Computer Networks

Project 3

Project Assigned: December 2
Due: December 17 – 12:01 AM
Show and Tell: December 17 - 19

Implementing a Routing Protocol

Description

In this assignment you will be asked to implement a distributed asynchronous distance vector (DV) routing protocol. This project will be completed using C/C++ over a network emulator already provided. No knowledge of Unix system calls will be needed to complete this project.

Details

1. **A detailed project description can be found on later slides.**
2. In this programming assignment, you will be writing the sending and receiving IP-level messages for routing data over a network
3. Your code must execute in an emulated hardware/software environment. The programming interface provided to your routines, i.e., the code that would call your entities from above and from below is very close to what is done in an actual Linux environment.
4. This assignment is worth **- 30 points**

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Submission

As a part of the submission you need to provide a zip file with the name

"your-wpi-login_project3.zip"

1. **All** the code and data files for the DV routing protocol implementation, including any code that was pre-provided as part of this project.
2. A ReadMe (txt) file that spells out exactly how to compile and run the code. Your code will be evaluated on CCC Linux. Optionally, you may wish to ALSO provide a Makefile that implements the instructions in your ReadMe – both compilation and execution. This will give us a warm feeling when evaluating your work.
3. A PDF design document with details of your protocol and what to expect in the output trace and what it means. Providing the output in #4 does not mean you understand that output. Convince us.
4. A PDF document with the output trace as described in the project description. See the description for the specified level of Debugging expected in this trace.

Submit your document electronically via Instruct Assist (http://cerebro.cs.wpi.edu/cs3516) by 12:01AM on the day the assignment is due. Make sure you choose "Project 3" under project drop-down in IA before uploading the zip file.

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Project Evaluation

Grade breakdown (out of 30 points) assuming all documents are present:

Functioning DV routing protocol code functioning on the default supplied configuration = 15

README/Makefile describing how to compile and run your code = 3

Design document routing protocol description = 3

DV routing protocol output trace = 3

Challenge Level: Ability to get correct result for "mystery" 4-node configuration = 3

Heart Stopping Excitement Level: Ability to get correct result for "mystery" 6-node configuration = 3

The grade will be a ZERO:

If the code does not compile or gives a run-time error

If README with detailed instructions on compiling the running the code is not present

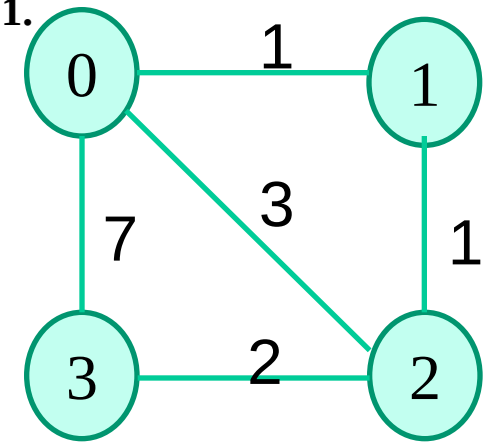
If you don't appear for Show and Tell.

Note: Since this assignment pushes up right against the end of the Quarter, there will be no late Show and Tell or makeups possible.

Implementing a Routing Protocol

Overview

In this lab, you will be writing a "distributed" set of procedures that implement a distributed asynchronous distance vector routing for the network shown in **Figure 1.**



The Basic Assignment

The routines you will write: For this assignment, you are to write the following routines which will ``execute" asynchronously within the emulated environment that we have written for this assignment.

These routines exist in node0.c, and similarly named routines live in each of the modeN.c files.

rtinit0() This routine will be called once at the beginning of the emulation. rtinit0() has no arguments. It should initialize the distance table in node 0 to reflect the direct costs to is neighbors by using GetNeighborCosts(). In Figure 1, representing the default configuration, all links are bi-directional and the costs in both directions are identical. After initializing the distance table, and any other data structures needed by your node 0 routines, it should then send to its directly-connected neighbors (in the Figure, 1, 2 and 3) its minimum cost paths to all other network nodes. This minimum cost information is sent to neighboring nodes in a *routing packet* by calling the routine tolayer2(), as described below. The format of the routing packet is also described below.

rtupdate0(struct rtpkt *rcvdpkt). This routine will be called when node 0 receives a routing packet that was sent to it by one if its directly connected neighbors. The parameter *rcvdpkt is a pointer to the packet that was received.

