A Tutorial for GNU libmicrohttpd

written for version 0.3.1 beta

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1 Introduction

This tutorial is aimed at developers who want to learn how they can add HTTP serving capabilities to their applications with the *GNU libmicrohttpd* library, abbreviated *MHD*, and who do not know how to start. It tries to help these developers to implement common basic HTTP serving tasks by discussing executable sample programs implementing different features.

The text is supposed to be a supplement to the API reference manual of *GNU libmicrohttpd* and for that reason does not explain many of the parameters. Therefore, the reader should always consult the manual to find the exact meaning of the functions used in the tutorial. In the same sense, the tutorial seeks to encourage the use of the *RFCs*, which document the conventions the Internet is built upon.

GNU libmicrohttpd is assumed to be already installed and it has been written with respect to version 0.3.1 beta. As the library is still in its beta stages, later versions may show different behaviour. At the time being, this tutorial has only been tested on *GNU/Linux* machines even though efforts were made not to rely on anything that would prevent the samples from being built on similar systems.

2 Hello browser example

The most basic task for a HTTP server is to deliver a static text message to any client connecting to it. Given that this is also very easy to implement, it is an excellent problem to start with.

For now, the particular filename the client asks for shall have no effect on the message that will be returned. In addition, the server shall end the connection after the message has been sent so that the client will know there is nothing more to expect.

The C program `hellobrowser.c`, which is to be found in the examples section, does just that. If you are very eager, you can compile and start it right away but it is advisable to type the lines in by yourself as they will be discussed and explained in detail.

After the unexciting includes and the definition of the port which our server should listen on

```
#include <microhttpd.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>
```

the desired behaviour of our server when HTTP request arrive have to be implemented. We already have agreed that it should not care about the particular details of the request, such as who is requesting what. The server will respond merely with the same small HTML page to every request.

The function we are going to write now will be called by *GNU libmicrohttpd* every time an appropriate request comes in. While the name of this callback function is arbitrary, its parameter list has to follow a certain layout. So please, ignore the lot of parameters for now, they will be explained at the point they are needed. We have to use only one of them, `struct MHD_Connection *connection`, for the minimalistic functionality we want to archive at the moment.

This parameter is set by the *libmicrohttpd* daemon and holds the necessary information to relate the call with a certain connection. Keep in mind that a server might have to satisfy hundreds of concurrent connections and we have to make sure that the correct data is sent to the destined client. Therefore, this variable is a means to refer to a particular connection if we ask the daemon to sent the reply.

Talking about the reply, it is defined as a string right after the function header

```
int AnswerToConnection(void *cls, struct MHD_Connection *connection,
    const char *url, const char *method, const char *version,
    const char *upload_data, unsigned int *upload_data_size, void **con_cls)
{
  const char *page  = "<html><body>Hello, browser!</body></html>";
```

HTTP is a rather strict protocol and the client would certainly consider it "inappropriate" if we just sent the answer string "as is". Instead, it has to be wrapped in certain layers, called headers, of additional information. Luckily, most of the work in this area is done by the library for us—we just have to ask. Our reply string packed in the necessary layers will be called a "response". To obtain such a response we hand our data (the reply–string) and its size over to the `MHD_create_response_from_data` function. The last two parameters basically tell *MHD* that we do not want it to dispose the message data for us when it has been sent and there also needs no internal copy to be done because the *constant* string won't change anyway.

```
  struct MHD_Response *response;
  int ret;

  response = MHD_create_response_from_data(strlen(page),
             (void*)page, MHD_NO, MHD_NO);
```

Now that the the response has been laced up, it is ready for delivery and can be queued for sending. This is done by passing it to another *GNU libmicrohttpd* function. As all our work was done in the scope of one function, the recipient is without doubt the one associated with the local variable `connection` and consequently this variable is given to the queue function. Every HTTP response is accompanied by a status code, here "OK", so that the client knows this response is the intended result of his request and not due to some error or malfunction.

Finally, the packet is destroyed and the return value from the queue returned, already being set at this point to either MHD_YES or MHD_NO in case of success or failure.

```
  ret = MHD_queue_response (connection, MHD_HTTP_OK, response);
  MHD_destroy_response (response);
  return ret;
}
```

With the primary task of our server implemented, we can start the actual server daemon which will listen on `PORT` for connections. This is done in the main function.

```
int main ()
{
  struct MHD_Daemon *d;

  d = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                       &AnswerToConnection, NULL, MHD_OPTION_END);
  if (d == NULL) return 1;
```

The first parameter is one of three possible modes of operation. Here we want the daemon to run in a separate thread and to manage all incoming connections in the same thread. This means that while producing the response for one connection, the other connections will be put on hold. In this chapter, where the reply is already known and therefore the request is served quickly, this poses no problem.

We will allow all clients to connect regardless of their name or location, therefore we do not check them on connection and set the forth and fifth parameter to NULL.

Parameter six is the address of the function we want to be called whenever a new connection has been established. Our `AnswerToConnection` knows best what the client wants and needs no additional information (which could be passed via the next parameter) so the next parameter is NULL. Likewise, we do not need to pass extra options to the daemon so we just write the MHD_OPTION_END as the last parameter.

As the server daemon runs in the background in its own thread, the execution flow in our main function will contine right after the call. Because of this, we must delay the execution flow in the main thread or else the program will terminate prematurely. We let it pause in a processing-time friendly manner by waiting for the enter key to be pressed. In the end, we stop the daemon so it can do its cleanup tasks.

```
  getchar();

  MHD_stop_daemon(d);
  return 0;
}
```

The first example is now complete.

