Engineering Networks in the Sky: Challenges and Potential

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***Index Terms*—UAV, RAN, Core, Backhaul, mmWave, 5G**

I. Motivation

Mobile connectivity has become pervasive akin to a basic utility like electricity or water. However, making this utility available to a significant chunk of the world's population in several developing and rural parts of the world, is still not economically viable. In addition, even in places, where such a connectivity infrastructure exists, one cannot completely rely on it in times of natural calamities and disasters, where it can be significantly compromised. Thus, while mobile cellular networks have ushered in an era of abundant data-rates, their 5G vision to deliver true "ubiquitous" connectivity still remains unfulfilled.

With recent significant advances in autonomous systems (unmanned aerial vehicles, UAVs and terrestrial autonomous ground vehicles, AGVs) and their proliferation in various everyday applications (delivery, transportation, etc.), one can now envision dynamic connectivity infrastructures that can be deployed and torn down "on-demand" by leveraging such platforms. This is further catapulted by the recent space race to deploy LEO satellite-based internet connectivity, of which project Starlink [1] and Kuiper [2] are great examples. Such autonomous systems in the sky have the potential to change the landscape of wide-area wireless connectivity by bringing a new dimension – "mobility" of the cellular network infrastructure itself. The goal of this tutorial is to expose the audience to both the challenges underlying the end-to-end design, as well as the potential unleashed by these new class of networks.

While Google's Project Loon is an example of high-altitude, long-endurance UAV-based connectivity effort in this direction, the telecom operators have been exploring low-altitude UAV-based LTE solutions for on-demand deployments as well. By deploying base stations on each of the UAVs, service providers can now deploy and tear-down these cellular networks "in the sky" in an on-demand and flexible manner. This allows them to supplement static mobile networks in areas where additional connectivity is needed, or provide stand-alone connectivity in areas where existing mobile networks are either absent or compromised. Understandably, these projects are in their early stages – realizing this vision of deploying heavy-weight cellular networks (e.g. LTE or 5G-NR) on light-weight, resource-constrained platforms such as UAVs, faces several formidable challenges both in design and deployment.

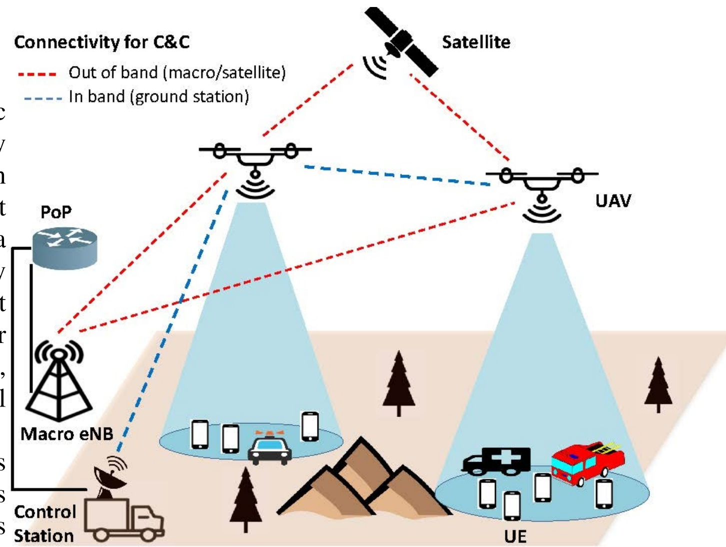

Fig. 1. Low-altitude UAV Network for Connectivity and Sensing

This is complicated by the complex nature of cellular networks that involve multiple interacting components – radio access network (RAN), evolved packet core (EPC) network and backhaul transport network.

The tutorial aims to discuss the end-to-end design space of such UAV-based connectivity networks particularly in the context of low-altitude UAV networks providing cellular connectivity. As an important step in this direction, it will unravel the challenges that span across multiple layers (access, core network, backhaul) in an inter-twined manner as well as the richness and complexity of the design space itself. It aims to help network practitioners navigate this complex design space towards a solution, with the help of a concrete end-to-end system called SkyLiTE [3] that we have architected, built and deployed. SkyLiTE is a self-organizing network of low-altitude UAVs that aim to provide optimized mobile connectivity and sensing capabilities in a desired geographic region 1, while leveraging both sub-6GHz and mmWave bands. "SkyLiTE" system is one of the first efforts to design and deploy an on-demand, un-tethered, multi-cell LTE network (on UAVs) that can self-configure itself in the sky. It consists of three main components - SkyRAN [5], SkyCore [4] and

SkyHaul [6] that re-architect the various components (RAN, core and backhaul transport respectively) of a cellular network, to make it deployable on challenging UAV platforms in highly dynamic environments.

In summary, the tutorial envisions to educate and help spur further innovation in this space and contribute to a new era of mobile networks that can be flexibly deployed at low cost and make connectivity and sensing, both abundant and ubiquitous.

II. Table of Contents

The following topics will be covered in the tutorial.

- Part 1
  - Current landscape of UAV and LEO satellite based network connectivity
  - Challenges in designing an end-to-end mobile network connectivity solution for Low-altitude platforms
  - Radio Access Network
    o Challenges, Design, Deployment
  - Mobile Core Network on the Edge
    o Challenges, Design, Deployment
- Part 2
  - Giga-bit Mesh Backhaul
    Challenges, Design, Deployment
  - Sensing Applications
    o Real-time tracking in GPS-denied environments
    o Real-time 3D reconstruction of environments
  - Potential Research Directions

III. Tutorial Format and Logistics

The tutorial will be delivered as a 3-hour talk remotely. The audience can participate over a video link without the need to access any hardware. Since the speaker will be remote, it might be best to host it for an online audience (or hybrid if deemed appropriate). The intended audience for this tutorial would include both undergraduate and graduate students as well as academic/research professionals and network practitioners interested in understand and exploring the design space of UAV-based connectivity and sensing solutions.

IV. Speaker Bio

Karthikeyan (Karthik) Sundaresan is a Professor in the School of ECE, Georgia Tech. Prior to that he spent fifteen years in wireless and telecom research at NEC Labs America, Princeton. His research interests are broadly in wireless networking and mobile computing, and span both algorithm design as well as system prototyping. He is the recipient of ACM Sigmobile's Rockstar award (2016) for early career contributions to mobile computing and wireless networking, as well as several best paper awards at prestigious ACM and IEEE conferences. He holds over fifty patents, and received business contribution awards for bringing research technology to commercialization at NEC. He also led the spin-out effort of an innovative, lab-grown research technology (TrackIO) for infrastructure-free tracking of first responders in GPS-denied environments. He has participated in various organizational and editorial roles for IEEE and ACM conferences and journals, and served as the PC co-chair for ACM MobiCom'16. He is a Fellow of the IEEE and an ACM distinguished scientist.

References

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