

# IoT i CIoT Devices – Smart Solutions

## LoRaWAN & GSM - Smart City



iSys – Intelligent Systems

**@City**

**@AirQ**

**@Bin**

**@Light @Metering @Trace**

**DRAFT**

## Table of Contents

1. Introduction.....	3
1.1 @City (IoT/CIoT) Communication.....	4
1.2. Hardware resources of IoT/CIoT Devices.....	4
0..4 programmable binary inputs.....	4
0..4 programmable binary outputs.....	4
0..4 counting inputs (nonvolatile counters).....	4
0..4 dimmers outputs (PWM or 0..10V).....	5
Infrared input + output.....	5
0..4 measurement inputs (ADC).....	5
serial interfaces SPI/I2C/UART/CAN.....	5
1.3. @City GSM Devices.....	6
1.4. @City LoRaWAN Devices.....	9
The module without LoRaWAN modem and processor may act as MEMs Sensor Module for @City GSM, WiFi, Ethernet, and other eHouse architectures (3v3..3v6 DC powered).....	10
2. General conditions of usage @City (LoRaWAN, GSM) Systems.....	11
2.1. Exclusive Conditions of @City GSM.....	11
2.2. Exclusive conditions for @City LoRaWAN.....	12
3. @City (LoRaWAN, GSM) Controller Configuration.....	13
3.1. @City Controller Configuration – Assigning names.....	13
3.2. General configuration of @City LoRaWAN & GSM Controllers.....	14
3.2.1 General configuration of @City GSM device.....	14
3.2.2. General Configuration of @City LoRaWAN controllers.....	17
3.3. Binary Inputs Configuration.....	18
3.4. Binary Outputs Configuration.....	19
3.5. Configuration of ADC Measurement Inputs and additional sensors (XIN).....	21
3.6. Dimmers Configuration PWM/0..10V.....	22
3.7. Calendar-scheduler Configuration.....	24
4. LoRaWAN Network Infrastructure Configuration.....	26
4.1. LoRaWAN Gateway Configuration.....	26
4.1.1. Basic configuration of LoRaWAN gateway.....	26
4.1.2. Semtech Packet Forwarder (SPF) Configuration.....	27
4.2. LoRaWAN Network/Application Server Configuration.....	28
4.2.1. LoRaWAN Network Server Configuration.....	29
5. Work condition of @City GSM / LoRaWAN devices.....	31

## 1. Introduction.

The **@City** system supports a number of electronic devices (controllers) - called as node, mote, device. Many types of communication (wired and wireless) are available depending on the available infrastructure, requirements and conditions.

Device types available in the @City system:

- **CIoT – Cellural Internet of Things (GSM/2G/3G/4G/NB-IoT/CATM1)**
- **IoT - Internet of Things (LoRaWAN)**
- Ethernet
- WiFi

All devices are integrated with each other via the **@City** cloud and there is a possibility of hybrid cooperation depending on the availability of a given communication infrastructure.

For buildings and availability of LAN or WiFi connected to the Internet we can use eHouse solutions via eHouse.PRO server (that can send/receive data to **@City** cloud):

- Ethernet
- WiFi
- CAN
- RF
- RS-485/RS-422

The following document describes **GSM** and **LoRaWAN** devices based on a single-chip microcontroller (microprocessor) and an external communication modem. This allows the system to be standardized despite the difference of communication modem.

For other communication variants please refer to **eHouse** documentation.

This enables similar functionality and equipment to be obtained, as well as easy migration to other communication variants or versions.

