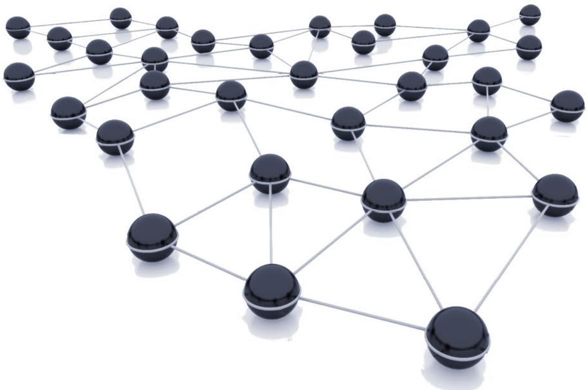
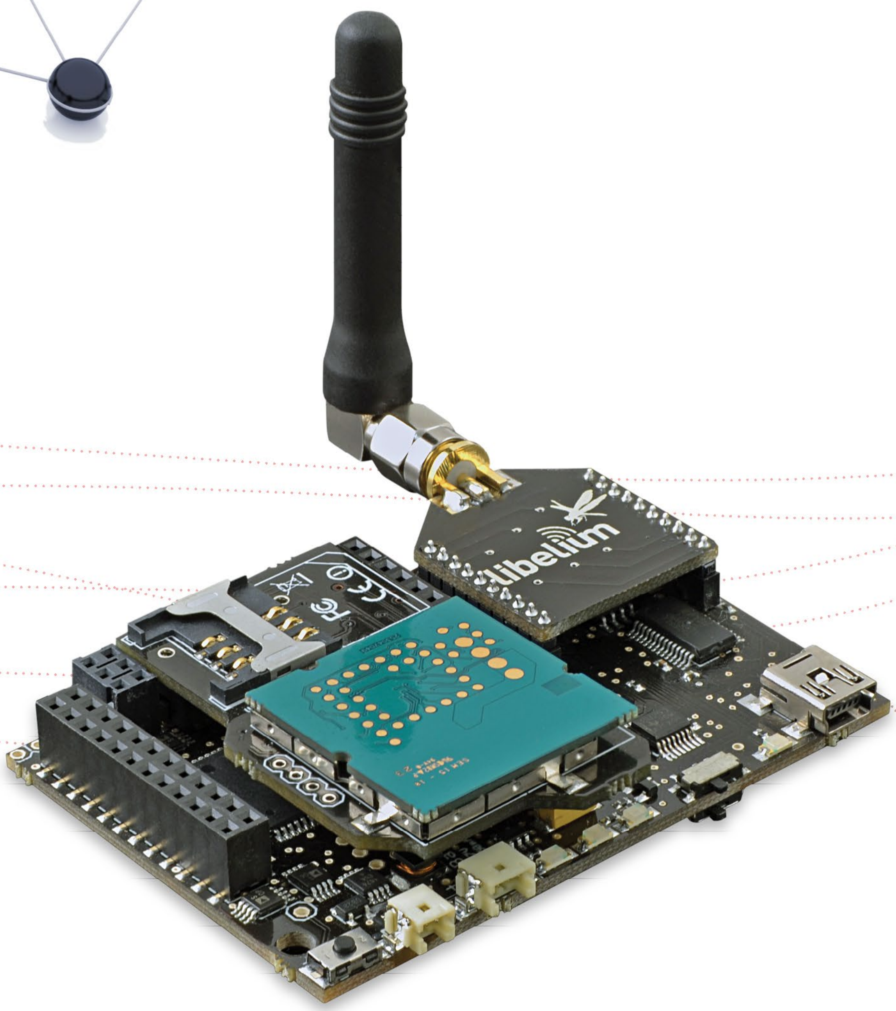
Waspmote Data Frame

Programming Guide





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Document Version: v5.0 - 10/2015
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1. General Considerations

1.1. Waspmote Frame Files

WaspFrame.h, WaspFrame.cpp, WaspFrameConstants.h

It is mandatory to include the WaspFrame library when using this class. The following line must be introduced at the beginning of the code:

```
#include <WaspFrame.h>
```

Libelium recommends the use of the official Data Frame format, explained in this guide. It is especially good for the projects with a Meshlium, because it can parse frames in an automatic way thanks to the feature "Sensor Parser".

1.2. Constructor

To start using the Waspmote Frame library, an object from the 'WaspFrame' class must be created. This object, called `frame`, is created inside the Waspmote Frame library and it is public to all libraries. It is used through the guide to show how the Waspmote Frame library works.

When creating this constructor, some variables are defined with a value by default.

1.3. API functions

Through this guide there are many examples of the WaspFrame class usage. In these examples, API functions are called to execute the commands, storing in their related variables the parameter value in each case.

Example of use

```
{
 frame.createFrame(); // create a new frame
}
```

1.4. Predefined constants

There are some predefined constants in a file called 'WaspFrame.h'. These constants define some parameters like the maximum size of each frame:

MAX_FRAME: (default value 150) specifies the maximum size of the frames to be created.
ASCII: this constant is used to define an ASCII frame mode.
BINARY: this constant is used to define a Binary frame mode.
EXAMPLE_FRAME: defines an example frame type.
TIMEOUT_FRAME: defines a timeout frame type.
EVENT_FRAME: defines an event frame type.
ALARM_FRAME: defines an alarm frame type.
SERVICE1_FRAME: defines a service1 frame type.
SERVICE2_FRAME: defines a service2 frame type.

Besides, there are sensor TAGs defined for each kind of sensor. These labels are used to set different fields inside the frame in order to distinguish between different sensor values and identify them.

2. Frame Structure

There are two kind of frames: ASCII and Binary.

2.1. ASCII Frame

These frames are supposed to facilitate the comprehension of the data to be sent. As the frame is composed by ASCII characters is easier to understand all the fields included within the payload.

It is possible to identify two different parts inside the frame. The first one corresponds to the header and its structure is always the same. The second one corresponds to the payload and it is where the sensor values are included.

The following figure describes the ASCII Frame structure:

HEADER										PAYLOAD						
<=>	Frame Type	Num Fields	#	Serial ID	#	Waspmote ID	#	Sequence	#	Sensor_1	#	Sensor_2	#	...	Sensor_n	#

Figure : ASCII Frame structure

2.1.1. ASCII Header

The structure fields are described below with an example:

HEADER										PAYLOAD					
<=>	0x80	0x03	#	35690284	#	NODE_001	#	214	#	Temp:35	#	GPS:31.200;42.100	#	DATE:12-01-01	#
A	B	C	D	E	D	F	D	G	D	sensor1	D	sensor2	D	sensor3	D

Figure : ASCII Frame example

A → Start Delimiter [3 Bytes]: It is composed by three characters: "<=>". This is a 3-Byte field and it is necessary to identify each frame starting.

