CS4411 Project 5: Link-State Routing

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(Original slides by Soumya Basu)

Main Goals of this Assignment

- Learn the userspace side of networking
- Learn to work with an existing codebase
- Learn the standard C socket API
- Learn how to handle multiple connections in a single application.

Three Main Parts to the Project

- Setting up connections between nodes
- Broadcasting packets through the network
- Calculate shortest paths using Dijkstra’s Algorithm

Revisiting Stream Based Networking

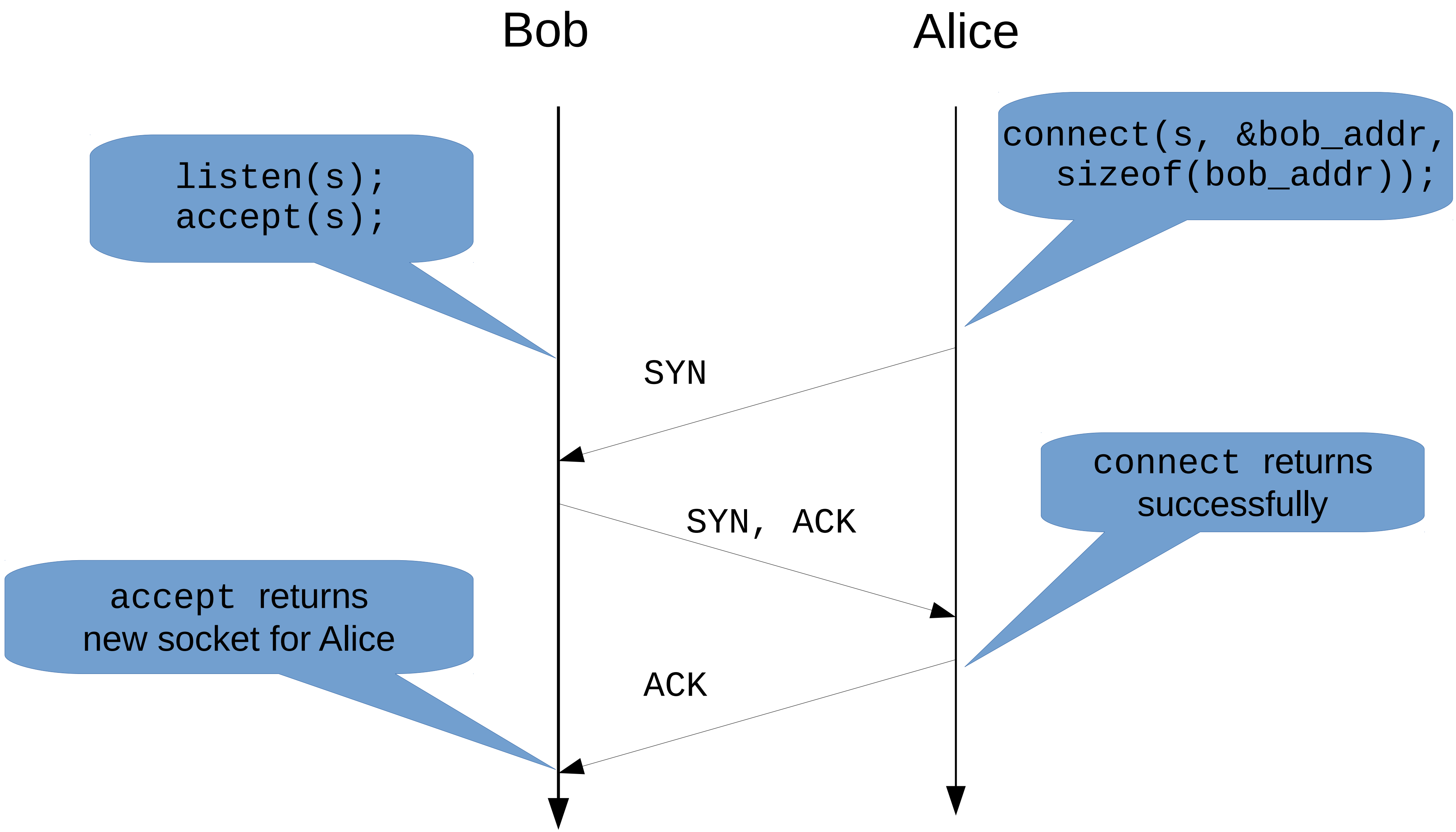
- TPC has no notion of messages
- one send() might be split into multiple recv()’s on the other side
  - and vice versa…
- Application layer needs to convert stream into messages (if needed)

Setting up the socket

```
int s = socket(AF_INET, SOCK_STREAM);

sockaddr_in addr;
addr.sin_port = htons(1337);
addr.sin_addr = IN_ADDR_ANY;

bind(s, &addr, sizeof(addr));
```

Make sure you handle errors in your implementation!

TCP is connection-based



TCP is stream-based

The kernel allocates a send and a receive buffer for each socket.

- Buffers are FIFO
- send() appends to the local send buffer
- receive() takes data from the front of the local receive buffers
- OS takes care of emptying send buffer and filling receive buffer

`epoll()`

wait for different kinds of events on multiple filedescriptors

poll() is fine too

Using a single blocking socket

Using multiple non-blocking sockets and epoll()

Creating an epoll() object

```
#include <sys/epoll.h>
int efd = epoll_create1();
```

Note: epoll only works on Linux

Setting up a socket for epoll()