Compile it with

```
cc hellobrowser.c -o hellobrowser -I$PATH_TO_LIBMHD_INCLUDES
  -L$PATH_TO_LIBMHD_INCLUDES -static -lmicrohttpd -pthread
```

with the two paths set accordingly and run it.

Now open your favorite Internet browser and go to the address `localhost:8888`, provided that is the port you chose. If everything works as expected, the browser will present the message of the static HTML page it got from our minimal server.

Remarks

To keep this first example as small as possible, some drastic shortcuts were taken and are to be discussed now.

Firstly, there is no distinction made between the kinds of requests a client could send. We implied that the client sends a GET request, that means, that he actually asked for some data. Even when it is not intended to accept POST requests, a good server should at least recognize that this request does not constitute a legal request and answer with an error code. This can be easily implemented by checking if the parameter `method` equals the string `"GET"` and returning a `MHD_NO` if not so.

Secondly, the above practice of queuing a response upon the first call of the callback function brings with it some limitations. This is because the content of the message body will not be received if a response is queued in the first iteration. Furthermore, the connection will be closed right after the response has been transferred then.

Both of these issues you will find addressed in the official `minimal_example.c` residing in the `src/examples` directory of the *GNU libmicrohttpd* package. The source code of this program should look very familiar to you by now and easy to understand.

For our example, the `must_copy` and `must_free` parameter at the response construction function could be set to `MHD_NO`. In the usual case, responses cannot be sent immediately after being queued. For example, there might be other data on the system that needs to be sent with a higher priority. Nevertheless, the queue function will return successfully—raising the problem that the data we have pointed to may be invalid by the time it is about being sent. This is not an issue here because we can expect the `page` string, which is a constant *string literal* here, to be static. That means it will be present and unchanged for as long as the program runs. For dynamic data, one could choose to either have *MHD* free the memory `page` points to itself when it is not longer needed or, alternatively, have the library to make and manage its own copy of it.

Exercises

- While the server is running, use a program like telnet or netcat to connect to it. Try to form a valid HTTP1.1 request yourself like

  ```
  GET /dontcare HTTP1.1
  Host: itsme
  <enter>
  ```

  and see what the server returns to you.
- Also, try other requests, like POST, and see how our server does not mind and why. How far in malforming a request can you go before the builtin functionality of *MHD* intervenes and an altered response is sent? Make sure you read about the status codes in the *RFC*.
- Add the option `MHD_USE_PEDANTIC_CHECKS` to the start function of the daemon in `main`. Mind the special format of the parameter list here which is described in the manual. How indulgent is the server now to your input?
- Let the main function take a string as the first command line argument and pass `argv[1]` to the `MHD_start_daemon` function as the sixth parameter. The address of this string will be passed to the callback function via the `cls` variable. Decorate the text given at the command line when the server is started with proper HTML tags and send it as the response instead of the former static string.

- *Demanding:* Write a separate function returning a string containing some useful information, for example, the time. Pass the function's address as the sixth parameter and evaluate this function on every request anew in `AnswerToConnection`. Remember to free the memory of the string every time after satisfying the request.

3 Exploring requests

This chapter will deal with the information which the client sends to the server at every request. We are going to examine the most useful fields of such an request and print them out in a readable manner. This could be useful for logging facilities.

The starting point is the *hellobrowser* program with the former response removed.

This time, we just want to collect information in the callback function, thus we will just return MHD_NO after we have probed the request. This way, the connection is closed without much ado by the server.

```
int AnswerToConnection(void *cls, struct MHD_Connection *connection,
    const char *url, const char *method, const char *version,
    const char *upload_data, unsigned int *upload_data_size, void **con_cls)
{
  ...
  return MHD_NO;
}
```

The ellipsis marks the position where the following instructions shall be inserted.

We begin with the most obvious information available to the server, the request line. You should already have noted that a request consists of a command (or "method") and a URI (e.g. a filename). It also contains a string for the version of the protocol which can be found in `version`. To call it a "new request" is justified because we return only `MHD_NO`, thus ensuring the function will not be called again for this connection.

```
printf("New request %s for %s using version %s\n", method, url, version);
```

The rest of the information is a bit more hidden. Nevertheless, there is lot of it sent from common Internet browsers. It is stored in "key-name" pairs and we want to list what we find in the header. As there is no mandatory set of keys a client has to send, each key–name pair is printed out one by one until there are no more left. We do this by writing a separate function which will be called for each pair just like the above function is called for each HTTP request. It can then print out the content of this pair.

```
int PrintOutKey(void *cls, enum MHD_ValueKind kind, const char *key,
    const char *value)
{
  printf("%s = %s\n", key, value);
  return MHD_YES;
}
```

To start the iteration process that calls our new function for every key, the line

```
MHD_get_connection_values(connection, MHD_HEADER_KIND, PrintOutKey, NULL);
```

needs to be inserted in the connection callback function too. The second parameter tells the function that we are only interested in keys from the general HTTP header of the request. Our iterating function `PrintOutKey` does not rely on any additional information to fulfill its duties so the last parameter can be NULL.

All in all, this constitutes the complete `logger.c` program for this chapter which can be found in the `examples` section.

Connecting with any modern Internet browser should yield a handful of keys. You should try to interpret them with the aid of *RFC 2616*. Especially worth mentioning is the host key which is often used to serve several different websites hosted under one single IP address but reachable by different domain names.

Conclusion

The introduced capabilities to itemize the content of a simple GET request—especially the URI—should already allow the server to satisfy clients' requests for small specific resources (e.g. files) or even induce alteration of how the server operates. However, the latter is not recommended as the GET method (including its header data) is by convention considered a "SAFE" operation, which should not change the server's state in a significant way, but temporally actions like searching for a passed string is fine.

Of course, no transmission can occur while the return value is still set to `MHD_NO` in the callback function.

