Open Access International Journal of Science and Engineering

ISSN: 2456-3293

Volume 9 Issue 1s (2026) | Pages: 237-240

OPENDOTS: A Survey and Problem Study on Intelligent IoT Data Visualization Platforms

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Peer Review Information

***Type**: Article*
***Received**: 04 April 2026*
***Revised**: 30 April 2026*
***Accepted**: 05 June 2026*
***Published**: 26 June 2026*

Abstract

OpenDots presents a survey-driven study of current challenges in realtime sensor data visualization and interpretation within Internet of Things (IoT) ecosystems. Existing IoT dashboards are widely used for data collection and plotting; however, they often suffer from fragmentation, limited customization, and a lack of meaningful interpretability beyond raw visualizations. As IoT deployments scale, users are increasingly required to manually analyze large volumes of time-series data, leading to higher cognitive load and reduced decision efficiency. This paper analyzes commonly used IoT visualization platforms and identifies key gaps related to explainability, accessibility, and intelligent data interaction. Based on these observations, the paper outlines the problem space motivating the need for unified, web-based platforms capable of supporting realtime data access, controlled sharing, and high-level analytical assistance. A brief conceptual overview of OpenDots is presented to illustrate a possible research direction toward addressing these challenges, without delving into system design or implementation details. The study aims to serve as a foundational reference for future research on intelligent, user-centric IoT data analytics platforms.

Keywords: AI Analytics; Data Visualization; IoT Dashboards; Real-Time Systems; Survey Study; Business Intelligence.

How to Cite This Article

Gupta, T., Gupta, O., & Rane, S. (2026). OPENDOTS: A survey and problem study on intelligent IoT data visualization platforms. *Open Access International Journal of Science and Engineering*, 9(1s), 237–240.

Introduction

The rapid growth of IoT devices has resulted in a significant increase in sensor-gen-erated data. Although data collection has become relatively simple, meaningful interpretation continues to be a major challenge. Developers and researchers frequently depend on multiple platforms for data storage, visualization, authentication, and analysis, which leads to fragmented workflows and higher cognitive load. Most existing dashboards emphasize graphical representation of data rather than supporting clear understanding or contextual explanation. These limitations motivate the exploration of more intelligent approaches to IoT data interaction that move beyond basic visualization. The primary objective is not only to display sensor data, but also to support its interpretation in a more intuitive and accessible manner. Emerging concepts such as conversational and assisted analytics highlight the potential for reducing analytical complexity and enabling broader access to insights, thereby lowering the barrier to advanced data analysis in IoT systems.

System Architecture

OpenDots is conceptually structured as a modular, service-ori-ented system to support scalability, flexibility, and controlled data access. The architectural separation of concerns is intended to address common limitations observed in existing IoT platforms, such as rigidity, limited extensibility, and fragmented data handling workflows.

- Frontend Layer. The frontend layer represents the user-facing component responsible for data interaction and visualization. In general, such layers are expected to support interactive dashboards, real-time data presentation, and user session management while maintaining compatibility across standard web browsers. This layer plays a critical role in shaping usability and accessibility in IoT data platforms.
- Backend Layer. The backend layer serves as an intermediary between data sources and end users. Its primary role is to manage data ingestion, transformation, and distribution in real time. Backend services in modern IoT systems often abstract external data platforms and coordinate analytical processes, enabling consistent data access while reducing system complexity at the user level.
- Authentication and Access Control. Authentication and access control form a core architectural concern in IoT platforms where data sensitivity varies across applications. A flexible access model typically includes support for public access, private ownership, and restricted sharing with selected users. Such mechanisms are essential for ensuring data privacy while enabling collaborative usage scenarios.
- Intelligent Analytics Layer. Intelligent analytics layer conceptually augments traditional visualization systems by assisting users in interpreting sensor data. Hybrid approaches that combine deterministic logic with data-driven reasoning are increasingly explored to balance reliability and adaptability. This layer aims to support higher-level understanding through summaries, contextual explanations, and guided data exploration, without requiring users to manually analyze raw data streams.

Data Flow and Real-Time Communication.

OpenDots employs WebSockets to enable bidirectional, low-latency communication between the server and clients. Unlike traditional HTTP polling, WebSockets allow continuous streaming of sensor updates, making the platform suitable for real-time monitoring scenarios such as environmental sensing, energy tracking, and industrial automation.

