typedef RequestHandler = void (*)(char*, int)

Inside start_server

```
// http-server.c
typedef void (*RequestHandler)(char *, int);
void start_server(RequestHandler handler, int port) {

  char buffer[2048];

  ... set up on the given port ...

  while(1) {
      // not the real system call names
      int client = accept_connection_from_internet();
int bytes = read_from_internet(buffer, client);
      buffer[bytes] = '\0';
      (*handler)(buffer, client);   <- this calls "our" code
      close(client);
  }
}
```

your PA5 code

```
// string-server.c
void handle(char *request, int client) { /* all of PA5 */ }

int main() { start_server(&handle, 2900); }
```

```
interface RequestHandler {
    void handle(char[] req, int client);
}
class Server {
    static void start_server(RequestHandler handler,
                             int port) {
        while(1) {...
            handler.handle(buffer, client);
        }
    }
}
class PA5Handler implements RequestHandler {
    void handle(char[] req, int client) {...}
}
```

Reference: sscanf

Reads formatted data from a string — the inverse of `sprintf`.

```
char name[50]; int age;
sscanf("Alice 30", "%s %d", name, &age);
// name is "Alice", age is 30
// %s stops at whitespace
```

Reference: strstr

`strstr(haystack, needle)` returns a pointer to the first occurrence of `needle` in `haystack`, or `NULL`.

```
char *p = strstr("key=value", "=");
// p points to "=value"
// p + 1 points to "value"
```

HTTP Request and Response

A request from `curl "localhost:2900/add?s=hello"`:

```
GET /add?s=hello HTTP/1.1\r\n
Host: localhost:2900\r\n
User-Agent: curl/8.7.1\r\n
```

A response sent back with `write(client, ...)`:

```
HTTP/1.1 200 OK\r\n
Content-Type: text/plain\r\n
\r\n
...response body...
```

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Inside start_server

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      (*handler)(buffer, client);   <- this calls "our" code
      close(client);
  }
}
```

your PA5 code

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void handle(char *request, int client) { /* all of PA5 */ }

int main() { start_server(&handle, 2900); }
```

```
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    void handle(char[] req, int client);
}
class Server {
    static void start_server(RequestHandler handler,
                             int port) {
        while(1) {...
            handler.handle(buffer, client);
        }
    }
}
class PA5Handler implements RequestHandler {
    void handle(char[] req, int client) {...}
}
```

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```
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HTTP Request and Response

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A response sent back with `write(client, ...)`:

```
HTTP/1.1 200 OK\r\n
Content-Type: text/plain\r\n
\r\n
...response body...
```

Review Questions

1. Given the following request string:

```
char request[] = "GET /add?s=goodbye HTTP/1.1\r\nHost: localhost:2900\r\n";
```

Write code that extracts `"goodbye"` into a variable called `value`. Use any functions you want, but also refer to `sscanf` and `strstr` from the handout if needed!

```
char str[256];
sscanf(request, "GET /add?s=%s", str);
```

2. Given the following request string:

```
char request[] = "GET /add-number?n=367 HTTP/1.1\r\nHost: localhost:2900\r\n";
```

Write code that extracts the number `367` into an `int` variable called `n`.

```
int n;
sscanf(request, "GET /add-number?n=%d", &n);
```

3. Our http server gives an `int client` value to the handler. What is that value used for?

It is a file descriptor for a socket connected back to client

We use it with write write(client, data, len)

Inside start_server

```
// http-server.c "a pointer to a function w/2 args returns void..."
typedef void (*RequestHandler)(char *, int);
void start_server(RequestHandler handler, int port) {

  char buffer[2048];

  ... set up on the given port ...

  while(1) {
      // not the real system call names
      int client = accept_connection_from_internet();
int bytes = read_from_internet(buffer, client);
      buffer[bytes] = '\0';
      (*handler)(buffer, client);
      close(client);
  }
}
```

calls "our" code

```
// strong-server.c
void handle(char *request, int client) { /* all of PA5 */  }

int main() { start_server(&handle, 2900); }
```

```
interface RequestHandler {
    void handle(char[] req, int client);
}
class HTTPServer {
    static void startServer(RequestHandler h, int port) {
        ... port setup ...
        while(true) {
            ...
            h.handle(buffer, client);
            ...
        }
    }
}
-------------------------------------------------------------
class StrongServer implements RequestHandler {
    public void handle(char[] req, int client) { /* our code */ }
}
class Main {
    HTTPServer.startServer(new StrongServer(), 2900);
}
```

Reference: sscanf

Reads formatted data from a string — the inverse of `sprintf`.

```
char name[50]; int age;
sscanf("Alice 30", "%s %d", name, &age);
// name is "Alice", age is 30
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`strstr(haystack, needle)` returns a pointer to the first occurrence of `needle` in `haystack`, or `NULL`.

