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Congestion Control in IoT Networks Using Artificial Intelligence Techniques

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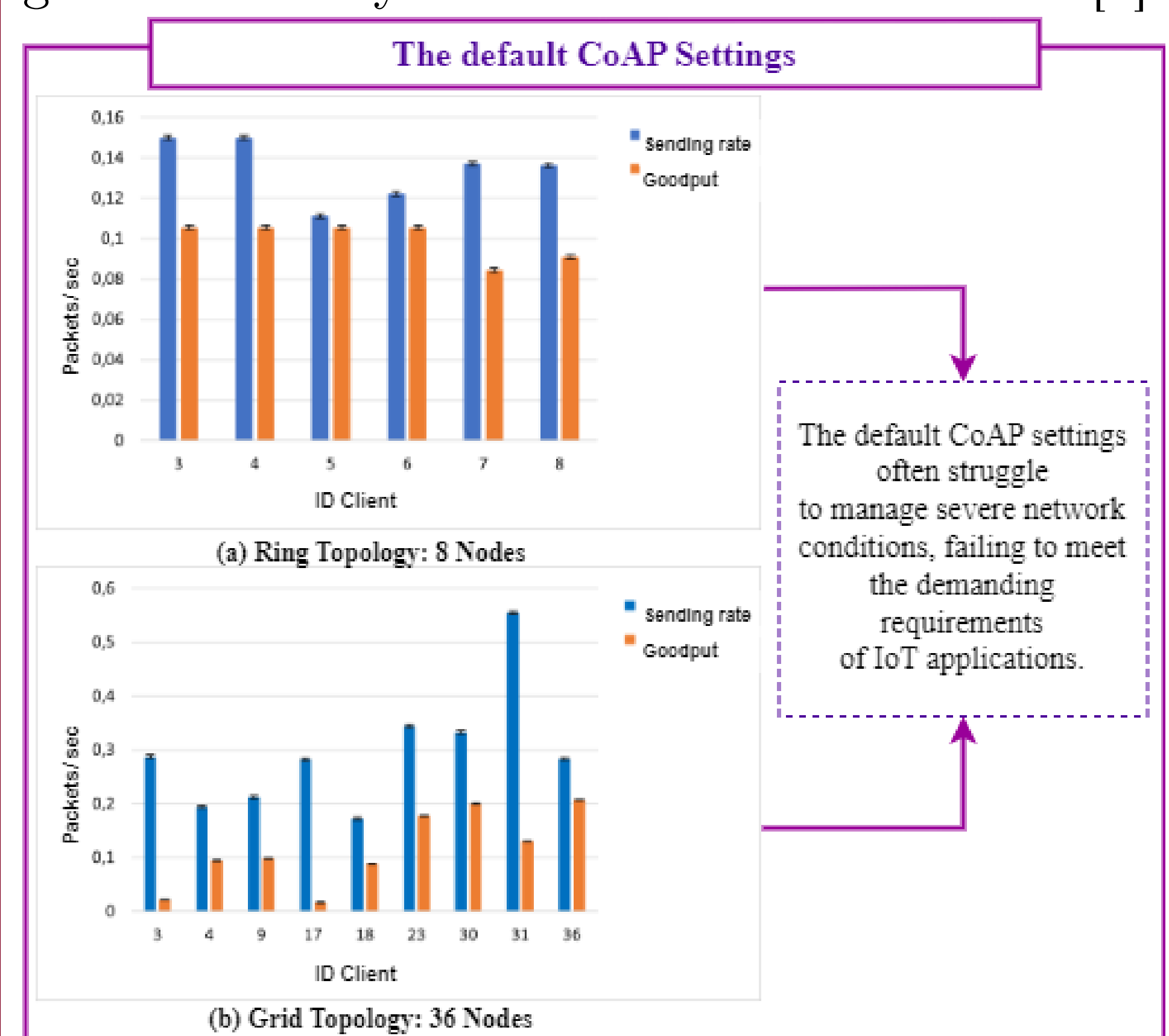
1. Context and Motivation

