한국외국어대학교
HANKUK UNIVERSITY OF FOREIGN STUDIES

Internet of Things (IoT) Systems

Week 12

Raspberry Pi Programming

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OUTLINE

- Last Lecture Overview
- Controlling Raspberry Pi Sensors via the Internet
- Using Web Server and PHP

What We Want to Achieve

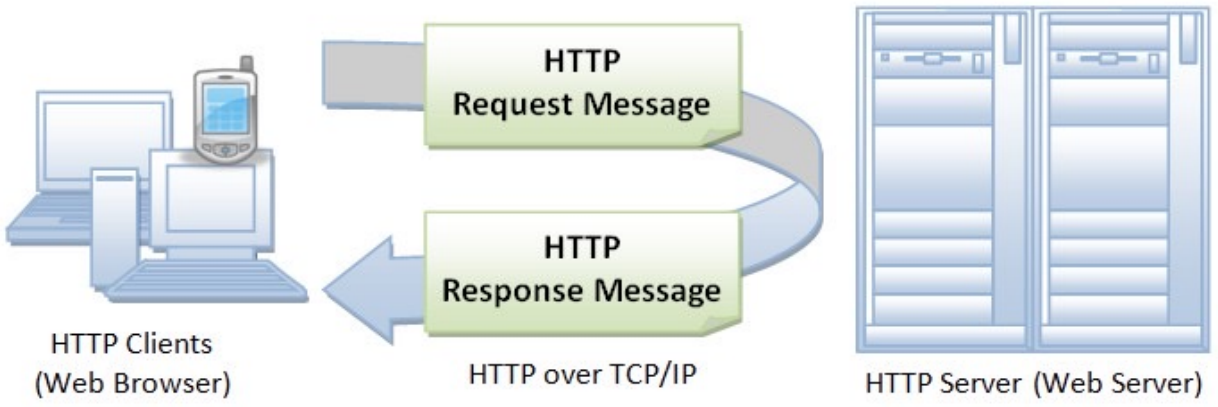
- Control different sensors from a phone or PC
- Build a web interface to send commands
  - Client: Web browser (PC or phone)
  - Server: Raspberry Pi
  - Protocol: HTTP
- **Goal:** Browser sends request → RPi executes command → sends back a response to the Client

What Tools Do We Need?

- HTML: HyperText Markup Language (for web pages)
  - HTML is used to **display contents on the client side**,
- Lighttpd: **light** + **tpd** (**t**hreaded **p**rocess-based **d**aemon) (web server)
  - lighttpd is used to **receive HTTP requests and serve web content**,
- PHP : **H**ypertext **P**reprocessor (server-side logic)
  - PHP is used to process the request and control sensors or generate responses,
- HTTP: **H**yper**T**ext **T**ransfer **P**rotocol (Communication Protocol)
  - HTTP is used to communicate between client (browser) and server (Raspberry Pi).
- GPIO: (Sensors and outputs)

HTTP

- HTTP is the communication protocol used to send and receive hypertext (HTML) documents on the Internet.
- HTTP functions as a request–response protocol in the client–server computing model
  - The client submits an HTTP request message to the server
  - The server returns a response message to the client



https://medium.com/@RayRay504/hypertext-transfer-protocol-http-6358be84964b

Overview of HTTP

- HTTP Requests
  - An HTTP request consists of a request method, a request URL, header fields, and a body
  - HTTP 1.1 defines the following request methods:
    - GET retrieves the resource identified by the request URL(page or file)
    - HEAD returns the headers identified by the request URL
    - POST sends data of unlimited length to the web server (login form)

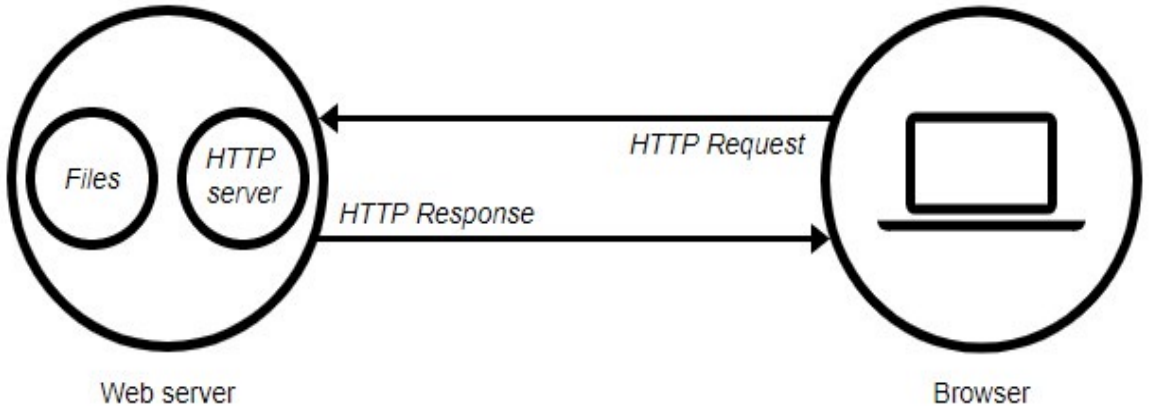
Method	Type of request (e.g., GET, POST)
URL	What resource is being requested (like /index.html)
Headers	Extra information (like browser type, language, cookies)
Body	Optional; usually used when sending form data (like login info)

Overview of HTTP

- HTTP Responses
  - An HTTP response contains a status code, header fields, and a body containing fetched resource
  - The HTTP protocol expects the result code and all header fields to be returned before any body content
  - Some commonly used status codes include:
    - 200 OK – Everything worked fine
    - 404 indicates that the requested resource is not available
    - 401 indicates that the request requires HTTP authentication
    - 500 indicates an error inside HTTP server which prevented it from fulfilling the request
    - 503 indicates that HTTP server is temporarily overloaded and unable to handle the request

