NDN Producer Regional Content Synchronization Method Based On ChronoSync

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Abstract. In order to solve the problems of high handover delay, loss of interest packets and reduction of content hit rate caused by producer movement in naming data networks, a method of NDN Producer Regional Content Synchronization (NPRCS) based on ChronoSync protocol was proposed. In this method, the content of producers is synchronized to the cache of neighboring nodes in the process of producer movement to improve the availability of content after producer movement. Simulation results show that compared with the operating mechanism of NDN, the NPRCS method reduces the handover delay and retrieval time, and improves the consumer hit rate.

1. Introduction

Named Data Networking (NDN) has the characteristics of taking content names as the core, routing based on content names, ubiquitous caching, natural support for multicast, and consumer-driven mode, etc. It has high performance in large-scale data distribution. Data forwarding efficiency [1]. In order to be able to provide high-quality and highly reliable network services in a mobile environment, research on consumer mobility and producer mobility in NDN has gradually become the focus of NDN. NDN’s unique consumer-driven model means that consumers only need to re-send the interest package after moving to easily solve the consumer’s mobile problem [2], but after the move of the producer, the consumer’s sent interest package is lost. The problem of reduced content hit rate and long retrieval time is still a difficult problem. NDN’s default solution to the problem of producer movement is to wait for the producer to stop moving and trigger the update of the entire network routing table. The advantage is that it not only maintains the consistency of data naming, but also ensures that the data before the mobile switch is still valid in the cache, and The planned path from consumer to producer is optimal. However, due to the high cost of convergence of the entire network routing table and long delay, it is difficult to ensure that the service can be restored in time within the consumer's communication tolerance [3]. In order to solve the problem of producer mobility, many methods have been proposed based on the
traditional TCP/IP network to solve the IP mobility problem. Although they have solved some of the problems of producer mobility, they are not in line with the original intention of designing NDN.

In order to better solve the problem caused by the movement of the producer and improve the usability of the content. Following the design principles of NDN and makes full use of NDN's intelligent routing strategy and caching mechanism, this article proposes a NDN producer regional content synchronization (NPRCS) method based on the ChronoSync protocol. The problem caused by the movement of the producer, which improves the usability of the content. The core idea of the NPRCS method is to synchronize the content generated by the producer to the cache of the synchronization node in the synchronization range during the movement of the producer. The synchronization range is defined as the set of nodes whose distance between the producer and the node is less than or equal to the threshold, and the synchronization node is defined as the node closest to the producer within the synchronization range. After the interest packet sent by the consumer arrives at the start position of the producer and finds that the target is lost, it only needs to be forwarded according to the routing and forwarding strategy, and the consumer's needs can be met at the neighboring synchronization node. The content synchronization between the producer and the synchronization node uses the ChronoSync, which takes full advantage of the NDN network architecture and can synchronize data for multiple users.

2. Background

Compares the mobility management of NDN with the existing Internet with IP as the core, and reexamines the mobility problem in NDN. The current research on the existing NDN mobility support solutions is still in its infancy. According to their design ideas and research ideas, mobility support schemes can be roughly divided into the following four categories:

2.1. Introduce the mobility support mechanism of location management and mapping relationship

[4]provides mapping relationship between content name and location by adding DNS server in NDN similar to that in TCP/IP network, so as to realize mobility support for producers. Of course, the mapping system is not just a DNS server. [5]adopts a Chord based distributed hash table as the mapping system. The advantage of the mapping-based scheme is that the current location of the producer can be queried, and the routing path is optimal. The disadvantage is that due to the need to maintain the DNS server and many processes, the signaling overhead and delay are relatively large. The NDN producer mobile solution imitating mobile-IP draws on the idea of mobile IP in the TCP/IP network. It solves the problem of lost requests while consumers do not need to resend requests.

2.2. Mobility support mechanism based on proxy node

This type of solution is mainly through setting up a attribution agent, proxy node [6] provide support for NDN producer mobility, and the overhead mainly comes from maintaining agent nodes and mapping information retrieval, and the delay is better than that of the NDN native solution that updates FIB tables in the entire network. However, this scheme has the problem of triangular routing. Although [7] proposes a solution combining NDN characteristics, which reduces the cost and avoids the triangular routing problem to a certain extent, the performance is poor when the producer moves frequently. [8] proposes a tunnel-based solution, which uses tunneling technology to import interest packets from the original access point to the new access point. This point-to-point solution will not only make the advantages of the intelligent routing and forwarding strategy in the NDN architecture disappear Exhaustion reduces the overall performance of NDN, adds more control information, reduce the efficiency of communication also consumes more network bandwidth.