The Internet of Things (IoT) networks are expanding rapidly, transforming connectivity across various sectors [1]. This growth enables cost-effective communication for diverse devices, driving unprecedented innovation. However, managing congestion in IoT networks presents a critical challenge. Congestion occurs when multiple flows share network resources, significantly impacting performance. This issue is particularly pronounced in low-power lossy networks (LLNs), leading to increased latency, packet losses, reduced throughput, and other capacity-related issues. Designing effective congestion control (CC) mechanisms for IoT networks is complex due to the need to ensure high quality of service (QoS) and network reliability[2].

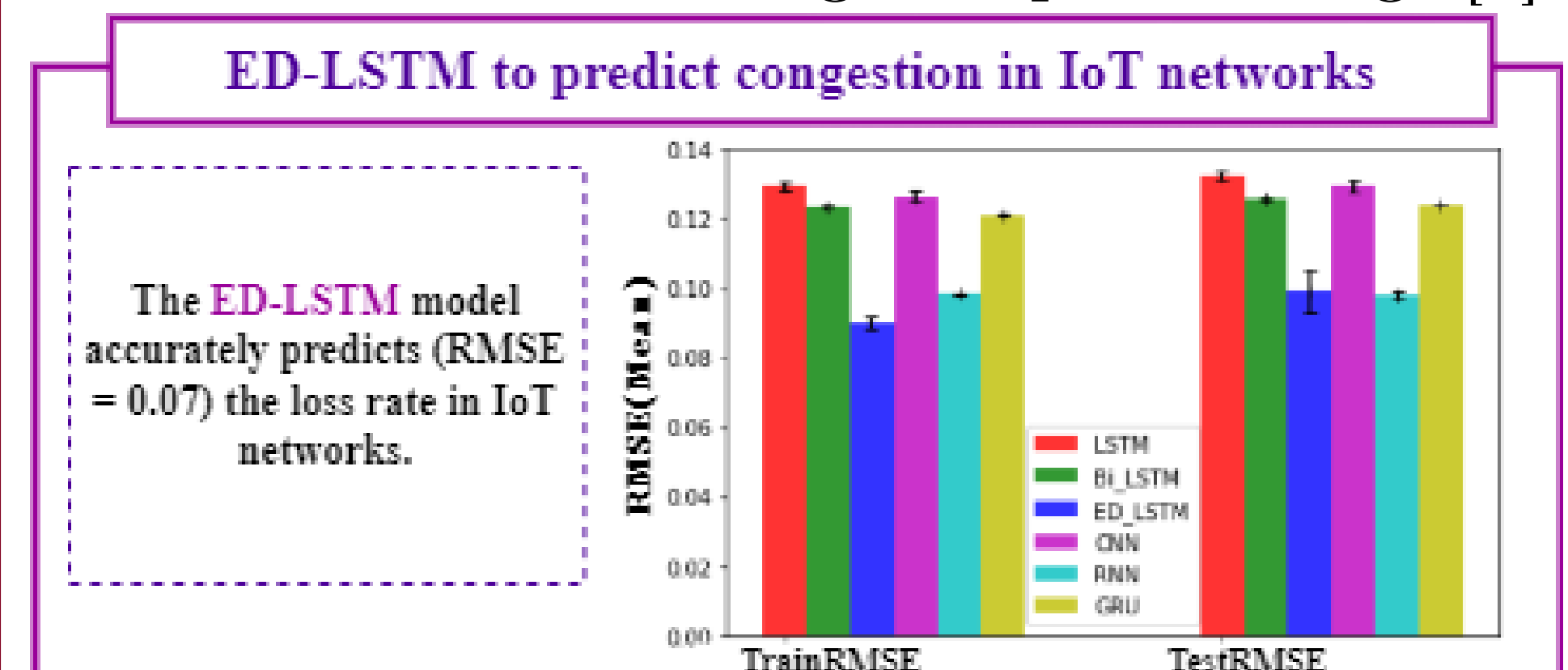
2. Goals

Enhance the IETF-standardized the Constrained Application Protocol (CoAP) congestion control protocol, specifically tailored for constrained IoT networks with limited processing capacity:

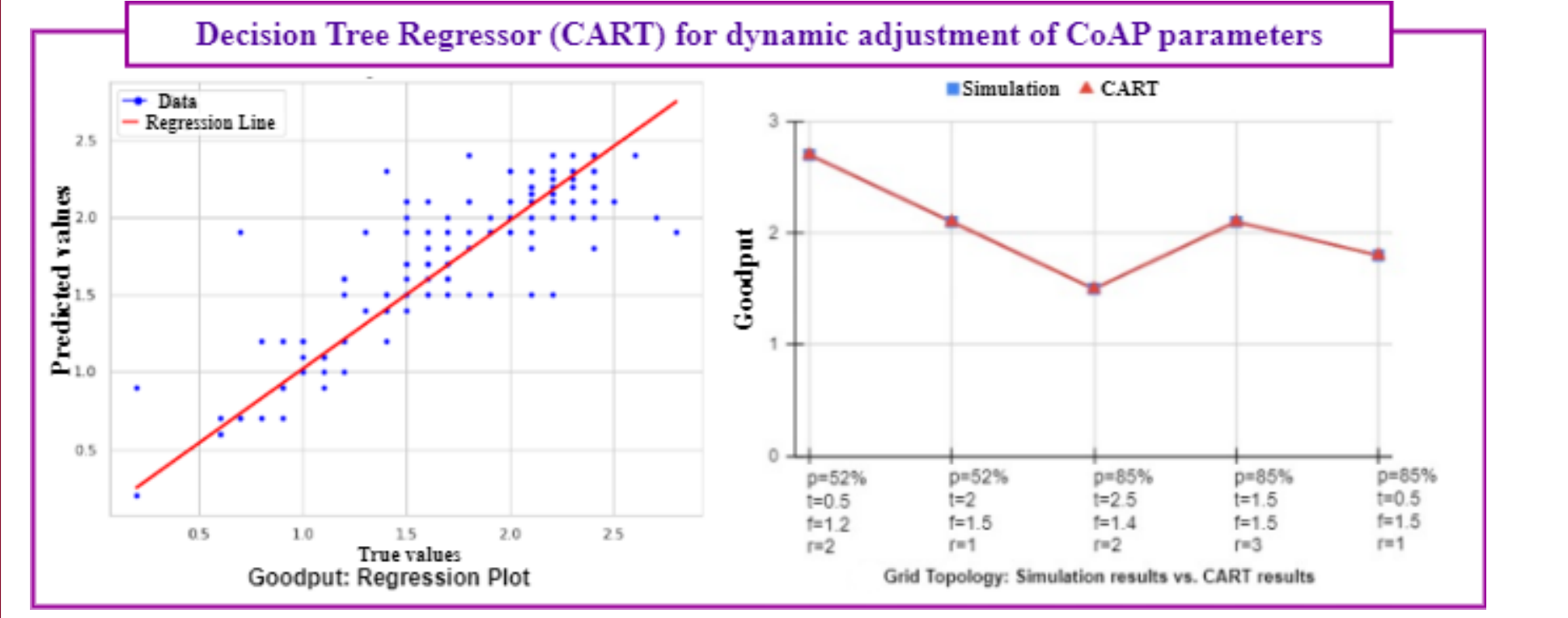
1- Performance evaluation and Congestion Analysis in IoT Networks [2]:



2- Predictive Modeling of Loss Ratio for CC in IoT Networks Using Deep Learning [3]:



3- Machine Learning-Based CoAP Modeling:



5. Conclusion and future work

The proposed AI-based Congestion Control scheme uses DL to predict network conditions and ML to adjust parameters accordingly, enhancing constrained IoT networks and better meeting IoT application demands.