B → Frame Type Byte [1 Byte]: This field is used to determine the frame type. There are two kind of frames: Binary and ASCII. But it also defines the aim of the frame such event frames or alarm frames. This field will be explained in the following sections.

C → Number of Fields Byte [1 Byte]: This field specifies the number of sensor fields sent in the frame. This helps to calculate the frame length.

D → Separator [1 Byte]: The '#' character defines a separator and it is put before and after each field of the frame.

E → Serial ID [10 Bytes]: This is at most a 10-Byte field which identifies each Waspmote device uniquely. The serial ID is get from a specific chip integrated in Waspmote that gives a different identifier to each Waspmote device. So, it is only readable and it can not be modified.

F → Waspmote ID [0Byte-16Bytes]: This is a string defined by the user which may identify each Waspmote inside the user's network. The field size is variable [from 0 to 16Bytes]. When the user do not want to give any identifier, the field remains empty between frame's separators: "##".

G → Frame sequence [1Byte-3Bytes]: This field indicates the number of sequence frame. This counter is 8-bit, so it goes from 0 to 255. However, as it is an ASCII frame, the number is converted to a string so as to be understood. This is the reason the length of this field varies between one and three bytes. Each time the counter reaches the maximum 255, it is reset to 0. This sequence number is used in order to detect loss of frames.

Note: *There is only one frame counter, so in the case two communication modules are used, this counter is incremented each time a new frame is created. If each module needs to create a new frame, the counter will be incremented by 2 in the same loop, one for each frame creation.*

2.1.2. ASCII Payload

The frame payload is composed by several sensor data. All data sent in these fields correspond to a predefined sensor data type in the sensor table. This sensor table is stored in Meshlium (gateway of the network) and it will be used in order to interact with the database.

There are three types of ASCII sensor fields:

- **Simple Data:** Sensor field is composed by a unique data. The format is: "`sensor_label:value`" and a separator character [#] is set at the end of the value. For example, a temperature field indicating 23ºC would be as follows:

  ```
  #TC:23#
  ```

- **Complex Data:** This is the format used to send data composed by two or three values. The format is: "`sensor_label:value;value;value`" and a separator character [#] is set at the end of the last value. Accelerometer and GPS measurements are some examples:

  ```
  #ACC:996;-250;-100#
  #GPS:41.680616;-0.886233#
  ```

- **Special Data:** Date and time are defined in a special format.

  Date is defined as "`yy-mm-dd`" where:
  - yy: year
  - mm: month
  - dd: day of month

  Example: #DATE:13-01-01#

  Time is formatted as "`hh-mm-ss+GMT`" where:

  - hh: hours
  - mm: minutes
  - ss: seconds
  - GMT: GMT is added after hh-mm-ss. It is possible to avoid this information in order to save frame size.

  Example without GMT: `#TIME:12-24-16#`
  Example with GMT: `#TIME:12-24-16+1#`

2.2. Binary Frame

This frame type has been designed to create more compressed frames. The main goal of defining binary fields is to save bytes in frame's payload in order to send as much information as possible. The main disadvantage is the legibility of the frame.

As the ASCII frames, the Binary frames are also composed by two different parts: header and payload. The header of the Binary frame is quite similar to the ASCII frame except for the frame sequence number and the separator at the end of the header.

The following figure describes the Binary Frame structure:

HEADER							PAYLOAD			
<=>	Frame Type	Num of bytes	Serial ID	Waspmote ID	#	Sequence	Sensor_1	Sensor_2	...	Sensor_n

Figure : Binary Frame structure

2.2.1. Binary Header

The structure fields are described below with an example:

HEADER							PAYLOAD								
<=>	0x00	0x17	0x74F94515	NODE_001	#	0x00	ID	Byte 1	Byte 2	ID	Byte 1	Byte 2	ID	Byte 1	Byte 2
A	B	C	E	F	D	G	Sensor 1			Sensor 2			Sensor 3		

Figure : Binary Frame example

A → Start Delimiter [3 Bytes]: It is composed by three characters: "<=>". This is a 3-Byte field and it is necessary to identify each frame starting.

B → Frame Type Byte [1Byte]: This field is used to determine the frame type. There are two kind of frames: Binary and ASCII. But it also defines the aim of the frame such event frames or alarm frames. This field will be explained in the following sections.

C → Number of Bytes [1Byte]: This field specifies the number of bytes after this field until the end of the payload is found.

D → Separator [1Byte]: The '#' character defines a separator and it is put between some fields which length is not specified. This helps to parse the different fields in reception.

E → Serial ID [4Byte]: This is a 4-Byte field which identifies each Waspmote device uniquely. The serial ID is get from a specific chip integrated in Waspmote that gives a different identifier to each Waspmote device. So, it is only readable and it can not be modified. Note that the Serial ID is sent as a binary field too.

F → Waspmote ID [variable]: This is a string defined by the user which may identify each Waspmote inside the user's network. The field size is variable [from 0 to 16Bytes]. When the user do not want to give any identifier, the field remains empty indicated by a unique '#' character.

G → Frame sequence [1Byte]: This field indicates the number of sent frame. This counter is 8-bit, so it goes from 0 to 255. Each time it reaches the maximum 255 is reset to 0. This sequence number is used in order to detect loss of frames.

Note: *There is only one frame counter, so in the case two communication modules are used, this counter is incremented each time a new frame is created. If each module needs to create a new frame, the counter will be incremented by 2 in the same loop, one for each frame creation.*

2.2.2. Binary Payload

The frame payload might be composed by several sensor data. All data sent in these fields correspond to a predefined sensor data type in the sensor table. Regarding the binary format, each sensor in the sensor table determines the number of necessary bytes to express the sensor value. The sensor table is stored in Meshlium (gateway of the network) and it will be used in order to interact with the database.