## **1.1 @City (IoT/CIoT) Communication**

The @City system currently uses one of the selected communication modules (modems):

- LoRaWAN (1.0.2) + BlueTooth + BLE4.0 + NFC
- GSM (2G/NB-IoT/CATM1) + GPS/GNNS
- 3G+GPS
- 4G+GPS

## **1.2. Hardware resources of IoT/CIoT Devices**

The whole "intelligence" of the system resides in microcontroller (microprocessor) and is not very dependent on the type of communication. The hardware resources of IoT/CIoT devices (microprocessor) are as follows:

- **0..4 programmable binary inputs**
  - monitoring the status of the inputs
  - assigning of a command executed when the state changes
  - generating advanced alarms
  - connecting any detectors/sensors
  - remote reporting
- **0..4 programmable binary outputs**
  - Turning on/off any electrical/electronic devices (single output)
  - Open/Close/Stop drive control: blinds, gates, awnings, solenoid valves, servomotors, servos (dual outputs)
  - controlling devices driven by multiple outputs, e.g. motors, fans (triple or quadruple outputs)
- **0..4 counting inputs (nonvolatile counters)**
  - electric energy
  - gas

- water
- warm
- event occurrences from alarm sensors
- saved in non-volatile memory
  
- **0..4 dimmers outputs (PWM or 0..10V)**
  - dimming LED lighting, LED power supplies
  - motor power control
  
- **Infrared input + output**
  - control from an infrared remote control or close communication between devices via infrared
  - sending infrared codes
  
- **0..4 measurement inputs (ADC)**
  - connection of any analog sensors
  - measurements of voltage, current, resistance, capacitance
  - measurements and adjustments of various physical parameters
  - generating alarms when programmed thresholds (min, max) are exceeded
  - executing control commands when exceeding programmed thresholds (min, max)
  
- **serial interfaces SPI/I2C/UART/CAN**
  - installation of any external sensors and extensions, e.g.
    - lighting level (ALS)
    - magnetic field - magnetometer 3 axis sensor (X, Y, Z)
    - turn on - gyroscope (X, Y, Z)
    - inclinometer (X, Y, Z)
    - proximity (proximeter) 10cm / time of flight (4m)

- acceleration/vibration (X, Y, Z)
- electronic compass
- temperature, pressure, humidity, overall air quality
- color (R, G, B, IR)
- Measurement of particulate air pollution (PPM 2.5 / 10um)
- the OTA firmware upgrade (Over The Air), allows you to update the software algorithms and configuration via the main communication interface

### **1.3. @City GSM Devices**

**@City GSM** devices connect through the cellular network of the GSM mobile operator through one or more technologies and services. These services are billed and depend on the operators and services individually. The service is authorized in the same way as in mobile phones through active SIM cards:

- standard nano SIM (plastic)
- MIM (in the form of a electronic chip (IC)).

The availability of selected services depends on the communication operator and the built-in GSM modem at the production stage:

#### 1) 2G (all operators)

- SMS
- TCP/IP (GPRS/EDGE)
- UDP (GPRS/EDGE)

#### 2) 2G/LTE CATM1 (Orange) – there is 2G fallback possibility when CATM1 is not available.

- SMS (2G/CATM1)
- TCP/IP (GPRS/EDGE/CATM1)
- UDP (GPRS/EDGE/CATM1)

#### 3) 2G/NB-IoT (T-Mobile/Deutsche Telecom) – there is 2G fallback possibility when NB-IoT is not available and operator allows it.

- TCP/IP (NB-IoT)

- UDP (NB-IoT)

4) 2G/3G (all operators)

- SMS
- USSD
- TCP/IP (GPRS/EDGE/3G)
- UDP (GPRS/EDGE/3G)

5) 4G/LTE (all operators)

- TCP/IP (4G)
- UDP (4G)

6) Other services combination might also be available depending on available modem and settings.

The first 3 solutions work on the same modem (NB-IoT/CATM1 + fallback 2G). In the case of using “plastic” Nano SIM cards it is possible to replace the card and remotely configure the device to work properly in another service. In the case of MIM (SIMs in the form of a chip (IC)), the decision is made at the stage of production of the device, and it is not possible to change the operator or service. NB-IoT is dedicated to a very small amount of transmitted data ~ 512kB per month (please negotiate this value to the operator), which is a significant obstacle for some CIoT/IoT solutions.

Solutions 4, 5 require the installation of other modems at the production stage.