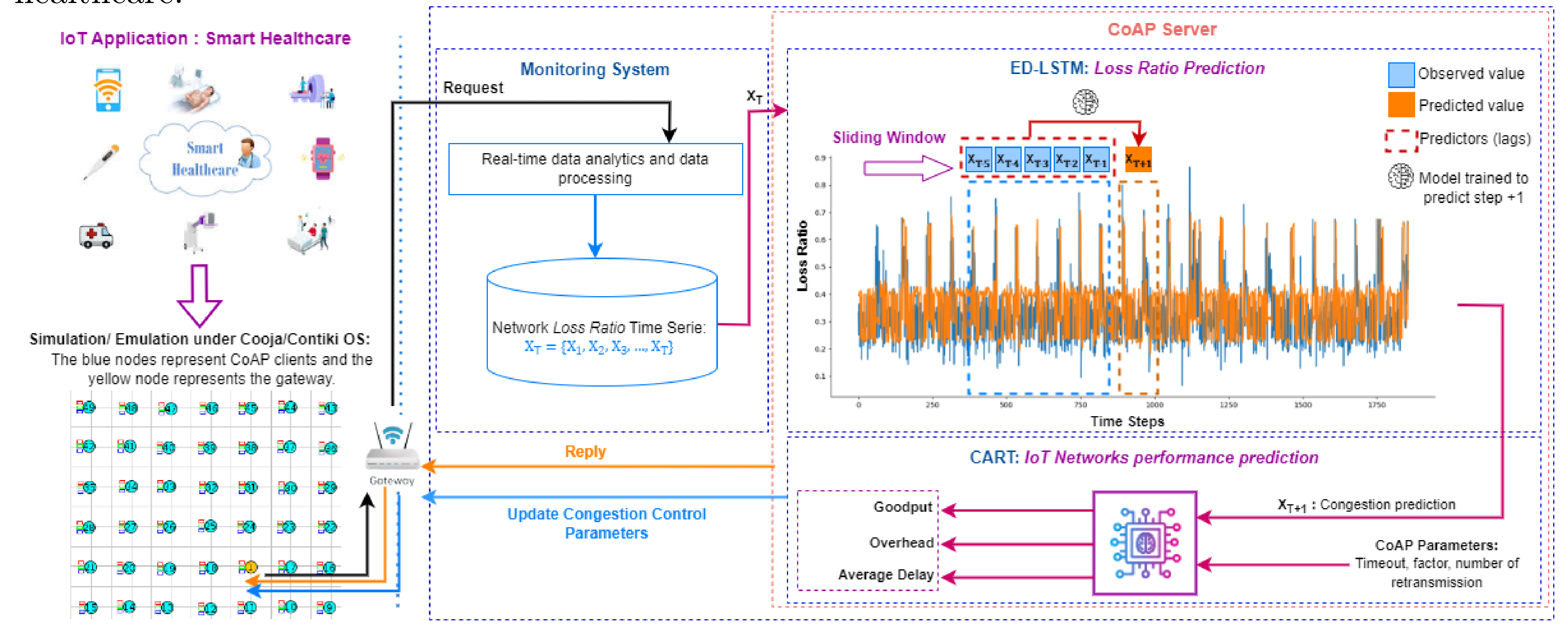
In future work, we propose to use large language models (LLMs) to enhance communication in IoT smart healthcare applications by providing more accurate and contextual data processing.

References

[1] Hamid Tahaei, et al. The rise of traffic classification in iot networks: A survey. *Journal of Network and Computer Applications*, 154:102538, 2020.
 [2] H. Benadji, et al. Performance evaluation and congestion analysis in iot network. In *2022 IEEE International Mediterranean Conference on Communications and Networking (MeditCom)*, pages 232–237, 2022.
 [3] H. Benadji, et al. Predictive modeling of loss ratio for congestion control in IoT networks using deep learning. In *GLOBECOM 2023 - 2023 IEEE Global Communications Conference*, pages 2814–2819. IEEE.

