

# A Reliable BitTorrent-like File Transfer Application

## Computer Networks

**Due: Dec. 20<sup>th</sup> 23:59**; Hand-in location: Elearning.

We will not be making any exceptions for late submissions.

## 1 Overview

In this assignment, you will implement a BitTorrent-like file transfer application. The application will run on top of UDP, and you will need to implement a reliability protocol (similar to TCP) for the application. The application will be able to simultaneously download different parts, called “chunks,” of a file from different servers. Please remember to read the complete assignment handout more than once so that you know exactly what is being provided and what functionality you are expected to add. Project documents, FAQ, and starter files are stored in FTP server. **Please read each README file carefully** to help you finish this project. We recommend you to do this project on a **32-bit system** or you may encounter several unexpected problems.

([http://releases.ubuntu.com/16.04/ubuntu-16.04.3desktop-i386.iso.torrent?\\_ga=2.80869335.1977138499.15098724881495741164.1509872488](http://releases.ubuntu.com/16.04/ubuntu-16.04.3desktop-i386.iso.torrent?_ga=2.80869335.1977138499.15098724881495741164.1509872488))

If you still insist to use the 64-bit system anyway, you may have 32-bit support installed:

```
sudo dpkg --add-architecture i386 libncurses5:i386
sudo apt-get update ibstdc++6:i386
sudo apt-get install libc6:i386
```

## 2 Project Outline

During the course of this project, you will do the following:

Implement a BitTorrent-like protocol to search for peers and download/upload file parts.

## 3 Project specification

### 3.1 Background

This project is loosely based on the BitTorrent Peer-to-Peer (P2P) file transfer protocol. In a traditional file transfer application, the client knows which server has the file, and sends a request to that specific server for the given file. In many P2P file transfer applications, the actual location of the file is unknown, and the file may be present at multiple locations. The client first sends a query to discover which of its many peers have the file it wants, and then retrieves the file from one or more of these peers.

While P2P services had already become commonplace, BitTorrent introduced some new concepts that made it really popular. Firstly, BitTorrent splits the file into different “chunks”. Each chunk can be downloaded independently of the others, and then the entire collection of chunks is reassembled into the file. In this assignment, you will be using a fixed-size chunk of 512 Kbytes.

BitTorrent uses a central “tracker” that tracks which peers have which chunks of a file. A client begins a download by first obtaining a “.torrent” file, which lists the information about each chunk of the file. A chunk is identified by the cryptographic hash of its contents; after a client has downloaded a chunk, it must compute the cryptographic hash to determine whether it obtained the right chunk or not. See Figure 1.

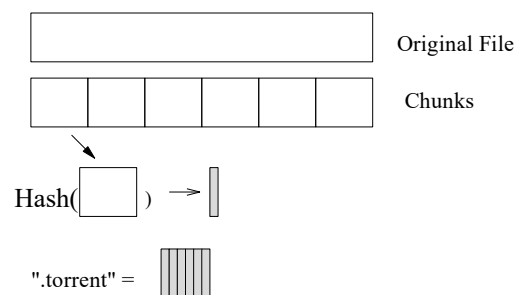


Figure 1: Diagram of bit torrent chunking and torrents: BitTorrent takes a large file and breaks it down into separate chunks which can be downloaded from different “peers”. Chunks are identified by a “hash-value”, which is the result of computing a well-known hash function over the data in the chunk. When a client wants to download a file, it first grabs a “torrent” file, which contains all of the hash values for the desired data file. The torrent lets the client know what chunks to request from other peers in the network.

To download a particular chunk, the receiving peer obtains from the tracker a list of peers that contain the chunk, and then directly contacts one of those peers to begin the download. BitTorrent uses a “rarest-chunk-first” heuristic where it tries to fetch the rarest chunk first. The peer can download/upload four different chunks in parallel.

You can read more about the BitTorrent protocol details from [http://webcache.googleusercontent.com/search?q=cache:Dm\\_oT-YzmiYJ:www.bittorrent.org/beps/bep\\_0003.html](http://webcache.googleusercontent.com/search?q=cache:Dm_oT-YzmiYJ:www.bittorrent.org/beps/bep_0003.html) (the original seems to have disappeared, so here is Google’s cache of it).

This project departs from real BitTorrent in several ways:

- Instead of implementing a tracker server, your peers will flood the network to find which peers have which chunks of a file. Each peer will know the identities of every other peer in the network; you do not have to implement routing.

- To simplify set-up and testing, all file data is actually accessed from a single “master data file”. Peers are configured with a file to tell them what chunks from this file they “own” upon startup.
- You do not have to implement BitTorrent’s incentive based mechanism to encourage good uploaders and discourage bad ones.

