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CCN에서 정보제공자의 이동성 지원을 위한 푸싱 기법

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Provider's Mobility Supporting Proactive Neighbor Pushing Scheme in CCN

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ABSTRACT

CCN(Content-Centric Network) enables users to retrieve content using the content's name. Researchers face critical challenges in terms of mobility. Since the routing information is part of the content name, when the provider moves, it is necessary to update all the routers routing information. However, this requires significant costs. In this paper, we propose PNPCCN(Proactive Neighbor Pushing CCN), considering the popularity and rarity of mobility support, for providers in CCN environments. Via simulation studies, we demonstrate that our solutions are effective in terms of shorter numbers of retransmitted Interest packets, and average download times and higher delivery ratios during mobility.

Key Words : ICN(Information-Centric Network), CCN(Content-Centric Network), NDN(Named Data Network), CS(Content Store), PIT(Pending Interest Table), FIB(Forwarding Information Base), PNPCCN(Proactive Neighbor Pushing CCN)

1. Introduction

Through advancements in networks, the Internet became a necessary tool in our lives. According to ITU statistics, within just 5 years, broadband users had tripled in size from nearly 61.5 million people in 2009[1]. Broadband mobile communication subscriber's data that was transmitted to the Internet increased exponentially. According to the Cisco Visual Networking Index, by 2018 worldwide mobile communication data trafficking will reach 15.9 Exabytes per month. This is an eleven-fold increase compared to that of 1.5 Exabytes per month in 2013[2]. Many researchers in the field of Information-Centric Networking(ICN) are spotlighting network architecture to disseminate effective contents for

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the future[3]. Other studies of ICN such as PSIRP, 4WARD, PURSUIT, SAIL, DONA, and CCN[4] are in progress. For the purposes of this paper, the focal point is on the research of CCN from the project Named Data Networking(NDN)[5] conducted in the USA.

CCN is a newly proposed future Internet architecture which focuses on what the provided contents are rather than where they are at. Also, the name of the contents is used in network routing. The consumer sends the Interest packet with the contents name in it to the router, disregarding the location of the contents, and the router seeks the contents which correspond to the received Interest packet. Consequently, CCN reduces any network trafficking congestion, loading problems, and response time. Also, CCN does not need to be connected to a host, unlike in the IP environment, making it advantageous in backing up mobility in nodes.

However, regardless of all these merits, there are many problems yet to be solved. Reference [6] prioritized the matter of support for mobility and conceptualized it into two categories: consumer and provider. According to [7], more than 97 % of the requested packets successfully reached the consumers with their high level of mobility. Yet, as seen in Fig. 1, when the provider moves, the location information changes from Domain A to Domain B and the routing data does no longer matches up. As a result, all routers need to manipulate routing information and need to perform extra tasks. However, the cost to alter routing information is remarkably high. On top of that, a critical problem occurs if the consumer does not find the contents before the change. At the point where mobile communications subscribers increased exponentially, CCN has fatal issues that need to be dealt with through an effective solution.

In this paper, the Proactive Neighbor Pushing CCN (PNPCCN) model is suggested as a solution, considering the popularity and rarity of contents, to solve problems that occur when the provider moves. PNPCCN and CCN were compared to prove that there are shorter numbers of retransmitted Interest packets and average download times and higher delivery ratios.