Exercises

- By parsing the `url` string and delivering responses accordingly, implement a small server for "virtual" files. When asked for `/index.htm{l}`, let the response consist of a HTML page containing a link to `/another.html` page which is also to be created "on the fly" in case of being requested. If neither of these two pages are requested, `MHD_HTTP_NOT_FOUND` shall be returned accompanied by an informative message.
- A very interesting information has still been ignored by our logger—the client's IP address. Implement a callback function

  ```
  int OnClientConnect(void *cls,
                      const struct sockaddr *addr,socklen_t addrlen)
  ```

  that prints out the IP address in an appropriate format. You might want to use the posix function `inet_ntoa` but bear in mind that `addr` is actually just a structure containing other substructures and is *not* the variable this function expects. Make sure to return `MHD_YES` so that the library knows the client is allowed to connect (and to request). If one wanted to limit access basing on IP addresses, this would be the place to do it. The address of your function will then be passed as the third parameter of the `MHD_start_daemon` call.

4 Response headers

Now that we are able to inspect the incoming request in great detail, this chapter discusses the means to enrich the outgoing responses likewise.

As you have learned in the *Hello, Browser* chapter, some obligatory header fields are added and set automatically for simple responses by the library itself but if more advanced features are desired, additional fields have to be created. One of the possible fields is the content type field and an example will be developed around it. This will lead to an application capable of correctly serving different types of files.

When we responded with HTML page packed in the static string previously, the client had no choice but guessing about how to handle the response, because the server hadn't told him. What if we had sent a picture or a sound file? Would the message have been understood or merely been displayed as an endless stream of random characters in the browser? This is what the mime content types are for. The header of the response is extended by certain information about how the data is to be interpreted.

To introduce the concept, a picture of the format *PNG* will be sent to the client and labeled accordingly with `image/png`. Once again, we can base the new example on the `hellobrowser` program.

```
#define FILENAME "picture.png"
#define MIMETYPE "image/png"

int AnswerToConnection(void *cls, struct MHD_Connection *connection,
    const char *url, const char *method, const char *version,
    const char *upload_data, unsigned int *upload_data_size, void **con_cls)
{
  struct MHD_Response *response;
  int ret=0;
```

We want the program to load the graphics file into memory:

```
long size;
  FILE *fp;
  int ret=0;

  if (0 != strcmp(method, "GET")) return MHD_NO;

  size = GetFileSize(FILENAME);
  if (size != 0)
  {
    fp = fopen(FILENAME, "rb");
    if (fp)
    {
      buffer = malloc(size);
      if (buffer)
        if (size == fread(buffer, 1, size, fp)) ret=1;
    }

    fclose(fp);
  }
```

The `GetFileSize` function, which returns a size of zero if the file could not be opened or found, is left out on this page for tidiness.

When dealing with files and allocating memory, there is a lot that could go wrong on the sider side and if so, the client should be informed with `MHD_HTTP_INTERNAL_SERVER_ERROR`.

```
  if (!ret)
  {
    const char *errorstr = "<html><body>An internal server error\
                            has occured!</body></html>";

    if (buffer) free(buffer);
    response = MHD_create_response_from_data(strlen(errorstr),
                                             (void*)errorstr, MHD_NO, MHD_NO);

    ret = MHD_queue_response (connection,
                              MHD_HTTP_INTERNAL_SERVER_ERROR, response);

    return MHD_YES;
  }
```

Note that we nevertheless have to create an response object even for sending a simple error code. Otherwise, the connection would just be closed without comment, leaving the client curious about what has happened.

But in the case of success a response will be constructed that contains the buffer filled with the file's content.

```
response = MHD_create_response_from_data(size, (void*)buffer, MHD_YES, MHD_NO);
```

Contrary to the above case where a static string will be sent, this time we have to keep track of the dynamically allocated buffer. As discussed in the Chapter 2 [Hello browser example], page 3, the buffer cannot be safely freed as soon as the function call returns. Instead, we ask the function to keep charge of freeing the buffer itself when it is not longer needed. Thus, no further `free` command is invoked by us.

Up to this point, there was little new. The actual novelty is that we enhance the header with the meta data about the content. Aware of the field's name we want to add, it is as easy as that:

```
MHD_add_response_header(response, "Content-Type", MIMETYPE);
```

We do not have to append a colon expected by the protocol hehind the first field—*GNU libhttpdmicro* will take care of this.

The function finishes with the well-known lines

```
  ret = MHD_queue_response (connection, MHD_HTTP_OK, response);
  MHD_destroy_response (response);
  return ret;
}
```

The complete program `responseheaders.c` is in the `examples` section as usual. Find a *PNG* file you like and save it to the directory the example is run from under the name `picture.png`. You should find the image displayed on your browser if everything worked well.

Remarks

The include file of the *MHD* library comes with the header types mentioned in *RFC 2616* already defined as macros. Thus, we could have written `MHD_HTTP_HEADER_CONTENT_TYPE` instead of `"Content-Type"` as well. However, one is not limited to these standard headers and could add custom response headers without violated the protocol. Whether and how the client would react to these custom header is up to the receiver. Likewise, the client is allowed to send custom

request headers to the server as well, opening up yet more possibilities how client and server could communicate with each other.

The method of creating the response from one big chunk of data is only feasible for smaller files. A public file server satisfying many request at the same time would be choking under these high demands on memory very soon. Serving responses in smaller parts would be more adequate here and will be a topic of a future chapter.

Exercises

- Remember that the original program was written under a few assumptions—a small, static response being one of them. In order to simulate a very large or hard to reach file that cannot be provided instantly, postpone the queuing in the callback with the `sleep` function for 30 seconds *if* the file `/big.png` is requested (but deliver the same as above). A request for `/picture.png` should provide just the same but without any artificial delays.