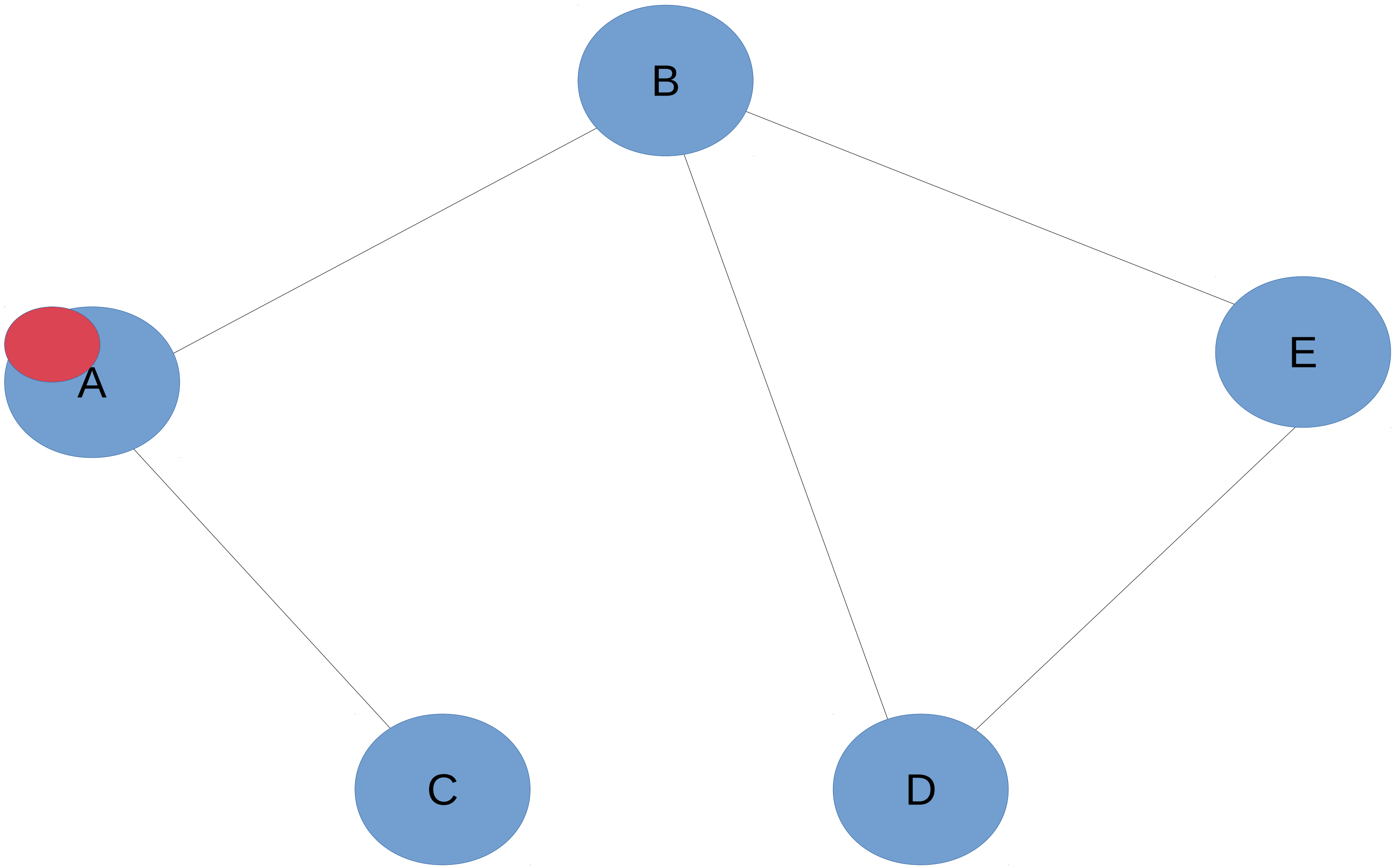
```
// make socket nonblocking
fctnl(s, F_SETFL, SO_NONBLOCK);

// hand socket to epoll
struct epoll_event event;
event.data.fd = s;
event.events = EPOLLIN | EPOLLOUT | EPOLLHUP;
epoll_ctl (efd, EPOLL_CTL_ADD, s, &event);
```

Bitmask specifies which events to wait for

Handling events with epoll()

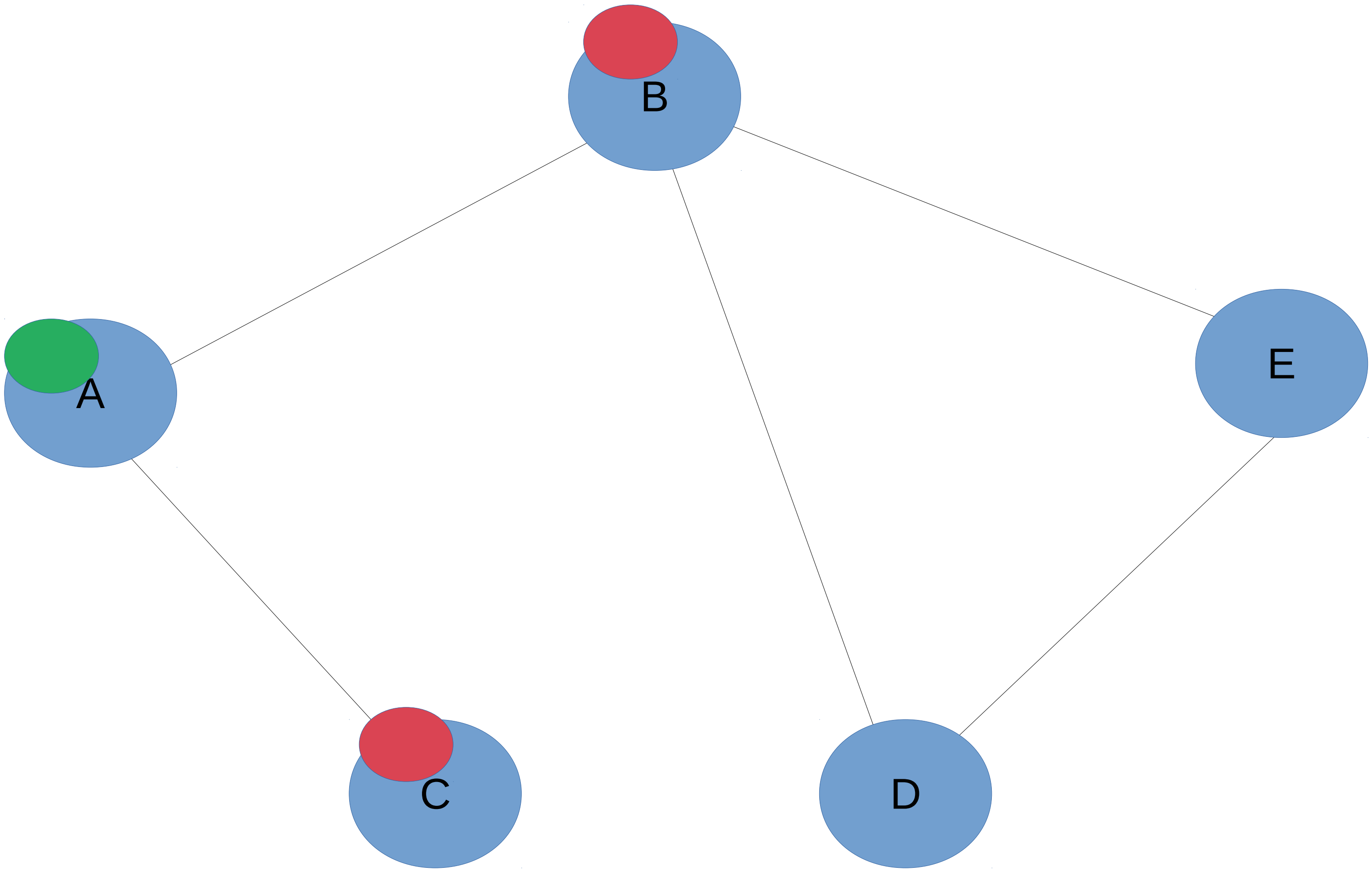
```
struct event *events = calloc (MAXEVENTS, sizeof(event));

while (true) { // loop during the lifetime of the program
     int n = epoll_wait (efd, events, MAXEVENTS, -1);
     for (int i = 0; i < n; i++) {
           if ((events[i].events & EPOLLERR) {
              // error happened
           } else if (events[i].events & EPOLLIN) {
               // socket is ready to read
           } else if (events[i].events & EPOLLOUT) {
               //  socket is ready to write
           }
     }
}
```