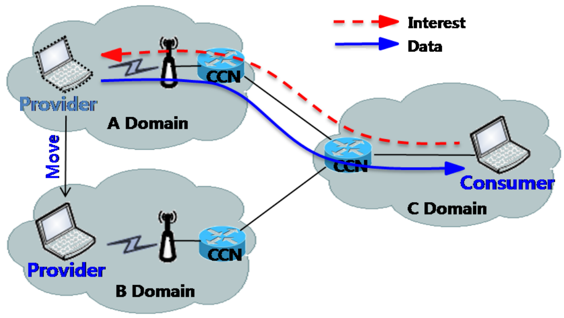

Fig. 1. CCN provider mobility problem

2. Related Works

2.1 Content-Centric Networking

CCN has been driven by consumer receiver-driven methods where the content name is used in a routing network. For example, the content name can be read by the user as '/kndu.ac.kr/ngnlab/ccn.txt,' and has a hierarchical structure. Consequently, CCN has scalability as it is flexible to any increases in users. Two types of packet communications are carried out by CCN-an Interest packet and a Data packet. The Interest packet is one that is issued when the consumer is looking for contents and has three options. First, is Content Name: the ability to search for contents. Second, is Selector: consisting of a parameter for selecting the content. Third is Nonce: to prevent iterative loop. The Interest packet is able to go to the provider that has the needed information through Longest Prefix Matching of Content Name. Now, the provider replies to another packet - the Data packet. The Data packet has four options. They are categorized as Content Name, Signature, Signed Info, and Data. Content Name is an option that can check wanted contents and a Signature is data that guarantees the original contents. Signed Info consists of data types and expiration dates and data is an option which includes wanted data. Data packet moves through a reverse path to deliver the Interest packet to the consumer.

For efficient data propagation, CCN's forwarding engine is made up of Content Store(CS), Pending Interest Table(PIT), and Forwarding Information Base(FIB). When an Interest packet arrives at the CCN router, the router first checks the Data Packet that matches the Content Name of the Interest packet in the Content Store. If the router finds it, then the Data packet is sent to the interface where the Interest packet came from. Otherwise, the router makes sure if there is a match for the PIT. If there is a match, then the router is joined by the newly added interface of the Interest packet. If there is no matching entry in the PIT, the router makes sure if there is a match for the FIB. If a match is found, the router is newly added to the PIT entry and according to the FIB, the Interest packet is sent. If it does not exist in the FIB entry, the Interest packet is discarded. A Data packet arrives at a CCN router, the router determines if it contains a match in the Content Store. If there is a match, a Data packet is discarded since the packet is present in Content Store. Otherwise, the router looks for the PIT. If there is a PIT match, it means the Data was solicited by Interests sent by the consumer. So, a Data packet is added to the Content Store. Then, a list is created from the interface list of the PIT entries which match the arriving Data packets, minus the Data packet's arriving interface. The Data packet is then sent out through all the remaining interfaces of the list. After sending the Data packet, the list is deleted. If there is no matching entry in the PIT, searches for the FIB. It means that the search for meaning has not been retrieved from the PIT, so arriving Data packets are deleted because the data are not required.

2.2 Mobility Support in CCN

As mentioned earlier, since it is not necessary for the CCN to maintain the connection between the hosts, it is better for mobility than an IP. However, problems occur with the content of the provider and, in order to resolve them many studies have been made. In [8], this problem "Home Repository(HR)" is solved by its introduction. After a provider moves to a new location, instead of announcing a new prefix, it tells the HR to forward a virtual Interest packet which includes the new location information. However, the Data packets move along the reverse path of the Interest packet, so HR is going to be forced to bypass. Data transfer delay time is increased due to the data packet being detoured along the interest packet's path.

In [9], the solution to the above-described problem is to bypass the HR packet location information in addition to the Data packet. When the producer informs HR of a change in its location information and the consumer requests to HR the provider's location information, the HR relays the correct location information to the consumer. However, this method is often moved to an environment where a provider problem arises. In other words, when the position is changed frequently, the user might experience delays as he cannot synchronize with the new location. The consumer will wait until the timeout event occurs and the Interest packet is sent back to the HR.

In [10], to solve the issue of detour and synchronization, a location identifier was added to Content Name and an additional server that manages content information was made. When the provider moves, it tells the additional server of this fact and the server transmits the moving information of the provider to the consumer. When the provider stops moving, location data is added to the Data packet and sent to the consumer. However, this method generates a delay because of the additional server. When a problem arises in the server, then the consumer will have trouble finding the contents.

According to the proposal made in [11], sending messages between the provider and the router was suggested to effectively update the associated routing table of the router. Unfortunately, this method may also cause a delay during the update and the consumer will not be able to find the contents during that time.

3. Proactive Neighbor Pushing

Proactive Neighbor Pushing CCN(PNPCCN) is proposed to solve mobility problems caused by the provider of a CCN. To briefly state the idea of PNPCCN, when the provider is close to moving and the consumer requests the contents, then the provider's contents are transmitted to the neighboring nodes. However, the provider transfers contents stochastically depending on surrounding conditions and content popularity. In the case of surrounding conditions, the provider checks if the neighboring nodes have a duplicate of the contents. If the neighboring nodes have a duplicate, then a provider does not need to transmit the contents when it moves; the consumer is able to receive the contents regardless. Also, if the popularity of the content is high, then many consumers in the future will request it, thus, the more contents it has, a higher probability is needed to transmit. PNPCCN calculates probability according to the content's popularity and rarity and this is defined as Transfer Probability.

