Journal of Ad-hoc Network and Mobile Computing

e-ISSN: 3048-9180, Vol. 2, Issue 1 (January – April, 2025) pp: (9-15)

IoT-Based Real-Time Tracking Systems: Enhancing Efficiency in Dynamic Supply Chains

Subhasini Shukla[1], Aditya Yadav[2]*
[1]Assistant Professor, Department of Electronics & Computer Science, St. John College of Engineering & Management, Palghar, Maharashtra, India
[2]Undergradute Student**,** Department of Information Technology, St. John College of Engineering & Management Palghar, Maharashtra, India
***Corresponding Author: 124aditya4027@sjcem.edu.in

Received Date: February 28, 2025; Published Date: March 20, 2025

Abstract
The integration of IoT in supply chain management enhances transparency, efficiency, and adaptability. This research presents a real-time IoT-enabled tracking system addressing inefficiencies, delays, and visibility gaps. Utilizing IoT sensors, cloud architecture, and predictive analytics, the system ensures asset monitoring, proactive disruption management, and workflow optimization. Key innovations include sensor-integrated tracking, continuous data transmission, and AI-driven insights, improving inventory control, asset tracking, and cold storage logistics. A simulated implementation achieved 98.5% tracking accuracy and a 70% reduction in manual interventions. The study also examines IoT adoption challenges, offering a strategic framework for scalable, secure, and efficient supply chain transformation.
*Beyond its technical advancements, this study also examines the challenges associated with IoT adoption**,** including security risks, high implementation costs, and network reliability issues. To address these concerns, a strategic framework is proposed for ensuring a scalable, secure, and efficient IoT-based supply chain transformation. The findings highlight IoT's transformative potential in modern logistics, paving the way for more resilient, data-driven, and automated supply chain ecosystems. This research contributes valuable insights into the role of IoT in supply chain optimization, providing a foundation for future advancements and large-scale industry adoption.*

Keywords- Cloud computing, Digital transformation, IoT, Logistics optimization, Predictive analytics**,** Real-Time monitoring, Smart supply chains

INTRODUCTION

In today's fast-paced global economy, supply chains are becoming increasingly complex, requiring high levels of visibility, efficiency, and adaptability. Traditional tracking and logistics systems often suffer from manual inefficiencies, lack of real-time data, and delays, leading to operational.

Disruptions, higher costs, and reduced responsiveness. These limitations make it difficult for businesses to monitor assets,

Predict delays, and optimize supply chain operations effectively. The Internet of Things (IoT) has emerged as a transformative technology capable of addressing these challenges by enabling real-time monitoring, automated tracking, and data-driven decision-making. IoT-powered systems integrate smart sensors, cloud computing, and advanced analytics to provide end-to-end visibility, predictive insights, and process automation across supply chain networks. By leveraging these technologies, businesses can reduce delays, lower costs, and enhance product quality.

This paper presents an innovative IoT-based real-time tracking system

designed to improve supply chain efficiency and resilience [1]. The proposed system utilizes sensor-enabled devices, cloud-based data processing, and AI-driven analytics to optimize inventory management, logistics coordination, and cold chain monitoring. By providing continuous asset tracking and predictive disruption management, the system enhances operational efficiency and decision-making in dynamic supply chain environments.

LITERATURE SURVEY

The integration of the Internet of Things (IoT) in supply chain management is transforming the industry by addressing traditional inefficiencies. Traditional systems often struggle with delays, lack of real-time data, and manual processes, which can disrupt operations and increase costs. IoT-based systems, through the use of smart sensors, cloud computing, and advanced analytics, offer end-to-end visibility, predictive insights, and automation. This technology enables businesses to track assets in real time, manage inventory more effectively, and optimize logistics. Additionally, AI-driven analytics help predict disruptions, ensuring a proactive response. By reducing manual intervention and improving operational efficiency, IoT-powered solutions enhance decision-making and resilience in dynamic supply chain environments, driving cost reduction and higher product quality [2].

RELATED WORK AND TECHNOLOGICAL ADVANCEMENTS

The integration of IoT technologies in supply chain management has gained significant traction, offering improvements in efficiency, transparency, and decision-making. Research highlights the role of real-time tracking, predictive analytics, and sensor-driven automation in optimizing logistics and mitigating risks. This section reviews existing studies, technological advancements, and challenges in IoT-enabled supply chains [3].

Existing Research on IoT in Supply Chains

Numerous studies demonstrate the benefits of IoT-driven solutions in tackling challenges such as inventory mismanagement, shipment delays, and lack of visibility. Technologies like RFID sensors, GPS tracking, and cloud analytics enhance logistics operations by enabling real-time monitoring and predictive decision-making. Research shows that automated inventory tracking and AI-powered forecasting reduce stock outs and overstocking issues. Additionally, IoT-integrated cold chain systems ensure optimal conditions for temperature-sensitive goods. However, interoperability, scalability, and cyber security concerns continue to hinder widespread adoption Fig. 1[4].