**The device's power consumption depends on the service and is shown from lowest to highest:**

- NB-IoT
- CATM1
- LTE
- 3G
- 2G/SMS/USSD/GPRS/EDGE

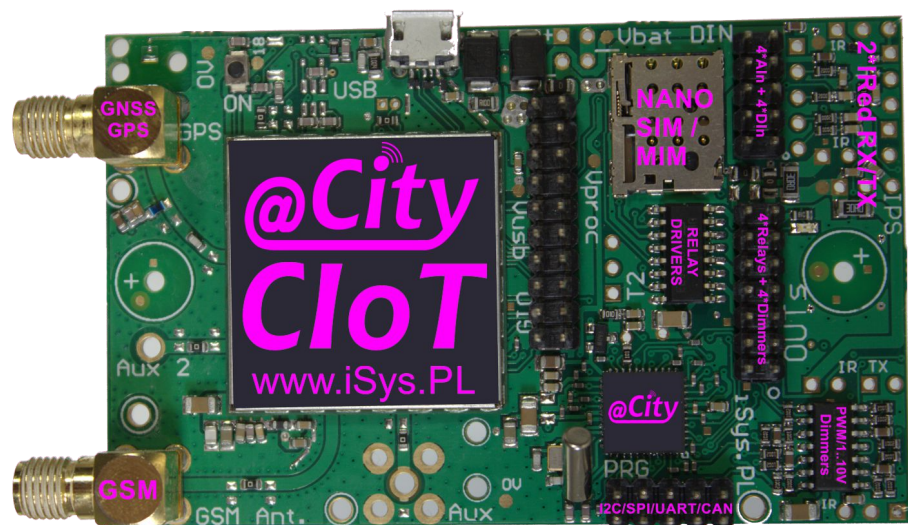
**Data transfer rate from lowest to highest:**

- NB-IoT
- CATM1

**@City LoRaWAN & GSM/LTE-M1/NB-IoT Devices supported by @City Platform**

- 2G/SMS/USSD/GPRS/EDGE
- 3G
- LTE

All @City GSM devices can be equipped with a GPS receiver for geolocation and automatic positioning on maps. They can also work mobile when there is a need for measurements or work in motion.



## **1.4. @City LoRaWAN Devices**

LoRaWAN is a long range communication solution (up to approx. 15km) working in open ISM bands (e.g. 433MHz, 868MHz, etc.). However, Very large ranges require a significant reduction in transmission speed and data packets length (e.g. for the highest range up to 250 bits per second and a maximum of 51 bytes of data - payload). Transmission with repetitions and confirmations can take a very long time, which may eliminate LoRaWAN in some solutions. The number of LoRaWAN gateways is also important to ensure a good range of devices, which allows you to work at higher speeds, fewer errors and less repetitions amount.

LoRaWAN devices communicate with the **@City cloud** via LoRaWAN Gateways, which have to provide coverage at the required level for all available LoRaWAN devices. In addition, these gateways must be connected to the LAN or the Internet via any link to be able to send data to the LoRaWAN network/application server (NS/AS).

The web server is used for two-way communication with LoRaWAN gateways and for sending information to/from LoRaWAN devices.

The network/application server can be located on the local LAN or in the service provider's data center. Data from the devices are sent from the network/application server via integration protocols to the **@City cloud** (via webhook). This allows direct integration of the **@City LoRaWAN** system with **@City databases**.

The application server can additionally implement extended logic & BIM (information modeling) for the system, processing data on reception, and sending control commands (events) to individual devices in response.