Web Server

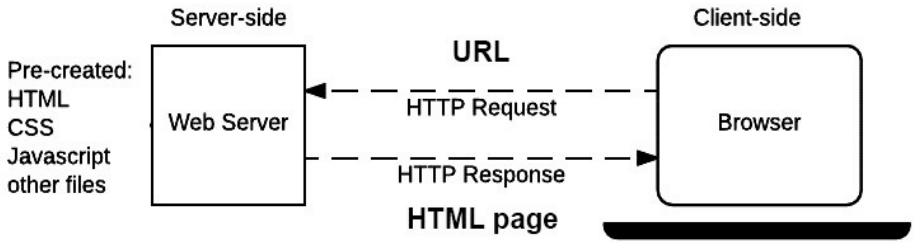
- The term web server can refer to hardware or software or both.
  - Hardware side (Raspberry Pi, cloud server)
    - A web server is a computer that stores web server software and website files
  - Software side (Apache, Nginx, lighttpd,)
    - At a minimum, web server is an HTTP server, a software that understands URLs and HTTP.
    - It's a program that handles HTTP requests and send back HTTP responses.

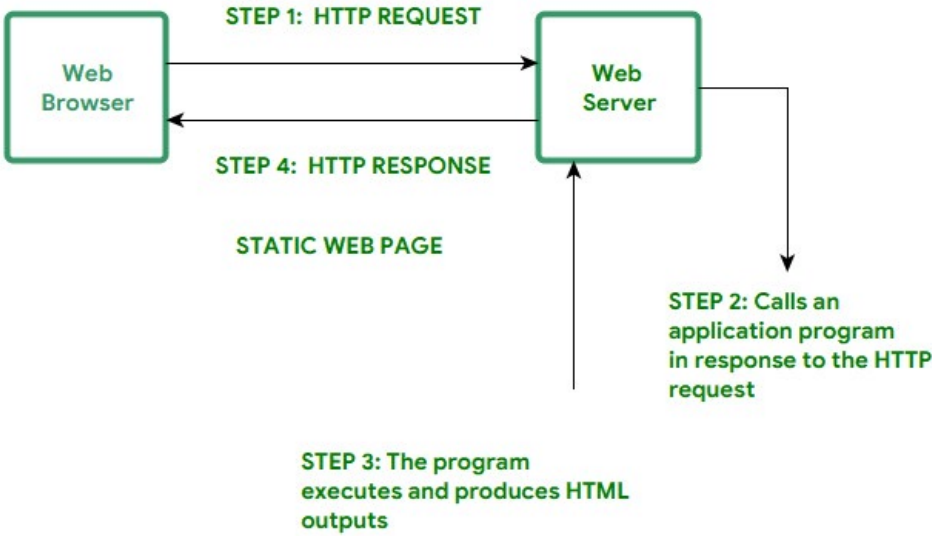


https://developer.mozilla.org/en-US/docs/Learn/Common_questions/What_is_a_web_server

Web Server

- A static web page is a web page that is delivered to the user's web browser exactly as stored
- A dynamic web page is one where contents are generated dynamically
- Static: Fixed content (HTML only)
- Dynamic: Changes based on user/action (HTML + PHP)





Web Server

- Client side and server side are web development terms that describe where application code runs
  - Client-side scripting simply means running scripts on the client device, usually within a browser, HTML, CSS
    - A script is a set of programming instructions that is interpreted at runtime
  - Server-side scripts run on the server instead of the client, often in order to deliver dynamic content to webpages in response to user actions
    - PHP
    - ASP
    - JSP
    - Perl

Lighttpd: A Lightweight Web Server

- Lighttpd stands for Light + threaded process-based daemon
- It is a fast, secure, and lightweight web server designed for low-resource systems like Raspberry Pi
- Ideal for serving static files or dynamic content using PHP (via FastCGI)
  - CGI (Common Gateway Interface) launches a new process for every request
  - FastCGI handle multiple requests
- Low memory usage and high performance
- Suitable for IoT and embedded applications

PHP

- PHP stands for Hypertext Pre-processor
- It is a server scripting language
- PHP scripts can only be interpreted on a server that has PHP installed.
- Can interact with files, databases, GPIO (on Raspberry Pi)
- Commonly used with web servers like lighttpd or Apache.

```
<html>
<body>

<?php
echo "My first PHP script!";
?>

</body>
</html>
```

Web Server Installation

- lighttpd is an open-source web server optimized for speed-critical environments
- Install lighttpd

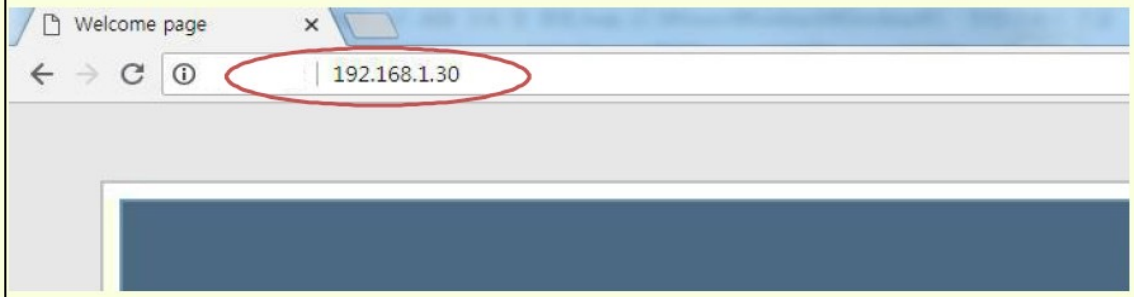
Enter 'sudo apt install lighttpd'

- Confirm installation

```
pi@raspberrypi:~ $ cd /var/www/html/
pi@raspberrypi:/var/www/html $ ls
index.lighttpd.html
```

[Figure 5-3] Confirming Lighttpd File

```
<!DOCTYPE html>
<html>
<head>
  <title>Welcome</title>
</head>
<body>
  <h1>Welcome to RPi</h1>
</body>
</html>
```



