Micromite GPS LoRa MOTE

Micromite GPS LoRa MOTE is targeted to design engineers to quickly evaluate LoRaWAN and its sensor applications. Micromite is a PIC32MX170 microcontroller firmware that is based on Geoff Graham's MMBasic interpreter that allows very convenient application software development in BASIC language. Micromite through its serial console interface provides support for program editing, debugging plus communication with the BASIC application. This is an excellent environment for LoRaWAN applications because no other compiler, no other hardware debugger and programmer is required for software development. The console port of Micromite has built in USB-UART bridge that allows single USB connection to the free MMEdit integrated development environment. The USB connection is used also for charging the internal LiPo battery. The GPS Mode is intended to analyze how large is the geographic coverage of LoRaWAN even from a moving vehicle. The Sensor Mode is targeted for demonstration of fixed position sensor networks. Beside internal sensors the Micromite GPS LoRa MOTE has a peripheral connector for handling external sensors or actuators. This option is demonstrated by GSS COZIR CO2 sensors, however, users are encouraged to implement their own sensor support through two UART, one I2C and three digital/analog/PWM peripheral lines to discover LoRaWAN capabilities in their own Proof of Concept projects. The latest BASIC program version and full documentation of the MOTE can be downloaded from here: http://www.chipcad.hu/letoltes/MMGPSMOTE.zip

Operation modes and changing between modes

- Console mode
  Purpose: MMBasic program development.
  MMBasic application can be broken by "control C" on Console
  MMBasic application can be restart again by "run" command.
  See: Micromite User Manual and Micromite Kézikönyv
- Service mode: *See: Appendix D, Service Mode*
- GPS Mode: *See below*
- Sensor mode: *See below*

Micromite GPS LoRa MOTE has one push button and three LEDs. The yellow LED lights while battery is charged from micro USB connector. The yellow light stops when battery is fully charged (4.2V). The built in **MCP73831T-2ACI/OT** battery charger circuit controls charging and during discharging it disconnects battery at 3.5V to avoid over discharge. The green and red LEDs are controlled by Micromite MMbasic application. While Micromite MMBasic application is up and running, one of them is pulsing once in every second. The green LED pulses during satellite acquisition and trace or sensor measurements then after valid values are captured red LED pulses till the end of LoRaWAN transmit. LEDs are dark during Micromite sleep. During satellite acquisition and trace Micromite monitors if push button is pressed. The program differentiates between short and long button presses. The short press should last less than a second and the long one should last till the red LED lights. The short button press initiates one sensor measurement and broadcast to LoRaWAN. The long button press changes operation mode from GPS to Sensor. In Sensor Mode the long button press can also be used to change mode back to GPS but because of long sleep times, the button should be pressed till green LED lights (not longer than a minute). Because of the long sleep times the short button press is not defined in Sensor Mode.

1. GPS Mode

Micromite GPS LoRa MOTE has a built in SQ-SEN-200 motion sensor that allows GPS operation in GPS Mode. While motion is detected the MOTE searches GPS/GNSS satellites and if valid coordinates are captured then broadcasts them to LoRaWAN four times in every minute. After 5 minutes without motion the MOTE goes to sleep for

unlimited time then only its SQ-SEN-200 motion sensor can wake it up. In a moving vehicle Micromite GPS LoRa MOTE operates continuously and after stopping the MOTE automatically puts itself in low power consumption sleep mode. The frequency of coordinate broadcasts will strongly influence total power consumption. After each transmission the MOTE goes to sleep for **short sleep time** that is at least 5 seconds but it can be extended up to 260 seconds by downlink message. The downlink message can modify cycle time of coordinate broadcast from quarter minute to four minutes. The 4minute cycle time consumes 16 times less energy than ¼ minute cycle time so it extends battery life 16 times longer. See: *Appendix B: GPS Modes of operation.*

Micromite GPS LoRa MOTE can handle external sensors and as example an optional CO2 COZIR sensor can be connected to its peripheral connector. When Micromite GPS LoRa MOTE is operated in a car and an optional CO2 sensor plus a buzzer is connected, the MOTE measures CO2 concentration before going to sleep. When CO2 value exceeds the programmable **CO2 concentration limit** an audible alert sound is generated to warn vehicle driver to switch on incoming fresh air inflow for avoiding drowsiness and finally prevent accidents. This danger is shown in BBC report with GSS.