@City LoRaWAN devices contains additional features as:

- Energy harvesting (buck or boost) power supply
- 3V3/1V8 LDOs
- on board optional sensors and extensions, e.g.
  - lighting level (ALS)
  - magnetic field - magnetometer 3 axis sensor (X, Y, Z)
  - turn on - gyroscope (X, Y, Z)
  - inclinometer (X, Y, Z)
  - proximity (proximeter) 10cm / time of flight (4m)
  - acceleration/vibration (X, Y, Z)
  - electronic compass
  - temperature, pressure, humidity, overall air quality

**@City LoRaWAN & GSM/LTE-M1/NB-IoT Devices supported by @City Platform**

- color (R, G, B, IR)
- Measurement of particulate air pollution (PPM 2.5 / 10um)
- LVD current/voltage (3 phases)



The module without LoRaWAN modem and processor may act as MEMs Sensor Module for @City GSM, WiFi, Ethernet, and other eHouse architectures (3v3..3v6 DC powered)

## **2. General conditions of usage @City (LoRaWAN, GSM) Systems**

**ATTENTION! Incorrect setting of the main communication interface parameters may cause destruction or permanent blocking of the device (to which we have no physical access).**

Any controller's update of a **firmware** and **final configuration** must be carried out and tested (for all devices and for at least a week for several devices) before installing them at the destination place.

The manufacturer is not responsible for improper configuration/software update performed by unauthorized persons, as well as their execution in places of installation of individual controllers.

All costs of deinstallation, services, repair, replacement, reinstallation are borne by the system user (not the Manufacturer).

In order to update the firmware and configuration it is necessary to ensure a sufficient signal level and the availability of the required services. The above activities may be impossible at the final installation locations of the controllers and in their enclosures. They may also depend on the season, weather, and radio wave propagation.

All costs of services related to the configuration/firmware change are borne by the user (additional fees for data transfer, possible uninstallation, installation of devices, unlocking, replacement, etc.).

**The maximum range is purely theoretical, measured under ideal radio propagation conditions and refers to the operation of devices (with external and matched antennas) in the field of view (without obstructions in the signal beam path). Depending on the urbanization of the area, trees, weather, location and method of installation, the range may be worse by several hundred times than the above data.**

### **2.1. Exclusive Conditions of @City GSM.**

The user bears the costs and is responsible for timely payment of the GSM operator subscription and @City server hosting. Lack of service continuity may cause irreversible changes of critical transmission parameters and blocking the entire system (e.g. change of static IP address, loss of internet domain, loss of data/configuration on the server, loss of software, backups, etc.).

In the event that the user pays the above-mentioned amounts as a flat rate to the producer of the @City system, the Producer is not responsible for the conditions changes of the offer or termination of services performed by external entities.

The system manufacturer is not responsible for the quality of services provided by third parties, including the GSM operator, external @City hosting. The manufacturer is not responsible for the deterioration of the range of radio wave propagation (e.g. due to the creation of new buildings, changes in the location of GSM broadcasting stations (BTS), trees, etc.).

In the case of data transfer limits (especially for NB-IoT), software configuration and update should be carried out at the beginning of the subscription period, with the lowest possible data consumption. Otherwise, it is possible to block the device until the end of the billing period, due to blockages associated with exceeding the transfer limit.

The GSM operator is responsible for the quality of the GSM connection, not the @City system manufacturer.

The User declares that he/she accepts the following information and agrees to it.

## ***2.2. Exclusive conditions for @City LoRaWAN.***

The user bears the costs and is responsible for the timely payment of lease and installation fees for the LoRaWAN gateway, LoRaWAN Network/Application Server and @City server hosting. Lack of service continuity may cause irreversible changes of critical transmission parameters and permanent system blocking (e.g. change of static IP address, loss of domain, loss of data/configuration on the server, loss of software, backups, etc.).

In the event that the user lays down the above obligations on a flat-rate basis to the @City producer, the producer is not responsible for changing the conditions or terminating the services provided by external entities.

The system manufacturer is not responsible for services provided by external entities, including any LoRaWAN operator, hosting for the LoRaWAN network/application server, external @City server hosting. The manufacturer is not responsible for the deterioration of the range of radio wave propagation (e.g. due to the creation of new buildings, changes in the location of LoRaWAN gateways, damage to LoRaWAN gateways, power outages, trees, interference, signal losses, etc.).

In the case of data transfer limits, software configuration and update should be carried out at the beginning of the subscription period, with the least current data consumption. Otherwise, it is possible to block the device until the end of the billing period due to blockages associated with exceeding the transfer limit. The update should be carried out one controller from beginning to end and testing the correctness of work. Running the update for all controllers may cause the radio band to be completely blocked for many days.

