

Homogenous Web Communication Platform in Non-homogenous Network Environment for Emerging Countries

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In recent years, there has been a more distinct gap in network bandwidths between developed countries and developing countries. In a "non-homogeneous network environment", which is a mixture of narrowband and broadband networks, the amount of time to obtain a Web file differs from one place to another. As a result, people in developing countries have difficulties downloading certain Web files, which prevents them from communicating fully with people in other faraway places. In this paper, we propose a platform for Web communication (e.g. social networking) in a non-homogeneous network environment in order to reduce the time to obtain Web files and reduce the usage of Internet connection bandwidths for users in developing countries. This paper describes the system structure of the proposed platform and presents the simulation results to verify its effectiveness.

Key words : Web communication, network platform, P2P, emerging countries

1. Introduction

Thanks to the improvement in network quality in developed countries (e.g. Japan and US), people now have full-time broadband access to the Internet. As Internet connection speed became higher, the purpose of the Internet has changed from browsing documents to communicating and sharing interests with people all over the world by building online communities. On the other hand, there are many developing countries that cannot afford full-time broadband access to the Internet. In this paper, we refer to a network environment composed of narrowband networks and broadband networks as a "non-homogeneous network environment".

In such a non-homogeneous network environment, there might be some setbacks for people in developing countries to use social network services (SNS) because of their low-speed Internet connections and frequent Internet connection failures.

In this paper, we propose a Web communication platform for a non-homogeneous network environment to provide users in developing countries

with an equivalent Web communication environment to that of developed countries.

The rest of the paper is organized as follow. In section 2, we define and explain the term "Web communication" and point out the problems with Web communication in a non-homogeneous network environment with some related work introduced in section 3. The overview of the proposed Web communication platform is described in section 4 and the details of its structure are given in section 5. We describe the simulation model of the proposed platform and the results in section 6, and examine the effectiveness of the proposed platform in section 7. Finally in Section 5, we summarize our work.

2. Non-homogeneous network environment

2.1 Web communication

Web communication is an activity of people in different places interacting with each other using SNSes. The participants in the Web communication could be any developed countries including Japan, US, and some of the developing countries in sub-Saharan Africa. In developing countries, each par-

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Table 1. Internet cost in each country.

	Japan	US	Uganda
Bandwidth	5 Mbps	4 Mbps	512 kbps
Payment /month	31.19 US\$	20.00 US\$	850 US\$
Payment /100kbps	0.07 US\$	0.49 US\$	166 US\$

icipating region has a “base” (e.g. schools, offices) where there is an Internet connection and a local area network (LAN) built. Computers at a base are connected to the LAN and users participate in Web communication from one of the computers connected to the LAN to access SNS sites.

2.2 Network architecture

There are three factors to determine the network quality in non-homogeneous network environments: Internet connection bandwidths, latency, and connection failure frequency. Table 1 shows the values of network bandwidths considered broadband in each country (i.e. Japan, US, and Uganda) and the fee for the broadband Internet connection¹⁾²⁾³⁾.

Low-speed satellite-based Internet connections are still widely used in developing countries while fiber-optic networks are widely built in developed countries to minimize the network latency. Because many developing countries have poor quality network infrastructure for Internet connection, they have frequent connection failures compared to developed countries.

2.3 Problems with Web communication in non-homogeneous network environment

The amount of time to obtain a Web file and the amount of time users can access the Internet differ from one place to another in a non-homogeneous network environment. This gap in network quality between different places may prevent the full utilization of Web communication.

3. Related work

3.1 Web cache server

A Web cache server is a proxy server which is generally deployed inside a LAN for the purpose

of reducing the time to obtain Web files by caching Web documents from Web servers. One of the most well-known examples using this method is called “Squid”⁴⁾. Developing countries have a limited number of available computers compared to developed countries. Therefore, it is impractical to install a Web cache server at each base in developing countries where computers are not affordable for many people. In addition to this problem, client computers can neither update a Webpage nor acquire files of a Webpage updated by a user in a different base when their Internet connections have been cut off.