2.3. NDN binding properties imitate mobile-IP tracing scheme

By utilizing and extending the state forwarding plane of NDN, [9] creates or updates a segment-by-segment reverse tracking path by sending interest packets containing tracking commands when producers move. If a trace path exists, the consumer's normal interest packets are forwarded along the trace path, otherwise it will be forwarded using the standard logic of NDN. The scheme adds additional
complexity due to changes to the interest package and the addition of too much information about the interest package flags and data structures.

2.4. Mobility support mechanism based on packaging ideas
This kind of mobility support mechanism mainly includes[10]. Its basic design idea is that when the Provider moves in advance, it will first send a switching notification message to the access router, and after receiving the notification message, will cache the Interest received. After the Provider is connected to the new access router, it will send the encapsulated specific prefix virtual Interest to change the FIB information of the intermediate router.

After receiving the virtual Interest, resends the cached Interest, and transfers it to the Provider to obtain the data content according to the updated FIB table. Finally, the Provider returns the Data Packet to the Consumer according to the PIT.

The solution in [11] updates the intermediate router by updating the path information between the original router and the new access router. This scheme avoids the triangular routing problem, ensures the minimum switching delay, and does not need to resend interest packets. However, because only local producer movement is considered, the complexity of the research problem is reduced, and the network performance is poor when faced with frequent producer movement.

So far, the above related solutions have provided support and contributions to solve the problem of producer movement, but there are still some shortcomings due to the lack of full consideration of the characteristics of using NDN.

3. NPRCS Strategy Design

3.1. Main Idea
As shown in Figure 1, since the data name in NDN is a hierarchical structure naming method similar to a URL, each layer represents a different meaning. According to the size of the moving range, the content name generated by the producer will also be changed automatically. Therefore, in order to meet the needs of consumers, the default mechanism of NDN needs to change a large amount of routing information, which brings a lot of overhead.

![Fig1. Problems with NDN producer movement](image)

Therefore, in order to weaken the impact of producer movement on consumer performance and reduce the cost of updating routing information throughout the network, this paper makes full use of the NDN intelligent routing and forwarding strategy and unique caching function while following the NDN principle, and proposes a ChronoSync-based The NPRCS method of local content synchronization of the protocol producer.
As shown in Figure 2, the core of the NPRCS strategy is to synchronize the content generated by the producer to the synchronization node that enters the synchronization range during the movement process through the ChronoSync protocol. The interest packet only needs to follow the route after reaching the start position of the producer and discovering that the target is lost. The forwarding strategy enables forwarding to complete the demand at the nearest synchronization node, which improves the content availability after the producer moves.

Before the producer moves to the final location of another domain, in order to meet the needs of consumers, the NDN default scheme requires a large amount of routing information to be changed, which seriously affects the overall performance of the network. As shown in Figure 3, the NPRCS strategy proposed in this paper synchronizes the content generated by the producer to the synchronization node, which weakens the impact on consumer performance before the producer reaches the final location, and improves the availability of content while also helping to satisfy the needs of other consumers.

In the NPRCS method, the moving speed of each producer is not necessarily the same, and the moving speed of a single producer is not necessarily fixed. Therefore, this paper also makes a comparative study on the relationship between the moving speed of the producer and the size of the synchronization range, which is a key parameter affecting the efficiency of the NPRCS method.
3.2. *ChronoSync protocol*

The NPRCS strategy uses the ChronoSync protocol to complete the synchronization of the content between the producer and the synchronization node. The protocol adopts a completely distributed system, which can synchronize the data of multiple users, and gives full play to the advantages of the NDN network architecture. The core idea of the protocol is to compactly encode the state of the data set into a state summary, exchange the state summary in the synchronization group, and when the state summary is different, obtain new data and update the state summary until the same state summary in the group reaches a stable state. The core part of the protocol is shown in Figure 4 and consists of two modules, namely the bottom-level ChronoSync module for sensing and synchronizing the state of the data set and the upper-level application logic module that responds to changes in the data set.