“Gossiping” messages



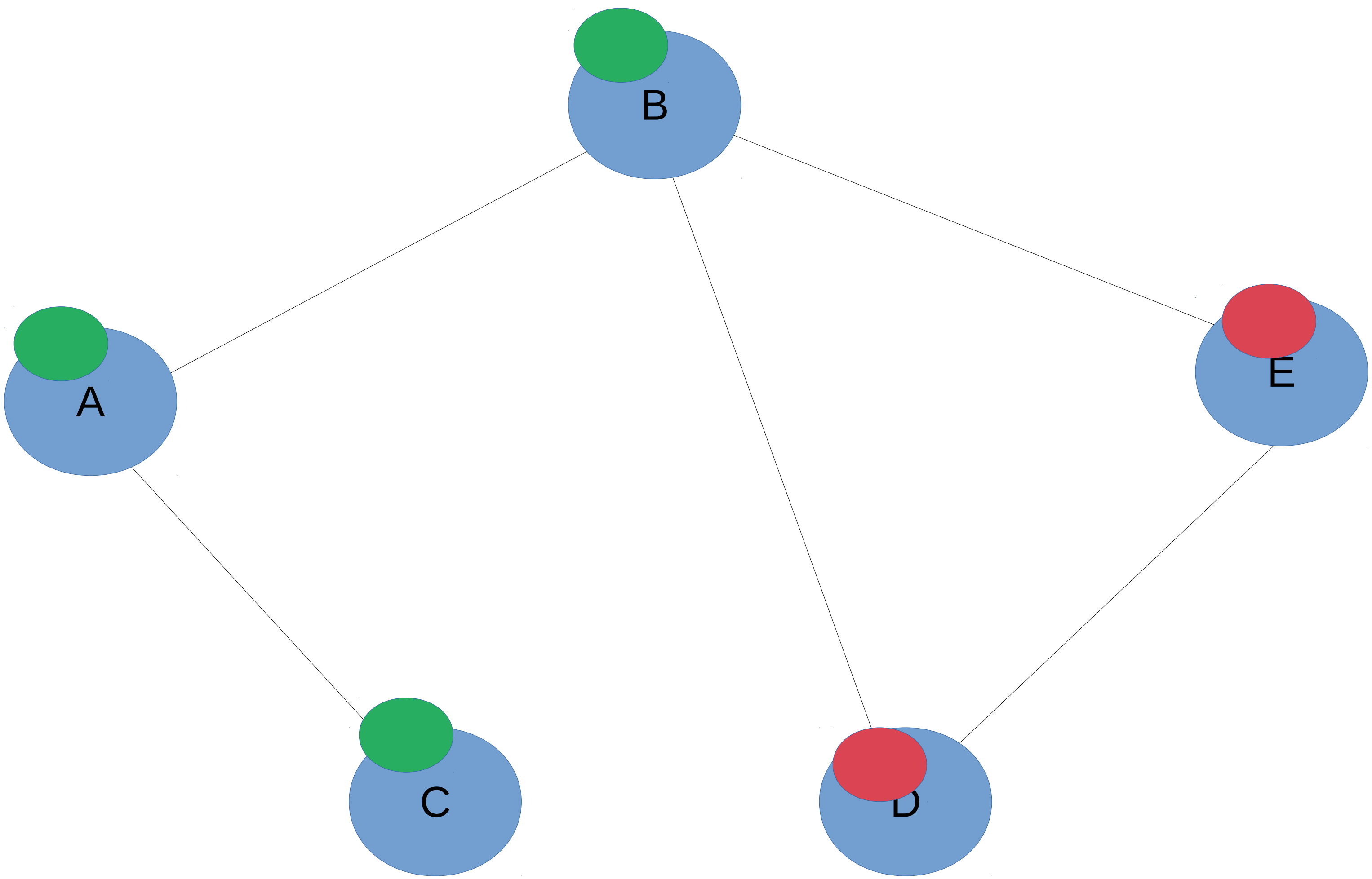
A has a message to send

“Gossiping” messages



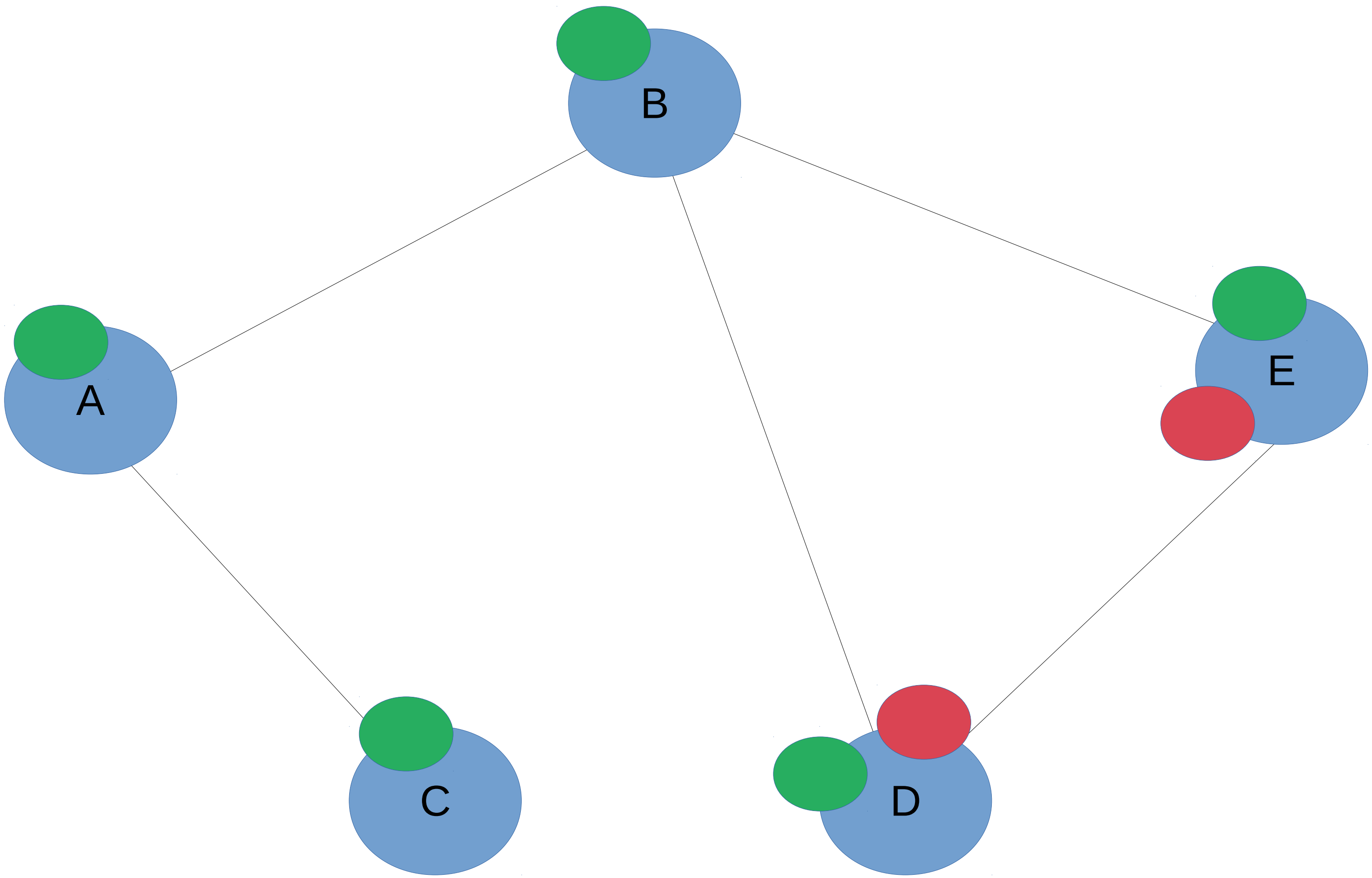
It forwards to all its neighbors

“Gossiping” messages



They do the same
Optimization 1: Ignore neighbor that sent original message

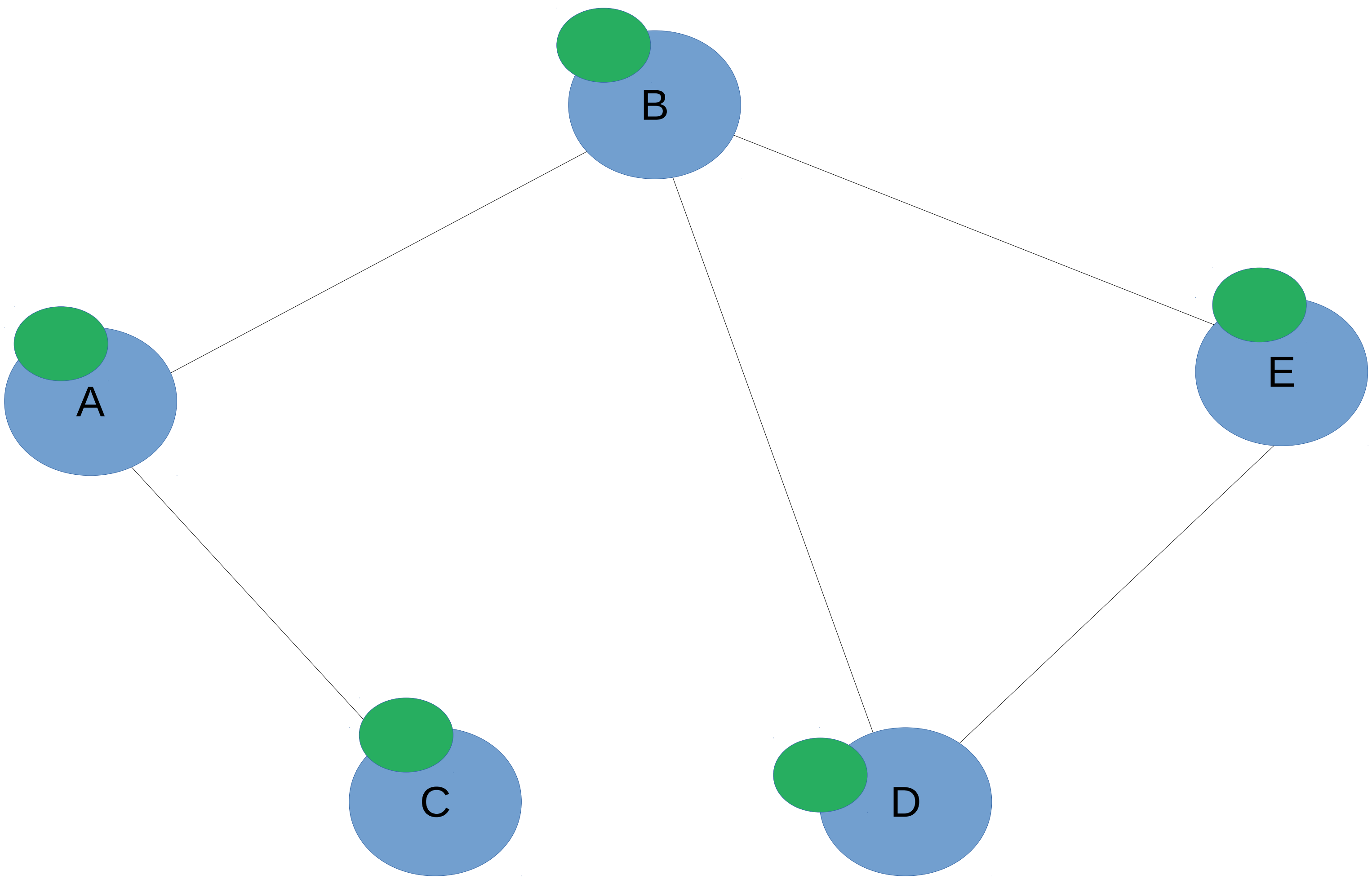
“Gossiping” messages



D and E forward.

Optimization 2: Ignore messages you already saw.

“Gossiping” messages



System is stable: All parties have received the message.

Let’s use Gossip for Link State Routing!

