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A STUDY ON INFORMATION-CENTRIC INTERNET OF HEALTHCARE THINGS WITH CACHING POLICY

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Abstract:

Information-Centric Networking (ICN) is a Content-Oriented Network and facilitates the content retrieval as well as calculates downstream paths without requirement of optimal topology. ICN inbuilt the mobility support features in baseline design. ICN is well-liked network architecture for Internet. Internet of Health Thing (IoHT) is network of healthcare devices to reduce the unnecessary visits to the hospital for minimizing the burden on medical-care system through providing connectivity over secure network between medical experts and patients. Information-Centric Networking with IoHT saves the time and money. Caching is described as temporarily saving data and objects at frequent predictive location or associated intervals. In recent times, many researchers carried out their research on Information-Centric Networking by using different methods. But, the delay was not minimized and network latency was not reduced through caching approach. In order to address these issues, many Information-Centric Networking with IoHT were studied in the research.

Keywords: **Information-Centric Networking; Downstream; Mobility Support; Caching; Medical-Care System; Internet of Health Thing;**

1. Introduction

Information-Centric Network (ICN) employs the request and acquired the information because essential behavior mode rather than end-to-end connection to distribute the content efficiently. ICN is applicable to large number of application situations in Internet of Things (IoT) network for distributing the large amount of information. IoT is an environment with large number of connected applications. IoT devices are employed to generate the data that transform into useful information and provides resources to end-users. IoT is an intelligent with in-depth research work on technologies. IoT devices make decisions through training and running. The devices in IoT have caching capabilities. Caching technology has unique importance for IoT.

Caching increased speed of data retrieval to minimize the IoT task execution delay. The caching related acceptance operations are expensive in terms of processing and power consumption.

This paper is organized as follows: Section 2 reviews the drawbacks on existing Information-Centric Internet of Healthcare Things with existing caching policies. Section 3 shows the study and analysis of existing information-centric internet of healthcare things with caching policies. Section 4 identifies the possible comparison between them. Section 5 discusses the limitations of existing techniques and Section 6 concludes the paper.

2. Literature Review

A Pre-Caching Strategy with Relevance of smart device request Content (PCSRC)was introduced [1]. PCSRC pre-cached remaining content chunks after first request of content chunk at smart device side. However, the delay was not reduced by designed pre-caching strategy. A deep reinforcement learning-based cooperative edge caching approach was introduced [2] to allocate the distributed edge servers for cooperating with each other. An edge server decided cache actions depending on local caching state. But, the network latency was not reduced by deep reinforcement learning-based cooperative edge caching approach.

A Software-Defined Information Centric-Internet of Things (IC-IoT) architecture was introduced [3] to provide the caching and computing capabilities for IoT network. A joint resource scheduling scheme was employed to handle the computing and caching resources. But, the request hop was not minimized. A Deep Reinforcement Learning (DRL) was introduced [4] for addressing the caching IoT data issues at an edge. IoT data caching policy was employed to strike balance between communication cost and data freshness loss. But, the computational cost was not minimized by DRL. A Variational Recurrent Neural Network (VRNN) was introduced [5] for determining time-variant popularity distribution in each Base Stations (BS) to compute the spatio-temporal difference of content popularity. But, the computational complexity was not reduced by VRNN.

An efficient caching policy was introduced [6] to organize Content Store (CS) of node with their neighbor nodes in distributed manner. The content objects were cached in neighborhood of the node. CS information was employed in the data plane of network to coordinate CS information among nodes. But, cache hit ratio was not improved by efficient caching policy.

A fog-assisted healthcare IoT system was designed [7] with fog computing to address the resource limitations of IoT nodes. The designed system developed in-network caching and request aggregation of content-centric networking to reduce the patient data retrieval latency. An ICN was introduced [8] with communication model in IoT environments for solving the mobility problems. The merger between ICN and IoT was employed to explain the emergence, evolution and mobility approach.

An appropriate architecture was introduced [9] with an Information-Centric Network (ICN). ICN was designed with future Internet architecture to handle large number of IoT devices and their content. ICN was employed in-network caching functionality for IoT to minimize the overhead of publisher with respect to content access. A caching scheme termed Central Control Caching (CCC) Scheme was designed [10] for IoT contents. CCC scheme placed central entity between autonomous systems to deal with caching and updated the content through maintaining information in table on different autonomous systems.

A data prioritization-based approach was designed [11] to avoid the ICN nodes from Content Store (CS) with inappropriate data. An inferior data was increased to improve the cache efficiency. Fog computing was employed in middle layer between IoT devices and ICN networks to address the decision-making problems. An ICN caching strategy was designed [12] for energy efficient and secure IoT environment. The designed strategy was employed to minimize energy consumption and bandwidth utilization.

