

```
1
2
3 void PassChain_IoT() {
4
5     /* Presentation of Alberto Montefusco */
6
7     const char *course = 'IoT Security';
8
9     const char *Prof = 'Christiancarmine Esposito';
10
11    const char *aa = '2022 - 2023';
12
13    Presentation.begin(course, Prof, aa);
14 }
```



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/* Sensors used and how did I connect them */

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04 Vulnerabilities_&_Security

/* Attacks and Security Solutions */

}

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01 {

[Introduction]

/* What is a PassWord Manager
and PassChain device */

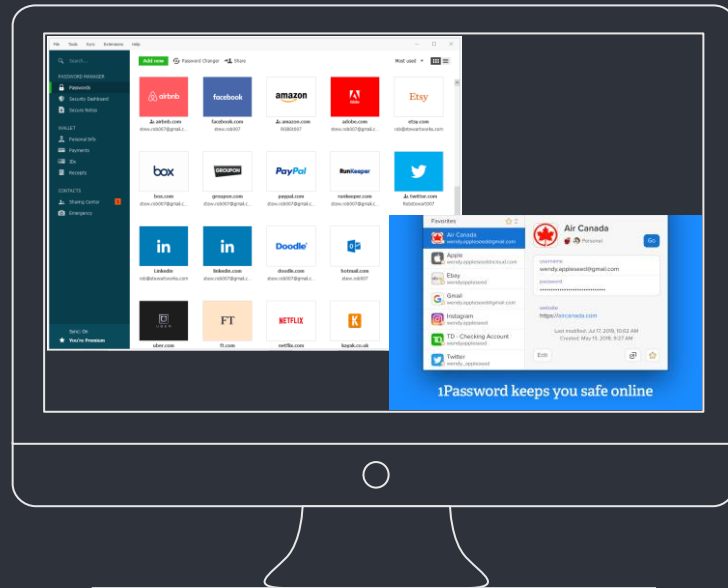
}

```
1 Password_Manager {
2
3     /* What are them? */
4
5     Serial.println('Online services that allow
6                     users to store password');
7
8     delay(100);
9
10
11     Serial.println(' and sync them across all your
12                    personal devices');
13
14 }
```

```
1  
2  
3  
4 tft.pushImage (
```

```
5  
6  
7  
8  
9 Dashlane and 1Password  
10 are most popular  
11 password manager  
12  
13  
14
```

```
) ;
```



```
1 Serial.println ( 'Advantages: ' +
2
3   |
4   |— Step 01 Apps available for all platforms
5   |
6   |— Step 02 Browser extensions allow to
7   |   automatically enter passwords
8   |
9   |— Step 03 Sync on all devices
10  |
11  |
12  |— Step 04 Fast access
13  |
14  );
```

```
1 Serial.println ( 'Disadvantages: ' +
2
3   Step 01 Online and cloud services can be
4   violated even remotely
5
6   Step 02 Need to install an application or
7   extension on each of your personal devices
8
9   Step 03 Less practical when using
10  non-personal devices
11
12  Step 04 Single Point of Failure because access to
13  all of your passwords is protected by a
14  single strong password
15 );
```

PassChain_IoT {

/* What is It? */

Serial.println('PassChain is an IoT device that aims to facilitate
the user in digital authentication');

delay(100);

Serial.println('but also to ensure their security through
its function of password manager');