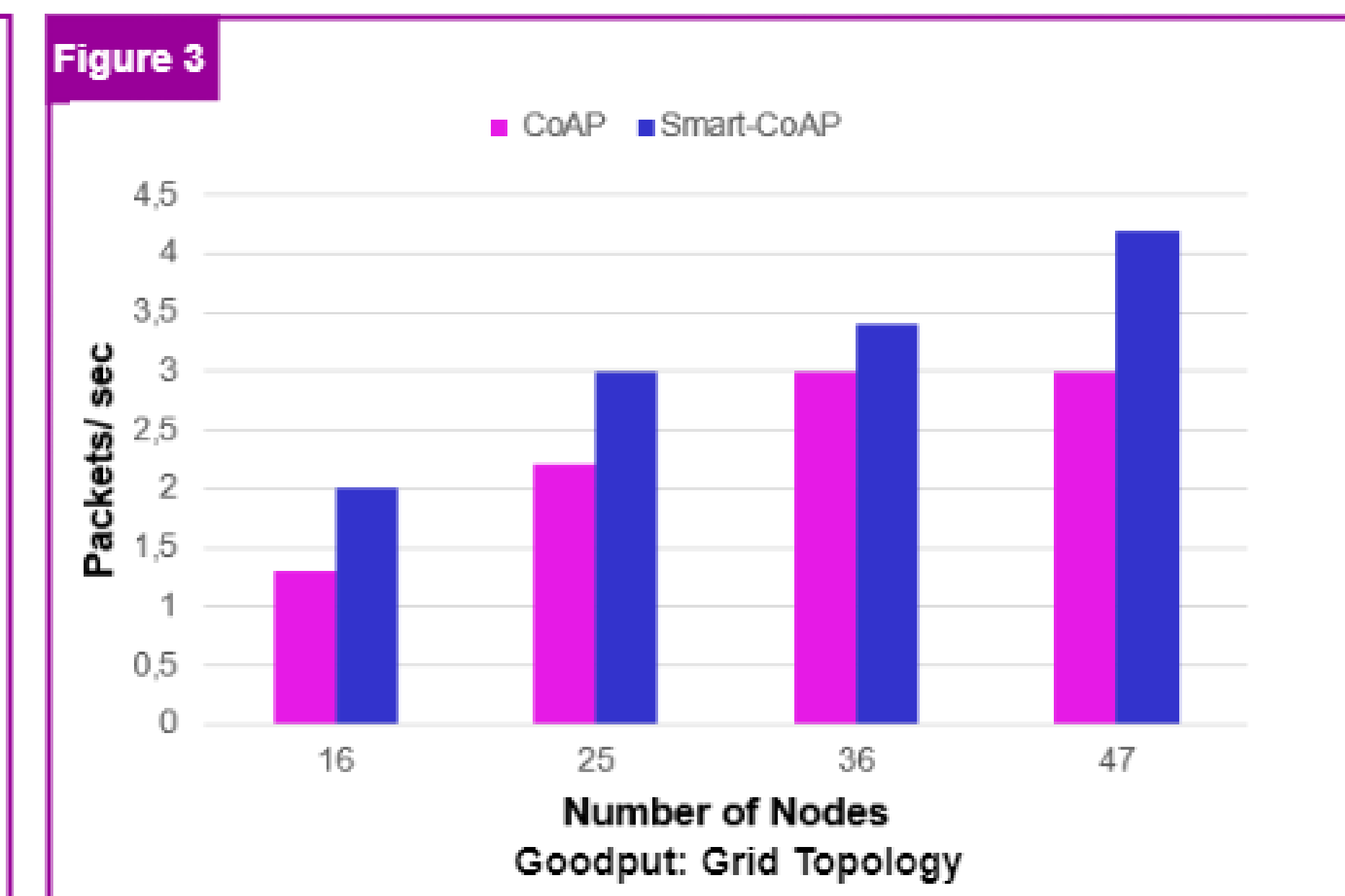
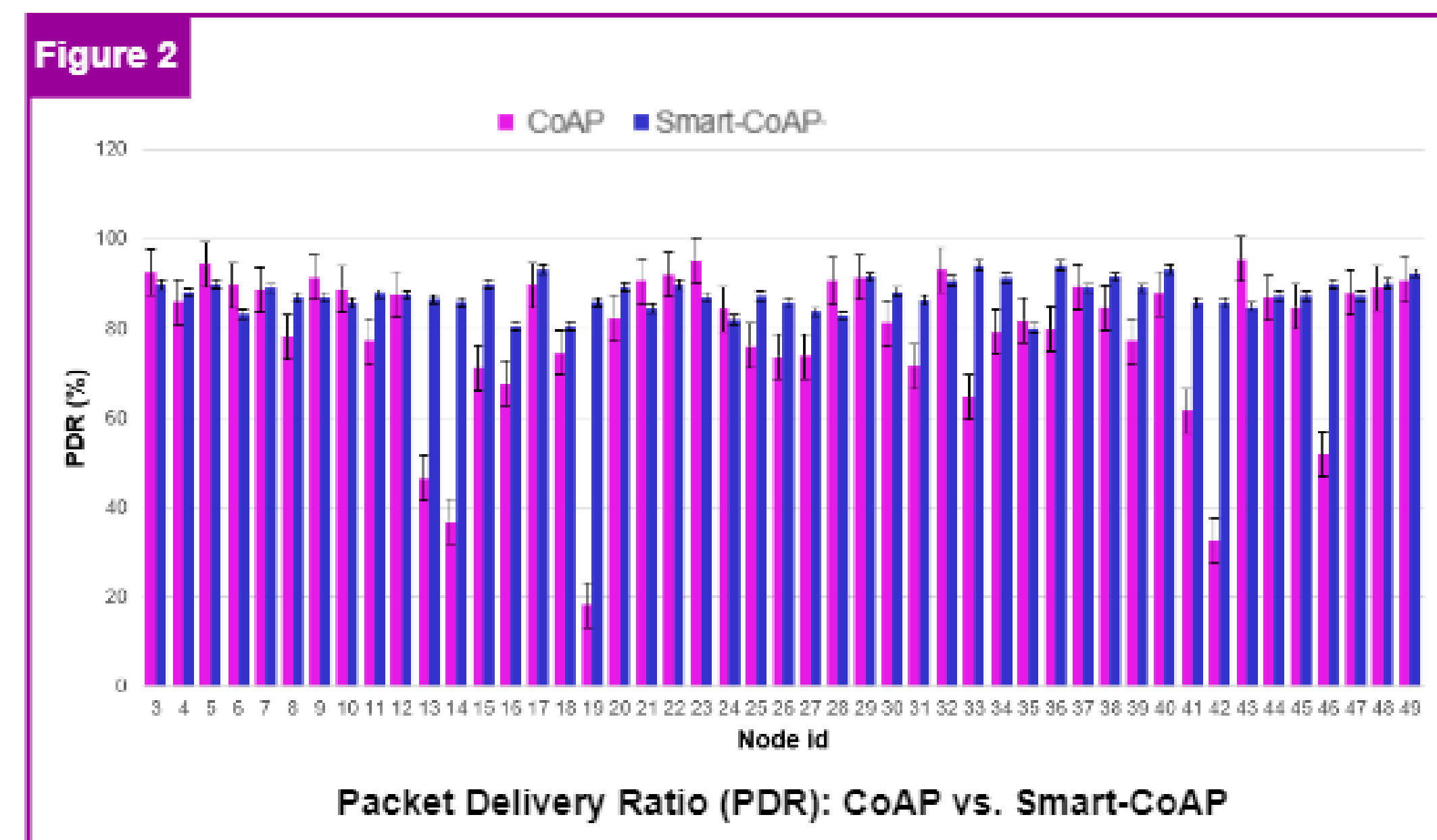
