Navigation Information-based Proxy Server Handoff for Mobile IPTV Services

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Abstract

This paper proposes a navigation information-based proxy server handoff (NIPH) scheme that aims to select appropriate proxy servers based on the estimation of proxy servers' hop and a terminal's movement using navigation information. The simulation results demonstrate that the proposed scheme has an advantage of minimal content delivery cost, which consists of transfer cost and proxy server handoff cost.

Keywords: content delivery, navigation, proxy server handoff

1. Introduction

Since video content requires a larger network bandwidth and storage capacity compared with text and voice content, IPTV service providers use proxy servers for caching. The number of hops for the IPTV content delivery reduces by locating cached content closer to the terminals. This enables servers to respond with a fast message feedback and it eliminates additional traffic load between the edge of the network and the original source server when there is more than one content request [1]. However, the benefits of caching at proxy servers disappear, as a terminal becomes a mobile terminal when driving or walking and mobile IPTV services become increasingly popular [2]. A proxy server initially connected to the mobile terminal may become more distant from this terminal due to the mobile terminal's movement. This causes loss of fast message feedback and additional traffic loads in the network although the physical handoff (e.g. base station handoff) supports maintaining accessibility to the network and IP handoffs allow the mobile terminal to maintain IP connectivity [3].

To solve this problem, there have been several studies about proxy server handoffs [1][3,4] that have proposed a architecture/platform [3,4] and an application layer handoff [1]; these studies showed the benefits of proxy server handoff by evaluating throughput and transmission quality. However, the proxy server handoff load has not been considered in their researches. Although the proxy server handoff reduces traffic loads in the network, it causes another load among the proxy servers. Therefore, it needs to consider trade-off relationship between the proxy server handoff load and traffic loads in the network and to optimize both loads.

In this paper, a novel navigation information-based proxy server handoff (NIPH) scheme for mobile IPTV services in vehicular environments is proposed. NIPH aims to select the appropriate proxy servers en route to eliminate unnecessary proxy server handoffs by using information of the terminal's movement obtained by the navigation. The mobile terminal follows a designated route determined by the navigation system in vehicular environments, and the network provider manages the proxy server content. Therefore, it is able to select an appropriate proxy server that caches serving content and is closest to the terminal. The simulation results show that the proposed scheme reduces the proxy server handoff load by reducing the number of proxy server handoffs that maintains a minimal delivery cost from the proxy server to the mobile terminal.

2. Network architecture for mobile IPTV service

Networks for mobile IPTV services consist of mobile terminals, a source server, and proxy servers. A mobile terminal is mounted in a vehicle in which a mobile IPTV user drives. The mobile terminal has a display function for IPTV and a global positioning system (GPS) function for navigation. The location, velocity, destination, and route information are delivered to a network provider periodically.

Figure 1 shows the overall architecture of the content delivery using a proxy server handoff for mobile IPTV services in vehicular environments. The proposed model considers a four-layer hierarchical tree network configuration. All leaves hold their own coverage with different sizes, and their coverage does not overlap. There are traffic switching nodes (e.g. routers) or access nodes at the root, branches, and leaves. The source server is located at the root and is the primary server for storing all IPTV content created by the content provider and for distributing the content to the proxy servers. Proxy servers are located at each leaf and are equipped with access nodes, and the access nodes are responsible for the leaves area. One or more proxy servers belong to

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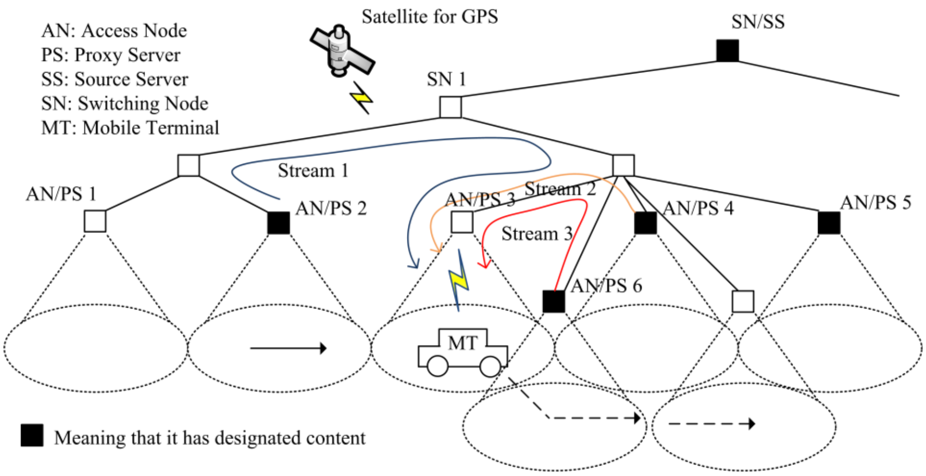