Bluetooth

< Connect to other devices with
Bluetooth to send user's credentials >



Authentication

< Every operation is done through
Fingerprint authentication >



Cryptography

< All data are encrypted with AES
128 bit – GCM mode >

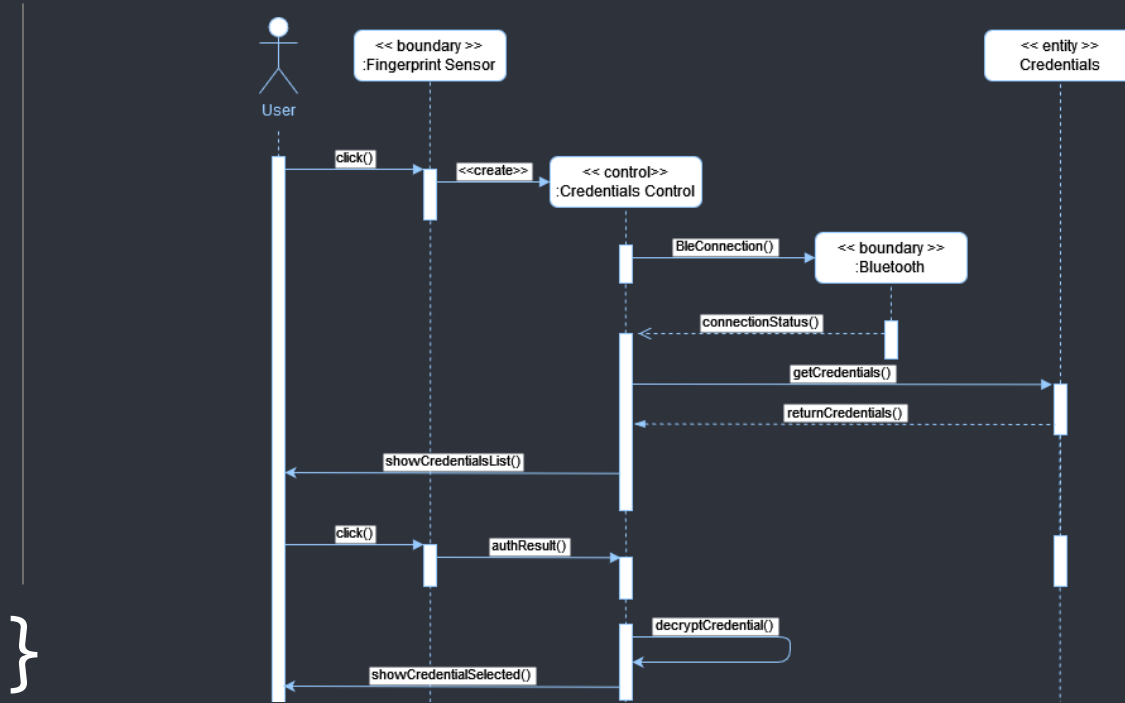


SSL Communication

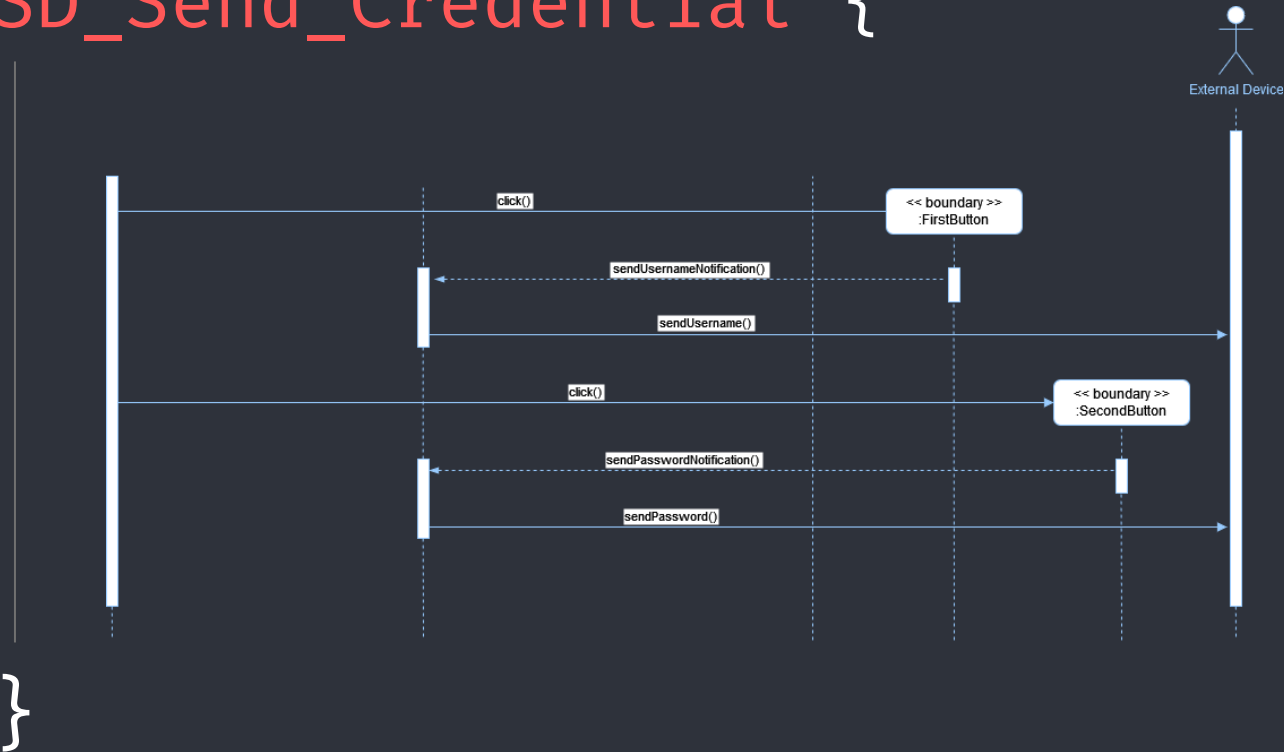
< SSL allows secure communication
with the python server >