[Figure 5-4] Confirming Access to Lighttpd Web

PHP Installation

- Install PHP

  Enter 'sudo apt install php'

- Install PHP CGI Package

```
sudo apt install php-cgi
sudo lighttpd-enable-mod fastcgi
sudo lighttpd-enable-mod fastcgi-php
sudo service lighttpd restart
```

```
pi@raspberrypi:~ $ sudo apt install php-cgi
```

[Figure 5-6] Installign PHP CGI

```
pi@raspberrypi:~ $ sudo lighttpd-enable-mod fastcgi fastcgi-php
Enabling fastcgi: ok
Met dependency: fastcgi
Enabling fastcgi-php: ok
already enabled
Run /etc/init.d/lighttpd force-reload to enable changes
```

[Figure 5-7] Activating PHP CGI

```
pi@raspberrypi:~ $ sudo service lighttpd force-reload
```

[Figure 5-8] Restarting Lighttpd

PHP Installation

- Write PHP installation verification program

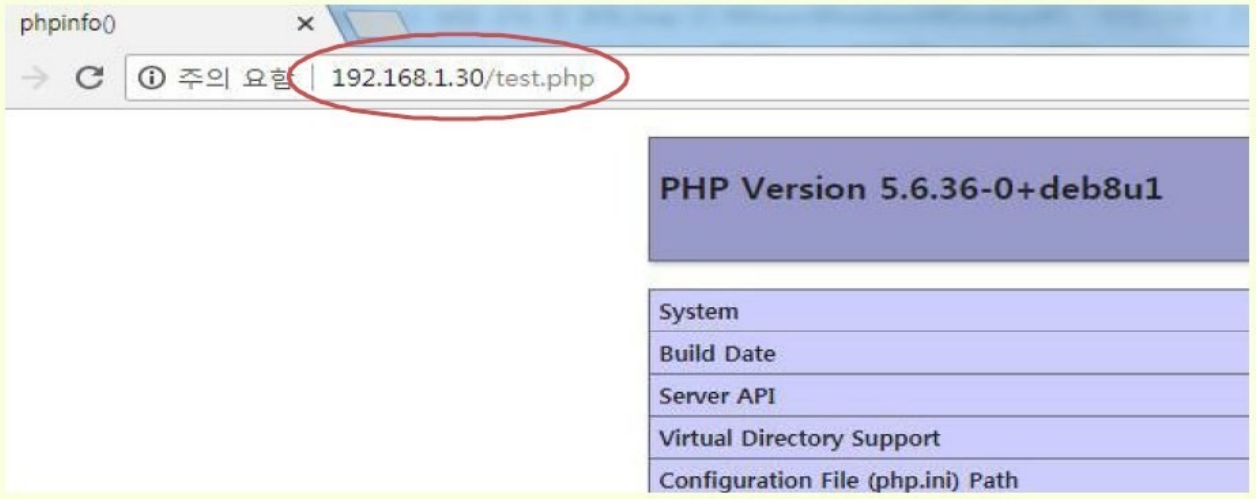
```
pi@raspberrypi:~ $ cd /var/www/html/
pi@raspberrypi:/var/www/html $
```

[Figure 5-9] Web Server Default Folder

```
pi@raspberrypi:/var/www/html $ sudo nano test.php
```

[Figure 5-10] Creating test.php File

```
<?php
phpinfo();
?>
```



[Figure 5-11] PHP Installation Information

Remote Control Using PHP

Program to control LED

```
1   #include <wiringPi.h>
2   #include <stdio.h>
3
4    #define PIN 7
5
6   int main(void) {
7       if(wiringPiSetup() == -1) return 1;
8       pinMode(PIN,OUTPUT);
9       digitalWrite(PIN,HIGH);
10      printf("1");
11  }
```

Part	Meaning
-rwsr-sr-x	File permissions and type
1	**Number of hard links** to the file
root	Owner (user) of the file
pi	Group that owns the file

```
pi@raspberrypi:~ $ gcc -o PHP_LEDON PHP_LEDON.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_LEDON
pi@raspberrypi:~ $ sudo chmod +s PHP_LEDON
```

[Figure 6-6] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-7] Changed Permissions & Owner

Remote Control Using PHP

Program to control LED

```c
#include <wiringPi.h>
#include <stdio.h>

 #define PIN 7

int main(void)  {

    if(wiringPiSetup() == -1) return 1;
    pinMode(PIN,OUTPUT);
    digitalWrite(PIN,LOW);
    printf("0");
}
```

```
pi@raspberrypi:~ $ gcc -o PHP_LEDOFF PHP_LEDOFF.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_LEDOFF
pi@raspberrypi:~ $ sudo chmod +s PHP_LEDOFF
```

[Figure 6-9] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-10] Changed Permissions & Owner

Create PHP file

```
pi@raspberrypi:~ $ cd /var/www/html
pi@raspberrypi:/var/www/html $ sudo nano remote_con.php
```

[Figure 6-11] Creating PHP File

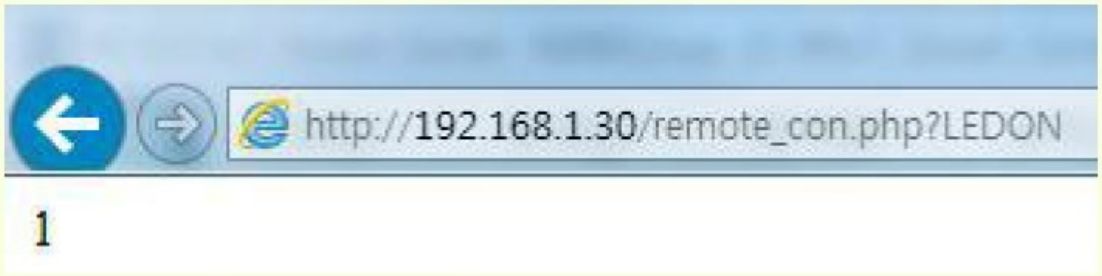
remote_con.php

```
<?php
        if(isset($_GET['LEDON'])){
                $value = shell_exec("/home/pi/PHP_LEDON");
                echo $value;
        }else if(isset($_GET['LEDOFF'])){
                $value = shell_exec("/home/pi/PHP_LEDOFF");
                echo $value;
        }
?>
```

