SSL and CGI and Everything else

15-441: Computer Networks

Yours Truly

Based on Slides By "Generations of TAs"

P1 Final Submission

(1) SSL

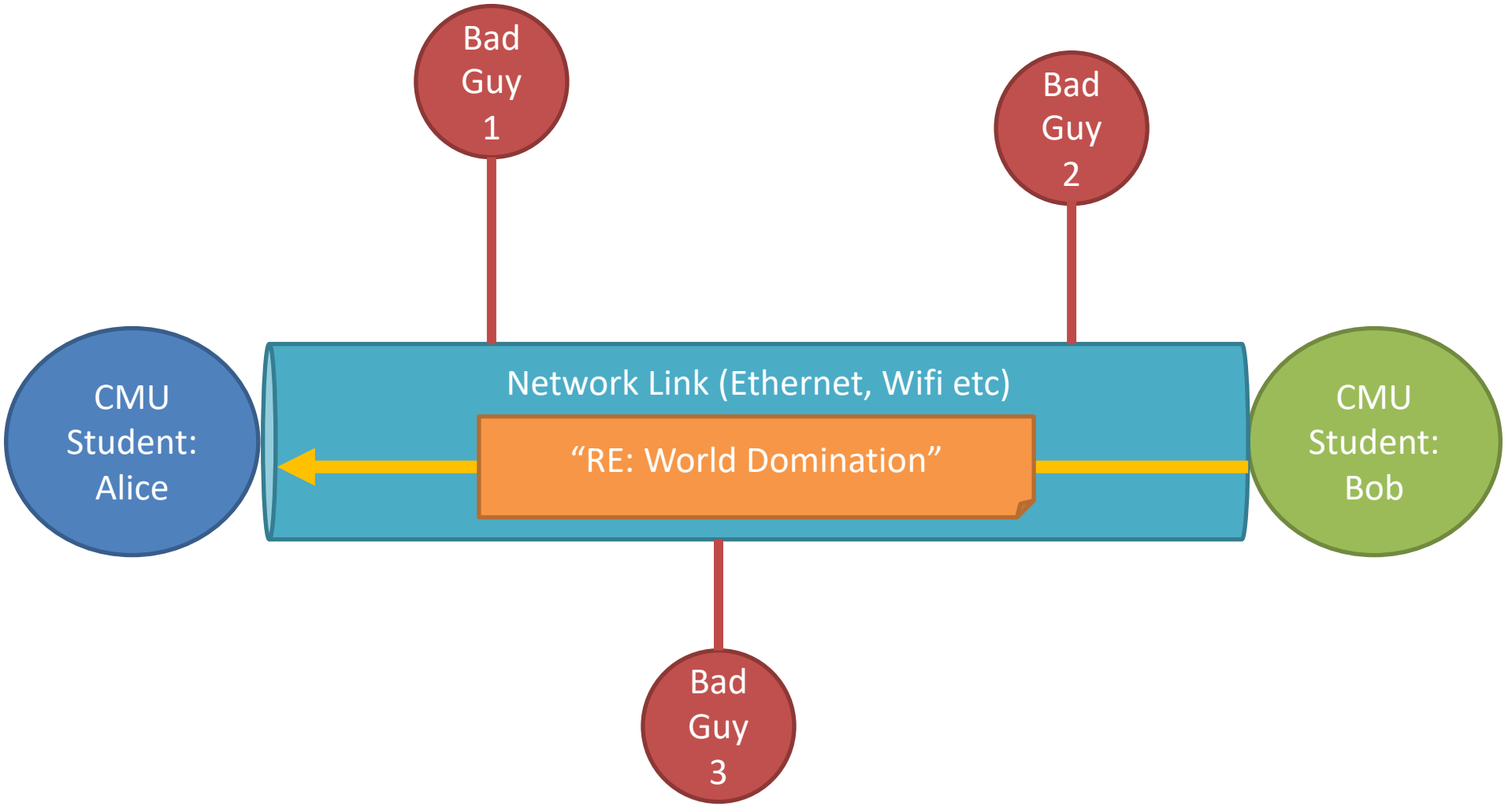
(2) CGI

(3) Daemonize

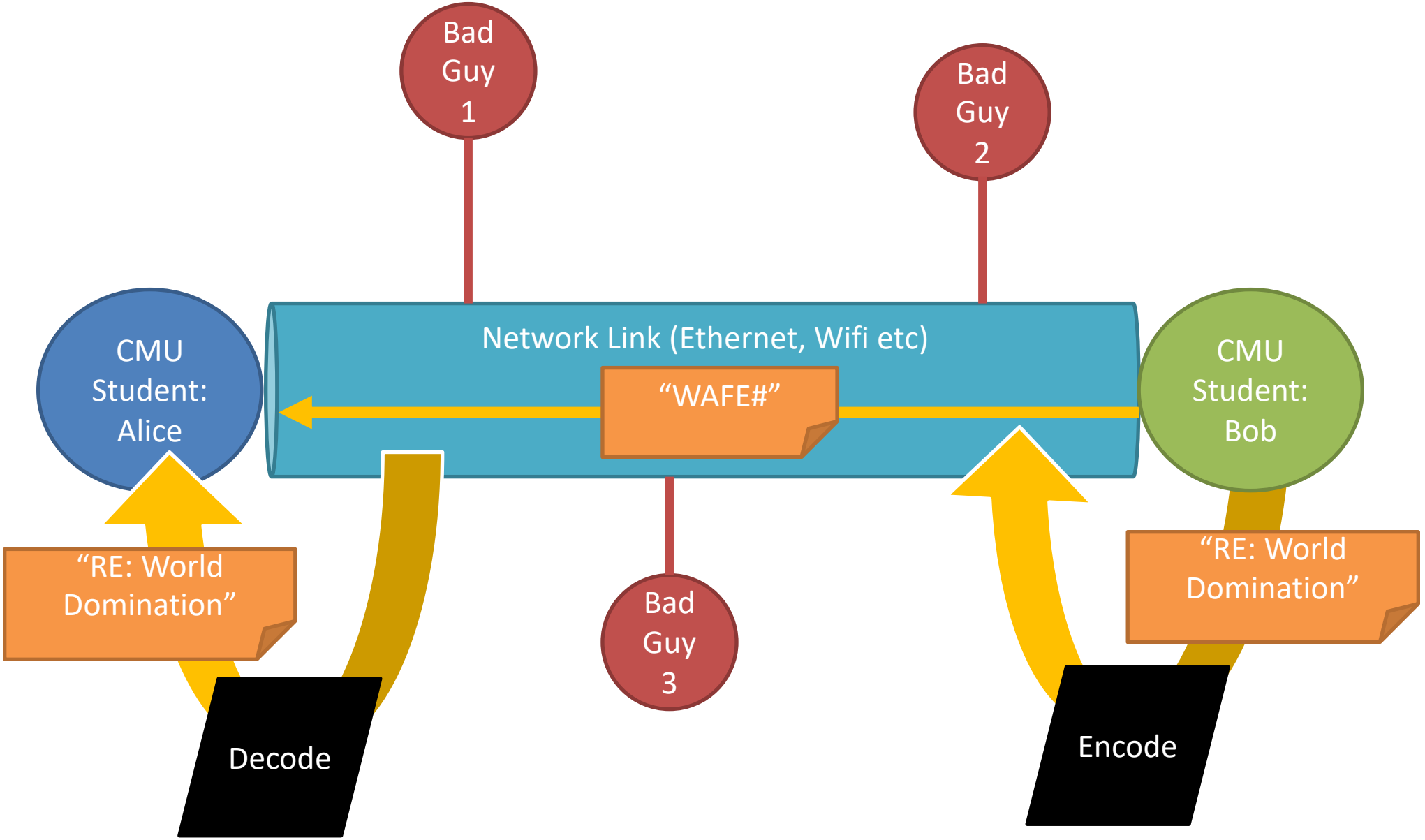
SSL

