DECADE
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Integration Examples of DECADE System
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Abstract

DECADE is an in-network storage infrastructure which is under discussions and constructions. It can be integrated into Peer-to-Peer (P2P) applications to achieve more efficient content distributions. This document represents two detailed examples of how to integrate DECADE into P2P applications (live streaming and file sharing). Specifically, it describes mainly about: 1) a preliminary DECADE client API; 2) a P2P live streaming integration with DECADE; 3) a P2P file sharing integration with DECADE; 4) tests on our DECADE integrarions and 5) an application performance analysis from the tests.

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1. Introduction

DECADE is an in-network storage infrastructure under discussions and constructions. It can be integrated into Peer-to-Peer (P2P) applications to achieve more efficient content distributions.

This draft introduces two instances of application integration with DECADE. In our example system, the core component includes DECADE server and DECADE-aware P2P clients (live streaming client and file-sharing client). A DECADE server runs at Linux platform and is designed to support interactive control and data transport for DECADE clients. For live streaming case, we deployed a P2P live streaming system called P2PLS (P2P Live Streaming). We also utilized a preliminary API (Application Programming Interface) set, which is supposed to be provided by DECADE, to enable P2PLS clients to leverage DECADE in their data transmission. For file-sharing case, we choose an open source P2P client software named Vuze which supports user defining plugin to extend software functions. In this draft, we introduce the structures of the both DECADE integration applications, the DECADE related control flow, the environment of tests on both integrations, and the system performance in the tests.

Please note that P2PLS and Vuze in this draft only represent the usage case of "live streaming" and "file-sharing" out of a large number of P2P applications, while DECADE itself can support other applications. The API set of DECADE is an experimental design and implementation. It is not a standard and is still under development. Currently, DECADE in this draft is only a preliminary framwork of in-network for P2P. It is designed to demonstrate the pros and cons of in-network storage utilized by P2P applications rather than to reach a final solution.

2. Concepts

2.1. P2P

Peer-to-Peer computing or networking is a distributed application architecture that partitions tasks or work loads between peers. Peers are equally privileged, equipotent participants in the application.

2.2. DECADE Server

A DECADE server is implemented with DECADE protocols, management mechanism and storage strategies. It is an important element to provide DECADE services. In a DECADE server, we have a number of Data Lockers each of which is a virtual account and private storage

space for applications.

2.3. DECADE Module

DECADE module is a functional component for application clients to utilize DECADE. This component serves as an application-specific interface between a particular application and DECADE servers. It can be a simple implementation of basic DECADE access APIs, or a smart realization which integrates application-specific control strategies with DECADE APIs.

2.4. P2P LiveStreaming Client (P2PLS Client)

P2P LiveStreaming Client (P2PLS Client) is our self-maintained version of a native P2P live streaming application. It is one example out of a large number of P2P applications.

2.5. DECADE Client

DECADE client is an integration of a native P2P client and a DECADE module. It is not required to embed DECADE module into native P2P clients, since it can also be an independent conponent running at a remote server.

2.6. Vuze

Vuze is an open source P2P application, which uses BitTorrent protocol for message and data exchanging. Vuze provides a set of interfaces which support users to develop particular extensions.

2.7. DECADE Plugin

A plugin built into Vuze to implement DECADE functions including getting/putting data from/to DECADE server and redirection

2.8. DECADE-Enabled Vuze

A Vuze client that is enabled by DECADE plugin.

2.9. Remote Controller

A controller which can control every Vuze client to start or stop downloading tasks. It also has a function of collecting statistic information of each Vuze client. It is a major operating platform.

3. DECADE Client API

In order to simplify the DECADE integration with P2P clients, we provide an API set which covers the communications with DECADE servers and token-generation. On top of this API, a P2P client can develop its own application-specific control and data distribution policies.

There are five basic interfaces:

- Get_Object: to get an object from a DECADE server with an authorized token. The get operation can be classified into two categories: Local Get and Remote Get. Local Get is to get an object from a local DECADE server. Remote Get is to use a client's local DECADE server to indirectly get an object from a remote DECADE server. The object will be firstly passed to the local DECADE server, then returned to the application client

- Put_Object: to store an object into a DECADE server with an authorized token. A client can either store an object into its local DECADE server or into other clients' DECADE servers, if it has an authorized token. Both of the operations are direct, for we don't provide indirectly storing (i.e. remote put).

- Delete_Object: to delete an object in a DECADE server explicitly with an authorized token. Note that an object can also be deleted implicitly by setting an expired time or a specific TTL.

