**18-842: Distributed Systems** **Spring 2015**
**Lab 0: Communications Infrastructure**

**Objective:** Students will develop an abstraction of the interprocess communication mechanisms that will be used for further labs. This communications “shim” will allow for fine grained testing and control of message passing between well-defined processes in a distributed system. Further, a sample configuration harness will be developed.

**Administrative details:** You will work in teams of two students. Your teammate will be randomly selected. The lab is due at 9:30 am on 30 January. At that time, an archive of your source code needs to be deposited on ALE. Each team will give a quick demo (maximum of 30 minutes), using the identical code, before 9:30 am on 4 February.

**Specification:** You will develop a “MessagePasser” object (in Java[1]) through which communication will pass. In later labs, your code will use this object to send messages to other processes on (potentially) other hosts. The destination process will also use a **`MessagePasser`** object to receive the messages. The **`MessagePasser`** interface is:

```
public class MessagePasser {

  public MessagePasser(String configuration_filename, String local_name);

  void send(Message message);

  Message receive( );  // may block.  Doesn't have to.

}

public class Message implements Serializable {

  public Message(String dest, String kind, Object data);

  // These settors are used by MessagePasser.send, not your app
  public void set_source(String source);
  public void set_seqNum(int sequenceNumber);
  public void set_duplicate(Boolean dupe);

 // other accessors, toString, etc as needed

}
```

**Discussion:** You will write an *interactive* application program that instantiates the MessagePasser just once. It will pass in two parameters that have been obtained via the command line (or via GUI if you prefer). The first parameter specifies a configuration file, format details below. The second parameter distinguishes this

[1] Use any version of java that both of you can agree on.

process from any others -- it is the **name** string of this particular process. Your **MessagePasser** object will parse the configuration file and set up sockets for communicating with all processes listed in the configuration section of the file. Port numbers listed are for initial communication, perhaps subsequent messages need to go to a different port. The constructor will initialize buffers to hold incoming and outgoing messages to the rest of the nodes in the system. Additional state (threads?) may be required as well. Use TCP as your transport. Details of exactly how the sockets get managed is up to you. What is important is that all processes will be able to communicate (send and receive). Additionally, you are supposed to be well-versed in network mechanics, so use them efficiently. In particular, you should ensure that a single TCP connection remains live between each pair of nodes. You don't want to go through the setup/teardown of the connection for each message.

Your application program can create messages (of class **Message**) and call the MessagePasser's **send** method to get them sent. **MessagePasser** will set the sequence number of the message before sending it. Sequence Numbers should be non-reused, strictly incrementing integer values, starting at zero. Each **Message** in your entire system will have a unique combination of source/sequence number.

Your application program can also call the receive method to get anything currently waiting in the MessagePasser's receive buffer. The easy implementation is to make **receive** block. Enterprising groups may wish to make non-blocking versions of the method as well.

The messages themselves are pretty easy to build, as they are static. They have a header and a payload. In the header is a destination node (by name), a sequence number (which the **MessagePasser** should generate and should be unique among all messages sent by the local node), a duplicate flag (used only by the **MessagePasser**, not your application) and a message kind (which need not be unique). The payload is any object you care to send. We won't worry too much about segmentation, MTU or any of that stuff, as I assume you learned it in your network class.

When the **send** method is called, the **MessagePasser** will check the message against any SendRules (specified in the configuration file and further explained below) before delivering the message to the socket.

On the receive side, the **MessagePasser** will be getting messages from the socket as they are delivered. The **MessagePasser** will be checking each received message against ReceiveRules (again, explained below) and storing them in an input queue. Whenever the application calls **MessagePasser.receive( )**, the **MessagePasser** will deliver a single message from the front of this input queue.

**The Configuration File:** The configuration file will allow you to determine at *runtime* how the object will handle each message. To facilitate testing on long-running processes, the file should be checked to see if it was modified and, if so, re-read before processing each send and receive method. It can be very useful to have the configuration file live on a distributed filesystem (like AFS or dropbox) so each node can read copies without needing to FTP them around.

The configuration file is in YAML format (see yaml.org). I recommend using snakeYAML (code.google.com/p/snakeyaml) library to parse the config file. If you aren't familiar with YAML, the wikipedia article can get you up to speed (en.wikipedia.org/wiki/Yaml) The first items are used for system configuration and thus should only be referenced during the initial setup in the constructor, even if they change at runtime.

```yaml
# Defines which nodes are used in the system and how to connect to them.
# This element should only be referenced during the constructor's initial
# setup.
# All names must be unique.
# No other nodes are known.
# These names will be used for src and dest addresses for the Message
# The local node’s name is included in this list
configuration :
  - name : alice
    ip   : 192.168.1.52
    port : 12344        # This is the incoming port on which MP will listen
                        # May be changed for further communication as usual
  - name : bob
    ip   : 192.168.1.112
    port : 14255
  - name : charlie
    ip   : 128.2.130.19
    port : 12998
  - name : daphnie
    ip   : 192.168.1.87
    port : 1987

sendRules :
  - action : drop # Ack message number 4 from bob to alice will not be sent
    src    : bob
    dest   : alice
    kind   : Ack
    seqNum : 4
  - action : delay # Every Lookup message in the system will be delayed
    kind   : Lookup

receiveRules :
  - action : duplicate      # 4th message from Charlie that anyone
    src    : charlie        # receives will be duplicated
    seqNum : 3
```

**Rule Processing:** The configuration section is pretty self explanatory. Unfortunately, the SendRules and ReceiveRules sections need some explanation.

