CAREL – Confidential



**REQUIREMENTS SPECIFICATION**

*Framework for*

*Gateway Middle End*

rev. 0.1

DRAFT

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1. Introduction
   1. Scope of the document

This document refers to the realization of a software framework, implementing the so called Middle End Gateway (GME). Such device is intended for collecting data from a single connected device and for sharing such information with a MQTT broker (to whom it is connected in WiFi or 2G). In detail, GME:

* gets data from a single Modbus RTU slave connected device via RS485
* temporarily keeps data and sends it to a MQTT broker (2G/WiFi)
* gets requests of changes of variable values from the MQTT broker and resends them to the connected device
* gets a file name and url (containing model info) via MQTT and accepts the file itself via HTTPS (for FW update).

This document aims at describing the basic functioning of the GME and at identifying the building blocks of the overall firmware.

The framework originated by this document is intended to be portable on different hw platforms. To this extent, Carel will provide documentation describing the functions to be called to implement different functions. In some cases, these functions will not be fully implemented but they will require HW/platform specific additional implementations to be filled in by USR.

This document is organized as follows. At first, the operating principle is described, focusing on actions to be carried on during initialization and during regular operation. Then, more detail on implementation is given.

TODO

* 1. Definitions, acronyms and abbreviations

AP = WiFi access point

GME\_AP = gateway that act as an access point  
GME\_WIFI = Gateway Middle End versione WiFi

GME = Gateway Middle End  
GSM = refer to 2G/4G/NB IoT connection  
FW = firmware

IoT = Internet of Things

MonDev = the device connected to the GME through the RS485 interface

OTA = Over The Air

SW = software  
MODEL\_TABLE = table defining the meaning of Modbus registers

1. Operating principle
   1. Initialization

Initialization of the gateway requires the following steps:

1. Initialization of operating system (if present)
2. Initialization and check of the file system
3. Recovery of configuration/model information
4. Connection to wifi access point/2G provider
5. Initialization of the RTC
6. Initialization of the RS485
7. Initialization of MQTT engine
8. Inizialization fo the polling engine

### Initialization of operating system

We assume that a real-time operating system is available. This way, running single tasks concurrently becomes easier and more efficient.

### Initialization of file system

We assume that a file system is available and that information can be stored/recovered using some primitive functions.

### Initialization of button/leds

Gpio pins corresponding to button and leds must be initialized.

At this step, a task monitoring the status of the button must start.

Button is intended as a reset button, with the following behaviour.

If during regular operation it is pressed for a short time (more than 2s, less than 5s), system must be rebooted.

If, at power up, it is pressed for more than 5s, GME is reverted to its factory default status: the installed model is deleted and connection parameters are reset to default.

As regards leds, TODO

### Recovery of configuration/model information

During this phase, it must be checked that a valid configuration file is available in file system. File must be checked and read. If such file is not present or if it’s invalid, a default configuration will be considered. These actions will be managed by Carel.

Configuration file contains info about:

* baud rate of the RS485 Modbus RTU link
* Modbus address of the connected device
* url and port of the ntp server from which time will be retrieved
* url, username and password for connection to the MQTT broker
* in case of 2G gateway, the APN for mobile connection
* in case of WiFi gateway, the AP and password for connection
* MQTT broker, port, user and password

Default configuration has:

* baud rate 19200bps

Configuration file cannot be updated.????

Successively, model must be recovered the same way.  
It no such file is present or if it is not valid, a default model is considered.

Model file contains:

* the variables list that will be cyclically read from the connected device via Modbus protocol
* data format of the RS485 link (data bits, stop bits, parity)

Default model has:

* data format 8-n-1

Model file can be updated during regular operation.

A file is valid if its CRC16 checksum, written at the end of the file, is valid and if it contains a well-defined header.

### Connection to wifi access point/2G provider

GME must connect to a wifi access point or to a 2G provider, depending on the HW on which we’re running.

In both cases, information about connection must be recovered from the configuration file.

TODO

### Initialization of dhcp client

A dhcp client must be initialized in case GME has to work in dhcp mode, as inferred from the configuration file.