- Status_Query: to query current status of an application itself, including listing stored objects, resource usage, etc.. Such information is private.

- Generate_Token: to generate an authorized token. The token can be used to access an application client's local DECADE server, or passed to other clients to allow them to access the client's local DECADE server.

4. DECADE Integration of P2P LiveStreaming Client

We integrate a DECADE module into a P2P live streaming application--P2PLS, in order that clients of this application can easily leverage DECADE in their data distributions.

4.1. DECADE Integration Architecture

The architecture of the P2PLS application and DECADE integration is shown in Figure 1:

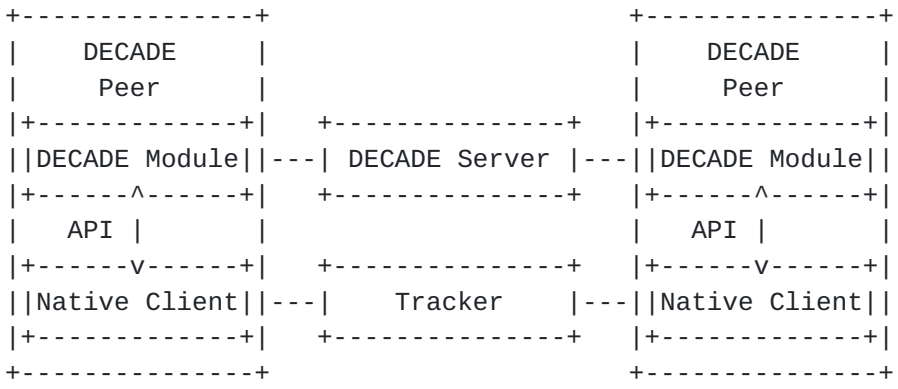


Figure 1

A DECADE-integrated P2PLS client uses DECADE module to communicate with its DECADE server and transmit data between itself and its DECADE server. It is compatible with its original P2P protocol, while it also uses a DECADE protocol to exchange DECADE related messages with other peers.

4.1.1. Data Access

DECADE module is called whenever a client wants to get data objects from (or put data objects into) its DECADE server. Each data object transferred between a client and its DECADE server should go through DECADE module. Neither the DECADE server and the original client knows each other. A data object is a data transfer unit between DECADE servers and application clients. Its size can be application-customized, according to variable requirements of performance or sensitive factors (e.g. low latency, high bandwidth utilization).

4.1.2. Message Control

Control and data plane decoupling is a design principle of DECADE. Control messages are propagated in an original P2P way. DECADE only introduces an additional control message between DECADE module which carries DECADE authorized token. By exchanging DECADE authorized tokens, P2P live streaming clients can retrieve or store data objects into or from others' DECADE servers.

4.2. Challenges in DECADE Integration

One essential objective of DECADE integration is to improve (or at least not to hurt) the application performance. However, as a brand new architecture, DECADE has some inherit challenges which will potentially be harmful to application performance. In our P2P live streaming case, we met mainly two such limitations of DECADE:

4.2.1. Limited Connection Slot

Limited Connection Slot: In native P2P systems, a peer can establish tens or hunderds of concurrent connections with other peers. However, this situation can hardly be ture when it is integrated with DECADE because it is too expensive for DECADE servers to maintain so many connections for each peer. Typically, each DECADE peer only have m connection slots, which means it can only at most have m active connections with its DECADE server simultaneously. A potential "side effect" of limited connection slot is that the content availability and downloading rate might be impacted negatively by fewwer connections carrying data traffic. This requests us to adjust the peer's behavior in resource allocation, downloading/uploading scheduling, etc. to fully utilize the connection slots to archieve a satisfying and robust data downloading.

- Batch Request: In order to fully utilize the connection bandwidth of a DECADE server and reduce overhead, a P2PLS client may combine multiple requests in a single request to DECADE server. Note that for the sake of improving data transfer efficiency in P2P live streaming, we may combine multiple data requests into a batch request. Generally, a batch may consist of different kinds of access requests.

- Data Object Size: In typical P2P live streaming application, the size of a data block is relatively small, considering to reduce end-to-end transport latency. However, existing data size may incur large control overhead and low transport utilization. A larger data object size may be needed to utilize DECADE more efficiently.

