A probability forwarding strategy for Named Data Networking based on congestion level of interface

Yu Tao*, Yujia Fan, Ruhui Huang
School of Computer Science and Communication Engineering,
Jiangsu University, Zhenjiang, China

Abstract: Named Data Networking(NDN) is a typical representative of the next-generation Interest architecture. In NDN, due to the existence of multi-source transmission, the traditional congestion control schemes cannot be applied to NDN directly. Aiming at the transmission features of NDN, we proposed a probability forwarding strategy based on congestion level of inter-face(PFS-CLI). Through calculating the congestion contribution of each flow passing by the router, PFS-CLI can calculate the congestion level of each interface, then probabilistically select the optimal interface for forward-ing interest packet. The simulation results show that PFS-CLI is effective for congestion control in NDN.

Keywords: Named data networking, Congestion control, Interface congestion, Probabil-ity forwarding

1 Introduction

Named Data Networking (NDN) is a typical representative of the next generation Interest architecture[1] [2], which builds a novel naming routing way based on the distributed caching mechanism. Theoretically, compared with the traditional IP network, NDN naturally has a certain capacity of traffic control due to its "Pull-based" communication mode and the design of requests aggregation. However, with the feature of multi-sources transmission, NDN still face a serious network congestion risk. In NDN, each in-network router is a potential content source, which owns a large cache to store the data packets passed by. Facing this unique multi-source transmission environment, the traditional IP congestion control methods cannot be directly applied and then how to design the suitable congestion control mechanism for NDN has become a challenge in current NDN research.

Since 2012, some related works about NDN congestion control[3] are given. Carofiglio et al. first proposed a consumer side protocol called ICP (Interest Control Protocol[4]), which controls the transmission rate of interest packet by adopting the AIMD (Additive Increase Multiplicative Decrease)[5] algorithm. For evaluating the congestion status, ICP sets the timer for each interest packet transmission, but this

* Corresponding author: Yu Tao (771545495@qq.com).
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setting produces huge computation and storage overhead. To improve the ICP, Carofiglio et al. further proposed the HR-ICP (Hop-by-hop and Receiver-Driven Interest) algorithm[6]. In this algorithm, router configures several credit counters associated with each data flow. By counting the number of received data packets, HR-ICP can detect whether the data flow is a bottleneck or not. According to the idea of hop by hop congestion control[7], Rozhnova et al. proposed the typical inter-node control algorithm named HoBHIS (Hop-By-Hop Interest Shaping)[8] .The HoB-HIS detects congestion level by monitoring the queue length of arrival data flow, and then adjusts the forwarding rate of interest packet. Xu C et al. further start with the multipath transmission mechanism[9], model the problem of congestion control un-der multipath to a global optimization problem that maximizes user bandwidth and minimizes network resource overhead. A rate based multipath aware congestion control algorithm called MIRCC(Multipath-aware ICN Rate-based Congestion Con-trol)[10] is proposed by Mahdian et al. Different from the usual rate control mecha-nism, MIRCC introduces a forwarding rate adjustment mechanism for each link to achieve good flow fairness and link utilization, but there is still a problem of high resource overhead.

From the aforementioned works, although some solutions have already proposed from different aspects, there are still some challenges restricting the feasibility of access control in NDN. Considering the congestion contribution of different data flows in the link, a probability forwarding strategy based on congestion level of interface (named as PFS-CLI in short) is proposed in this paper. In PFS-CLI, the router first estimates the congestion contribution of each flow on a specific interface, then calculates its congestion level, and then generates the forwarding probability according to the congestion calculation result. By selecting an optimal forwarding interface with high probability, the router can effectively realize congestion control while promoting the utilization of link.

2 DESIGN OF PFS-CLI

PFS-CLI is designed for solving the problem of massive packet loss on the bottleneck link. To describe PFS-CLI in detail, the parameter settings and notations used in the strategy are defined as follows.