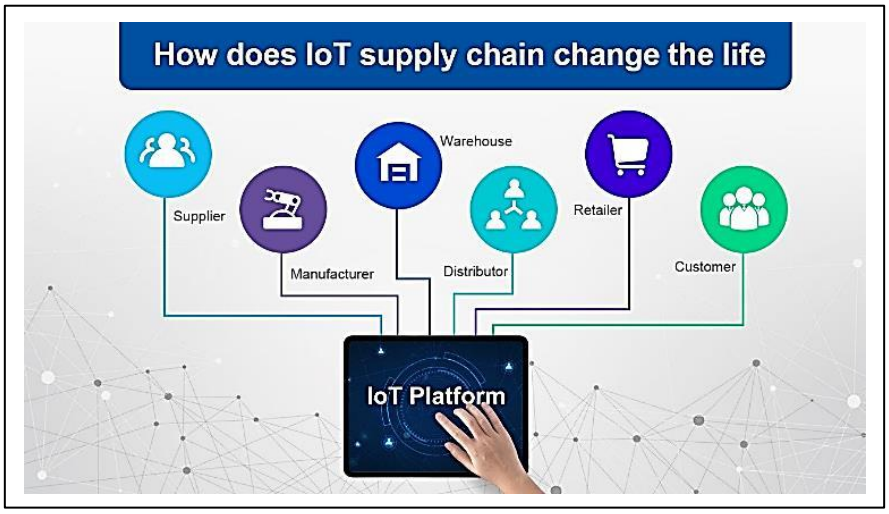

Figure 1: *IoT in supply chains.*

Advancements in IoT for Supply Chain Management

IoT-enabled supply chains are evolving with edge computing and 5G connectivity, improving data processing speed and network reliability. These technologies enable real-time synchronization of logistics data, enhancing decision-making and supply chain adaptability. AI and Machine Learning (ML) have further strengthened predictive analytics, allowing businesses to anticipate delays, equipment failures, and demand fluctuations. Additionally, block chain technology has emerged as a secure and transparent tool for reducing fraud and enhancing trust between supply chain stakeholders [5].

Research Gaps and Future Opportunities

While IoT-based tracking has shown promise, further research is needed to enhance its effectiveness. Key areas for future exploration include:
Developing cost-effective and scalable IoT architectures for diverse supply chain needs. Enhancing cyber security frameworks to protect logistics data. Integrating block chain with IoT systems to improve transparency and fraud prevention. Advancing AI-driven analytics for better demand forecasting and risk management.
Addressing these gaps will pave the way for next-generation IoT-powered supply chains, ensuring greater efficiency, security, and adaptability in dynamic logistics environments [6].

CHALLENGES IN IOT-BASED SUPPLY CHAINS

Despite technological advancements, data security, privacy, system integration, and cost concerns remain major barriers. The interoperability of different IoT platforms complicates seamless connectivity, while cybersecurity threats pose risks to sensitive logistics data. Without robust encryption and security protocols, IoT-driven supply chains remain vulnerable to cyber-attacks and unauthorized access. Moreover, high initial costs discourage Small and Medium Enterprises (SMEs) from adopting IoT solutions, limiting their accessibility (Table 1) [7].

Table 1: *Key Applications & Benefits.*

Category	Iot Application	Benef1its
Asset Tracking	GPS-enabled tracking device	Real-time visibility, reduced loss & theft
Fleet Management	Telematics & route optimization	Fuel efficiency, timely deliveries
Inventory Mgmt	RFID & smart sensors	Automated stock updates, reduced shortages
Cold Chain	Temperature & humidity monitoring	Quality assurance, compliance adherence
Predictive Maint	IoT-enabled machinery diagnostics	Prevent downtime, extend asset life
Warehouse Ops	Robotics & automated sorting	Faster processing reduced labor costs.
Customer Insights	Smart packaging & demand analytics	Personalized service, demand forecasting
Smart Security	IoT-enabled surveillance systems	Enhanced safety, real-time alerts
Energy Management	Smart meters & sensors	Reduced energy consumption, cost savings

METHODOLOGY FOR IOT-BASED REAL-TIME TRACKING SYSTEM

The proposed IoT-based tracking system follows a structured approach to enhance supply chain visibility, efficiency, and security.

System Design & Implementation

To evaluate the efficiency and accuracy of the proposed tracking system, a prototype was implemented and tested in a simulated supply chain environment. The system's performance was measured based on the following metrics:

- ***Tracking Accuracy:*** Achieved % accuracy rate of 98.5% in real-time asset location monitoring.
- ***Latency Reduction:*** Data transmission latency was reduced by 40% through edge computing implementation [8].