 Six byte, "**Short payload**" uplink format in GPS Mode:

Seq #	Port	Payload
275	202	4370550d860b

Sequential number 275, port number 202
Payload:
latitude 24bit signed number, angle domain -90 to +90 degrees
longitude 24bit signed number, angle domain -180 to +180 degrees

Minimum LoRaWAN broadcast cycle time range: 15sec - 270sec

Eleven byte, "**Long payload**" uplink format in GPS Mode:

Seq #	Port	Payload
275	202	4370550d860b00830112ca

Sequential number 275, port number 202
Payload:
latitude 24bit signed number, angle domain -90 to +90 degrees
longitude 24bit signed number, angle domain -180 to +180 degrees
height above sea level 16bit unsigned number, height domain 0 to 10000 meters
HDOP accuracy of L86 GPS/GNSS receiver, ten times the Dilution of Precision, domain 1 to 250
Temperature 8bit signed number, internal temperature, domain -128 to 127 degrees
Battery voltage 8bit BCD number, percentage domain 1%-99%, relative charged voltage between 3.5V-4.2V

Minimum LoRaWAN broadcast cycle time range: 25sec - 280sec

In GPS Mode the MOTE uses fix DR=0 with SF12 and 25mW. The transmit duty cycle is 1% per channel at 15second cycle time of six byte payload.

2. Sensor Mode

Sensor Mode is targeted to fixed position applications. GPS/GNSS receiver is switched off, the MOTE uses internal and optional external sensors. The internal temperature and battery voltage sensors can be extended by external GSS COZIR sensors or by any other sensor of users' choice. The MOTE periodically measures sensors and broadcasts their measured values to LoRaWAN. Between measurements Micromite switches off all peripherals and goes to sleep for **long sleep time** that is at least 1minute but it can be extended up to 256 minutes by downlink message. Extending the **long sleep time** will significantly lower power consumption. The application server can modify the CO2 measurement frequency to meet application requirements. For example, in outdoor citywide environment during nights the frequency can be lowered while in rush hours it can be increased to accurately measure pollution of vehicles in changing traffic environments.

The Mote uses adaptive data rate, automatically employs the highest bit rate for reliable LoRaWAN communication. See Appendix E

Though long sleep time can be extended up to 256 minutes Micromite wakes up once in every minute for a short while. In these short operation states Mote can be switched back to GPS Mode by pressed button. The MOTE can recognize long button press right after wakeup then changes back to GPS Mode. A long green LED flash confirms the Mode change button press. The Mote has an intelligent CO2 concentration measurement mode to optimize power consumption. CO2 concentration upper limit can be programmed by downlink message. If CO2 limit is not activated, the Mote wakes up once in every minute of long sleep time and if button is not pressed, it will measure sensors only at the end of long sleep time then will transmit to LoRaWAN. If upper limit is activated, the CO2 concentration is measured once in every minute and compared with upper limit. If it is higher the Mote transmits sensor data to LoRaWAN immediately whatever time is set in long sleep time. If it is lower than **CO2 limit** it goes back to sleep without transmit.