}

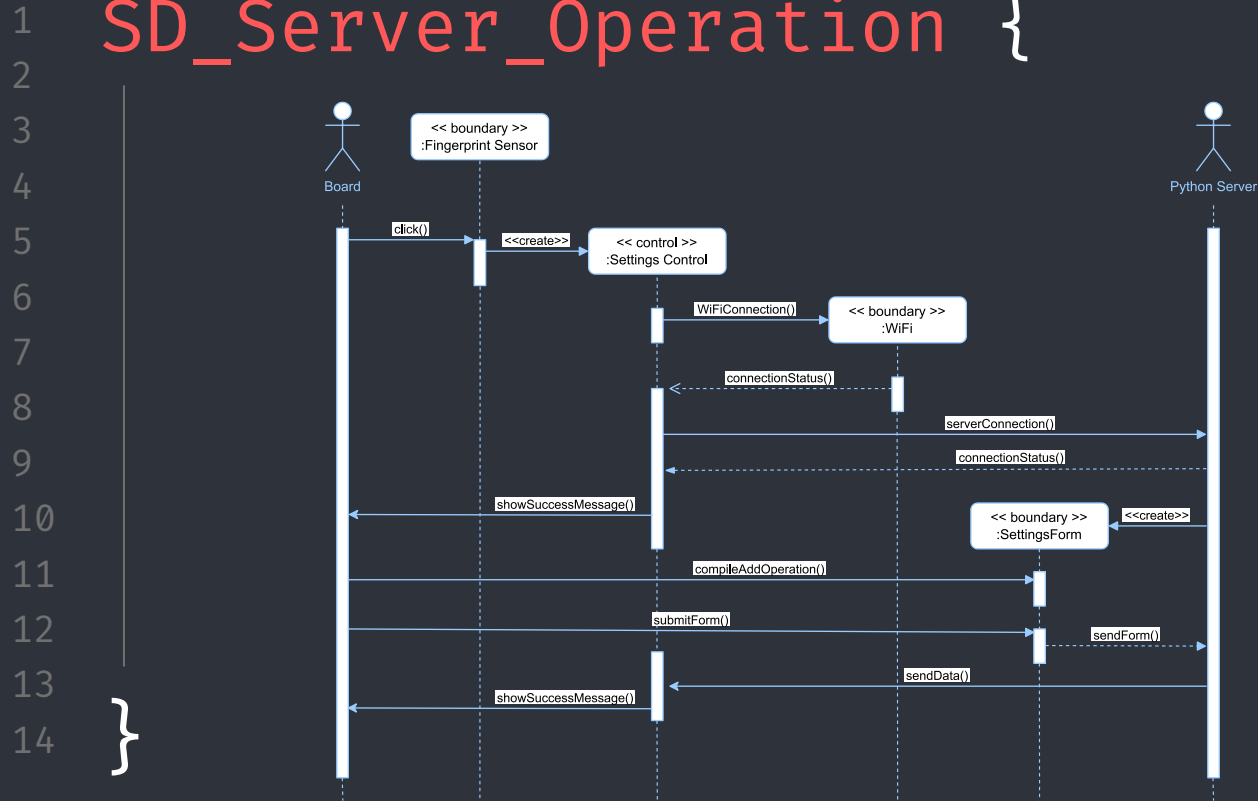
SD_Send_Credential {



SD_Send_Credential {



SD_Server_Operation {



```
1      02 {
2
3
4
5      [Hardware]
6
7
8      /* Lora TTgo Esp32 16 Mb,
9         Fingerprint, Battery */
10
11
12     }
13
14
```

```
1 void Lora_TTgo_Esp32 () {
```



```
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```

< The board has an integrated 0.96'' OLED display, two programmable buttons and one for restarting, a power connector for batteries and a type-C port for connecting devices and powering the board itself. It has a memory of 16 Mb with SPIFFS as file system >

```
15 void Fingerprint () {
```



```
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99  
100
```

< Capacitive fingerprint sensor allows to authenticate the user. The sensor ensures the uniqueness of the user. The sensor can store 126 fingerprint: one of them is used to go back to the settings >