- Each node in the network forwards it’s current configuration (i.e. list of neighbors using gossip)

- Once a node receives a new message, it runs Dijkstra to find optimal route

- Simplification: All edges have weight 1

  → But your Dijstra implementation needs to work with other weights too

Message Handling

Two ways to receive messages:

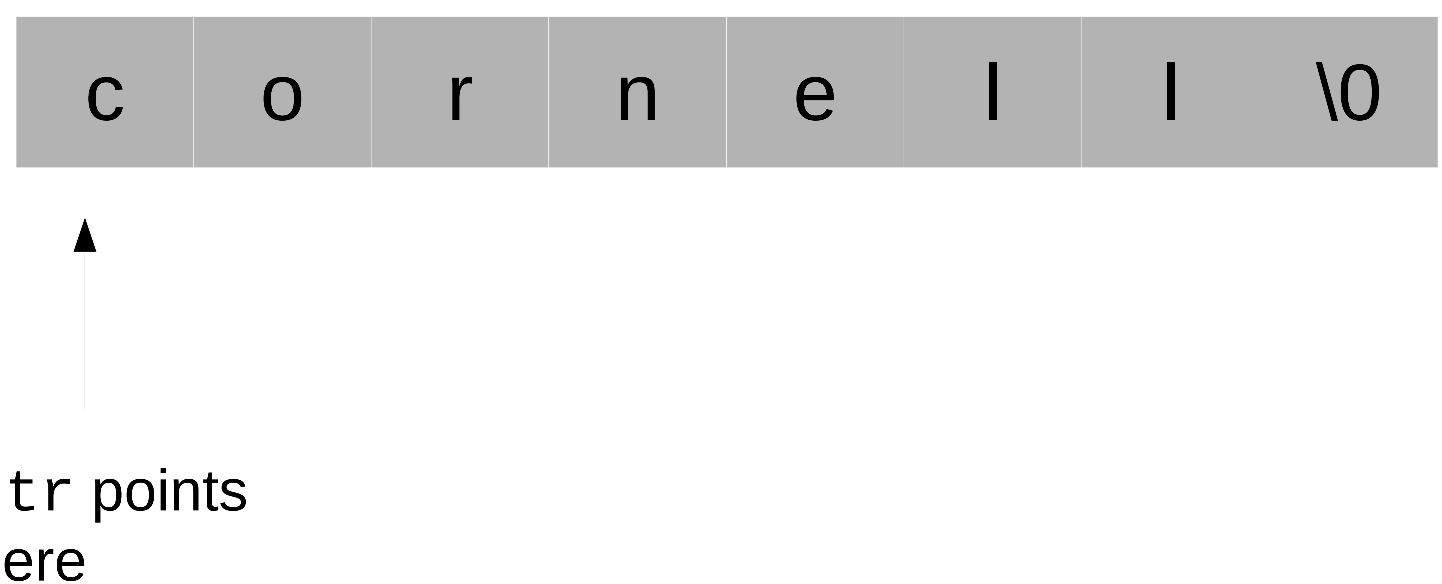
- Through user input in a command prompt (i.e., you type the messages in the console)
- As a network package from another node

