

Method of Managed Content Distribution for Time-Constrained Distribution

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Abstract—As modern media for presenting information, digital signage has been widely adapted by the related industries. Beyond the way for showing commercial advertisement or public campaign, nowadays, digital signage is used for showing a building map and even the information of public transportation at transportation stops. Its wide deployment opens the chance that digital signage can be used as the method for the public announcement like disaster alert. In order to be used for the purpose, it is important to rapidly distribute content to the target terminals. More specifically, a certain required time can be set for the distribution. This paper proposes the method for distributing content to the digital signage terminals within the specified time constraint.

Keywords—digital signage; content; rapid distribution

I. INTRODUCTION

As modern media for presenting information, digital signage has been widely adapted by the related industries. In addition to commercial advertisement and public campaign, nowadays, digital signage is used for showing a building map and even the information of public transportation at bus stops and train stations. It is obvious that lots of digital signage terminal have been deployed in various area so that they are well exposed to public. Its wide deployment opens the chance that digital signage can be used as the method for the public announcement like disaster alert. In other words, a common content needs to be distributed to all terminals or a specific group of terminals as soon as possible. More specifically, a certain required time can be set for the distribution.

There are various ways for the content distribution. The most famous and simplest way depends on origin server(s). One or more origin servers pushes the content to every target terminal. In general, the content provider, which are service provider or public authority managed by government, maintains the origin servers. This client-server fashion requires lots of computation power and network capacity, and space for servers like private data center is also required. The burden on maintenance will be increased linear to the number of target terminals. Content delivery network (CDN) is alternative solution. The content provider just sends the content to one or more ingest servers. Then the ingest servers will distribute the content to the geographically distributed edge servers. CDN service provider maintains the ingest servers and the edge servers. Thus the content provider can be free from maintenance. It is enough to have capabilities for sending the

content to few ingest servers. However, using CDN service takes monetary cost. Since the cost is generally based on the amount of outbound traffic from edge servers to the target receivers, using CDN service may take lots of monetary cost. Peer-to-peer (P2P) networking is cost effective solution for content distribution. Industries and consumers already have used P2P networking-based content distribution in various services such as file distribution and multimedia streaming. In P2P networking, an origin server sends the content to a part of target receivers. The receivers, then, shares the content with rest receivers by forming a logical network called P2P network (or overlay network). To alleviate the burden on the origin server and to accelerate distribution, the content can be fragmented into multiple pieces. Then the origin server sends part of pieces to receivers instead of sending a content. In such case, distribution unit is a piece rather than a content. The weakness of P2P networking comes from the freedom of receivers. For example, receivers can make connection and send data without consideration on physical network. The content distribution over P2P communications can be enhanced, if communications among receivers can be managed. From such insight, ITU-T Q.8/11 has developed the ways to manage various aspects of P2P communications; this paper uses P2P networking and P2P communications interchangeably, and P2P network and overlay network are also used interchangeably.

This paper briefly introduces managed P2P (MP2P) communications and the content distribution over the MP2P communications. Then this paper proposes the method for content distribution within the specified time constraint. The rest of this paper is organized as follows. Section II introduces the MP2P communications. Section III describes the proposed content distribution method. This paper is concluded in section IV.

II. MANAGED P2P COMMUNICATIONS

A. Overview

ITU-T Q.8/11 has developed the technologies related to the managed peer-to-peer (MP2P) communications. The purpose of MP2P communications is to interact among users, service providers, and Internet service providers (ISPs) by managing the P2P networking, which is not managed in general. Through the interaction among them, peers can organize the well-formed P2P network. Consequently, users can experience better quality of service, and ISPs will be suffered by less

amount of traffic, especially inter-domain traffic, generated by P2P networking.

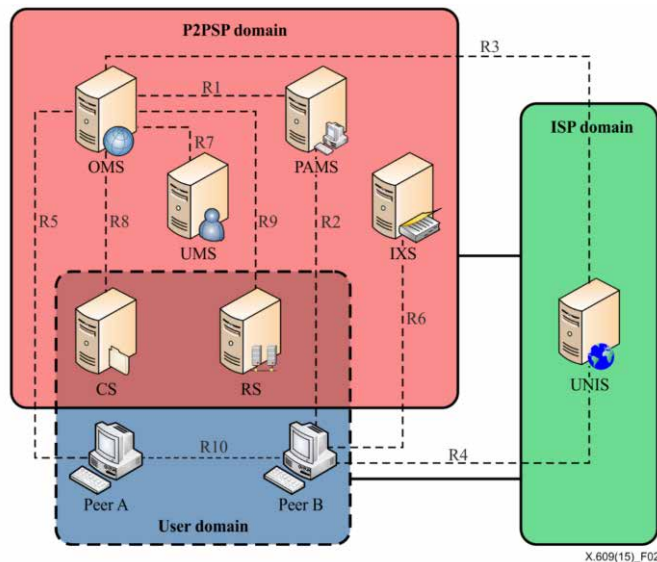


Figure 1. Architecture of MP2P communications [2]; R_n shows an interface between two entities.