```
1 void Lora_Ttgo_Esp32 () {
```



```
2  
3 < LiPo battery 1 cell of 500 mAh 3.7 V allows  
4 to have a portable and independent device >  
5
```

```
6 }  
7
```

```
8 void show_circuit (Board esp32, Sensor fingerprint,  
9                   Sensor battery) {  
10
```

```
11     Circuit circuit = new Circuit(Esp32, fingerprint, battery);  
12     tft.pushImage(circuit.show());  
13
```

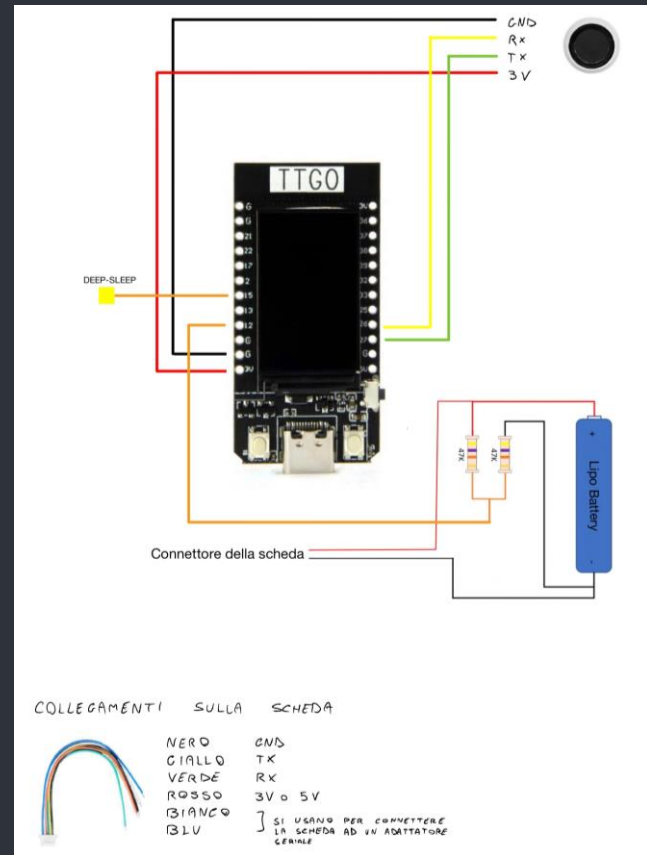
```
14 }
```

```

1
2
3
4 tft.pushImage (
5
6
7
8
9
10
11
12
13
14 );

```

- GPIO 15: metal plaque to wake up the device when it goes in deep sleep after a constant time
- GPIO 12: battery circuit

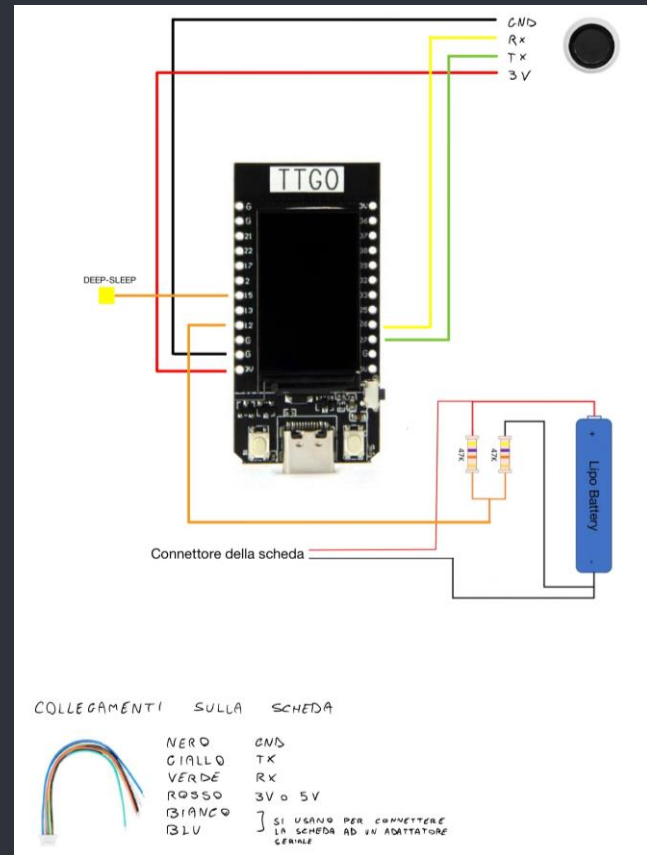