There are three types of Binary sensor fields:

- **Simple Data:** The sensor field is composed by a unique data. The format of this field is: the first byte codifies the sensor type. Following the first byte and according to the sensor table, there is a number of bytes which correspond to the sensor value. For example, the temperature sensor is a float number, so it is a 4-byte field. Thus, the sensor field for 27ºC will be set as follows:

ID (1 Byte)	Byte1	Byte2	Byte3	Byte4
SENSOR_TCA	0x00	0x00	0xD8	0x41

Figure : Binary simple sensor field

Note: *Floats are codified so they are not a simple conversion.*

- **Complex Data:** This is the format used to send data composed by more than one value. The format of this field is: the first byte codifies the sensor type. Then, the different values are codified using as many bytes as they specify in the sensor table. For example, the GPS field is composed by both latitude and longitude floats, which means that 8 bytes are needed for both float values:

ID (1 Byte)	Byte1	Byte2	Byte3	Byte4	Byte1	Byte2	Byte3	Byte4
SENSOR_GPS	0x59	0x9D	0x26	0x42	0xE0	0x10	0x61	0xBF

Figure : Binary complex sensor field

Note: *Floats are codified so they are not a simple conversion.*

- **String:** This is the only field that is formed differently: the first byte codifies the sensor type, the second byte defines the string length, and the rest of the bytes belong to the string itself according to the length previously defined. For example, the string "hello" is formatted as follows:

ID (1 Byte)	Length	Byte1 ('h')	Byte2 ('e')	Byte3 ('l')	Byte4 ('l')	Byte5 ('o')
SENSOR_STR	0x05	0x68	0x65	0x6C	0x6C	0x6F

Figure : Binary string sensor field

2.3. Frame Types

As it was said before, there is a specific field in the header which specifies the frame type. This field is defined by a byte noted as the sequence of the following bits: $b_7b_6b_5b_4b_3b_2b_1b_0$:

b_7: The most significant bit specifies if the frame is ASCII (b_7=1) or Binary (b_7=0).

b_6-b_0: The rest of the bits determine the frame type which might be an event frame, a time out frame, etc.

Frame Types				
Frame Type Byte		**Decimal value**	**Identifier**	**Description**
bit7	**bit6-bit0**			
0 (Binary)	0000000	0	Example	Regular frame for examples
	0000001	1	TimeOut	Frame sent when time is out
	0000010	2	Event	Frame sent when an event occurs
	0000011	3	Alarm	Frame sent when an alarm occurs
	0000100	4	Service1	Frame for "keep alive" advertisement
	0000101	5	Service2	Frame for "low battery" advertisement
	…	6 to 96	…	Reserved types
	1100001	97	AES128_ECB_FRAME	AES-128 Encrypted frame
	1100010	98	AES192_ECB_FRAME	AES-192 Encrypted frame
	1100011	99	AES256_ECB_FRAME	AES-256 Encrypted frame
	…	100 to 119	…	Reserved types
	1111000	120	delete_firmware	OTA packet to delete a firmware from boot.txt
	1111001	121	check_new_program	OTA packet to give starting information
	1111010	122	new_firmware_received	OTA packet to start receiving a new firmware
	1111011	123	new_firmware_packets	OTA packet to receive firmware packets
	1111100	124	new_firmware_end	OTA packet to end a firmware transmission
	1111101	125	upload_firmware	OTA packet to run a new firmware to Waspmote
	1111110	126	request_ID	OTA packet to request the mote ID
	1111111	127	request_bootlist	OTA packet to request the boot.txt list
1 (ASCII)	0000000	128	Example	Regular frame for examples
	0000001	129	TimeOut	Frame sent when time is out
	0000010	130	Event	Frame sent when an event occurs
	0000011	131	Alarm	Frame sent when an alarm occurs
	0000100	132	Service1	Frame for "keep alive" advertisement
	0000101	133	Service2	Frame for "low battery" advertisement
	…	134 to 255	…	Reserved types
	10011011	155	Time Sync	Frame for HTTP query with Time Stamp inf o from Meshlium
	…	156 to 255	…	Reserved types

Figure : Frame types

2.4. Sensor fields

The following table describes all possible sensor fields.

Reference: This column refers to the sensor reference given by Libelium to each sensor in the sensor catalog.

Sensor TAG: This column defines the constants needed to add each sensor to the frame using `addSensor()` function.

SENSOR ID: Each sensor field has its own identifier. Depending on the Sensor TAG chosen, a different identifier will be set as sensor identifier. ASCII frames use a string label as sensor identifier. Binary frames use a byte as sensor identifier so as to save frame size.

Number of Fields: Defines the number of different fields a sensor value presents. Most of sensors only need a unique field. But there are some cases which need more than one, i.e. the GPS module which needs 2 fields for both latitude and longitude measurements.

Type and Size: Indicates the variable type which has to be used for each sensor. The possibilities are: uint8_t (1 Byte), int (2 Bytes), float (4 Bytes), unsigned long (4 Bytes), string (variable size). ASCII frames don't have constraints when adding sensor fields in order to facilitate the user to insert new sensor data.

Default Decimal Precision: Defines for each sensor the number of decimals used in ASCII frames when using float variable types.

Units: This column defines the units used for each sensor.

	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Gases (Smart Environment)	Carbon Monoxide	9229	SENSOR_CO	0	CO	1	float	4	3	voltage
	Carbon Dioxide	9230	SENSOR_CO2	1	CO2	1	float	4	3	voltage
	Oxygen	9231	SENSOR_O2	2	O2	1	float	4	3	voltage
	Methane	9232	SENSOR_CH4	3	CH4	1	float	4	3	voltage
	Liquefied Petroleum Gases	9234	SENSOR_LPG	4	LPG	1	float	4	3	voltage
	Ammonia	9233	SENSOR_NH3	5	NH3	1	float	4	3	voltage
	Air Pollutants 1	9235	SENSOR_AP1	6	AP1	1	float	4	3	voltage
	Air Pollutants 2	9236	SENSOR_AP2	7	AP2	1	float	4	3	voltage
	Solvent Vapors	9237	SENSOR_SV	8	SV	1	float	4	3	voltage
	Nitrogen Dioxide	9238	SENSOR_NO2	9	NO2	1	float	4	3	voltage
	Ozone	9258	SENSOR_O3	10	O3	1	float	4	3	voltage
	Hydrocarbons	9201	SENSOR_VOC	11	VOC	1	float	4	3	voltage
	Temperature Celsius	9203	SENSOR_TCA	12	TCA	1	float	4	2	° C
	Temperature Fahrenheit	9203	SENSOR_TFA	13	TFA	1	float	4	2	° F
	Humidity	9204	SENSOR_HUMA	14	HUMA	1	float	4	1	%RH
	Pressure atmospheric	9250	SENSOR_PA	15	PA	1	float	4	2	Kilo Pascales