Figure 1 shows the architecture of MP2P communications. The MP2P communications is composed of three domains. P2P service provider (P2PSP) domain includes servers operated by the service provider. Overlay management server, OMS, manages the information about overlay networks (a.k.a. P2P networks), such as overlay network ID or list of participants. Index server, IXS, manages the information about content to be served, such as ID of corresponding overlay network, and the address of OMS maintaining the information of the overlay network. User management server, UMS, has the service-specific information like usage pattern. Peer activity management server, PAMS, manages the information about peer's configuration. The configuration shows the capability of each peer. PAMS and OMS can utilize it when they need to determine the structure of overlay network. Cache server, CS, and relay server, RS, are considered as overlay resources to be used for specific purpose, such as increasing stability or NAT/FW traversal. ISP domain contains underlying network information server, UNIS, which manages the information about underlying physical network. OMS can interact with UNIS in order to get the network cost between certain two peers when it needs to determine the configuration of overlay networks. User domain includes peers.

B. Content Distribution over MP2P Communications

Recently ITU-T Q.8/11 started a new work item for developing the efficient content distribution, especially for the service like digital signage which has specific target receivers. In addition to the entities in Figure 1, the new work item defined a new server, namely version management server, in P2PSP domain. Version management server, VMS, manages the version of content being distributed over an overlay network and the version is increased by one whenever the content is modified. The intention is the synchronization

among peers so that the peers have exactly same content which a source wants to distribute.

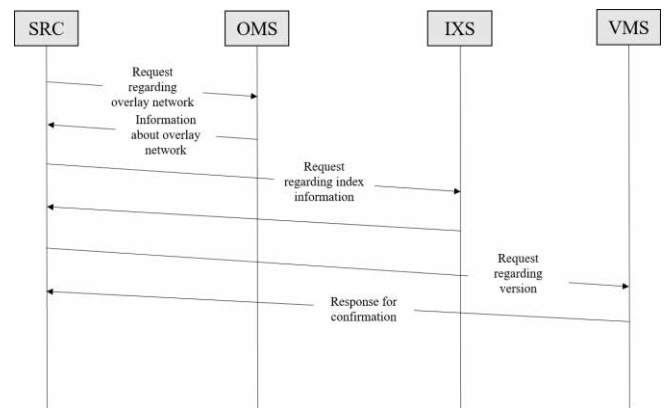


Figure 2. Source-side process of content distribution

Figure 2 depicts the process of content distribution initiated by a source, named as SRC in Figure 2. When a source wants to distribute a certain content to receivers, it can interact with OMS and IXS. Then OMS establishes a new overlay network for the content, and IXS registers a new post describing the details of content. Additionally, the source also interacts with VMS so that any changes in the content can be notified to the receivers.

The above process can be happened for even already established overlay network. In other words, a source can conduct the above interaction after distributing the initial content. The source can change the target receivers by interacting with OMS or it can interact with IXS to modify the description of the content. In any case, the source needs to contact VMS for the notification.

Different from traditional content distribution over P2P communications, which peers find the information about content from IXS and contact OMS to join the corresponding overlay network, VMS initiates the distribution in this distribution method. VMS-initiated distribution implies that peers may not join any overlay network before receiving any notification. In digital signage service, digital signage terminals receive the content only when the source injects it to the terminals. Thus the VMS-initiated distribution is useful for such services. In addition, VMS-initiated distribution can select specific target receivers so that only the targets can retrieve the latest content.

Figure 3 shows peer-side process. Upon receiving the request from VMS, peers can recognize that the version of the content distributed over the overlay network has been changed. The notification can also indicate the establishment of a new overlay network which the receivers should join. To send the notification to the appropriate target peers, every peer should register itself to VMS as bootstrap operation. By receiving the notification, peer requests OMS to send the information about the corresponding overlay network. The information includes a list of peers in the overlay network. Peers also interact with IXS in order to retrieve the description about the content. With

the information obtained from OMS, the peer can interact with other peers for content distribution.

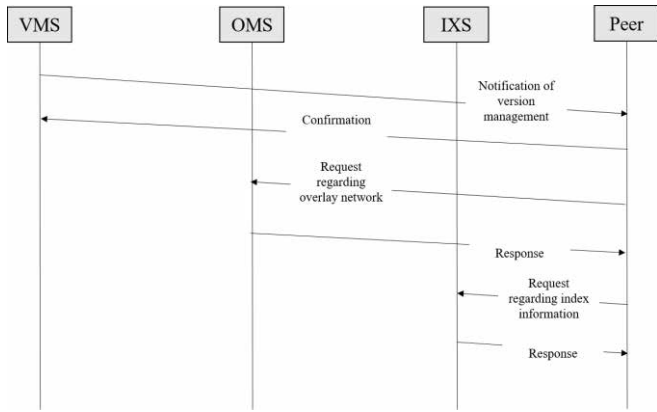


Figure 3. Peer-side process of content distribution/synchronization

III. METHOD FOR TIME-CONSTRAINED CONTENT DISTRIBUTION

The previous section describes how a source and VMS can initiate content distribution and how peers can be notified. This section describes the method for forming the overlay network which is organized to achieve content distribution among peers within the predefined time constraint.

