ABSTRAK

Bufferbloat merupakan salah satu permasalahan performa jaringan yang terjadi akibat penumpukan paket secara berlebihan pada *buffer* perangkat jaringan, sehingga menyebabkan peningkatan *latency* atau *Round Trip Time* (RTT) secara konsisten meskipun tidak selalu disertai *packet loss* yang signifikan. Deteksi *bufferbloat* umumnya masih dilakukan menggunakan pendekatan berbasis aturan yang membandingkan nilai RTT terhadap estimasi *delay* minimum jaringan, namun pendekatan ini memiliki keterbatasan dalam menangkap pola trafik jaringan yang kompleks dan dinamis. Penelitian ini mengusulkan pendekatan berbasis *machine learning* menggunakan *Convolutional Neural Network* satu dimensi (CNN 1D) untuk mendeteksi akar masalah *bufferbloat* berdasarkan data *packet capture* (PCAP).

Penelitian ini menggunakan *dataset* HIKARI-2021 dalam format PCAP. Data diproses melalui pembentukan *flow* berdasarkan *4-tuple*, identifikasi *flight*, perhitungan RTT, estimasi RTprop, dan pelabelan kondisi Normal/*Bufferbloat* menggunakan metode EVA. Setiap *flight* diekstraksi menjadi lima fitur sekuensial (*payload_size*, *window_size*, TCP *flags*, *inter-arrival time*, dan *direction*), dinormalisasi menggunakan StandardScaler, dan direpresentasikan sebagai matriks 80×5 sebagai input model CNN 1D. Prediksi pada tingkat *flight* kemudian diagregasi ke tingkat *flow* menggunakan *majority voting*.

Model CNN 1D terbaik diperoleh pada konfigurasi *Custom-C* (dua lapisan Conv1D 64 dan 128 filter, *kernel size* 3, *dense layer* 64, *dropout* 0,3, *batch size* 32, *learning rate* 0,001). Pada tingkat *flight*, model memperoleh *accuracy* 78%, *precision Bufferbloat* 67%, *recall Bufferbloat* 85%, dan *F1-score Bufferbloat* 75%. Setelah agregasi ke tingkat *flow*, sistem memperoleh *accuracy* 84%, precision *Bufferbloat* Flow 75%, recall *Bufferbloat Flow* 85%, dan F1-score *Bufferbloat Flow* 80%. Hasil ini menunjukkan bahwa CNN 1D mampu mempelajari pola temporal paket TCP untuk mendeteksi kondisi *bufferbloat* secara otomatis. Kontribusi penelitian ini adalah pipeline deteksi *bufferbloat* berbasis PCAP yang memadukan pelabelan EVA, representasi fitur sekuensial tingkat *flight*, model CNN 1D, dan agregasi hasil prediksi ke tingkat *flow*.

Kata Kunci: *Bufferbloat*, CNN 1D, EVA, PCAP, *Flow* Jaringan

ABSTRACT

Bufferbloat is a network performance problem caused by excessive packet accumulation in network device buffers, leading to a consistent increase in latency or Round Trip Time (RTT), though not always accompanied by significant packet loss. Bufferbloat detection is commonly performed using rule-based approaches that compare RTT values against estimated minimum network delay; however, such approaches have limitations in capturing complex and dynamic network traffic patterns. This study proposes a machine learning-based method using a one-dimensional Convolutional Neural Network (1D CNN) to detect the root cause of bufferbloat from packet capture (PCAP) data.

This study uses the HIKARI-2021 dataset in PCAP format. Data is processed through flow formation based on 4-tuples, flight identification, RTT calculation, RTprop estimation, and labeling of Normal/Bufferbloat conditions using the EVA method. Each flight is extracted into five sequential features (payload_size, window_size, TCP flags, inter-arrival time, and direction), normalized using StandardScaler, and represented as an 80×5 sequence matrix as input to the 1D CNN model. Flight-level predictions are then aggregated to the flow level using majority voting.

The best 1D CNN model was obtained with the Custom-C configuration (two Conv1D layers with 64 and 128 filters, kernel size 3, dense layer of 64 units, dropout 0.3, batch size 32, learning rate 0.001). At the flight level, the model achieved an accuracy of 78%, Bufferbloat precision of 67%, Bufferbloat recall of 85%, and Bufferbloat F1-score of 75%. After aggregation to the flow level, the system achieved an accuracy of 84%, Bufferbloat Flow precision of 75%, Bufferbloat Flow recall of 85%, and Bufferbloat Flow F1-score of 80%. These results indicate that the 1D CNN model is able to learn temporal patterns in TCP packet sequences to automatically detect bufferbloat conditions. The contribution of this study is a PCAP-based bufferbloat detection pipeline that combines EVA labeling, flight-level sequential feature representation, a 1D CNN model, and flow-level prediction aggregation.

Keywords: *Bufferbloat, 1D CNN, EVA, PCAP, Network Flow*