1. Assuming that one router has M optional output interfaces, each interface main-tains N flows (flow means interest packet transmission queue), denotes an optional output interface i of router $(1 \leq i \leq M)$,$f(i,j)$ represents the data flow $j(1 \leq j \leq N)$ on interface j .
2. Let $N_{exp}(i,j)$ and $N_{act}(i,j)$denote the expected number and actual number of packets received within a RTT (Round-Trip Time)interval of $f(i,j)$ respectively, $RTT_{con}(i,j)$ and $RTT_{nor}(i,j)$ denote the average RTT delay(exclude timeout in-terest packages) of $f(i,j)$ under congestion status and normal status respectively.
3. Further assume $B(i,j)$ is the congestion level of interface i caused by flow j. Ob-viously, $B(i,j)$ can be regarded as the inverse ratio of actual link rate and expected link rate, as given in the equation (1).

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$$B(i,j) = 1 - \frac{N_{act}(i,j)/RTT_{con}(i,j)}{N_{exp}(i,j)/RTT_{nor}(i,j)} \quad (1)$$

The detailed execution of the PFS-CLI include initialization stage and running stage.

Initialization Stage: While an interest package passes through the router, after querying in CS (Content Store) and PIT (Pending Interest Table), it will be outputted to different links with different probability, instead of performing routing query in FIB (Forwarding Information Base).

Considering that the bandwidth reflects the actual capacity of link, the initial forwarding probability of each interface can be determined according to the actual link capacity. If $C(i)$ (bps) represents the actual link bandwidth of interface i, $P(i)$ is the forwarding probability of interface i , $P(i)$ can be initialized as the equation (2).

$$P(i) = \frac{C(i)}{\sum_{j=1}^{M} C(j)} i \in [1, M] \quad (2)$$

Running Stage: By measuring the average RTT and the number of packets received within a RTT interval, the router estimates the congestion status of flow (i,j) , then further calculates the congestion level $B(i)$ of interface i using equation (3).

$$B(i) = \sum_{j=1}^{N} w(i,j) * B(i,j) \quad (3)$$

where, $B(i,j)$ is the flow proportion weight of flow *j* on interface i. Based on the congestion results, the forwarding probability of interface i can be updated as equation (4).

$$P(i) = 1 - \frac{B(i)}{\sum_{j=1}^{M} B(j)} i \in [1, M] \quad (4)$$

During the running stage, the $P(i)$ will be periodically adjusted according to the average life cycle of PIT entry. Benefited from this design, the router can select the interface under low congestion for forwarding with high probability

3 SIMULATIONS AND PERFORMANCE ANALYSIS

To analyze the performance of PFS-CLI, an simulation environment is built based on the NdnSim[11]. We select ICP[4] and HR-ICP[6] as the contrast strategies in our simulations. The topology is shown in Figure 1, which is a common multipath topology structure.

The simulation conditions are set as follows.

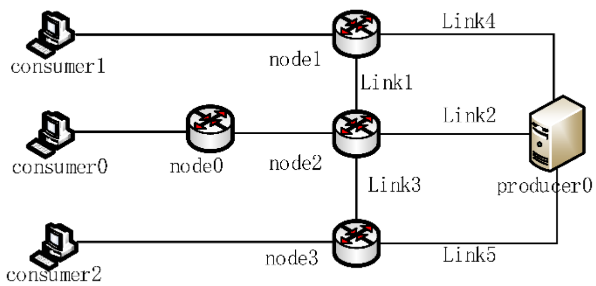

Fig. 1. Topology with multiple optional forwarding paths

1. Content producer (producer0) provides three kinds of contents, including "/files/sample.bin" with size 300Mbit, "/video/a.bin" with size 100 Mbit, "/video/b.bin" with size 200 Mbit. The content is transmitted in the form of chunks (the version number and the chunk number will be added to the end of content name). For example, data chunk called "/files/sample.bin /version_number/segment_number", represents the chunk No. segment_number of the content "/files/sample.bin" with version version_number.
2. The bandwidth of Link4 is 5 Mbps, the bandwidth of others are 10 Mbps. comsumer0 only requests content "/files/sample.bin" at the rate of 5 Mbps, consumer1 and consumer2 request another two contents separately at the rate of 5 Mbps and 10 Mbps respectively.
3. The cache size of each router is the same, which is configured as 1/200 of the total amount of contents. The router adopts LRU (Least Recently Used) as its cache replacement policy.
4. The flow is defined as a specific content name in this simulation.