But the project adds one complexity: BitTorrent obtains chunks using TCP. Your application will obtain them using **UDP**, and you will have to implement reliability. It is a good idea to review TCP, from both lecture and the textbook.

## 3.2 Programming Guidelines

Your peer must be written in the C programming language, no C++ or STL is allowed. You must use UDP for all the communication for control and data transfer. Your code must compile and run correctly on unix based machines.

For network programming, you are not allowed to use any custom socket classes. We will provide a hashing library, but not any code performing higher-level functionality.

## 3.3 Provided Files

Your starter code includes:

- `hupsim.pl` - This file emulates a network topology using `topo.map` (Section 6)
- `sha.[ch]` - The SHA-1 hash generator
- `input_buffer.[ch]` - Handle user input
- `debug.[ch]` - helpful utilities for debugging output
- `bt_parse.[ch]` - utilities for parsing command line arguments.
- `peer.c` - A skeleton peer file. Handles some of the setup and processing for you.
- `nodes.map` - provides the list of peers in the network
- `topo.map` - the hidden network topology used by `hupsim.pl`. This should be interpreted only by the `hupsim.pl`, your code should **not** read this file.

- `make-chunks` - program to create new chunk files given an input file that contains chunk-id, hash pairs, useful for creating more larger file download scenarios.

### 3.4 Terminology

- `master-data-file` - The input file that contains ALL the data in the network. All nodes will have access to this file, but a peer should only read the chunks that it “owns”. A peer owns a chunk if the chunk id and hash was listed in that peer’s `has-chunk-file`.
- `master-chunk-file` - A file that lists the chunk IDs and corresponding hashes for the chunks in the master data file.
- `peer-list-file` - A file containing list of all the peers in the network. For a sample of the `peer-list-file`, please look at `nodes.map`.
- `has-chunk-file` - A per-node file containing list of chunks that a particular node has at startup. However, peers will have access to more chunks as they download the chunks from other peers in the network.
- `get-chunk-file` - A file containing the list of chunk ids and hashes a peer wants to download. This filename is provided by the user when requesting a new download.
- `max-downloads` - The maximum number of simultaneous connections allowed in each direction (download / upload)
- `peer-identity` - The identity of the current peer. This should be used by the peer to get its hostname and port from *peer-list-file*
- `debug-level` - The level of debug statements that should be printed out by `DPRINTF()`. For more information, please look at `debug.[h,c]`.

### 3.5 How the file transfer works

The code you write should produce an executable file named “peer”. The command line options for the program are :

```
peer -p <peer-list-file> -c <has-chunk-file> -m <max-downloads>
```

```
    -i <peer-identity> -f <master-chunk-file> -d <debug-level>
```

The peer program listens on standard input for commands from the user. The only command is “GET <get-chunk-file> <output filename>”. This instruction from the user should cause your program to open the specified chunks file and attempt to download all of the chunks listed in it (you can assume the file names contain no spaces). When your program finishes downloading the specified file, it should print “GOT <get-chunk-file>” on a line by itself. You do not have to handle multiple concurrent file requests from the user. Our test code will not send another GET command until the first has completed; you’re welcome to do whatever you want internally. The format of different files are given in Section 3.7.

To find hosts to download from, the requesting peer sends a “WHOHAS <list>” request to all other peers, where <list> is the list of chunk hashes it wants to download. The list specifies the SHA-1 hashes of the chunks it wants to retrieve. The entire list may be too large to fit into a single UDP packet. You should assume the maximum packet size for UDP as 1500 bytes. The peer must split the list into multiple WHOHAS queries if the list is too large for a single packet. Chunk hashes have a fixed length of 20 bytes. If the file is too large, your client may send out the GET requests iteratively, waiting for responses to a GET request’s chunks to be downloaded before continuing. For better performance, your client should send these requests in parallel.

Upon receipt of a WHOHAS query, a peer sends back the list of chunks it contains using the “IHAVE <list>” reply. The list again contains the list of hashes for chunks it has. Since the request was made to fit into one packet, the response is guaranteed to fit into a single packet.

The requesting peer looks at all IHAVE replies and decides which remote peer to fetch each of the chunks from. It then downloads each chunk individually using “GET <chunk-hash>” requests. Because you are using UDP, you can think of a “GET” request as combining the function of an application-layer “GET” request *and* a the connection-setup function of a TCP SYN packet.