Uplink message in Sensor Mode:

Seq #	Port	Payload
275	209	12ca02ed01e91c

Sequential number 275, port number 209
The Payload length depends on external COZIR sensor. If it is not connected, then length is only 2bytes. If COZIR measures only CO2 concentration, then the payload is 4bytes. If it measures humidity plus temperature, the payload becomes 7bytes long automatically.
Temperature 8bit signed number, temperature domain -128 to 127 degrees
Battery voltage 8bit BCD number, percentage domain 1%-99%, relative charge, voltage between 3.5V-4.2V
The battery voltage is updated at every wakeup from sleep. The battery voltage is also available for network server to request through packet header. The 3.5V-4.2V battery voltage domain is normalized to 1 to 254 single byte value. The network server can request this value any time.
COZIR CO2 concentration 16bit unsigned number, ppm domain: 400 to 10000
COZIR relative humidity 16bit unsigned number, ‰ domain: 0-1000
COZIR temperature 8bit signed number, temperature domain: -128 to 127 degrees

3. Downlink: Control from application server in both modes

The operation parameters can be modified from application server in GPS and Sensor Modes by downlink message:

Port	Payload
209	01caed07d0

Port number 209

Control: 8bit unsigned number

00 no mode change, no sensor data request, only operation parameters can be modified

01 in GPS Mode the application server requests a single sensor measurement. Same as short push button press.

02 mode change. In GPS Mode changes to Sensor Mode and in Sensor Mode back to GPS Mode. Same as long push button press.

03 changes between short and long payload formats in GPS Mode.

Short Sleep Time: 8bit unsigned number. In GPS Mode the sleep time will be this parameter plus 5 seconds at short payload and 15 seconds at long payload formats. Time domain: 0 to 255 seconds

Long Sleep Time: 8bit unsigned number. In Sensor Mode sleep time will be this parameter plus 1 minute. Time domain: 0 to 255 minutes.

CO2 upperlimit: 16bit unsigned number. Concentration domain: 0 to 65535 ppm or 6.5535%

4. Using external peripheral connector
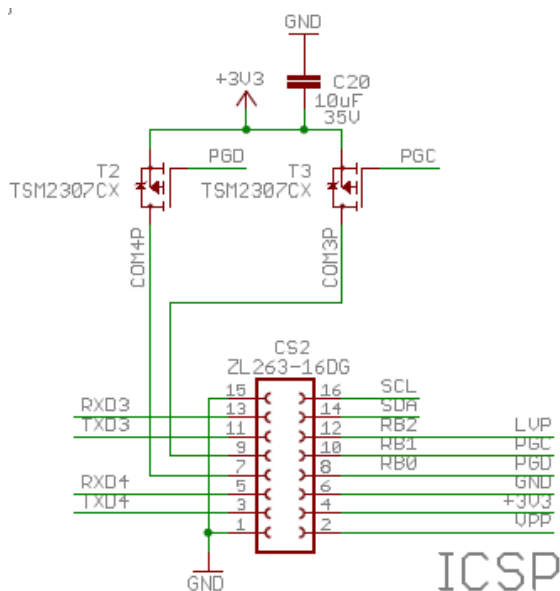
Micromite GPS LoRa MOTE has a 16pin connector that is aimed for several purposes:
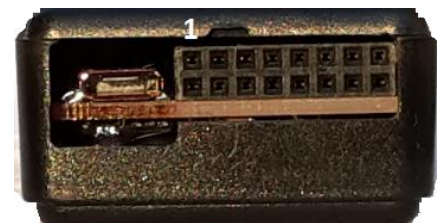
- **C2: 2, 4, 6, 8, 10, 12 ICSP pins** can accommodate a PICKit3 programmer for Micromite firmware update.

- **C2: 1, 2 reset pins**. Micromite GPS LoRa MOTE spends most of its time in sleep mode. Hardware reset may help to initiate Micromite console mode even from sleep. No reset button is provided but with an external wire jumper the MOTE can easily be reset.

- **C2: 9, 11, 13, 15 COM3 port**. COM3 sensor can be operated from switched COM3P 3.3V power supply to minimize its power consumption.

- **C2: 1, 3, 5, 7 COM4 port**. COM4 sensor can be operated from switched COM4P 3.3V power supply to minimize its power consumption.

- **C2: 14, 16 I2C bus**.

- **C2: 8, 10, 12 digital, analog I/O or three PWM channels** (for driving RGB LED).