```
char *p = strstr("key=value", "=");
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```

HTTP Request and Response

A request from `curl "localhost:2900/add?s=hello"`:

```
GET /add?s=hello HTTP/1.1\r\n
Host: localhost:2900\r\n
User-Agent: curl/8.7.1\r\n
```

A response sent back with `write(client, ...)`:

```
HTTP/1.1 200 OK\r\n
Content-Type: text/plain\r\n
\r\n
...response body...
```

Program 4: Keeping state across requests

Goal is to have this kind of behavior:

```
$ curl "localhost:2900/add?s=hello"
hello
$ curl "localhost:2900/add?s=world"
hello
world
$ curl "localhost:2900/add?s=goodbye"
hello
world
goodbye
```

A server runs forever. Data that persists between requests can't live on the stack — it needs to be in global variables or on the heap.

What if **add_string** just stores the pointer?

```
void add_string(char *s) {
    strings[num_strings] = s;
    num_strings++;
}
```

Where does s "point to"?

What address?

some small offset into path[256]

likely overwritten on each call to handle (pointer into stack)

```
4  char *HTTP_200 = "HTTP/1.1 200 OK\r\nContent-Type: text/plain\r\n\r\n";
5  char *HTTP_404 = "HTTP/1.1 404 Not Found\r\nContent-Type: text/plain\r\n\r\n";
6
7  void send_404(int client, char *message) {
8      write(client, HTTP_404, strlen(HTTP_404));
9      write(client, message, strlen(message));
10 }
11
12 #define MAX_STRINGS 100
13
14 char *strings[MAX_STRINGS];
15 int num_strings = 0;
16
17 void add_string(char *s) {
18     if (num_strings >= MAX_STRINGS) { return; }
       char* str = malloc(strlen(s)+1);
       strcpy(str, s);
       strings[num_strings] = str;
21     num_strings++;
22 }
23
24 void respond_with_list(int client) {
25     write(client, HTTP_200, strlen(HTTP_200));
26     for (int i = 0; i < num_strings; i++) {
         write(client, strings[i], strlen(strings[i]));
28       write(client, "\n", 1);
29     }
30 }
31
32 void handle(char *request, int client) {
33     char path[256];
34     sscanf(request, "GET %s", path);
                          → copies into path
35
36     if (strncmp(path, "/add", 4) == 0) {
37         char *query_start = strstr(path, "?s=");
38         if (query_start) {
39             char *string_start = query_start + 3;
40             add_string(string_start);
41             respond_with_list(client);
42         } else {
43             send_404(client, "Missing ?s= parameter");
44         }
45     } else {
46         send_404(client, "Unknown path");
47     }
48 }
49
50 int main() { start_server(&handle, 2900); }
```

Review Questions

1. Given the following request string:

```
char request[] = "GET /add?s=goodbye HTTP/1.1\r\nHost: localhost:2900\r\n";
```

Write code that extracts **"goodbye"** into a variable called **value**. Use any functions you want, but also refer to **sscanf** and **strstr** from the handout if needed!

strstr(request, "s=")
... strtok ...

```
char str[256];
sscanf(request, "GET /add?s=%s", str);
```

2. Given the following request string:

```
char request[] = "GET /add-number?n=367 HTTP/1.1\r\nHost: localhost:2900\r\n";
```

Write code that extracts the number **367** into an **int** variable called **n**.

```
int n;
sscanf(request, "GET /add-number?n=%d", &n);
```

3. Our http server gives an **int client** value to the handler. What is that value used for?

"socket" abstraction for a connection to another computer or process

int client = file descriptor for a socket
a thing you can send + receive bytes to/from

write(client, buffer, len)
1 = stdout

Function Pointers: Java vs C

In Java, you pass behavior using an *interface*:

```
// http-server.java
interface RequestHandler {
  void handle(String request, int client);
}

class Server {
  static void startServer(RequestHandler handler, int port) {
    // server implementation
    ... handler.handle(requestFromClient, clientFileDescriptor);
        ...
  }
}
```

```
// string-server.java
class StringHandler implements RequestHandler {
    public void handle(String request, int client) { /* ... */  }
}
class Main {
  public static void main(String[] args) {
    Server.startServer(new StringHandler(), 2900);
  }
}
```