Adding the "S" in HTTPS

Lets talk about Security



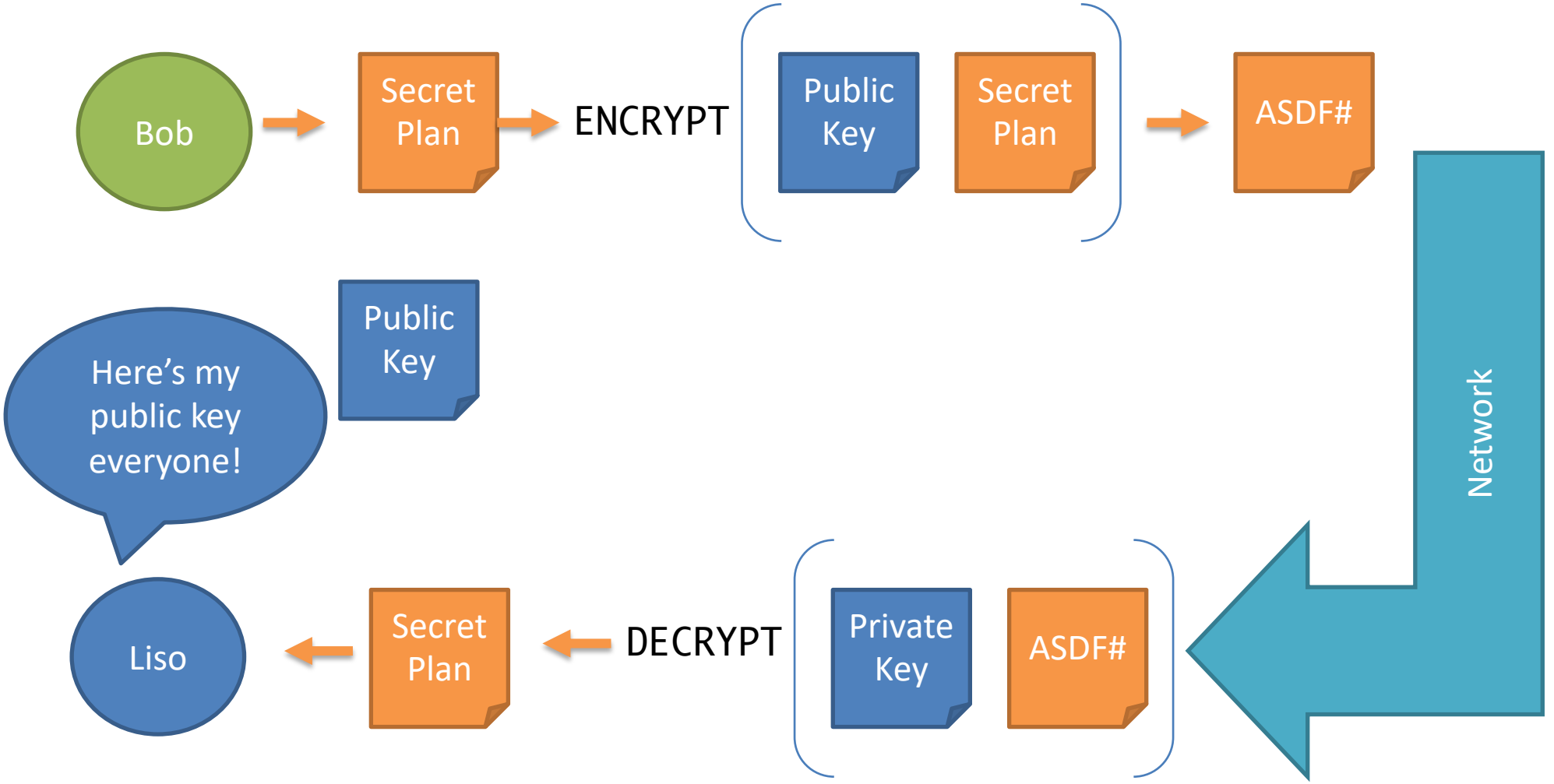
Lets talk about Security



Public-Private Key Encryption

1. Generate two keys – **Private Key** and **Public Key**
2. Messages can be **encrypted** using the **Public Key**