	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Events (Smart Security)	Pressure/Weight	9219	SENSOR_PW	16	PW	1	float	4	3	Ohms
	Bend	9218	SENSOR_BEND	17	BEND	1	float	4	3	Ohms
	Vibration	9221 / 9222	SENSOR_VBR	18	VBR	1	uint8_t	1	0	Open / Closed
	Hall Effect	9207	SENSOR_HALL	19	HALL	1	uint8_t	1	0	Open / Closed
	Liquid Presence	9243	SENSOR_LP	20	LP	1	uint8_t	1	0	Open / Closed
	Liquid Level	9239 / 9240 / 9242	SENSOR_LL	21	LL	1	uint8_t	1	0	Open / Closed
	Luminosity	9205	SENSOR_LUM	22	LUM	1	float	4	3	Ohms
	Presence	9212	SENSOR_PIR	23	PIR	1	uint8_t	1	0	presence / Not presence
	Stretch	9217	SENSOR_ST	24	ST	1	float	4	3	Ohms
	Temperature Celsius	9203	SENSOR_TCA	12	TCA	1	float	4	2	° C
	Temperature Fahrenheit	9203	SENSOR_TFA	13	TFA	1	float	4	2	° F
	Humidity	9204	SENSOR_HUMA	14	HUMA	1	float	4	1	%RH
	Luminosity (socket D)	9205	SENSOR_LUM_D	109	LUM_D	1	float	4	3	Ohms
	Luminosity (socket E)	9205	SENSOR_LUM_E	110	LUM_E	1	float	4	3	Ohms
	Luminosity (socket F)	9205	SENSOR_LUM_F	111	LUM_F	1	float	4	3	Ohms
	Liquid Presence (socket D)	9243	SENSOR_LP_D	112	LP_D	1	uint8_t	1	0	Open / Closed
	Liquid Presence (socket E)	9243	SENSOR_LP_E	113	LP_E	1	uint8_t	1	0	Open / Closed
	Liquid Presence (socket F)	9243	SENSOR_LP_F	114	LP_F	1	uint8_t	1	0	Open / Closed
	Liquid Level (socket D)	9239 / 9240 / 9242	SENSOR_LL_D	115	LL_D	1	uint8_t	1	0	Open / Closed
	Liquid Level (socket E)	9239 / 9240 / 9242	SENSOR_LL_E	116	LL_E	1	uint8_t	1	0	Open / Closed
	Liquid Level (socket F)	9239 / 9240 / 9242	SENSOR_LL_F	117	LL_F	1	uint8_t	1	0	Open / Closed
	Hall Effect (socket D)	9207	SENSOR_HALL_D	118	HALL_D	1	uint8_t	1	0	Open / Closed
	Hall Effect (socket E)	9207	SENSOR_HALL_E	119	HALL_E	1	uint8_t	1	0	Open / Closed
	Hall Effect (socket F)	9207	SENSOR_HALL_F	120	HALL_F	1	uint8_t	1	0	Open / Closed

Group	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Smart Cities	Microphone	9259	SENSOR_MCP	25	MCP	1	uint8_t	1	0	dBA
	Crack detection gauge	9321	SENSOR_CDG	26	CDG	1	uint8_t	1	0	true/false
	Crack propagation gauge	9322	SENSOR_CPG	27	CPG	1	float	4	3	Ohms
	Linear Displacement	9319	SENSOR_LD	28	LD	1	float	4	3	mm
	Dust	9320	SENSOR_DUST	29	DUST	1	float	4	3	mg/m^3
	Ultrasound	9246 / 9213	SENSOR_US	30	US	1	float	4	2	m
	Temperature Celsius	9203	SENSOR_TCA	12	TCA	1	float	4	2	° C
	Temperature Fahrenheit	9203	SENSOR_TFA	13	TFA	1	float	4	2	° F
	Humidity	9204	SENSOR_HUMA	14	HUMA	1	float	4	1	%RH
	Luminosity	9205	SENSOR_LUM	22	LUM	1	float	4	3	Ohms
	Temperature (DS18B20)	86949	SENSOR_TCC	106	TCC	1	float	4	2	ºC
	Ultrasound (3V3)	9246 / 9213	SENSOR_US_3V3	107	US	1	float	4	2	m
	Ultrasound (5V)	9246 / 9213	SENSOR_US_5V	108	US	1	float	4	2	m
Parking	Magnetic Field	N/A	SENSOR_MF	31	MF	3	int	2	0	LSBs
	Parking Spot Status	N/A	SENSOR_PS	32	PS	1	uint8_t	1	0	"Occupied / Empty"
Ambient Control	Temperature	9247	SENSOR_TCB	33	TCB	1	float	4	2	° C
	Humidity	9247	SENSOR_HUMB	35	HUMB	1	float	4	1	%RH
	Luminosity	9205	SENSOR_LUM	22	LUM	1	float	4	3	Ohms
	Luminosity	9325	SENSOR_LUX	88	LUX	1	float	4	2	luxes
Smart Agriculture	Temperature ºC (Sensirion)	9247	SENSOR_TCB	33	TCB	1	float	4	2	° C
	Temperature ºF (Sensirion)	9247	SENSOR_TFB	34	TFB	1	float	4	2	° F
	Humidity (Sensirion)	9247	SENSOR_HUMB	35	HUMB	1	float	4	1	%RH
	Soil Temperature	9255	SENSOR_SOILT	36	SOILT	1	float	4	2	ºC
	Soil Moisture	9248	SENSOR_SOIL	37	SOIL	1	float	4	2	Frequency
	Leaf Wetness	9249	SENSOR_LW	38	LW	1	float	1	3	%
	Solar Radiation	9251	SENSOR_PAR	39	PAR	1	float	4	2	$\mu mol*m^{-2}*s^{-1}$
	Ultraviolet Radiation	9257	SENSOR_UV	40	UV	1	float	4	2	$\mu mol*m^{-2}*s^{-1}$
	Trunk Diameter	9252	SENSOR_TD	41	TD	1	float	4	3	mm
	Stem Diameter	9253	SENSOR_SD	42	SD	1	float	4	3	mm
	Fruit Diameter	9254	SENSOR_FD	43	FD	1	float	4	3	mm
	Anemometer	9256	SENSOR_ANE	44	ANE	1	float	4	2	km/h
	Wind Vane	9256	SENSOR_WV	45	WV	1	uint8_t	1	N/A	Direction
	Pluviometer	9256	SENSOR_PLV	46	PLV	1	float	4	2	mm/min
	Temperature Celsius	9203	SENSOR_TCA	12	TCA	1	float	4	2	° C
	Temperature Fahrenheit	9203	SENSOR_TFA	13	TFA	1	float	4	2	° F
	Humidity	9204	SENSOR_HUMA	14	HUMA	1	float	4	1	%RH
	Luminosity	9205	SENSOR_LUM	22	LUM	1	float	4	3	Voltage
	Pluviometer (current hour)	9256	SENSOR_PLV1	96	PLV1	1	float	4	2	mm
	Pluviometer (previous hour)	9256	SENSOR_PLV2	97	PLV2	1	float	4	2	mm/h