3.1 Transfer Probability

Transfer Probability is judged by popularity and rarity and content popularity is assumed to be followed by Zipf-like distribution[12]. In the Zipf-like distribution, Ci reference probability of the i th($1 \leq i \leq N$) content is expressed in PN(i) and is as represented by (1). Zipf exponent $\alpha(0 \leq \alpha \leq 1)$ is the index for how much it follows Zipf distribution. If it is 0, all the contents have the same transfer probability. If it is 1, then, it follows an exact Zipf distribution. The first content's popularity PN(1) in the Zipf-like distribution has the highest reference probability.

$$P_N(i) = \frac{1}{i^{\alpha}} \cdot \left(\sum_{j=1}^{N} \frac{1}{j^{\alpha}} \right)^{-1} \tag{1}$$

To measure the popularity of reference probability, Zipf-like distribution was used and a popular name of the scale factor is defined as Popularity Ratio Pp(i). Popularity Ratio is equal to the ratio of the reference probability of the received content PN(i) to the most popular content PN(1). For example, if PN(i) is equal to the most popular content PN(1), the Popularity Ratio Pp(i) will be 100 %.

$$P_p(i) = \frac{P_N(i)}{P_N(1)} \tag{2}$$

Rarity is another measure of Transfer Probability. Centering on the provider, Rarity Ratio Pr(i) can be defined as how much rarity (without overlapping) the 1 hop distanced neighboring node[briefly, neighboring node(s)] have of content Ci, and it is expressed as (3). neighbor is the number of neighboring nodes that are excluded from the provider. ni,duplication is the repeated number of neighboring nodes with Ci content excluding the provider. The provider calculates ni,duplication by exchanging neighboring nodes with new types of Interest packets and Data packets. This part will be developed further in detail in section B. When it comes to Rarity Ratio, for example, if there are three neighbor nodes and they all do not have contents, Rarity Ratio is 100 %.

$$P_r(i) = 1 - \frac{n_{i,\,duplication}}{n_{\neq ighbor}} \tag{3}$$

The final Transfer Probability is expressed as Pt(i) as in (4), and is composed of Popularity Ratio, Rarity Ratio, and Transfer Probability exponent β. β controls the weighted value of Popularity Ratio and Rarity Ratio and when distributed equally, β will become 0.5.

$$P_t(i) = \beta \cdot P_p(i) + (1-\beta) \cdot P_r(i) \tag{4}$$

3.2 Packet Design

In PNPCCN, we planned a new type of packet as shown in Fig. 2. We divided the B-Interest packet and M-Interest packet by adding Type option to Interest packet of CCN. The B-Interest packet has the same function as the Interest packet of CCN, where the M-Interest packet is used to check if the provider has contents which are being transmitted to neighbor nodes when movements are approached. In the Data packet, we added a Type option and divided it into a B-Data packet, an A-Data packet and an M-Data packet. The B-Data packet has the same function as the Data packet of CCN. The A-Data packet is a response packet(ACK) to the M-Interest packet. If the node possesses the specified contents in the M-Interest packet, then it transmits the A-Data packet. The A-Data packet does not consist of Data unlike the B-Data packet. The M-Data packet has a data pushing mechanism where the provider can transmit Data without a request from the node. In CCN, it requires a list from the PIT entry in order to store the Data packet in the Content Store. Otherwise, it is discarded. In PNPCCN, even if it is not on the PIT entry of receiver, when using the M-Data packet, it does not discard it but stores the contents. To prevent needless occupation of the Content Store and infinitely duplicated contents on the network, in the M-Data packet Lifetime is set and transmitted, when Lifetime expires, the M-Data packet will be discarded. During Lifetime, it's free from cache policy and set according to the provider's movement time and FIB update time. The node receiving the M-Data packet needs to keep the contents in the Content Store to provide them to the consumer continuously because the provider updates the FIB after moving.