3. Information-Centric Internet of Healthcare Things with Caching Policy

Information Centric Network (ICN) is the kind of network that varies the users focus from terminal to the content. ICN separated the content from terminal location and provided storage as well as communication services through publish/subscribe model. ICN changed the pattern of IP network. It is differentiated by fact that network carries large quantity of contents. The user's main behavior was to access the definite contents. IoT applications slowly incorporated into all areas of production and daily lives. IoT is an intelligent with in-depth research work on technologies. IoT devices make decisions through training and running. Network latency is reduced even caching in IoT node with small storage. IoT strategy aimed on increasing the speed of propagation rather than long-term caching.

3.1 *A pre-caching strategy based on the content relevance of smart device's request in information-centric IoT*

With fast growth of Internet of Things (IoT), new development of smart devices has become comprehensive application of new generation for information technology. Information-Centric Internet of Things (IC-IoT) used content caching characteristics with Information-Centric Networking features. An efficient caching strategy was introduced for IC-IoT to increase the smart device efficiency. A Pre-Caching Strategy depending on the relevance of smart device request content (PCSRC)was introduced. PCSRC pre-cached the rest of content chunks after receiving the first request of content chunk at smart device side. There were two types of cached content chunks, namely actual requested content chunks and pre-caching content chunks. Actual requested content chunks were pushed forward hop-by-hop consistent with local activity trends.

PCSRC was introduced depending on relevance of smart device requests. IC-IoT used ICN characteristics where the request and return of content tracked the similar path. When smart device initiated request for content chunk, PCSRC cache subsequent content chunks that follow content chunk of smart device request and smart device was the user. The content types in network were actual request content and the pre-caching content correspondingly. In PCSRC, router ID list field was predefined in interest packet to attain request path. The pre-caching content was determined by the router ID list of interest packet. The content in the second half of the path was stored to exploit the cache space. With development of request content popularity, the popular contents were advanced to the edge nodes. The sojourn time was reduced to reduce the storage space for cached content.

3.2 Cooperative edge caching: a multi-agent deep learning based approach

Internet of Things (IoT) devices has many innovations in the developing network model. IoT edge caching is considered as a promising method to manage the explosive growth in network data traffic with improved Quality of Service (QoS) and reduced energy consumption. An intrinsic storage constraint of edge servers poses the critical challenge for IoT edge caching system. Edge servers were enabled with each other to provide potential perspective for increasing the edge storage utilization. A caching system increased the communication overhead that makes caching system more complex. Therefore, a deep reinforcement learning-based cooperative edge caching approach was introduced to allow the distributed edge servers cooperate with each other. An edge servers determined cache actions depending on the local caching state. The remote centralized server estimated the actions and feedback the results to edge servers for successive caching action optimization.

With help of appropriate reward function, the designed approach promoted the cooperation between edge servers and enhanced thee system hit rate. A deep reinforcement learning-based cooperative edge caching approach combined deep reinforcement learning characteristics and IoT edge caching system. The feature and action spaces was described to handle the obstacles created by the inconsistent IoT data item size and reward function to promote the cooperation between edge server. In multi-agent actor-critic algorithm, every edge server had taken the caching decisions locally. The remote centralized server determined the action depending on global caching information to optimize their subsequent caching decisions.

3.3 DQN inspired joint computing and caching resource allocation approach for software defined information-centric internet of things network

With fast growth of Internet of Things (IoT) network, IoT devices perform the artificial intelligence (AI) model for taking the decisions based on particular service needs in dynamic environment. The generation of AI model perform large amount of communication, computing and caching resource. The network resource scheduling was carried out to perform the rapid generation and propagation of AI models. A software-defined Information Centric-Internet of Things (IC-IoT) architecture was introduced to perform the caching and computing capabilities to IoT network. Depending on IC-IoT architecture, joint resource scheduling scheme was employed to consistently handle the computing and caching resources. IC-IoT architecture was employed to increase the performance of short-term reward and long-term reward through caching AI models. The resource scheduling problem was considered as the multi-dimensional optimization problem. A new deep Q-learning method was introduced to address the complexity problem.

3.4 Caching transient data for internet of things: a deep reinforcement learning approach

Connected devices in Internet-of-Things (IoT) generate large amount of transient data requested by IoT application users like autonomous vehicles. IoT data transmission through wireless networks resulted in congestion and long delay that was tackled by caching IoT data at the network edge. It was challenging one to jointly consider the IoT data-transiency and dynamic context characteristics. A Deep Reinforcement Learning (DRL) was introduced to address the caching issues of IoT data at edge without knowing future IoT data popularity, user request pattern and context characteristics. Through describing the data freshness metrics, IoT data caching policy was employed to strike balance between communication cost and the data freshness loss. An edge caching based IoT system framework was introduced for caching and transmitting the transient IoT data. A cost function was used to tradeoff between data freshness and communication cost when fetching IoT data. A cache replacement problem was considered as a Markov Decision Process (MDP) problem to reduce the long-term cost of fetching IoT data.