When a peer receives a GET request for a chunk it owns, it will send back multiple “DATA” packets to the requesting peer (see format below) until the chunk specified in the GET request has been completely transferred. The peer may not be able to satisfy the GET request if it is already serving maximum number of other peers. The peer can ignore the request or queue them up or notify the requester about its inability to serve the particular request. Sending this notification is optional, and uses the DENIED code. Each peer can only have 1 simultaneous download from any other peer in the network, meaning that the IP address and port in the UDP packet will uniquely determine which download a DATA packet belongs to. Each peer can however have parallel downloads (one each) from other peers.

When a peer receives a DATA packet it sends back an ACK packet to the sender to notify that it successfully received the packet. Receivers should acknowledge all DATA packets.

## 3.6 Packet Formats

### ● Package Header

All the communication between the peers use UDP as the underlying protocol. All packets begin with a common header:

1. Magic Number [2 bytes]
2. Version Number [1 byte]
3. Packet Type [1 byte]
4. Header Length [2 bytes]
5. Total Packet Length [2 bytes]
6. Sequence Number [4 bytes]
7. Acknowledgment Number [4 bytes]

All multi-byte integer fields must be transmitted in network byte order (the magic number, the lengths, and the sequence/acknowledgment numbers). Also, all integers must be unsigned.

The magic number should be 15441, and the version number should be 1. Peers should drop packets that do not have these values. The “Packet Type” field determines what kind of payload the peer should expect. The codes for different packet types are given in Table 1. By changing the header length, the peers can provide custom optimizations for all the packets (if you choose). Sequence number and Acknowledgment number are used for reliable transmission mechanisms similar to TCP.

### ● WHOHAS and IHAVE packets

The payload for both WHOHAS and IHAVE contain the number of chunk hashes (1 byte), 3 bytes of empty padding space to keep the chunk 32-bit aligned, and the list of hashes (20 bytes each) in them. The format of the packet is shown in Figure 2(b).

### ● GET packets

The payload of GET packet is even more simple: it contains only the chunk hash for the chunk the client wants to fetch (20 bytes).

Packet Type	Code
WHOHAS	0
IHAVE	1
GET	2
DATA	3
ACK	4
DENIED	5

Table 1: Codes for different packet types.

## ● DATA and ACK packets

Figure 2(c) shows an example DATA packet. DATA and ACK packets do not have any payload format defined; normally they should just contain file data.