  Now start two instances of your browser (or even use two machines) and see how the second client is put on hold while the first waits for his request on the slow file to be fulfilled.

  Finally, change the sourcecode to use `MHD_USE_THREAD_PER_CONNECTION` when the daemon is started and try again.

- Did you succeed in implementing the clock exercise yet? This time, let the server save the program's start time `t` and implement a response simulating a countdown that reaches 0 at `t+60`. Returning a message saying on which point the countdown is, the response should ultimately be to reply "Done" if the program has been running long enough,

  A non official, but widely understood, response header line is `Refresh: DELAY; url=URL` with the uppercase words substituted to tell the client it should request the given resource after the given delay again. Improve your program in that the browser (any modern browser should work) automatically reconnects and asks for the status again every 5 seconds or so. The URL would have to be composed so that it begins with "http://", followed by the *URI* the server is reachable from the client's point of view.

  Maybe you want also to visualize the countdown as a status bar by creating a `<table>` consisting of one row and `n` columns whose fields contain small images of either a red or a green light.

5 A basic authentication

With the small exception of IP address based access control, requests from all connecting clients where served equally until now. This chapter discusses a first method of client's authentication and its limits.

A very simple approach feasible with the means already discussed would be to expect the password in the *URI* string before granting access to the secured areas. The password could be separated from the actual resource identifier by a certain character, thus the request line might look like

```
GET /picture.png?mypassword
```

In a situation, where the client is customized enough and the connection occurs through secured lines (e.g., a embedded device directly attached to another via wire), this can be a reasonable choice.

But when it is assumed that the user connecting does so with an ordinary Internet browser, this implementation brings some problems about. For example, the URI including the password stays in the address field or at least in the history of the browser for anybody near enough to see. It will also be inconvenient to add the password manually to any new URI when the browser does not know how to compose this automatically.

At least the convenience issue can be addressed by employing the simplest built-in password facilities of HTTP compliant browsers, hence we want to start there. It will however turn out to have still severe weaknesses in terms of security which need consideration.

Before we will start implementing *Basic Authentication* as described in *RFC 2617*, we should finally abandon the bad practice of responding every request the first time our callback is called for a given connection. This is becoming more important now because the client and the server will have to talk in a more bi-directional way than before to

But how can we tell whether the callback has been called before for the particular connection? Initially, the pointer this parameter references is set by *MHD* in the callback. But it will also be "remembered" on the next call (for the same connection). Thus, we will generate no response until the parameter is non-null—implying the callback was called before at least once. We do not need to share information between different calls of the callback, so we can set the parameter to any adress that is assured to be not null. The pointer to the `connection` structure will be pointing to a legal adress, so we take this.

Not even the headers will be looked at on the first iteration.

```
int AnswerToConnection(void *cls, struct MHD_Connection *connection,
    const char *url, const char *method, const char *version,
    const char *upload_data, unsigned int *upload_data_size, void **con_cls)
{
  if (0 != strcmp(method, "GET")) return MHD_NO;
  if(*con_cls==NULL) {*con_cls=connection; return MHD_YES;}

  ...
  /* else respond accordingly */
  ...
}
```

Note how we lop off the connection on the first condition, but return asking for more on the other one with `MHD_YES`. With the framework improved, we can proceed to implement the actual authentication process.

Request for authentication

Let us assume we had only files not intended to be handed out without the correct username/password, so every "GET" request will be challenged. *RFC 2617* describes how the server shall ask for authentication by adding a *WWW-Authenticate* response header with the name of the *realm* protected.

We let an extra function function do this.

```
int AskForAuthentication(struct MHD_Connection *connection, const char *realm)
{
  int ret;
  struct MHD_Response *response;
  char *headervalue;
  const char *strbase = "Basic realm=";

  response = MHD_create_response_from_data(0, NULL, MHD_NO, MHD_NO);
  if (!response) return MHD_NO;

  headervalue = malloc( strlen(strbase) + strlen(realm) + 1);
  if (!headervalue) return MHD_NO;

  strcpy(headervalue, strbase);
  strcat(headervalue, realm);

  ret = MHD_add_response_header(response, "WWW-Authenticate", headervalue);
  free(headervalue);
  if (!ret) {MHD_destroy_response (response); return MHD_NO;}

  ret = MHD_queue_response (connection, MHD_HTTP_UNAUTHORIZED, response);

  MHD_destroy_response (response);

  return ret;
}
```

`#define` the realm name according to your own taste, e.g. "Maintenance" or "Area51" but it will need to have extra quotes.

But the client may send the authentication right away, so it would be wrong to ask for it without checking the request's header–where the authentication is expected to be found.

Authentication in detail

Checking *RFC 2617* again, we find that the client will pack the username and password, by whatever means he might have obtained them, in a line separated by a colon—and then encodes them to *Base64*. The actual implementation of this encoding are not within the scope of this tutorial although a working function is included in the complete source file of the example.

An unencoded word describing the authentication method (here "Basic") will precede the code and the resulting line is the value of a request header of the type "Authorization".