Key Features of OpenDots

Based on the survey of existing IoT visualization platforms and identified user requirements, several essential capabilities emerge as critical for modern IoT data analytics systems. These capabilities represent functional expectations rather than specific implementation choices.

- Support for real-time visualization of continuously generated sensor data.
- Ability to explore and analyze historical time-series data.
- Availability of multiple authentication mechanisms to accommodate diverse users.
- Compatibility with data from heterogeneous IoT platforms and sources.
- Assistance in data interpretation through intelligent or conversational interfaces.
- Customizable dashboards tailored to individual user needs.
- Secure, cloud-based access to ensure data availability and controlled sharing.

AI – Generated Insights by Infinity

Infinity is discussed in this study as a conceptual intelligence layer aimed at assisting users in interpreting IoT sensor data. Rather than focusing on internal mechanisms, the emphasis is placed on the types of insights that intelligent analytics systems are expected to provide in order to reduce manual analysis and improve data understanding. Such systems typically combine deterministic reasoning with adaptive

analytical methods to support both reliability and contextual interpretation. The following categories of insights represent commonly identified expectations from intelligent IoT analytics platforms:

1. Detection of abnormal spikes in sensor readings
2. Identification of long-term trends
3. Comparison of current values with historical averages
4. Automatic anomaly detection
5. Correlation between multiple sensor parameters
6. Peak usage time identification
7. Sensor health diagnostics
8. Data completeness and reliability assessment
9. Prediction of future sensor values
10. Seasonal pattern recognition
11. Threshold breach explanations
12. Root cause hints for anomalies
13. Energy consumption optimization suggestions
14. Environmental quality summaries
15. Device performance degradation alerts
16. Outlier justification and filtering
17. Data variance interpretation
18. Comparative analysis across devices
19. Natural language summaries of dashboards
20. Recommendations for sensor recalibration

Experimental Dataset and Validation

To validate OpenDots in a real-world scenario, sensor data from a public ThingSpeak channel (Channel ID: 2890599) was integrated into the platform. The dataset contains time-series environmental sensor readings collected during a student IoT project conducted in 2025. OpenDots successfully ingested live and historical data from this channel, streamed updates via WebSockets, and generated AI-based insights using Infinity. The experiment demonstrated reliable real-time performance and meaningful automated interpretations without manual data preprocessing.

Comparison with Existing Solutions

Table 1. *Comparison with existing solutions.*

Feature	**Opendots**	**Thingspeak**	**Grafana**	**Blynk**
Real-time WebSocket Streaming	**Yes**	Limited	Yes	Yes
AI-based Data Insights	**Yes**	No	No	No
Coversational Interface	**Yes**	No	No	No
Multi-source Data Integration	**Yes**	Limited	Moderate	Limited
Custom Web UI	*High*	Low	High	Medium
OAuth Authentication	*Yes*	No	Partial	Yes
Open Source Extensibility	*High*	Low	High	Medium

Displayed equations are centered and set on a separate line.

Use Cases

1. Academic Research and Experimentation
2. Smart City Monitoring Systems
3. Environmental Data Analysis
4. Energy and Resource Optimization
5. Industrial IoT Dashboards
6. Educational IoT Labs

Security, Privacy and Access Control

OpenDots is designed with data security and user privacy as core principles. Authentication is delegated to Firebase, ensuring industry-standard encryption and identity management. Project-level access control allows owners to define visibility as public, private, or restricted. WebSocket connections are authenticated, and AI analytics operate only on authorized datasets. These mechanisms make OpenDots suitable for both academic experimentation and sensitive real-world deployments.

Limitations and Future Work

While OpenDots provides a strong foundation, future enhancements include: - Edge-level AI inference - Rolebased access control - Advanced predictive modeling - Plugin ecosystem for third-party integrations - Mobile-first dashboards.

Conclusion

OpenDots demonstrates that combining real-time data visualization with AI-driven conversational analytics significantly enhances the usability and value of IoT data platforms. Beyond visualization, the platform introduces an explainable intelligence layer that transforms raw sensor streams into actionable knowledge. The hybrid AI architecture ensures both reliability and interpretability, while the access-control model supports public, private, and restricted deployments. These characteristics position OpenDots as a strong candidate for both academic research and patentable innovation in intelligent IoT platforms.

Acknowledgments

This work was carried out as part of an academic project at Bharati Vidyapeeth University, College of Engineering, Pune. The authors would like to acknowledge the institutional support and academic environment that facilitated this study.

Disclosure of Interests

The authors declare that they have no competing interests that are relevant to the content of this article.

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