LoRaWAN uses publicly available „open radio bands” (433 or 868 MHz for EU), which may be disturbed or occupied by other devices operating on the same frequencies. The manufacturer is not responsible for the quality of communication in the above case.

The user is responsible for covering the area with the appropriate number of LoRaWAN gates and their location to obtain the appropriate level of signals for all devices and the entire @City LoRaWAN system.

@City GSM devices can be used in places highly exposed to signal interference.

The User declares that he/she accepts the following information and agrees to it.

### 3. @City (LoRaWAN, GSM) Controller Configuration

System configuration is carried out via the web interface. Configuration is very critical for @City controllers and incorrect settings may cause the system to completely block. It is recommended that the full template configuration (default settings) be carried out and tested by the @City system manufacturer.

#### 3.1. @City Controller Configuration – Assigning names

Smart City Automation. Names Editor

Device Name: 0000000000000000 (0000000000000000) (GSM)  
Vendor Code: 11223344 File Code: 55667788

Output 1: Output 1 Output 2: Output 2  
Output 3: Output 3 Output 4: Output 4  
Output 5: @Output 5 Output 6: @Output 6  
Output 7: @Output 7 Output 8: @Output 8

Input 1: Input 1 Input 2: Input 2  
Input 3: Input 3 Input 4: Input 4  
Input 5: @Input 5 Input 6: @Input 6  
Input 7: @Input 7 Input 8: @Input 8

ADC 1: Light Level % Inv ADC 2: Temperature MCP9700  
ADC 3: Temperature3 MCP9700 ADC 4: Temperature4 MCP9700  
ADC 5: PPM 2.5ug PPM 2.5u ADC 6: PPM 10ug PPM 10u  
ADC 7: Adc 7 MCP9700 ADC 8: Adc 8 MCP9700

XADC 1: Temperature {R} XADC 2: Pressure {R}  
XADC 3: Accelerate X {R} XADC 4: Accelerate Y {R}  
XADC 5: Accelerate Z {R} XADC 6: Magnet X {R}  
XADC 7: Magnet Y {R} XADC 8: Magnet Z {R}  
XADC 9: Color [R] {R} XADC 10: Color [G] {R}  
XADC 11: Color [B] {R} XADC 12: Color [IR] {R}  
XADC 13: Color [G2] {R} XADC 14: Proximity {R}  
XADC 15: Ambient Light H {R} XADC 16: Ambient Light L {R}

Dimmer 1: Dimmer 1 Dimmer 2: Dimmer 2  
Dimmer 3: Dimmer 3 Dimmer 4: Dimmer 4

Counter 1: Counter 1 Counter 2: Counter 2  
Counter 3: Counter 3 Counter 4: Counter 4

Update Names

All Controllers Settings Change Names Scheduler Reset Controller Logout

Controller address: 0000000000000000 (15 zeros for GSM/16 for LoRaWAN) is the default address that applies to

all controllers in the family (i.e. for the same **Vendor Code** and **File Code**, and the same type of LoRaWAN/GSM controller. If the controller does not have its own individual configuration defined, the default configuration is loaded into it.

In the case of GSM controllers, this address corresponds to the unique IMEI number (15 characters) assigned by the manufacturer of the GSM modem.

In the case of LoRaWAN controllers, this address corresponds to the unique "Dev EUI" number given by the manufacturer of the LoRaWAN modem (16 characters in hexadecimal code).

**Vendor Code** - is a unique parameter for the customer (user)

**File Code** - is a parameter denoting the type of firmware (depends on the equipment and available algorithms)

In most cases, it is sufficient to configure this one device (default) for the whole system or as a template for other drivers. When creating a new controller configuration, these settings are copied from the template.

Both firmware and configurations for all installations (instances) are located on the servers of the @City system manufacturer available via the WWW, to which the user may have limited access. However, the correct configuration is very critical, and it is not recommended to make changes without testing on several devices with full physical access (on the desk). For more information, please check the general conditions of the @City system and the specific conditions for a particular way of communication.