```

1
2
3
4 tft.pushImage (
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```

- G: connection with GND
- Red line is connected to 3V
- GPIO 26: TX on the board
- GPIO 27: RX on the board




```
1
2      03 {
3
4
5      [Software]
6
7
8      /* Libraries used, SSL communication,
9       server Python */
10
11
12      }
13
14
```

```
1 Libraries_used(bool external) {
2
3     if (!external) { /* details of Arduino's libraries */
4
5         < TFT_eSPI.h > * Arduino library used to write text or
6                        * images on display OLED.
7
8         < SD.h > * Arduino library to read and write on
9                 * memory. The file system used is SPIFFS.
10
11         < ArduinoJson.h > * Arduino library used to manage JSON
12                           * file in which stored user and HotSpot
13                           * credentials
14
```

```
1
2   < WiFiClientSecure.h > * Arduino libray used to create and setup
3                           * SSL communication
4
5   < mbedtls/gcm.h >      * Used to encrypt and decrypt credentials
6                           * with cipher AES - 128 bit GCM mode
7
8   } else { /* details of external libraries */
9
10      < BleKeyboard.h >    * Used to simulate a virtual keyboard and
11                           * to send messages with Bluetooth
12
13      < Adafruit_Fingerprint.h > * Used to enroll and delete user's
14                                * fingerprints
15  }
16 }
```

SSL_Communication {

```
1  
2  
3  /*****  
4  * In this case, I create a secure communication between my Esp32 and *  
5  * the external device that works as server to setup board's data.    *  
6  *****/
```

Create Certificates



< CA and client certificates
with the key associated to
the client >

Store certificates



< The certificates are
stored in Arduino code and
send to server >

Start Server Python



< Load server certificate
and verify it and client
certificate >

Receive datas



< Server creates a
socket and receives
data by Esp32 >

```
14 }
```

Server_Python {

```
1  
2  
3 /*****  
4  * It allows to setup Esp32 data. The operations concern: Add, Update, *  
5  * Delete, Setup Fingerprints, Setup Hotspot credentials *  
6  *****/
```

Start server



< welcome string, number
of fingerprints, user and
hotspot JSON credentials >

CRUD operations



< To setup Esp32, we can run
CRUD operations on data:
hotspot and credentials >

Setup Fingerprints



< Server verify if exist at
least two FP: one to confirm
operation and one to come
back to settings in Esp32 >

Setup Hotspot



< Server can modify the
SSID and password
hotspot >

}

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04 {

[Vulnerabilities &
Security]

/* Attacks and Security
Solution */

}

```
1 void MITM_attack (Adv, Alice, Bob) {
```

```
2  
3  /*****  
4   * PassChain is vulnerable to MITM attack about Bluetooth because *  
5   * it misses authentication between two devices. One solution is *  
6   * to use BLE v4.2 BR/EDR using ECDH based encryption and using *  
7   * the numeric compare binding model for authentication. *  
8   *****/
```

```
9   < This solution is not strong because v4.2 to 5.0 have a vulnerability  
10  called "BLURtooth" which exploits CTDK >
```

```
11  
12  < This detection has been protected by the  
13  GATT protocol available in the latest  
14  versions of devices equipped with BLE >
```

```
}
```



```
1 void Exploit_FP (memory) {
2
3
4     /*****
5      * PassChain use Fingerprint to authenticate when user want run
6      * some operation.
7      *****/
8
9     < The vulnerability consists in UART exploitation because this
10      sensor uses TTL Serial to communicate. For example, we can use
11      Attify Badge to emulate a serial connection to access the target
12      device >
13
14     < A solution is to isolate PassChain from this device, in
15     particular, user must not leave the device unattended >
16 }
```

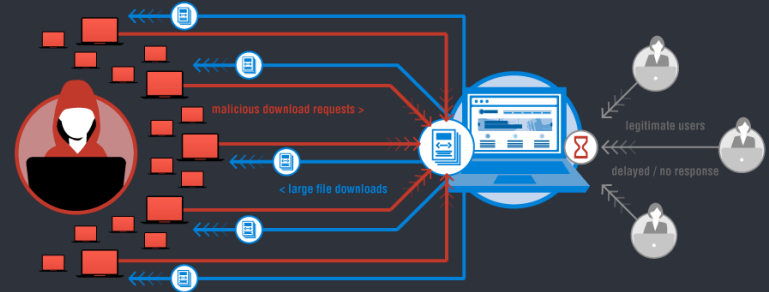



```
1 void DoS_attack (resources) {
```

```
2  
3  
4 /*****  
5  * User can do setup of PassChain connecting the board to the *  
6  * server Python. *  
7  *****/
```

