

SlotMachine – A Privacy-preserving Marketplace for Slot Management

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To enable more efficient management of airport departure and landing slots, SlotMachine envisions a new kind of marketplace in air traffic management. The platform will enable a more flexible, fast and scalable semi-automated flight prioritisation process for airlines in a fair and trustworthy way. Built with a privacy-first approach it will protect sensitive airline data from competitors and airport operators but fully unleash the potential of inter-airline slot swapping.

In times of growing air traffic and limited capacity, it is crucial to improve the utilisation of resources (airports, airlines and air navigation service providers) and to mitigate the economic impact of disruptions. When airports operate at the limit of their capacity, a small disruption, e.g., bad weather, may cause delays to many flights. Delays result in additional costs for airlines, such as compensation for passengers and costs associated with crew changes. To minimise the overall costs caused by delays, airlines want to be able to dynamically rearrange and prioritise certain flights. This is already possible within a fleet [1] but to minimise costs, airlines need to be able to prioritise delayed flights across airline boundaries and would like to do so without prolonged negotiations. This is inherently difficult because airlines as competitors are very careful not to disclose any business secrets such as the flight-specific

estimated costs associated with delays of different severities.

SlotMachine [L1] tackles this challenge by combining tools for privacy preserving computation on data based on multiparty computation (MPC) with evolutionary algorithms and blockchain technology to build a decentralised system that enables collaboration for optimal flight sequencing in challenging conditions. It introduces a new approach to cooperative slot management and establishes a platform for on-demand automated operation. The platform serves as a marketplace for airlines with the overall aim of developing a novel flight prioritisation platform – the SlotMachine architecture – to improve the use of available resources at airports and reduce costs for airlines.

To achieve this, secure and trustworthy modules for optimisation of flight lists

based on evolutionary algorithms are combined with privacy preserving methods based on cryptography to protect sensitive input data from individual participants while optimising operation at airports. Finally, a proof-of-concept implementation offering privacy-preservation will also demonstrate how fairness and equity will be guaranteed in the long run by managing delay associated tokens in a blockchain.

In general, the following phases must be supported in hotspot situations when demand by airlines exceeds the airport capacity, typically because of unplanned events rendering the original flight plan unfeasible.

(1) When identifying a hotspot, the air traffic manager (ATFM) needs to reschedule flights to later slots, imposing delays. With SlotMachine in place, ATFM then initiates a flight pri-

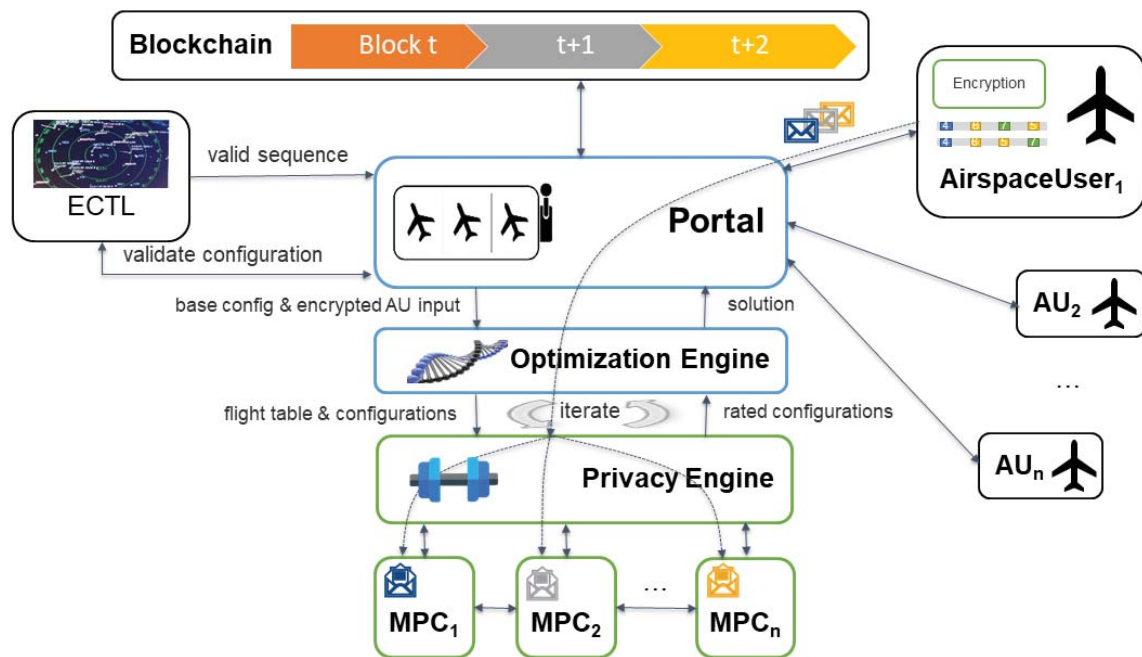


Figure 1: SlotMachine architecture with main components. Inputs provided by airspace users are processed within the privacy engine, used by the optimisation engine and served over the portal. Final results are approved by the network manager (Eurocontrol) and recorded in a blockchain.

optimisation process – with the goal of finding a better reconfiguration.

(2) During the flight prioritisation process airlines submit preferences for their flights (i.e., margins: time-not-before/time-not-after). Preference values may represent cost savings or additional costs. SlotMachine guarantees to process preference values in a privacy-preserving manner in order not to disclose a flight’s cost structure to any party, not even to the SlotMachine platform provider. In fact, all sensitive data reside within the privacy engine (PE) which is based on MPC and guarantees that sensitive information is never used in plaintext within the system, which still allows for reasonable performance in the optimisation [2]. The PE assists the optimisation process and assures that input data is well-formed according to the rules for fairness and equity.

(3) The goal of a flight prioritisation process is to find a near optimum reconfiguration by considering airlines’ constraints and private preference values as well as ATFM/ATC’s constraints and appropriateness criteria. The combinatorial size of the problem means that it is not feasible to find an optimum reconfiguration. Evolutionary algorithms make it possible to find near optimum solutions for such complex problems. In evolutionary configuration

optimisation, the constraints of airlines and ATFM/ATCs, including possible slots for flights, guide the generation and recombination of reconfigurations.

(4) SlotMachine will also keep track – in a privacy-preserving manner – of positive and negative benefits for each airline in a way that guarantees equity in the long run [3]. This will be realised by giving credit to each airline and by updating this credit after each flight prioritisation process (increasing the credit for a flight allocated to a slot with a negative preference value and decreasing the credit for a flight allocated to a slot with a positive preference value). By extending MPC with verifiability and maintaining all public data in a Blockchain accessible to all airlines, the trustworthiness of the system will be increased. Additionally, transparency can be increased by managing metadata about auctions and transactions in the blockchain in privacy preserving form using zero-knowledge proof techniques.

In summary, SlotMachine will enable a completely new form of collaboration among competing airlines to optimise air traffic by introducing more flexibility for all participants. The project is a joint effort between industry and academia, comprising all relevant stakeholders. It will contribute to a more flexible and efficient management of air traffic based on increased collaboration

between airlines and lead to better usage of existing resources thus also contributing to the European Green Deal.

Link:

[L1] <https://kwz.me/h68>

References:

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