# A Percolation Theory Based Approach for Identification of Bottleneck Links in an Airway Network

Chunyao Ma*, Qing Cai†, Sameer Alam‡, Vu N. Duong§
Air Traffic Management Research Institute, School of Mechanical and Aerospace Engineering
Nanyang Technological University, Singapore
Email: *M180146@e.ntu.edu.sg, {†qcai | ‡sameeralam | §vu.duong}@ntu.edu.sg

Abstract— The ever increasing demand for air travel is likely to induce air traffic congestion which will elicit great economic losses. As air traffic congestion usually originate and propagate from a small region in an airway network, it is becoming important to identify the bottleneck links of an airway network. In this paper, we characterize the organization of air traffic flow as a percolation process. From a percolation process, it can be observed that the global air traffic is dynamically formed by clusters of local air traffic flows which are connected by the bottleneck links. We developed a data driven method to identify such bottleneck links in an airway network based on percolation theory. This method aims to identify links, at the percolation threshold, whose malfunction potentially disintegrate the global air traffic flow into large isolated local flows. These links are identified as bottleneck links since they reduce the efficiency of air traffic flow in the airway network and induce air traffic congestion. With the proposed method, we have carried out a case study on Singapore airway network using one month ADS-B data. Results show there appears to be a presence of airway links that may be bottlenecks in Singapore airway network. When the bottleneck links are dysfunctional, large-scale local traffic flows are unable to exchange freely which can lead to global traffic congestion. This provides an approach to manage air traffic congestion with minor adjustments such as improving the flight efficiency on the bottleneck links.