Each of these sections specify a list of rules, each of which must contain an Action and may contain Src, Dest, Kind, SeqNum and Duplicate fields. Before sending each message, the send method will compare the fields in the message (src, dest, kind, sequenceNumber and duplicate) against the fields in the rule. If **all** of the fields in the rule match variables in the message, then the rule's action will be fulfilled and rule processing will be stopped (i.e. The first rule to match the message is the only one that will be acted upon). Any fields not specified are *wildcard* and match all values of that variable. A rule consisting of just an Action field will match all messages. If no actions are to be taken, then the message will be sent. Likewise, the networking object on the receiver will compare a received message against all Actions. If no actions are to be taken, then the message will be delivered to the application via the receive method.

There are three possible values for the Action field of a rule: drop, duplicate, and delay.

**Drop:** Any message which matches a drop rule will be ignored. It will not be sent (if this is a SendRule), nor will it be delivered to the application (if this is a ReceiveRule).

**Duplicate:** Any message which matches a duplicate rule will be duplicated (i.e. send two copies if this is a SendRule. Deliver two copies to the application if this is a ReceiveRule). Note that it is possible for an application to **`receive()`** 4 copies of a message if it is duplicated at sender and receiver. If a duplicate is created due to a SendRule, the first message will have the duplicate field set to False and the second message will have the duplicate field set to True. The duplicate fields *only*[2] use is to be able to distinguish them for ReceiveRule processing (i.e. you can Drop just the duplicate at the receiver, which would otherwise be impossible). With the exception of the duplicate field, the duplicate messages will be identical — in particular, ensure they have the same sequenceNumber.

**Delay:** Any message which matches a delay rule will be set aside temporarily and not sent / delivered until after after another non-delayed message is sent / delivered. Note that this means that multiple messages may be set aside, if they all match a delay rule. In such a case, a single non-delayed message sent / received will trigger the sending / receiving of all such delayed messages.

**Demonstrate:** Develop a testing harness that allows you to send and receive enough messages among 4 processes on at least 2 different computers to prove your infrastructure works well.

Your testing harness needs to allow for interactive specification of messages to be sent. It must have a User Interface, which need not be Graphical. No compilation can be required in order to have a different scenario. If a TA asks that you run a particular scenario (i.e send a message of kind "Request" from Alice to Bob) you must be able to execute this scenario without changing your code or recompiling.

It would be possible for your scenario to be specified in another file that your testing harness reads. However, this is difficult to demonstrate, so is discouraged. Note that such an approach can be really useful for your project work, as you can keep a set of files that detail regression tests and run them automatically.

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[2] Only use! Applications can't distinguish duplicated messages, for instance.

Finally, be prepared to demonstrate the actual network message content using Wireshark. In particular, be able to show that there is only one TCP connection between each pair of participants, and that the connection remains throughout the entire demo.

# 18-842 Lab Teams

**Teams 1-9 demo to Krish**

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**Teams 10-18 demo to Utsav**

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**Teams 27 - 34 demo to Akshay**

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Team 33: Jonathan Lim (jlim2) and Shan Gao (shang)

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**Teams 35-42 demo to Vishvesh**

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Team 36: Rohith Jagannathan (rjaganna) and Huiyuan Wang (huiyuanw)

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Team 39: Pushen Gao (pusheng) and Minghan Chen (minghan2)

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**Grading Scheme**

**Demonstrations:** Students will need to demonstrate an application program that exercises their MessagePasser class. At a **minimum**, they should be able to:

1. Discuss the system architecture in some detail. It would be very helpful to show up to the demo with an architectural diagram showing the components of your solution.
2. Set up 4 processes on at least two distinct machines and show that at least one message can be passed to and from each process (i.e. P1 sends a message to P2, P2 sends a message to P3, P3 sends a message to P4 and P4 sends a message to P1). Students may use ssh in order to show all 4 user interfaces from a single computer.
3. Show that a message with a particular kind is dropped, delayed and duplicated (one at a time) based on entries in the configuration file. For instance, P2 sends a message with kind="HTTP_REPLY" to P4, followed by second message with kind="IRRELEVANT". The config file contains "SendRules: - Action : Delay - Kind : HTTP_REPLY" and you can show that P4 receives the second message before it receives the first.
4. Show a message duplicated at the sender side and dropped at the receive side via use of the “Duplicate” field. Ensure that a single message is received.
5. Show that messages are sent with increasing sequence numbers, unique to each process. For instance, the first message from P1 should probably have sequence number 0 (though the spec was a bit loose on this point). The second message should have the next sequence number. The first message from P2 can also have sequence number 0.
6. Make sure that reception can be interleaved from multiple sources. For instance, P1 sends a message whose kind will get it delayed at the receiver, P2. If the next message is sent from P3 to P2, does P2 get it before the message from P1?

**Going Forward:** Make certain that all students understand that errors in the MessagePasser class need to be fixed quickly, as future labs will expect to have a perfectly working infrastructure.