This header line thus is of interest to the function checking a connection for a given username/password:

```
int IsAuthenticated(struct MHD_Connection *connection,
                    const char *username, const char *password)
{
```

```
  const char *headervalue;
  ...

  headervalue = MHD_lookup_connection_value (connection,
                                             MHD_HEADER_KIND, "Authorization");

  if(headervalue == NULL) return 0;
```

where, firstly, the authentication method will be checked.

```
const char *strbase = "Basic ";
...
if (strncmp(headervalue, strbase, strlen(strbase))!=0) return 0;
```

Of course, we could decode the passed credentials in the next step and compare them directly to the given strings. But as this would involve string parsing, which is more complicated then string composing, it is done the other way around—the clear text credentials will be encoded to *Base64* and then compared against the headerline. The authentication method string will be left out here as it has been checked already at this point.

```
  char *expected_b64, *expected;
  int authenticated;

  ...
  strcpy(expected, username);
  strcat(expected, ":");
  strcat(expected, password);

  expected_b64 = StringToBase64(expected);
  if(expected_b64 == NULL) return 0;

  strcpy(expected, strbase);

  authenticated = (strcmp(headervalue+strlen(strbase), expected_b64) == 0);

  free(expected_b64);

  return authenticated;
}
```

These two functions—together with a response function in case of positive authentication doing little new—allow the rest of the callback function to be rather short.

```
  if (!IsAuthenticated(connection, USER, PASSWORD))
    return AskForAuthentication(connection, REALM);

  return SecretPage(connection);
}
```

See the `examples` directory for the complete example file.

Remarks

For a proper server, the conditional statements leading to a return of `MHD_NO` should yield a response with a more precise status code instead of silently closing the connection. For example, failures of memory allocation are best reported as *internal server error* and unexpected authentication methods as *400 bad request*.

Exercises

- Make the server respond to wrong credentials (but else correct requests) with the recommended *401 unauthorized* status code. If the client still does not authenticate correctly within the same connection, close it and store the client's IP address for a certain time. (It is OK to check for expiration not until the main thread wakes up again on the next connection.) If the client fails authenticating three times during this period, add it to another list whose entries the `AcceptPolicyCallback` function denies connection (temporally).
- With the network utility *netcat* connect and log the response of a `"GET"` request as you did in the exercise of the first example, this time to a file. Now stop the server and let *netcat* listen on the same port the server used to listen on and have it fake being the proper server by giving the file's content as the response (e.g. `cat log | nc -l -p 8888`). Pretending to think your were connecting to the actual server, browse to the eavesdropper and give the correct credentials.

  Copy and paste the encoded string you see in netcat's output to some of the Base64 decode tools available online and see how both the user's name and password could be completely restored.

6 Processing post data

The previous chapters already have demonstrated a variety of possibilities to send information to the HTTP server, but it is not recommended that the *GET* method is used to alter the way the server operates. To induce changes on the server, the *POST* method is preferred over and is much more powerful than *GET* and will be introduced in this chapter.

We are going to write an application that asks for the visitor's name and, after the user has posted it, composes an individual response text. Even though it was not mandatory to use the *post* method here, as there is no permanent change caused by the post, it is an illustrative example on how to share data between different functions for the same connection. Furthermore, the reader should be able to extend it easily.

GET request

When the first *GET* request arrives, the server shall respond with a HTML page containing an edit field for the name.

```
const char* askpage="<html><body>\
                     What's your name, Sir?<br>\
                     <form action=\"/namepost\" method=\"post\">\
                     <input name=\"name\" type=\"text\"\
                     <input type=\"submit\" value=\" Send \"></form>\
                     </body></html>";
```

The `action` entry is the *URI* to be called by the browser when posting, and the `name` will be used later to be sure it is the editbox's content that has been posted.

We also prepare the answer page, where the name is to be filled in later, and an error page as the response for anything but proper *GET* and *POST* requests:

```
const char* greatingpage="<html><body><h1>Welcome, %s!</center></h1></body></html>";

const char* errorpage="<html><body>This doesn't seem to be right.</body></html>";
```

Whenever we need to send a page, we use an extra function `int SendPage(struct MHD_Connection *connection, const char* page)` for this, which does not contain anything new and whose implementation is therefore left out here.

POST request

Posted data can be of arbitrary and considerable size; for example, if a user uploads a big image to the server. Similar to the case of the header fields, there may also be different streams of posted data, such as one containing the text of an editbox and another the state of a button. Likewise, we will have to register an iterator function that is going to be called maybe several times not only if there are different POSTs but also if one POST has only been received partly yet and needs processing before another chunk can be received.

Such an iterator function is called by a *postprocessor*, which must be created upon arriving of the post request. We want the iterator function to read the first post data which is tagged `name` and to create an individual greeting string based on the template and the name. But in order to pass this string to other functions and still be able to differentiate different connections, we must first define a structure to share the information, holding the most import entries.

```
struct ConnectionInfoStruct
{
  int connectiontype;
  char *answerstring;
```

```
  struct MHD_PostProcessor *postprocessor;
};
```

With these information available to the iterator function, it is able to fulfill its task. Once it has composed the greeting string, it returns `MHD_NO` to inform the post processor that it does not need to be called again. Note that this function does not handle processing of data for the same `key`. If we were to expect that the name will be posted in several chunks, we had to expand the namestring dynamically as additional parts of it with the same `key` came in. But in this example, the name is assumed to fit entirely inside one single packet.

```
int IteratePost(void *coninfo_cls, enum MHD_ValueKind kind, const char *key,
                const char *filename, const char *content_type,
                const char *transfer_encoding, const char *data, size_t off, size_t size)
{
  struct ConnectionInfoStruct *con_info = (struct ConnectionInfoStruct*)(coninfo_cls);


  if (0 == strcmp(key, "name"))
  {
    if ((size>0) && (size<=MAXNAMESIZE))
    {
      char *answerstring;
      answerstring = malloc(MAXANSWERSIZE);
      if (!answerstring) return MHD_NO;

      snprintf(answerstring, MAXANSWERSIZE, greatingpage, data);
      con_info->answerstring = answerstring;
    } else con_info->answerstring=NULL;

    return MHD_NO;
  }

  return MHD_YES;
}
```