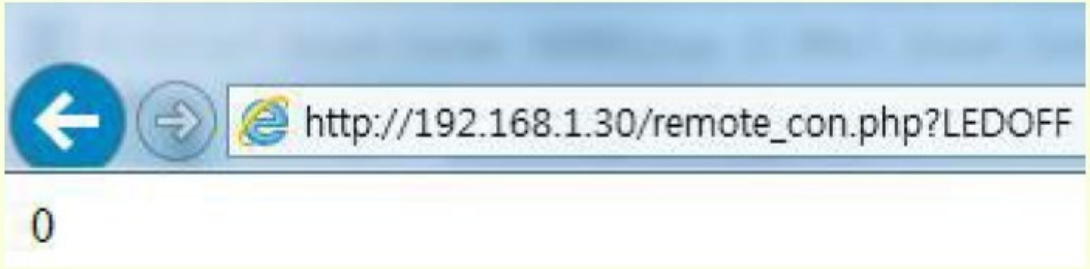
Make Sure:

- The file is executable (chmod +x)
- The path is correct and accessible to PHP
- Ownership and permissions are properly set

Check result



[Figure 6-12] Requesting LED ON



[Figure 6-13] Requesting LED OFF

Remote Control Using PHP

remote_con.php

```
<?php
        if(isset($_GET['LEDON'])){
                $value = shell_exec("/home/pi/PHP_LEDON");
                echo $value;
        }else if(isset($_GET['LEDOFF'])){
                $value = shell_exec("/home/pi/PHP_LEDOFF");
                echo $value;
        }
?>
```

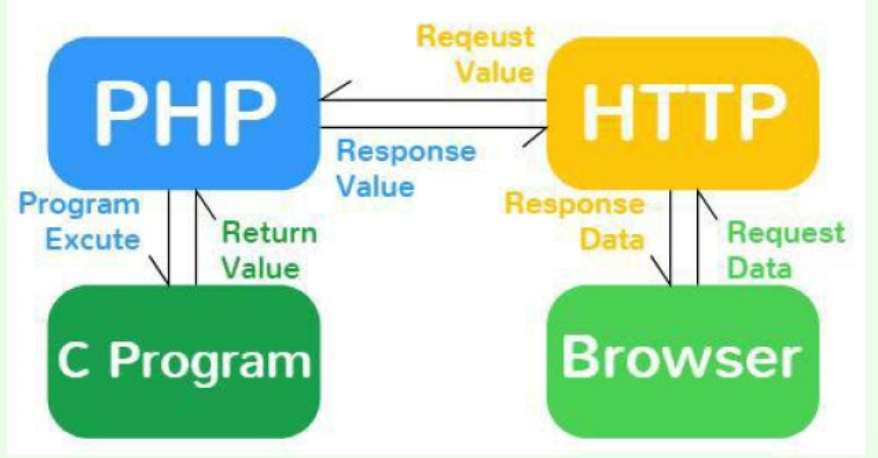
isset function returns true if the variable exists and is not NULL, otherwise it returns false

$_GET can be used to collect data sent in the URL

shell_exec function is used to execute the commands via shell and return the complete output as a string

How this process work?

- Client (browser) sends an HTTP request (e.g., clicking a button).
- lighttpd web server receives the request.
- If the request is for a .php file, lighttpd sends it to the PHP engine.
- PHP script runs on the server (Raspberry Pi):
  - Reads the request
  - Decides what to do (e.g., turn on LED)
  - Interacts with the system (calls shell command or Python code)
- The PHP script sends a response back to the client (HTML, text, sensor values).
- Browser displays the result.



Program for human detection sensor

```c
#include <wiringPi.h>
#include <stdio.h>

 #define PIN 2

int main(void)  {

    if(wiringPiSetup() == -1) return 1;
    pinMode(PIN,INPUT);
    printf("%d",digitalRead(PIN));
}
```

```
pi@raspberrypi:~ $ gcc -o PHP_PIR PHP_PIR.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_PIR
pi@raspberrypi:~ $ sudo chmod +s PHP_PIR
```

[Figure 6-15] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-16] Changed Permissions & Owner

