JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Efficient Caching Methodology for ICN-IoT Networks

[1]Pruthvi C N, [2]H S Viamla,
[1]Research Scholar, [2]Professor
[12]Dept. of CSE,
[1]University Visweswarayya College of Engineering

Abstract : Information-Centric Networking (ICN) has emerged as a promising paradigm for the Internet of Things (IoT) by decoupling content from specific locations, allowing efficient content distribution. However, caching in ICN-IoT remains a challenge due to resource-constrained IoT nodes. This paper proposes a novel caching methodology that selects the most efficient caching nodes while dynamically replacing unwanted data based on network conditions and data popularity.

IndexTerms **– ICN, ICN-IoT, Caching.**

(1) INTRODUCTION

Information-Centric Networking (ICN) is an emerging paradigm that shifts the focus from host-based communication to content-based data retrieval, making it particularly well-suited for the Internet of Things (IoT). ICN-IoT caching enhances network efficiency by storing frequently accessed data closer to end users, reducing latency, alleviating network congestion, and improving content availability [1]. By leveraging in-network caching, ICN mitigates the challenges of traditional IP-based IoT architectures, such as high dependency on centralized servers and increased energy consumption. Efficient caching strategies in ICN-IoT optimize resource utilization, enhance data dissemination, and support seamless connectivity, making them critical for scalable and responsive IoT ecosystems [2].

Information-Centric Networking (ICN) introduces a content-centric approach to data dissemination, where content is named and retrieved based on its identity rather than its location. A key feature of ICN is in-network caching, which enables intermediate nodes to store and serve frequently requested content, reducing redundant data transmissions and improving network efficiency [3]. By leveraging caching, ICN minimizes latency, alleviates network congestion, and enhances content availability, making it particularly beneficial for dynamic and resource-constrained environments such as the Internet of Things (IoT) and edge computing. Effective caching strategies in ICN play a crucial role in optimizing resource utilization, improving user experience, and supporting scalable and resilient communication networks [4].

II. LITERATURE SURVEY

This study introduces a novel caching strategy that optimally places content at highly requested nodes, significantly enhancing caching efficiency in ICN-based IoT systems. The proposed approach is evaluated against existing caching methods, focusing on key performance metrics such as data retrieval latency, cache hit ratio, and the average number of hops. The results consistently demonstrate a substantial improvement in cache performance. Looking ahead, the adoption of this caching strategy is expected to play a crucial role in the evolution of fog, edge, and ad hoc networks, aligning with the advancements in IoT and emerging technologies like 5G and 6G [9].

This paper presents a popularity, freshness, and recency based cache content eviction policy designed to retain essential content in NDN-IoT networks. Extensive simulations are conducted to evaluate PFR against benchmark NDN cache eviction policies. The results indicate that, on average, PFR surpasses existing policies, achieving improvements of 27.43% in cache hit ratio, 21.56% in server hit reduction, 15.85% in average response delay, and 7.24% in energy consumption [10].

This work presents a novel content replacement scheme that proactively tracks the number of requests and access time of content in the Pending Interest Table (PIT) while considering key attributes such as request count, remaining lifetime, and anticipated request waiting time before replacement. This approach helps retain vital content in the cache. The proposed scheme is evaluated using the ndnSIM framework of NS-3, comparing its performance against widely used benchmark replacement schemes across six different caching strategies. Experimental results show that, on average, the proposed scheme improves the cache hit ratio and server hit reduction ratio by 28.94% and 27.49%, respectively, while reducing response delay and energy consumption by 22.30% and 30.64% compared to NDN-FIFO, NDN-LRU, and NDN-LRFU [11].

PROPOSED CACHING METHODOLOGY

The proposed methodology consists of two main components:

2.1. Efficient Node Selection for Caching

- A caching efficiency metric (CEM) is introduced, considering factors such as node energy level, connectivity, processing capacity, and historical cache hit ratio.
- Nodes with higher CEM values are prioritized for caching, ensuring that resource-constrained devices avoid unnecessary caching responsibilities.
- A clustering-based approach is employed to identify optimal caching nodes within localized IoT environments.

2.2. Adaptive Content Replacement Strategy

- The Least Recently Used (LRU) and Least Frequently Used (LFU) policies are combined with a machine learning-based popularity predictor to retain frequently requested content.
- Data importance is assessed based on context-aware IoT parameters, such as real-time sensor data relevance, user demand patterns, and data expiration time.
- An eviction threshold dynamically adjusts based on network traffic and node resource availability, preventing cache overflow while minimizing unnecessary replacements.

3. PERFORMANCE EVALUATION

Simulations are conducted to evaluate the effectiveness of the proposed methodology against traditional caching schemes. Key performance indicators such as cache hit ratio, energy consumption, and latency reduction are analyzed. The results demonstrate significant improvements in cache utilization efficiency and network performance.