5. Connection of COZIR CO2 sensor and buzzer

COZIR CO2 sensors uses 9600 baud UART serial communication with 3.3V logical level that matches to Micromite, only a 4-wire M2F is required. The Micromite GPS LoRa MOTE uses COM3 for COZIR sensor on its COM3 UART port:

C2:15   COZIR GND
C2:09   COZIR 3V3
C2:11   COZIR RX
C2:13   COZIR TX
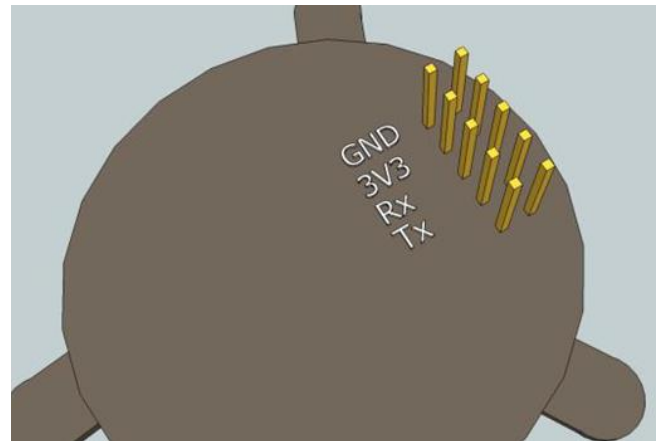
Micromite can drive a buzzer in GPS mode when a COZIR CO2 sensor is connected. After sending GPS/GNSS coordinates to LoRaWAN the Micromite measures CO2 concentration and if it is higher than upper limit then drives a buzzer with one second warning signal. The buzzer frequency is equal in Hertz with the CO2 concentration in PPM value. Car drivers can easily test the effect of closing fresh air inflow to the car. The warning buzzer can be connected to C2 peripheral connector:

C2: 8   buzzer
C2:12   buzzer

6. Opening and closing plastic case of Micromite GPS LoRa MOTE

The Micromite GPS LoRa MOTE is housed in a black plastic case (78mm*40mm*22mm). The case has a base and a cover part and for the push button a plastic mechanical button extender. The case has no screw to fix the case but the PCB board is mechanically fixed among case part. The cased Micromite GPS LoRa MOTE can easily be moved to its locations and is resistive against environment stresses. However, the PCB is designed to meet additional requirements. The cased device can accommodate a 750mAh LiPo battery but if longer duration is required the board can be powered by 2000mAh battery also but due to its larger size without case. In its case GPS/GNSS receiver uses its internal patch antenna but the PCB can accommodate external antenna also. For example, in bicycle tracking one of the main design challenges is how to hide electronics against sabotage. The external antenna connector of both GPS/GNSS and LoRa radios can support experiments with hidden electronics and antenna designs in such projects right away.

When the case is open the firmware of RN2483 module can be updated by a PICKit 3 programmer through ICSP pads beside the module. The measurement of power consumption is supported by a 10 Ohm Shunt resistor that is short circuit with a jumper. After opening the case the jumper can be removed and a storage oscilloscope can be connected instead.

The PCB and the 750mAh standard LiPo battery can easily be placed in the case but with one trick. Let's put an insulator strip, or rubber tape onto the outer surface of the upper case to fully cover the slot of push button. Insert the mechanical button extender in the inner side of the cover and push firmly to allow the tape to hold it. Place the PCB and battery into the case playing attention that the battery wires face to LoRa antenna position and wires come to upper side battery connector on the PCB. Place the cover case onto bottom case part and firmly push them together. In its normal position the push button can easily be pressed and the case holds the PCB properly.

7. Packing list of Micromite GPS LoRa MOTE package

- Micromite GPS LoRa MOTE (cased with 750mAh battery)   1 piece
- ISM-868 SMA ant. + swivel 868MHz monopole antenna   1 piece
- Reset wire   1 piece
- micro USB cable   1 piece

The Micromite GPS LoRa MOTE is activated and tested in ChipCAD LoRaWAN but later it can easily be moved to other networks.