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rtupdate0() is the "heart" of the distance vector algorithm. The values it receives in a routing packet from some other node *i* contain *i*'s current shortest path costs to all other network nodes. rtupdate0() uses these received values to update its own distance table (as specified by the distance vector algorithm). If its own minimum cost to another node changes as a result of the update, node 0 informs its directly connected neighbors of this change in minimum cost by sending them a routing packet. Recall that in the distance vector algorithm, only directly connected nodes will exchange routing packets. Thus, for the example in Figure 1, nodes 1 and 2 will communicate with each other, but nodes 1 and 3 will not communicate with each other.

As we saw in class, the distance table inside each node is the principal data structure used by the distance vector algorithm. You will find it convenient to declare the distance table as a N-by-N array of int's, where entry [i,j] in the distance table in node 0 is node 0's currently computed cost to node i via direct neighbor j. If 0 is not directly connected to *j*, you can ignore this entry. We will use the convention that the integer value 9999 is ``infinity."

Figure 2 provides a conceptual view of the relationship of the procedures inside node 0.

Similar routines are defined for nodes 1, 2 and 3. Thus, you will write, at a minimum, 8 procedures in all: `rtinit0(), rtinit1(), rtinit2(), rtinit3(),rtupdate0(), rtupdate1(), rtupdate2(), rtupdate3()`

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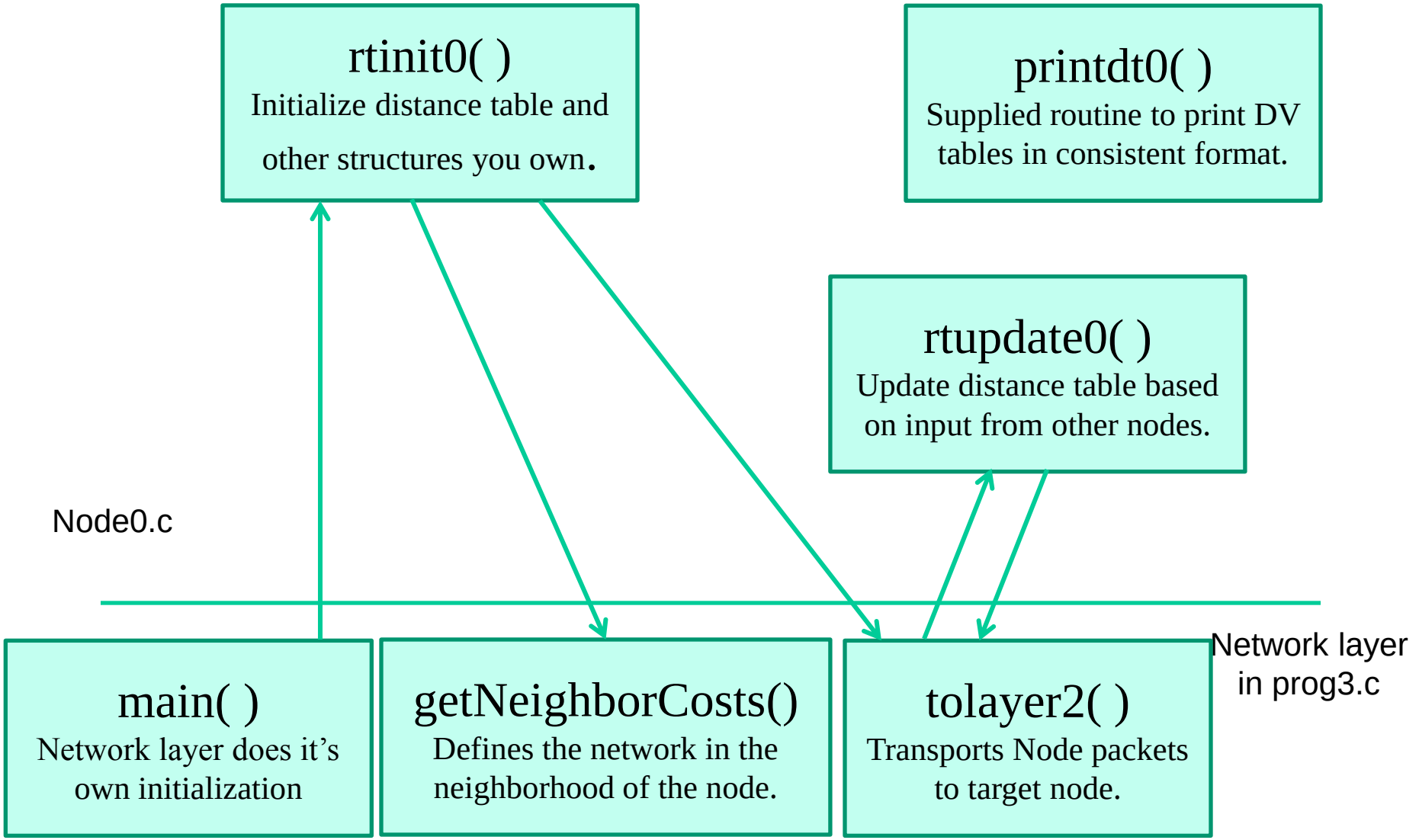