3. Messages can be **decrypted** using the **Private Key**
4. Everyone knows my public key – that's why it's "public"
5. Only I know my private key - that's why it's "private"

Public-Private Key Encryption



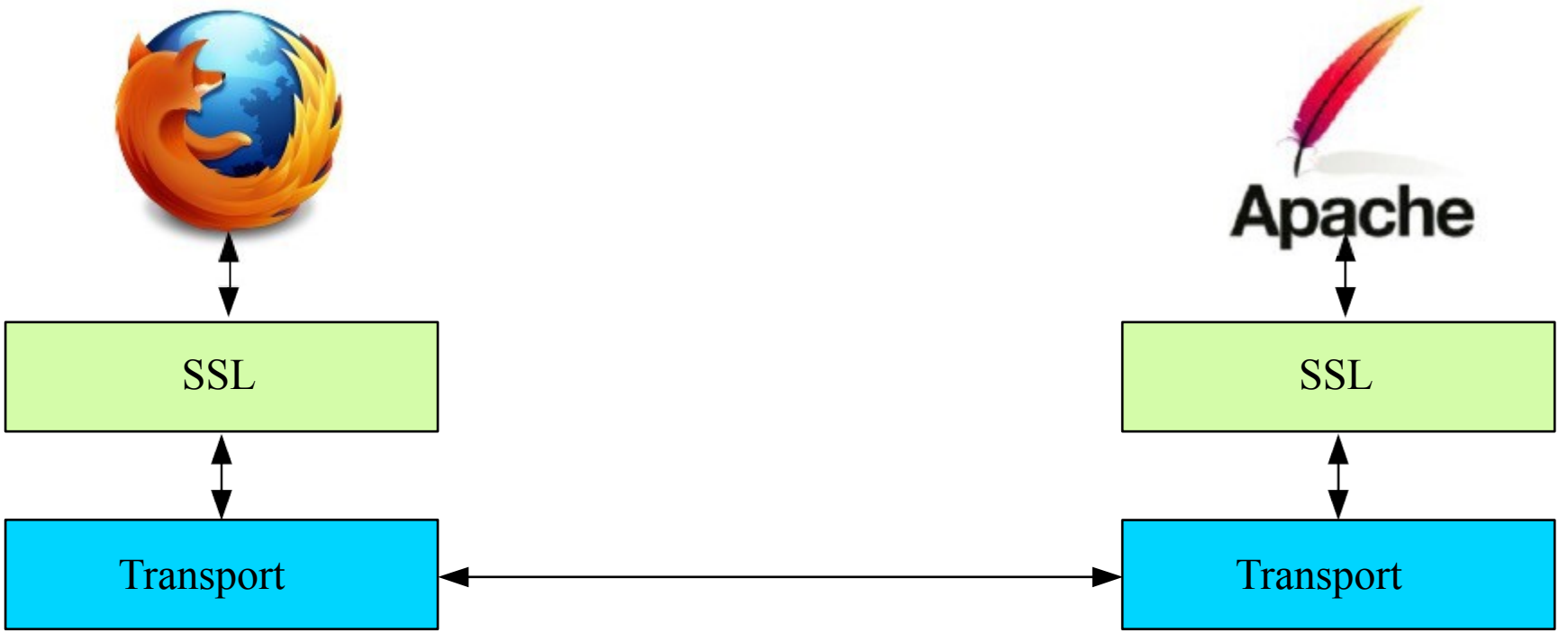
Implementing an...

