Scalability Problem for Interest Diffusion in Content-Centric Network

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Abstract

Internet communication paradigm is moving from host-oriented to content-oriented network. Under this movement, the location where content is located is no more important, and the content itself is the more important. Content-Centric Network (CCN) is proposed as a solution for architecture supports the content-oriented networking, by using its 'Interest' packets to request a contents and forwarding data packets reply to the Interest packet. From this mechanism a scalability problem in the size of interest cache table. In this paper, we tackled this problem with several simulations and make a suggestion for the problem.

I. Introduction

In the beginning of the Internet, TCP/IP protocol is designed to connect and enable communication between two endpoints. Every communicating entity needed to know where the opponent of communication is located, and marked the address of communication opponent's in a packet header. Routers in the Internet forwarded the packets according the address recorded in the packet header, and the Internet did not need to know what the packet carries in its payload, and just route the packet to an appropriate interface, according to the prefix of IP address, which is obtained before the packet is sent to the Internet through DNS query.

After many tens of years have passed, nowadays the Internet is not only a network of research, but also an infrastructure for industry and commerce. The users of the Internet is changed from researchers and students to general public who does not have any knowledge or interests about the way how the Internet works. The purpose of the Internet usage is focused to 'what they want to get', not 'where or how they can get it'. In this way, the fact that we should know about where the content is located to get the content is not an efficient way to distribute content.

To meet the changed requirement, i.e. communication paradigm, lots of researches tried to change the network into a network that cares what the data is and what their characteristic is, more than the Content-Centric Networking (CCN) is proposed by Van Jacobson[1], which insists the paradigm of communication over Internet should shift to content-oriented, not host-oriented. In CCN, an 'Interest' packet is sent to the network, and the matching data to the interest is returned as a reply to the interest, so the end user, or endpoint, needs not to be aware of the location where the content is stored.

This paper reviews the content distribution mechanism of CCN, and excavates some scalability issues that can be occurred under content distribution mechanism used in CCN. The paper is composed like this: Section II will give brief introduction about Content-Centric Networking, and basic operation of CCN. The scalability problem in PIT management will be introduced in the following section. We simulated a simple CCN model with a number of contents to see the impact of PIT table size in various situations.

II. Networking for Content Distribution

Van Jacobson[1] proposed a concept of Content-Centric Networking. Content-Centric Network is composed of CCN Nodes, which caches and forwards "Interest" packets from users and other CCN nodes, and transmits 'Data' from other CCN nodes or sources to the requested CCN nodes and users. We now give a brief introduction about basic concepts of CCN in the following paragraphs.

Each CCN node maintains three databases: ContentStore, Pending Interest Table(PIT), and Forwarding Information Base(FIB). FIB is the forwarding information base in the conventional IP router, which stores IP prefixes and their matching interface to forward the incoming packet. The difference between CCN FIB and IP router FIB is that, the IP prefix is replaced with "Content Name" prefix, and the interface is exchanged with 'face', which includes hardware network interfaces, as well as a process that requires content.

ContentStore is a content cache: In CCN, the location of content server is not important. Actually, the content may be located in a single server (which may be the publisher of the content) but as the time goes by, the content is cached during transmission of the content to users. While the content is forwarded over the CCN nodes, each CCN node stores the content data in its own cache. After caching, the additional request ("Interest") for the same content cached in a CCN node will be directly replied at the CCN node cached the content, not by the

Pending Interest Table is cache table for 'interest' packet. Every interests that requests a contents is forwarded to connected node. When a node receives an interest packet firstly and the node does not have the contents requested by the interest packet, then the node will store the interest (content and originated face) in the PIT. Then the node will forward the interest packet, according to a decision based on its FIB, like packet forwarding in IP routing. If a node receives another interest packet which demands same contents from other nodes, then incoming face information will be stored in the PIT, and the interest packet will be discarded.

The content distribution in Content-Centric Network is like following: a user who wants contents sends "Interest" packet to the network, which includes the content name, other selectors and nonce value for prevention of loop. When a CCN node receives an interest, there are three actions available for the node: reply to the interest with content, redirecting the interest according to the FIB, or just keeping the information of face the interest came from. If the CCN node cached the requested data by the interest packet, then the CCN node can directly reply to the interest with cached data. The interest will be discarded.

If there is no cached content data, the interest is forwarded according to the FIB information, and the interest information (the face from which the interest has come from) is stored in the PIT. If the CCN node already received an interest that have the same content name, there will be an entry about the interest that already had been forwarded, so the source face for current interest will be appended to the entry in PIT table. If there is no entry already stored, then new entry is generated and stored.

III. Scalability for Interest Diffusion in CCN

As we described above, when a CCN node receives an interest packet, information about the interest (the face from which the interest has come from) is stored in Pending Interest Table (PIT). One interest may issue one entry in PIT of a CCN node. In specific, a single interest packet that requires different content generates one entry for PIT. Consequently, the number of PIT entries will increase as number of contents increases.

Moreover, as an interest is re-distributed by its receiver until reception of matching data, the number of entries in the PIT will be increased exponentially for overall network. For just one CCN node, or a small network, the problem may not seem to be severe, but if we scale the network and number of contents largely, there may be scalability problem.

If the network is large and the number of contents requested is also large, the PIT table size will grow rapidly till content request is satisfied. The PIT entry can be removed only after the node which has the PIT entry receives the requested data; interests requesting non-popular content remain for a long time, and would be a large portion in the PIT table over the whole network.