Figure 1: Proxy server handoff architecture for mobile IPTV services.

an upper node. The proxy servers may or may not store IPTV content because the content hit ratio is defined as less than one. When a mobile terminal requests content delivery, the proxy server that is closest to the terminal and that stores the designated content is selected. The proxy server sends the IPTV content to the mobile terminal and provides the caching function to the mobile terminal's operation, such as the trick mode (i.e. fast forward, pause, and rewind). In addition, the hop distance between a mobile terminal and the source server is four, and the hop distance between a mobile terminal and the closest proxy server is one.

The content delivery cost consists of the transfer cost and the proxy server handoff cost. The transfer cost C_i is defined as follows:

$$C_i = t_i R h, \quad (1)$$

where t_i denotes the terminal residence time at the ith proxy server area, R denotes the average traffic rate, and h is the hop distance (i.e. number of hops from proxy server to mobile terminal). The transfer cost reflects traffic loads in the network caused by the terminal. In addition, when C_{ph} denotes the proxy server handoff cost, which reflect the proxy server handoff load, the content delivery cost while the mobile terminal moves through ith proxy server areas is defined as follows:

$$C = C_1 + C_2 + \ldots + C_i + nbC_{ph}, \quad (2)$$

where n denotes the number of proxy server handoffs during the delivery time and b is the weight factor that is used to normalize the proxy server handoff cost over the transfer cost. If it is assumed that t_i and R are fixed values and there is no proxy server handoff, C increases as the hop distance increases. It needs to consider trade-off relationship between the transfer cost and the proxy server handoff cost to minimize content delivery cost.

3. Proposed proxy server handoff scheme

This paper proposes a new scheme to select appropriate proxy server with minimal content delivery cost. It is assumed that the mobile terminal has a destination, route, and current location information acquired from the navigation system. Because the mobile terminal follows a designated route determined by the navigation system, it is able to estimate the future terminal's location and the next candidate proxy servers en route. Accuracy of this estimation schemes is high [5]. Therefore, the basic concept of the proposed scheme is the selection of a proxy server that will have the minimum number of hops from the mobile terminal in the future among the current candidate proxy servers. Table 1 describes the proposed proxy server selection

Table 1: Proposed algorithm for NIPH

Algorithm for finding appropriate proxy server with minimum cost

Declaration

P_{cur}: Current proxy servers of which area covers the mobile terminal

P_{can}: Candidate proxy servers which stores designated content

L_{can}: List of candidate proxy servers that store designated content at the current location

$L_{next,i}$: List of candidate proxy servers at next ith designated route

$N\{L\}$: Number of list elements

```
if P_cur includes designated content then
    P_can = P_cur
else do
find L_can which stores designated
  Content with smallest hop from P_cur
If N{L_can} >1 do
    i = 1
    while designated route ends do
        find L_next,i
        If N{L_next,i} == 0 do
            Break
        Else if N{L_next,i} == 1 do
            L_can = L_next,i; Break
        Else do
            L_can = L_can ∩ L_next,i
            i++
        End if
    End while
    P_can = one of L_can's element
End if
If P_can's hop < P_cur's hop do
    Do proxy server handoff with P_can
End if
```

algorithm for NIPH. It selects the proxy server that will result in the minimum number of proxy server handoffs among the candidate proxy servers and it does not affect the content transfer cost.