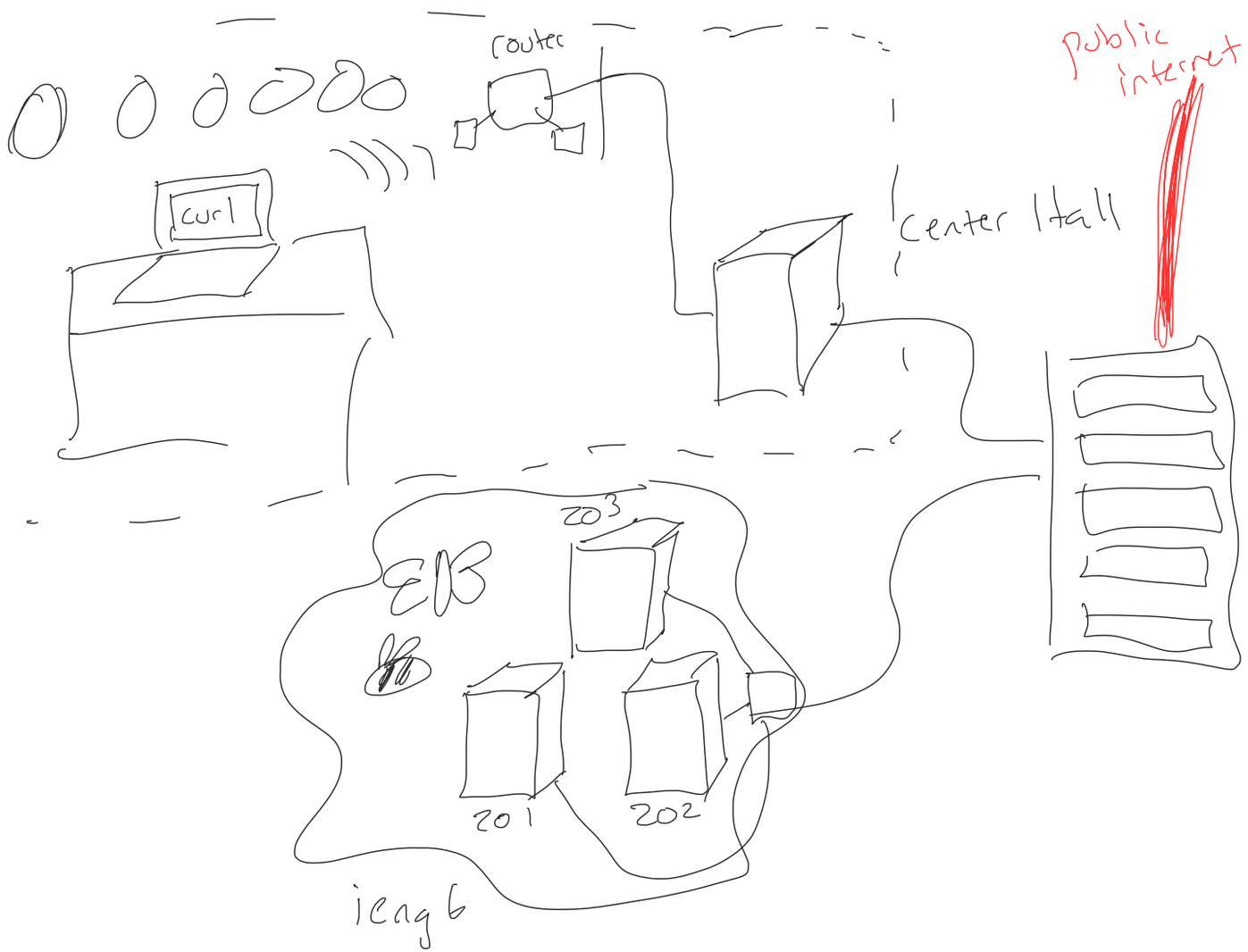
In C, there are no interfaces. We pass a *function pointer* — the address of a function. We can use a `typedef` to name the type to make it look more like Java:

```
// http-server.c
typedef void (*RequestHandler)(char *, int);

void start_server(RequestHandler handler, int port) {
    // server implementation
    ... (*handler)(request_from_client, client_file_descriptor); ...
}
```

```
// string-server.c
void handle(char *request, int client) { /* ... */  }

int main() { start_server(&handle, 2900); }
```