Appendix

A: Micromite GPS LoRa Mote version history.

V1 was developed for [ChipCAD IoT Conference](#) June 6th 2016 but was never released to market, only used for demonstrations and in house experiments. It was exclusively designed as a LoRaWAN GPS tracker.

V2 combined LoRaWAN GP tracker with sensor functions, it was released to market on August 5 2016, MMTR-06A_SCH.pdf.
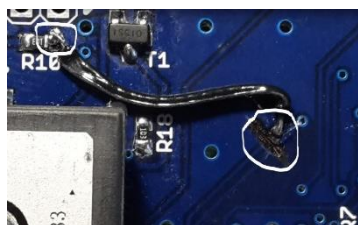
V3 released to market on March 22 2017, MMTR-07_SCH.pdf. Major software release improves GPS power management for accurate localization. It has minor hardware modification also: instead of CTS/RTS control, Micromite becomes able to reset RN2483 module. It is highly recommended to cut off RTS/CTS to RB13/RB12 and with a small piece of wire connect RB12 to 32, reset pin of RN2483. Micromite firmware should be 5.36 or higher.

B: GPS modes of operation. Removing jumper of R13 10 Ohm Shunt resistor, current consumption can be measured. The 100mV vertical scale of below scope diagrams corresponds to 10mA supply current. After waken up by motion sensor the GPS receiver gets continues power for 5 minutes in FULL ON mode. Then for saving battery power Micromite sends periodically GPS/GNSS receiver into standby after receiving valid coordinates:
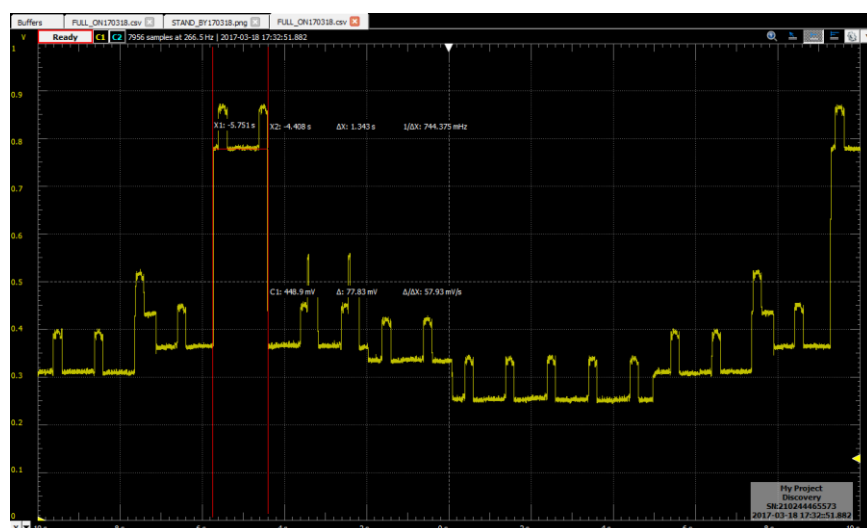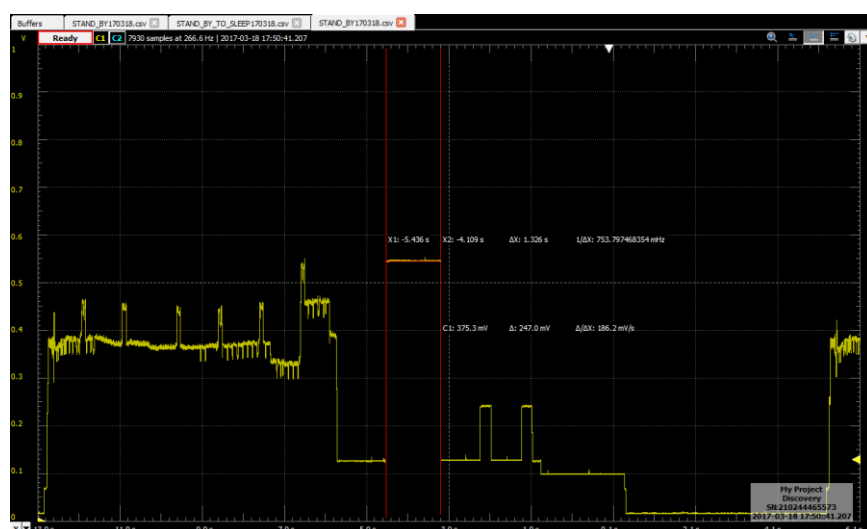