![Fig4. ChronoSync protocol structure](image)

In the ChronoSync protocol, the underlying ChronoSync module maintains an understanding of all messages in the group in the form of a summary tree, and records changes to the state of the data set in the form of a summary log. During the data synchronization process, the ChronoSync module of each node in the synchronization group will always send a synchronization interest packet containing the summary of the state that the node is maintaining at the root of the summary tree. At this time, if a node generates new data, the ChronoSync of the node After the module detects that the status summary has changed through the comparison summary tree, the synchronization data packet containing the latest status summary is used to reply to the synchronization interest packet sent by other nodes. After other nodes in the group receive the synchronization data packet, the underlying ChronoSync module passes the comparison log to obtain the newly generated data, and informs the upper-layer application logic module to send normal interest packets to obtain the newly generated data. Based on the communication properties of NDN, the newly generated data is efficiently multicast to other nodes in the group. After receiving the data, other nodes update the summary tree to reflect the changes to the state of the data set, and continue to send the latest state. The summary of the synchronization interest packet, until all nodes in the group have the same knowledge of the data set, the system is in a balanced state.

3.3. *Producer synchronization range size setting*

In addition to the synchronization protocol used in the NPRCS strategy, the size of the synchronization range also has the most direct impact on the efficiency of the NPRCS strategy. The synchronization
range is set too small, and the time from entering the synchronization range to leaving the synchronization node is too short to complete content synchronization; the synchronization range setting is too large, too many nodes appear in the synchronization range at the same time, which affects the content synchronization efficiency of the producer. It also increases unnecessary overhead. Considering that in reality, the movement of producers is irregular, and the speed of movement is unknowable and not necessarily constant. Therefore, we simulated the producer’s speed in several real-life movement modes, and completed the experiment in the simulation environment to compare the producer’s influence on consumer performance under different movement speed settings and the size of the synchronization range setting.

4. Simulation Environment and Analysis of Experimental Results

Use a mobile model that simulates the way humans move during simulation is very important for the study of mobile networks. Almost all mobile devices are attached to and used or controlled by humans. Choosing an appropriate mobile model can better measure and evaluate the efficiency of the producer’s mobile solutions.

This article uses a slaw model that combines the LATP, irregular waypoints, and personal walking model, to enable the producer to simulate the movement mode of human beings after movement occurs. The SLAW model can capture meaningful data in human movement and effectively reflects the characteristics of human movement. To evaluate the performance of the method proposed in this chapter, the NDNSIM network simulator based on NS-3 is used for experimental simulation. The size of the simulation scene is 200m*200m, the number of scene nodes is 30, and the movement mode of mobile nodes refers to the slaw model. The movement speeds of the producers are 1m/s, 2m/s, 5m/s. The ratio between the number of mobile nodes and the total number of nodes can be adjusted.

And no other nodes except mobile nodes will move. Randomly select 3 nodes from all nodes as producers, including 50 initial content objects. In the simulation process, 5 nodes except data source nodes are randomly selected to generate corresponding interest packets with a time interval of 5s, and the other nodes are all used as network routing nodes.

Each node in the network runs a client program that generates content requests. The simulation process starts with an empty cache in the NDN router, and the simulation cycle is 30 times.

By comparing the impact of changing the size of the synchronization range on the hit rate and retrieval time of consumer content under different moving speeds of producers, we compared the performance difference between the NPRCS strategy and the NDN default mechanism. It mainly involves two evaluation indexes of content hit rate and content retrieval time. The content hit rate refers to the percentage of consumers successfully retrieving content, and a higher hit rate indicates that the content has higher usability. The content retrieval time refers to the time when the consumer retrieves the consumer of the content object from the nearest content provider. The result is shown in the figure:

![Fig5. The influence of the range L on the hit rate(1m/s)](image1)

![Fig6. The influence of the range L on the hit rate(2m/s)](image2)
4.1 Content Hit Rate

It can be seen from Figure 5-7 that under the default mechanism of NDN, when the producer just moves due to the small moving time and distance, after the interest packet loses the target, the producer can still be rerouted and forwarded to find the content, so the hit rate is affected. Very small. However, as the travel time and distance increase, the effective effect of routing and forwarding decreases, and the consumer content hit rate is greatly affected. The NPRCS strategy effectively improves the content hit rate of consumers when producers are moving at different speeds and synchronization ranges of producers. In this paper, the time during which the synchronization node can perform content synchronization from entering the synchronization range to leaving the synchronization range is defined as the synchronization time.