Once a connection has been established, it can be terminated for many reasons. As these reasons include unexpected events, we have to register another function that cleans up any resources that might have been allocated for that connection by us, namely the post processor and the greetings string. This cleanup function must take into account that it will also be called for finished requests other than *POST* requests.

```
void RequestCompleted(void *cls, struct MHD_Connection *connection, void **con_cls,
                      enum MHD_RequestTerminationCode toe)
{
  struct ConnectionInfoStruct *con_info = (struct ConnectionInfoStruct*)(*con_cls);


  if (NULL == con_info) return;

  if (con_info->connectiontype == POST)
  {
    MHD_destroy_post_processor(con_info->postprocessor);
    if (con_info->answerstring) free(con_info->answerstring);
  }
```

```
  free(con_info);
}
```

GNU libmicrohttpd is informed that it shall call the above function when the daemon is started in the main function.

```
...
daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                          &AnswerToConnection, NULL, MHD_OPTION_NOTIFY_COMPLETED,
                          RequestCompleted, NULL, MHD_OPTION_END);
...
```

Request handling

With all other functions prepared, we can now discuss the actual request handling.

On the first iteration for a new request, we start by allocating a new instance of a `ConnectionInfoStruct` structure, which will store all necessary information for later iterations and other functions.

```
int AnswerToConnection(void *cls, struct MHD_Connection *connection, const char *url,
    const char *method, const char *version, const char *upload_data,
    unsigned int *upload_data_size, void **con_cls)
{
  if(*con_cls==NULL)
  {
    struct ConnectionInfoStruct *con_info;

    con_info = malloc(sizeof(struct ConnectionInfoStruct));
    if (NULL == con_info) return MHD_NO;
```

If the new request is a *POST*, the postprocessor must be created now. In addition, the type of the request is stored for convenience.

```
  if (0 == strcmp(method, "POST"))
    {
      con_info->postprocessor = MHD_create_post_processor(connection, POSTBUFFERSIZE,
                                                          IteratePost, (void*)con_info);

      if (NULL == con_info->postprocessor)
      {
        free(con_info);
        return MHD_NO;
      }

      con_info->connectiontype = POST;
    } else con_info->connectiontype = GET;
```

The address of our structure will both serve as the indicator for successive iterations and to remember the particular details about the connection.

```
 *con_cls = (void*)con_info;
    return MHD_YES;
  }
```

The rest of the function will not be executed on the first iteration. A *GET* request is easily satisfied by sending the question form.

```
  if (0 == strcmp(method, "GET"))
  {
    return SendPage(connection, askpage);
  }
```

In case of *POST*, we invoke the post processor for as long as data keeps incoming, setting `*upload_data_size` to zero in order to indicate that we have processed—or at least have considered—all of it.

```
  if (0 == strcmp(method, "POST"))
  {
    struct ConnectionInfoStruct *con_info = *con_cls;

    if (*upload_data_size != 0)
    {
      MHD_post_process(con_info->postprocessor, upload_data, *upload_data_size);
      *upload_data_size = 0;
      return MHD_YES;
    } else return SendPage(connection, con_info->answerstring);
  }
```

If they are neither *GET* nor *POST* requests, the error page is returned finally.

```
  return SendPage(connection, errorpage);
}
```

These were the important parts of the program `simplepost.c`.

Appendix A Bibliography

API reference

- The *GNU libmicrohttpd* manual by Christian Grothoff 2008 http://gnunet.org/libmicrohttpd/microhttpd.html

Requests for comments

All referenced RFCs can be found on the website of *The Internet Engineering Task Force* http://www.ietf.org/

- *RFC 2616*: Fielding, R., Gettys, J., Mogul, J., Frystyk, H., and T. Berners-Lee, "Hypertext Transfer Protocol – HTTP/1.1", RFC 2016, January 1997.
- *RFC 2617*: Franks, J., Hallam-Baker, P., Hostetler, J., Lawrence, S., Leach, P., Luotonen, A., and L. Stewart, "HTTP Authentication: Basic and Digest Access Authentication", RFC 2617, June 1999.

Recommended readings

- A well–structured *HTML* reference can be found on http://www.echoecho.com/html.htm
  For those readers understanding German or French, there is an excellent document both for learning *HTML* and for reference, whose English version unfortunately has been discontinued. http://de.selfhtml.org/ and http://fr.selfhtml.org/

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Version 1.2, November 2002

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Appendix C Example programs

C.1 hellobrowser.c

```
#include <microhttpd.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>

#define PORT 8888

int AnswerToConnection(void *cls, struct MHD_Connection *connection, const char *url,
    const char *method, const char *version, const char *upload_data,
    unsigned int *upload_data_size, void **con_cls)
{
  const char *page  = "<html><body>Hello, browser!</body></html>";
  struct MHD_Response *response;
  int ret;

  response = MHD_create_response_from_data (strlen (page), (void*) page, MHD_NO, MHD_NO);
  ret = MHD_queue_response (connection, MHD_HTTP_OK, response);
  MHD_destroy_response (response);
  return ret;
}

int main ()
{
  struct MHD_Daemon *daemon;

  daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                            &AnswerToConnection, NULL, MHD_OPTION_END);
  if (daemon == NULL) return 1;

  getchar();

  MHD_stop_daemon(daemon);
  return 0;
}
```