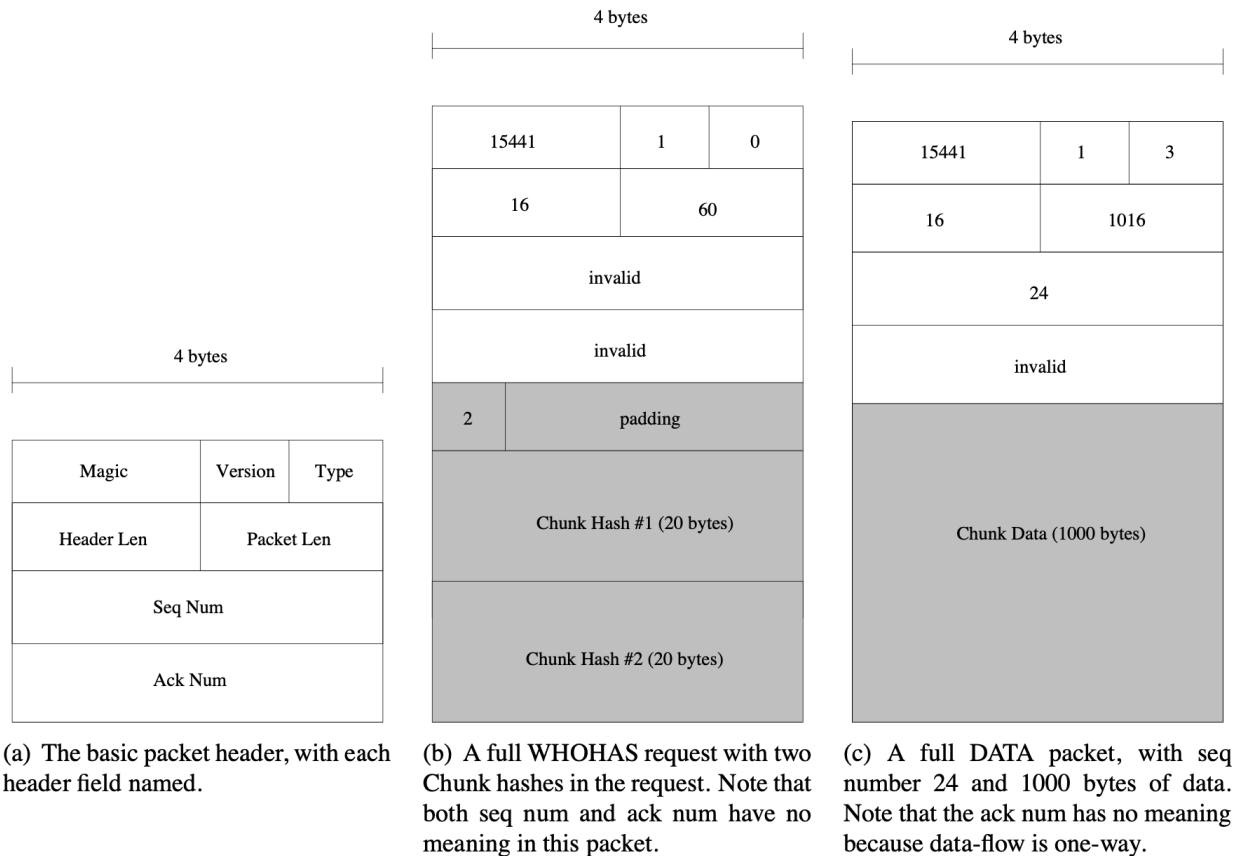


Figure 2: Packet headers.

The sequence number and acknowledgment number fields in the header have meaning only in DATA and ACK packets. In this project the sequence numbers always start from 1 for a new “GET connection”. A receiving peer should send an ACK packet with acknowledgment number 1 to acknowledge that it has received the data packet with sequence number 1 and so on.

Even though there are both a sequence number and an acknowledgment number fields in the header, *you should not combine DATA and ACK packets*. Do not use a DATA packet to acknowledge a previous packet and do not send data in a ACK packet. This means that for any DATA packet the ACK num will be invalid and for any ACK packet the SEQ num field will be invalid. Invalid fields still take up space in the packet header, but their value should be ignored by the peer receiving the packet.

## 3.7 File Formats

### Chunks File:

File: <path to the file which needs sharing>

Chunks:

id chunk-hash

.....  
.  
.....  
.

The *master-chunks-file* has above format. The first line specifies the file that needs to be shared among the peers. The peer should only read the chunks it is provided with in the peer's *has-chunks-file* parameter. All the chunks have a fixed size of 512KB. If the file size is not a multiple of 512KB then it will be padded appropriately.

All lines after "Chunks:" contain chunk ids and the corresponding hash value of the chunk. The hash is the SHA-1 hash of the chunk, represented as a hexadecimal number (it will not have a starting "0x"). The chunk id is a decimal integer, specifying the offset of the chunk in the master data file. If the chunk id is  $i$ , then the chunk's content starts at an offset of  $i \times 512k$  bytes into the master data file.

## Has Chunk File

This file contains a list of the ids and hashes of the chunks a particular peer has. As in the master chunk file, the ids are in decimal format and hashes are in hexadecimal format. For the same chunk, the id of the chunk in the has-chunk-file will be the same as the id of that chunk in the master-chunks-file.

id chunk-hash id

chunk-hash .....

## Get Chunk File

The format of the file is exactly same as the has-chunk-file. It contains a list of the ids and hashes the peer wishes to download. As in the master chunk file, the ids in decimal format and hashes are in hexadecimal format. For the same chunk of data, the id in the get-chunk-file might NOT be the same as the id of that chunk in the master-chunks-file. Rather, the id here refers to the position of the chunk in the file that the user wants to save to.

id chunk-hash id

chunk-hash

.....



## Peer List File

This file contains the list of all peers in the network. The format of each line is:

```
<id> <peer-address> <peer-port>
```

The *id* is a decimal number, *peer-address* the IP address in dotted decimal format, and the *port* is port integer in decimal. It will be easiest to just run all hosts on different localhost ports.

## 4 Example

Assume you have two images A.gif and B.gif you want to share. These two files are available in the ‘example’ subdirectory of the code. We **strongly** suggest that you walk through these steps as you read them in order to get a better understanding of what each file contains (the hash values in this document are not the actual hash values, to improve readability).

