Cyber-Physical System Foundation to Enable Robust Airborne Networking in the National Airspace System

Yan Wan, Assistant Professor
Electrical Engineering, University of North Texas
Address: 3940 N. Elm Street, Discovery Park B261, Denton, TX, 76207
Email: Yan.wan@unt.edu, Phone: 940-369-5115
Web: https://engineering.unt.edu/electrical/drwan/home

Unmanned airborne networks (ANs) which utilize flight-to-flight communication for information exchange, safe maneuvering, and the coordination of time-critical missions are envisioned as an appealing platform for future civilian transportation and information systems. Promising applications of ANs include next-generation air traffic control, search and rescue, surveillance, cargo transportation, and on-demand creation of communication network infrastructure after disasters, among others. These applications are made possible by the unique advantages of ANs, such as transportability, wide coverage and unmanned maneuvering, and also by direct flight-to-flight communication schemes such as small delay, high throughput and flexibility.

Despite the exciting advantages and applications, ANs using direct in-flight communication do not yet exist in the National Airspace System (NAS), except for few simple proof-of-concept field tests. Enabling reliable ANs in the NAS needs to conquer daunting technical challenges and operational issues. Major technical challenges include the following. Firstly, high mobility and frequent network topology variation cause difficulty to maintain communication connectivity. Secondly, unlike ground vehicles, aerial vehicles have stringent maneuvering requirements to maintain safety. Thirdly, the addition of ANs into the NAS further reduces already limited airspace resources. Unmanned ANs need to respond in a timely manner to the highly dynamic and uncertain airspace environment, affected by convective weather, traditional traffic, wind, birds, and other vehicles.

In order to enable robust ANs in the NAS, we need to build a novel Cyber-Physical System (CPS) foundation for the design and evaluation of ANs. We note that ANs represent a highly challenging CPS, in which the physical mobility, control, and response to complex environment are the physical components, and sensing, data processing, and network communication are the cyber components. These components need to be seamlessly integrated. In particular, the evaluation and design of multi-hop networking protocols is no longer a traditional communication problem, but need to consider the unique mobility attributes of aerial vehicles. Similarly, the cooperative control of ANs for a variety of missions cannot be simply treated as a decentralized control problem, but also need to consider challenging realistic communication issues such as delay, throughput, and highly dynamic and unsteady communication topologies. In addition, both communication and control need to consider uncertain environmental impact, and nimbly adapt to environmental conditions. New fundamental theories, tools, test-beds, and educational activities are badly needed to build the above CPS foundation for ANs, and prepare future workforces to in this and broad CPS areas.

We envision that the above development will produce far-reaching societal impact in enabling a range of civilian AN applications, and as a consequence significantly enhance national security, save human lives in natural or man-made disasters, reduce revenue loss, and increase the efficiency of transportation networks.