4.2.2. Additional Control Latency

Addtional Control Latency: In native P2P systems, when an uploader decides to reply a request for a piece, it sends the piece out directly. Nevertheless, in DECADE-aware P2P systems, the uploader typically only replies with a token of the piece. And then the downloader will leverage this token to fetch the piece from the uploader's DECADE server. This process obviously introduces

additional control latency compared with native P2P systems. It is even more serious in latency sensitive applications such as P2P live streaming. We need to consider how to reduce such additional delay or how to compensate the lose with other inherit advantages of DECADE.

- Range Token: One way to reduce request latency is to use range token. A P2PLS client may piggyback a range token when it propagates its bitmap to its neighbors, to indicate that all available pieces in the bitmap are accassable by this range token. Then instead of requesting specific pieces from this client and waiting for response, the neighbors can directly use this range token to access data in DECADE servers. Note that this method not only reduce request latency, but also reduce message overhead.

With these adjustments and strategies, DECADE clients' performance was not impacted by the liminations of DECADE and was even better than native clients' as we will see in following sections.

5. DECADE Integration of P2P Filesharing Client

We integrate DECADE with a popular P2P file-sharing application--Vuze.

5.1. Vuze Client Design

Note that Vuze client is classified into two different kinds - Native Vuze and DECADE-Enabled Vuze. When running Native Vuze, it behaves as ordinary BitTorrent client: some Vuze clients upload data for others to download. When using DECADE-Enabled Vuze, the communication and data exchange processes are changed. The uploader uploads data to its DECADE server, and downloaders download data from DECADE servers. By this means, uplink traffic can be reduced sharply and download performance can be improved. It is beneficial for ISPs to save the last-mile uplink bandwidth.

5.2. DECADE-Enabled Vuze architecture Design

DECADE plugin is a key component of our demo system. It has several interfaces with other components as following:

Interface between DECADE plugin and DECADE server: DECADE plugin can upload and download data from DECADE server. It also includes other functions such as user registration, application registration etc.

Interface between DECADE plugin and Vuze client: DECADE plugin can register a listener to intercept the BitTorrent message such as

"BT_Request" message from or to Vuze client, encapsulate the data from DECADE server into "BT_Piece" message and put the "BT_Piece" message into incoming message queue, read the block/piece data from the disk when seeding (to upload the data to DECADE server), and start or stop the download tasks, all these functions are supported in the Plugin API provided by Vuze.

Interface between DECADE plugins: When DECADE plugin intercepts the "BT_Request" message from other Vuze clients, local DECADE plugin sends "Redirect" message to remote DECADE plugin to authorize it to download the piece data from the DECADE server.

Interface between DECADE plugin and Remote Controller: DECADE plugin registers with Remote Controller after starting up, Remote Controller can control all the Vuze clients to start, stop or resume the download tasks through DECADE plugins.

The system architecture is as follow:

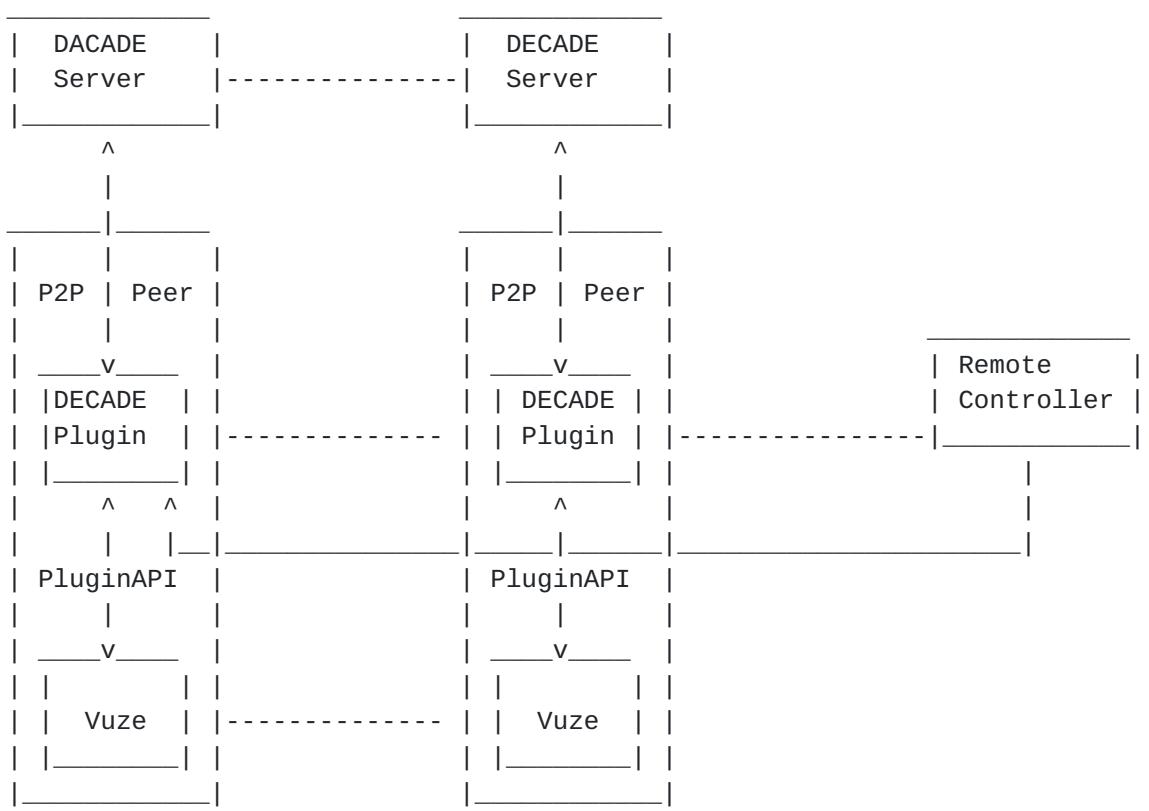


Figure 2

5.3. DECADE-Enabled Vuze Communication Procedure

A DECADE plugin can change the data path of BitTorrent download by using a "Redirect" message.

The detailed communication procedure is as following:

- When each client starts the download task ,it will try to connect the tracker to get peer list and then send "BT_Request" message to other peers in peer list.

- If the DECADE plugin is enabled, then it will intercept the incoming "BT_Request" message from other Vuze clients, and then reply with a "Redirect" message which includes DECADE server's address, authorization token and so on to the requester.

- When a DECADE plugin receives a "Redirect" message, it will connect to the DECADE server according to message context and send "Remote Get" message to the DECADE server to request the data, then wait for response.

- When a DECADE server receives a "Remote Get" message, it will check the server IP address in the message, Case 1: if the address equals to its own IP address, then it will send the data to the requester from its local disk/memory; Case 2: if the address is not equal to its own IP address, then it will send the "Remote Get" message to that address, to fetch the data, and then send the data to the requester. The data will be cached in the server locally for use by other requesters.

- When a DECADE plugin obtains the data, it will encapsulate the data into a standard "BT_Piece" message and send to Vuze client, then the client can write the data block into storage.

The detailed communication diagram is as follow:

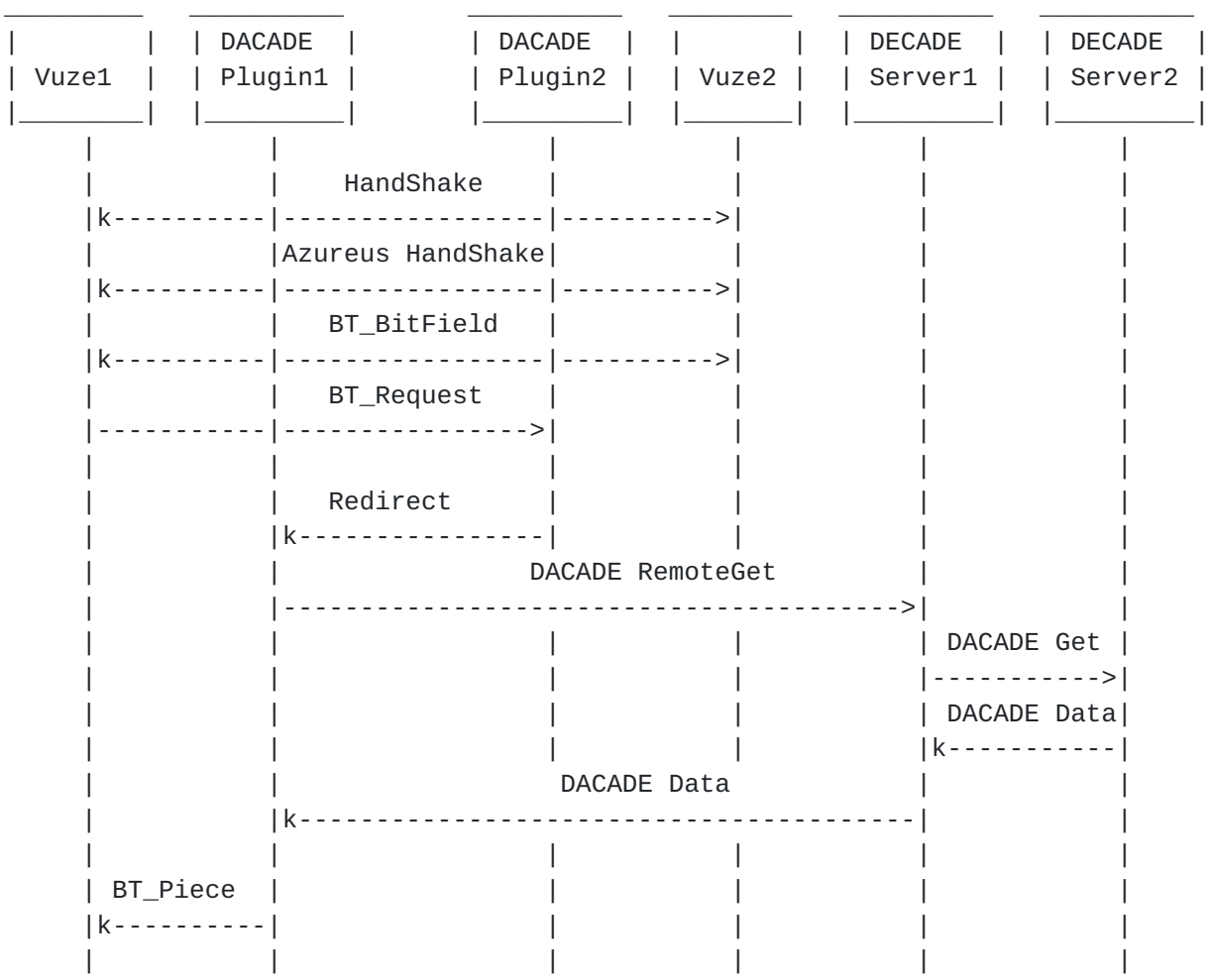


Figure 3

6. Test Environment and Settings

In order to demonstrate the performance of our DECADE implementation and DECADE-integrated P2P live streaming and file-sharing applications, we conduct some experimental tests in Amazon EC2 and PlanetLab. We perform a pair of comparative experiments: DECADE integrated P2P application v.s. native P2P application, in the same environment using the same settings.

6.1. Test Settings

Our tests ran on a wide-spread area and diverse platforms, including a famous commercial cloud platform, Amazon EC2 and a well-known testbed, PlanetLab. The environment settings are as following:

- EC2 Regions: we setup DECADE servers in Amazon EC2 cloud, including all four regions around the world, US east, US west, Europe and Asia.

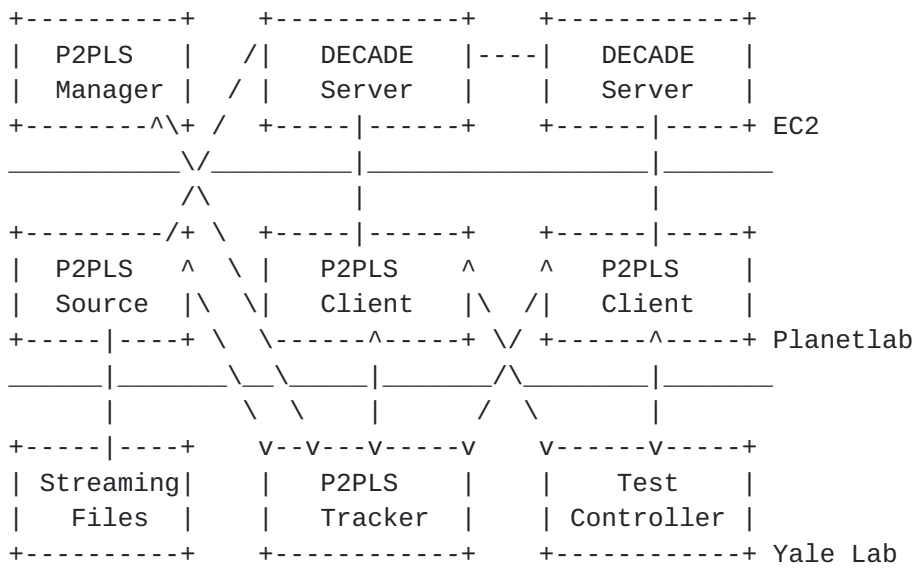
- PlanetLab: we run our P2P live streaming clients and P2P file-sharing clients (both DECADE integrated and native clients) on PlanetLab of a wild-spread area.

- Arrival pattern: we made all the clients join into the system within a short duration to simulate a flash crowd scenario.