	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Smart Agriculture	Pluviometer (last 24h)	9256	SENSOR_PLV3	98	PLV3	1	float	4	2	mm/day
	Soil Moisture (socket C)	9248	SENSOR_SOIL_C	99	SOIL_C	1	float	4	2	Frequency
	Soil Moisture (socket D)	9248	SENSOR_SOIL_D	100	SOIL_D	1	float	4	2	Frequency
	Soil Moisture (socket E)	9248	SENSOR_SOIL_E	101	SOIL_E	1	float	4	2	Frequency
	Soil Moisture (socket F)	9248	SENSOR_SOIL_F	102	SOIL_F	1	float	4	2	Frequency
	Soil Moisture (watermark1)	9248	SENSOR_SOIL1	103	SOIL1	1	float	4	2	Frequency
	Soil Moisture (watermark2)	9248	SENSOR_SOIL1	104	SOIL2	1	float	4	2	Frequency
	Soil Moisture (watermark3)	9248	SENSOR_SOIL1	105	SOIL3	1	float	4	2	Frequency
	Soil Temperature (DS18B20)	86949	SENSOR_TCC	106	TCC	1	float	4	2	ºC
Radiation	Geiger tube	N/A	SENSOR_RAD	47	RAD	1	float	4	6 or 0	uSv/h or cpm
Smart Metering	Current	9266	SENSOR_CU	48	CU	1	float	4	2	A
	Water flow	9296 / 9297 / 9298	SENSOR_WF	49	WF	1	float	4	3	l/min
	Load cell	9260 / 9261 / 9262	SENSOR_LC	50	LC	1	float	4	3	voltage
	Distance Foil	9267 / 9268	SENSOR_DF	51	DF	1	float	4	3	Ohms
	Temperature (DS18B20)	86949	SENSOR_TCC	106	TCC	1	float	4	2	ºC
	Ultrasound (3V3)	9246 / 9213	SENSOR_US_3V3	107	US	1	float	4	2	m
	Ultrasound (5V)	9246 / 9213	SENSOR_US_5V	108	US	1	float	4	2	m
	Water flow (socket C)	9296 / 9297 / 9298	SENSOR_WF_C	121	WF_C	1	float	4	3	l/min
	Water flow (socket E)	9296 / 9297 / 9298	SENSOR_WF_E	122	WF_E	1	float	4	3	l/min
Additional	Battery	N/A	SENSOR_BAT	52	BAT	1	uint8_t	1	0	%
	Global Positioning System	WGPS	SENSOR_GPS	53	GPS	2	float	4	6	degrees
	GPS speed over the ground	N/A	SENSOR_SPEED	89	SPEED_OG	1	float	4	2	km/h
	GPS course over the ground	N/A	SENSOR_COURSE	90	COURSE_OG	1	float	4	2	degrees
	GPS altitude	N/A	SENSOR_ALTITUDE	91	ALT	1	float	4	2	m
	GPS HDOP	N/A	SENSOR_HDOP	92	HDOP	1	float	4	3	N/A
	GPS VDOP	N/A	SENSOR_VDOP	93	VDOP	1	float	4	3	N/A
	GPS PDOP	N/A	SENSOR_PDOP	94	PDOP	1	float	4	3	N/A
	RSSI	N/A	SENSOR_RSSI	54	RSSI	1	int	2	0	N/A
	MAC Address	N/A	SENSOR_MAC	55	MAC	1	string	variable	N/A	N/A
	Network Address (XBee)	N/A	SENSOR_NA	56	NA	1	string	variable	N/A	N/A
	Network ID origin (XBee)	N/A	SENSOR_NID	57	NID	1	string	variable	N/A	N/A
	Transmision level (XBee)	N/A	SENSOR_TX_PWR	85	TX_PWR	1	uint8_t	1	N/A	N/A
	XBee DM awake time	N/A	SENSOR_DM_ST	86	DM_ST	3	uint8_t	1	N/A	N/A
	XBee DM asleep time	N/A	SENSOR_DM_SP	87	DM_SP	3	uint8_t	1	N/A	N/A
	Date	N/A	SENSOR_DATE	58	DATE	3	uint8_t	1	N/A	N/A
	Time	N/A	SENSOR_TIME	59	TIME	3 or 4	uint8_t	1	N/A	N/A
	GMT	N/A	SENSOR_GMT	60	GMT	1	int	1	N/A	N/A

	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Additional	Free_RAM	N/A	SENSOR_RAM	61	RAM	1	int	2	0	bytes
Additional	Internal_temperature	N/A	SENSOR_IN_TEMP	62	IN_TEMP	1	float	4	2	ºC
Additional	Accelerometer	N/A	SENSOR_ACC	63	ACC	3	int	2	0	mg
Additional	Millis	N/A	SENSOR_MILLIS	64	MILLIS	1	ulong	4	0	ms
Additional	Luxes sensor	9325	SENSOR_LUX	88	LUX	1	float	4	2	luxes
Additional	Finite State Machine	N/A	SENSOR_FSM	95	FSM	1	uint8_t	1	N/A	N/A
Additional	Timestamp (Unix/Epoch)	N/A	SENSOR_TST	123	TST	1	ulong	4	0	seconds
Additional	Version of API	N/A	SENSOR_VAPI	125	VAPI	1	uint8_t	1	N/A	N/A
Additional	Version of program	N/A	SENSOR_VPROG	126	VPROG	1	uint8_t	1	N/A	N/A
Additional	Version of bootloader	N/A	SENSOR_VBOOT	127	VBOOT	1	uint8_t	1	N/A	N/A
Special	String	N/A	SENSOR_STR	65	STR	1	string	variable	N/A	N/A
Meshlium	Meshlium BT Scanner	N/A	SENSOR_MBT	66	MBT	1	string	variable	N/A	N/A
Meshlium	Meshlium WiFi Scanner	N/A	SENSOR_MWIFI	67	MWIFI	1	string	variable	N/A	N/A
RFID	Unique Identifier	N/A	SENSOR_UID	68	UID	1	string	variable	N/A	N/A
RFID	RFID block	N/A	SENSOR_RB	69	RB	1	string	variable	N/A	N/A
Smart Water	Water pH	9328	SENSOR_PH	70	PH	1	float	4	2	N/A
Smart Water	Oxidation ReductionPotential	9329	SENSOR_ORP	71	ORP	1	float	4	3	voltage
Smart Water	Disolved oxygen	9327	SENOR_DO	72	DO	1	float	4	1	%
Smart Water	Water Conductivity	9326	SENSOR_COND	73	COND	1	float	4	1	mS/cm
Smart Water	Water Temperature	9255	SENSOR_WT	74	WT	1	float	4	2	ºC
Smart Water	Turbidity	9353	SENSOR_TURB	124	TURB	1	float	4	1	NTU
Smart Water	Water pH (socket A)	9328	SENSOR_PH_A	166	PH_A	1	float	4	2	N/A
Smart Water	Water pH (socket B)	9328	SENSOR_PH_B	167	PH_B	1	float	4	2	N/A
Smart Water	Water pH (socket C)	9328	SENSOR_PH_C	168	PH_C	1	float	4	2	N/A
Smart Water	ORP (socket A)	9329	SENSOR_ORP_A	169	ORP_A	1	float	4	3	voltage
Smart Water	ORP (socket B)	9329	SENSOR_ORP_A	170	ORP_B	1	float	4	3	voltage
Smart Water	ORP (socket C)	9329	SENSOR_ORP_A	171	ORP_C	1	float	4	3	voltage