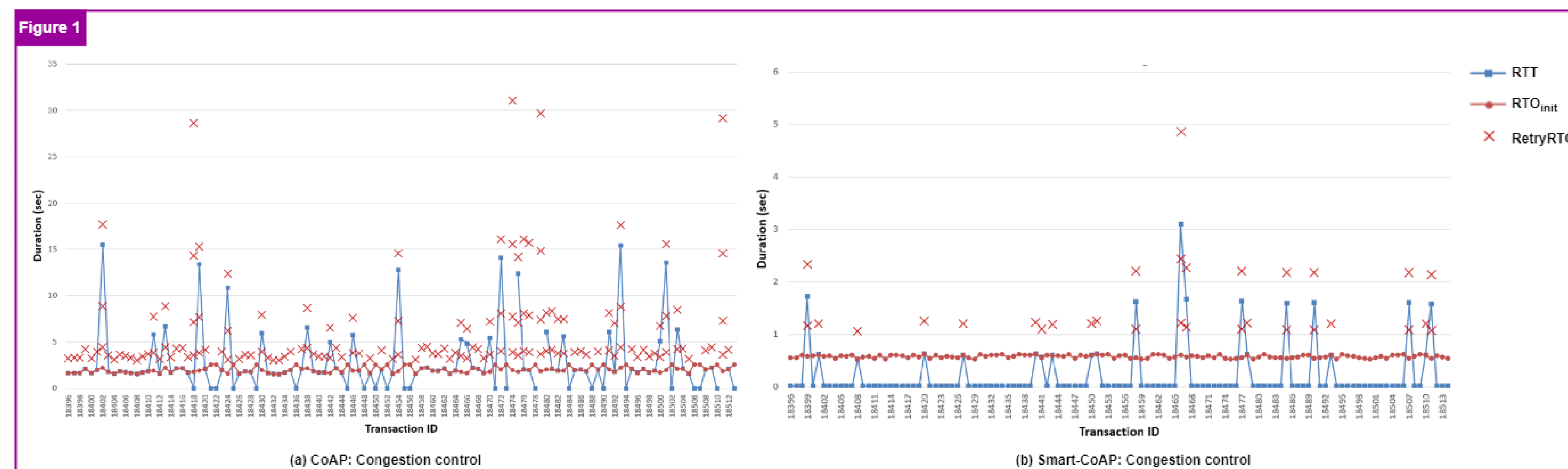
3. AI-based congestion control scheme