### Initialization of dns client

A DNS client must be initialized to allow GME to convert alpha-numeric names into the numeric IP addresses that are required for access to external network resources on the Internet.

### Initialization of RTC

Clock setting is performed via NTP. UTC time is obtained directly enquiring a NTP server. URL of the server and the port used for NTP connection are written in configuration file.

AB: Alternatively for the 2G model is possible to use the time retrieved from the GSM network and adapted to return a UTC value. This in the case you have serious memory constraint and the space for the NTP library is not compatible with the available memory.

VC: Yes, in mobile connections there are other ways to get time (<https://www.raviyp.com/embedded/244-gsm-network-time-synchronization-for-rtc-using-at-clts-command>) BUT what do we do in case of WiFi?

### Initialization of certificates

The GME must natively contain 2 certificate files. The GME attempts to validate the first: if it is not valid or not validated by the server, the second is checked. The validity of certificates is checked as soon as the gateway has obtained a valid time from network.

Certificate files can be updated during regular operation.

### Initialization of RS485

The serial RS485 port must be initialized at the physical characteristics contained in model and configuration files (baud rate, data bits, stop bits, parity).

### Initialization of Modbus slave communication

All buffers required to store Modbus samples before sending must be statically allocated, polling engine is not yet started: it will be as soon as MQTT connection is established.

### Initialization of https client

An https client must be initialized.

TODO

### Initialization of MQTT connection

Connection towards a MQTT server must be initialized.

GME uses parameters in configuration file or, if they are not available, it uses default parameters to finally get actual parameters.

* 1. Regular operation

After initialization, GME regular operation starts.

GME continuously and periodically polls the connected device via Modbus protocol to get required variable values. This mechanism is called “polling engine” and it will be completely developed by Carel. USR will only expose primitives for writing/reading to/from RS485 interface, via Modbus protocol. Since it must be possible to temporarily stop polling engine, a semaphore mechanism offering this chance will be available.   
The whole variables set and corresponding sampling times are stored in model file.

Gathered data must be transferred via MQTT to a broker. USR will be responsible for such communication, whereas MQTT payload packing will be implemented by Carel.

* 1. File transfer on GME

GME must be able to download one or more files from a remote location. Those files could be model or configuration files, certificates, FW updates for the connected device or FW updates for the GME itself.

File transfer is carried on through connection to a HTTPS server.   
Hence, GME must implement HTTPS client functionalities.

USR must share with Carel all the primitives needed to complete HTTPS file transfer.

AB: About the possibility to perform a GME FW updates a good choice if possible is to use

HTTPS file transfer to upgrade the GME itself, in this way all the files to the GME are transferred in the same way, is it possible ?

1. Implementation

To ease source code sharing between Carel and USR, Carel will provide a set of files, organized in files that can be easily identified. Files containing Carel provided source code will all have the suffix \_CAREL.\*, whereas files requiring USR action will have suffix \_IS.\*.

Files will be called after their functionality, in an intuitive manner (i.e. RTC functions will be saved in RTC\_\*.\* file).

The following table shows a summary of features and identifies who should implement different parts.