All messages use a simple plaintext protocol*

*That is probably not something you want to do for a serious project but sufficient for Prac

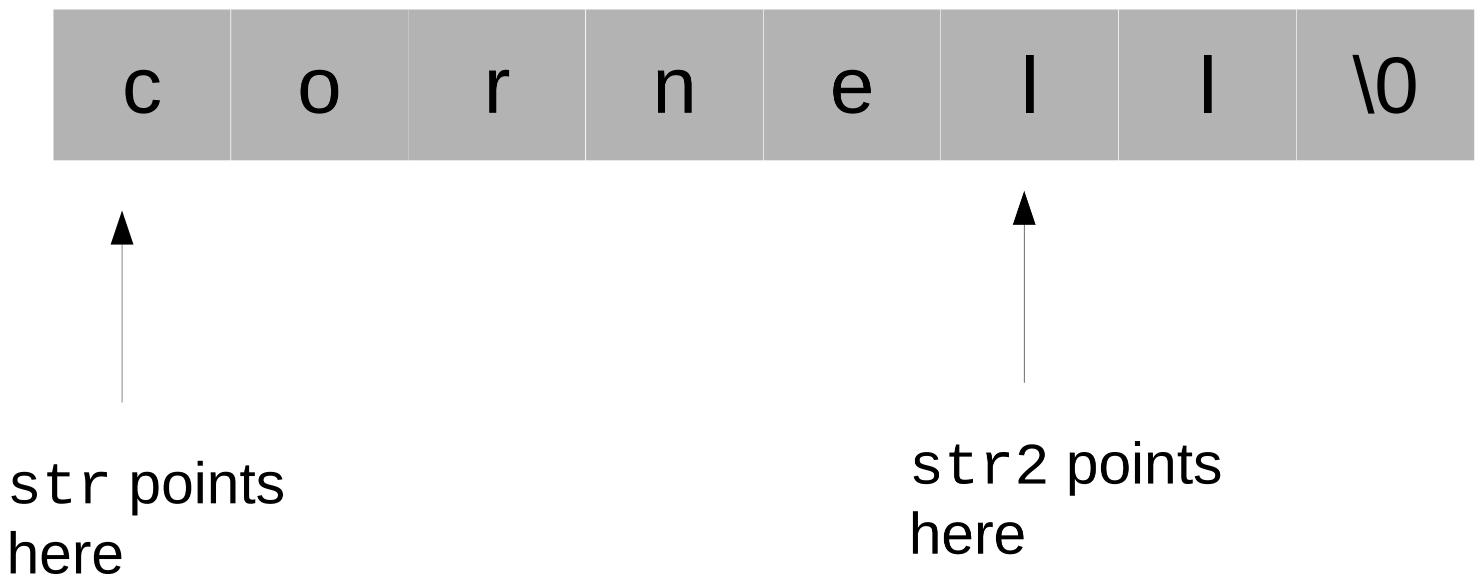
Strings in C

```
char *str = “cornell”;
```



Strings in C

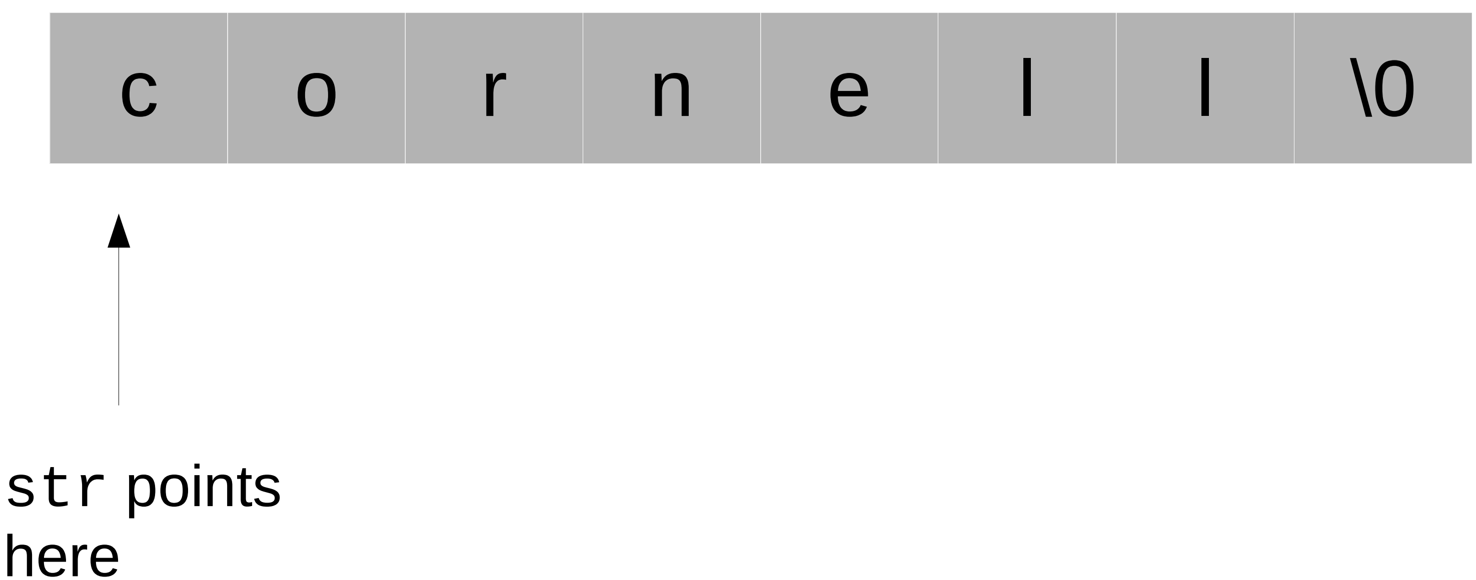
```
char *str = “cornell”;
char *str2 = str+5;
```



Note: Make sure you don’t overflow your buffer. strlen() is your friend!