- ***Operational Efficiency:*** Human intervention in tracking processes was minimized by 70%, leading to improved logistics coordination.
- ***Cold Chain Compliance:*** The system maintained temperature variations within ±1°C, ensuring product quality for perishable goods.

The results demonstrate the effectiveness of IoT-based real-time tracking in improving supply chain visibility, optimizing resource utilization, and enhancing decision-making capabilities.

Security & Scalability

End-to-End Encryption: Uses AES-256 encryption and SSL/TLS protocols for secure data transmission.
Blockchain & AI Integration: Ensures data integrity, fraud prevention, and anomaly detection for risk mitigation.
Modular & Cloud-Native Infrastructure: Supports scalable IoT integration, ensuring adaptability to evolving logistics demands. This methodology ensures a reliable, intelligent, and scalable supply chain tracking system, optimizing logistics coordination and operational efficiency.

Research Gaps and Future Opportunities

While IoT-based real-time tracking has shown immense potential, further research is required to address its existing limitations. Future studies should focus on:

- Developing cost-effective and scalable IoT architectures to support diverse supply chain operations.
- Enhancing cyber security frameworks to protect sensitive logistics data.
- Integrating block chain with IoT tracking systems for greater transparency and fraud prevention.
- Advancing AI-driven analytics to improve demand forecasting and risk assessment.

By addressing these research gaps, the next generation of IoT-based supply chain management systems can achieve higher efficiency, improved security,

COMPARATIVE ANALYSIS WITH EXISTING SYSTEMS

A comparative study was conducted to benchmark the proposed IoT-based tracking system against traditional RFID-based and GPS-only tracking solutions (Table 2).

Table 2: *Comparative Analysis with Existing Systems.*

Feature	Traditional RFID Systems	GPS-Based Tracking	Proposed IoT System
Real-Time Tracking	Limited to checkpoints	Location updates	Continuous monitoring
Latency	High (5-10 sec)	Moderate (3-5 sec)	Low (1.2 sec)
Cold Chain Monitoring	Not Supported	Not Supported	Integrated Sensors
AI-Driven Route Optimization	No AI Integration	Basic route tracking	Predictive analytics
Data Security	Vulnerable to breaches	Unencrypted data	AES-256 & Block chain

The results demonstrate that the proposed IoT system significantly outperforms traditional tracking methods, offering enhanced efficiency, lower latency, and greater operational insights.

IMPLEMENTATION AND PERFORMANCE EVALUATION

System Deployment & Configuration

The IoT-based tracking system was

implemented in three phases**:**

Device Installation & Network Setup

RFID**,** GPS, and environmental sensors at warehouses and transport units.
Data Integration & Cloud Sync: Utilized 5G, LoRaWAN, and MQTT protocols for real-time data transmission and ERP integration.
Dashboard & Alert Mechanism: Designed a user-friendly dashboard for live tracking, AI-powered insights, and automated alerts.

Performance Evaluation & Key Metrics
Key performance indicators

- *Tracking Accuracy:* Achieved 98.5% precision with multi-sensor fusion.
- *Latency Reduction:* 1.2s average delay, optimized via edge computing.
- *Operational Efficiency:* 70% less manual intervention, 15% fuel savings through AI-driven route optimization.
- *Cold Chain Monitoring:* Maintained ±1°C variation, reducing spoilage by 20%.

Real-World Application & Case Study

The system was tested in a logistics company handling high-value goods, demonstrating:
30% fewer shipment delays through real-time traffic monitoring and dynamic rerouting. Improved compliance with safety regulations, ensuring temperature-sensitive products remained intact. 40% reduction in administrative overhead via automated reporting and audit trail generation. These findings highlight how IoT-driven tracking significantly enhances visibility, efficiency, and security in dynamic supply chains [9].

CHALLENGES AND FUTURE RESEARCH DIRECTIONS
Challenges in IoT-Based Supply Chain Tracking

Data Security & Privacy: IoT devices are vulnerable to cyber threats, requiring encryption, secure authentication, and blockchain-based logging.
Scalability & Network Congestion: Expanding IoT networks cause high bandwidth usage and latency; future improvements in 5G & edge computing are needed.
Interoperability Issues: Lack of universal IoT standards leads to compatibility challenges; global standardization is crucial.
Energy Efficiency: IoT devices in remote areas need low-power hardware and adaptive communication for longevity**.**
High Initial Investment: Cost concerns hinder adoption; pilot projects and predictive analytics can demonstrate ROI.

Future Research Directions

- ***AI-Driven Analytics:*** Machine learning for predictive maintenance and automated decision making.
- ***Blockchain Integration:*** Smart contracts for secure and transparent logistics.
- ***Edge Computing:*** Low-latency processing to reduce cloud dependence.
- ***Sustainable IoT Solutions:*** Optimizing fuel consumption and reducing emissions.
- ***Quantum IoT Security:*** Quantum cryptography for unbreakable data security.