First, create two files whose sizes are multiple of 512K, using:

```
tar cf - A.gif | dd of=/tmp/A.tar bs=512K conv=sync count=2
```

```
tar cf - B.gif | dd of=/tmp/B.tar bs=512K conv=sync count=2
```

With padding, A.tar and B.tar are exactly 1MB big (ie: 2 chunks long). Let's run two nodes, one on port 1111 and one on port 2222. Suppose that the SHA-1 hash of the first 512KB of A.tar is 0xDE and the second 512KB is 0xAD. Similarly, for B.tar the 0-512KB chunk hash is 0x15 and the 512KB-1MB chunk hash is 0x441. First, do the following:

```
cat /tmp/A.tar /tmp/B.tar > /tmp/C.tar make-
```

```
chunks /tmp/C.tar > /tmp/C.chunks make-chunks
```

```
/tmp/A.tar > /tmp/A.chunks make-chunks
```

```
/tmp/B.tar > /tmp/B.chunks
```

This will create the *master data file* of /tmp/C.tar. The contents of C.chunks will be:

0 000de

```
1 000000000000000000000000000000000000000000000000000ad
```

```
2 0000000000000000000000000000000000000000000015
```

[illegible]

Recall that *ids* are in decimal format, while the *hash* is in hexadecimal. The contents of `A.chunks` will be:

```
0 0000000000000000000000000000000000000000000de
```

```
1 000000000000000000000000000000000000ad
```

The contents of B.chunks will be:

```
0 0000000000000000000000000000000000000000000000000000000015
```

```
1 00000000000000000000000000000000000000000000441
```

Next, edit the C.chunks file to add two lines and save this as C.masterchunks:

File: /tmp/C.tar Chunks:

```
0 0000000000000000000000000000000000000000000de
```

```
1 000000000000000000000000000000000000000000000000000ad
```

2 00015

[illegible]

Next create a peer file called `/tmp/nodes.map` It should contain

1 127.0.0.1 1111

2 127.0.0.1 2222

Finally, you need to create files that describe the initial content of each node. Let node 1 have all of file A.tar and none of file B.tar. Let node 2 have all of file B.tar and none of A.tar.

Create a file /tmp/A.haschunks whose contents are:

0 000de

```
1 000000000000000000000000000000000000000000000000000ad
```

Create a file `/tmp/B.haschunks` whose contents are:

```
2 0000000000000000000000000000000000000000000015
```

3 000441

**Note** that the ids in the above two files are obtained from C.masterchunks, which in turn refers to the offset in the master data file.

Now, to run node 1, type:

```
peer -p /tmp/nodes.map -c /tmp/A.haschunks -f /tmp/
C.masterchunks -m 4 -i 1
```

and to run node 2, type in a different terminal:

```
peer -p /tmp/nodes.map -c /tmp/B.haschunks -f /tmp/
C.masterchunks -m 4 -i 2
```

After the peer for node 1 starts, you can type

```
GET /tmp/B.chunks /tmp/newB.tar
```

This command tells your peer to fetch all chunks listed in /tmp/B.chunks and save the downloaded data chunks to the file /tmp/newB.tar ordered by the id values in /tmp/B.chunks. Here is an example of what your code should do (note that messages are displayed here in plain text, but the actual packet content will be binary). Node 1 should send a

WHOHAS 2 00...15 00...441

(for the 2 chunks that are named 00...15 and 00...441) to all the peers in nodes.map. It will get one IHAVE reply from node 2 that has

IHAVE 2 00...15 00...00441

. Node 1 should then send a message to Node 2 saying

GET 00...15

. Node 2 starts sending Data packets and Node 1 sends ACK packets as it gets them. After the GET completes (i.e. 512KB has been transferred), Node 1 should then send a message to Node 2 saying

GET 00...441

and should perform this transfer as well.

At the end, you should have new file called /tmp/newB.tar. To make sure you got it right, you can compare this file with /tmp/B.tar to make sure they are identical (use the unix “diff” utility ).

In summary, there are basically three chunk description formats (get-chunks, has-chunks and master-chunks) and a peer list format.

## 5 Project Tasks

This section details the requirements of the assignment. This high-level outline roughly mirrors the order in which you should implement functionality.

### 5.1 Task - 100% Reliability & Sliding Window

The first task is to implement a 100% reliable protocol for file transfer (i.e., DATA packets) between two peers with a simple flow-control protocol. Non-Data traffic (WHOHAS, IHAVE, GET packets) does not have to be transmitted reliably or with flow-control. The peer should be able to search the network for available chunks and download them from the peers that have them. All different parts of the file should be collected at the requesting peer and their validity should be ensured before considering the chunks as received. You can check the validity of a downloaded chunk by computing its SHA-1 hash and comparing it against the specified chunk hash.