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Software Interfaces:

The procedures described above are the ones that you will write. We have written the following routines that can be called by your routines:

toLayer2(struct rtpkt pkt2send); where struct rtpkt is defined below. The purpose of this routine is to provide communication between the various nodes in your network. The procedure **tolayer2()** is defined in the file project3.c

getNeighborCosts(int myNodeID); This routine allows your node to discover what other nodes are around it and what are the costs to those nodes. This routine returns a pointer to a **struct NeighborCosts** that is defined on a later slide. **getNeighborCosts()** is implemented in project3.c

printdt0(int MyNodeNumber, struct NeighborCosts *neighbor, struct distance_table *dtptr);

will pretty print the distance table for node 0. Please look in your node0.c code for an explanation of how it works and what you need in order to call it. What should be of special interest to you is that this print code is the same in each of the nodes; in other words, I'm using the input parameters to tailor the routine to work in general for all nodes. There is no need for me to write a separate and unique routine for each node.

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Software Structures:

These are the data structures that you will use to communicate with the routines in Layer 2. You will certainly need additional structures of your own crafting to maintain additional information.

```
extern struct rtpkt {
    int sourceid;           // id of node sending this packet, 0, 1, 2, or 3
    int destid;             // id of router to which pkt is sent
    int mincost[MAX_NODES]; // min cost to node 0 ... N
};
```

An instance of this structure is declared in your starter node0.c … node3.c code.

```
struct NeighborCosts   {
    int  NodesInNetwork;         // The total number of nodes in the entire network
    int  NodeCosts[MAX_NODES];   // An array of
};
```

An instance of a pointer to this structure is declared in your starter node0.c … node3.c code. Note that the filled-in structure is allocated in the function getNeighborCosts() and a pointer to this structure is returned by this function. Here's the information returned as seen by gdb in my node0.c when using the default configuration shown in Figure 1.

```
(gdb) p *neighbor0
$2 = {NodesInNetwork = 4, NodeCosts = {0, 1, 3, 7, 9999, 9999, 9999, 9999, 9999, 9999}}
```

MAX_NODES is set to 10. The simulator is able to support a network containing up to 10 nodes.

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The Simulated Network Environment

Your procedures rtinit0(), rtinit1(), rtinit2(), rtinit3() and rtupdate0(), rtupdate1(), rtupdate2(), rtupdate3() send routing packets (whose format is described above) into the medium. The medium will deliver packets in-order, and without loss to the specified destination. Only directly-connected nodes can communicate. The delay between sender and receiver is variable (and unknown).

When you compile your procedures and my procedures together and run the resulting program, you will be asked to specify only one value regarding the simulated network environment:

- **Tracing.** Setting a tracing value of 1 or greater will print out useful information about what is going on inside the emulation (e.g., what's happening to packets and timers). A tracing value of 0 will turn this off. A tracing value greater than 2 will display all sorts of odd messages that are for my own emulator-debugging purposes.

A tracing value of 2 is reserved for your use in your code. We will typically be running Show and Tell with a trace level of 1, so the output will not be encumbered with your output at that time. In the initial node0.c code, *TraceLevel* is given to you as an external.