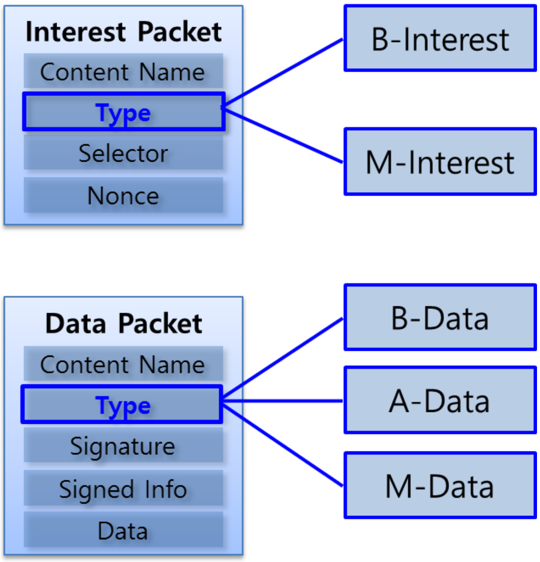

Fig. 2. Packet types of PNPCCN

3.3 Forwarding Engine Design

In PNPCCN, we designed a forwarding engine to process the Data packet and Interest as shown in Fig. 3 and Fig. 4. When an Interest packet arrives at the PNPCCN router, the router first checks if it is a B-Interest packet. If it is a B-Interest packet, the PNPCCN router is treated in the same manner as an Interest packet of CCN. If it isn't a B-Interest packet, the PNPCCN router makes sure whether it is an M-Interest packet or not. If it is not an M-Interest packet, the packet is discarded. If it is an M-Interest packet, the PNPCCN router will check whether there is a match with the content in the Content Store. If there is a match with the content in the Content Store, the PNPCCN router sends an A-Data packet to the incoming interface of the Interest packet. If there isn't a match with the content, the Interest packet is discarded.

When a Data packet arrives at a PNPCCN router, the PNPCCN router make sure whether it is a B-Data packet or not. If it is a B-Data packet, the PNPCCN router is treated in the same manner as a Data packet of CCN. Otherwise, it will check if it is an A-Data packet. If it is an A-Data packet, the PNPCCN router adds 1 for ni,duplication, then calculates the Transfer Probability after a certain amount of time(i.e., Round Trip Time in one hop). The reason for waiting a certain amount of time is that any neighbor nodes may send an A-Data packet to the PNPCCN router. If it isn't an A-Data packet, the PNPCCN router confirms whether it is an M-Data packet or not. If it is an M-Data packet, the PNPCCN router stores the data contained in the M-Data packet in the Content Store. Otherwise, the Data packet is discarded.