GPS power FULL ON.

While motion sensor senses continuous motion Micromite controls a periodic sequence:

1. sleeps for short sleep time
2. reads valid GPS/GNSS coordinates
3. sends coordinates to LoRaWAN
4. sends RN2483 to sleep mode
5. goes to sleep for sleep time

During this sequence GPS/GNSS gets continuous power for five minutes after waken up by motion sensor.

GPS Power STANDBY Mode.

While motion sensor senses continuous motion Micromite controls a periodic sequence:

1. sleeps for short sleep time
2. switches GPS/GNSS to FULL ON
3. reads valid GPS/GNSS coordinates
4. switches GPS/GNSS to STANDBY
5. sends coordinates to LoRaWAN
6. sends RN2483 to sleep mode
7. goes to sleep for sleep time
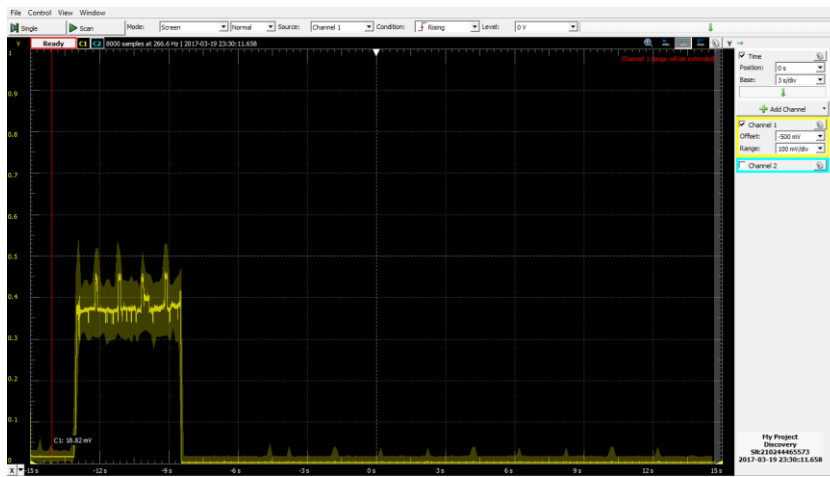
GPS sleep mode.

While Mote is moving its motion sensor restarts an inactivity motion timer. After stopping the motion sensor allows inactivity timer to reach its limit. After reaching maximum inactivity limit Micromite switches power off for all peripherals and goes to sleep for unlimited time. Only motion sensor can wake Micromite up again and the whole sequence starts again through FULL ON then STANDBY modes.

Quectel: L86 Hardware Design (Rev. L86_Hardware_Design_V1.0)
Quectel: L86 GNSS Protocol Specification (Rev. L86_GNSS_Protocol_Specification_V1.1)