Array Semantics on C Strings

```
char *str = “cornell”;
char c1 = str[3];
char c2 = *(str+1);
```



Comparing string in C

```
char *str1 = “foo”;
char *str2 = “foo”;
char *str3 = “fo”;
```

What is the difference? Which of those is true?

- `str1 == str2`
- `str1[2] == str2[2]`
- `strcmp(str1, str2, strlen(str1)) == 0`
- `strcmp(str1, str3, strlen(str3)) == 0`
- `strcmp(str1, str3, strlen(str1)) == 0`

Telling a node to do stuff

```
C<addr>:<port>\n
```

- Connect to the specified address

```
S<dst_addr:port>/<TTL>/<payload>\n
```

- Send data over the network
- TTL specifies maximum number of hops
- Payload is the actual content of the message

Gossip protocol

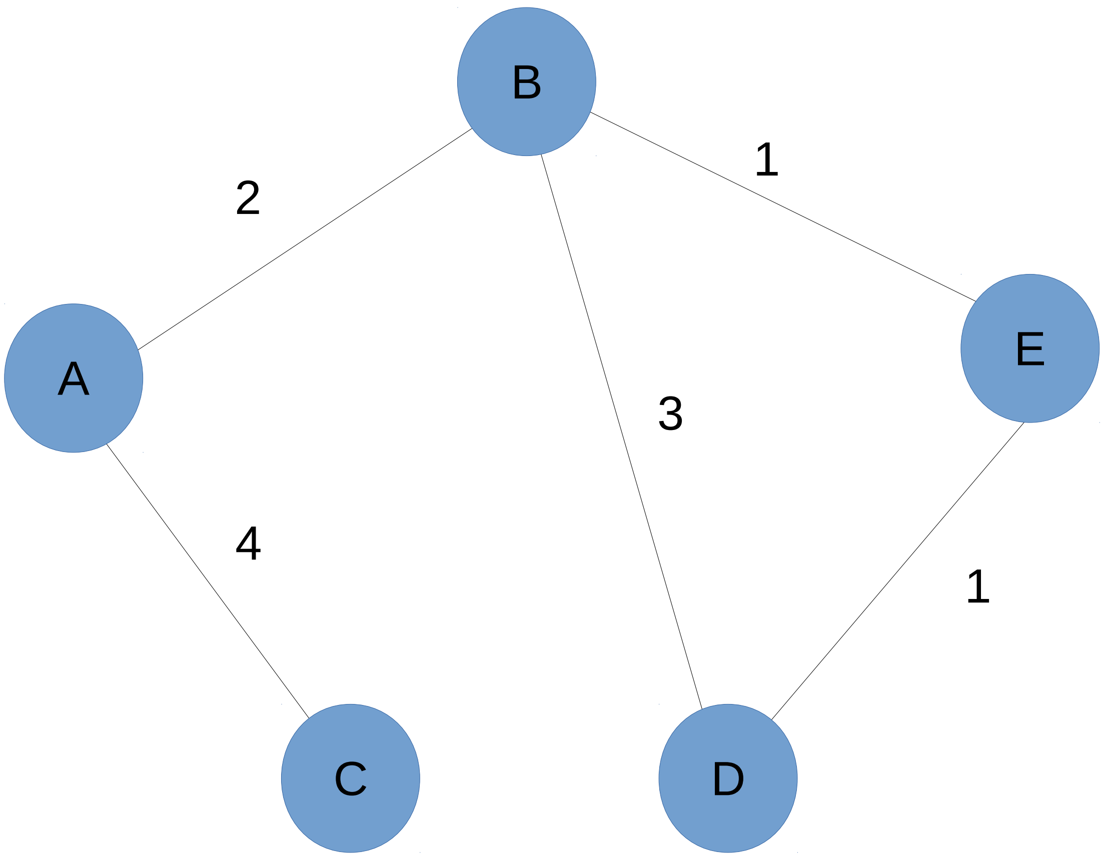
```
G<src_addr>:<src_port>/<counter>/<payload>\n
```

- Counter is a message ID used to detect duplicate messages
- It should increase with every new gossip message

Where the payload is the list of neighbors:

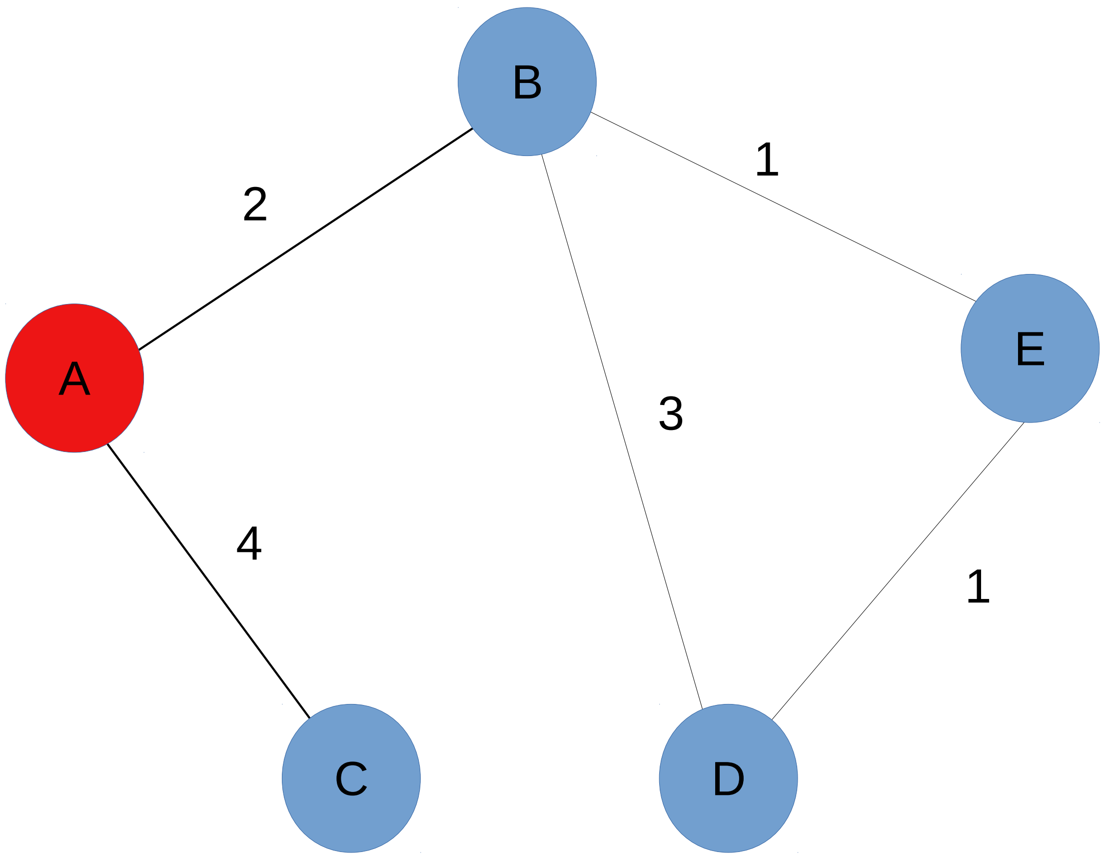
```
;<addr1:port1>;<addr2:port2>;<addr3:port3>...
```

