Adaptive Forwarding of Persistent Interests in Named Data Networking

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ABSTRACT

Persistent Interests (PIs) are a promising approach to introduce push-type traffic in Named Data Networking (NDN), in particular for conversational services such as voice and video calls. Forwarding decisions for PIs are crucial in NDN because they establish a long-lived path for the data flowing back toward the PI issuer. In the course of studying the use of PIs in NDN, we investigate *adaptive* PI forwarding and present a strategy combining regular NDN forwarding information and results from *probing* potential alternative paths through the network. Simulation results indicate that our adaptive PI forwarding approach is superior to the PI-adapted *Best Route* strategy when network conditions change due to link failures.

CCS CONCEPTS

• **Networks → Network protocol design**; **Packet-switching networks**; Network simulations;

KEYWORDS

Information-Centric Networking; Named Data Networking; Persistent Interests; Adaptive Forwarding

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1 INTRODUCTION

The importance of conversational services on the Internet has increased steadily over the last decade. The demands for low-delay real-time conversation as well as the variable bit rate (VBR) of produced content are challenging factors for the underlying computer networks. Current IP-based solutions utilize push-based approaches for the delivery of such data streams, since pull-based solutions suffer from a two-way delay and are not aware of the amount of data to request due to VBR.

In *Named Data Networking* (NDN, [10]), a promising candidate for a Future Internet architecture, each Data packet is requested by a system-wide unique name via an Interest packet. Due to its strict pull-based nature, NDN is facing the afore mentioned challenges when being used for conversational services. Pioneering work by Jacobson et al. [3] proposed to request *future* Data packets to reduce the two-way delay to a one-way delay as offered by push-based solutions. This can be easily applied to constant bit rate (CBR) traffic, but is rather challenging for VBR traffic. In the course of more recent work, *NDN-RTC* [2] – a library for real-time audio and video conferencing over NDN – was developed. The system uses Jacobson's approach to pre-request data which has not yet been produced, to keep the end-to-end delay low. However, the authors point out that pre-requesting leads to the problem of consumer–producer synchronization, which basically means that a consumer does not exactly know when to issue Interests for which Data packets. Furthermore, it is challenging for clients to issue the correct number of Interests or the correct names of the corresponding Data packets for future audio and video segments.

Besides these pull-based approaches, *Persistent Interests* (PIs, [9]) were proposed to yield a push-based alternative for real-time traffic over NDN. A PI is an Interest which is not only valid for one Data packet, but for all Data packets which are produced during a pre-defined period of time. Evaluations showed [5] that PIs are well-suited for conversational services and reduce overall network load and processing requirements, due to fewer Interest packets in the network. Good forwarding strategies and decisions are crucial for PIs since each PI does not only affect one Data packet, but several ones. Unfortunately, most adaptive forwarding strategies [6] intended for classical Interests are not applicable for PIs because metrics such as the Interest satisfaction ratio cannot be used to assess the quality of a path. One possible solution for mitigating this problem is by using a *probing* approach, as already investigated for classical Interests by Schneider et al. [7].

In this paper, we propose an *adaptive forwarding strategy* for Persistent Interests in NDN. Forwarding decisions are based on a combination of information from the Forwarding Information Base (FIB) and probing results. In addition to PIs, clients issue probing Interests in order to rate paths through the network. All probe-receiving routers can use them to evaluate the performance of already known paths, but also to explore new, possibly better paths. This enables our strategy to react to network changes.

2 THE INTERPLAY OF PROBING AND FORWARDING

Basically, our forwarding strategy makes decisions based on information from two components. Initial decisions are based on the *Forwarding Information Base* (FIB) which contains information like which name is reachable on which face and at what costs. These decisions are then refined with the help of information from the second component which uses *probing* results to assess link qualities and enables the strategy to react to network changes.

