IoT-XPLAIN: Intelligent Fault Detection and Natural Language Explanation for IoT Systems using ML and LLMs

Harshit Vashisht*, Sunil K. Singh*, Sudhakar Kumar*, Nipun Singh*, Varsha Arya**, Kwok Tai Chui**, Brij B. Gupta***

** Department of Computer Science and Engineering,*
Chandigarh College of Engineering and Technology (CCET),
Chandigarh, India

*** Hong Kong Metropolitan University,*
Hong Kong SAR, China

**** Department of Computer Science and Information Engineering,*
Asia University, Taichung, Taiwan

harshitvashisht07@gmail.com, sksingh@ccet.ac.in, sudhakar@ccet.ac.in, co22347@ccet.ac.in, varya@hkmu.edu.hk, jktchui@hkmu.edu.hk, bbgupta@asia.edu.tw

Modern IoT deployments face challenges in maintaining fault resilience due to limited observability, dynamic conditions, and constrained edge resources. Traditional detection methods often lack flexibility and explainability. This paper introduces IoT-XPLAIN, a hybrid framework integrating Random Forest classification with large language models (LLMs) for automated anomaly detection and human-readable fault explanations. Trained on TON IoT telemetry with DNS layer metadata, the model detects transport-and application-level anomalies, including synthetic DNS faults. Upon detection, GPT-4o generates summaries of fault patterns, causes, and recovery steps. IoT-XPLAIN enables interpretable, efficient fault analysis for smart manufacturing, remote monitoring, and fault-aware edge infrastructures.

Internet of Things (IoT), Fault Detection, Anomaly Detection, Random Forest, GPT-4o, Explainable AI, DNS Fault Injection

Harshit Vashisht is an undergraduate student in the Department of Computer Science and Engineering at Chandigarh College of Engineering and Technology (CCET), Chandigarh, India. He is pursuing his bachelor's degree in computer science and engineering, with a primary academic focus on machine learning, Internet of Things, and explainable artificial intelligence. He has practical experience in developing machine learning pipelines for anomaly detection using network and DNS-layer telemetry. He has worked on IoT fault detection, dataset preprocessing, feature engineering, and LLM-assisted explanation systems. His research interests include IoT security, fault-tolerant systems, edge intelligence, and human-interpretable AI models

Prof. Sunil K. Singh is Professor and Head of the Computer Science & Engineering Department at Chandigarh College of Engineering and Technology (Degree Wing), a premier Chandigarh (UT) Government institute affiliated with Panjab University, Chandigarh, India. He holds B.E., M.E., and Ph.D. degrees in Computer Science and Engineering and has over 240 publications, 7 granted patents, and extensive reviewing experience for more than 135 international journals. His expertise spans high-performance computing, Linux/Unix, NLP, IoT, machine learning, cyber security, computer architecture, and computer networks, and he has supervised multiple Ph.D. scholars at Panjab University

Dr. Sudhakar Kumar is a Senior Member of the Association for Computing Machinery (ACM) and the IEEE Computer Society. He is presently serving as an Assistant Professor in the Department of Computer Science and Engineering at Chandigarh College of Engineering and Technology, Sector 26, Chandigarh, functioning under the Chandigarh Union Territory Administration. He obtained his Doctor of Philosophy (Ph.D.) in the field of high-performance computing (HPC) with a focus on algorithmic design and compiler optimization from Panjab University, Chandigarh, India. He completed his Master of Technology (M.Tech.) at the Indian Institute of Technology (IIT) Guwahati, India. His scholarly interests encompass HPC, compiler optimization, machine learning (ML), artificial intelligence (AI), and human-computer interaction (HCI). Dr. Kumar has an extensive record of academic contributions, comprising more than one hundred twenty research publications in reputed international and national journals, conferences, and book chapters. In addition, he holds four design patents.

Nipun Singh is an undergraduate student in the Department of Computer Science and Engineering at Chandigarh College of Engineering and Technology (CCET), Chandigarh, India. He is pursuing his bachelor's degree in computer science and engineering. He has contributed to data analysis, experimentation, and evaluation of IoT anomaly detection models. His academic interests include IoT analytics, data preprocessing, and intelligent monitoring systems.

Mrs. Varsha Arya is a researcher affiliated with Hong Kong Metropolitan University, Hong Kong SAR, China, working in the broad area of computer science and intelligent systems. Her work spans topics such as network fault tolerance, cybersecurity, transfer learning, and deeplearning–based models for applications including digital forensics and biomedical signal analysis. She actively collaborates with international teams and contributes to multidisciplinary research at the intersection of artificial intelligence, networking, and data-driven optimization.

Prof. Kwok Tai Chui is a Distinguished is a Professor in the School of Science and Technology at Hong Kong Metropolitan University, Hong Kong SAR, China. He received his B.Eng. in Electronic and Communication Engineering with a Business Intelligence minor and his Ph.D. in Electronic Engineering from City University of Hong Kong, both with first-class honors and multiple international IEEE awards, including the 2014 IEEE Region 10 Student Paper Contest (Postgraduate Category) prize and Best Paper Awards at IEEE International Conference on Consumer Electronics-China in 2014 and 2015. His research interests include computational intelligence, energy monitoring and management, pattern recognition, machine learning algorithms, optimization, smart healthcare, and intelligent transportation systems.

Prof. Brij B. Gupta is a Distinguished Professor in the Department of Computer Science and Information Engineering at Asia University, Taiwan, and Director of the International Center for AI and Cyber Security Research and Innovations. He received his Ph.D. in Information and Cyber Security from the Indian Institute of Technology Roorkee and, over nearly two decades of academic and research experience, has published more than 500–600 research papers, 35–40 books, and around 10–12 patents, with over 30,000–40,000 citations and multiple appearances in Clarivate's Highly Cited Researchers list and Stanford's top 2% scientist rankings. His research focuses on cyber security, cloud computing, artificial intelligence, intrusion detection, blockchain, cyber-physical systems, and Internet of Things security, and he serves on editorial boards and leadership roles in several international journals and IEEE societies, including Member-in-Large on the Board of Governors of the IEEE Consumer Technology Society.