# Abstract

This research investigates a blockchain-based queuing system that models the transaction process under varying combinations of user priority and impatience, while incorporating ON/OFF operational states to reflect the stochastic availability of block generation and the consensus phase. The system consists of two sequential queues: a customer queue, where users wait to be grouped into a block, and a block queue, where grouped users await consensus. A partial batch generation mechanism is employed, allowing up to users to be batched into a block. During OFF periods, block generation and consensus operations are suspended, although customer arrivals continue.

To capture the behavioral and structural characteristics of the system, four distinct scenarios are modeled: (1) single-class customers without impatience, (2) two-class customers without impatience, (3) single-class customers with impatience, and (4) two-class customers with impatience. For each scenario, a multi-dimensional Markov chain is constructed to describe the system state. Balance equations are derived and solved iteratively to obtain the steady-state distribution, from which key performance metrics, including throughput, blocking probability, and average waiting times, are calculated.

To validate the analytical results, a discrete-event simulation is implemented in C++, faithfully replicating the event logic and service rules of each scenario. The simulation confirms the analytical trends and highlights several notable system behaviors, including the trade-off between fairness and efficiency in non-preemptive priority settings, the performance benefits introduced by impatience mechanisms, and the system-level effects of partial batch size and ON/OFF dynamics.

**Keywords: blockchain, non-preemptive priority, impatience, batch service, ON/OFF mechanism, block generation, consensus**

摘要

隨著去中心化技術的迅速發展，區塊鏈系統的效能分析逐漸受到關注。在區塊鏈應用中，使用者提交的交易需經歷封包打包、區塊生成與共識等階段，這些程序常受限於資源限制與動態網路環境。為了精確描述此一行為，本研究採用排隊理論方法來建構區塊鏈交易模型，並著重於系統容量、服務規則與共識機制的隨機可用性。

系統由兩個有限容量的佇列組成：一為顧客佇列，用於等待被打包進區塊；一為區塊佇列，代表等待進行共識的區塊。區塊生成採用部分批次服務機制，且系統會在 ON 與 OFF 狀態間隨機切換，以模擬現實中可能發生的中斷與連線故障。此外，我們考慮更貼近現實的使用者行為，包含非搶先式優先權排程與不耐煩離開，即若等待時間超過耐心閾值，使用者可能提前離開系統。

本研究針對四種情境進行建模分析：(1) 無不耐煩的單一使用者類型、(2) 有優先權的兩種使用者類型、(3) 單一使用者類型具不耐煩特性、(4) 同時具備優先權與不耐煩的雙類型使用者。透過構建馬可夫鏈並求解平衡方程，我們取得系統的穩態機率分布，進一步計算吞吐量、平均延遲、阻塞率與離開率等效能指標。

我們使用 C ++實作成是模擬，模擬涵蓋到達事件、區塊生成、共識服務、不耐煩離開及 ON/OFF 切換等流程。模擬結果顯示，在各情境下，解析模型與模擬結果高度一致，驗證了本模型在反映使用者行為、系統穩定性與區塊鏈服務機制間複雜互動的準確性與實用性。

**關鍵字：區塊鏈、非搶佔優先權、不耐煩、批量服務、隨機可用性。**