Dijkstra's Algorithm
(from A's point of view)



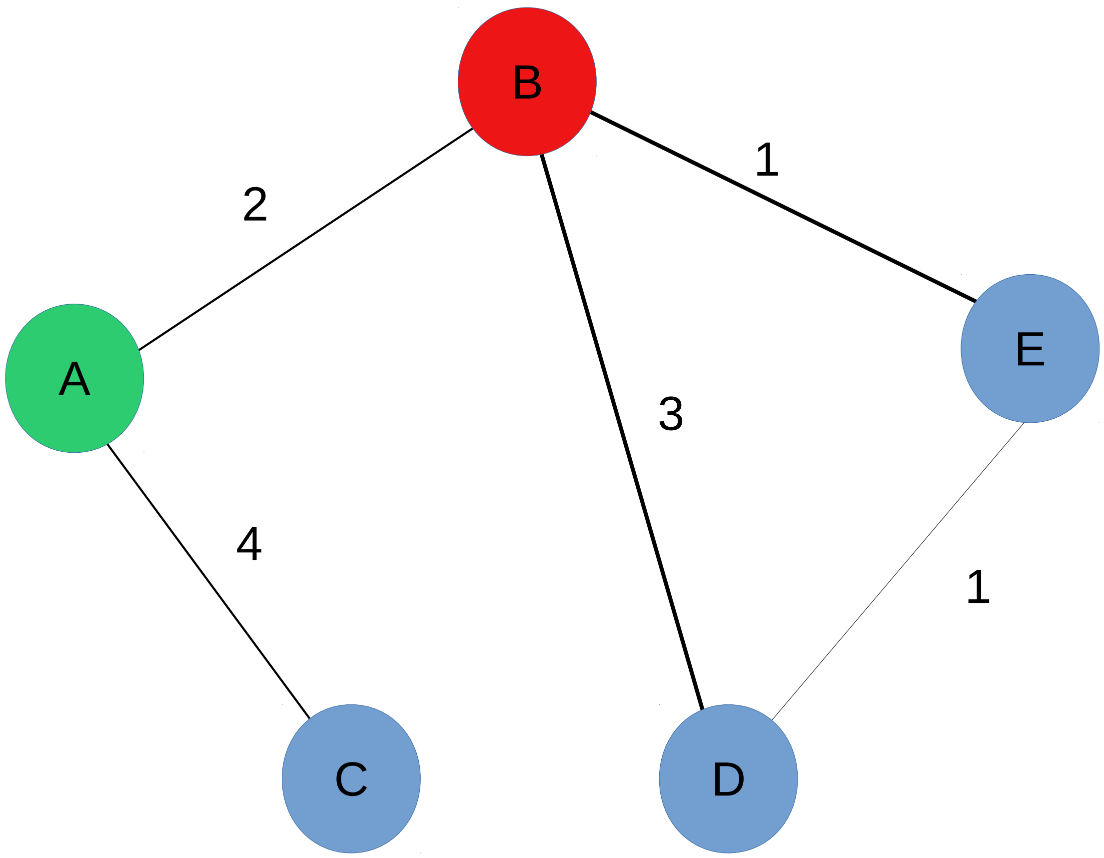
Target	Distance	Route
A	0	
B	∞	
C	∞	
D	∞	
E	∞	

Dijkstra's Algorithm
(from A's point of view)



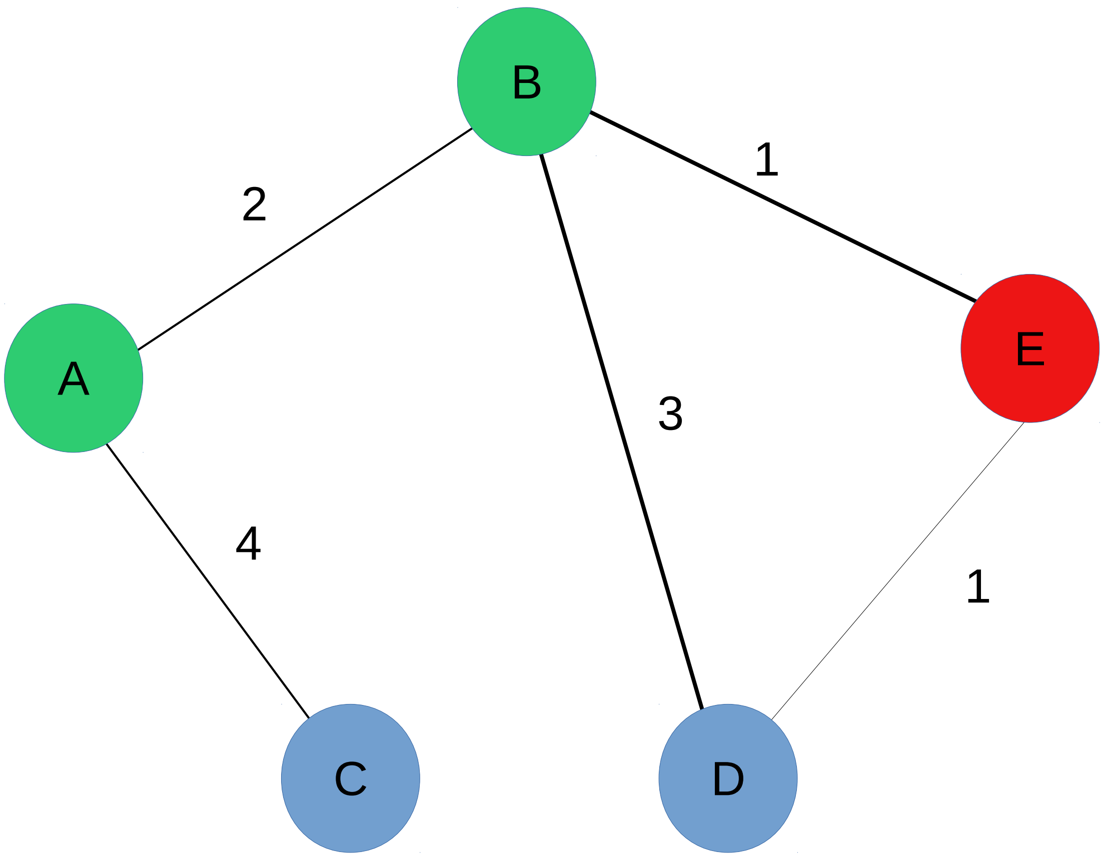
Target	Distance	Route
A	0	empty
B	**2**	**B**
C	**4**	**C**
D	∞	
E	∞	

Dijkstra's Algorithm
(from A's point of view)



