Traffic Management Challenges in Advanced Air Mobility by Hamsa Balakrishnan, 5/18/23

Jason Luo

Part I. Literature (for further reading about Advanced Air Mobility)


Part II. Recent News


Part III: Q&A

Jinhua Zhao notes that there are around 100 flights in Paris daily, so even if it is increased 200-fold, it is a far cry from the millions of vehicles. He asks about the two contrasting control philosophies and asks which side this field will go towards, as well as if there is a third option.
Hamsa responds by saying that one approach that she has used so far is that in extreme cases a comparison can be made to say that things may work in the air if they work on the road. However, for planes, the costs are much higher. Affordable inefficiencies on the ground may not be affordable in the air, meaning the kind of inefficiencies that you have in a congested city may not translate to a viable business model for the air. Also the industry is moving towards having someone else in charge of responsibility which incites competition. Service providers are incentivized to say "Use my airspace because it is more efficient". The right answer might be somewhere in between.

Jinhua mentions that the safety standards and norms for air traffic and road traffic are very different. He asks if the idea for this technology is to enforce zero tolerance for accidents or will there be some allowable threshold.

Hamsa says the community is a bit divided on this issue. Some people want similar standards of safety as commercial aviation. In theory aircraft are supposed to tactically avoid each other but when the amount of aircraft gets higher we have less of an idea of what might happen. We do have large collections of drones that avoid each other but that is different from what it would be like in a competitive environment with multiple different operators.

Later questions were more or less answered in aggregate.

Alex Jacquillat asks about the potential impact of weather on the reliability and safety of the system.

Hamsa responds by saying that weather conditions can pose challenges, mostly for smaller and cheaper aircraft. Urban environments in particular may have wind tunnels that may impact the stability of these aircraft. Having a good understanding of weather impacts is an important topic, and businesses are incentivized to have drones that are resistant to bad weather conditions.

Alex asks about the unintended consequences of these systems such as public acceptance and noise impacts.

Hamsa says that public acceptance and noise impacts are indeed important considerations. This answer also ties into the next question about early deployments being in rural areas. Additionally public acceptance will depend on public perception on reliability, safety, and affordability.

Thomas Magnanti asks whether early deployments of this will be in rural areas or specific neighborhoods.

Hamsa says that the first deployments are indeed likely to be in rural areas for disaster response scenarios because these areas have fewer alternatives, implying a greater need. Also, use of this technology in cities will be a long road because there are issues such as public acceptance, safety, infrastructure, etc. The answer will also depend on equity concerns.

Part IV. Summary of Memos.

Themes from memos:

Safety is a key factor. People need to be able to believe that the technology is safe before it can be widely adopted. This can be done through ads and public events.
Collaboration between different companies is important to make a sufficient infrastructure network to support this kind of technology. Attention needs to be paid to make it not only profitable but also sustainable.

Many of the typical considerations of factors for regulation of transportations systems apply here: public acceptance, fairness, privacy, competition, efficiency, safety, etc. Many memos mentioned similarities between more common areas of research such as EVs and autonomous vehicles with urban air mobility.

The idea of having a big company such as Amazon own the logistics and delivery systems of this technology was mentioned. There was also discussion about nationalizing a company like Uber to get such a technology up and running.

My Reflection

This week we had the pleasure of listening to Hamsa Balakrishnan give a talk on some of the largest challenges and open questions ahead for advanced air mobility, or the use of autonomous aircraft as a form of transportation. More than a century ago, there were already test flights for this technology. However, a century later, this technology is still yet to be efficiently and safely usable on a regular basis. One barrier to this is the lack of investment in traffic management systems for this type of new technology, where difficulties arise from having multiple operators with potentially limited communication. Balakrishnan discussed the shift to venture capital to raise funds for this technology, where there is a large potential upside for companies even in the face of these issues. These issues are compounded when the aircraft are autonomous and numerous, leading to the desire for some sort of centralized traffic control system. Thus, there is a need to perform further research to address these issues. In addition, dealing with efficiency when scalability gets in the way may be another issue. Also, the technology would have to be able to balance different objectives for competing interests, such as fairness, equity, safety, privacy, etc. Balakrishnan also talked on ideas involving public policy and regulation for the new technology. Overall I thought professor Balakrishnan's talk was very informative and served as a great introduction to problems in the sphere of autonomous aircraft. This information can be used by researchers in closely related areas to potentially apply their research in a previously unanticipated area. In that way, it seems that this is a very effective presentation for a seminar where there are transportation researchers of all kinds and many with no background in an area related to autonomous aircraft.

Part V. Other Information


Traffic Management Challenges in Advanced Air Mobility

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MIT Mobility Forum, April 2023
The Vision of Advanced Air Mobility

Image: NASA: https://www.nasa.gov/aero/taking-air-travel-to-the-streets-or-just-above-them
More Than a Century of Transformation in the Air

[Lawrence Sperry and Emil Cachin, 1914]
More Than a Century of Transformation in the Air

“Air Force officers speculated on the possibility of loading robot planes... For peaceful purposes, it was suggested that they might be used as cargo carriers.”