Group	Sensor	Sensor Reference	Sensor TAG	SENSOR ID		Number Of Fields	Binary		ASCII	Unit
				Binary	ASCII		Type of variable	Size per Field (Bytes)	Default Decimal Precision	
Gases PRO (Smart Environment PRO)	Chlorine	9386-P	SENSOR_GP_CL2	128	GP_CL2	1	float	4	3	ppm
	Carbon Monoxide	9371-P	SENSOR_GP_CO	129	GP_CO	1	float	4	3	ppm
	Ethylene Oxide	9385-P	SENSOR_GP_ETO	130	GP_ETO	1	float	4	3	ppm
	Hydrogen	9380-P	SENSOR_GP_H2	131	GP_H2	1	float	4	3	ppm
	Hydrogen Sulphide	9381-P	SENSOR_GP_H2S	132	GP_H2S	1	float	4	3	ppm
	Hydrogen Chloride	9382-P	SENSOR_GP_HCL	133	GP_HCL	1	float	4	3	ppm
	Hydrogen Cyanide	9383-P	SENSOR_GP_HCN	134	GP_HCN	1	float	4	3	ppm
	Ammonia	9378-P	SENSOR_GP_NH3	135	GP_NH3	1	float	4	3	ppm
	Nitrogen Monoxide	9375-P	SENSOR_GP_NO	136	GP_NO	1	float	4	3	ppm
	Nitrogen Dioxide	9376-P	SENSOR_GP_NO2	137	GP_NO2	1	float	4	3	ppm
	Oxygen	9373-P	SENSOR_GP_O2	138	GP_O2	1	float	4	3	ppm
	Phospine	9384-P	SENSOR_GP_PH3	139	GP_PH3	1	float	4	3	ppm
	Sulfur Dioxide	9377-P	SENSOR_GP_SO2	140	GP_SO2	1	float	4	3	ppm
	Methane	9379-P	SENSOR_GP_CH4	141	GP_CH4	1	float	4	3	%/LEL
	Ozone	9374-P	SENSOR_GP_O3	142	GP_O3	1	float	4	3	ppm
	Carbon Dioxide	9372-P	SENSOR_GP_CO2	143	GP_CO2	1	float	4	3	ppm
Gases PRO (Smart Environment PRO)	Temperature Celsius	9370-P	SENSOR_GP_TC	144	GP_TC	1	float	4	3	ºC
	Temperature Fahrenheit	9370-P	SENSOR_GP_TF	145	GP_TF	1	float	4	2	ºF
	Humidity	9370-P	SENSOR_GP_HUM	146	GP_HUM	1	float	4	2	%RH
	Pressure	9370-P	SENSOR_GP_PRES	147	GP_PRES	1	float	4	0	Pa
	Temperature Celsius	9387-P	SENSOR_OPC_TC	148	TC	1	float	4	2	ºC
	Temperature Fahrenheit	9387-P	SENSOR_OPC_TF	149	TF	1	float	4	2	ºF
	Pressure	9387-P	SENSOR_OPC_P	150	P	1	float	4	0	Pa
	PM1	9387-P	SENSOR_OPC_PM1	151	PM1	1	float	4	4	µg/m3
	PM2.5	9387-P	SENSOR_OPC_PM2_5	152	PM2_5	1	float	4	4	µg/m3
	PM10	9387-P	SENSOR_OPC_PM10	153	PM10	1	float	4	4	µg/m3
	Particle counter	9387-P	SENSOR_OPC_PART	154	PART	2	float	4	0	N/A
Smart Water Ions	Calcium Ions	9352	SENSOR_SWI_CA	155	SWICA	1	float	4	3	ppm
	Fluoride Ions	9353	SENSOR_SWI_FL	156	SWIFL	1	float	4	3	ppm
	Fluoroborate Ions	9354	SENSOR_SWI_FB	157	SWIFB	1	float	4	3	ppm
	Nitrate Ions	9355	SENSOR_SWI_NO	158	SWINO	1	float	4	3	ppm
	Bromide Ions	9356	SENSOR_SWI_BR	159	SWIBR	1	float	4	3	ppm
	Chloride Ions	9357	SENSOR_SWI_CL	160	SWICL	1	float	4	3	ppm
	Cupric Ions	9358	SENSOR_SWI_CU	161	SWICU	1	float	4	3	ppm
	Iodide Ions	9360	SENSOR_SWI_IO	162	SWIIO	1	float	4	3	ppm
	Lead Ions	9361	SENSOR_SWI_PB	163	SWIPB	1	float	4	3	ppm
	Silver Ions	9362	SENSOR_SWI_AG	164	SWIAG	1	float	4	3	ppm
	pH	9363	SENSOR_SWI_PH	165	SWIPH	1	float	4	3	N/A

Figure : Field types

3. Usage

The following sections show how to create frames and add sensor fields.

3.1. Setting the Waspmote Identifier

There is a function which allows the user to store the Waspmote ID in the EEPROM memory. This function is named `setID()`. The Waspmote ID will be used to set the corresponding field in the frame's header when calling `createFrame()` function.

Example of use:

```
{
 // store Waspmote ID in EEPROM memory (16-Byte max)
 frame.setID("Waspmote_Pro");
}
```

3.2. Creating new Frames

The function in charge of creating a new frame is: `createFrame()`. This function selects the frame mode:

- **ASCII**
- **BINARY**

Besides, it is possible to define the Waspmote ID which will be included in the frame's header (16 bytes maximum) instead of using the mote identifier stored in the EEPROM memory.