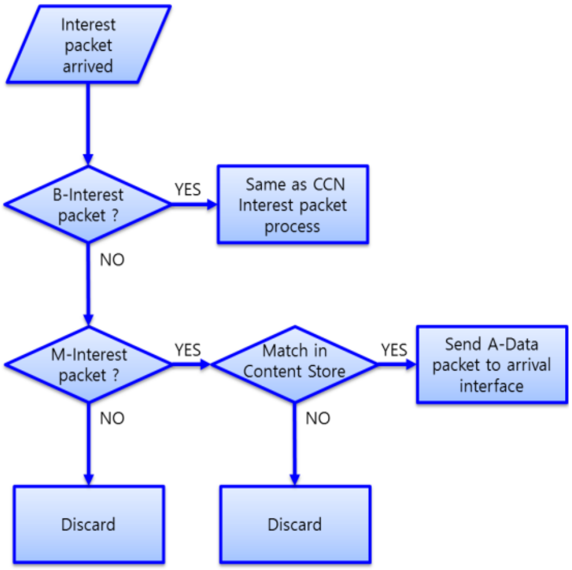

Fig. 3. Interest packet processing flowchart

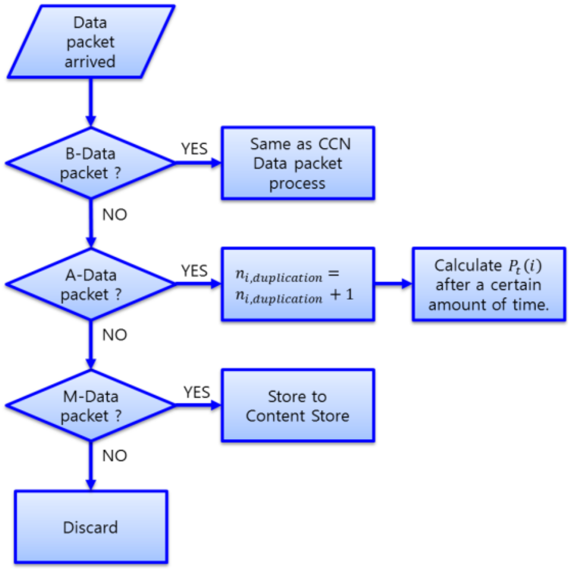

Fig. 4. Data packet processing flowchart

3.4 Operation Algorithm

The PNPCCN must design the SCAN and PUSH function in order to operate. SCAN is an operation that calculates Pt(i) in transmitting content Ci. To calculate Pt(i), the provider must issue an M-Interest packet like the transmitting Content Name of content Ci and transmits the M-Interest packet to all interfaces with the exception of the interface that the packet was transmitted from. Neighbor nodes check if there is the same content with the Content Name of the M-Interest packet, and if there is, transmit an A-Data packet. If not, they do not transmit any packets to lessen needless overhead near the provider. The provider calculates Rarity Ratio with the number of A-Data packets, which is transmitted by neighbor nodes using (3). And it calculates Popularity Ratio with popularity of content Ci and (2), and finally with (4), it attains Pt(i).

PUSH is an operation which transmits content Ci with the determined Transfer Probability. The provider transmits according to the Transfer Probability which is calculated in the SCAN operation. The remaining Data packet is transmitted to the interface that the Interest packet has arrived at according to the Transfer Probability which is calculated in the SCAN operation. To transmit the Data packet, it uses an M-Data packet, and sets Lifetime and it is sent to the interface that the Interest packet came by. The node that accepted this packet, stores Data in the Content Store even if is not on the PIT entry.

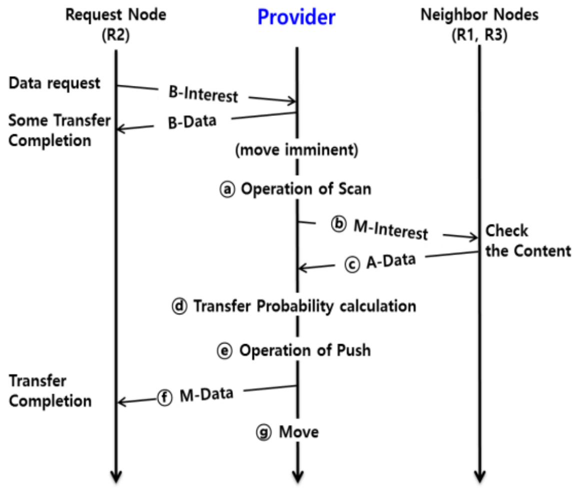

Fig. 5. Content provider moving process

Fig. 5 explains the whole operation algorithm, giving an example of an arbitrary network. In Fig. 6, the consumer is asking for content from the provider via PNPCCN router2, R2. And PNPCCN router1, R1 and PNPCCN router3, R3 have no content requests. It assumes that the provider knows when to move using RSSI(receive signal strength indicator) or RCPI(received channel power indicator) values which use a handoff at a link layer. The whole process is the same as shown in Fig. 5. When movement is imminent, ⓐ Provider begins the SCAN operation. ⓑ Provider transmits M-Interest packets to all neighbor nodes and, ⓒ if they have contents, transmits A-Data packets to the provider. ⓓ Provider computes Transfer Probability(4). ⓔ Depending on the Transfer Probability, the provider does or does not perform PUSH operation, ⓕ transmits remaining Data packets using M-Data packets to request nodes. ⓖ Provider moves.

If the size of content is large, any Data packet that fails to be delivered is generated. However, if the provider moves to another area after some of the data packets are forwarded to the R2, the provider compensates for the FIB update time. In other words, during the time which the consumer requests the transferred Data packets from R2, the provider updates the FIB. Therefore, a mobile provider can more seamlessly support the consumer.