SSL Server

What is SSL?

- Standard behind secure communication on the Internet.

- Provides confidentiality & integrity
- Sits between transport & application



Implementing SSL: Getting the files

1. Get free domain name from www.noip.com

2. Get the public certificate file and private key file from https://project1.myheartisinthenetwork.com

Extra slides at the end will have more detailed info on how to go about this…

Implementing SSL: Coding

1. Look at the provided SSL Example code and learn how to wrap a connection with SSL
2. Modify your server to take in a HTTPS port
3. Bind socket to this port and add it to your select read_fds
4. When you get a new connection on this port, accept connection, wrap it in SSL
5. Do the rest as usual, but read and write using SSL_read and SSL_write functions

CGI

What is CGI?

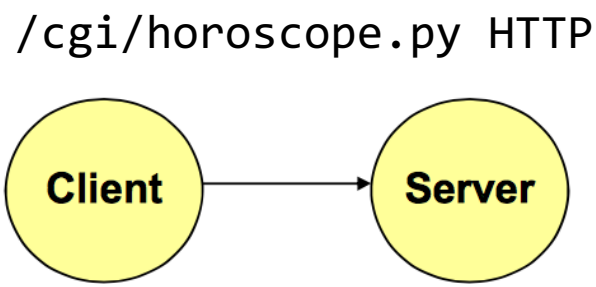
- A standard method used to generate dynamic content on Web pages and Web applications.

- Provides an interface between the Web server and programs that generate the Web content.

- Usually written in a scripting language.

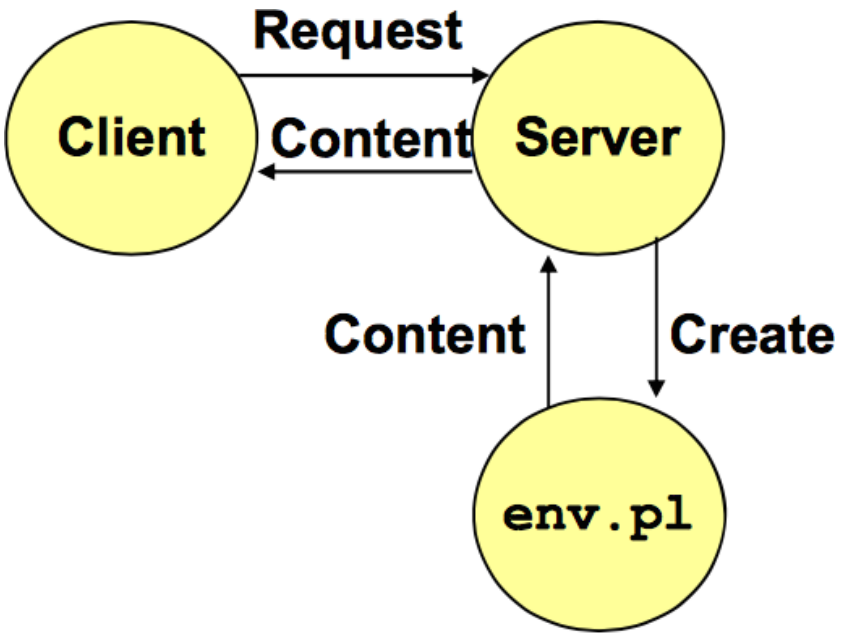
Serving Dynamic Content

- A Web server that supports CGI can be configured to interpret a URL that it serves as a reference to a CGI script.
- A common convention is to have a `cgi/` directory containing the CGI scripts.



- The server forks a child process and runs the program identified by the URI in that process.

- The server captures the content of the child and forwards it without modification to the client.



How does the client pass arguments to the server?

- GET: The arguments are appended to the URI can be encoded directly in a URL typed to a browser or a URL in an HTML link.
  - A question mark appended to the URL, followed by param=value pairs.
  - e.g. http://name.com/cgi/find?first=justine&last=sherry

- POST: The arguments are passed in the request body.
  - e.g. name="mark"

How does the server pass arguments to the cgi program?

- Environment Variables
  - set before execution.
  - passed through execve.
  - list of required environmental variables is available on the writeup
- Request body
  - request body passed to the cgi program's stdin using dup2 and pipe

Implementing CGI: Coding

1. Check if URI starts with "/cgi/"
2. Parse the args in the URI
3. Fork a child
4. Set environment variables
5. Execute script
6. Pass in request body from parent through pipe
7. Add child -> parent pipe to select loop
8. Pass on everything you get from the child, back to the client…you are now a proxy (cue 213 flashbacks)

Daemonizing

What is a daemon?