The New York Times, September 23, 1947
The Changing Skies

Future of urban mobility
My kind of flyover

Artist’s rendition: Airbus. Vehicle images: Amazon Prime Air, Joby Aviation, CNN/Alphabet Wing
The Changing Skies

20,000 flights per hour over Paris by 2035

2-3 million sUAS by 2023

[Airbus UTM Blueprint for the Skies, 2018] [FAA UTM Concept of Operations, 2020]
$5bn USD investment in eVTOL sector in 2021

Aerospace America, Apr ’22

$7.9bn USD investment in the global drone industry in 2021


$4.8bn USD investment in the global drone industry in 2022

Emerging System Challenges

Unprecedented numbers

20K flights/hr over Paris
2-3M small drones

How do we achieve efficiency at these scales?

New competitive landscape

- United
- Delta
- AirFrance
- KLM
- Amazon Prime Air
- Joby
- Wing

A Star Alliance Member
Emerging System Challenges

Unprecedented numbers

20K flights/hr over Paris
2-3M small drones

How do we achieve efficiency at these scales?

New competitive landscape

How do we improve privacy and incentivize information sharing?

New privacy concerns

Fairness to users

How do we equitably serve airspace users with differing priorities?
Who Manages Advanced Air Mobility Traffic?

“[T]he FAA will not play an active operational role in managing the UAM aircraft [similar provisions for UAS] under nominal conditions (i.e., ATM services will nominally not be actively provided by the FAA to UAM aircraft).”
Three Challenges Highlighted Today

• How can a service provider manage traffic (of different fleet operators) in an efficient and fair manner?

• How can a fleet operator serve its customers in an efficient and fair manner?

• How can we incentivize cooperation among different service providers?
Three Challenges Highlighted Today

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A Service Provider’s Challenge: Very Large-Scale Traffic Flow Management

- Distributed optimization algorithms for large-scale air traffic flow management
- Protocol-based ("rules-of-the-road") AAM congestion management algorithms that prioritize different fairness metrics
  - e.g., balance delays or excess delays across aircraft operators
  - Cost-aware congestion management protocols

Chin et al. ATM Seminar 2021; Qin & Balakrishnan ICRAT 2022.
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A Fleet Operator’s Challenge: Navigating Efficiency-Fairness Tradeoffs in Shared Mobility

**Fleet of 5 drones** (battery life of 15 min)

Five apps (customers) that submit sensing tasks

**Traffic**
- Speed (m/s): 5.6 m/s, 5.2 m/s, 7.2 m/s

**Parking**
- Image: 12 parked cars

**iPerf**
- TCP Tput (Mbps)

**Air Quality**
- PM 2.5 sensor (measured PM 2.5: 5.6 m/s, 5.2 m/s, 7.2 m/s)

**Roof**
- Image: Residential roofs

Sensing tasks are spread over a city

Cambridge, MA

How do we efficiently multiplex tasks from different applications on each flight, but also share the throughput equitably across applications?

Balasingam et al., ACM Mobisys 2021
Navigating Efficiency-Fairness Tradeoffs in Shared Mobility Platforms: Mobius

Fleet of 5 drones (battery life of 15 min)

Five apps (customers) that submit sensing tasks

Sensing tasks are spread over a city

Cambridge, MA

Traffic
Parking
iPerf
Air Quality
Roof

Continuous monitoring
Measure every 10 min
Cyclic monitoring
One-time tasks
One-time tasks

TCP
Tput
\( \text{(Mbps)} \)

Roof app joins late

Recharge
Traffic
Parking
iPerf
Air Quality
Roof

Balasingam et al., ACM Mobisys 2021
Three Challenges Highlighted Today

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• How can we incentivize cooperation among different service providers?
A System Designer’s Challenge: Incentivizing Cooperation Among Service Providers

We focus on the Service Providers (SP) i.e., the PSU or USS, providing traffic management services.
What is Expected of Service Providers?

• Federated set of (possibly private) actors over a distributed PSU network

• Multiple PSUs can provide services in the same geographical area

• Same entities could play multiple roles (e.g., aircraft operators and service providers)

• Strategic deconfliction (i.e., demand-capacity balancing) is exercised by PSUs (e.g., through congestion management protocols)

• PSUs could support tactical deconfliction: primarily responsibility of aircraft operators
A Notional Illustration of AAM Airspace

- Federated, possibly private SPs
- Multiple SPs can provide services in the same geographical area
- Same entities could be aircraft operators and service providers

Our solution approach:
Design a profit-sharing mechanism that incentivizes cooperation between traffic management service providers
Open Challenges

- Federated, possibly private SPs
- Multiple SPs can provide services in the same geographical area
- Same entities could be aircraft operators and service providers

Open Challenges:
Interaction with intra-SP traffic management

How do multiple SPs manage traffic in the same airspace?

Mitigating “net-neutrality” type effects
When do market mechanisms work and when is regulatory action necessary?
“Walmart and DroneUp will offset the cost of delivery with revenue from other drone-related services, such as insurance inspections, emergency response and construction oversight”

“Walmart's DroneUp delivery network will expand to 34 sites by the end of the year, potentially reaching 4 million U.S. households”
Traffic Management Challenges for AAM

Unprecedented numbers

New competitive landscape

New privacy concerns

Fairness to users

Provide efficient, equitable, and sustainable airspace access for a wide range of Advanced Aerial Mobility vehicles and services