The impact of scalability problem in PIT is two-folded. The size of PIT itself may be a problem, and the number of entries in PIT can be also a problem from the point of lookup time. Each PIT entry occupies more than several tens of bytes, regarding each PIT entry should include the content name of which length will be so. We cannot assume anything about the number of contents but it will be very large, more than several millions. So the size of PIT can be more than several tens of MBs, which can be too large to be stored in a cache: to be processed quickly, the PIT should be stored in a very fast memory which is very expensive.

Another problem is the number of PIT entries. Recently the routing scalability problem in current Internet has attracted many researchers in this field. The main point of the problem is that there are so many PI (Provider-Independent) addresses that cannot be aggregated into a single prefix, so each PI address will occupy a single entry in routing table of a router, and there are more than several hundreds of thousands of entries in BGP table [3], which is problematic for core routers that need a fast lookup. The same problem can arise in CCN. Every reception of interest at a content router needs PIT lookup, so the size of PIT table can be problematic for performance of a content router, which can be result in overall performance downgrade in the whole network.

The actual impact of PIT size to performance of a content router (and content network) can be varied over device specification and implementation of each component in the network. So in this paper, we will not treat the issue directly, but we will look in the variety of PIT size according to different network environment.

IV. Simulation and Discussion

We ran simulation to analyze the PIT size variance in a network. Our CCN network is composed of 5000 CCN nodes, and to simplify the situation, we assumed all types of the contents have same popularity and demands.

The network is generated by a network topology generator 'inet'[2]. 'inet' can generate an AS-level representation of the Internet which generates a network topology according to power-law distribution.

For simplicity, every single contents and an interest will be forwarded to next hop router at once for each loop of the simulation loops, while original CCN will divide a single contents into several 'chunks' and forward it. Also we do not adopt any routing algorithm or so, therefore all nodes in our simulation will broadcast the interest packet to every connected router.

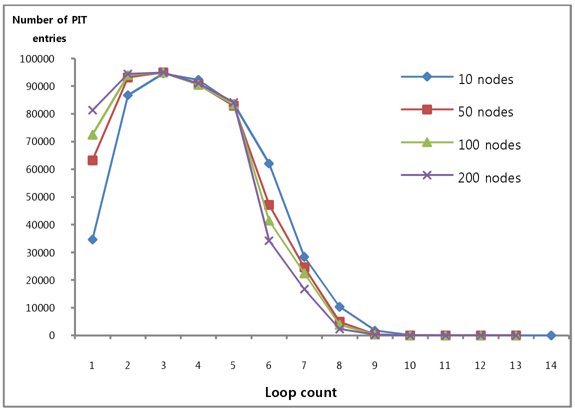

Figure 1 Number of total PIT entries in the network according to number of user nodes

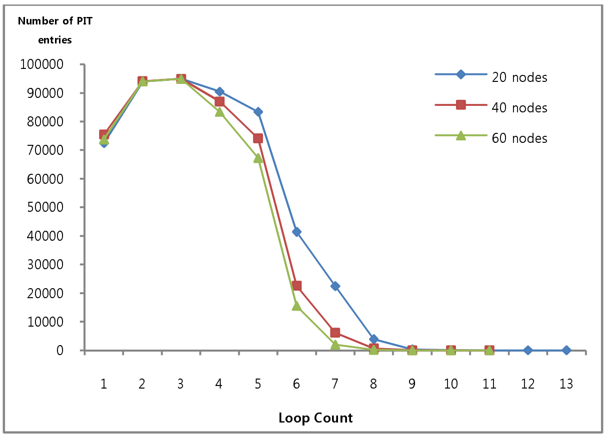

Figure 2 Number of total PIT entries in the network according to number of content nodes

In our first simulation, the impact of user nodes that requests contents is analyzed. Figure 1 shows the variance of numbers of PIT entries in a 5000-node CCN network. As we can see in the figure 1, the number of PIT entries increases rapidly for the beginning of content distribution, and after small time of content searching (by forwarding and redistributing the interest packets stored in PIT of each CCN node), the number of PIT decreases quickly, because lots of CCN nodes cached the data and forward it according to the interest information stored in their PITs. As we can see, even if small amount of content users requests the contents, the number of interest packet is far more than the number of users. It is debatable that our simulation does not consider any routing algorithms, but if the user is distributed uniformly over the network, then the interest packet should be forwarded as it can be to retrieve the contents as soon as possible, so the interest packet will forwarded like broadcast.

Another interesting point is, if the number of original content server is fixed, then number of users that request the contents does not affect much to the number of PIT variance. The number of PIT entries are varies from thirty thousands to eighty thousands at first time, but as the simulation loop goes, the number of PIT entries rapidly converges and shows almost same movement.

In the figure 2, we varied the number of content server nodes. We have 20 types of contents, and there are 20, 40, 60 content servers, respectively. Similar to the figure 1, the number of PIT entries decreases from 6^{th} iteration of simulation loop. That means the number of content server may have a limited effect to the movement of number of PIT entries in the network.

VI. Conclusion

In this paper, we have studied for PIT scalability issues in CCN. As the simulation result showed, interests for non-popular or rare contents will remain a long time in PIT table, so the PIT table size may be too large to perform efficiently. A large amount of interested will be forwarded, and it consumes the network capacity more than it needs. Moreover, if the number of content server (or a content router caches a certain content) is small, then the PIT will be remain longer and it may decrease the content router performance.

We can expect if appropriate policy for FIB construction is applied to the CCN then the number of entries in PIT can be greatly reduced if we consider our simulation used broadcast routing algorithm. We will study this issue more precisely for our future work.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MKE/KEIT [10035245: Study on Architecture of Future Internet to Support Mobile Environments and Network Diversity].

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