Analyzing the Resilience of the Global Aviation Network

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1. Introduction

The global air travel system is a vast and intricate network connecting thousands of cities worldwide. This high level of connectivity allows for the efficient movement of people and goods. However, it also means that disruptions—whether due to weather, conflict, or technical issues—can quickly spread, causing widespread delays and disconnections far from the original source.

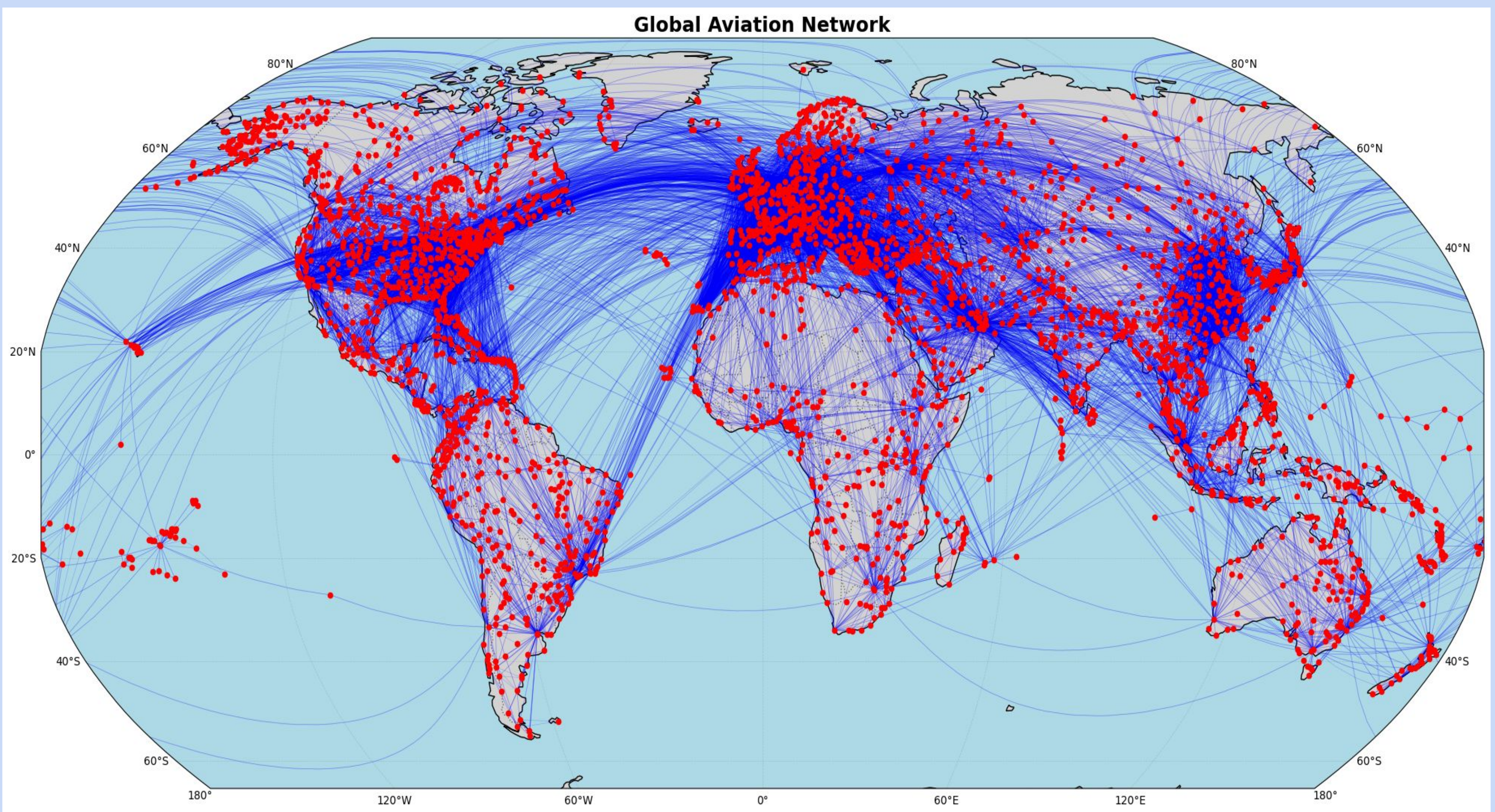


Figure 1: Global Aviation Network

2. Research Questions

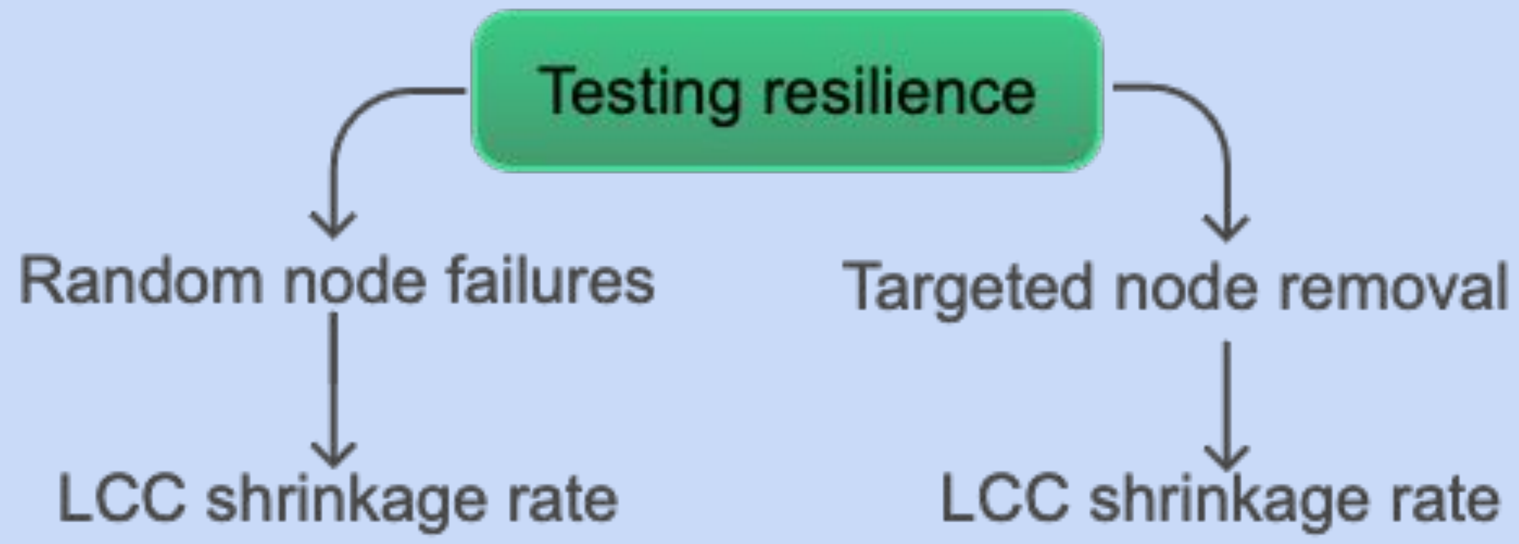
1. How many airport failures can the global flight system handle before it breaks down? (failure here is defined as when the largest component falls below, say, 50% of the original nodes)
2. How quickly does the system fall apart as more airports stop functioning?
3. Is the system more vulnerable to targeted disruptions at major airports than random disruptions to airports?
4. What happens to global air travel if an entire region's airports are shut down?

3. Datasets

- Sourced global **airports and routes data** then from the [OpenFlights GitHub repository](https://github.com/jpatokal/openflights/tree/master/data), which can be accessed here: https://github.com/jpatokal/openflights/tree/master/data .

4. Methodology

- To assess the network's robustness and vulnerability, we conducted the following analysis:



- Used **Louvain algorithm** to cluster airports into functional regions.
- Stimulated failure in each community and measured the **impact on the LCC.**