3.2 P2P Web cache system

A P2P Web cache system is a decentralized load-sharing, fault-tolerant system where every node has a cache function. One of the well-known examples using this method is called “Squirrel”⁵⁾. In developing countries where they have narrowband connections to the Internet, there are delays in downloading Web files. A P2P Web cache system can speed up the access to Websites if one of the nodes in the same LAN has already cached the files of the Webpage. However, if a node at a different base has the cached Web files, the Web files are downloaded via the Internet, which poses a problem for developing countries that has low-speed Internet connections. As in Web cache servers, client computers can neither update a Webpage nor acquire files of a Webpage updated by a user in a different base when their Internet connections have been cut off.

4. Proposed platform

4.1 Hierarchical network structure

In order to solve the above problems, we propose a Web communication platform for a non-homogeneous network environment. The proposed platform is aimed at reducing the time to obtain Web files and the usage of Internet connection bandwidths. The proposed platform contains two main features.

As shown in figure 1, nodes at each base are connected to a lower-layer P2P network that runs its own DHT (Distributed Hash Table) file system to speed up the time to obtain Web files. Because the DHT file system stored all the data of Web files

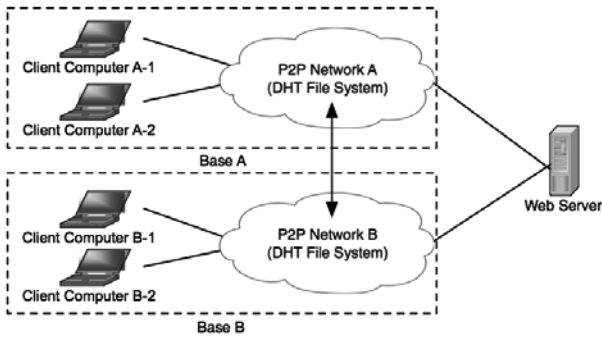


Fig. 1. Hierarchical network structure.

among the nodes in its base, there is no need to obtain a file from outside its LAN. This means that Web files are available at any time even when an Internet connection is cut off. All the requests for data acquisition, registration, and update are addressed to the DHT file system at the base nodes belong to.

Since every base has its own DHT file system built, they need to synchronize the data with other DHT file systems in case a Web file has been updated in one of the DHT file systems. In the proposed platform, DHT file systems are connected to each other on a higher-layer P2P network so that they can exchange data synchronous messages.

4.2 File data segmentation for distributed caching

In the proposed platform, Web files are divided into several pieces of sub-data in order to reduce Internet traffic. If Web files are stored in a DHT file system without being segmented, the whole Web file must be attached to a data synchronous message no matter how small a part of a Web file is updated. The proposed platform can reduce the size of a data synchronous message because Web files are divided into several pieces of sub-data. All the sub-data of Web files are stored in every DHT file system, and a node can obtain the sub-data piece by piece. When some part of a Web file is updated, not the whole Web file, but only the piece of sub-data that should be updated is attached to a data synchronous message.

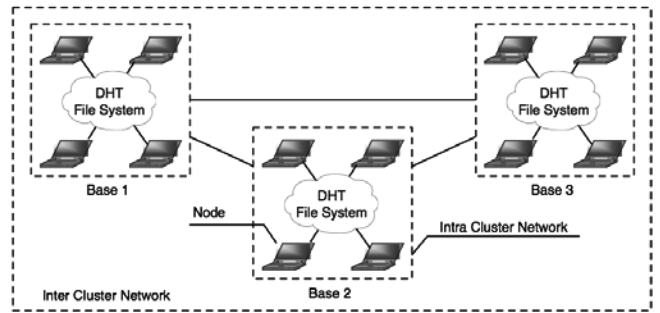


Fig. 2. Structure of the proposed platform.

5. System structure

5.1 Network structure

The overall structure of the proposed platform is shown in figure 2. The platform consists of nodes, intra-cluster networks, an inter-cluster network, cluster head nodes, and local proxy software.

A client computer at a base is referred to as a “node”. Local proxy software is running at each node. In the proposed platform, Web browsers use the local proxy software as a proxy server to cache Web data.

5.2 Intra-cluster network (lower-layer network)

At each base, nodes in the same LAN are connected to each other on a P2P network called “intra-cluster” network where an independent DHT file system is running. All the sub-data of Web files are distributed among nodes in the same intra-cluster network. All the requests for data acquisition and update are exchanged within a LAN at each base.

