Homework #7

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Due: 02-28-2017 11:59pm

In this homework, we will implement data transferring functionality in our simulator. Data transferring will be modeled by passing raw pointers to the `Datagram` class around. We will implement 4 new member functions of the `Node` class in Section 2 and three system operations in Section 3. Together, they model the start, on going and the end of a data transfer process.

Please do not modify `datagram.h`, `machines.h` or the lines "`friend class Grader;`" in homework 7. These are needed for grading.

Data Transfer Process

The data transfer process we are modeling allows the user to transfer a piece of message from the source machine to the destination machine even with these two machines might not be directly connected. The process starts with the source machine allocating a new instance of `Datagram` containing the message to be sent. The `Datagram` is then being transferred repeatedly from one machine to another, moving closer toward its destination. When the `Datagram` arrives at its destination, it will be placed in the receive buffer in the destination machine, waiting for the user to process it.

We will implement 4 new member functions of `Node` in section 2 to simulate this process. Though the given algorithm for sending datagrams is pretty naïve, we guarantee that every datagram will be able to arrive at its destination.

- `Node::allocate_datagram` allocates a new instance of `Datagram`.
- `Node::send` sends the datagrams in the send buffer to the best-suited machines connected to the current machine.
- `Node::receive` receives a datagram from another machine. The current machine might or might not be the destination of the incoming datagram. If the current machine is not the destination, the datagram will be sent out by later invocations of `Node::send`.
- `Node::release_datagram` processes the received message and frees the datagram in the buffer.

Raw Pointer Memory Management

In our system, an object that possesses a non-null raw pointer to a `Datagram` object takes the responsibility to free that `Datagram` upon the destruction of the owning object itself. We also need to ensure that no two classes can have raw pointers to the same `Datagram` at the same time.

Exactly two classes can own raw pointers to `Datagram`s in this homework. A `Node` can own a raw pointer `Datagram*` in `Node::incoming_`. A `ListNode` in a linked-list can also own a raw `Datagram` pointer in `ListNode::data`. When a node `Node` or a `ListNode` is being destructed, it needs to delete the `Datagram` if it has a non-null raw pointer to that `Datagram`.

If we ever want to pass the raw pointer to a `Datagram` to another class, we have to set the original raw pointer to the `Datagram` to `nullptr`. For example, we can extract the raw pointer from a `ListNode` below, pass it to another `Node` class. Then, we must set the original `head->data` to `nullptr`. This not only represents that the ownership of the the `Datagram` has been transferred to `*m`, but also prevents `head` from erroneously deleting the `Datagram`.

```
// data_list_ is a List and m is a shared_ptr<Node>
shared_ptr<ListNode> head = pop_front(data_list_);

m->receive(head->data);  // Now m possesses the raw pointer to head->data,
head->data = nullptr;    // so we set head->data to nullptr
```

1 Linked-List Library, Revisited

We will reuse our `linked_lib` in homework 4 to implement the data buffer in `Node`. The type of `data` field has been changed to `Datagram*` to store raw pointers to the `Datagram` class.

Copy your homework 4 solution to `linked_lib.cpp` in the provided code. Complete the implementation of the constructor and the destructor of `ListNode`. Upon creation, initialize the `ListNode::data` field with `nullptr`. Upon destruction, `delete` the allocated `Datagram` if the `ListNode::data` field is non-null.

2 Transferring Data Across the Network

Two new data members are added to the `Node` class. One data member is `data_list_` of type `List` (from homework 4) representing the send buffer; the other data member is `incoming_` of type `Datagram*` representing the receive buffer.

Implement the four new member functions and the destructor below. They model the creation, dispatching and delivery of datagrams. Be sure to transfer the ownership of `Datagram*`.

- In `~Node()`, delete the `Datagram` pointed by `incoming_` if it is not `nullptr`.
- The `allocate_datagram` member function initiates a data transmission. It allocates a new `Datagram` in the memory and pushes the `Datagram*` to back of the linked-list `data_list_`.
- The `release_datagram` member function returns the message of the received datagram in the `incoming_` buffer by calling `Datagram::get_msg` if the `incoming_` buffer is not `nullptr` or an empty string otherwise.

  The datagram, if exists, will be deleted and the `incoming_` buffer will be set to `nullptr` again.
- When `node_list_` is not empty, `send` member function sends out every `Datagram*` in the `ListNode`s in `data_list_`. If the destination of the `Datagram` is in the connected machines, send the datagram to that machine. Otherwise, find the connected machine whose IP address's first octad is closest to the destination's first octad, and send it there.

  Send the datagram by calling the recipient machine's `receive` member function with the datagram. If the recipient throws an `err_code::recv_blocked` exception, keep the datagram in `data_list_`. Finally, return the number of successfully sent `Datagram`s. One possible way to implement this is given in Section 6.
- In `receive` member function, there are two possibilities. If the destination of the `Datagram` is the current machine (compare `Datagram::get_destination()` with `Node::local_ip_`), either it will be delivered or blocked, depending on whether the `incoming_` buffer is `nullptr` or not. In particular, if `incoming_` is `nullptr` then it should be set to the incoming `Datagram`; otherwise throw an `err_code::recv_blocked` exception to indicate that the `incoming_` buffer is full.

  If the destination of the `Datagram` is not the current machine, then the `Datagram` is pushed to the back of the linked-list `data_list_`.

3 Some More User Commands

Extend the simulator to handle three more commands in this homework.