## 3.2. General configuration of @City LoRaWAN & GSM Controllers

### 3.2.1 General configuration of @City GSM device

Before starting the configuration, please read the general conditions of the @City system and system-specific conditions for @City GSM.

Vendor Code: 11223344 File Code: 55667788 PIN No: 1234  
SMS Nr: 123456789 ☐ SMS Enable  
USSD Str: 123456 ☐ USSD Enable  
APN: Internet WWW address: example.com WWW Page: /page/ ☐ HTTP Enable  
TCP/UDP Address: 123.123.123.123 TCP Port: 9876 ☐ TCP Enable  
UDP Port: 123.123.123.123 ☒ UDP Enable  
Aux Address: Aux Port: ☐ AUX Enable  
Aux2 Address: Aux2 Port: ☐ AUX2 Enable  
☐ Temp, pressure, humidity, GAS ☐ B1 ☐ B2 ☐ B3 ☐ B4 ☐ B5 ☐ B5 ☐ B6 ☐ Temp+pressure ☐ Gyroscope ☐ Magnetometer ☐ Accelerometer ☐ Color ☐  
Ambient+proximeter ☐ R1 ☐ R2  
GSM Commands:   
Hash Code: FFFFFFFFFFFFFFFFFFFFFFFF  
☐ Transfer http ☐ H2 ☐ H3 ☐ H4 ☐ H5 ☐ H6 ☐ H7 ☐ H8 Global Address: 0000000000  
GSM Mode: Auto Scheduler:   
EEPROM SIZE: 515

**Vendor Code** - contains 8 characters stored in hexadecimal code dedicated to one customer (user). It is granted at the controller production stage. An attempt to change may cause permanent damage of the

controller.

**File Code** - contains 8 characters stored in hexadecimal code, dedicated to one controller firmware version. It is granted at the controller production stage and may depend on the type of communication (GSM / LoRaWAN) and additional equipment, e.g. sensors, the number of inputs/outputs and individual algorithms. The change may cause permanent damage or blocking of the controller.

**PIN No.** - 4-digit pin number if set for the SIM card. Setting PINs is not recommended. For plastic SIM cards, you can remove them on your mobile phone. The introduction of an incorrect SIM may cause permanent blocking of the card in the device (to which we will ultimately not have physical access).

**SMS No.** - SMS number when sending status via SMS. This option is available depending on the service and the operator (2G/CATM1/NB-IoT). It also requires turning on the flag: **SMS Enable**.

**USSD Str** - USSD command for sending statuses via USSD. This option is available only for selected types of GSM modems (2G/3G + GPS). The option: **USSD Enable** is required. The operator must provide and activate the USSD service.

**APN** - Access Point Name. The name of the internet access point, e.g. **internet** (for special services like LTE-M1 or NB-IoT, it can be assigned individually by the operator).

**WWW Address** – web address (domain or IP) for HTTP access.

**WWW Page** – web page address, where controllers statuses and commands are sent.

**HTTP Enable** - Enables HTTP data transmission. This method generates many times more data transfer than all other communication methods, which may result in increased costs, exceeding the transfer limit or inability to use some services, such as NB-IoT.

**TCP/UDP Address** - IP address of the @City server for receiving and transmitting data between the cloud and devices. It is recommended to use a fixed IP address, not an internet domain address.

**TCP Port** – TCP/IP port for communication

**TCP Enable** - Allows you to enable TCP/IP transmission. Transmission frames and TCP confirmations increase the amount of data in relation to UDP transmissions, however, they ensure correctness of data, confirmations and guarantee their delivery, if communication is available.

**UDP Port** - Port for receiving status via UDP

**UDP Enable** - Turn on transmission UDP

**Aux Address, Aux Port, Aux Enable** - future applications

**Aux2 Address, Aux2 Port, Aux2 Enabled** - future applications

**Activation of sensor support** (they must be physically mounted on the @City module). Otherwise, the device may work much slower and less stable. Sensors are installed at the production stage for the entire production series.