To start with the project, use a fixed-size window of **8 packets** (Note that TCP uses a byte-based sliding window, but your project will use a packet-based sliding window. It’s a bit simpler to do it by packet. Also, unlike TCP, you only have a sender window, meaning that window size does not need to be communicated in the packet header.) The sender should not send packets that fall out of the window. The Figure 3 shows the sliding windows for both sides. The sender slides the window forward when it gets an ACK for a higher packet number. There is a sequence number associated with each packet and the following constraints are valid for the sender (hint: your peers will likely want to keep state very similar to that shown here):

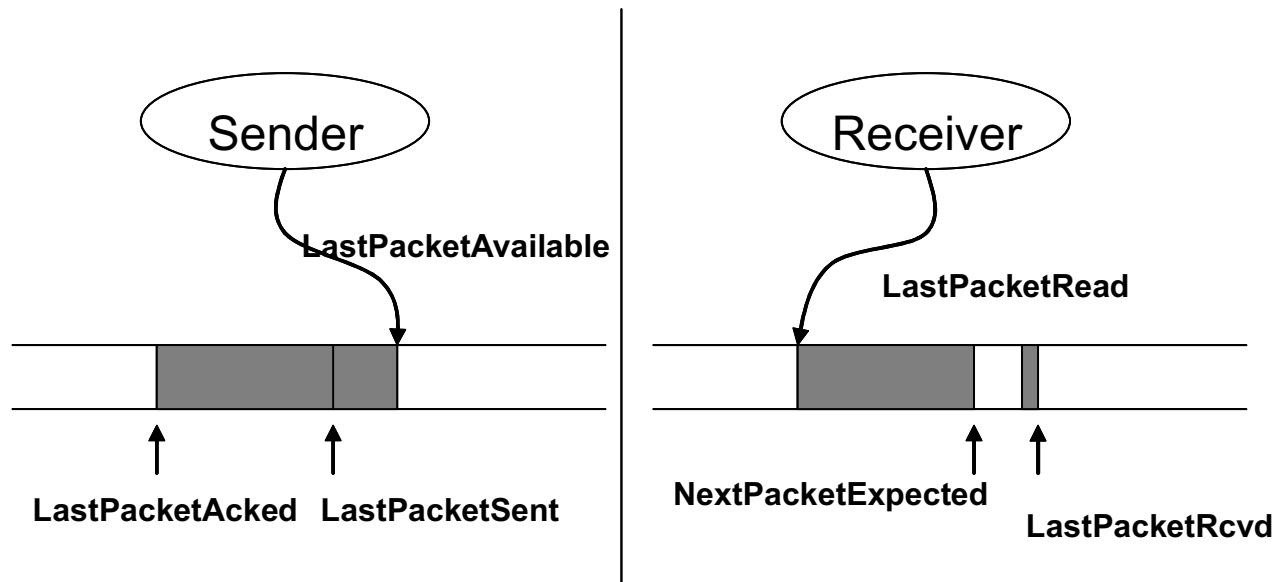


Figure 3: Sliding Window

### Sending side

- $\text{LastPacketAked} \leq \text{LastPacketSent}$
- $\text{LastPacketSent} \leq \text{LastPacketAvailable}$
- $\text{LastPacketAvailable} - \text{LastPacketAked} \leq \text{WindowSize}$
- packets between  $\text{LastPacketAked}$  and  $\text{LastPacketAvailable}$  must be “buffered” – you can implement this either by buffering the packets or by being able to regenerate them from the data file.

When the sender sends a data packet it starts a timer for it. It then waits for a fixed amount of time to get the acknowledgment for the packet. Whenever the receiver gets a packet it sends an acknowledgment for  $\text{NextPacketExpected} - 1$ . That is, upon receiving a packet with sequence number = 8, the reply would be “ACK 8”, but only if all packets with sequence numbers less than 8 have already been received. These are called cumulative acknowledgements. The sender has two ways to know if the packets it sent did not reach the receiver: either a time-out occurred, or the sender received “duplicate ACKs.”

- If the sender sent a packet and did not receive an acknowledgment for it before the timer for the packet expired, it resends the packet.
- If the sender sent a packet and received duplicate acknowledgments, it knows that the next expected packet (at least) was lost. To avoid confusion from re-ordering, a sender counts a packet lost only after 3 duplicate ACKs in a row.

If the requesting client receives a I HAVE from a host, and then it should send a GET to that same host, set a timer to retransmit the GET after some period of time (less than 5 seconds). You should have reasonable mechanisms in your client to recognize when successive timeouts of DATA or GET traffic indicates that a host has likely crashed. Your client should then try to download the file from another peer (reflooding the WHOHAS is fine). We will test your basic functionality using a network topology similar to Figure 4(a). A more complicated topology like Figure 4(b) will be used to test for concurrent downloads and robustness to crashes. As suggested by the checkpoints, you can first code-up basic flow control with a completely loss free virtual network to simplify development.