The function prototypes are the following:

- Create an ASCII frame. The Waspmote ID is get from the EEPROM memory that `setID()` function has previously set:

```
{
	frame.createFrame(ASCII);
}
```

- Create an ASCII frame. The Waspmote ID (i.e. "Waspmote_Pro") is set as an input parameter:

```
{
	frame.createFrame(ASCII,"Waspmote_Pro");
}
```

- Create a Binary frame. The Waspmote ID (i.e. "Waspmote_Pro") is set as an input parameter:

```
{
	frame.createFrame(BINARY,"Waspmote_Pro");
}
```

3.3. Setting the Frame Size

The class constructor initializes the attribute `_maxSize` to `MAX_FRAME` constant, which is used to limit the maximum frame size. This constant defines a maximum **default size of 150 bytes**per frame. As this is the maximum possible value, it can be modified in WaspFrame.h in order to create frames with larger sizes.

On the other hand, `setFrameSize()` is the function which permits to set the frame size according to the user's consideration. Besides, it is possible to set the frame size depending on the XBee module, link encryption mode and AES encryption use. The following table defines the maximum frame size to be used for each communication protocol and several encryption possibilities:

Module			Maximum frame size
XBee – 802.15.4	Link Encrypted	@16bit Unicast	98 Bytes
		@64bit Unicast	94 Bytes
		Broadcast	95 Bytes
	Link Unencrypted		100 Bytes
XBee – 868			100 Bytes
XBee – 900	Link Encrypted		80 Bytes
	Link Unencrypted		100 Bytes
XBee - Digimesh			73 Bytes
XBee - ZigBee	Link Encrypted	@64bit Unicast	66 Bytes
		Broadcast	84 Bytes
	Link Unencrypted	@64bit Unicast	74 Bytes
		Broadcast	92 Bytes
Bluetooth – transparent connection			Limited by `MAX_FRAME`
GPRS			Limited by `MAX_FRAME`
3G			Limited by `MAX_FRAME`
LoRa / SX1272			Limited by `MAX_FRAME`
WiFi			Limited by `MAX_FRAME`

Figure : Maximum frame size per protocol

Note: `MAX_FRAME` *is 150 bytes but can be changed by the user.*

In the case that AES Encryption libraries are used to encrypt a Waspmote Frame, it is necessary to use the `setFrameSize()`. This function sets the maximum payload for the Waspmote Frame depending on the XBee protocol, addressing mode and link-encryption mode used.

The function prototypes are:

Set frame size depending on the protocol, addressing, link-encryption and encryption libraries used:

```
void setFrameSize(uint8_t protocol,
                  uint8_t addressing,
                  uint8_t linkEncryption,
                  uint8_t AESEncryption);
```

Where "protocol" specifies the XBee module protocol between:

```
XBEE_802_15_4
ZIGBEE
DIGIMESH
XBEE_900
XBEE_868
```

"addressing" specifies the addressing mode between:

`UNICAST_16B:` for Unicast 16-bit addressing (only for XBee-802.15.4)
`UNICAST_64B:` for Unicast 64-bit addressing
`BROADCAST_MODE:` for Broadcast addressing

"linkEncryption" specifies the XBee encryption mode between:

`ENABLED` : 1

`DISABLED` : 0

"AESEncryption" specifies if AES encryption is used or not:

`ENABLED` : 1

`DISABLED` : 0

Set frame size depending on the protocol and encryption used (default UNICAST_64B addressing):

```
void setFrameSize(uint8_t protocol,
                  uint8_t linkEncryption,
                  uint8_t AESEncryption);
```

Examples of use:

```
{
  // set frame size to 125 Bytes
  frame.setFrameSize(125);

  // XBee-802, unicast 16-b addressing, XBee encryption Disabled, AES encryption Disabled
  frame.setFrameSize(XBEE_802_15_4, UNICAST_16B, DISABLED, DISABLED);

  // XBee-868, unicast 64-b addressing, XBee encryption Enabled, AES encryption Enabled
   frame.setFrameSize(XBEE_868, ENABLED, ENABLED);

   // XBee-ZigBee, Broadcast addressing, XBee encryption Enabled, AES encryption Disabled
   frame.setFrameSize(ZIGBEE, BROADCAST, ENABLED, DISABLED);

  // XBee-900, unicast 64-b addressing, XBee encryption Disabled, AES encryption Enabled
  frame.setFrameSize(XBEE_900, DISABLED, ENABLED);

  // XBee-Digimesh, Broadcast addressing, XBee encryption Enabled, AES encryption Enabled
  frame.setFrameSize(DIGIMESH, BROADCAST, ENABLED, ENABLED);

 }
```

Set frame size via parameter given by the user:

```
void setFrameSize(uint8_t size);
```

Where "size" must be less than `MAX_FRAME`, if not `MAX_FRAME` will be set as frame maximum size

Example:

• How to set the frame size depending on the protocol and encryption used:

http://www.libelium.com/development/waspmote/examples/frame-05-set-frame-size

3.4. Setting the Frame Type

There is a function which allows the user to set the required frame type. This function must be called after calling `createFrame()` function. In the case it is not called, a default "EXAMPLE_FRAME" type is chosen by `createFrame()`. The function that permits the setting of the frame type is `setFrameType()`. It is possible to select between different constants predefined in WaspFrame.h in order to set the sort of packet to be sent:

EXAMPLE_FRAME
TIMEOUT_FRAME
EVENT_FRAME
ALARM_FRAME
SERVICE1_FRAME
SERVICE2_FRAME

These constants permit to set the Frame Type in spite of the frame mode (ascii or binary).

Example of use:

```
{
 frame.setFrameType(TIMEOUT_FRAME); // set a TIMEOUT frame type
}
```

Example:

• How to set the frame type:

http://www.libelium.com/development/waspmote/examples/frame-06-set-frame-type

3.5. Adding Sensor Fields

This is the function which appends new sensor fields to the frame. The first parameter is the sensor tag to identify the sensor to be added. The sensor identifier is followed up by the sensor values which might be presented in various types: int, float, strings, etc. This function is defined by several prototypes so as to permit so many input possibilities.

Depending on the sensor field a specific type is needed for Binary frames. If a mismatch occurs, a message will appear through USB port. The sensor table shows the needed data type for each sensor.

Each call to this function appends a new field if there is enough space for the new field. If not, the field will not be attached.

