High-performance Measurement in Adaptive Forwarding of Named Data Networking

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ABSTRACT

Adaptive forwarding is one unique architectural benefit of Named Data Networking (NDN). However, it suffers from high cost of realtime path performance measurement. We propose efficient measurement techniques in NDN's adaptive forwarding. Specifically, we eliminate the longest prefix matching operation at each data retrieval by decoupling the measurement and the FIB, which is proved to achieve the same effectiveness of the measurement while saving operation costs when network conditions are stable.

CCS CONCEPTS

• **Networks** → **In-network processing**; **Network monitoring**; *Data path algorithms.*

KEYWORDS

Named Data Networking (NDN), Adaptive Forwarding, In-network Measurement, Measurement Table

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1 INTRODUCTION

Adaptive forwarding [5] is one unique architectural benefit of Named Data Networking (NDN) [1, 6]. Thanks to NDN's stateful forwarding plane and its pull communication model, NDN is able to passively measure paths performance, e.g., round trip time, at each data retrieval. This path performance measurement can also be active by occasionally multicasting requests to alternative paths. With this capability, NDN is able to measure network conditions (e.g., partial network failures and congestions) on the fly, and make better forwarding decisions accordingly.

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However, the current adaptive forwarding design[5] and implementation [2] incur significant operation cost at data path. Specifically, for each data retrieval, it records a round trip time at the measurement table, which is bound with the *forwarding information base* (FIB), indicating the next hop's performance on each routable name prefix. Since FIB lookup is one longest prefix match on a data name, the current adaptive forwarding adds an extra longest prefix match to the data processing pipelines. Because most data processing in NDN's original stateful forwarding only requires exact name matching, the current adaptive forwarding adds significant overhead to the data pipelines.

This problem was first pointed out in [3, 4], which did not provide detailed specification. In this poster, we explain how high-performance measurement can be achieved.

2 DESIGN

2.1 Overview

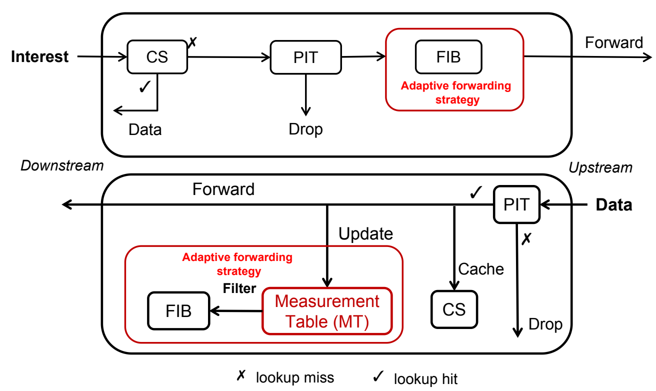

Figure 1: Optimized NDN forwarding pipelines with an adaptive forwarding strategy: bind Measurement Table to PIT

NDN has two types of packet, *Interest* and *Data*, and it applies the pull communication model, meaning that an Interest packet is sent to retrieve a Data packet. Both Interest and Data are identified by names, and they are processed with stateful forwarding plane. The optimized NDN forwarding pipelines with an adaptive forwarding strategy (i.e., ASF strategy [2]) are depicted in Fig. 1. *Interest* processing involves lookups of three state tables, i.e., *Content Store* (CS), *Pending Interest Table* (PIT), and *Forwarding Information Base* (FIB). The basic *Data* processing involves lookups of two state tables, i.e., PIT and CS. The adaptive forwarding strategy adds one lookup of *Measurement Table* (MT).

In common cases, PIT and CS lookups in data processing require exact name matching [1]. Given that MT is bound to FIB, which involves longest prefix matching, hence adaptive forwarding adds significant overhead to Data processing pipelines, causing performance bottlenecks.

2.2 Binding MT to PIT

To reduce the overhead of MT lookup, we propose to bind MT to PIT. As a result, MT lookup can be merged to PIT lookup which is already conducted in the pipelines. In addition, FIB lookup is only necessary when path ranking is changed, which is supposed to be uncommon. Next, we explain the rationale and details of the PIT binding design.

2.2.1 What is adaptive forwarding truly measuring? Path ranking. Greedily, the adaptive forwarding strategy chooses the best path, i.e., having the lowest round trip time, to forward Interests. Therefore, path ranking is the essential information to guide interest forwarding. Moreover, we observe that path ranking changes along with the following mechanisms:

- **Interest retransmission**: when a link fails or congested, the path is unable to bring data back in an expected time; as a result, a consumer will retransmit the Interest, and the adaptive forwarding strategy considers it as an application's retransmission and will forward it to an alternative path. Multiple retransmissions can trigger data retrieval on multiple paths. Therefore, multiple path can be measured, resulting in a new measured path ranking.
- **Interest probing**: instead, adaptive forwarding also actively explore other paths by occasionally multicast Interest to alternative paths, which achieves the same goal of ranking the performance of multiple paths.

2.2.2 Why binding MT to PIT is semantically correct? The lifetime of a PIT entry is extremely short compared to a FIB entry. Binding MT to PIT means that the path measurement stays as long as a PIT entry's lifetime. We prove that it is long enough to measure path ranking. This is because a PIT entry's lifetime is not only based on one Interest's lifetime, instead it will be cleared if the lifetime of all its outgoing records expire. Therefore, for either Interest retransmission or Interest probing, a PIT entry will not be cleared until path ranking has been collected. To conclude, binding MT to PIT is able to measure path ranking before its state is cleared, hence it is semantically correct.

Specifically, we use elaborate the design with the pseudocode (Algorithm 1). When a Data is received, the path performance measurement is conducted on the incoming Face (i.e., an abstraction of a next hop). Then this information is used to generate a new path ranking (line 2). Next, the new path ranking is compared with the current path ranking. Assume that network conditions are commonly stable, meaning that most data retrieval can be satisfied by one path, and multipath measurement does not change path ranking; path ranking changes only in rare cases. Here are three different situations:

- In common cases, when only one path is used for Interest forwarding, its performance measurement is unable to generate a new path ranking, hence FIB update will not be triggered. resulting in a new measured path ranking (line 8).
- In some cases, when multiple paths are measured, either Interest retransmission or Interest probing, as long as the path ranking is unchanged, FIB update will not be triggered (line 8).
- In rare cases, when the network condition has a dramatic change, a different path ranking will be measured hence triggering FIB update (line 6).

Last, we analyze the effectiveness of the proposed design. Comparing with the current design that each Data reception triggers a FIB update, the proposed design can significantly reduce FIB updates, hence improving the Data processing performance by eliminating a majority of longest prefix matching.

Algorithm 1 Measurement logics in adaptive forwarding

```
1: procedure onIncomingData()
2:     newRanking ← makeRanking(incomingFaceId, rtt)
3:     curRanking ← getCurRouteRanking()
4:     if newRanking! = curRanking then
5:         newNamspaceInfo.updateRouteRanking()
6:         UpdateFIB()
7:     else
8:         continue
```

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[1] PIT lookups may involve prefix matching [4], but they are used for version discovery, hence not common