- A background process that is supposed to run "forever"
- Does not exit when you exit the terminal
- Does not receive any input from or write to stdin/out
- Hard to observe or accidentally kill
- We want liso**d** to be a daemon, that's what the "d" was for all along
- We provide most of the code for daemon-izing so don't worry

Extras

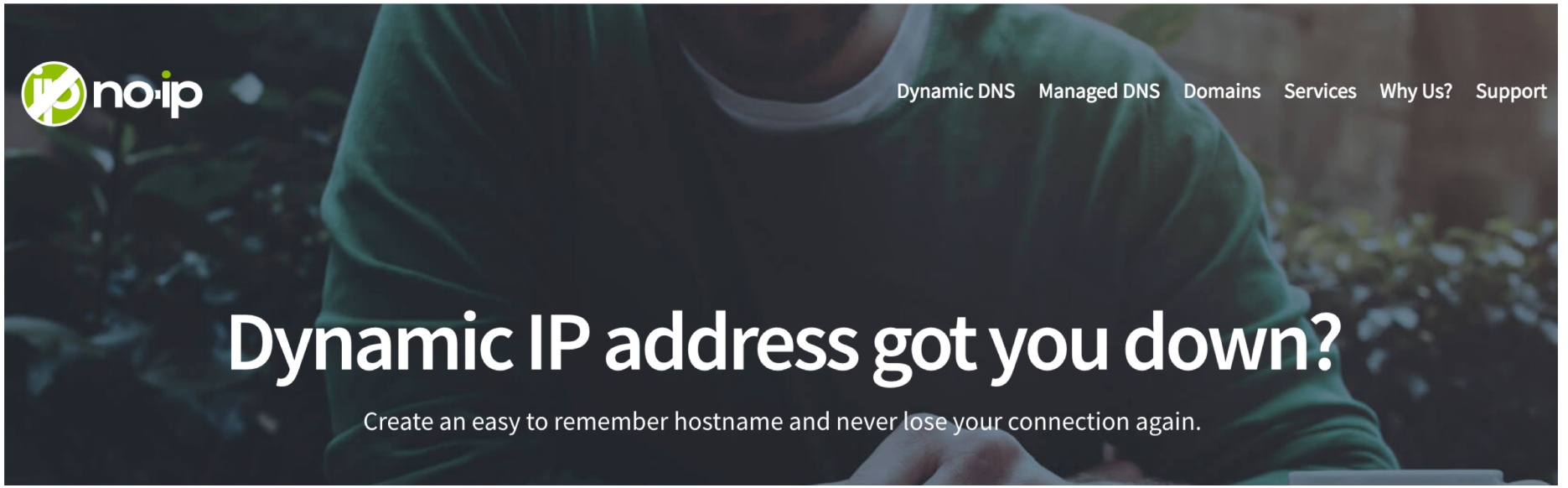
Look at handout for SSL examples, CGI code, and daemonize.c

Getting a...