To evaluate the performance of our strategy, now we select consumer0 to observe its transmission quality. Figure 2 gives the actual forwarding rate of three link in node2 and Figure 3 gives the RTT measurement of consumer0. From Figure 2, we can find that the selected link of node2 changes three times during the transmission of flow "/files/sample.bin". Due to PFS-CLI periodically detects the congestion status of each link, it will transfer the transmission task to other link by adjust the forwarding probability and then avoid the link congestion. Figure 3 proves the effect of PFS-CLI. It can be clearly seen that the RTT of flow "/files/sample.bin" decreases to a relative-ideal scope when node2 select a optimal link.

Figure 4 gives the performance comparison of PFS-CLI,ICP and HR-ICP in congestion control capability. As we can see in the figure, PFS-CLI shows very good performance under different bottleneck link bandwidth(link4). Both ICP and HR-ICP algorithms use explicit congestion feedback to send congestion information back to the consumer, which is unsuitable for NDN with the multi-source transmission. Instead, PFS-CLI has made a finer control by estimating the contribution of network congestion,

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which implements the congestion control effectively and decreases the number of packet loss by a large margin.

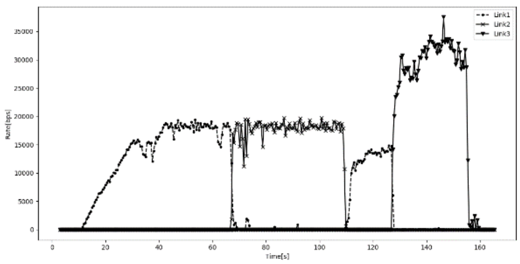

Fig. 2. Forwarding rate to each link in node2

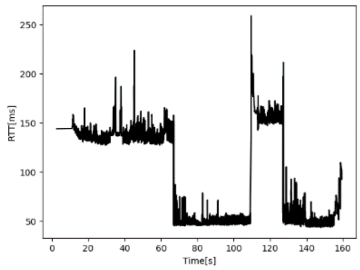

Fig. 3. RTT of consumer0 for specific flow

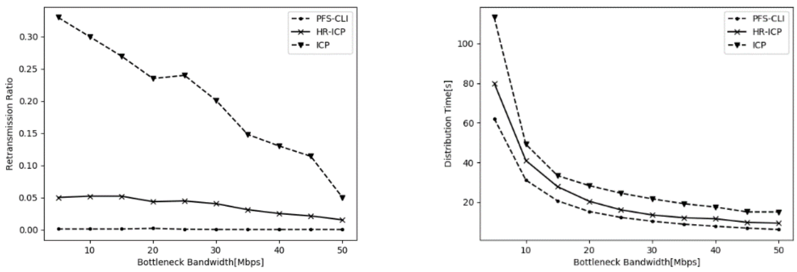

Fig. 4. Performance comparison of PFS-CLI,ICP and HR-ICP

4 CONCLUSION AND EXPECTATION

Aiming at the congestion problem of NDN network, we propose a probability forwarding strategy based on congestion level of interface. According to the congestion evaluation, this strategy dynamically adjusts the forwarding probability of each interface. The simulation results prove that PFS-CLI is effective for congestion control in NDN.

In this paper, we only research the congestion control at router side. In the future, we will further combine the consumer side with router side to explore the hybrid congestion control method.

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