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Multi-node Negotiation Driver Architecture for Real-time Traffic in Information Centric-Networking based on Congestion Game

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Abstract

In Information-Centric Networking (ICN), it often requires a lot of interest packets to request continuous data for the real-time business. When dealing with real-time business, if we still use the traditional communication mode of ICN that an interest packet corresponds to a data packet, it will waste a lot of upward bandwidth and increase the cost of communication costs. Therefore, we propose a consumer-driven architecture for real-time business in ICN. After the consumer sends an interest packet, the providers carry out group negotiation by congestion game. Finally, providers send the requested data and relevant subsequent data back to the consumer, so that one interest packet can correspond to multiple data packets. Therefore, this architecture can save the communication resources, reduce the communication delay, improve the communication efficiency, and finally achieve Nash equilibrium.

Keywords

Real-time Business; Information Centric-Networking; Provider-driven; Consumer-driven.

1. Introduction

With the continuous growth of network traffic and the introduction of a large number of new applications to meet emerging requirements, network architecture has created new requirements, such as forwarding scalable applications, support for mobility, security, and so on. The traditional TCP/IP network is hard to meet these requirements because the TCP/IP architecture was not designed with these considerations in mind. To solve these problems, ICN (Information-Centric Networking) has emerged. Scholars from all over the world have also conducted various studies on ICN. ICN maintains the same hourglass model as the traditional TCP/IP network, but the difference is that the thin waist of the ICN model replaces the original IP address with the content block. By naming information at the network layer, ICN facilitates the deployment of in-network caching and multicast mechanisms to facilitate the efficient and timely delivery of information to users. ICN decouples content and location. And ICN requests data by content name. ICN decouples content and location, and ICN requests data by content name. In this way, it is unnecessary to convert required content into IP address during communication, greatly saving communication costs and improving communication efficiency.

ICN simplifies the communication process by decoupling content and location, but without the host-to-host protocol, it makes network traffic control more complex [1]. When multiple users compete for access to network resources such as queues, bandwidths, and buffers, it is important to provide appropriate flow control for users to use resources effectively and fairly. The flow control of traditional TCP/IP networks [2] is inadequate for ICN, which cannot sustain end-to-end communication flows between hosts. In the existing TCP/IP-like traffic scheduling work, several flow-based mechanisms [3][4] have been proposed to adapt to ICN. However, traffic control in ICN is inefficient. Because ICN naturally supports multi-source and multi-path, the data content may be retrieved from different databases or caches of multiple sources, which makes the state of each flow difficult to identify and control. Therefore, in ICN, the study of network traffic scheduling methods is an important problem for researchers and network providers.

At the same time, we also face another challenge. In traditional ICN, the same request mode and reply mode are often implemented singly, and traffic scheduling is carried out indiscriminately for different services. This makes ICN unable to meet the needs of personalized business services and often unable to efficiently complete the task of content distribution and acquisition. To solve this problem, we propose a multi-node negotiation mechanism for real-time [5][6][10]business. When the sender sends a request, it is divided into real-time service interest packets and non-real-time service interest packets. For real-time business interest packets, we default to the sender requiring subsequent data. First, we should label real-time business or non-real-time business in the interest packets. If the service is not real-time, it still responds according to the traditional mode of one interest packet for one data packet. However, in the case of real-time service, if the original packet-by-packet request mechanism is still adopted, a large amount of uplink bandwidth will be consumed and more time will be spent.

2. Related Work

In recent years, compared with the other architecture[7]-[9], traffic control under ICN architecture has attracted more and more attention from future network architecture researchers. Because the traffic control is a complex global problem involving multiple nodes, researchers focus on different methods to study this problem.

In-network cache is an important feature of ICN architecture. In the study of flow control combined with cache replacement strategy, Atsushi and Eum et al. [11] proposed a cache replacement method using content name filtering. Since optimized cache replacement can provide far better performance than a simple policy-based algorithm, The existing ICN cache replacement strategy is designed to achieve significant performance improvements. However, these policies consume a lot of computing resources and processing delay when dealing with the traffic of real-time services in the network. Therefore, the author proposes a strategy of using the switched hash table as a network cache, which can identify and retain the content with high popularity in the network environment. Since the hash table is a data structure with low overhead, this method can greatly reduce the cost. The author carries out a numerical simulation experiment on the proposed method, and the experiment shows that the algorithm can achieve better cache hit for traffic tracking, while the hit ratio of traditional algorithms such as FIFO and LRU is very low. Najla and Alanoud et al. [12] proposed that the cache replacement strategy usually needs to consider the hit ratio and hit distance. In some complex scenarios, it also needs to consider the replacement strategy to decide which cache content to eliminate. Due to the importance of cache replacement strategy in traffic optimization and scheduling, the author proposed a random LFU (Least Frequently Used) method in this paper, which carried out random cache replacement by considering content popularity and time complexity. Simulation results show that the performance of random LFU is better than conventional cache replacement strategies such as FIFO and LRU, which can effectively improve the cache hit ratio and hit distance, and improve the overall efficiency of the network. It can be seen that the ICN feature of the in-network cache has the most direct impact on traffic optimization and control. Any positive changes based on cache, such as improving cache hit ratio and reducing cache hit distance, will improve network performance.