In general, in a poor environment where there is packet loss, network performance is degraded. Also, in PNPCCN if a packet is lost, determining the exact Transfer Probability will be difficult. However in PNPCCN if due to an increased loss rate, the M-Interest packet and A-Data packet are lost, the Transfer Probability increase to ni,duplication is less. As a result, PNPCCN has good adaptability and robustness due to it reflecting the Transfer Probability according to the network environment.

4. Performance Evaluation

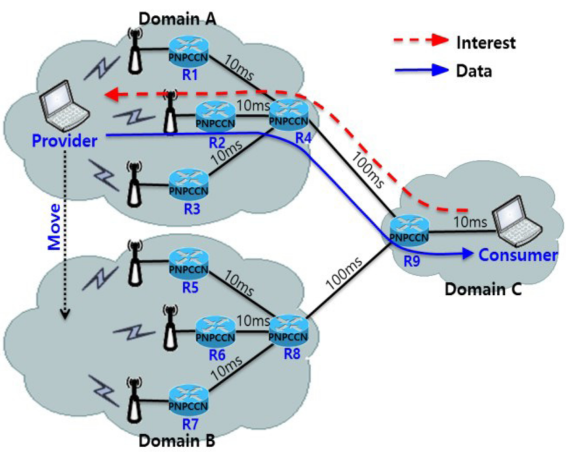

Fig. 6. PNPCCN simulation topology

4.1 Simulation Environment

To evaluate PNPCCN's performance, we modified the NDN simulator ndnSIM[13], and made a network model with 9 PNPCCN routers, 1 consumer and 1 provider such as Fig. 6. Set links in domain at 10 ms delay, 1 Mbps capacity, and set links between domains at 100 ms, 1 Mbps capacity. The consumer transmitted 10 Interest packets per second via PNPCCN router9, R9. The provider moves to randomly determined locations in domain A to domain B, and the velocity of movement is 15 m/s.

PNPCCN packets (i.e., Interest, Data packet) compete at the links with FIFO queue management. The size of each content is 300 kbyte, and each is divided into a fixed 1 KB size. We set Zipf exponent at α = 0.8, and Transfer Probability exponent at β = 0.5. We conducted the experiment increasing the Transfer Probability from 0 % to 100 %, and performed the experiment 10 times per each probability to produce the average numerical value.

4.2 Simulation Results

We focused on the number of retransmitted Interest packets, delivery ratios, and average download times depending on the Transfer Probability. The number of retransmitted Interest packets is the number of additionally transmitted Interest packets, not the number of Data packets composing a content. And the delivery ratio is a proportion of Data packets contrasted to the number of Interest packets (including the retransmitted Interest packet) that the consumer sent. We then calculated the average download time required of all simulations to download content.

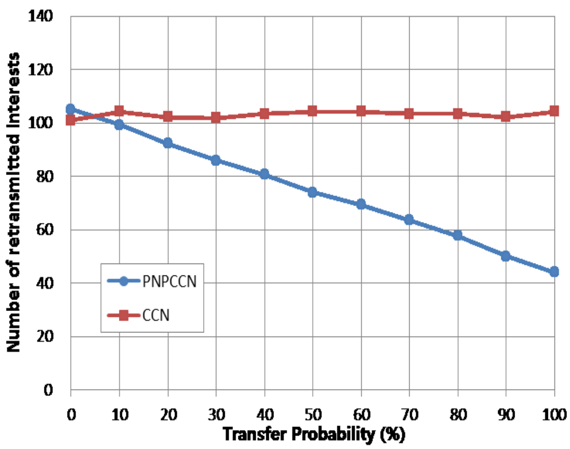

Fig. 7. Number of retransmitted interests

Fig. 7 is the result of the number of retransmitted Interest packets according to the Transfer Probability of CCN and PNPCCN. This result indicates the efficiency ratio of network resources. As seen from Fig. 7, in increasing the Transfer Probability, PNPCCN shows better result than CCN. When the Transfer Probability is 0 %, PNPCCN is performing the SCAN operation, the number of retransmitted Interest packets of CCN is slightly less. However, when the Transfer Probability is above 10 %, the number of retransmitted Interest packets, is decreasing due to the probability that that PNPCCN transmits the contents right before movement increases. On top of that, when the Transfer Probability is 100 %, the difference is 60 for retransmitted Interest packets. This indicates that PNPCCN consumes fewer amounts of network resources.