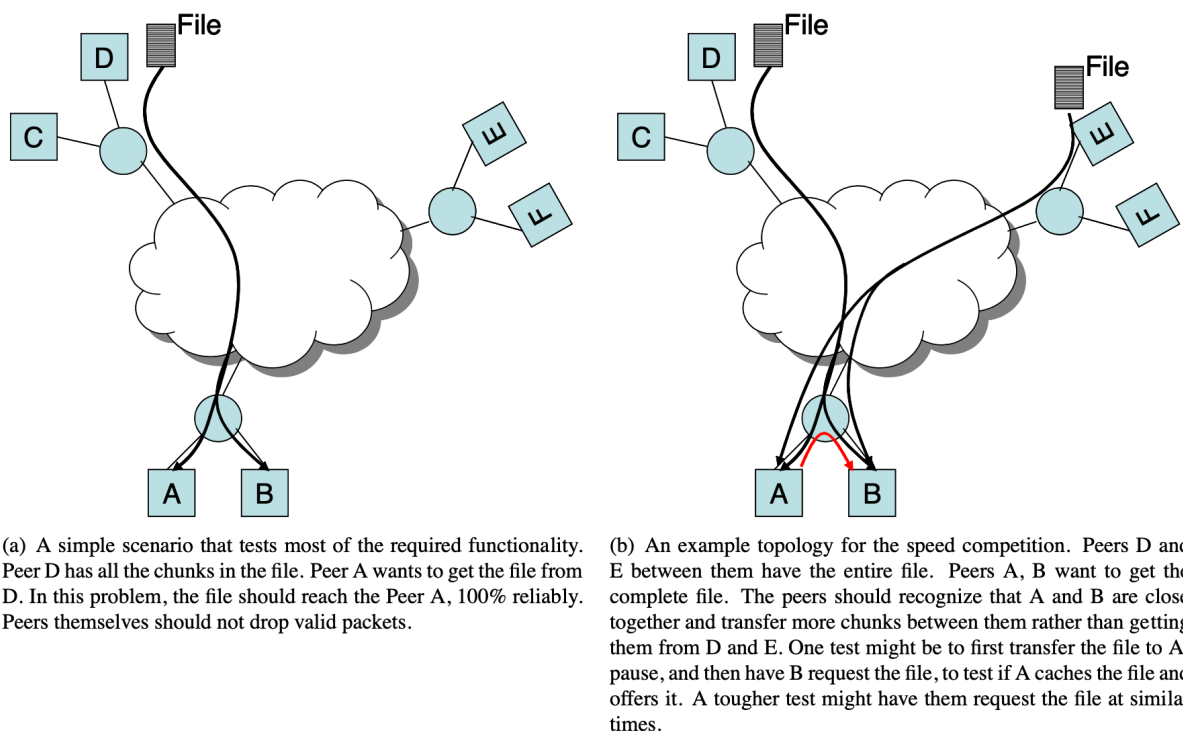


Figure 4: Test topologies

## 6 Spiffy: Simulating Networks with Loss

To test your system, you will need more interesting networks that can have loss and delay. To help you with this, we created a simple network simulator called “Spiffy” which runs completely on your local machine. The simulator is implemented by `hupsim.pl`, which creates a series of links with limited bandwidth and queue sized between nodes specified by the file `topo.map`. To send packets on your virtual network, change your `sendto()` system calls to `spiffy sendto()`. `spiffy sendto()` tags each packet with the id of the sender, then sends it to the port specified by `SPIFFY_ROUTER` environment variable. `hupsim.pl` listens on that port (which needs to be specified when running `hupsim.pl`), and depending on the identity of the sender, it will route the packet through the network specified by `topo.map` and to the correct destination. You hand `spiffy sendto()` the

exact same packet that you would hand to the normal UDP `sendto()` call. All packets should be sent using `spiffy` and `spiffy sendto()`.

## 6.1 hupsim.pl

`hupsim.pl` has four parameters which you must set.

```
hupsim.pl -m <topology file> -n <nodes file> -p <listen  
port> -v <verbosity>
```

- `<topology file>`: This is the file containing the configuration of the network that `hupsim.pl` will create. An example is given to you as `topo.map`. The ids in the file should match the ids in the `<nodes file>`. The format is:

```
src dst bw delay queue-size
```

- The `bw` is the bandwidth of the link in bits per second. The delay is the delay in milliseconds. The queue-size is in packets. Your code is **NOT** allowed to read this file. If you need values for network characteristics like RTT, you must infer them from network behavior.
- `<nodes file>`: This is the file that contains configuration information for all nodes in the network. An example is given to you as `nodes.map`.
- `<listen port>`: This is the port that `hupsim.pl` will listen to. Therefore, this port should be DIFFERENT than the ports used by the nodes in the network.
- `<verbosity>`: How much debugging messages you want to see from `hupsim.pl`. This should be an integer from 1-4. Higher value means more debugging output.

