Interest Set Mechanism to Improve the Transport of Named Data Networking

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General Terms

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1. INTRODUCTION

NDN (Named Data Networking) provides a pipeline, whilst Interest packets perform the same flow control and sequencing function as TCP ACK Packets. Since NDN packets are independently named, the pipeline does not stall on a loss. The equivalent of TCP SACK (Selective ACKnowledgement) is intrinsic. Meanwhile, NDN provides more sophisticated sequencing mechanism for requesting individual pieces from large collections of data. The conventional/automatic parts in the name of chunk, are typically the version marker and segmentation marker. [1]

The pipeline service provided by NDN is proved to work well. But NDN pays a high price in order to maintain the pipeline. For example, the data consumer of VoCCN (Voice Over CCN) has to send more than 50 Interests per second and every Interest is forwarded according to FIB (Forwarding Information Base) and leaves traceable footprints on every router from consumer (The application which requests data) to provider (The application which provides data originally). The fundamental reasons for the high spending are two-fold. Time and space uncertainty of data transfer:

- Time Uncertainty: Consider applications like live Video. Data packets are made up of samples at quite high rate and must be transmitted as quickly as possible in order to provide better user experience. Original NDN opens the pipeline to fetch Data by sending Interest frequently, which is quite inefficient. Making thing worse, the pipeline can transmit a specified Data only during a short period due to PIT entries' lifetime is limited. While the exact moment of Interest arriving is not absolutely predictable, which may be unable to match the "rhythm" of sampling, leading to invalid PIT entries and complexity of application implementation. One solution is to set a long live PIT entries, but this creates a potential security vulnerability.
- Space Uncertainty: Consider applications like large file transfers. The file has to be split into chunks with proper size, since too large chunk size results in a high loss rate over a best-efforts underlying service, such as 802.3/IP/UDP. The consumer has to send those corresponding Interest packets in order to get the whole file.

In both cases above, the network amplifies the spending by a factor of hops between consumer to producer (Though cache decreases this factor). This means, by reducing the number of Interest packets sent by consumer, the spending will decrease a lot.

Our solution is quite simple, we aggregate several Interest packets from the same flow into one packet, which we call Interest Set packet. Note that here we distinguish between Interest packet and Interest Set packet. For short, we will refer to Interest packet as Interest, and Interest Set packet as Set. The problem here is that PIT entry may timeout in a short time before all Data packets are returned. Our trick is to reset the lifetime timer of the PIT entry after receiving any corresponding data packet. Here, valid means the name of the data belongs to the Set and the data has not been returned before. Thus, solving inefficiencies caused by time and space uncertainty, we maintain the pipeline with a much lower spending for a relatively longer period.

2. METHODOLOGY

2.1 Packet Description

Interest Set packet, as the name implies, contains multiple Interests in one packet. Those Interests must share the same name prefix. For example, names of different segments of a large file, names of different data samples from a live video conference application. Here, we use *sequence number* to represent the different parts. A Set contains a set which is made up of different sequence numbers. The number of elements in the set is called *cardinality.* Set contains a Nonce in order to get ride of looping, just like normal Interest packets.

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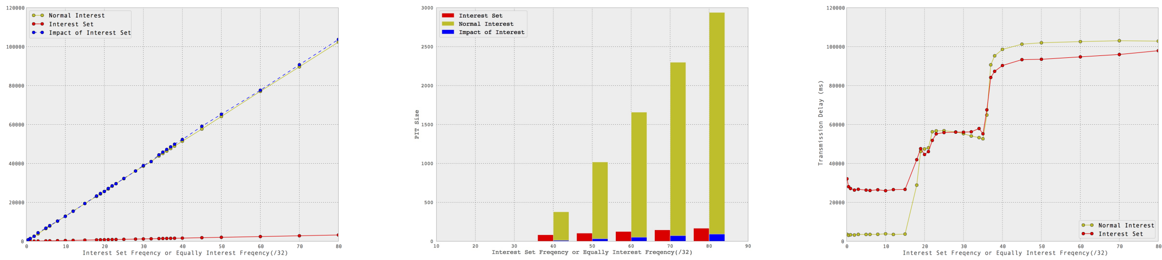

(a) FIB Lookup Overhead (b) PIT Compression (c) Average Round Trip Delay

Figure 1: Simulation results

2.2 Node Model

NDN routers are updated in order to recognize Set, create PIT entries attached with Set and execute the trick operation, reset lifetime timer of corresponding PIT entry if a valid Data is returned. The main part of node model remains constant. The preudocode of node model can be found in our tech report [2].

Basically, Set mechanism does not break any principles of NDN. It just aggregates similar Interests into one packet and enhance NDN routers to construct the special pipeline. This pipeline would close if no valid data is returned during PIT entry's lifetime. Thus, resources can be recycled, which potentially defends the attack to routers by sending massive amounts of Set.

3. EVALUATION & SIMULATION

We use ndnSIM[3] to evaluate the performance with PoP (Point of Presence) topology of Sprint, which includes 52 nodes and 84 links with real weights. The provider located on the center of the topology while 8 consumers located on the edge. Other nodes also request data to provide background traffic if necessarily. Considering sample rate of real applications, such as YouTube, Skype, VoIP, every Set contains 32 sequence number, i.e. $Cardinality = 32$.

The obvious benefits of Set are reducing the number of FIB based forwarding and size of PIT. Figure 1a presents the lookup overhead. The red line is the number of FIB based forwarding with Set mechanism. The blue line shows the impact of Set mechanism (Y-axis value is Cardinality $\times$ Number of Lookup with Set). The impact line nearly overlaps with normal Interest line, which means, using Set mechanism, number of FIB based forwarding is reduced to $1/Cardinality$ while keeping data throughput limited.

Figure 1b shows the PIT compression effect. The Set bars are clearly much lower than corresponding Interest bars, but higher than blue bars, which is $1/Cardinality$ of PIT size with nomral Interest.

Another parameter is round trip delay, which includes queueing delay, propagation delay and transmission delay. When the traffic is light, transmission delay, which is proportional to packet size, contributes most to round trip delay. While when the traffic is heavy, queueing delay contributes the most. Since Set packet which contains sequence number is larger than normal Interest packet, the transmission delay of Set mechanism is longer. However, number of packets under Set mechanism is less, and the queueing delay is shorter. The simulation result presented in Figure 1c agrees the analysis. When frequency of sending Interest Set is between 0 and 20 per second, the Set line is higher than Interest line. While, when the frequency is above 40 per second, Set line is lower since.

4. CONCLUSIONS

In this paper, we propose Set mechanism to solve the inefficiency caused by time and space uncertainty of data transmission. The benefits include:

- Set mechanism decreases overhead greatly: it reduces the number of FIB based Forwarding to $1/Cardinality$, while the size of PIT in reduced more than an order of magnitude in our evaluation.
- Round Trip Delay: When the network traffic is heavy, Set mechanism can decrease round trip delay by 10 percents, which is of great value for those real-time applications.

Except for the benefits above, we do realize that Set mechanism may lead to inflexibility to data plane and data burst, etc. But by adjusting Cardinality dynamically and setting a reasonable PIT entry's lifetime, the disadvantages can be fixed or limited. This should be included in our future work.

More details on chunk size analysis, applications description, pseudocode and experiment results are presented in our technical report[2].

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