

Reinforcing Zero-Trust Security with AI: Federated and Self-Supervised Learning for Adaptive Intrusion Detection

¹Dr. C. Nagesh, ²Dr. V. Sujay, ³Y. Venkatalakshmi, ⁴Chatta Balaji

Associate Professor, Department of CSE, GATES Institute of Technology, Gooty¹

Associate Professor, Department of AI, GATES Institute of Technology, Gooty²

Assistant Professor, Department of CSE, GATES Institute of Technology, Gooty³

Assistant Professor, Department of CSE, Tadipatri Engineering College, Tadipatri⁴

Abstract: *The increasing sophistication of cyber threats, combined with distributed cloud-edge infrastructures and remote work environments, has rendered traditional perimeter-based security models obsolete. Zero Trust Architecture (ZTA) has emerged as a foundational cybersecurity paradigm that assumes no implicit trust within or outside the network boundary. However, static rule-based intrusion detection systems (IDS) within Zero Trust frameworks struggle to detect evolving, zero-day, and polymorphic attacks. This paper proposes an **AI-Driven Zero Trust Intrusion Detection Framework (AZT-IDF)** that integrates federated learning (FL) and self-supervised learning (SSL) to enable adaptive, privacy-preserving, and scalable threat detection across distributed environments. The framework combines decentralized anomaly detection, encrypted model aggregation, behavioral profiling, and continuous authentication mechanisms. Experimental evaluation on benchmark cybersecurity datasets demonstrates improved detection accuracy, reduced false positive rates, and enhanced resilience against adversarial and novel attack patterns compared to centralized and supervised-only approaches. The results indicate that integrating federated and self-supervised learning within Zero Trust architectures significantly enhances adaptability, privacy compliance, and real-time threat intelligence in modern enterprise networks.*

Keywords: Zero Trust Architecture, Intrusion Detection System, Federated Learning, Self-Supervised Learning, Adaptive Security, Cybersecurity AI, Distributed Threat Detection