In terms of overall hit rate performance, the hit rate in Figure 5 is the best when the speed is V1, and the performance in Figure 7 is the worst when the speed is V5. On the one hand, due to the increase in speed, the time and the number of contents that can be synchronized by the synchronization node from entering the synchronization range to leaving are reduced. On the other hand, the increase in speed results in the movement distance of the producer per unit time and the distance from the producer. The distance from the starting position increases, and the distance for the interest packet to be rerouted and forwarded after losing the target increases, which increases the risk of interest packet loss.

In Figure 6, the consumer's content hit rate at L1 is slightly lower than that of L2, while the overall hit rate at L2-L5 is not much different. Similar situations are also reflected in Figures 7 and 8. However, in Figure 8, because the producer moves too fast, in L1 and L2, the extremely short content synchronization time and the extremely small number of content synchronization results in a stable and poor hit rate. This situation occurs because, assuming that the producer moves a unit time when the synchronization range is small, the synchronization time is less than the unit time of the movement, and the synchronization time increases with the increase of the synchronization range until the synchronization time is equal to the unit time of the movement. At this time, the number of synchronized content per unit time is the largest. As the synchronization range continues to increase, the synchronization time is sufficient for the producer and the synchronization node to complete the synchronization of all content. At this time, the number of content in the synchronization node is the
largest, and the consumer's content hit rate is the highest. After that, as the producer continues to move, the synchronization range increases in internal synchronization nodes and the increase in the number of content copies in the network make the content hit rate more stable in terms of stability.

4.2 Content Retrieval Time

It can be seen from Figures 8-10 that with the increase in the time and distance of the producer's movement under the NDN default mechanism, the consumer's content retrieval time also increases accordingly. And according to the moving speed of the producer and the distance of the producer in the corresponding unit time, the increase of the retrieval time is also different. The NPRCS strategy effectively solves the problem of a substantial increase in retrieval time after the producer moves.

In Figure 8-10, when the producer just moved, the retrieval time values of L1-L5 showed obvious differences. This is because the larger the synchronization range at the beginning, the longer the synchronization time, and the more synchronized content, the retrieval time is shorter. The obvious decreasing trend after the movement is due to the continuous increase in the number of synchronization nodes and content copies in the network.

As the synchronization range continues to increase, when the content between the producer and the synchronization node is completely synchronized, the retrieval time reaches the minimum. As producers continue to move, the increase in synchronization nodes within the synchronization range and the increase in the number of content copies in the network make the retrieval time more stable. The synchronization range continues to increase after the content between the producer and the synchronization node is completely synchronized, which can reduce the time for the retrieval time to converge to the minimum.

In Figure 10, the retrieval time showed varying degrees of floating growth after converging to the minimum value for a period of time. This is due to the timeliness of the cache. As the producer moves time and distance increases, the producer synchronizes to the previously synchronized node. The content may be replaced by other content. After the interest packet is forwarded to the synchronization node, the demand cannot be met, and it needs to continue to be forwarded to other synchronization nodes, which increases the retrieval time. The reason why this is not clearly shown in Figure 8-9 is that there are many copies of content in the network when the speed is low, and the distance between synchronization nodes is very close.

The overall search time of L1-L5 in Figure 8 is not much different. This is because after the producer moves unit time at a low speed, the distance between the producer and the starting position and the distance between the synchronization nodes is very close, and the overall search time is the shortest. At this time, the synchronization content time under different synchronization ranges and the difference in the number of synchronization content have a relatively small impact on the retrieval time, so the overall retrieval time under different synchronization ranges is not much different. In Figure 10, after the producer moves unit time at a high speed, the time for content synchronization is relatively too short, the total number of content synchronization is small, and the distance between the producer and the starting position and the distance between synchronization nodes are very far, the longest overall retrieval time. At this time, the synchronization content time under different synchronization scopes and the difference in the number of synchronization content have a greater impact on the retrieval time, so the retrieval time performance under different synchronization scopes varies greatly.

5. Conclusion

Based on the premise of following the NDN principle and making full use of the key functions of NDN, this article proposes an NPRCS strategy to solve the problems of high handover delay, interest packet loss, and content hit rate reduction caused by producer movement in NDN. NDN's built-in operating mechanism has a significant drop in consumer content hit rate, a huge increase in switching delays and retrieval time, to improve the availability of content during the movement of producers and help fulfill the needs of other consumers. The goal of. Through statistical analysis of the data obtained after
simulation, the performance of the NPRCS strategy at high speed can increase the hit rate by 52% and reduce the retrieval time by 63%.

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