- Total Bandwidth: for a fair comparison, we set the system's total supply bandwidth to be exact the same in both test.

6.2. Platforms and Components of P2PLS

In the tests, we have different functional components running in different platforms, including DECADE servers, P2P live streaming clients(DECADE integrated or Native), Tracker, Source server and Test Controller, as shown in Figure 4.



P2PLS represents to P2P LiveStreaming.

Figure 4

6.2.1. EC2 DECADE Server

DECADE Servers ran on Amazon EC2 small instances, with bandwidth constraint.

6.2.2. PlanetLab P2P LiveStreaming Client

Both DECADE integrated and Native P2P live streaming clients ran on planetlab which spreads in various locations around the world. The DECADE integrated P2P live streaming clients connect to the closest DECADE server according to its Geo-location distance to the servers. DECADE integrated P2P live streaming clients use their DECADE servers to upload to neighbors, instead of their own "last-mile" bandwidth.

6.2.3. Tracker

A native P2P live streaming tracker ran at Yale's laboratory and served both DECADE integrated clients and native clients during the test.

6.2.4. Source Server

A native P2P live streaming source server ran at Yale's laboratory and serve both DECADE integrated clients and native clients during the test. The capacity of source is equivalently constrain for both cases.

6.2.5. Test Controller

Test Controller is a manager to control all machines' behaviors in both EC2 and PlanetLab during the test.

6.3. Platforms and Components of Vuze

Test platforms includes Vuze client, tracker, DECADE Plugin, DECADE Servers and other supportive components such as HTTP Server, FTP Server and Remote Controller.