5.3 Inter-cluster network (higher-layer network)

File data stored in each intra-cluster network must be synchronized with the identical file data in other intra-cluster networks in case Web files are updated. For this purpose, intra-cluster networks are connected to a higher-layer P2P network referred to as an “inter-cluster network” so that messages for data synchronization can be exchanged between intra-cluster networks.

5.4 Cluster head node

A cluster head node is a node that acts as a leader of an intra-cluster network. Cluster head nodes are chosen according to their fault tolerance

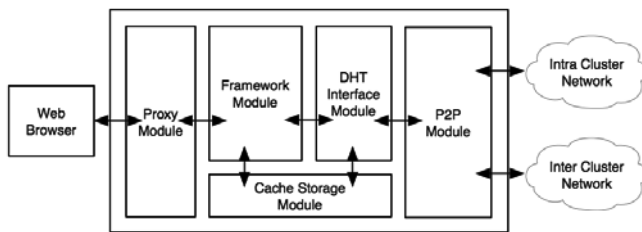


Fig. 3. Module architecture of the local proxy.

and their performance⁶⁾. Once a node is chosen as a cluster head node, it acts as a go-between for relaying data synchronous messages. In order for cluster head nodes to be able to receive messages from other intra-cluster networks through the Internet, port forwarding must be configured on routers in LANs.

5.5 Local proxy software

The proposed platform functions by running local proxy software on a client computer. Figure 3 illustrates the module architecture of the local proxy software. The role of each module is listed as follow.

- Proxy module: It provides a function of an HTTP proxy server to a Web browser.
- Framework module: It divides a Web file into pieces of sub-data and also integrates pieces of sub-data into a Web file.
- DHT interface module: It provides DHT PUT, GET methods to the framework module.
- Cache storage module: It caches and manages sub-data of Web files.
- P2P module: It connects the computer to the intra-cluster network and the inter-cluster network and establishes P2P connections to other nodes.

The Web browser sends all the HTTP requests to the proxy module. When the proxy module receives an HTTP request, it forwards it to the framework module. The framework module then analyzes the HTTP request. If the request is for Web file acquisition, the framework module searches the sub-data of the Web file. When all the sub-data are received, the framework module integrates them into a Web file. On the other hand, if the HTTP request

Table 2. Different types of Internet connection.

Network media	Latency	Bandwidth
Fiber Line	1 ms	10 Gbps
DSL	50 ms	1 Mbps
Dialup	220 ms	56 Kbps
Ethernet	10ms	10 Gbps

is for Web file update, the framework module extracts the updated piece of sub-data from the Web file and stores it on the intra-cluster network. The data structure of sub-data differs according to the type of Web content. For that reason, the local proxy software needs all the framework modules that support the data structures of each Web content type.

The P2P module consists of an intra-cluster network module and an inter-cluster network module. The intra-cluster network module uses a certain DHT algorithm. The structure of the intra-cluster, the routing method, and the routing table management method vary according to the DHT algorithm it applies. The inter-cluster network module holds all the global IP addresses of other bases connected to the inter-cluster network. If sub-data stored in the cache storage module have been updated, the inter-cluster network module sends data synchronous messages to all the global address it holds over the inter-cluster network.

6. Evaluation

6.1 Web content model

We ran some simulation tests to evaluate the proposed platform. The simulation model we designed is based on the assumption that users communicate with each other on a social networking Website. Each user has his own personal page where he can publish posts of his diary. The personal page shows a list of posts of the user's diary. When a post title on the list is clicked, a new page opens and shows the title of the post, the content of the post, and the comments on the post. The comments can be made by anyone including the author himself and other users.

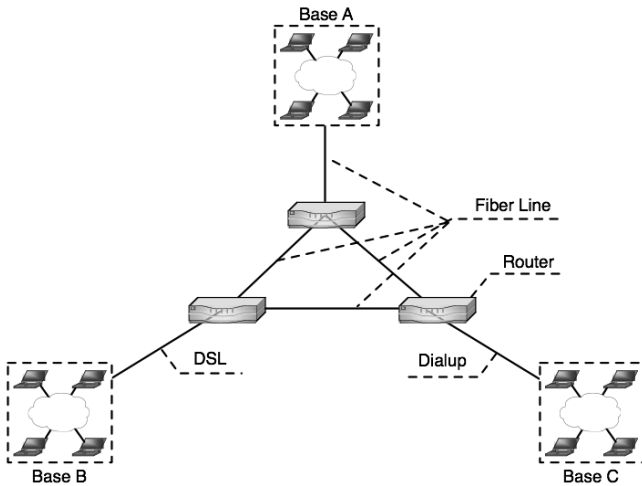


Fig. 4. Network model.