|  |  |  |  |
| --- | --- | --- | --- |
| **FEATURE** | **OPERATION** | **CAREL** | **USR** |
| Real-time OS |  |  |  |
|  | Create task |  | ✓ |
| File system |  |  |  |
|  | Open/Read/Write file |  | ✓ |
|  | Check file | ✓ |  |
| WiFi |  |  |  |
|  | Connect |  | ✓ |
|  | Disconnect |  | ✓ |
|  | Get connection status |  | ✓ |
| 2G |  |  |  |
|  | Connect |  | ✓ |
|  | Disconnect |  | ✓ |
|  | Get connection status |  | ✓ |
|  | Receive SMS |  | ✓ |
| NTP client |  |  |  |
|  | Get UTC time |  | ✓ |
| MQTT client |  |  |  |
|  | Connect |  | ✓ |
|  | Disconnect |  | ✓ |
|  | Publish |  | ✓ |
|  | Subscribe |  | ✓ |
|  |  |  |  |
| MQTT payload manager |  |  |  |
|  | Compose payload | ✓ |  |
|  | Parse payload | ✓ |  |
| RS485 driver |  |  |  |
|  | Configure serial |  | ✓ |
|  | Write single/multiple data |  | ✓ |
|  | Read single/multiple data |  | ✓ |
|  |  |  |  |
| Modbus master RTU |  |  |  |
|  | Read/write single/multiple coil | ✓ |  |
|  | Read/write single/multiple HR | ✓ |  |
|  | Read/write single/multiple IR | ✓ |  |
|  | Read/write single/multiple DI | ✓ |  |
|  | Manage report slave id | ✓ |  |
|  |  |  |  |
| Polling engine |  |  |  |
|  | Sample variables (low/high frequency) | ✓ |  |
|  | Sample alarms | ✓ |  |
|  | Start polling | ✓ |  |
|  | Stop polling | ✓ |  |
|  | Reset buffer record | ✓ |  |
|  | Get status slave device | ✓ |  |
| https client |  |  |  |
|  | Connect |  | ✓ |
|  | Disconnect |  | ✓ |
|  | Post |  | ✓ |
|  | Get |  | ✓ |
|  | GetResponse |  | ✓ |
| dhcp client |  |  |  |
|  |  |  | ✓ |
| dns client |  |  |  |
|  |  |  | ✓ |
| LED driver |  |  |  |
|  | On |  | ✓ |
|  | Off |  | ✓ |
| Button |  |  |  |
|  | GetStatus |  | ✓ |
| Timer |  |  |  |
|  | TimerStart | ✓ |  |
|  | TimerReset | ✓ |  |
|  | TimerElapsed | ✓ |  |

* 1. Data structures

The following data structures are required to store useful data:

Configuration file contains the following:

typedef struct configuration\_file

{

C\_UINT32 RS485\_baudrate;

C\_UINT16 address;

C\_BYTE gateway\_mode;

C\_CHAR ap\_ssid[30];

// C\_BYTE ap\_ssid\_hidden; ???

C\_CHAR ap\_pswd[30];

C\_CHAR ap\_ip[15];

C\_CHAR ap\_netmask[15];

// C\_BYTE ap\_dhcp\_mode;

// C\_CHAR ap\_dhcp\_ip[15];

C\_CHAR sta\_ssid[30];

// C\_CHAR sta\_encryption[30]; ???

C\_CHAR sta\_pswd[30];

C\_BYTE sta\_dhcp\_mode;

C\_CHAR sta\_static\_ip[15];

C\_CHAR sta\_netmask[15];

C\_CHAR sta\_gateway\_ip[15];

C\_CHAR apn\_name[30];

C\_CHAR sta\_primary\_dns[15];

C\_CHAR ntp\_server[30];

C\_UINT16 ntp\_port;

}configuration\_file;

Model file contains:

typedef struct model\_file{

C\_CHAR header\_signature[8];

C\_UINT16 header\_version;

C\_BYTE mod\_guid[16];

C\_UINT32 mod\_version;

C\_BYTE RS485\_stopbits;

C\_BYTE RS485\_parity;

C\_UINT16 low\_coils;

C\_UINT16 low\_di;

C\_UINT16 low\_hr;

C\_UINT16 low\_ir;

C\_UINT16 high\_coils;

C\_UINT16 high\_di;

C\_UINT16 high\_hr;

C\_UINT16 high\_ir;

C\_UINT16 alarm\_coils;

C\_UINT16 alarm\_di;

C\_UINT16 alarm\_hr;

C\_UINT16 alarm\_ir;

/\*other modbus stuff\*/

}model\_file;

TODO

* 1. Initialization procedure

### Initialization of operating system

Initialization of OS is completely up to USR. For convenience, we assume it is done calling something like:

void RTOS\_Init();

### Initialization of file system

File system initialization is up to USR and must include all the actions required to properly initialize file system.

This function must be implemented by USR and, once run, allows Carel to access file system using common stdio library functions (such as fopen, fread, fseek, fwrite, fclose, …).

For convenience, we assume it is done calling something like:

File\_System\_Init();

### Initialization of button/leds

Button must be initialized calling a function that, besides configuring GPIO pins, starts a task to monitor button all through the GME life:

Button\_Init();

If the button is pressed when the task is started, a timer is started to check if button is still pressed after 5 seconds. If so, the following function must be called to reset parameters at its factory status:

Set\_Factory();

Whose implementation is up to Carel.