Initially, a mobile terminal requests the proxy server with the smallest hop from the mobile terminal to deliver content with a minimal transfer cost. When the mobile terminal moves and enters another access node area, the proxy server that was originally allocated and serving content is no longer the closest proxy server to the mobile terminal. If the mobile terminal maintains a stream session with the initial proxy server, the path of the stream is changed as stream 1 through switching node 1. This indicates that the maintenance of an existing stream session causes an increase of transfer cost. Therefore, a new proxy server needs to be allocated that is the smallest hop to the mobile terminal and to change the stream session, which is called a proxy server handoff, to maintain the smallest transfer cost. Although the proxy server handoff causes additional costs, C_{ph}, it is assumed that the transfer cost is larger than the proxy server handoff cost.

In this case, the stream delivered from proxy server 3 is the best solution in Fig. 1. However, if proxy server 3 does not store the designated content, the second closest proxy server needs to be selected. It is possible to have several candidates for the second closest proxy server. The number of proxy servers that are second closest and the geographical distribution vary with the content hit ratio. In Fig. 1, proxy servers 4 and 6 are the second closest proxy servers and the path of the stream may be changed to stream 2 or stream 3 in the example case. The policy of proxy server selection between proxy servers 4 and 6 affects the content delivery cost by varying the proxy server handoff cost, although it does not affect the transfer cost. Therefore, a reduction method for the number of proxy server handoffs needs to be considered in order to reduce the proxy server handoff cost when selecting a proxy server. In Fig. 1, the mobile terminal's route passes through proxy server 6's area. Therefore, it does not need to perform a proxy server handoff when the mobile terminal enters proxy server area 6, if proxy server 6 is selected for the proxy server handoff rather than proxy server 4.

4. Performance evaluation

For the performance evaluation, the no proxy server handoff scheme (NOPH) and random proxy server handoff scheme (RAND) are evaluated for comparison with NIPH through simulation. In NOPH, there is no proxy server handoff during the content delivery time. The original proxy server allocated maintains the stream session to the mobile terminal until termination. In RAND, a proxy server is randomly selected from the available proxy servers with the same number of hops to maintain minimal content transfer cost. In NIPH, a proxy server is selected using the proposed algorithm 1.

The switching nodes and access nodes are configured in the four-level hierarchical tree and there are 1, 10, 100, and 1000 nodes at each level, from levels 1 to 4. Level 4 nodes (proxy server/access node) are scattered in 1000 by 1000 orthogonal coordinates with a random node area size. Higher level nodes are also scattered with a random number of child nodes. A mobile terminal moves on the orthogonal coordinates following a designated route to a randomly determined destination. It is assumed that the radius of the access node is 3 km, the mobile terminals velocity is 120 km/h, and the IPTV content delivery time is one hour. Therefore, a mobile terminal passes through an average of approximately 19 access node areas. This means that hops from the proxy server, which is connected, may change approximately 19 times.

Figure 2 shows the effect of the proxy server handoff by comparing the average hop of content transfers during the delivery time varying the content hit ratio. The average hop of NOPH is higher than that of the other cases (i.e. RAND, NIPH). The result is almost uniform at approximately 5.8, except when the content hit ratio is lower than 0.2. It appears that there is few proxy server that store the designated content and it is easy for a mobile terminal to initially receive content from the source server with four hops when the hit ratio is smaller than 0.2. In this case, the hop distance is maintained at four until the content delivery ends. In addition, there is negligible average hop difference between RAND and NIPH. That is clear because both schemes always select the next proxy server with the minimum number of hops during the delivery time. Therefore, both RAND and NIPH achieve a minimal content transfer cost.

For the number of proxy server handoffs while the mobile terminal moves, the two schemes are not the same as shown in Fig. 3. The number of proxy server handoffs in NIPH is much lower than that of RAND. It means that RAND causes more proxy server handoff cost than NIPH. The gap is maximized at a content hit