C: Sensor modes of operation

In sensor mode Mote measures its internal and external sensors then sends results to LoRaWAN. Between measurement the Mote switches off its peripherals and goes to sleep for programmable long sleep time. The minimum sleep time is one minute but can be extended with 255 minutes by download message. Without connecting external CO_2 sensor, the Mote sends two byte payload of internal temperature and buttery charge. The channel transmission duty cycle is 0.55sec/60sec/8channels=0.1% at SF11 and 0.02% at SF7.
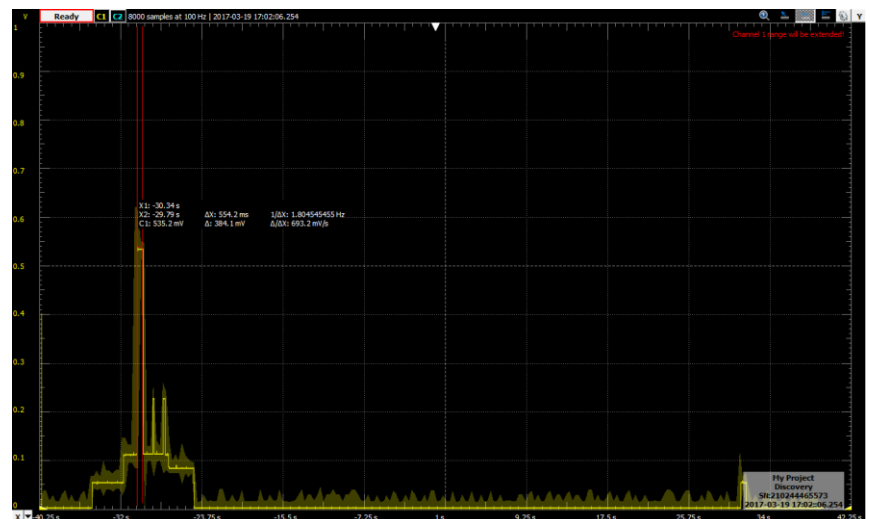
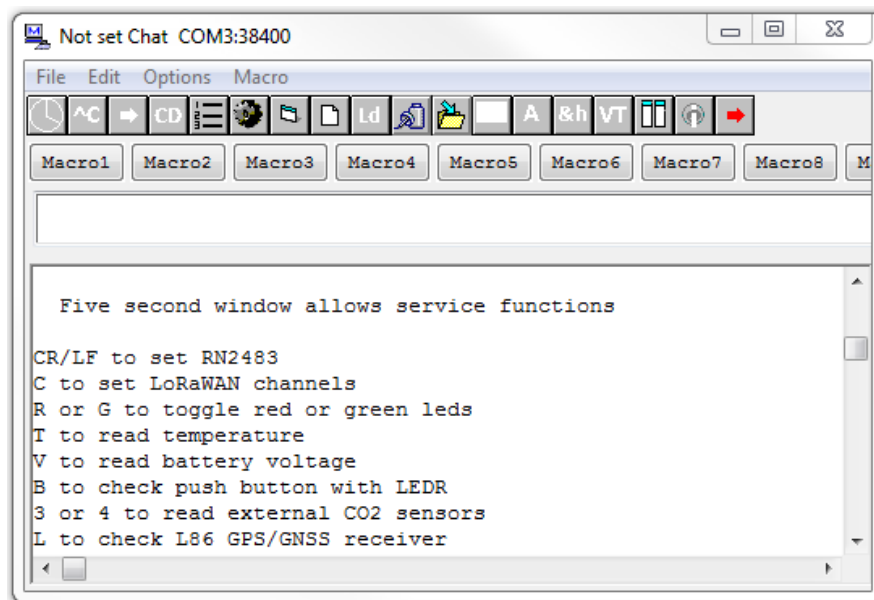With external COZIR sensor the payload length is set automatically depending upon the sensor type. Beside CO_2 concentration humidity and temperature values can be inserted automatically. The longest payload can be 7 bytes long. The channel transmission duty cycle is 0.83sec/60sec/8channels=0.18% at SF11 and 0.015% at SF7. The Mote can be operated in smart sensor mode with automatic CO_2 concentration upper limit monitoring. The long sleep time can be programmed up to 256 minutes but at every minute Micromite checks

its button if it is pressed and measure CO_2 value if the upper limit is switched on, not 0ffffH. When the upper limit checking is allowed and the measured CO_2 exceeds this limit, the Mote send sensor data whatever sleep

time is programmed. In smart sensor mode the power consumption can be kept low while the network server is kept informed about too high sensor value limit.