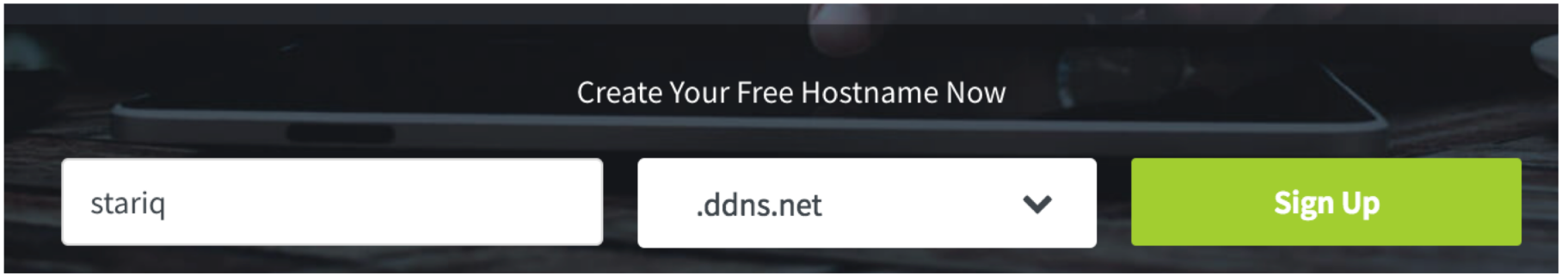
Domain Name

Create a Domain Name

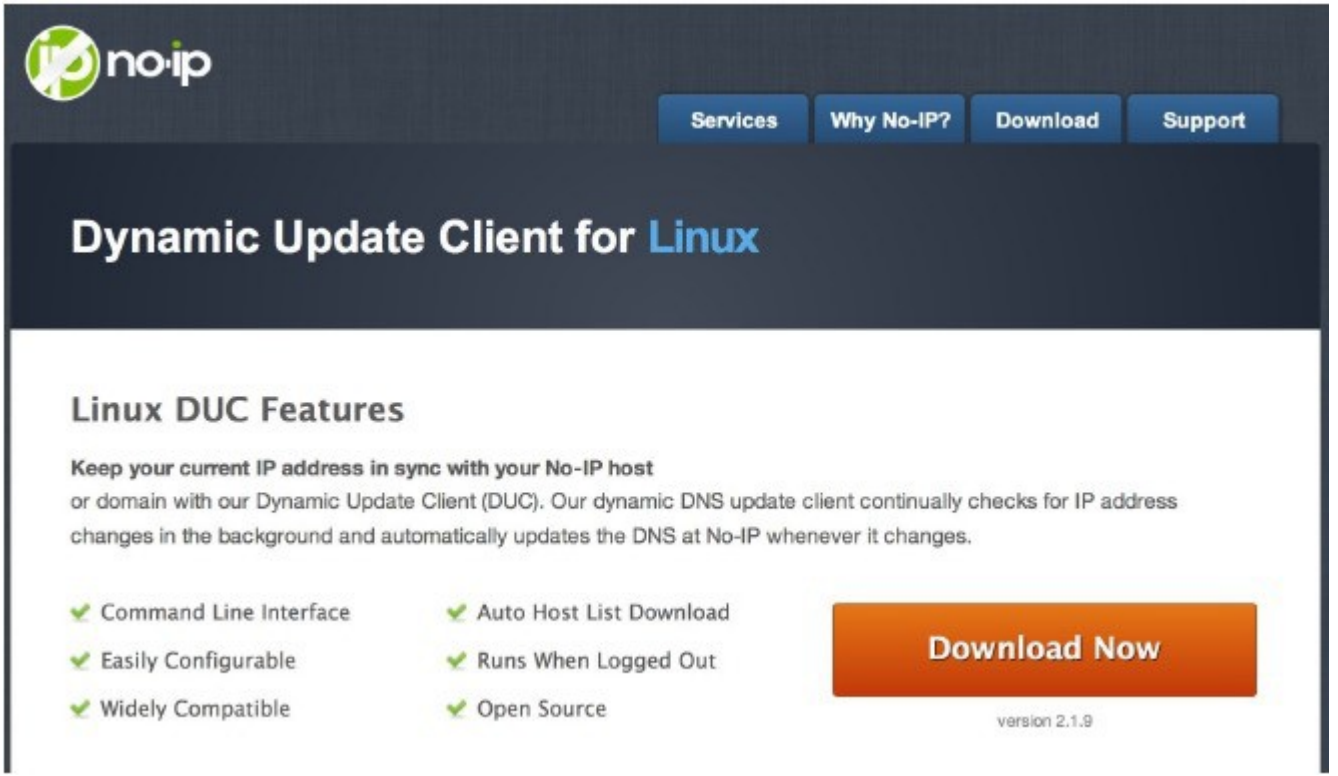
- Get a free domain name from https://www.noip.com/



- Use your Andrew ID as the hostname



Get the Update Client



- You don't have root, so...
  - Just build (make), don't install (make install)
  - Run manually when your IP changes

Create No-IP Conf File

./noip2 -C -c noip.conf

[stariq@unix3 ~/noip-2.1.9-1]$ **./noip2 -C -c noip.conf**

Auto configuration for Linux client of no-ip.com.

Please enter the **login/email** string for no-ip.com **<username>**

Please enter the **password** for user '<username>' *******************

Only one host [stariq.ddns.net] is registered to this account. It will be used.

Please enter an update interval:[30]

Do you wish to run something at successful update?[N] (y/N)

New configuration file 'noip.conf' created.

Update Your IP Address

./noip2 -c noip.conf -i 108.17.82.243

[stariq@unix3 ~/noip-2.1.9-1]$ ./noip2 -c noip.conf -i 108.17.82.243 IP address detected on command line.

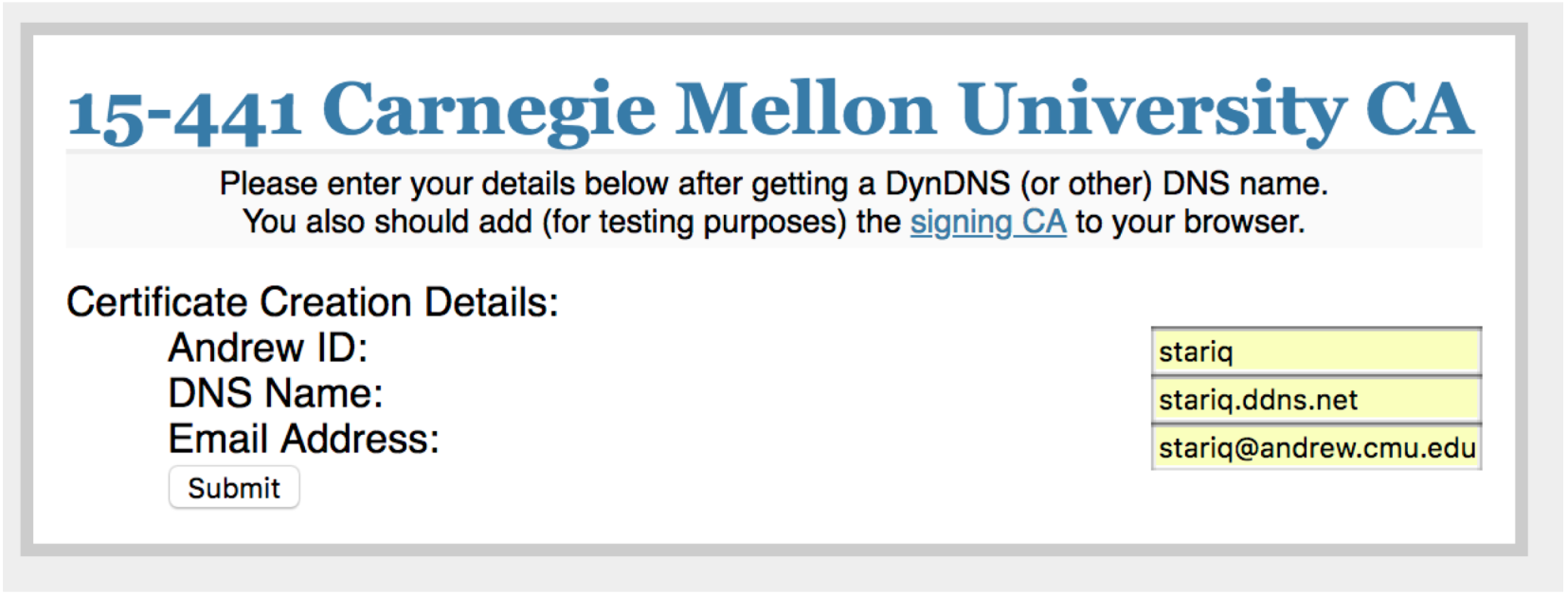
Running in single use mode.