## 6.2 Spiffy Example

We have created a sample server and client which uses `spiffy` to pass messages around as a simple example.

### 6.2.1 To make:

```
gcc -c spiffy.c -o spiffy.o  
gcc server.c spiffy.o -  
server gcc client.c spiffy.o -  
o client
```

### 6.2.2 Usage:

```
usage: ./server <node id> <port>
usage: ./client <my node id> <my port> <to port> <magic
number>
```

Since server and client use spiffy, you must specify the `<node id>` and `<port>` to match `nodes.map`. `<magic number>` is a number we put into the packet header and the server will print the magic number of the packet it receives.

### 6.2.3 Example run:

This example assumes you did not modify `nodes.map` or `topo.map` that was given.

```
setenv SPIFFY_ROUTER 127.0.0.1:12345
```

```
./hupsim.pl -m topo.map -n nodes.map -p 12345 -v 0 &
```

```
./server 1 48001 &
```

```
./client 2 48002 48001 123
```

The client will print

```
Sent MAGIC: 123
```

and the server will print

```
MAGIC: 123
```

## 7 Grading

This information is subject to change, but will give you a high-level view of how points will be allocated when grading this assignment. Notice that many of the points are for basic file transmission functionality. Make sure these work well before moving to more advanced functionality or worrying about corner-cases.

- **Search for chunks and reliably retrieve files [50 points]:** the peer program should be able to generate WHOHAS queries and correctly respond (if needed) with an IHAVE for a simple configuration of two hosts. And the peer program should be able to search for chunks and request them from the remote peers. We will test if the output file is exactly the same as the file peers are sharing. Note, in addition to implementing WHOHAS, IHAVE, and GET, this section requires reliability to handle packet loss. There are three checkpoints to verify its correctness.
  - i    **Checkpoint1:** 10 points
  - ii   **Checkpoint2:** 20 points



### iii Checkpoint3: 20 points

- **Support and Utilize Concurrent Transfers [20 points]:** The peer should be able to send and retrieve content from more than one node simultaneously (note: this does *not* imply threads!). Your peers should simultaneously take advantage of all nodes that have useful data, instead of simply downloading a chunk from one host at a time.
- **Robustness [10 points] :**
  1. **Peer crashes:** Your implementation should be robust to crashing peers, and should attempt to download interrupted chunks from other peers.
  2. **General robustness:** Your peer should be resilient to peers that send corrupt data, etc.

Note: While robustness is important, do not spend so much time worrying about corner cases that you do not complete the main functionality!

- **Style and Document [10 points]:** Well-structured, well documented, clean code, with well defined interfaces between components. Appropriate use of comments, clearly identified variables, constants, function names, etc.  
A file containing a thorough description of your design and implementation is also required. For example, the code structure of your project, the description of some important functions, and your design details.
- **Short video [10 points]:** A short video to 1) demonstrate your file transfer application, and 2) briefly describe your design and implementation (i.e., code).
- **Total [100 points]**

## 8 Auto Testing

There are totally four scripts (check points) for you to pass through.

The entry of this project is peer.c in starter\_code. After you have implemented it, you need to make it and copy the binary code to each checkpoint folder, and check if you have passed each of them.

**IMPORTANT:** To facilitate grading, make sure you can pass the script by running the following steps starting in your trunk directory:

```
% make
% cp peer cp*/
% cd cp*/
% ruby checkpoint*.rb
```

**Please make sure that you have read the README files in each folder.**

## **9 Submit**

Please hand in the following materials in Elearning before **2020/12/20 23:59**.

- All of your source code files
- Checkpoints.pdf: File containing screenshots of the execution results on the four checkpoints. We will also compile and copy the binary file to each of the Checkpoints. **Code that can not be compiled will NOT be graded.**
- Design.pdf: File containing a thorough description of your design and implementation
- Video: A short video to 1) demonstrate your file transfer application, and 2) briefly describe your design and implementation (i.e., code)

If you have any question for this project, feel free to contact me:

TA: Yi Lu

Email: [19212010040@fudan.edu.cn](mailto:19212010040@fudan.edu.cn)

### **Warning:**

**Be sure to complete the project independently and NO plagiarism is allowed! We will check it before grading. If we find any cheating in your project, you'll get NO grade!**