The traditional communication mode of one packet of interest corresponding to one packet is inefficient, consumes more resources and has a large delay, and may lead to problems such as a large PIT table or flood of interest packets. If multiple data can be packaged and sent back to the sender, the link cost and transmission delay will be greatly reduced. Therefore, Xiaobin Tan and Weiwei Feng et al. [17] proposed the stream-based NDN architecture supporting stream transmission and changed PIT at the same time by transforming the interest packet structure. The structure of FIB and CS tables, which add fields to the head of interest packets and store the field information used for

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connection senders and receivers, establishing connections, transmitting streams, and disconnecting connections. The weights are introduced into the link and the rate control is carried out to achieve the optimal rate. The simulation experiment proves that this method greatly reduces the number of interest packets to be sent and the link cost and delay. Zhao Zhifan and Tan Xiaobin [13] et al proposed the idea that one interest packet corresponds to multiple packets as early as 2016. Experiments show that this method can greatly improve network performance. It can be seen from the above research that changing the inherent architecture of ICN may become an effective method to improve network performance. By changing the traditional ICN interest packet and packet one-to-one communication mode, it can improve the communication efficiency and throughput, reduce the delay and unnecessary resource consumption.

In ICN traffic problems, the combination with other future network architectures can solve the traffic optimization and control problem well. Fan Yang and Yun Jiang [14] proposed the integration of SDN and ICN traffic detection systems, which can identify abnormal traffic and predict traffic according to network conditions. The system also analyzes traffic information and other relevant information in ICN network, so the system can comprehensively master all aspects of network information in real-time. It provides more basis for traffic optimization and scheduling. Therefore, for traffic optimization and scheduling problems, cross-architecture fusion is another breakthrough method, and the advantages of each architecture can be appropriately fused to optimize network performance from a macro perspective.

It can be seen that in recent years, researchers have explored various methods to solve the problem of traffic optimization and scheduling, and obtained relatively ideal results from both macro and micro perspectives, accelerating the solution of ICN traffic problems. Although the ICN all aspects of the research is not yet mature, ICN as the structure of the great advantages in the future network architecture, for the development of future network provides reference research problems, promote the development of the future network, not only provides a new way of thinking to the development of the domestic network, more world Internet development has brought new inspiration.

3. Multi-node Negotiation Mechanism

3.1 Problem Definition

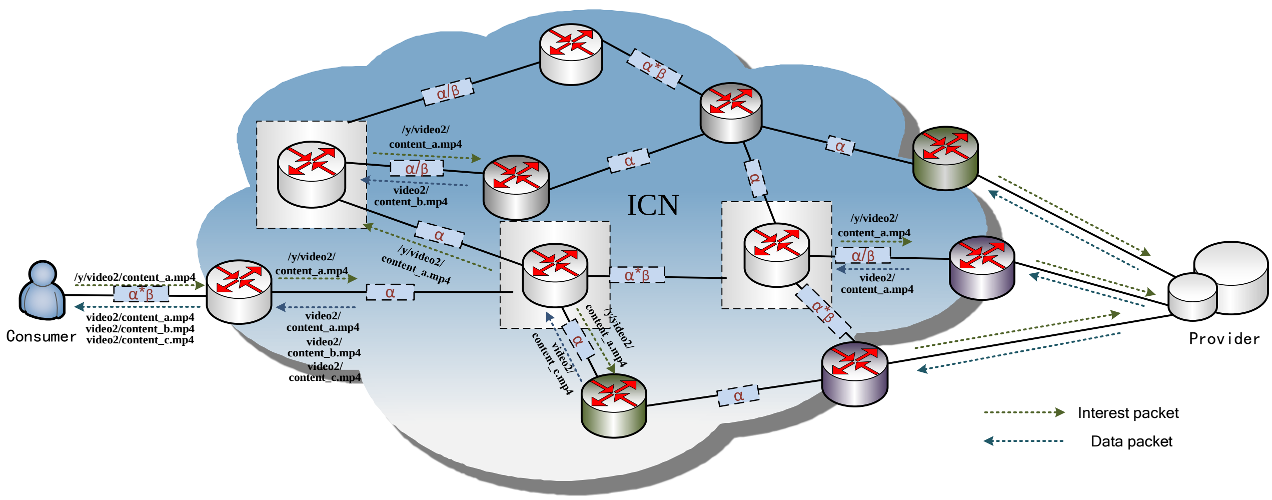

Fig. 1 The multi-node negotiation mechanism for real-time services

In this paper, we propose a multi-node negotiation mechanism in which the receiver decides whether to send back the subsequent data. The sender's job is to provide the optimal traffic scheduling policy according to the needs of the receiver and send data back according to the policy. Different from discrete data such as text files involved in non-real-time services, real-time services often require

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continuous data such as video streams. When the sender receives the interest packet, it first determines whether the receiver needs to request subsequent data. If not, it sends back data according to the traditional way of one interest packet corresponding to one data packet. If the following content is required, each routing node negotiates the scheduling policy p according to the link weight, and finally sends data back through p. The multi-node negotiation mechanism for real-time services is shown in Fig. 1.