Target	Distance	Route
A	0	empty
B	2	B
C	4	C
D	**5**	**B→D**
E	**3**	**B→E**

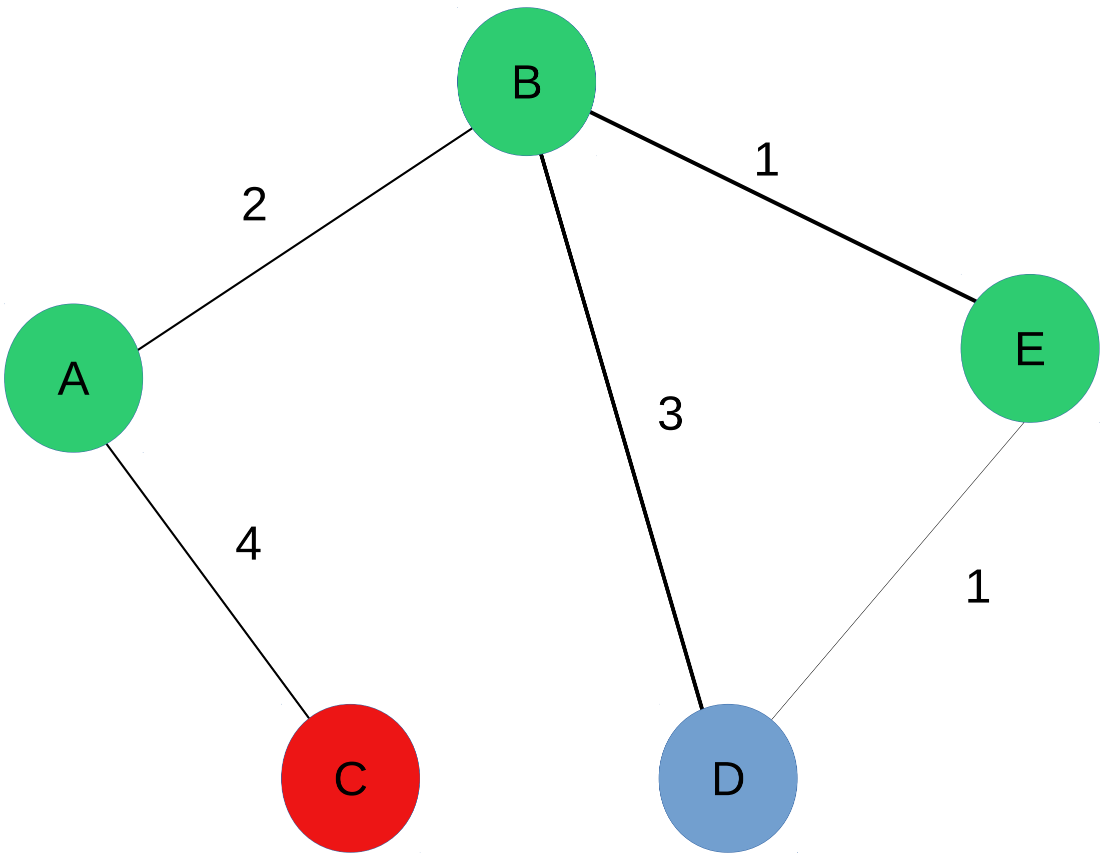
Dijkstra's Algorithm
(from A's point of view)



We found a shorter route to D!

Target	Distance	Route
A	0	empty
B	2	B
C	4	C
D	**4**	**B→E→D**
E	3	B→E

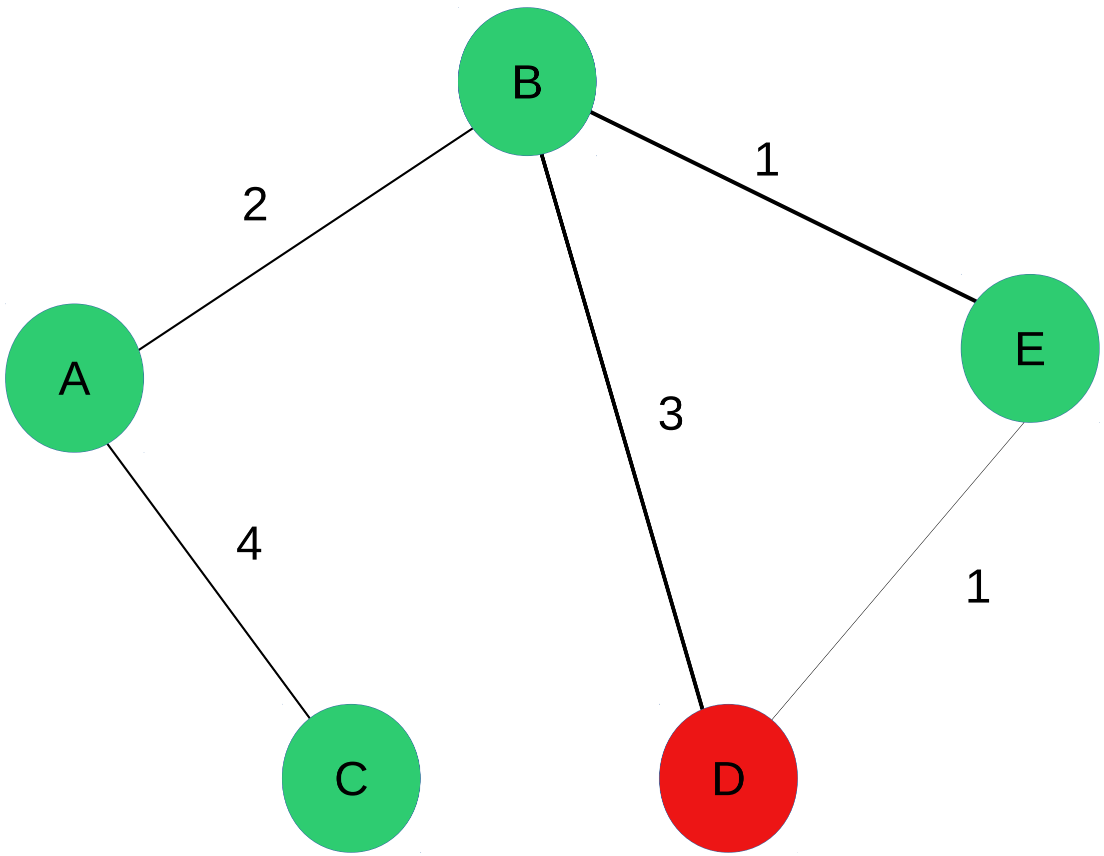
Dijkstra's Algorithm
(from A's point of view)



No change!

Target	Distance	Route
A	0	empty
B	2	B
C	4	C
D	4	C→E→D
E	3	C→E

Dijkstra's Algorithm
(from A's point of view)



Target	Distance	Route
A	0	empty
B	2	B
C	4	C
D	4	B → E → D
E	3	B → E

No change and done!

How to approach the project

- Start by reading the skeleton code
  - You can modify it but it is a good point to start with
- Optional: Write some “unit tests” for your Dijkstra implementation
- Try to get connections between two peers to work.
- Then figure out the rest...

Don’t forget to test!

- Can you successfully connect a network of nodes?
  - They can all run on the same VM
- Do your routes reconfigure once a node (dis-)connects?
- Can you successfully send messages using the established routes?

Questions?