Further, during regular operation, button management task must ensure that, if pressed for more than 2s and less than 5s, system is rebooted.

As regards leds, TODO

### Recovery of configuration/model information

USR will load configuration and model to dedicated statically allocated memory structures of type configuration\_file and model\_file (described above) calling:

C\_RES File\_System\_Config\_Load(C\_CHAR\* CFile);

C\_RES File\_System\_Model\_Load(C\_CHAR \* MFile);

Parameters are the names of the configuration and model files respectively. Implementation of these functions is up to Carel.

### Connection to wifi access point/2G provider

In case of WiFi gateway, it can act as both station (STA) and access point (AP). Information about the mode to be used is written in configuration file and can be retrieved calling:

C\_BYTE Get\_WiFi\_Mode(void);

which returns 0 if no such info is available, 1 if mode is AP and 2 if it is STA.

In case STA mode is set, connection must be established towards and AP, whose ssid and psk can be retrieved calling:

C\_CHAR\* Get\_WiFi\_Station\_SSID();

C\_CHAR\* Get\_WiFi\_Station\_PSK()

which respectively return a pointer to a C\_CHAR buffer of size 30 containing ssid and psk of the AP.

IP address acquisition can be performed in dhcp mode or statically. The choice between the 2 is read with:

C\_BYTE Get\_WiFi\_Station\_DHCP\_mode();

which returns 0 if no such info is available in configuration file, 1 if dhcp mode is to be used and 2 if address will be assigned statically.

In latter case, static address must be read using:

C\_CHAR\* Get\_WiFi\_Station\_StaticIP();

which returns a char pointer of size 15 containing the static IP address selected in configuration file. Similarly, netmask and gateways IP can be read from:

C\_CHAR\* Get\_WiFi\_Station\_Netmask();

C\_CHAR\* Get\_WiFi\_Station\_Gateway();

In case AP mode is set, the GME acts as an AP, having ssid and psk that can be retrieved calling:

C\_CHAR\* Get\_WiFi\_AP\_SSID();

C\_CHAR\* Get\_WiFi\_AP\_PSK();

Its IP and netmask address is read using:

C\_CHAR\* Get\_WiFi\_AP\_IP();

C\_CHAR\* Get\_WiFi\_AP\_Netmask();

In case of GSM, the GME attempts to connect to 2G network using the APN indicated in configuration file and retrieving such info using function:

C\_CHAR\* Get\_GSM\_APN();

which returns an array of 30 chars containing the APN name.

All the above functions will be implemented by Carel. USR will implement the functions required to connect to networks using the information obtained from the above functions. We assume connection is handled by calls to:

WiFi\_Init();

GSM\_Init();

TODO

### Initialization of dhcp client

In case dhcp mode must be active, as deduced from calling function Get\_WiFi\_Station\_DHCP\_mode(), DNS must start a dhcp client.

### Initialization of dns client

DNS client must be initialized by USR with dedicated functions.

The IP address of the DNS server to be used can be retrieved from configuration file with:

C\_CHAR\* Get\_DNS();

returning a pointer to a char array containing the IP address.

### Initialization of RTC

URL of the NTP server and the port used for NTP connection are written in configuration file. Both can be read from configuration file calling:

C\_CHAR\* Get\_NTP\_Server();

C\_UINT16 Get\_NTP\_Port();

returning an array of 30 chars for the server name and a C\_UINT16 containing the port respectively. These functions will be implemented by Carel.

Initialization must be implemented by USR in function:

C\_RES RTC\_Init();

that will recover ntp server name and port and start connection and return SUCCESS as soon as time is available.

### Initialization of certificates

Provided that time is properly retrieved from network, certificate validity can be checked calling:

C\_RES File\_System\_Check\_Cert(C\_CHAR\* file);

that returns SUCCESS if certificate is validated.