We initialize the weight of all links as α. When the link is unblocked or the remaining traffic of the link is less than the size fd required for transmitting a packet, we update the weight with a β, the formula is as follows:

$$\begin{matrix} \alpha = \alpha / \beta, C_l - F_l \geq f_d \\ \alpha = \alpha * \beta, C_l - F_l \leq f_d \end{matrix}, \alpha > 0, \beta < 0, \tag{1}$$

The weight of path p, η, is expressed as follows:

$$\eta = (\sum_{l \in L} \alpha) / n \tag{2}$$

Here, n indicates the number of links. If multiple senders have the same content, the system selects the sender to send back data based on the path weight. The higher the weight, the higher the probability of being selected. When a link is underutilized, its weight keeps increasing, making policies more inclined to select the link, which improves the link utilization.

3.2 The Model and the Cost Function

We express the path chosen by the user as P, where P is the policy set p = {p1, p2, …, pk}, k competitors have k policies, and the competitor set K= {1, …, k}. Each competitor selects a path p according to the weight value and adds the weight of unit 1 to each link contained in path p. All competitors form the set of links l contained in the flow f, path p, which is expressed as L, L= {l1, l2, ..., ln} the traffic passing through link L is Fl, and Cl is the link capacity.

$$0 \leq F_l \leq C_l, l \in L, C_l \geq 0 \tag{3}$$

We use the traffic fl on each link to represent the traffic fp on the path, and the formula is as follows:

$$f_p = \sum_{l \in p} f_l \tag{4}$$

Each link has a throughput function expressed as $T_l : R^+ \to R^+$. The cost function is defined as the throughput function. The cost of each path in the communication process is determined by the communication cost of each link, and the formula is as follows:

$$C_l(f_l) = T_l(f_l) \tag{5}$$

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$$C_p(f_p)=\sum_{l\in p}T_l(f_l) \tag{6}$$

Cp(fp) is the throughput cost on each path that each user wants to minimize, then the total throughput cost of stream f is expressed as:

$$C(f)=\sum_{p\in P}f_p \bullet C_p(f_p) \tag{7}$$

The number of times for each link to be multiplexed by policy p is ml(p). The utility of policy p selected by each user is expressed as follows:

$$U(p)=\sum_{l\in p}T_l(m_l(p)) \tag{8}$$

According to Rosenthal's theorem[15], the objective function φ is defined as follows:

$$\Phi(p)=\sum_{l\in p}\sum_{i=1}^{m_l(p)}C_l(i) \tag{9}$$

There are m users are participating in the game, from the strategy set P, P={p1, p2, ..., pn-1, pn, pn+1, ..., pm} to the strategy set P ', P '={ p1, p2, ..., pn-1, pn, pn+1, ..., pm }, then ΔU represents the difference of the utility of the two strategy sets, and the formula is as follows:

$$\begin{aligned}\Delta U &= U(p^{'})-U(p)\\ &= \sum_{l\in p^{'}\backslash p}T_l(m_l(p+1))-\sum_{l\in p\backslash p^{'}}T_l(m_l(p))\end{aligned} \tag{10}$$

Meanwhile, the objective function of the two strategies is expressed as φ(p) and φ(p'), and the difference between the objective function of the two strategies is expressed as Δφ, the formula is as follows:

$$\begin{aligned}\Delta\Phi &= \Phi(p^{'})-\Phi(p)\\ &= \sum_{l\in p^{'}\backslash p}\sum_{i=1}^{m_l(p+1)}C_l(i)+\sum_{l\in p\backslash p^{'}}\sum_{i=1}^{m_l(p^{'})}C_l(i)-\\ &\quad \sum_{l\in p\backslash p^{'}}\sum_{i=1}^{m_l(p^{'}-1)}C_l(i)-\sum_{l\in p^{'}\backslash p}\sum_{i=1}^{m_l(p)}C_l(i)\\ &= \sum_{l\in p^{'}\backslash p}C_l(m_l(p+1))-\sum_{l\in p\backslash p^{'}}C_l(m_l(p))\\ &= \sum_{l\in p^{'}\backslash p}T_l(m_l(p+1))-\sum_{l\in p\backslash p^{'}}T_l(m_l(p))\end{aligned} \tag{11}$$

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It can be seen that Δφ=ΔU. According to Rosenthal's theorem, in any selfish routing game, if the cost function has an actual value, there must be at least one equilibrium flow. Since the range of φ is finite, the φ function has real values at all times. In a route selection policy for traffic scheduling, the cost for each route selection is calculable. If the cost function decreases when a user selects a route, the policy is allowed to be executed. Repeat the above steps until the cost function cannot be reduced further, then the current network has reached Nash equilibrium.

4. Summary

To make the user experience better when dealing with real-time business, we propose a multi-node negotiation mechanism for ICN real-time service. This architecture aims to obtain a large number of packets by sending only a small number of interest packets, reduce uplink bandwidth, save communication resources, and finally achieve Nash equilibrium.

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