- Sending New Datagrams: `System::allocate_datagram`

  Invoke `allocate_datagram` on the designated machine to initiate a data transmission from IP_{src} to IP_{dst} with data "*message*". The corresponding command for this member function is "`send` IP_{src} IP_{dst} *message*".

- Consuming Datagrams: `System::release_datagram`

  Invoke `release_datagram` on the designated machine to "process" the data and end the data transmission. The corresponding command for this member function is "`recv` IP"

- Time Ticking: `System::time_click`

  Invoke `send` on **all** machines to route datagrams one step further. The corresponding command for this member function is: "`tick`"

4 Handling Errors

For error handling,

- `System::time_click`, `Node::send`, `Node::allocate_datagram` and `Node::release_datagram` will never throw an exception. `Node::send` simply does nothing when there are no connected machines.
- `Node::receive` should throw an `err_code::recv_blocked` exception if the destination of the input `Datagram` is the current machine and `Node::incoming_` is not `nullptr`.
- `System::allocate_datagram` and `System::release_datagram` should throw an `err_code::no_such_machine` exception if the designated machine is not found in `network_`.

5 Unit Testing

Write comprehensive unit tests to check the behavior of the `Node` class for the data transfer functionality. See `networksim_test.cpp` for an example of how to check that `Node::send` sends the datagram to the best connected `Node` specified in Section 2.

Append the new unit tests in `networksim_test.cpp`. You have to figure out how to setup unit tests to check the behavior of `Node::release_datagram`, `Node::send` and `Node::receive` to ensure that the required functions work properly. We will also grade on the completeness of unit test coverage in the form of self-evaluation as in Homework 4.

6 Hints: *Node::send*

One trick is to use another linked-list to keep the `Datagram`s that failed to be sent. While `data_list_` is not `nullptr`, we call `pop_front`, extract the `Datagram`, and find the best node to send to. If `Node::receive` failed, we push the `Datagram` to the back of the new linked-list. At the end of `Node::send`, replace `data_list_` by the new linked-list

```
new_list <- empty linked-list
while data_list_ is not nullptr, do
    List head <- pop_front data_list_

    # Take the ownership of head->data. Setting head->data to nullptr is very important.
    # Otherwise, head will delete the datagram after it goes out of scope.
```

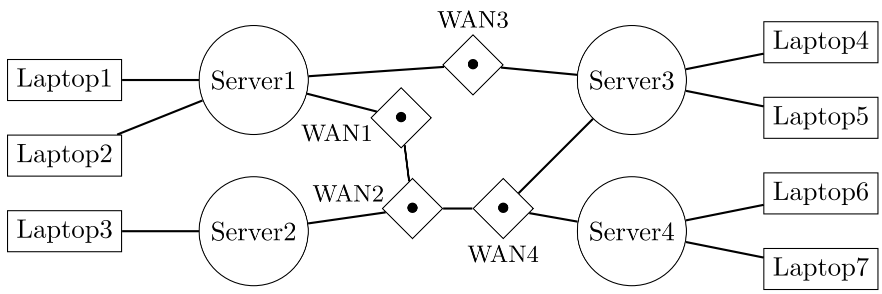
```
    Datagram* d = head->data
    head->data <- nullptr

    If the machine d->get_destination() is in node_list_, let m be that machine.
    Otherwise, Find the node m in node_list_ that minimizes the difference between
    d->get_destination().first_octad() and m->get_ip().first_octad().
    If there are ties, choose whichever you like.

    Call m->receive(d). If m throws an exception, pushes d to the back of new_list

data_list_ <- new_list
```

Appendix: Project Introduction: Homework 5-8



In this project, we are going to build a tiny network simulator modeling a small system that has laptops, servers and WAN (Wide Area Network) nodes. We will also model datagram transmission between them. A laptop must first be connected to a server. A server can connect multiple laptops, building a LAN (Local Area Network) between them. A server can also be connected to multiple WANs, in which case it will be able to transfer datagrams indirectly to other servers and finally to other laptops outside LAN. A WAN node can connect not only to arbitrary servers, but also to other WAN nodes.

Starting from homework 6, we will implement one class for each of the constructs in this system: a `System` class for the entire network system, a `Datagram` class for datagrams and machine classes `Laptop`, `Server`, `WAN_node` for laptops, servers, and WAN nodes respectively. The `System` class will have member functions corresponding to network operations. These include: sending and receiving a datagram on a `Laptop`, adding and removing machines from the network, and a time ticking function for servers and WAN nodes to route datagrams one step toward their destination.

The simulator, aside from the `System` class modeling the entire network, also contains a command line interface to interact with the user. The user can enter commands to control the system and view the status of the network system. In this homework 5, we implemented three utility parsing functions that help the command line interface convert input strings into commands and accompanying data in order to invoke the corresponding member functions of the `System` class.

In provided the code, `main.cpp` and `interface.cpp` implement the command line interface. In `main.cpp`, the `main` function repeatedly reads a line from the user, parses the input into tokens by the `tokenize` function, and calls `execute_command` to perform the corresponding operations. If an error is thrown, it catches the error code `err_code` and prints an error message.

In `interface.cpp`, the `execute_command` function first identifies the input command by searching through the `command_syntaxes` list, match the command string and obtain the `cmd_code` for the input command. `execute_command` then parses the accompanying data (some by `parse_IP` and invokes the member function of `System`.