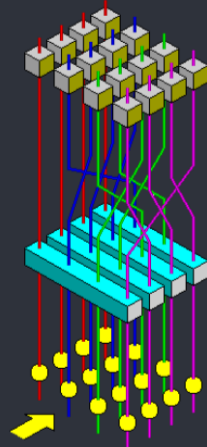
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```



```
1 void Security_Solution (crypto, SSL) {
2
3     < The security solutions adopted are cryptography and
4     SSL communication >
5
6     Tag AES_128 (plainText, * The user's credentials are stored
7                          key, IV); * encrypted using the AES-128 bit
8                                * in GCM mode
9
10
11     void SSL (certs); * Data are sended by server Python to
12                    * Esp32 in clear because the
13                    * communication are made by SSL that
14                    * allows confidentiality, integrity and
15                    * authentication
16 }
```

```
1 Tag AES_128 (plainText, key, IV) {
2
3
4   /*****
5    * AES-GCM is a block cipher provides authentication, confidentiality *
6    * and integrity.
7    *****/
8
9   < We have 4 input:
10
11   — Secret key (128-bit);
12
13   — IV (96-bit);
14
15   — Plaintext;
16
17   — Optional addition authenticated data (AAD) >
18
19 }
```



```
1 Tag AES_128 (plainText, key, IV) {
2
3     /*****
4      * The key must be generated randomly, for example by implementing      *
5      * PUFs in Esp32.                                                         *
6      *****/
7
8     < This is useful because the PUF is used to create keys that are
9     generated on-demand and instantaneously erased once used. The PUF
10    key value never exists in digital form within the circuitry of the
11    security IC and the key is derived and produced on-demand from
12    physical characteristics of circuit elements, they are never present
13    in the device's nonvolatile memory >
14
15    < In our case we have a hard-coded non-random
16    test key >
17 }
```



```
1 Tag AES_128 (plainText, key, IV) {
2
3     /*****
4      * The IV are generated casually by Esp32 RNG Hardware.      *
5      *****/
6
7     < The function esp_random() produces true random numbers if
8     Wi-Fi or Bluetooth are enabled. The function returns an integer
9     of 32 bit, so the string IV is builded in append by generating
10    more TRNs to output a 96-bit string (12 byte) >
11
12    < Every credential is own IV stored in clear
13    and IV associated changes at each new
14    encryption of the same credential >
```

IV

```
1 Serial.println ( 'AES Advantages: ' +
2
3   Step 01 It is a fast algorithm
4
5   Step 02 The key can be 128 – 192 – 256 bit
6           long not allowing brute force attacks
7
8   Step 03 The block size is 128 bits
9
10  Step 04 GCM mode allows authentication,
11          confidentiality and integrity
12
13 );
14
```

```
1 Serial.println ( 'AES Disadvantages: ' +
2
3   Step 01 In the case of nonce reuse both integrity and
4   confidentiality properties are violated
5
6   Step 02 Short tags produce message forgeries
7
8
9   Step 03 GCM implementations are vulnerable
10  to timing attacks
11
12  Step 04 GCM is vulnerable against cycling
13  attacks
14 );
```

```
1 void SSL (certs) {
2
3     /*****
4      * SSL was used to create a secure channel during data exchange between *
5      * the Python server and the board.                                     *
6      *****/
7
8     < SSL allows us to authenticate the PassChain boards through the use
9     of certificates. In fact, before the data exchange takes place, the
10    server checks the client and server certificates and then the
11    exchange takes place >
12
13    < The disadvantages are that it uses a heavy protocol
14    due to the continuous encryption and decryption of data
15    when it departs and arrives at destination and to
16    generate new certificates for every new board that
17    connects to the server >
18 }
```




```
1 Serial.println ( 'SSL Advantages: ' +
2
3
4
5 Authentication Client uses the server's public key to
6 encrypt the data; the server uses the public
7 key in the client certificate to decrypt the
8 data the client sends
9
10
11 Integrity SSL provides data integrity by calculating a
12 message digest
13
14 Confidentiality SSL uses a combination of symmetric
15 and asymmetric encryption to ensure
16 message privacy
17 );
```

```
1
2
3 void thank_you () {
4
5
6     Serial.println('Thank you');
7
8     Serial.println('For your Attention');
9
10
11 }
12
13
14
```