6.2 Network model

Figure 4 and table 2 describe the network model we designed for the simulation tests. The network model shows that users at three bases participate in the Web communication and all the three bases have different types of Internet connection. In this network model, we assume that base A supposedly in a developing country has a fiber-optic connection, base B supposedly in an emerging country has a dial-up connection, and base C supposedly in developing country has a DSL connection. The LAN at each base uses Ethernet technologies, the details of which are shown in table 3.

6.3 User behavior model

The followings are the behavior models of users participating in Web communication from computers at their bases.

- Page browsing: to access their own or others' post pages.
- Post publishing: to publish a post.
- Post editing: to edit the title or the content of their post.
- Comment posting: to post a new comment on the post they are browsing.
- Comment editing: to edit their comment they made on the post they are browsing.

Table 3. Implementation for simulation.

OS	Ubuntu 8.10
Network simulator	OMNeT++ (3.4b2)
P2P simulator	OverSim (20080919)

6.4 Simulation environment

We used a message-driven network simulator called “OMNet++”⁷⁾ to evaluate the proposed platform. OMNet++ treats every element of a network structure as a module. The simulator runs by writing and executing programs that defines the procedures for control message exchanges between modules. We also used a P2P simulator called “OverSim”⁸⁾ that runs overlay network simulations by using the functions provided by OMNet++. OverSim provides several libraries of P2P protocols including Chord⁹⁾, Pastry¹⁰⁾, and Kademlia¹¹⁾ to facilitate the implementation of a DHT file system. OverSim helps simulate P2P network conditions on an IP network.

To verify the effectiveness of the proposed platform, we have run simulations under four conditions: (1) a condition where a hierarchal network structure and file data segmentation for distributed caching are adopted, (2) a condition where a hierarchal network structure is adopted but file data segmentation for distributed caching is not adopted, (3) a condition where a hierarchal network structure is not adopted but file data segmentation for distributed caching is adopted, and (4) a condition where neither a hierarchal network structure nor file data segmentation for distributed caching are adopted.

6.5 Simulation results

Table 4 shows the parameters used in the simulations.

We define the access time to a post page as the time from when a node sends a request for a post page until it receives the responses. The result of the average access time is shown in figure 5. Average access time *avg* is calculated as follow.

$$avg = \frac{\text{Total access time of all nodes at base}}{(\text{Nodes at base}) \times (\text{Nodes accessed posts})}$$

We measured Internet traffic at the bases under

Table 4. Simulation parameters.

Item	Parameter
Simulation time	7200 sec
Number of nodes at each base	16
DHT algorithm	Kademlia
Access interval to a post page	120 sec
Post publishing interval	600 sec
Each user's post editing interval	600 sec
Probability of posting comment	50%
Probability of editing comment	50%
Size of diary page tile	50 bytes
Size of diary page content	250 bytes
Size of comment	100 bytes

each of the four conditions. The results of the total traffic are shown in figure 6. Here, the total traffic refers to the sum of the size of messages transferred between the LAN and the Internet, including data synchronous messages under the conditions where a hierarchical network structure is adopted and control messages for intra-cluster network maintenance under the conditions where a hierarchical network structure is not adopted.