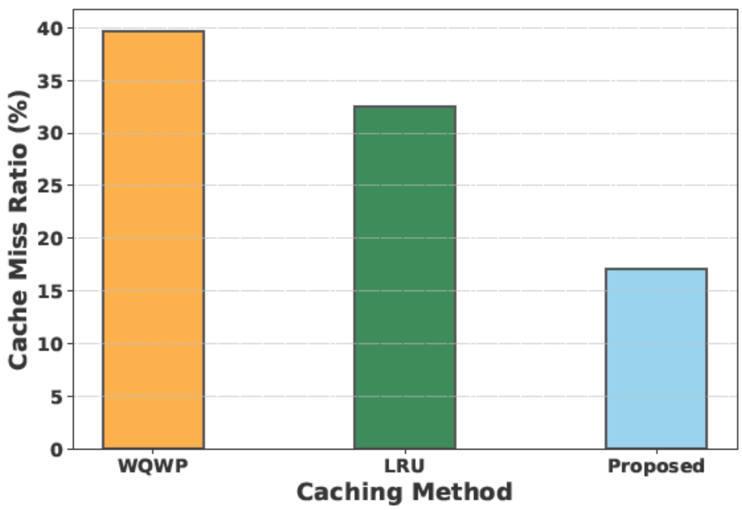

 Fig. 1. Cache Replacement Rate

Fig. 1. This graph compares the cache replacement rate (measured in replacements per second) among three caching methods: WQWP, LRU, and the Proposed Caching Method.

[1] The replacement rate indicates how frequently cached content is being replaced, which impacts overall efficiency.
[2] A lower replacement rate suggests better cache stability, reducing unnecessary data swaps.
[3] Observations: The Proposed Caching Method likely has a lower replacement rate compared to LRU, indicating a more efficient content retention strategy.

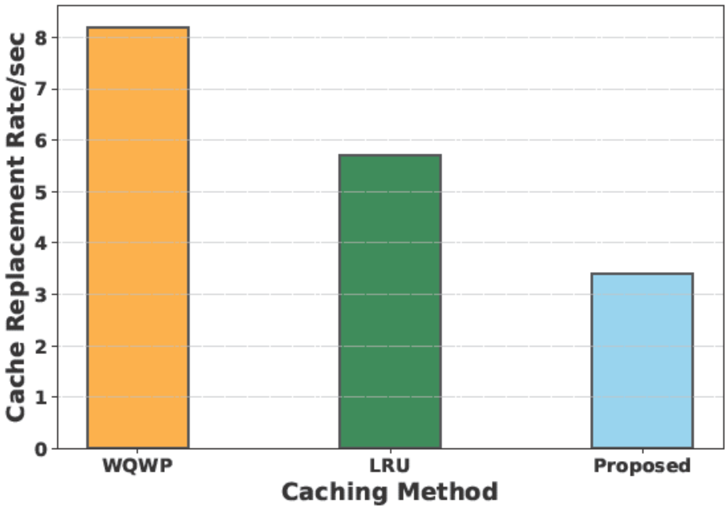

Fig. 2. Cache Miss Ratio

Fig. 2. This graph illustrates the cache miss ratio (percentage) for WQWP, LRU, and the Proposed Caching Method.

TABLE I. The cache miss ratio represents how often a requested item is not found in the cache, leading to additional network requests.

TABLE II. A lower cache miss ratio is desirable, as it signifies better cache hit performance.

Observations: The Proposed Caching Method shows a lower cache miss ratio than LRU and WQWP, indicating improved content availability and optimized caching.

4. Conclusion

This paper presents a novel ICN-IoT caching methodology that selects efficient nodes for caching and dynamically replaces unwanted data. By incorporating a caching efficiency metric and an adaptive content replacement strategy, the proposed approach enhances resource utilization, reduces network congestion, and improves content availability in IoT environments.

References:

[1] Ullah, I., Raza, G. M., & Kim, B. S. (2024). Smart Proactive Caching: Paving the Way for Efficient Caching in Vehicular ICN. *IEEE Access*.

[2] Luo, H., Yan, T., & Hu, S. (2024). Caching Policy in Low Earth Orbit Satellite Mega-Constellation Information-Centric Networking for Internet of Things. *Sensors*, *24*(11), 3412.

[3] Naeem, M. A., Din, I. U., Meng, Y., Almogren, A., & Rodrigues, J. J. (2024). Centrality-Based On-Path Caching Strategies in NDN-Based Internet of Things: A Survey. *IEEE Communications Surveys & Tutorials*.

[4] Zahedinia, M. S., Khayyambashi, M. R., & Bohlooli, A. (2024). IoT data management for caching performance improvement in NDN. *Cluster Computing*, *27*(4), 4537-4550.

[5] Pruthvi, C. N., Vimala, H. S., & Shreyas, J. (2024, October). RLWF-An Efficient Content Caching and Replacement Algorithm for ICN-IoT. In *2024 Global Conference on Communications and Information Technologies (GCCIT)* (pp. 1-5). IEEE.

[6] Naeem, M. A., Yahui, M., & Abrar, A. (2025). Optimizing data retrieval latency in IoT through information centric in-network caching. *Alexandria Engineering Journal*, *111*, 468-481.

[7] Wang, X., & You, X. (2024). Efficient data sharing and caching for information-centric IoT. *IEEE Internet of Things Journal*, *11*(10), 18074-18081.

[8] Hou, J., Elhadef, M., & Nayak, A. Icn-Enabled Intelligent Edge Caching Strategies for Optimizing Iot Services. *Available at SSRN 5031769*.

[9] Javaheri, A., Bohlooli, A., & Jamshidi, K. (2024). Enhancing computation reuse efficiency in ICN-based edge computing by modifying content store table structure. *Computing*, *106*(9), 2949-2969.

[10] Mishra, S., Jain, V. K., Gyoda, K., & Jain, S. (2024). A novel content eviction strategy to retain vital contents in NDN-IoT networks. *Wireless Networks*, 1-23.

[11] Mishra, S., Jain, V. K., Gyoda, K., & Jain, S. (2024). An efficient content replacement policy to retain essential content in information-centric networking based internet of things network. *Ad Hoc Networks*, *155*, 103389.