**Temp, presure, humidity, gas** - integrated temperature, pressure, humidity and air quality sensor

**Temp + Presure** - Integrated temperature and pressure sensor

**Gyroscope** - Gyroscope sensor in 3 axes (X, Y, Z)

**Magnetometer** - Magnetic sensor in 3 axes (X, Y, Z)

**Accelerometer** - Acceleration / vibration sensor in 3 axes (X, Y, Z)

**Color** - Color sensor (R, G, B, IR, G2)

**Ambient + proximeter** - integrated light level and (10cm range) proximeter sensor

**GSM Commands** - additional modem initialization commands

**Hash Code** - An additional encryption code. Do not change.

**HTTP transfer** - Additional HTTP communication options

**Global Address** - The global address of the controller for device-to-device control.

**GSM Mode** - GSM communication mode (2G Only, LTE Only, CATM1, NBIoT, 2G + CAT M1, LTE 800, LTE 1800). Incorrect setting of communication mode may result in permanent blocking of device communication.

### **3.2.2. General Configuration of @City LoRaWAN controllers**

Most options are the same as in the GSM controller. In principle, all fields related to GSM communication are not used during LoRaWAN controller operation. LoRaWAN devices have different firmware which support LoRaWAN module instead GSM.

On the **@City LoRaWAN** device side, configuration is very simple:

**Application EUID** - Application ID for LoRaWAN server (16 characters in hex code) - application defined on the LoRaWAN Network/Application Server to which we send data.

**Application Key** - application authorization key for LoRaWAN server (as above)

**Disable Adaptive Data Rate** - Disables adaptive speed selection. This allows you to force a constant speed of the device. In some situations, this can cause big communication problems. It should be taken into account that as the RSSI and SNR parameters improve in the adaptive mode, the speed increases significantly. This significantly reduces the time of data transmission by radio "On The Air Time" and much more often information can be transmitted between the device and the server and vice versa.

**Data Rate (DR)** - LoRaWAN link speed selection. This speed does not apply to Bootloader. In case the controller works in the adaptive speed setting mode, it is only the start value, because the controller after several attempts of transmission, autonomously selects the optimal speed to limit the time of message transmission in the air.

**Update Settings** - saves the startup configuration of controller - all settings

The rest of the @City LoRaWAN configuration is located in the remaining elements of the LoRaWAN configuration screens in Chapter 4.

### 3.3. Binary Inputs Configuration

The screenshot displays the 'Inputs Settings' window with four identical configuration sections for Input 1 through Input 4. Each section contains the following elements:

- 1) Input 1:** ☐ Invert, ☐ Alarm, Alarm Delay: 0 h, 0 m, 0 s, Remember State: 0 h, 0 m, 0 s, ☐ Disable Execution, Run, Copy
- Event On:** [text input], **Direct Event On:** [text input]
- Event Off:** [text input], **Direct Event Off:** [text input]
- Alarm Event:** [text input], **Direct Alarm Event:** [text input], Run

Sections 2, 3, and 4 follow the same layout with their respective input numbers.

Binary inputs have a number of functions and parameters that enable autonomous operation of the controller:

**Invert** - input negation when sensors “normally connected” (NC) are connected.

**Alarm** - activation of the alarm function.

**Alarm Delay** - Alarm delay time. If the input state returns to its original state before this time has expired, the alarm will not be activated.