TABLE 1. Notation and definition

Notation	Definition
T_{CONST}	The predefined time constraint. All peers should receive the content within the time.
$T_{ELAPSED}$	The expected elapsed time for content delivery from source to the current peer.
N_{TOT}	The total number of peers participating in content distribution.
N_{IHOP}	The number of peers that receives fragments from source directly over the overlay network in tree topology.
U	The available uplink capacity of a peer.
S_{FRAG}	The size of a fragment.
$N_{TOTFRAG}$	The total number of fragments.
T_{SEND}	The required time for sending a fragment from peer i to a child peer. $T_{SEND} = S_{FRAG}/U$
N_{PFRAG}	The total number of fragment that a peer needs to send. $N_{PFRAG} = N_{TOTFRAG}/N_{IHOP}$
T_{TOT}	The total required time for sending N_{PFRAG} fragments from peer i to all children. $T_{TOT} = N_{PFRAG} * T_{SEND}$
$N_{CHILDREN}$	The total number of children that peer i can have. $N_{CHILDREN} = (T_{CONST} - T_{ELAPSED})/T_{TOT}$

Table 1 lists notations and definition. When an overlay network is organized, only N_{IHOP} peers will receives fragments of the content. Each peer receives distinct fragment. Thus they need to send the received fragments to all other peers in the

overlay network so that every peer in the overlay network can merge all fragments into the original content. Note that a fragment is relayed up to 2-hop in order to minimize the transmission delay, and the structure of the organized overlay network is tree topology. It is well known that tree topology is not robust against peer churn, which means dynamic join and leave of peer. However, the content distribution described in this paper has specific target receivers which conducts join and leave controlled by source and VMS. In addition, the status of target receivers is generally monitored and managed by service provider. Thus tree topology can be used without consideration on the peer churn.

- Sort all peers in descending order

$prevN_{IHOP} = 0;$

$N_{IHOP} = 1;$

$findProperNumber = false;$

do while ($findProperNumber == true$)

if $N_{IHOP} == N_{TOT}$

break;

end if

$N_{PFRAG} = N_{TOTFRAG}/N_{IHOP};$

select top N_{IHOP} peers from the sorted list.

for every peer in the selection

Calculate $N_{CHILDREN};$

end for

if the lowest $N_{CHILDREN} \geq N_{IHOP} - 1$

$prevN_{IHOP} = N_{IHOP};$

$N_{IHOP} = N_{IHOP} + 1;$

else

if $prevN_{IHOP} == 0$

SRC covers all peers directly;

else

$N_{IHOP} = prevN_{IHOP};$

Calculate $N_{CHILDREN}$ w.r.t $N_{IHOP};$

$findProperNumber = true;$

end if

end if

end do

Organize the overlay network in tree topology with the lowest $N_{CHILDREN}$ peers;

Organize client-server connection with $(N_{TOT} - N_{CHILDREN})$ peers;

Figure 4. Algorithm for determining $N_{CHILDREN}$ and N_{IHOP}

In order to organize the appropriate overlay network in tree topology, OMS interacts with PAMS to calculate N_{IHOP} and $N_{CHILDREN}$. Note that PAMS collects the information about configuration and capability of peers, and [3] defines the signaling protocol for the interaction between OMS and PAMS. To determine the two values, OMS follows the algorithm shown in Figure 4. First, OMS sorts all peers in ascending order. The sorting criterion is the available uplink capacity of each peer. Then OMS calculates $N_{CHILDREN}$ of all peers. Based on the result of comparison between $N_{CHILDREN}$ and $(N_{IHOP}-1)$, OMS can decide whether it can increase N_{IHOP} . The comparison indicates that the peer received fragments from the

source directly should be capable to share the received fragments to all other peers which also received fragments from the source directly. By assuring to do so, the peers can get all fragments so that they can merge the fragments into the content. After determining two values, OMS organizes an overlay network in tree topology. The overlay network includes top N_{IHOP} peers in the sorted list. If the lowest $N_{CHILDREN}$ of the top N_{IHOP} peers is larger than N_{IHOP} , the overlay network additionally can include $(N_{CHILDREN}-N_{IHOP})$ peers. Consequently, the organized overlay network can accommodate at most $N_{CHILDREN}$ peers. Note that the additional peers will not receive fragments from source but they can get all fragments from the N_{IHOP} peers. The rest $(N_{TOT}-N_{CHILDREN})$ peers will get whole fragments from source directly. In other words, peers outside of the overlay network in tree topology will get the content from the source directly. It is client-server fashion but the burden on the source can be alleviated.

IV. CONCLUSION

This paper introduces managed P2P communications and the content distribution over the managed P2P communications. Different from conventional content distribution, the content distribution shown in this paper has specific target receivers. Thus a source and a specific management entity initiate the distribution. This paper introduces the standardization activities about managed P2P communications and content distribution over the managed P2P communications. To distribute content within the predefined time constraint, this paper proposes the method for forming an overlay network. Based on capability of target receivers, overlay management server determines the structure of the overlay network. It is expected that the proposed method will be applied in the appropriate service like digital signage.

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