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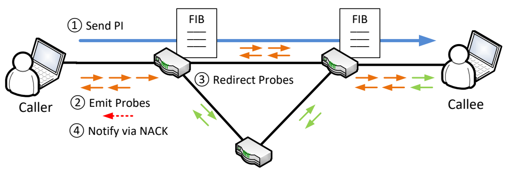

Figure 1: Evaluation of new paths by using classical Interests as probes

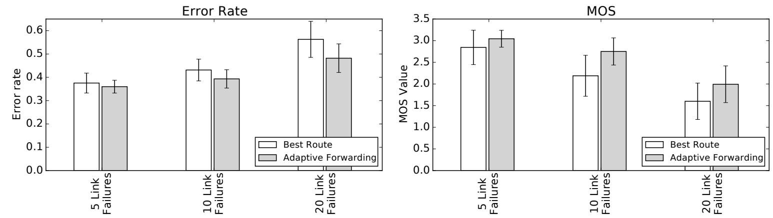

Figure 2: Average error rate and estimated Mean Opinion Score of simulated voice traffic

The overall workflow of our strategy is visualized in Figure 1. Initially, when the caller first requests a certain name via a PI, no probing results are available. Therefore, the PI is forwarded according to the best FIB entries on all forwarding routers (see ①), which we call the *working path*. At the same time, the caller starts issuing a steady stream of classical Interests requesting empty data packets as probes along the working path (see ②). These are used to calculate the delay and loss on the current working path. In addition, each node can redirect a small amount of probes (e.g., 10 %) to alternative faces, in order to test path qualities. These newly explored paths are then called *alternative paths* (see ③). Unlike probes on the working path, these redirected probes can only be used by the redirecting node to rate the alternative path. All other nodes must exclude redirected probes from their metric calculation, to prevent tampering the probing measurements of the current working path. Therefore, a NACK notifies all previous nodes (see ④) that the redirected probe has to be excluded from loss and delay calculations.

Changing network conditions such as congestion or link failure on the working path are indicated by increasing delay or loss values. When the measurements cross predefined thresholds, the alternative path's probing results can be used to redirect the working path to a well performing alternative by simply forwarding the next PI to the corresponding face.

3 EVALUATION

We conducted network simulations on a virtual representation of the *Abilene* topology [1] using *ns-3/ndnSIM* [4]. Two randomly selected nodes simulate voice clients, which communicate for ten minutes utilizing the G.711 voice codec (100 packets per second, each 80 bytes in size). During the simulation temporally evenly distributed link failures, each lasting between 94 and 144 seconds, are simulated. The number of link failures varied from 5 to 20. Our strategy is compared to a PI-adapted version of *Best Route* from [5].

Our results show that our adaptive forwarding strategy behaves well for changing network conditions. Our result figures depict 95 % confidence intervals, resulting from 20 simulation runs per setting. As displayed in Fig. 2 our strategy has a lower error rate than *Best Route* in all configurations, with the error rate being the percentage of lost Data packets. This characteristic becomes more apparent with increasing number of link errors, which is likely due to the fact that our strategy uses probes to find alternatives in advance and is therefore better prepared to adapt to changing network conditions than *Best Route*.

The estimated *Mean Opinion Score* (MOS) according to the simplified E-Model [8], which allows the estimation of user satisfaction by observing packet statistics, is shown in Fig. 2. Our strategy was able to reach a higher estimated user satisfaction than the *Best Route* strategy in all configurations.

4 CONCLUSION

Persistent Interests (PIs) enable a promising push-based alternative for real-time traffic over NDN. However, they suffer from having no inherent way to calculate metrics like the Interest satisfaction ratio and representing a substantial forwarding commitment due to their persistent nature. These special properties need to be taken into account by *adaptive* forwarding strategies that support PIs. We propose such a strategy which uses *probing* to identify possible alternative paths through the network in order to cope with changing conditions. We show by means of experiments that our strategy is overall more suitable to guide PIs through the network than its competitor *Best Route*. Despite all probing overhead, the overall traffic is reduced because of a lower number of sent Interests compared to pull-based approaches [5]. The source code of our simulation system is published on Github (https://github.com/phylib/pips-scenario) and open for use by other researchers. We acknowledge the code base of Schneider et al. [7] which our code builds upon.

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