5. Results

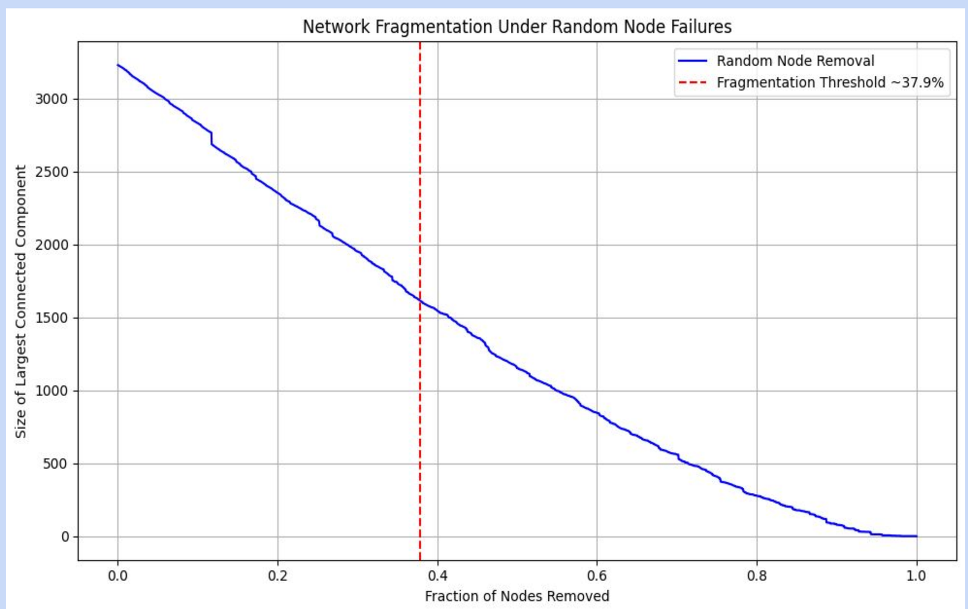


Figure 2: Random attack simulation on the network

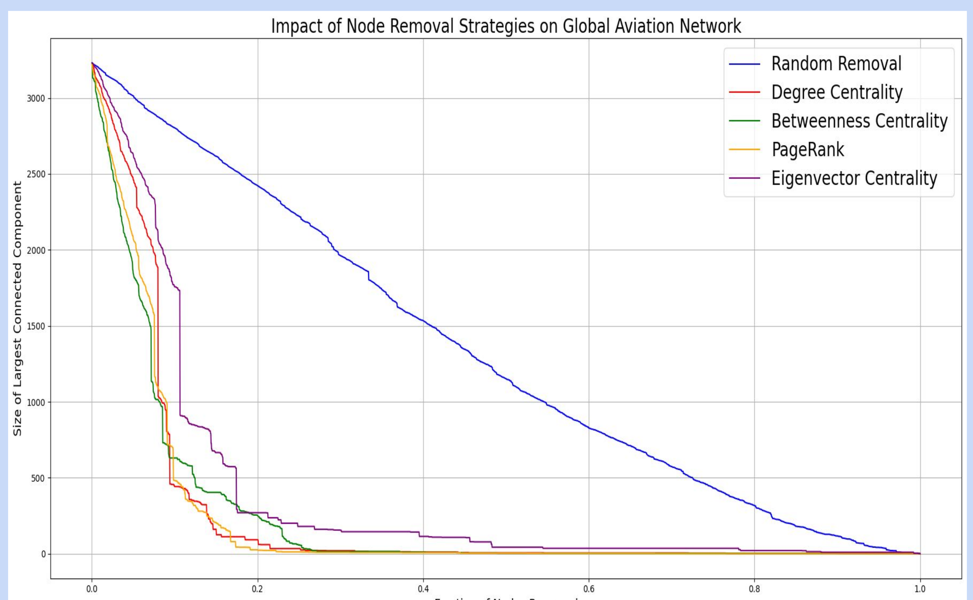


Figure 3: Random and Targeted attack simulation on the network

- The network fragmented after **37.9%** of the nodes were randomly removed.
- The network was observed to be **robust** under random failures, **fragile** under targeted attacks.
- The LCC size **drops sharply** with the removal of just a small fraction of highly central nodes.