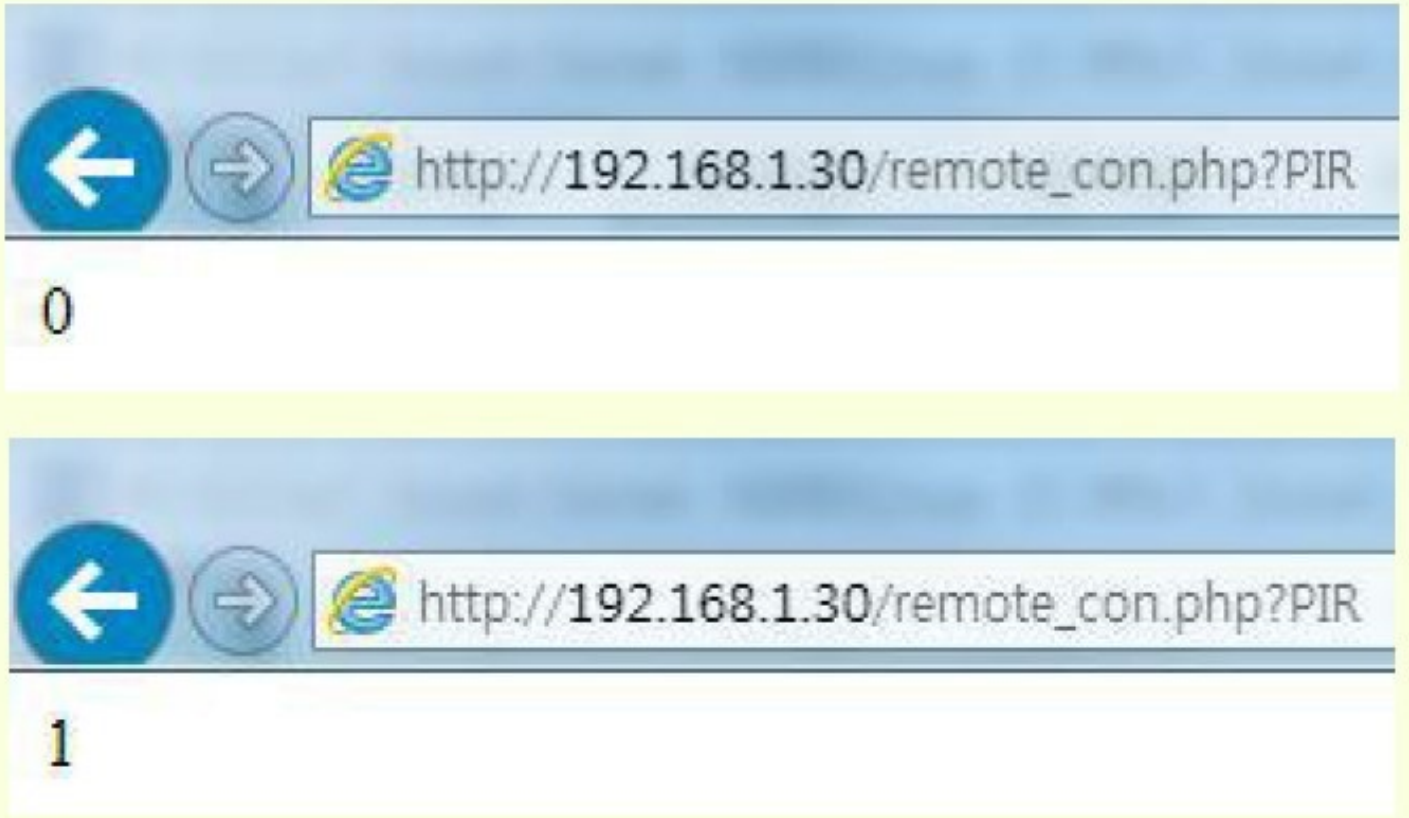
```
pi@raspberrypi:~ $ cd /var/www/html
pi@raspberrypi:/var/www/html $ sudo nano remote_con.php
```

[Figure 6-17] Modifying PHP File

```
<?php
        if(isset($_GET['LEDON'])){
                $value = shell_exec("/home/pi/PHP_LEDON");
                echo $value;
        }else if(isset($_GET['LEDOFF'])){
                $value = shell_exec("/home/pi/PHP_LEDOFF");
                echo $value;
```

```
        }else if(isset($_GET['PIR'])){
                $value = shell_exec("/home/pi/PHP_PIR");
                echo $value;
        }
?>
```

Check result



[Figure 6-18] Requesting the Value of Human Detection Sensor

Any Questions!

Program for sound sensor

```c
#include <stdio.h>
#include <wiringPi.h>

#define SPI_CH 0
#define ADC_CH 2
#define ADC_CS 29
#define SPI_SPEED 500000

int main(void){
    int value=0, i;
    unsigned char buf[3];
    if(wiringPiSetup() == -1) return 1;
    if(wiringPiSPISetup() == -1) return -1;
    pinMode(ADC_CS,OUTPUT);
    buf[0] = 0x06 | ((ADC_CH & 0x04)>>2);
    buf[1] = ((ADC_CH & 0x03)<<6);
    buf[2] = 0x00;
    digitalWrite(ADC_CS,0);
    wiringPiSPIDataRW(SPI_CH,buf,3);
    buf[1]=0x0F & buf[1];
    value = (buf[1]<<8) | buf[2];
    digitalWrite(ADC_CS,1);
    printf("%d",value);
}
```

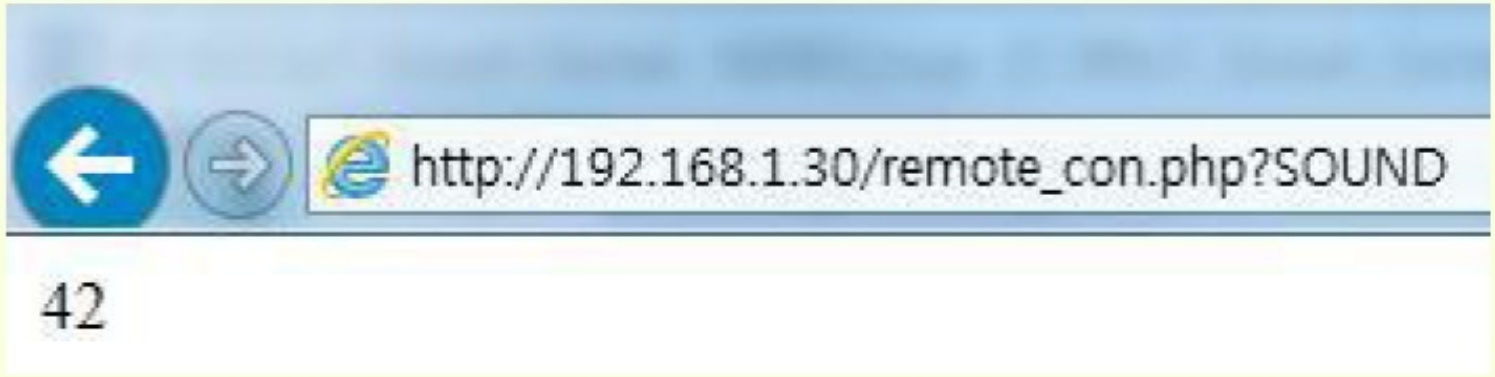
```
pi@raspberrypi:~ $ gcc -o PHP_SOUND PHP_SOUND.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_SOUND
pi@raspberrypi:~ $ sudo chmod +s PHP_SOUND
```