### Initialization of RS485

Initialization of the serial RS485 port will be implemented by USR calling:

C\_RES RS485\_Init();

This function must recover info on baud rate and data format from model and configuration file, calling:

C\_UINT32 Get\_BaudRate();

C\_BYTE Get\_StopBits();

C\_BYTE Get\_Parity();

Which respectively return baud rate, number of stop bits and parity of the serial data. Number of data bits is set at 8.

### Initialization of Modbus slave communication

All buffers required to store Modbus samples before sending must be statically allocated, polling engine is not yet started: it will be as soon as MQTT connection is established.

Polling engine initialization is up to Carel and will be implemented in:

Polling\_Engine\_Init();

Considering that polling engine may be occasionally stopped to let other actions occur, a semaphore mechanism must be implemented, using a global variable Stop\_Polling that prevents polling engine from running when set to true. Immediately after initialization of the polling engine, polling will be stopped until MQTT will be initialized.

### Initialization of https client

TODO

### Initialization of MQTT connection

Connection towards a MQTT server must be initialized.

GME uses parameters in configuration file or, if they are not available, it uses default parameters to finally get actual parameters.

### Initialization flow

/\* RTOS initialization \*/

RTOS\_Init();

/\* File system initialization \*/

File\_System\_Init();

/\* GPIO initialization\*/

LED\_Init();

Button\_Init();

/\* Check and load configuration \*/

File\_System\_Config\_Load(“config.bin”);

/\* Connect to 2G provider or WiFi access point according to part number \*/

#if (NETWORK\_INTERFACE == WIFI\_INTERFACE)

WiFi\_Init(“your\_ap”,”psk”);

#elif (NETWORK\_INTERFACE == GSM\_INTERFACE)

GSM\_Init(“your.apn.com”);

#endif

/\* Clock initialization and certificate validation \*/

if(RTC\_Init() == SUCCESS)

if(File\_System\_Check\_Cert(“cert1.crt”) == SUCCESS)

File\_System\_Cert\_Load(“cert1.crt”);

else if(File\_System\_Cert\_Check(“cert2.crt”) == SUCCESS)

File\_System\_Cert\_Load(“cert2.crt”);

else

**???? //no valid certificate**

else

**???? // time cannot be retrieved, what to do?**

/\* Check and load model \*/

File\_System\_Model\_Load(“model.bin”);

/\* RS485 initialization \*/

RS485\_Init();

/\* Polling engine initialization, temporarily stopped \*/

Stop\_Polling = TRUE;

Polling\_Engine\_Init();

/\* MQTT connection initialization and polling start \*/

if(MQTT\_Init() == SUCCESS)

STOP\_Polling=FALSE;

* 1. Regular operation procedure

Periodically, the following operations must be executed:

1. Send status information about connected device via MQTT to the configured broker
2. Process incoming MQTT messages
3. In case polling is enabled, poll variables and, if it’s time to send values via MQTT, do that,
4. If polling is disabled, evaluate other actions: is a file to be transferred? Are there any MQTT-variable changes to be performed?

*USB??? (vedi document che descrive l’aggiornamento ota)*

*Non mi è chiaro cosa succede se il file di modello non è valido*

*E se non è valido quello di configurazione?*

Based on the above, the rest of the paragraph gives more detail on needed files and functions.

### Real-time OS

### File system

It may occasionally happen that a new file has to be written in file system. In such occasion, USR can call dedicated functions, depending whether the file is a configuration, model or certificate respectively.

C\_RES File\_System\_Configuration\_Store(C\_CHAR\* name, C\_BYTE\* stream); //è previsto?

C\_RES File\_System\_Model\_Store(C\_CHAR\* name, C\_BYTE\* stream);

C\_RES File\_System\_Cert\_Store(C\_CHAR\* name, C\_BYTE\* stream);

where name is the name of the file to be written and stream is a buffer containing the file.

### Button and leds

During regular operation button has the behaviour described in section dealing with initialization.

As regards leds TODO

### RTC

Time synchronization to the NTP server must be guaranteed at least once a day by a dedicated task implemented by USR.

In any moment, it must be possible to get current UTC time with a call to:

C\_TIME RTC\_Get\_UTC\_Current\_Time(void);

which returns an epoch time (seconds from 1/1/1970), UTC-aligned.

Implementation of this function is up to USR.

### RS485

### Modbus

### MQTT