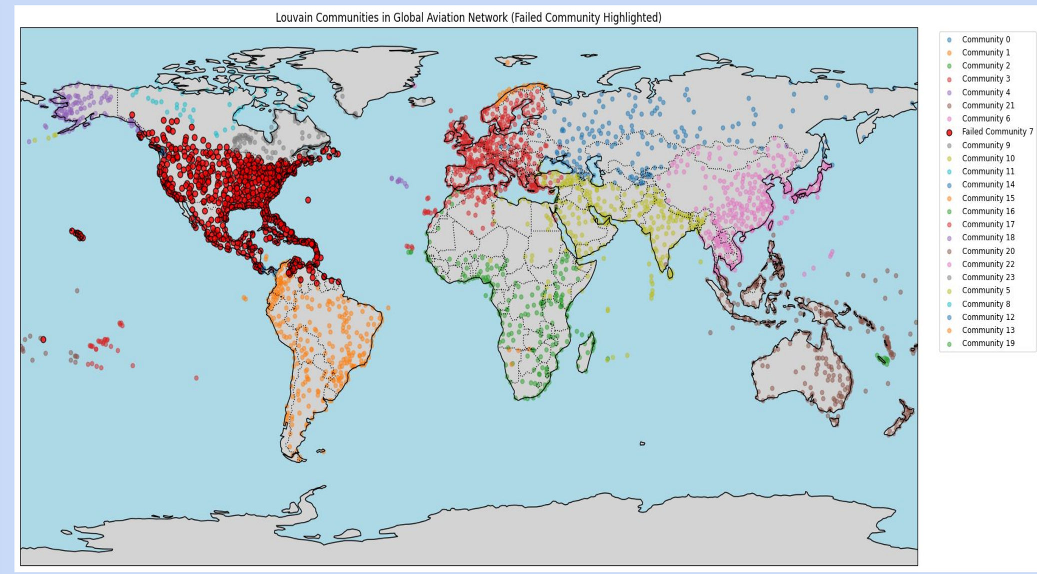


Figure 4: Largest failed(highest impact) community highlighted

- North American community is the l**argest community**, with 663 nodes.
- LCC before: 3231, after removal LCC: 2431; Impact: **24.76%**
- Significant but not catastrophic global fragmentation.

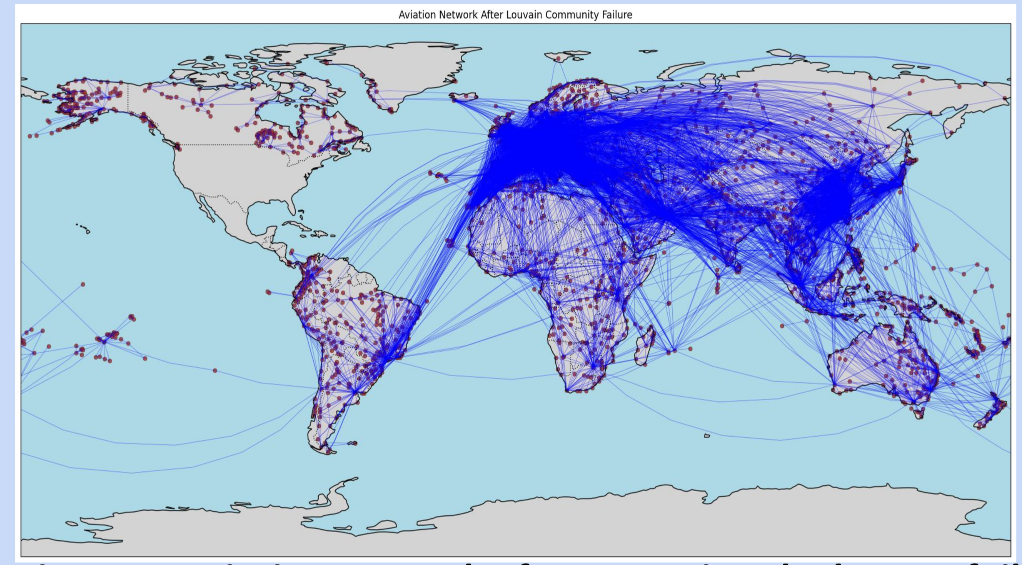


Figure 5: Aviation network after removing the largest failed community

- Even though only one community failed, the effect was not localized—it fragmented parts of the global network.
- Post-failure, Europe becomes a global rerouting hub.
- The network is still largely operational.

6. Conclusions

- The global flight network **can handle random failures** well. Even if many airports (<38%) shut down unexpectedly, the system keeps working without falling apart quickly.
- But if a few **major airports** are knocked out, the entire global network can **collapse fast**.
- When a large region, like the **U.S. air network,** shuts down, it causes much **bigger disruptions** because it controls a huge share of airports and flights. But with plenty of backup routes and alternative paths, even such **major breakdowns don't completely stop** worldwide travel.

7. References

- A. Barabási, "Network science by Albert-László Barabási," BarabásiLab, http://networksciencebook.com/
- Airport, airline and route data, https://openflights.org/data.php

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