[Figure 6-20] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-21] Changed Permissions & Owner

```
        }else  if(isset($_GET['SOUND'])){
                $value  =  shell_exec("/home/pi/PHP_SOUND");
                echo  $value;
        }
?>
```



[Figure 6-23] Requesting the Sensor Value

Program for DC Motor

```c
#include <wiringPi.h>
#include <stdio.h>

 #define PIN 26

int main(void)  {

    if(wiringPiSetup() == -1) return 1;
    pinMode(PIN,OUTPUT);
    digitalWrite(PIN,HIGH);
    printf("1");
}
```

```
pi@raspberrypi:~ $ gcc -o PHP_DCMON PHP_DCMON.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_DCMON
pi@raspberrypi:~ $ sudo chmod +s PHP_DCMON
```

[Figure 6-34] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-35] Changed Permissions & Owner

Program for DC Motor

```c
#include <wiringPi.h>
#include <stdio.h>

 #define PIN 26

int main(void)  {
    if(wiringPiSetup() == -1) return 1;
    pinMode(PIN,OUTPUT);
    digitalWrite(PIN,LOW);
    printf("0");
}
```

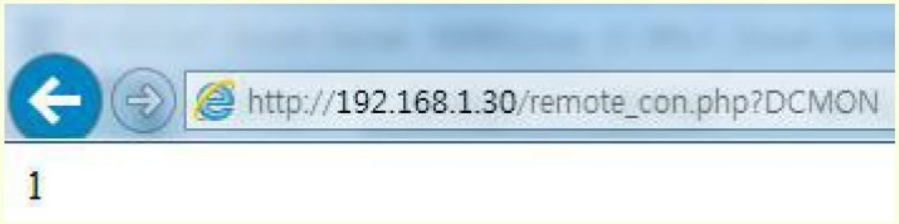
```
pi@raspberrypi:~ $ gcc -o PHP_DCMOFF PHP_DCMOFF.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_DCMOFF
pi@raspberrypi:~ $ sudo chmod +s PHP_DCMOFF
```

[Figure 6-37] Compiling File & Providing PHP Execution Permission

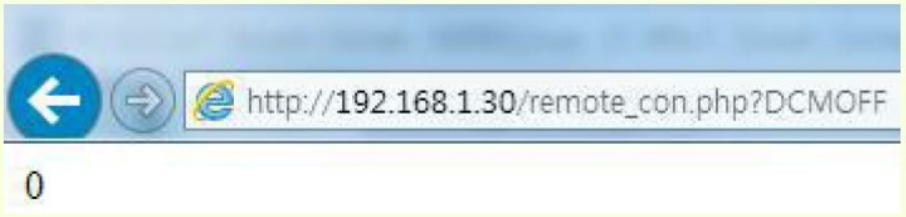
```
-rwsr-sr-x 1 root pi
```

[Figure 6-38] Changed Permissions & Owner

```
else if(isset($_GET['DCMON'])){
        $value = shell_exec("/home/pi/PHP_DCMON");
        echo $value;
}else if(isset($_GET['DCMOFF'])){
        $value = shell_exec("/home/pi/PHP_DCMOFF");
        echo $value;
}
```



[Figure 6-40] Requesting DC Motor ON



[Figure 6-41] RequestingDC motor OFF

Program for Step Motor

```
#include <wiringPi.h>
#include <stdio.h>

 #define PIN_1A 27
 #define PIN_1B 0
 #define PIN_2A 1
 #define PIN_2B 24

int main(void)  {

        int i;

        if(wiringPiSetup() == -1) return 1;

        pinMode(PIN_1A,OUTPUT);
        pinMode(PIN_1B,OUTPUT);
        pinMode(PIN_2A,OUTPUT);
        pinMode(PIN_2B,OUTPUT);
```

Program for Step Motor

```
20          for(i=0; i<500; i++){
21                  digitalWrite(PIN_1A,HIGH);
22                  digitalWrite(PIN_1B,LOW);
23                  digitalWrite(PIN_2A,LOW);
24                  digitalWrite(PIN_2B,LOW);
25                  usleep(8000);
26                  digitalWrite(PIN_1A,LOW);
27                  digitalWrite(PIN_1B,HIGH);
28                  digitalWrite(PIN_2A,LOW);
29                  digitalWrite(PIN_2B,LOW);
30                  usleep(8000);
31                  digitalWrite(PIN_1A,LOW);
32                  digitalWrite(PIN_1B,LOW);
33                  digitalWrite(PIN_2A,HIGH);
34                  digitalWrite(PIN_2B,LOW);
35                  usleep(8000);
36                  digitalWrite(PIN_1A,LOW);
37                  digitalWrite(PIN_1B,LOW);
38                  digitalWrite(PIN_2A,LOW);
39                  digitalWrite(PIN_2B,HIGH);
40                  usleep(8000);
41          }
42
43          printf("1");
44  }
```

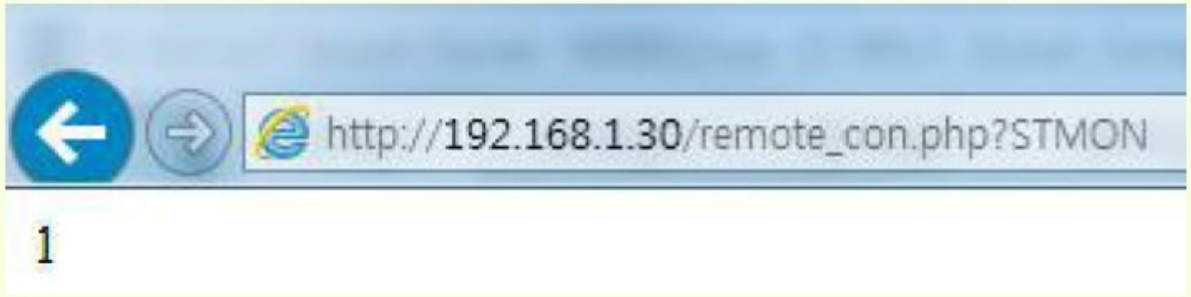
```
pi@raspberrypi:~ $ gcc -o PHP_STMON PHP_STMON.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_STMON
pi@raspberrypi:~ $ sudo chmod +s PHP_STMON
```