4. Comparison of Information-Centric Internet of Healthcare Things with Caching Policy and Suggestions

In order to compare the information-centric internet of healthcare things with caching policy, number of cache nodes and cache space is taken to perform the experiment. Various parameters are used for improving the information-centric internet of healthcare things with caching policy performance by reducing delay and increasing cache hit ratio.

4.1 Impact on cache hit ratio

Cache Hit Ratio (CHR) is the ratio of response number of requests and total number of requests in particular time period. CHR is computed as,

$$CHR = \frac{Response}{Count} \quad (1)$$

In (1), '$Response$' denotes the response number for cached node. '$Count$' symbolizes the number of requests obtained by the nodes. When CHR value is higher, validity of a caching scheme is high and content redundancy is less.

Cache hit ratio is determined with respect to cache space. It is clear that cache hit ratio of PCSRC is higher than deep reinforcement learning-based cooperative edge caching approach, software-defined IC-IoT architecture and DRL. This is due to pre-cached content chunks after receiving the first request of content chunk at smart device side. In PCSRC, router ID list field was predefined in the interest packet to achieve the request path. The pre-caching content was determined by router ID list of interest packet. The content in second half of path was stored to develop the cache space. By this way, the cache hit ratio gets improved. It is arrived that from research in PCSRC has 23% higher cache hit ratio than deep reinforcement learning-based cooperative edge caching approach, and much higher cache hit ratio than software-defined IC-IoT architecture and drastically than DRL.

4.2 Impact on average request hop

Average Request Hop (ARH) is defined as the average number of routes transmitted when interest packet hits the request content. It is formulated as,

$$ARH = \frac{\sum rep \epsilon REP \; g_{rep}}{Number\ of\ response\ that\ an\ interest\ packet\ is\ responded} \quad (2)$$

Where 'g_{rep}' symbolizes the number of hops that interest packet is responded. 'REP' represent the set of user request. When ARH is lesser, hops of response are less.

Average request hopis calculated with respect to different cache space. It is clear that average request hopof deep reinforcement learning-based cooperative edge caching approach is lesser than PCSRC, software-defined IC-IoT architecture and DRL. This is because of applying multi-agent actor-critic algorithm where every edge server taken caching decisions locally. The remote centralized server identified action depending on the global caching information to optimize subsequent caching decisions. By this way, the average request hop gets reduced. It is observes that research in deep reinforcement learning-based cooperative edge caching approach has lesser average request hop than PCSRC, also lesser average request hop than software-defined IC-IoT architecture and much promising result than DRL.

4.3 Impact on average request delay

Average Request Delay (ARD) is defined as the average delay from transmitting the interest packets to the receiving response data packet.

$$ARD = \frac{Transmitting\ interest\ packets\ to\ the\ receiving\ response\ data\ packet}{n} \quad (3)$$

In equation (3), 'n' denotes the number of cache nodes. When the average request delay is lesser, the method is efficient.

Average request delay is determined with respect to different cache space. It is clear that average request delay of software-defined IC-IoT architecture is lesser than PCSRC, deep reinforcement learning-based cooperative edge caching approach and DRL. This is due to application of joint resource scheduling scheme was employed to consistently handle the computing and caching resources. IC-IoT architecture increased the short-term reward and long-term reward performance through caching AI model. A new deep Q-learning method addressed the complexity issues. Research in software-defined IC-IoT architecture claims lesser average request delay than PCSRC, much lesser average request delay than deep reinforcement learning-based cooperative edge caching approach and highest lesser average request delay than DRL.

5. Discussion and Limitation on Information-Centric Internet of Healthcare Things with Caching Policy

Pre-Caching Strategy depending on Relevance of requested Content for Collaboration between nodes. The subsequent content chunks of request were pre-cached depending on relevance of content. The sojourn time was determined for every content chunk consistent with their popularity. PCSRC pushed popular content to the edge of network efficiently. PCSRC technique minimized the hop count and increased the user experience. Though the hop count was reduced, the delay was not reduced by designed pre-caching strategy. The deep reinforcement learning based cooperative caching approach was employed for performing the IoT edge caching. The caching states and caching actions were employed to handle the obstacles through the inconsistent data item size. A reward function increased the cooperation performance between edge servers. But, the network latency was not reduced through designed caching approach.

