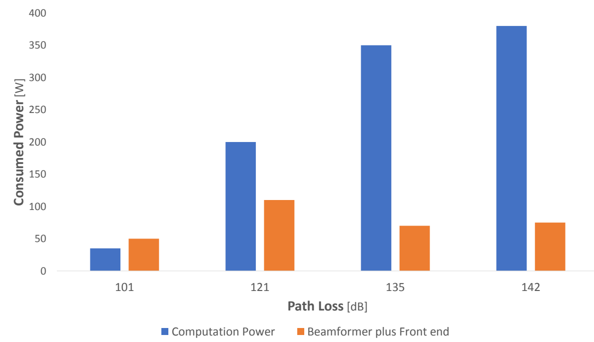

Fig. 2. Power consumption of a UAV-assisted wireless network at different distances from the core network

VI. CONCLUSION

We investigated flying BS and flying RRH as promising architectures to provide wireless coverage over the sea for Search and Rescue operations. For the proposed approaches, we have evaluated the feasibility of satisfying needs and power constraints.

REFERENCES

[1] I. D. A. Centre, "The central mediterranean route: Migrant fatalities," *CoRR*, vol. abs/1710.03701, 2017. [Online]. Available: https://missingmigrants.iom.int/sites/default/files/c-med-fatalities-briefing-july-2017.pdf

[2] Y. Zeng, R. Zhang, and T. J. Lim, "Wireless communications with unmanned aerial vehicles: opportunities and challenges," *IEEE Commun. Mag.*, vol. 54, no. 5, pp. 36–42, May 2016.

[3] H. Ahmadi, K. Katzis, and M. Z. Shakir, "A novel airborne self-organising architecture for 5G+ networks," in *IEEE VTC17-Fall*, Sept 2017, pp. 1–5.

[4] M. Chen, M. Mozaffari, W. Saad, C. Yin, M. Debbah, and C. S. Hong, "Caching in the sky: Proactive deployment of cache-enabled unmanned aerial vehicles for optimized quality-of-experience," *IEEE Jour. Sel. Areas in Commun.*, vol. 35, no. 5, pp. 1046–1061, May 2017.

[5] S. O. Murphy, K. N. Brown, and C. Sreenan, "Demo: Cellphone localisation using an autonomous unmanned aerial vehicle and software defined radio," in *Proceedings of the 2017 International Conference on Embedded Wireless Systems and Networks*. Junction Publishing, 2017, pp. 254–255.

[6] W. Khawaja, Ö. Özdemir, and I. Güvenç, "UAV air-to-ground channel characterization for mmwave systems," *CoRR*, vol. abs/1707.04621, 2017.

[7] S. Chandrasekharan, K. Gomez, A. Al-Hourani, S. Kandeepan, T. Rasheed, L. Goratti, L. Reynaud, D. Grace, I. Bucaille, T. Wirth *et al.*, "Designing and implementing future aerial communication networks," *IEEE Commun. Mag.*, vol. 54, no. 5, pp. 26–34, 2016.

[8] X. Ge, J. Yang, H. Gharavi, and Y. Sun, "Energy efficiency challenges of 5g small cell networks," *IEEE Communications Magazine*, vol. 55, no. 5, pp. 184–191, May 2017.

[1] values of computation power taken from [8]