D: Service mode

Service mode can be accessed after resetting Micromite. During five second service time window any of the service function can be initiated from console:


```
     Not set Chat   COM3:38400

     File   Edit   Options   Macro

     [toolbar icons]

     Macro1  Macro2  Macro3  Macro4  Macro5  Macro6  Macro7  Macro8  M


       Five second window allows service functions

     CR/LF to set RN2483
     C to set LoRaWAN channels
     R or G to toggle red or green leds
     T to read temperature
     V to read battery voltage
     B to check push button with LEDR
     3 or 4 to read external CO2 sensors
     L to check L86 GPS/GNSS receiver
```

- **CR/LF** to set RN2483	Allows manual control of RN2483. This service function can be finished by pressing ^C, or pressing [^C] button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **C** to set LoRaWAN channels	Configures 8 LoRaWAN channels according to Semtech EU868 standard. This service runs automatically then continues to GPS Mode .
- **R** or **G** to toggle red or green leds	This service function keeps for additional 5 second after pressing R or G.
- **T** to read temperature	This service function keeps for additional 5 second after pressing T.
- **V** to read battery voltage	This service function keeps for additional 5 second after pressing V.
- **B** to check push button with LEDR button	This service function can be finished by pressing ^C, or pressing [^C] of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **3** or **4** to read external CO2 sensors	COZIR sensors can be tested on either COM3 or COM4. This service mode can be finished by pressing ^C, or pressing [^C] button of toolbar in Micromite Chat window. Then RUN the BASIC program again.
- **L** to check L86 GPS/GNSS receiver	After switching on GPS/GNSS receiver, its records are transferred to console port till pressing ^C, or pressing [^C] button of toolbar in Micromite Chat window.

E: Adaptive Data Rate, ADR

Adaptive Data Rate is a nice feature of LoRaWAN. It assures reliable two-way communication between end device and network server in changing environments. The process allows adaption of LoRa modulation (bit rate, spreading factor, data rate) to different radio conditions and even to changing network topologies of gateways.

The ADR is a combined process of network server plus end device. In Loriot network server the process needs these steps:

- Network server account must be commercial. This is a must because of the need for downlink direction.
- The whole process can be enabled and disabled by the application of end device. The "mac set adr on" allows and "mac set adr off" command disables it. In GPS Mode adr is off and in Sensor Mode switched on.

- When adr is enabled, this information is transmitted in the header of every uplink message. Then Loriot network server checks radio reports of gateways and after receiving 12 uplink messages successfully it may increase the data rate of the end device by sending a downlink message. This decision calculates enough decoding margin to gateways. The mac layer of RN2483 understands this and will increase its data rate by one without the intervention of application. If application needs actual data rate information it should read it by a "mac get dr" command after each transmission.

- The opposite data rate correction is made by the mac layer of RN2483. Whenever an uplink message requires confirmation, the RN2483 repeats the message if it lacks confirmation. First the repeated message is using the same data rate but on a different channel. Then if the second message is not confirmed either, it lowers data rate by one and repeats. This process can iterate down till gets the reliable data rate for given conditions. Users should pay attention on the parameters of repetition, the number of available channels and transmission duty cycle control of the module and also, on the fact that when an end device gets confirmation in RX1 window, this downlink transmission disables reception of the gateway on other channels. The more it confirms the less it can listen! So do not use confirmation requests too frequently. Every 10th uplink may request confirmation if there is no important event behind. This number may depend on the number of end devices and the number of gateways, on the robustness of the whole LoRaWAN network.

The adr process is not very quick, slower than the adaptive capabilities of mobile devices of GSM network. But this limitation doesn't matter. Mobile LoRaWAN devices do not use adr and fix position end devices can enjoy adaptive data rate for slow changes in the radio conditions and network topologies.

In GPS Mode DR=0 and while in Sensor Mode adaptive data rate process set DR between 1 and 5. With this approach mobile devices will never interfere with fixed position sensor network in spite their higher transmit duty cycle.