Smart-CoAP: The AI-based congestion control scheme is deployed on an AI agent to interact seamlessly with the Cooja/Contiki OS simulator and tested on a patient monitoring service in smart healthcare.



4. Simulation results and discussion

Performance evaluation results of CoAP and Smart-CoAP:



Main results:

- Figure 1: CoAP and Smart-CoAP Congestion Control** CoAP's initial fixed parameters can result in extended waiting times during congestion events, with $RTO_{init}=2s$ potentially escalating to 40s, as exemplified by $RetryRTO$ in transaction 18474 in Fig. 1(a), which is unsuitable for smart healthcare applications that require delays under 10s. In contrast, Smart-CoAP dynamically adjusts congestion control values based on network conditions, effectively meeting IoT application requirements with $RetryRTO$ less than 5s, as shown in Fig. 1(b).
- Figure 2: PDR: CoAP and Smart-CoAP Congestion Control** Simulation results show that Smart-CoAP achieves near 100% PDR for all nodes, ensuring network fairness. In contrast, CoAP in the same topology shows significant disparity, with some nodes like node 19 having a PDR less than 20% and node 42 having a PDR of 30%.
- Figure 3: Goodput: CoAP and Smart CoAP** Results show that as the number of nodes increases in the same topology from 16 to 47 nodes, Smart-CoAP achieves better goodput compared to CoAP. This demonstrates Smart-CoAP's ability to manage and adapt to network congestion under various IoT conditions.