In DRL-based caching policy, an edge caching based IoT system framework was employed for caching and transmitting the transient IoT data. The cache replacement problem was addressed to reduce the long-term cost of fetching IoT data. DRL-based caching policy determined the caching policy without any assumptions. But, the computational cost was not minimized by DRL. A software-defined IC-IoT network architecture was used with application scenarios of IC-IoT. A joint resource allocation scheme has been handled and organized the caching as well as computing resources. However, the request hop was not minimized.

6. Conclusion

A comparison of different information-centric internet of healthcare things with caching policy techniques is considered. From the survival study, it is observed that the existing the network latency was not reduced through designed caching approach. In addition, the request hop was not minimized. The computational cost was not minimized by DRL and the request hop was not minimized. The wide range of experiment on existing methods determines the performance of information-centric internet of healthcare things with caching policies with its limitations. Finally, from the result, the research work can be carried out using machine learning techniques for improving the performance of information-centric internet of healthcare things using caching policy with lesser delay.

References

1. M. Zhang, B. Hao, R. Wang and Y. Wang, "A Pre-Caching Strategy Based on the Content Relevance of Smart Device's Request in Information-Centric IoT," in *IEEE Access*, vol. 8, pp. 75761-75771, 2020, doi: 10.1109/ACCESS.2020.2988926.
2 Y. Zhang et al., "Cooperative Edge Caching: A Multi-Agent Deep Learning Based Approach," in IEEE Access, vol. 8, pp. 133212-133224, 2020, doi: 10.1109/ACCESS.2020.3010329.
3. F. Xu, F. Yang, S. Bao and C. Zhao, "DQN Inspired Joint Computing and Caching Resource Allocation Approach for Software Defined Information-Centric Internet of Things Network," in IEEE Access, vol. 7, pp. 61987-61996, 2019, doi: 10.1109/ACCESS.2019.2916178.
4. H. Zhu, Y. Cao, X. Wei, W. Wang, T. Jiang and S. Jin, "Caching Transient Data for Internet of Things: A Deep Reinforcement Learning Approach," in IEEE Internet of Things Journal, vol. 6, no. 2, pp. 2074-2083, April 2019, doi: 10.1109/JIOT.2018.2882583.
5. S. Chen, Z. Yao, X. Jiang, J. Yang and L. Hanzo, "Multi-Agent Deep Reinforcement Learning-Based Cooperative Edge Caching for Ultra-Dense Next-Generation Networks," in IEEE Transactions on Communications, vol. 69, no. 4, pp. 2441-2456, April 2021, doi: 10.1109/TCOMM.2020.3044298.
6. N.-T. Dinh, Y. Kim, "An Efficient Distributed Content Store-Based Caching Policy for Information-CentricNetworking," in Sensors (Basel), vol. 22, no. 4, pp. 1424-8220, February 2022, doi:10.3390/s22041577
7. X. Wang and Y. Li, "Fog-Assisted Content-Centric Healthcare IoT," in IEEE Internet of Things Magazine, vol. 3, no. 3, pp. 90-93, September 2020, doi: 10.1109/IOTM.0001.2000005.
8. B. Nour et al., "Internet of Things Mobility Over Information-Centric/Named-Data Networking," in IEEE Internet Computing, vol. 24, no. 1, pp. 14-24, 1 Jan.-Feb. 2020, doi: 10.1109/MIC.2019.2963187.
9. H. Asmat, I. U. Din, F. Ullah, Muhammad Talha, Murad Khan, M.Guizani, "ELC: Edge Linked Caching for content updating in information-centric Internet of Things," in Computer Communications,Elsevier,vol. 156, pp. 174-182, 2020, doi:org/10.1016/j.comcom.2020.03.049.
10. H. Asmat, F. Ullah, M. Zareei, A. Khan and E. M. Mohamed, "Energy-Efficient Centrally Controlled Caching Contents for Information-Centric Internet of Things," in IEEE Access, vol. 8, pp. 126358-126369, 2020, doi: 10.1109/ACCESS.2020.3008193.
11. M.S. Zahedinia, M.R. Khayyambashi, and A. Bohlooli, "Fog-based caching mechanism for IoT data in information centric network using prioritization," in Computer Networks, Elsevier , vol. 213. pp. 1389-1286, June 2022, doi:10.1016/j.comnet.2022.109082
12. I. U. Din, S. Hassan, A. Almogren, F. Ayub, and M. Guizani, "PUC: Packet update caching for energy efficient IoT-based information-centric networking," in Future Generation Computer Systems, Elsevier,vol. 111, 2020, pp.634-643, doi:10.1016/j.future.2019.11.022