Getting ...

Keys

Get your public certificate and private key

https://project1.myheartisinthenetwork.com



Get your public certificate and private key

SSL

Extra

OpenSSL Toolkit

- Command line tools, SSL library, and crypto library
- Can do a lot more than SSL
  - Message digests
  - Encryption and decryption of files
  - Digital certificates (more later)
  - Digital signatures
  - Random number generation

Open SSL headers

```
/*  OpenSSL  headers  */
#include  <openssl/bio.h>
#include   <openssl/ssl.h>
#include  <openssl/err.h>
```

SSL Server Basics

```
/*step 1: Initialize Library */
SSL_load_error_strings();
SSL_library_init();
/* Step 2: Initialize SSLContext to v1 */
ssl_context = SSL_CTX_new(TLSv1_server_method()))
/* Step 3: Add your private key to the context */
SSL_CTX_use_PrivateKey_file(ssl_context, "my.key",
                                        SSL_FILETYPE_PEM)
/* Step 4: Add your public key (certificate) to the context */
SSL_CTX_use_certificate_file(ssl_context, "my.crt",
                                         SSL_FILETYPE_PEM)
/* Step 5: Make a listening socket and wait for a connection */
/* Step 6: Accept an incoming connection */
 client_sock =accept(sock, (struct sockaddr *) &cli_addr,
          &cli_size))
/* Step 7: Create a new instance of the context for the client */
client_context = SSL_new(ssl_context)
/* Step 8: Wrap the client socket with TLS */
SSL_set_fd(client_context, client_sock)
/* Step 9: Finalize the SSL Connection */
SSL_accept(client_context)
/* Step 10: Add to the select loop like any other socket but
remember that this socket uses SSL*/
/* Step 11: Use SSL_read and SSL_write to receive and send data
SSL_read(client_context, buf, BUF_SIZE)
```

SSL Server Basics

```
    /* Step 7: Create a new instance of the context for the client */
    client_context = SSL_new(ssl_context)
    /* Step 8: Wrap the client socket with TLS */
    SSL_set_fd(client_context, client_sock)
    /* Step 9: Finalize the SSL Connection */
    SSL_accept(client_context)
    /* Step 10: Add to the select loop like any other socket but remember
that this socket uses SSL*/
    /* Step 11: Use SSL_read and SSL_write to receive and send data
    SSL_read(client_context, buf, BUF_SIZE)
    /* Step 12: Clean Up State
    SSL_shutdown(client_context);
    SSL_free(client_context);
    close_socket(client_sock);
    close_socket(sock);
    SSL_CTX_free(ssl_context);
```

Initialization Steps

- Global System Initialize
  - SSL_library_init()
  - SSL_load_error_strings()
- Initialize SSL_METHOD and SSL_CTX
  - meth=SSLv23_method();
  - ctx=SSL_CTX_new(meth);
- Loading keys
  - SSL_CTX_use_certificate_file(...)
  - SSL_CTX_use_PrivateKey_file(...)

Global Initialization

- SSL_library_init()
  - registers the available SSL/TLS ciphers and digests.
- SSL_load_error_strings()
  - Provide readable error messages.

SSL_METHOD

- To describe protocol versions
- SSLv1, SSLv2 and TLSv1

```
SSL_METHOD*  meth  =  TLSv1_method();
```

SSL_CTX

- Data structure to store keying material
- Reused for all connections; make ONE for your server

```
SSL_CTX*  ctx  =  SSL_CTX_new(meth);
```

SSL_CTX_use_certificate_file()

- Loads the first certificate stored in file into ctx.
- The formatting type of the certificate must be specified from the known types
  - SSL_FILETYPE_PEM
  - SSL_FILETYPE_ASN1.
  - Our CA generates files of PEM format

```
int   SSL_CTX_use_certificate_file(SSL_CTX  *ctx,
const  char  *file,  int  type);
```

SSL_CTX_use_PrivateKey_file()

- Adds the first private key found in file to ctx.
- The formatting type of the certificate must be specified from the known types:
  - SSL_FILETYPE_PEM
  - SSL_FILETYPE_ASN1.
  - Our CA generates files of PEM format

```
int SSL_CTX_use_PrivateKey_file(SSL_CTX *ctx, const
char *file, int type);
```

Wrapping Connections

- Create new SSL structure using SSL_new()
- Connect it to the socket using SSL_set_fd()
- Perform handshake using SSL_accept()
- Read and write using SSL_read() and SSL_write()
- Perform shutdown at the end, also need to clear state and close underlying I/O socket etc.
- As always, check for return value and handle errors appropriately!