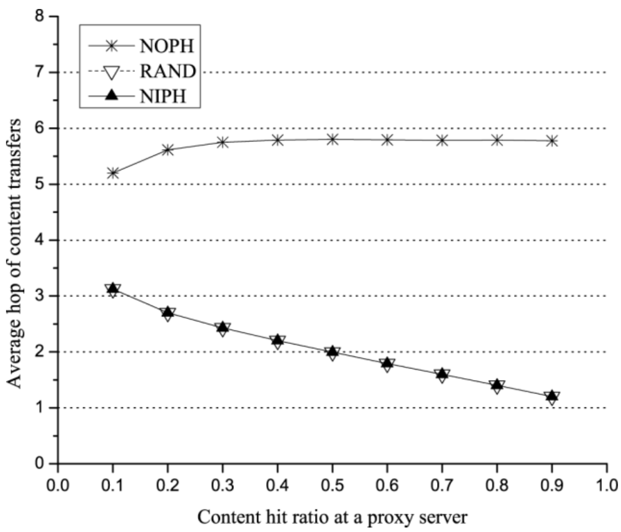

Figure 2: Number of proxy server handoffs during the delivery time

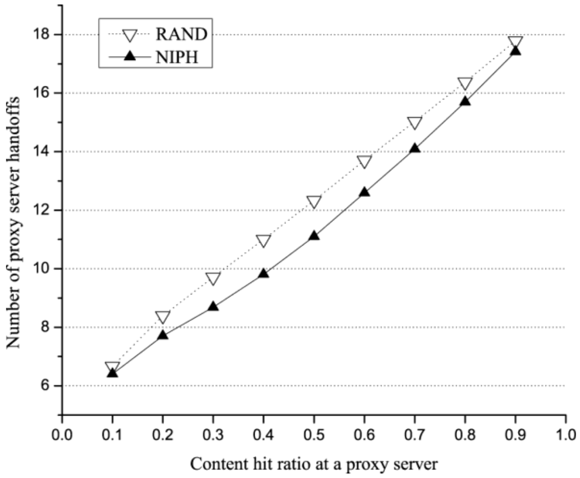

Figure 4: Average hop of content transfers during the delivery time

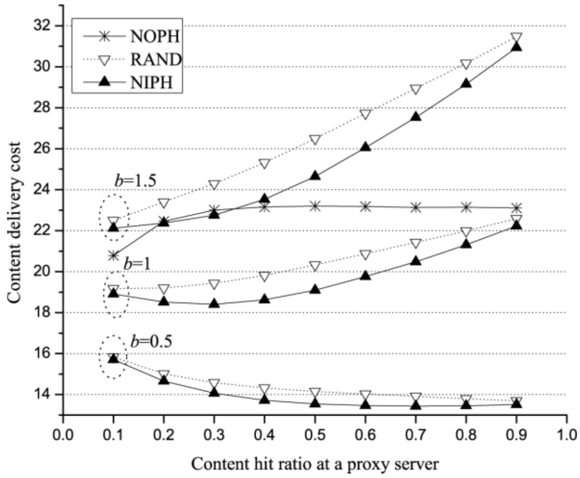

Figure 3: Content delivery cost
($R(t_1 + t_2 + ... + t_i) = 4$; $C_{ph} = 1$)

ratio 0.5 with approximately 10% benefit. The benefit decreases as the content hit ratio varies but centers around 0.5, and it shows that the effect of the next proxy server estimation reduces. The reasons for this performance includes that the low hit ratio is analyzed as having few opportunities to change proxy servers and the high hit ratio is analyzed as having more opportunities to change proxy servers. When the content hit ratio is 0.9, the mobile terminal performs a proxy server handoff almost whenever it enters a new proxy server area, and the number of proxy server handoffs is approximately 18.

Figure 4 shows the content delivery cost. Because it needs to consider a trade-off between the transfer cost and the proxy server handoff cost, the content delivery cost is evaluated with vary *b*. When *b* is smaller than about 1, the graph shows that NIPH achieves the smallest content delivery cost compared with NOPH and RAND.

5. Conclusion

In this paper, NIPH, which is a novel scheme to provide next proxy server selection algorithm, is proposed. It selects appropriate proxy servers based on the estimation of a terminal's movement and proxy servers' hop using navigation information. As a consequence, the proposed scheme provides minimal content delivery cost by reducing the number of proxy server handoffs while maintaining minimal content transfer cost. As the effect of NIPH depends on the accuracy of the route estimation, this issue requires further study.

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