C.2 logging.c

```
#include <microhttpd.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>

#define PORT 8888


int PrintOutKey(void *cls, enum MHD_ValueKind kind, const char *key, const char *value)
{
  printf("%s = %s\n", key, value);
  return MHD_YES;
}

int AnswerToConnection(void *cls, struct MHD_Connection *connection, const char *url,
    const char *method, const char *version, const char *upload_data,
    unsigned int *upload_data_size, void **con_cls)
{

  printf("New request %s for %s using version %s\n", method, url, version);

  MHD_get_connection_values(connection, MHD_HEADER_KIND, PrintOutKey, NULL);
```

```
  return MHD_NO;
}

int main ()
{
  struct MHD_Daemon *daemon;

  daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                            &AnswerToConnection, NULL, MHD_OPTION_END);
  if (daemon == NULL) return 1;

  getchar();

  MHD_stop_daemon(daemon);
  return 0;
}
```

C.3 responseheaders.c

```
#include <microhttpd.h>
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

#define PORT 8888
#define FILENAME "picture.png"
#define MIMETYPE "image/png"


long GetFileSize(const char *filename)
{
  FILE *fp;

  fp = fopen(filename, "rb");
  if (fp)
  {
    long size;

    if ( (0!=fseek(fp, 0, SEEK_END)) || (-1==(size=ftell(fp))) )
      size = 0;

    fclose(fp);
    return size;
  } else return 0;
}


int AnswerToConnection(void *cls, struct MHD_Connection *connection, const char *url,
    const char *method, const char *version, const char *upload_data,
    unsigned int *upload_data_size, void **con_cls)
{
  unsigned char *buffer;
  struct MHD_Response *response;
  long size;
  FILE *fp;
  int ret=0;

  if (0 != strcmp(method, "GET")) return MHD_NO;

  size = GetFileSize(FILENAME);
  if (size != 0)
  {
    fp = fopen(FILENAME, "rb");
```

```
    if (fp)
    {
      buffer = malloc(size);
      if (buffer)
        if (size == fread(buffer, 1, size, fp)) ret=1;
    }

    fclose(fp);
  }

  if (!ret)
  {
    const char *errorstr = "<html><body>An internal server error has occured!\
                           </body></html>";

    if (buffer) free(buffer);
    response = MHD_create_response_from_data(strlen(errorstr), (void*)errorstr,
                                             MHD_NO, MHD_NO);

    ret = MHD_queue_response (connection, MHD_HTTP_INTERNAL_SERVER_ERROR, response);
    MHD_destroy_response (response);
    return MHD_YES;
  }

  response = MHD_create_response_from_data(size, (void*)buffer, MHD_YES, MHD_NO);

  MHD_add_response_header(response, "Content-Type", MIMETYPE);

  ret = MHD_queue_response (connection, MHD_HTTP_OK, response);
  MHD_destroy_response (response);
  return ret;
}


int main ()
{
  struct MHD_Daemon *daemon;

  daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                            &AnswerToConnection, NULL, MHD_OPTION_END);

  if (daemon == NULL) return 1;

  getchar();

  MHD_stop_daemon(daemon);
  return 0;
}
```

C.4 basicauthentication.c

```
#include <microhttpd.h>
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

#define PORT 8888

#define REALM     "\"Maintenance\""
#define USER      "a legitimate user"
#define PASSWORD  "and his password"
```

```
char* StringToBase64(const char *message);


int AskForAuthentication(struct MHD_Connection *connection, const char *realm)
{
  int ret;
  struct MHD_Response *response;
  char *headervalue;
  const char *strbase = "Basic realm=";

  response = MHD_create_response_from_data(0, NULL, MHD_NO, MHD_NO);
  if (!response) return MHD_NO;

  headervalue = malloc( strlen(strbase) + strlen(realm) + 1);
  if (!headervalue) return MHD_NO;

  strcpy(headervalue, strbase);
  strcat(headervalue, realm);

  ret = MHD_add_response_header(response, "WWW-Authenticate", headervalue);
  free(headervalue);
  if (!ret) {MHD_destroy_response (response); return MHD_NO;}

  ret = MHD_queue_response (connection, MHD_HTTP_UNAUTHORIZED, response);

  MHD_destroy_response (response);

  return ret;
}

int IsAuthenticated(struct MHD_Connection *connection, const char *username,
                    const char *password)
{
  const char *headervalue;
  char *expected_b64, *expected;
  const char *strbase = "Basic ";
  int authenticated;

  headervalue = MHD_lookup_connection_value (connection, MHD_HEADER_KIND, "Authorization");
  if(headervalue == NULL) return 0;
  if (strncmp(headervalue, strbase, strlen(strbase))!=0) return 0;

  expected = malloc(strlen(username) + 1 + strlen(password) + 1);
  if(expected == NULL) return 0;

  strcpy(expected, username);
  strcat(expected, ":");
  strcat(expected, password);

  expected_b64 = StringToBase64(expected);
  if(expected_b64 == NULL) return 0;

  strcpy(expected, strbase);

  authenticated = (strcmp(headervalue+strlen(strbase), expected_b64) == 0);

  free(expected_b64);

  return authenticated;
}


int SecretPage(struct MHD_Connection *connection)
{
  int ret;
```

```
  struct MHD_Response *response;
  const char *page = "<html><body>A secret.</body></html>";

  response = MHD_create_response_from_data(strlen(page), (void*)page, MHD_NO, MHD_NO);
  if (!response) return MHD_NO;

  ret = MHD_queue_response (connection, MHD_HTTP_OK, response);

  MHD_destroy_response (response);

  return ret;
}


int AnswerToConnection(void *cls, struct MHD_Connection *connection,
    const char *url, const char *method, const char *version,
    const char *upload_data, unsigned int *upload_data_size, void **con_cls)
{
  if (0 != strcmp(method, "GET")) return MHD_NO;
  if(*con_cls==NULL) {*con_cls=connection; return MHD_YES;}

  if (!IsAuthenticated(connection, USER, PASSWORD))
    return AskForAuthentication(connection, REALM);

  return SecretPage(connection);
}


int main ()
{
  struct MHD_Daemon *daemon;

  daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                            &AnswerToConnection, NULL, MHD_OPTION_END);

  if (daemon == NULL) return 1;

  getchar();

  MHD_stop_daemon(daemon);
  return 0;
}


char* StringToBase64(const char *message)
{
  const char *lookup = "ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789+/";
  unsigned long l;
  int i;
  char *tmp;
  size_t length = strlen(message);

  tmp = malloc(length*2);
  if (tmp==NULL) return tmp;
  tmp[0]=0;

  for(i=0; i<length; i+=3)
  {
    l = ( ((unsigned long)message[i])<<16 ) |
                (((i+1) < length) ? (((unsigned long)message[i+1])<<8 ) : 0 ) |
                (((i+2) < length) ? ( (unsigned long)message[i+2] ) : 0 );


    strncat(tmp, &lookup[(l>>18) & 0x3F], 1);
    strncat(tmp, &lookup[(l>>12) & 0x3F], 1);
```

```
    if (i+1 < length) strncat(tmp, &lookup[(l>> 6) & 0x3F], 1);
    if (i+2 < length) strncat(tmp, &lookup[(l ) & 0x3F], 1);
  }

  if (length%3) strncat(tmp, "===", 3-length%3) ;

  return tmp;
}
```