[Figure 6-43] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-44] Changed Permissions & Owner

```
else  if(isset($_GET['STMON'])){
            $value  =  shell_exec("/home/pi/PHP_STMON");
            echo  $value;
}
```



[Figure 6-46] Requesting Step Motor ON

Program for Light Sensor

```
pi@raspberrypi:~ $ gcc -o PHP_LIGHT PHP_LIGHT.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_LIGHT
pi@raspberrypi:~ $ sudo chmod +s PHP_LIGHT
```

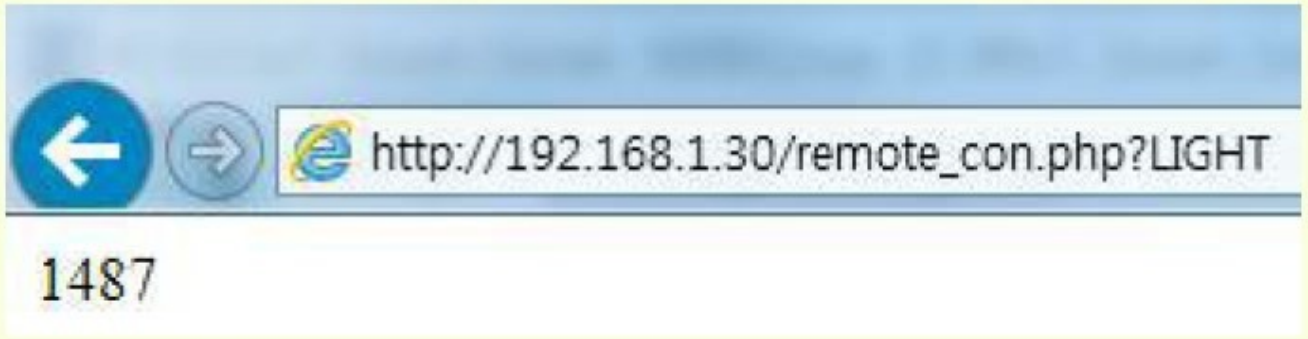
[Figure 6-53] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-54] Changed Permissions & Owner

```c
#include <stdio.h>
#include <wiringPi.h>

#define SPI_CH 0
#define ADC_CH 0
#define ADC_CS 29
#define SPI_SPEED 500000

int main(void)  {

        int value=0, i;
        unsigned char buf[3];

        if(wiringPiSetup() == -1) return 1;

        if(wiringPiSPISetup() == -1) return -1;

        pinMode(ADC_CS,OUTPUT);

        buf[0] = 0x06 | ((ADC_CH & 0x04)>>2);
        buf[1] = ((ADC_CH & 0x03)<<6);
        buf[2] = 0x00;

        digitalWrite(ADC_CS,0);

        wiringPiSPIDataRW(SPI_CH,buf,3);

        buf[1]=0x0F & buf[1];

        value = (buf[1]<<8) | buf[2];

        digitalWrite(ADC_CS,1);

        printf("%d",value);
}
```

```
else  if(isset($_GET['LIGHT'])){
            $value  =  shell_exec("/home/pi/PHP_LIGHT");
            echo  $value;
}
```



[Figure 6-56] Requesting Sensor Value

Program for Temperature Sensor

```c
#include <stdio.h>
#include <stdint.h>
#include <wiringPi.h>

#define MAX_TIME 100
#define PIN 25

int val[5] = {0,0,0,0,0};

int main(void)  {

        uint8_t lststate = 1;
        uint8_t cnt = 0;
        uint8_t j=0,i;

        if(wiringPiSetup() == -1) return 1;

        pinMode(PIN,OUTPUT);

        digitalWrite(PIN,LOW);
        delay(18);
        digitalWrite(PIN,HIGH);
        delayMicroseconds(40);
        pinMode(PIN,INPUT);
```

```
26          for(i=0;i<MAX_TIME;i++) {
27
28                  cnt=0;
29
30                  while(digitalRead(PIN) == laststate){
31                          cnt++;
32                          delayMicroseconds(1);
33                          if(cnt == 255) break;
34                  }
35
36                  laststate = digitalRead(PIN);
37
38                  if(cnt == 255) break;
39
40                  if((i>=4) && (i%2==0))  {
41                          val[j/8]<<=1;
42                          if(cnt>16) val[j/8]|=1;
43                          j++;
44                  }
45          }
46
47          if((j>=40) && (val[4] == ((val[0]+val[1]+val[2]+val[3]) & 0xFF)))   {
48              printf("%d",val[2]);
49          } else
50           printf("-1");
51  }
```