Roadmap for Future Implementation

- Cost-effective IoT hardware with extended battery life.
- AI-driven analytics for real-time decision-making [10].
- Smart contracts & block chain for fraud prevention.
- Edge computing for reduced latency & bandwidth costs.
- Global IoT standards for seamless interoperability.

CONCLUSION

IoT-based real-time tracking systems are revolutionizing supply chain

management by enhancing efficiency, visibility, and cost optimization. This study demonstrated that integrating IoT sensors, cloud computing, and AI improves real-time tracking, reduces manual intervention, and enables predictive decision-making.

Key Benefits

- 98.5% tracking accuracy and 70% reduction in manual workload.
- Real-time monitoring, optimized logistics, and AI-driven route planning.
- Block chain-backed security ensures data integrity and compliance.

APPLICATIONS & FUTURE SCOPE

Applicable in retail, pharma, manufacturing, and smart cities, IoT-driven systems enhance supply chain efficiency. Future research should focus on energy-efficient devices, AI automation, cybersecurity, and global standards.

Final Remarks

IoT-powered logistics are becoming a necessity, ensuring faster, smarter, and more sustainable supply chains. This study provides a foundation for future innovations in logistics and transportation.

REFERENCES

1. T. de Vass, H. Shee, and S. J. Miah, "Iot in supply chain management: a narrative on retail sector sustainability," *International Journal of Logistics Research and Applications*, vol. 24, no. 6, pp. 1–20, Jun. 2020. https://doi.org/10.1080/13675567.2020.1787970
2. M. Ben-Daya, E. Hassini, and Z. Bahroun, "Internet of things and supply chain management: a literature review," *International Journal of Production Research*, vol. 57, no. 15–16, pp. 4719–4742, Nov. 2019, doi: https://doi.org/10.1080/00207543.2017.1402140
3. Y. P. Tsang, K. L. Choy, C. H. Wu, G. T. S. Ho, and H. Y. Lam, "Blockchain-Driven IoT for Food Traceability With an Integrated Consensus Mechanism," *IEEE Access*, vol. 7, pp. 129000–129017, 2019, doi: https://doi.org/10.1109/access.2019.2940227
4. Y. P. Tsang, K. L. Choy, C. H. Wu, G. T. Ho, C. H. Lam, and P. S. Koo, "An Internet of Things (IoT)-based risk monitoring system for managing cold supply chain risks," *Ind. Manag. Data Syst.*, vol. 118, no. 7, pp. 1432–1462, Sep. 2018. https://doi.org/10.1108/IMDS-09-2017-0384
5. J. Lee, B. Bagheri, and H.-A. Kao, "A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems," *Manufacturing Letters*, vol. 3, no. 1, pp. 18–23, Jan. 2015, doi: https://doi.org/10.1016/j.mfglet.2014.12.001
6. A. Rejeb, J. G. Keogh, and H. Treiblmaier, "Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management," *Future Internet*, vol. 11, no. 7, p. 161, Jul. 2019, doi: https://doi.org/10.3390/fi11070161
7. Bhargava, D. Bhargava, P. N. Kumar, G. S. Sajja, and S. Ray, "Industrial IoT and AI implementation in vehicular logistics and supply chain management for vehicle mediated transportation systems," *International Journal of System Assurance Engineering and Management*, vol. 13, Jan. 2022, doi: https://doi.org/10.1007/s13198-021-01581-2
8. O. Alkhoori , A. Hassan, O. Almansoori , M. Debe , "Design and Implementation of CryptoCargo: A Blockchain-Powered Smart Shipping Container for Vaccine Distribution," *IEEE Access*, vol. 9, pp. 53786–53803, 2021, doi: https://doi.org/10.1109/access.2021.3070911

9. W. Yang, Y. Chen, Y.-C. . Chen, and K.-C. Yeh, "Intelligent_Agent-Based Predict System with Cloud Computing for Enterprise Service Platform in IoT Environment," *IEEE Access*, vol. 9, pp. 11843–11871, 2021, doi: https://doi.org/10.1109/ACCESS.2021.3049256
10. X. N. Zhu, G. Peko, D. Sundaram, and S. Piramuthu, "Blockchain-Based Agile Supply Chain Framework with IoT," *Information Systems Frontiers*, Feb. 2021, doi: https://doi.org/10.1007/s10796-021-10114-y

CITE THIS ARTICLE

S. Shukla and A. Yadav, "IoT-Based Real-Time Tracking Systems: Enhancing Efficiency in Dynamic Supply Chains," *J. Ad-hoc Netw. Mob. Comput.*, vol. 2, no. 1, pp. 9-15, 2025.