You can set the trace level as the only input on the command line: "`Program3 1`".

The Assignment

You are to write the procedures rtinit0(), . . . rtinitN() and rtupdate0(), . . . rtupdate3(), which together will implement a distributed, asynchronous computation of the distance tables for the topology and costs shown in Figure 1.

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You should put your procedures for nodes 0 through 3 in files called node0.c, ... node3.c. You are **NOT** allowed to declare any global variables that are visible outside of a given C file (e.g., any global variables you define in node0.c. may only be accessed inside node0.c). This is to force you to abide by the coding conventions that you would have to adopt is you were really running the procedures in four distinct nodes. To compile your routines:

```
gcc project3.c node0.c node1.c node2.c node3.c –o project3
```

This assignment can be completed on any machine supporting C I did my development on a windows machine supporting gcc; a Linux machine will work equally well.

Manifest:

Here are the files you will need for this project:

project3.c
project3.h
node0.c
node1.c
node2.c
node3.c
NodeConfigurationFile

Implementing a Routing Protocol

Output Trace (for submission): For your sample output, your procedures should print out a message whenever your rtinit0(), rtinit1(), rtinit2(), rtinit3() or rtupdate0(), rtupdate1(), rtupdate2(), rtupdate3() procedures are called, giving the time (available via my global variable clocktime).

For rtupdate0(), rtupdate1(), rtupdate2(), rtupdate3() you should

(1) Print the identity of the sender of the routing packet that is being passed to your routine,

(2) Whether or not the distance table is updated, print the contents of the distance table (you should use my pretty-print routines),

(3) A description of any messages sent to neighboring nodes as a result of any distance table updates.

The submitted output will be an output listing with a TraceLevel value < 2. Highlight the final distance table produced in each node. Your program will run until there are no more routing packets in-transit in the network, at which point our emulator will terminate.

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Here's a sample output produced with my solution of the problem I believe it follows the guidelines on the previous page. It is not the intent that you should slavishly follow this character for character.

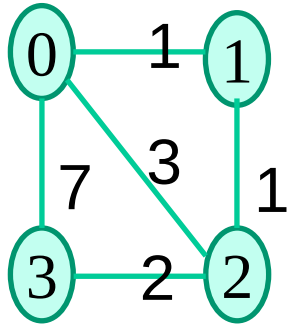
```
G:\Courses\3516\Project3\solution>p3 1
At time t=0.000, rtinit0() called.
                via
   D0 |     1     2     3
  ----|-------------------------------
dest 1|     1  9999  9999
dest 2|  9999     3  9999
dest 3|  9999  9999     7

At time t=0.000, node 0 sends packet to node 1 with:   0  1  3  7
At time t=0.000, node 0 sends packet to node 2 with:   0  1  3  7
At time t=0.000, node 0 sends packet to node 3 with:   0  1  3  7

At time t=0.000, rtinit1() called.
                via
   D1 |     0     2
  ----|-------------------------------
dest 0|     1  9999
dest 2|  9999     1
dest 3|  9999  9999

At time t=0.000, node 1 sends packet to node 0 with:   1  0  1  9999
At time t=0.000, node 1 sends packet to node 2 with:   1  0  1  9999
```

Implementing a Routing Protocol

NodeConfigurationFile:

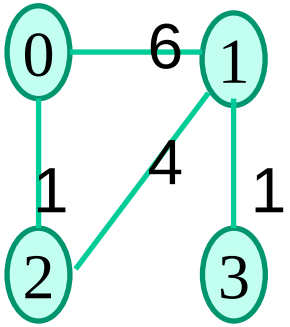
The "challenge" part of this project asks that you ensure that your code works with arbitrary network configurations. Many people will decide that just getting *anything* working is challenging enough, but I know some people like to take on new excitement.

So for additional adventure, you will need to generate your own NodeConfigurationFile. Here are several examples from which you will be able to understand how to do it.



This is the original configuration:

```
4
   0,    1,    3,    7
   1,    0,    1, 9999
   3,    1,    0,    2
   7, 9999,    2,    0
```



The file for this configuration:

```
4
   0,    6,    1, 9999
   6,    0,    4,    1
   1,    4,    0, 9999
9999,    1, 9999,    0
```