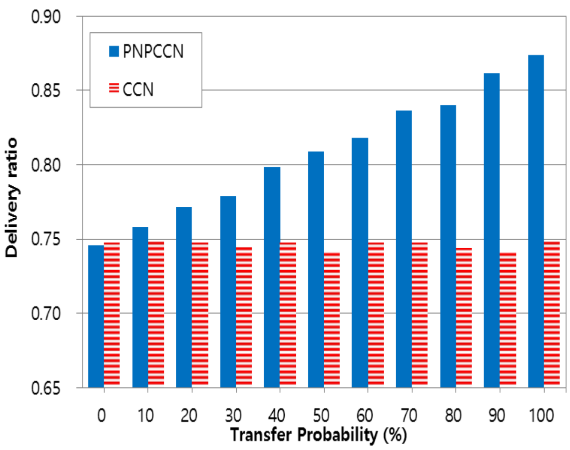

Fig. 8. Delivery ratio

Fig. 8 shows the delivery ratio according to the Transfer Probability of CCN and PNPCCN. With Fig. 8, except for the case of 0 %, the delivery ratio of PNPCCN is higher than that of CCN. Same as the number of retransmitted Interest packets, when the probability is 0 %, due to SCAN movement enaction, and CCN's ratio is higher. However, as the Transfer Probability increases, PNPCCN shows a higher delivery ratio. When the ratio is 100 %, it presents about a 0.12 delivery ratio difference. This is because that the consumer can get more Data packets due to the advantage in the provider delivering the contents. PNPCCN shows that with fewer Interest packets issued, it's able to attain the same contents for a consumer.

From Fig. 9, it shows the average download time according to the Transfer Probability. When the Transfer Probability is low, CCN has a lower time than that of PNPCCN. As with the former result, it's because of SCAN movement. As Transfer Probability increases the average download time decreases, and when it is 100 %, average download time has a difference of 6 seconds. When the Transfer Probability increases, the transmitted contents are increased, then contents are cached in advance on the Content Store of PNPCCN router, R2. The contents cached in advance are not influenced by the provider's movement; the average download time has been decreased.

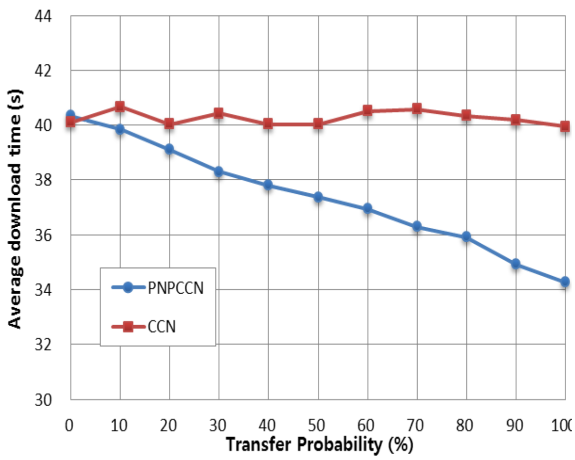

Fig. 9. Average download time

To put the simulation results into order, the number of retransmitted Interest packets and the average download time of PNPCCN is decreased, and the delivery ratio of it is increased in comparison with CCN. In other words, PNPCCN shows better performance than CCN does.

5. Conclusion

From the paper, we suggested PNPCCN to improve mobility support of CCN which has been receiving attention as the future of network architecture. We added SCAN, and PUSH functions considering the popularity and rarity of the contents when they were moved. And with the simulation, we figured out that performance of PNPCCN was more improved than that of CCN.

PNPCCN still has things to research and we will make steady progress on future research concerning various issues. First, we will examine the precise measure of popularity. We assumed that it follows popularity research called Zipf-like distribution, but there will be differences in assumption and in reality between the popularity of contents. To lessen the gap, we will progress our research towards calculating the Transfer Probability more minutely by allowing the CCN router to measure popularity regionally. Secondly, is the optimal Transfer Probability exponent β with this study. We distributed the Transfer Probability exponent β equally as 0.5. However, it's predicted that the performance will change according to β and we will study which β is appropriate for better performance.

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