In Python, functions can be passed directly, which is more like C:

```
# http-server.py
def start_server(handler, port):
    ... handler(request_from_client, client_file_descriptor) ...

# string-server.py
def handle(request, client): ...

start_server(handle, 2900)
```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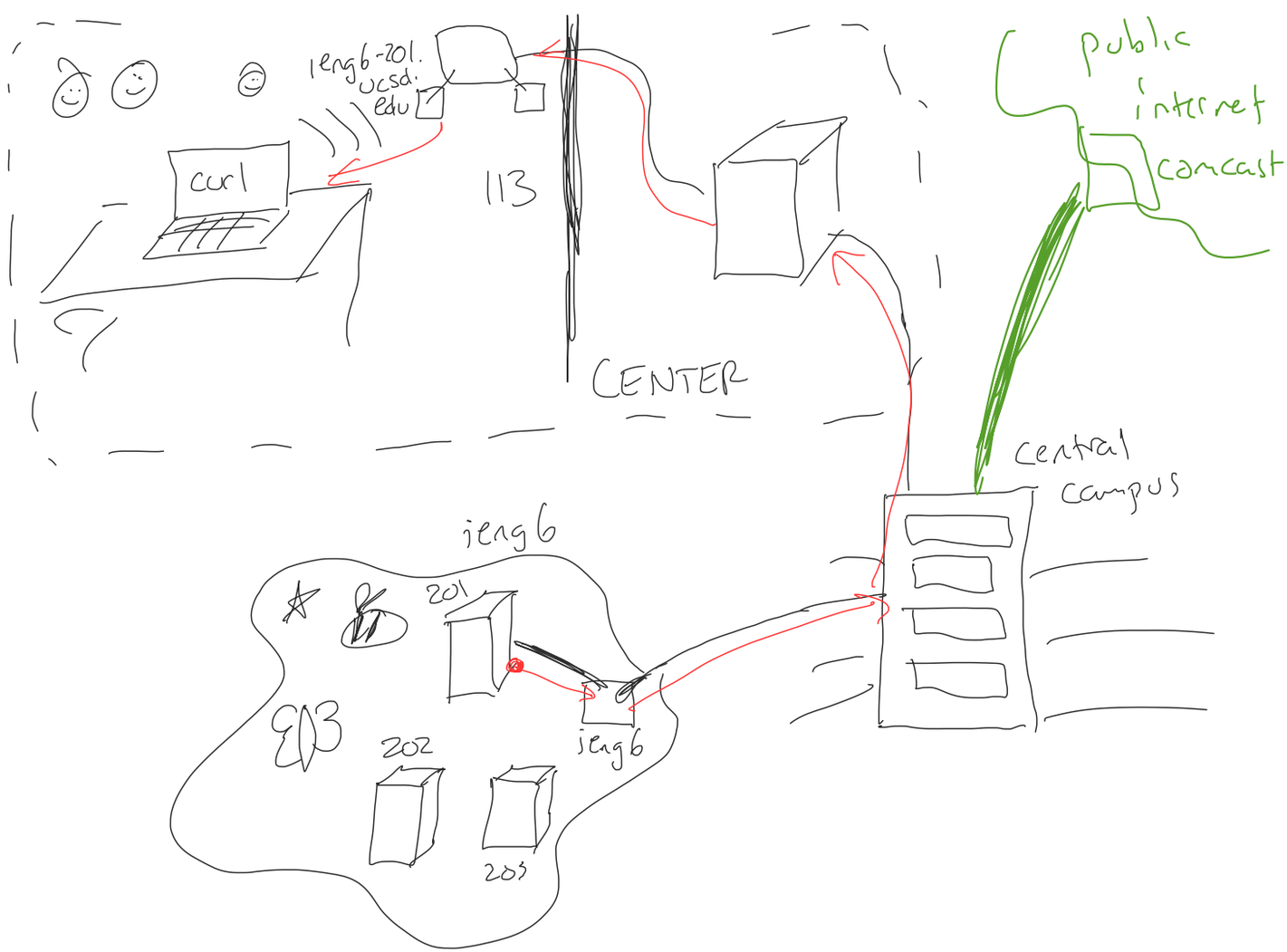
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