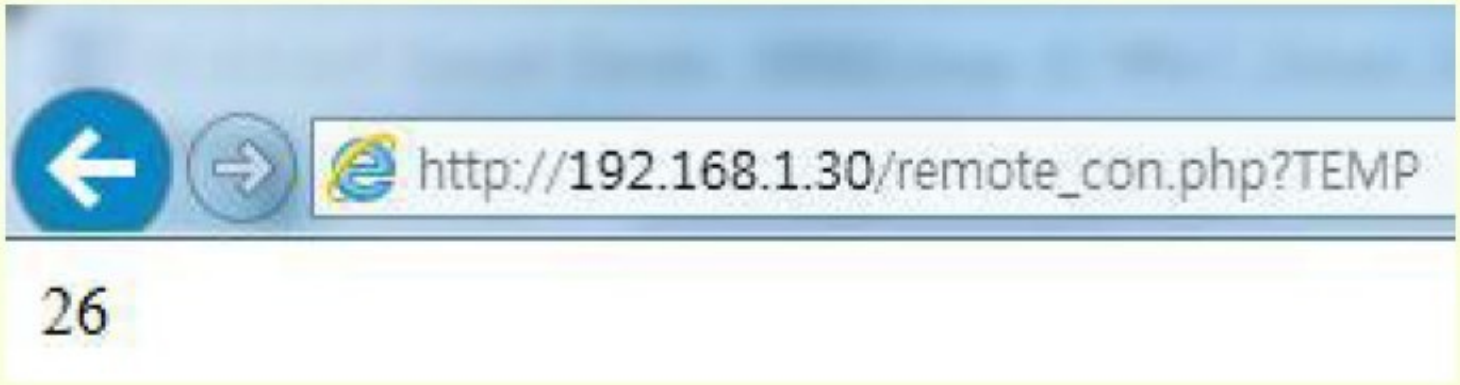
```
pi@raspberrypi:~ $ gcc -o PHP_TEMP PHP_TEMP.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_TEMP
pi@raspberrypi:~ $ sudo chmod +s PHP_TEMP
```

[Figure 6-63] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-64] Changed Permissions & Owner

```
else  if(isset($_GET['TEMP'])){
        $value  =  shell_exec("/home/pi/PHP_TEMP");
        echo  $value;
}
```



[Figure 6-66] Requesting Sensor Value

Program for Touch Sensor

```c
#include <wiringPi.h>
#include <stdio.h>

 #define PIN 6

int main(void)  {

        if(wiringPiSetup() == -1) return 1;
        pinMode(PIN,INPUT);
        printf("%d",digitalRead(PIN));
}
```

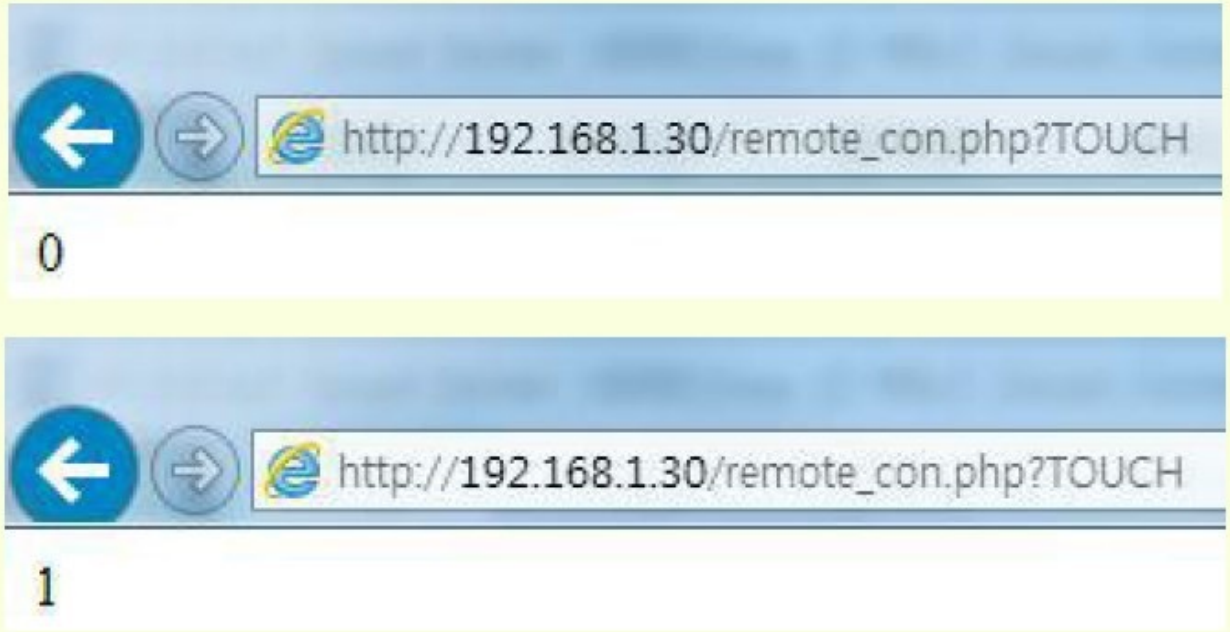
```
pi@raspberrypi:~ $ gcc -o PHP_TOUCH PHP_TOUCH.c -lwiringPi
pi@raspberrypi:~ $ sudo chown root PHP_TOUCH
pi@raspberrypi:~ $ sudo chmod +s PHP_TOUCH
```

[Figure 6-78] Compiling File & Providing PHP Execution Permission

```
-rwsr-sr-x 1 root pi
```

[Figure 6-79] Changed Permissions & Owner

```
else if(isset($_GET['TOUCH'])){
        $value = shell_exec("/home/pi/PHP_TOUCH");
        echo $value;
}
```



[Figure 6-81] Requesting Sensor Value

Any Questions!

1. **Client** (browser) sends an HTTP request (e.g., clicking a button).
2. **lighttpd** web server receives the request.
3. If the request is for a `.php` file, lighttpd sends it to the **PHP engine**.
4. **PHP script runs on the server** (Raspberry Pi):
    - Reads the request
    - Decides what to do (e.g., turn on LED)
    - Interacts with the system (calls shell command or Python code)
5. The PHP script sends a **response back to the client** (HTML, text, sensor values).
6. **Browser displays** the result.

•**C**
bu
•**li**
•If the request is for a .php file, lighttpd sends it to the **PHP engine**.
•**PHP script runs on the server** (Raspberry Pi):
•Reads the request
•Decides what to do (e.g., turn on LED)
•Interacts with the system (calls shell command or Python code)