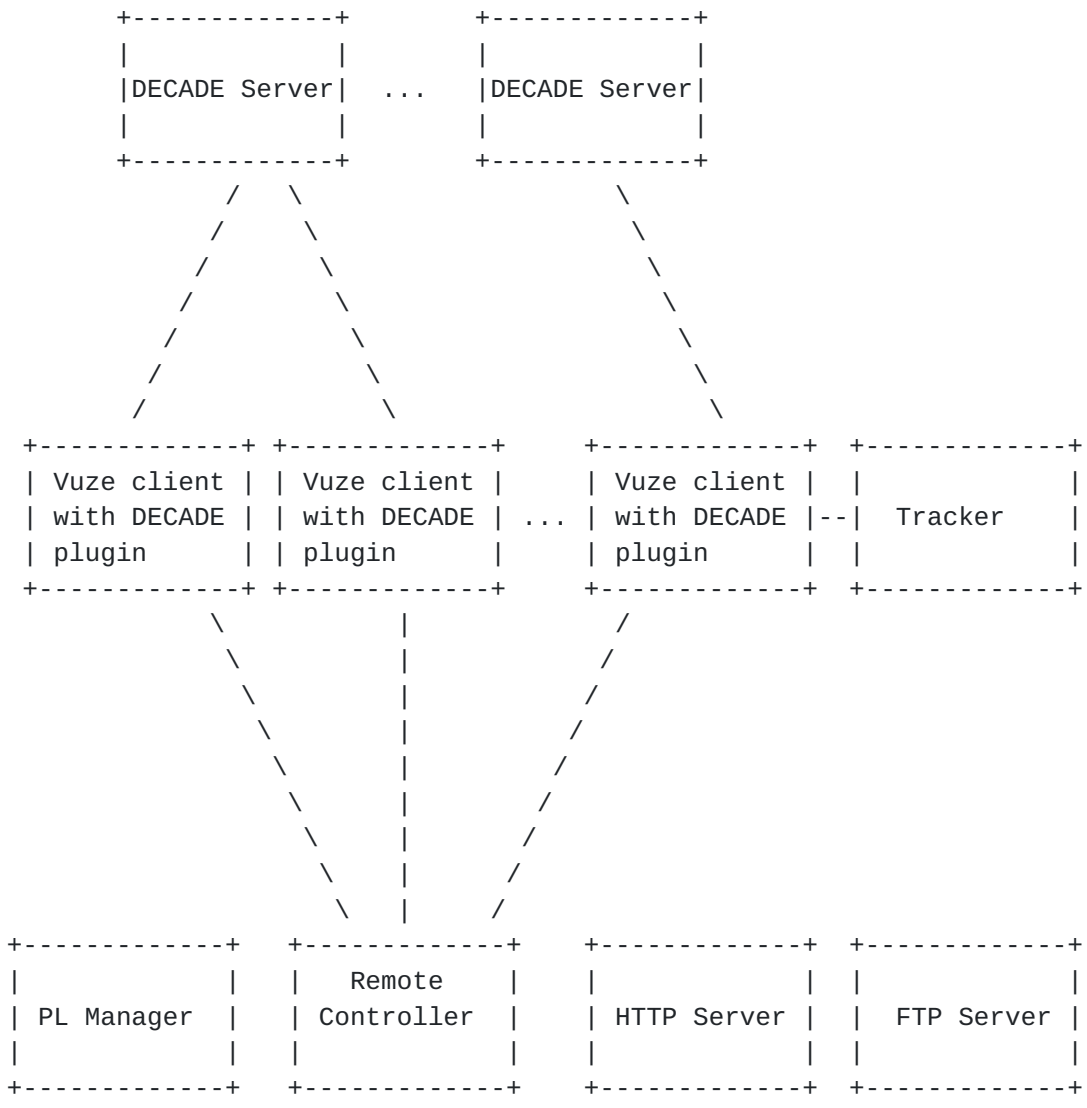


Figure 5

6.3.1. EC2 DECADE Server

DECADE Servers ran on Amazon EC2 small instances, with bandwidth constraint.

6.3.2. Vuze Client with DECADE Plugin

Vuze clients are divided into one seeding client and multiple leechers. Leechers run at PlanetLab, while the seeding client runs at the Window 2003 server. DECADE Plugin will be automatically loaded and run after Vuze client starts up.

6.3.3. Remote Controller

Remote controller can list all the Vuze clients in user interface and control them to download a specific BitTorrent file. It runs at the same Window 2003 server with the seeding client.

6.3.4. Tracker

Vuze client provides tracker capability, so we did not deploy our own tracker. Vuze embedded tracker is enabled when making a torrent file, the seeding client is also a tracker in this test.

6.3.5. HTTP Server

Torrent file will be put in the HTTP Server and the leechers will retrieve the torrent file from HTTP Server after receiving the download command from Remote Controller. We use Apache Tomcat which is an open source software as HTTP Server.

6.3.6. PL Manager

PL Manager (PlanetLab experiment Manager)is a tool developed by University of Washington, which presents a simple GUI to control PlanetLab nodes and perform common tasks such as:

- Selecting nodes for your slice.
- Choosing nodes for your experiment based on CoMon information about the nodes.
- Reliably deploying you experiment files.
- Executing commands / sets of commands on every node in parallel.
- Monitoring the progress of the experiment as a whole, as well as viewing console output from the nodes.

7. Performance Analysis

During the test, Both DECADE integrated P2P live streaming clients and DECADE integrated P2P file-sharing clients achieved impressively better performance than native clients.

7.1. Performance Metrics

7.1.1. P2P Live Streaming

To measure the performance of a P2P live streaming client, we employ mainly four metrics:

- Startup Delay: the duration from a peer joins the channel to the moment it starts to play.
- Piece Missed Rate: the number of pieces a peer loses when playing over the total number of pieces.
- Freeze Times: the number of times a peer re-buffers during playing.
- Average Peer Uploading Rate: Average uploading bandwidth of a peer.

7.1.2. Vuze

For the performance comparison of Native Vuze and DECADE-Enabled Vuze, the same system bandwidth is provided through some parameter settings. In Native Vuze, the system bandwidth is defined as the amount of the uplink bandwidth from all the Vuze clients. The maximum upload bandwidth (Bu) is configured to every Vuze client before the test. Suppose the number of the Vuze clients is N, the system bandwidth is Bu * N. In the DECADE-Enabled Vuze case, the same bandwidth (Bu * N) is configured to the corresponding Ethernet port of DECADE Server.

7.2. Result and Analysis

7.2.1. P2P Live Streaming

- Startup Delay: In the test, DECADE integrated P2P live streaming clients startup around 35~40 seconds. some of them startup at about 10 seconds. Native P2P live streaming clients startup around 110~120 seconds. less than 20% of them startup within 100 seconds.

- Piece Missed Rate: In the test, both DECADE integrated P2P live streaming clients and native P2P live streaming clients achieved a good performance in pieces missed rate. Only about 0.02% of total pieces missed in both cases.

- Freeze Times: In the test, native P2P live streaming clients suffered from more freezing than DECADE Integrated P2P live streaming clients by 40%.