7. Examination of effectiveness

According to the simulation results, the proposed platform, which adopts a hierarchical network structure, reduces the average access time to a post page by 88% from comparative platform 2 and by 60% from comparative platform 3, both of which do not adopt a hierarchical network structure. The reason for this improvement is because all the sub-data of Web files are accessible within an intra-cluster network (i.e. a LAN) in a hierarchical network structure. Base-wise, the proposed platform reduces the average access time by 75% at base A and 91% at base C from comparative platform 2. From this result, we confirmed that the poorer quality Internet connection a base has, the more amount of access time could be reduced for nodes at the base by adopting a hierarchical network structure. However, the access time in the proposed platform, which adopts file data segmentation, is 3.5 times longer than the

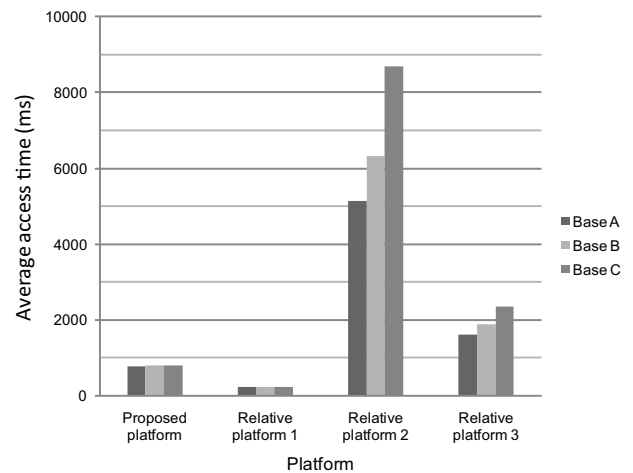


Fig. 5. Average access time to a post page.

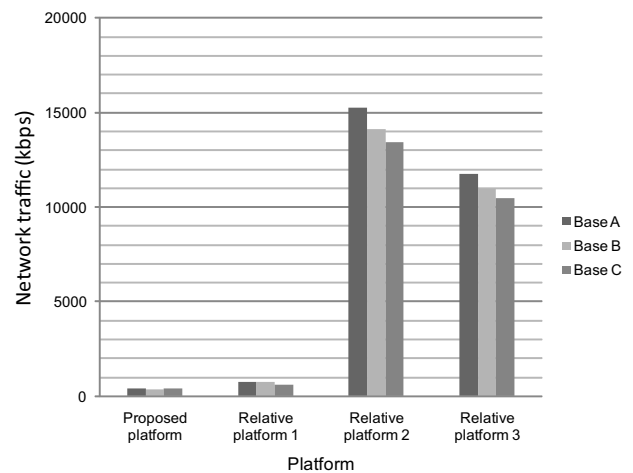


Fig. 6. Network traffic for Internet connection.

access time in comparative platform 2. This is because the proposed platform needs extra time to collect all the segmented pieces of sub-data distributed in an intra-cluster network to obtain a Web file.

On the other hand, the propose platform reduces total Internet traffic by 97% from comparative platform 2 and by 96% from comparative platform 3. This is because there is no need to send DHT PUT/GET messages and control messages for DHT file system maintenance to other bases through the Internet in a hierarchical network structure. From this result, we confirmed that Internet traffic could be reduced by building a hierarchical network structure. Also, Internet traffic in the proposed platform is reduced by 45% from comparative platform

1. This is because when a post is updated, only the segmented pieces of sub-data that have been changed are attached to a data synchronous message in the proposed platform. If Web files are not segmented, the whole Web file needs to be attached to a data synchronous message even when only a small part of the Web file has been updated, which could be a burden for low-speed Internet connections. Therefore, file data segmentation has an effect of reducing Internet traffic.

The proposed platform adopts a hierarchical network structure that builds an intra-cluster network at each base and an inter-cluster network that connects the bases over the Internet. In the proposed platform, all the segmented pieces of sub-data of Web files are stored among nodes in each intra-cluster network. For this reason, all the Web files can be obtained within a base through the intra-cluster network. When a node updates a Web file, it sends an update request to a node that has the piece of sub-data that need to be changed in the same intra-cluster network. After the sub-data have been updated in the intra-cluster network, the cluster head node sends a message to synchronize the updated sub-data. Therefore, nodes can access Web pages without sending requests to a Web server by using this proposed platform.

8. Conclusion

In this paper, we described the problems with Web communication in a non-homogeneous network environment. To solve the problems, we proposed a Web communication platform that (1) reduces the time to obtain Web files for users in developing countries, (2) reduces the Internet traffic, and (3) increases the accessibility to Web content in case of Internet connection failures. We implemented the proposed platform and evaluated its effectiveness by running simulations. We verified that the goals of the proposed platform could be successfully achieved by applying a hierarchical network structure and file data-segmentation for distributed caching.

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