Example of use:

```
{
 // set frame fields (String - char*)
 frame.addSensor(SENSOR_STR, (char*) "STRING");

 // set frame fields (Battery sensor - uint8_t)
 frame.addSensor(SENSOR_BAT, (uint8_t) PWR.getBatteryLevel());

 // set frame fields (Temperature in Celsius sensor - float)
 frame.addSensor(SENSOR_IN_TEMP, (float) RTC.getTemperature());
}
```

The last example would create a **frame payload** with the following structure (depending on the frame mode):

- **ASCII frame.** Payload length: 32Bytes

Payload																															
S	T	R	:	S	T	R	I	N	G	#	B	A	T	:	8	7	#	I	N	_	T	E	M	P	:	2	7	.	2	5	#
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Figure : ASCII frame payload example

- **Binary frame.** Payload length: 15Bytes

Payload									
SENSOR_STR	Length	"STRING"	SENSOR_BAT	0x57	SENSOR_IN_TEMP	0x00	0x00	0xDA	0x41
0	1	2-7	8	9	10	11	12	13	14

Figure : Binary frame payload example

Examples:

• Create ASCII frames with simple sensor data (1 field per sensor):

http://www.libelium.com/development/waspmote/examples/frame-01-ascii-simple

• Create ASCII frames with complex sensor data (more than 1 field per sensor):

http://www.libelium.com/development/waspmote/examples/frame-02-ascii-multiple

• Create BINARY frames with simple sensor data (1 field per sensor):

http://www.libelium.com/development/waspmote/examples/frame-03-binary-simple

• Create BINARY frames with complex sensor data (more than 1 field per sensor):

http://www.libelium.com/development/waspmote/examples/frame-04-binary-multiple

3.6. Adding New Sensor types

In case the user is interested in adding new sensor types, this guide explains how to do this process.

a) Define the new sensor identifier. As the rest of the sensors, it is necessary to define a unique identifier for the new sensor in WaspFrameConstants.h:

```
#define SENSOR_CO     0
#define SENSOR_CO2    1
#define SENSOR_O2     2
#define SENSOR_CH4    3
...
#define NEW_SENSOR    ?
```

b) Define label for the new sensor. As the rest of the sensors, it is necessary to define a unique label for the new sensor in WaspFrameConstants.h:

```
prog_char    str_CO[]          PROGMEM = “CO”;     // 0
prog_char    str_CO2[]         PROGMEM = “CO2”;    // 1
prog_char    str_O2[]          PROGMEM = “O2”;     // 2
prog_char    str_CH4[]         PROGMEM = “CH4”;    // 3
...
prog_char    str_NEW[]         PROGMEM = “NEW_LABEL”;     // ?
```

c) Fill the Flash Memory tables respecting the defined index in section "a". The Flash Memory tables are:

- SENSOR_TABLE: This is a string table in order to define the sensor labels. For ASCII frames.
- SENSOR_TYPE_TABLE: This is a uint8_t table which specifies the type of sensor depending on the type of value the user must put as input. Only for Binary frames.
- SENSOR_FIELD_TABLE: This is a uint8_t table which specifies the number of fields for each sensor.
- DECIMAL_TABLE: This is a uint8_t table which specifies the number of decimals a float must be set when adding each sensor to an ASCII frame.

3.7. Showing the actual Frame

There is a function called `showFrame()` which prints the frame structure at the moment this function is called.

Example of use:

```
{
  frame.showFrame();
}
```

4. Encrypted frames

In this chapter, how to create encrypted frames using the Waspmote AES libraries is explained.

4.1. Encrypted frame format

The encrypted frame is a special binary frame which encapsulates the real encrypted frame as the payload of a new frame. The format of the encrypted frame is as follows:

<=>	Frame Type	Num Bytes	Serial ID	Waspmote ID	#	Encrypted Payload
3B	1B	1B	4B	Variable	1B	Multiple of 16B

Where the "Encrypted Payload" is the original frame after being encrypted using the AES algorithm.

4.2. Encrypting frames

The process follows these steps:

1. Create a new Frame (ASCII or BINARY)
2. Encrypt the frame and use it as Encrypted Payload of the new Encrypted Frame

The function `encryptFrame()` is used to encrypt the original frame and generate the new one. It is necessary to indicate the type of AES encryption used regarding the key size: `AES_128`, `AES_192` or `AES_256`. Besides, the AES private key must be specified as a string of ASCII characters.

Example of use:

```
{
   // 1. create the original frame
   frame.createFrame( ASCII );
   frame.addSensor( SENSOR_BAT, battery_level );

   // 2. create the AES-128 encrypted frame
   frame.encryptFrame( AES_128, "libeliumlibelium" );

   // 3. show Encrypted frame contained in 'frame.buffer'
   frame.showFrame();
}
```

Example of how to use encryption with Waspmote Frames:

www.libelium.com/development/waspmote/examples/frame-07-encrypted-frames

5. Code examples

In the Waspmote Development section you can find complete examples:

http://www.libelium.com/development/waspmote/examples

6. API changelog

Keep track of the software changes on this link:

www.libelium.com/development/waspmote/documentation/changelog/#Frame

7. Documentation changelog

From v4.9 to v5.0

- Fix Smart Water Ions tags in Sensor Fields section
- Fix leaf wetness tags in Sensor Fields section
- Fix luminosity unit in Sensor Fields section

From v4.8 to v4.9

- Added new sensor definitions in 'Sensor fields' chapter related to P&S Smart Water

From v4.7 to v4.8

- Added new sensor definitions in 'Sensor fields' chapter related to the Smart Water Ions board
- Added Ambient Control sensor definitions in 'Sensor fields' chapter

From v4.6 to v4.7:

- Added new sensor definitions in 'Sensor fields' chapter related to the Gases PRO board

From v4.5 to v4.6:

- Added new sensor definitions in 'Sensor fields' chapter

From v4.4 to v4.5:

- Added new sensor definitions in 'Sensor fields' chapter
- Deleted chapter related to frame decryption

From v4.3 to v4.4:

- Added fixes to Binary frame specification
- Added encrypted frames chapter
- Link to the new online API changelog

From v4.2 to v4.3:

- Added new sensor fields: GPS speed over the ground, GPS course over the ground, GPS altitude, GPS VDOP, GPS HDOP, GPS PDOP, XBee DigiMesh asleep time, XBee DigiMesh awake time, XBee transmision level and luxes
- API changelog updated to API v011

From v4.1 to v4.2:

- Added Smart Water sensors to Waspmote Frame

From v4.0 to v4.1:

- Added references to 3G/GPRS Board in section: Expansion Radio Board
- Added 3G/GPRS in table *maximum frame size per protocol*
- Added changes respect to maximum frame size for GPRS, 3G y BT in table *maximum frame size per protocol*
- Added changes respect to Serial ID in ASCII and Binary
- Added changes in tables binary Frame structure and binary Frame example