C.5 simplepost.c

```
#include <microhttpd.h>
#include <string.h>
#include <stdlib.h>
#include <stdio.h>

#define PORT            8888
#define POSTBUFFERSIZE  512
#define MAXNAMESIZE     20
#define MAXANSWERSIZE   512

#define GET             0
#define POST            1

struct ConnectionInfoStruct
{
  int connectiontype;
  char *answerstring;
  struct MHD_PostProcessor *postprocessor;
};

const char* askpage="<html><body>\
                     What's your name, Sir?<br>\
                     <form action=\"/namepost\" method=\"post\">\
                     <input name=\"name\" type=\"text\"\
                     <input type=\"submit\" value=\" Send \"></form>\
                     </body></html>";

const char* greatingpage="<html><body><h1>Welcome, %s!</center></h1></body></html>";

const char* errorpage="<html><body>This doesn't seem to be right.</body></html>";


int SendPage(struct MHD_Connection *connection, const char* page)
{
  int ret;
  struct MHD_Response *response;


  response = MHD_create_response_from_data(strlen(page), (void*)page, MHD_NO, MHD_NO);
  if (!response) return MHD_NO;

  ret = MHD_queue_response(connection, MHD_HTTP_OK, response);

  MHD_destroy_response(response);

  return ret;
}


int IteratePost(void *coninfo_cls, enum MHD_ValueKind kind, const char *key,
                const char *filename, const char *content_type,
                const char *transfer_encoding, const char *data, size_t off, size_t size)
{
```

```
  struct ConnectionInfoStruct *con_info = (struct ConnectionInfoStruct*)(coninfo_cls);


  if (0 == strcmp(key, "name"))
  {
    if ((size>0) && (size<=MAXNAMESIZE))
    {
      char *answerstring;
      answerstring = malloc(MAXANSWERSIZE);
      if (!answerstring) return MHD_NO;

      snprintf(answerstring, MAXANSWERSIZE, greatingpage, data);
      con_info->answerstring = answerstring;
    } else con_info->answerstring=NULL;

    return MHD_NO;
  }

  return MHD_YES;
}

void RequestCompleted(void *cls, struct MHD_Connection *connection, void **con_cls,
                      enum MHD_RequestTerminationCode toe)
{
  struct ConnectionInfoStruct *con_info = (struct ConnectionInfoStruct*)(*con_cls);


  if (NULL == con_info) return;

  if (con_info->connectiontype == POST)
  {
    MHD_destroy_post_processor(con_info->postprocessor);
    if (con_info->answerstring) free(con_info->answerstring);
  }

  free(con_info);
}


int AnswerToConnection(void *cls, struct MHD_Connection *connection, const char *url,
    const char *method, const char *version, const char *upload_data,
    unsigned int *upload_data_size, void **con_cls)
{
  if(*con_cls==NULL)
  {
    struct ConnectionInfoStruct *con_info;

    con_info = malloc(sizeof(struct ConnectionInfoStruct));
    if (NULL == con_info) return MHD_NO;

    if (0 == strcmp(method, "POST"))
    {
      con_info->postprocessor = MHD_create_post_processor(connection, POSTBUFFERSIZE,
                                                          IteratePost, (void*)con_info);

      if (NULL == con_info->postprocessor)
      {
        free(con_info);
        return MHD_NO;
      }

      con_info->connectiontype = POST;
    } else con_info->connectiontype = GET;

    *con_cls = (void*)con_info;
```

```
    return MHD_YES;
  }

  if (0 == strcmp(method, "GET"))
  {
    return SendPage(connection, askpage);
  }

  if (0 == strcmp(method, "POST"))
  {
    struct ConnectionInfoStruct *con_info = *con_cls;

    if (*upload_data_size != 0)
    {
      MHD_post_process(con_info->postprocessor, upload_data, *upload_data_size);
      *upload_data_size = 0;
      return MHD_YES;
    } else return SendPage(connection, con_info->answerstring);
  }

  return SendPage(connection, errorpage);
}

int main ()
{
  struct MHD_Daemon *daemon;


  daemon = MHD_start_daemon(MHD_USE_SELECT_INTERNALLY, PORT, NULL, NULL,
                            &AnswerToConnection, NULL, MHD_OPTION_NOTIFY_COMPLETED,
                            RequestCompleted, NULL, MHD_OPTION_END);

  if (NULL == daemon) return 1;

  getchar();

  MHD_stop_daemon(daemon);
  return 0;
}
```