- Average Peer Uploading Rate: In the test, according to our settings, DECADE integrated P2P live streaming clients had no upload in their "last-mile" access network. While in the native P2P live streaming system, more than 70% of peers uploaded in a rate that is much more than streaming rate. In another word, DECADE can shift uploading traffic from clients' "last-mile" to in-network devices, which saves a lot of expensive bandwidth on access links..

7.2.2. Vuze

Performance advantage is shown according to the test result of experiment:

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  There is no upload data traffic from Vuze clients in the DECADE-Enabled Vuze experiment, but in the Native Vuze experiment, the upload data traffic from Vuze clients is the same as download data traffic. Bandwidth resource is reduced in the last mile in the DECADE-Enabled Vuze experiment. The test result is illustrated in the following table. The download traffic and upload traffic include data traffic and signal traffic. For the upload traffic in the DECADE-enable Vuze, the data traffic is zero so the all traffic is signal overhead. Though we used the same torrent file in those two cases, the number of Vuze client was not the same because the nodes in the Planet-lab are not always stable. Therefore, the download traffic is a little different in two cases.

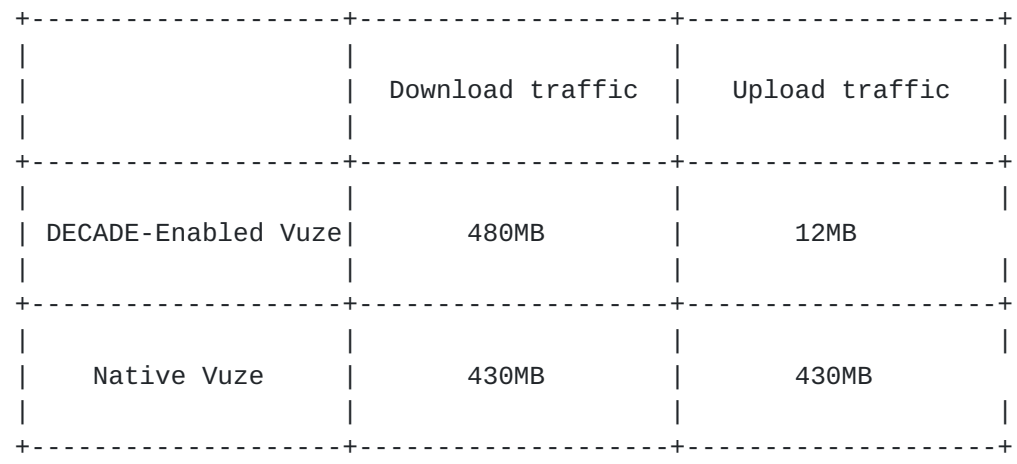

Figure 6

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Higher system resource efficiency in the DECADE-Enabled Vuze experiment, system resource efficiency is defined as the ratio of system download rate to the total system bandwidth. The test result is illustrated in the following figure.

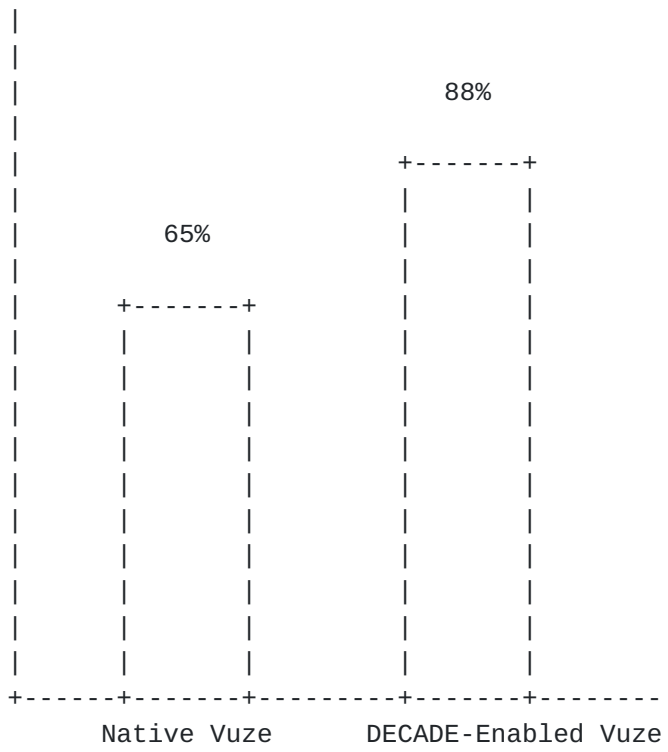

Figure 7

8. Security Considerations

This document does not contain any security considerations.

9. IANA Considerations

This document does not have any IANA considerations.

10. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

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