SSL_new()

- Creates a new SSL structure
- Create one per connection
- Inherits the settings of the underlying context.

```
SSL*  ssl  =  SSL_new(ctx);
```

SSL_set_fd()

- Tell the SSL object which socket it will wrap

```
int  SSL_set_fd(SSL  *ssl,  int  fd);
```

SSL_accept

- SSL_accept - wait for a TLS/SSL client to initiate a TLS/SSL handshake

```
int  SSL_accept(SSL  *ssl)
```

- (Do this after a standard accept().)

SSL_read and SSL_write

- SSL_read to read bytes from a TLS/SSL connection

  ```
  int SSL_read(SSL *ssl, void *buf, int  num);
  ```

- SSL_write to write bytes to a TLS/SSL connection

  ```
  int SSL_write(SSL *ssl, const void *buf, int  num);
  ```

- NOTE:
  - The data are received in records (with a maximum record size of 16kB for SSLv3/TLSv1).
  - Only when a record has been completely received, it can be processed (decryption and integrity check)

SSL_shutdown

- Shuts down an active TLS/SSL connection.

```
int  SSL_shutdown(SSL  *ssl);
```

- (Then do a standard close().)

BIO - Optional

- I/O abstraction provided by OpenSSL
- Hides the underlying I/O and can set up connection with any I/O (socket, buFer, ssl etc)
- BIOs can be stacked on top of each other using push and pop!
- NOTE: You don't have to necessarily use BIO for this project! The next few slides describe creating BIO and working with it.

BIO_new()

- Returns a new BIO using method type.
- Check BIO_s_socket(), BIO_f_buffer(), BIO_f_ssl()
- Check BIO_new_socket()

```
BIO  *      BIO_new(BIO_s_socket());
BIO_set_fd(sbio,  sock,  BIO_NOCLOSE);
```

SSL_set_bio()

- Connects the BIOs rbio and wbio for the read and write operations of the TLS/SSL (encrypted) side of ssl

```
void SSL_set_bio(SSL *ssl, BIO *rbio, BIO *wbio)
```

Example of Stacking BIOs

```
  buf_io = BIO_new(BIO_f_buffer());
  /* create a buffer BIO */
  ssl_bio = BIO_new(BIO_f_ssl());
/* create an ssl BIO */
  BIO_set_ssl(ssl_bio, ssl, BIO_CLOSE);
/* assign the ssl BIO to SSL */
  BIO_push(buf_io, ssl_bio);
```

BIO_read() and BIO_write()

- Attempts to read len bytes from BIO b and places the data in buf.

  ```
  int BIO_read(BIO *b, void *buf, int len);
  ```

- Attempts to write len bytes from buf to BIO b.

  ```
  int BIO_write(BIO *b, const void *buf, int len);
  ```

Daemonizing

Extra

How to make a daemon?

- Start by making an orphan
- Fork the process to create a copy (child)

  Let parent exit!
- The child will become child of **init** process
  - Start operating in the background

```
int pid = fork();
if (pid < 0) exit(EXIT_FAILURE); /* fork error */
if (pid > 0) exit(EXIT_SUCCESS); /* parent exits */
/* child (daemon) continues */
```

Process Independence

- Process inherits parent's controlling tty; need to detach
- Server should not receive signals from the process that started it
- Operate independently from other processes

```
setsid()  /*obtain  a  new  process  group*/
```

Close File Descriptors

- Close all open descriptors inherited

```
int  i;
for  (i  =  getdtablesize();  i  >=  0;  --i)
        close(i);
```

- Connect standard I/O descriptors (stdin 0, stdout 1, stderr 2) to /dev/null

```
i  =  open("/dev/null",O_RDWR);                    /*  open  stdin  */
dup(i)  /*  stdout  */
dup(i)  /*  stderr  */
```

File Creation Mask

- Servers run as super-user
- Need to protect the files they create
- File creation mode is 750 (complement of 027)

```
umask(027);
```

Running Directory

- Server should run in a known directory

```
chdir(“/servers/”);
```

Mutual Exclusion

- We want only one copy of the server (file locking)
- Record pid of the running instance!
  - 'cat lisod.lock' more efficient than 'ps -ef | grep lisod'

```
lfp = open(lock_file, O_RDWR|O_CREAT, 0640);  if
(lfp < 0)
        exit(EXIT_FAILURE); /* cannot open */  if
(lockf(lfp, F_TLOCK, 0) < 0)
        exit(EXIT_SUCCESS); /* cannot lock */
sprintf(str, "%d\n", getpid());
write(lfp, str, strlen(str)); /*record pid to lockfile */
```

Logging

- You sent stdout and stderr to /dev/null, so you need to log to a file!