UNDERGRADUATE THESIS

ACCURACY AND INFERENCE TIME OPTIMIZATION USING MULTI-OBJECTIVE XGBOOST ON THE NF-UNSW-NB15 DATASET

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INFORMATICS STUDY PROGRAM
SURABAYA
2026

APPROVAL SHEET

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ABSTRACT

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Thesis Title: ACCURACY AND INFERENCE TIME OPTIMIZATION USING MULTI-OBJECTIVE XGBOOST ON THE NF-UNSW-NB15 DATASET

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In the era of digital transformation, Network Intrusion Detection Systems (NIDS) serve as a critical frontline against cyber threats. However, modern machine learning-based NIDS often experience evaluation bias, orienting exclusively toward maximizing detection accuracy while neglecting computational inference latency, which can cause catastrophic packet queuing in high-speed networks. This study addresses this multi-objective optimization problem by developing an efficient NIDS framework utilizing the eXtreme Gradient Boosting (XGBoost) algorithm enhanced with cost-sensitive hybrid class weighting to mitigate extreme class imbalance on the NF-UNSW-NB15-v3 dataset. To navigate the extensive hyperparameter space under conflicting criteria, this study evaluates and compares two distinct optimization strategies: the evolutionary Non-dominated Sorting Genetic Algorithm II (NSGA-II) and the Bayesian probability-based Tree-structured Parzen Estimator (TPE), against a default XGBoost baseline. Furthermore, a trace-driven prototype simulation was developed using Streamlit to validate the system's pseudo-real-time feasibility. Empirical outcomes on unseen testing data (473,085 samples) demonstrated that both optimization methods significantly outperformed the default baseline model. The TPE-optimized configuration achieved the superior overall performance, yielding a Macro F_1-Score of 0.8632 (a +3.84% relative gain over the baseline's 0.8313) while maintaining an exceptionally low inference latency of 2.1681 µs/sample, rendering it 47.5% faster than the NSGA-II model (4.7720 µs/sample). Formal Kruskal-Wallis hypothesis testing confirmed that these performance discrepancies were statistically significant ($p < 0.05$). Notably, the hybrid weighting mechanism induced a substantial +17.8% recall jump for the minority Denial of Service (DoS) class. Explainable AI (XAI) analysis based on global feature gain consistently highlighted temporal and packet-volume indicators (MIN_TTL and MIN_IP_PKT_LEN) as the most sensitive network anomalies, establishing a balanced, reliable, and deployable framework for resource-constrained architectures.

Keywords: *Network Intrusion Detection System, Multi-Objective Hyperparameter Optimization, XGBoost, Class Imbalance, Real-Time Simulation.*

ACKNOWLEDGEMENTS

Praise and gratitude be to Allah SWT for His boundless blessings, guidance, and grace, which have enabled the author to successfully complete this undergraduate thesis titled **“ACCURACY AND INFERENCE TIME OPTIMIZATION USING MULTI-OBJECTIVE XGBOOST ON THE NF-UNSW-NB15 DATASET”.**

This thesis was conducted to fulfill one of the requirements for obtaining a Bachelor's Degree in Informatics (S1) at the Faculty of Computer Science, Universitas Pembangunan Nasional “Veteran” Jawa Timur.

Throughout the research and writing process, the author received immense support, guidance, and assistance from various parties. Therefore, the author wishes to express the deepest gratitude and appreciation to:

1. Bapak Andreas Nugroho Sihananto, S.Kom., M.Kom., as the thesis coordinator, for his assistance in streamlining the administrative processes.
2. Bapak Prof. Dr. Basuki Rahmat, S.Si., MT., ITS-AI., and Bapak Dr. Eng. Agussalim, MT., as the thesis advisors, for their exceptional guidance, insights, and continuous support throughout the development of this research.
3. Ibu Eva Yulia Puspaningrum, S.Kom., M.Kom., and Ibu Yisti Vita Via, S.ST., M.Kom., as the thesis examiners, for their valuable feedback, constructive critiques, and corrections toward perfecting this thesis.
4. Ibu Dr. Ir. Kartini, S.Kom., MT., as the academic advisor, for her continuous advice, guidance, and encouragement since the beginning of the author's university studies.
5. The Administrative Staff, Facilities Caretakers, and Security Personnel of the Faculty of Computer Science, such as Pak Aries, Mas Lilik, and Mas Pur, for maintaining a conducive environment and ensuring the smooth operation of campus facilities throughout the author's studies.
6. My Beloved Family: Bapak Suliyanto, Ibu Emi, Mas Tomy, Mbak Umi, Mbak Suci, Mas Adi, and the entire extended family, for their endless prayers, profound affection, and unwavering support that served as the author's ultimate source of strength.
7. Wahyu, my close friend since junior high school, for his relentless loyalty, assistance, and incredible support across all circumstances, and thanks to all of his Densus Friend that supports me as well.
8. The Pemuda Hijrah Friends: Abdi, Adib, Bagas, Daffa, Ivan, Desta, Raihan, and Dani, for the companionship, insightful discussions, and moral support through both academic and non-academic challenges.
9. The Mamino Friends: Kupluk, Basroil, Fadika, Ryan, Ken, Yassar, Kevin, Acil, Irfan, Bram, Alief, Rizki, Leon, Ojan, Yossie, Slotong, Aji, and Erlang,

for the unforgettable memories, camaraderie, and solidarity that lightened the academic workload.

10. The Mabes Langgeng Friends, who cannot be mentioned individually, thank you for the solidarity, support, and invaluable shared memories over the years in Langgeng.
11. My Peer Mentors and Study Partners: Mas Gosal, Mas Aghis, Mas Miftah, Mas Nizar, Mbak Dhavina, Mbak Ica, Yuana, Anjas, Hafidz, Habib, Dwi, Rahma, Tiara, Shalsa, Ribka, and Aimee, for their companionship and for generously sharing their knowledge.
12. My Kiddos : Hilmi, Hikma, Rejak, Iwang, Icha, Isna, Syanda, Nana, Tasya, Inul, Ariel, and Jazuli for their dedication, hard work, and brilliant synergy during my tenure as their department head. Thank you for trusting my leadership, sharing the workload, and making the bureau feel like a true family.
13. The Executive Board of Students (BEM) of the Faculty of Computer Science (Odysseus Cabinet 2024 and Astranova Cabinet 2025) and the Informatics Student Association (HIMATIFA), for providing a collaborative platform to grow, voice aspirations, and shape the author's intellectual and organizational journey.
14. The Seniors and Juniors of the Faculty of Computer Science, UPN "Veteran" Jawa Timur, for sharing experiences, references, motivation, and for bringing joy and vibrant cooperation into campus life.
15. All Fellow Students of the Faculty of Computer Science, Class of 2022, for the strong solidarity, late-night discussions, shared laughter, and collective struggles at this Bela Negara campus.
16. To a certain unexpected presence who stopped by my life just long enough to leave a lasting impact. Thank you for the brief moment you were there for me, helping me carry the weight of this journey. Though our paths crossed only for a moment and have now diverged, I am truly grateful for the shared chapters and the person you helped me become.
17. Last but not least, to myself, for the unwavering resilience and discipline through countless sleepless nights, and for never walking away when the code broke or when the weight of it all felt endless. Thank you for showing up every single day and turning the late-night grinds into reality. Remember. Be Bold. Be Original. Be [Title Card].

Surabaya, June 23, 2026

Author

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