**Remember State** - Time to remember the input state change.

**Disable Execution** - Blocking of running events related to the input.

**Run** - Run the input configuration command (Ad-Hoc)

**Copy** – Copy input configuration command to the clipboard

**Event On** - Description of how to run the event for the high input level (1)

**Direct Event On** - Event code to be run when the input is on (0 => 1)

**Event Off** - Description of event activation for low input level (0)

**Direct Event Off** - Event code to be run when the input is off (1 => 0)

**Alarm Event** - Description of the Alarm event.

**Direct Alarm Event** - The event code to be triggered when an alarm occurs

**Update Settings** - saves the startup configuration for all settings

### 3.4. Binary Outputs Configuration

1) Output 1 : ☐ Disable ☐ Admin  Repeats: 0 Time On: 0 h, 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

2) Output 2 : ☐ Disable ☐ Admin  Repeats: 0 Time On: 0 h, 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

3) Output 3 : ☐ Disable ☐ Admin  Repeats: 0 Time On: 0 h, 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

4) Output 4 : ☐ Disable ☐ Admin  Repeats: 0 Time On: 0 h, 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

Double Output Settings [+/-stop] (rollers, gates, drives, cut-off) - One Output => One Direction:

1) Output 1/Output 2 : ☐ Disable ☐ Admin ☐ Somfy N/A Repeats: 0 Time On: 0 h, 0 m, 0 s Disable Time: 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

2) Output 3/Output 4 : ☐ Disable ☐ Admin ☐ Somfy N/A Repeats: 0 Time On: 0 h, 0 m, 0 s Disable Time: 0 m, 0 s Time Off: 0 h, 0 m, 0 s Run Copy

Intelligent binary outputs can work as single or double. The form allows you to create a startup configuration for the controller (if you confirm it with the Update button).

The form also serves as an event creator for outputs that can be started by pressing the Run button or copied to the clipboard for use in the controller configuration, e.g.

- scheduler-calendar
- autonomous work
- assigning outputs to binary inputs (responding to a change of state)
- assigning outputs to measuring inputs (reacting to threshold change)

#### Configuration of single outputs:

**Disable** - Blocking the output in single mode (e.g. if it is used to control drives so as not to accidentally damage roller shutters, gates, actuators)

**Admin** - An administrative flag is required when changing critical settings

**State** - state selection (initial configuration or launching the event with the “**run**” button)

**Repeats** - Number of repetitions (cyclical state changes)

**Time On** - Time of output activation

**Time Off** - Time of turning off the output (it is important when repeating events)

**Run** - Run the event for exit

**Copy** - Copy the event to the clipboard

**Update Settings** - saves the startup configuration for all settings

**Double output configuration:**

**Disable** - Lock out a pair of outputs in dual mode (e.g. if used as single inputs)

**Admin** - An administrative flag is required when changing critical settings such as drive mode

**Somfy** - drives mode (checked => Somfy / unchecked => Direct Servo)

**State** - state selection (for initial configuration or launching the event with the “**run**” button)

**Repeats** - Number of repetitions (cyclical change of states)

**Time On** - Time of turn on the given state

**Disable Time** - Time to block outputs (minimum time between outputs changes) to protect drives against damage.

**Time Off** - Time of turning off the output (it is important when repeating events)

**Run** - Run the event for the drive

**Copy** - Copy the event to the clipboard

**Update Settings** - saves the startup configuration for all settings

### 3.5. Configuration of ADC Measurement Inputs and additional sensors (XIN)

ADC Measurement Settings:

1) ADC 1 : ☐ Invert ☐ Alarm L ☐ Alarm H , Alarm Delay: 0 h, 0 m, 0 s ☐ Event Disable ☐ Admin  
LOW Event:  LOW Direct:  Low Level 0  
OK Event:  OK Direct:   
HIGH Event:  HIGH Direct:  High Level 0 Run Copy Run

2) ADC 2 : ☐ Invert ☐ Alarm L ☐ Alarm H , Alarm Delay: 0 h, 0 m, 0 s ☐ Event Disable ☐ Admin  
LOW Event:  LOW Direct:  Low Level 0  
OK Event:  OK Direct:   
HIGH Event:  HIGH Direct:  High Level 0 Run Copy Run

3) ADC 3 : ☐ Invert ☐ Alarm L ☐ Alarm H , Alarm Delay: 0 h, 0 m, 0 s ☐ Event Disable ☐ Admin  
LOW Event:  LOW Direct:  Low Level 0  
OK Event:  OK Direct:   
HIGH Event:  HIGH Direct:  High Level 0 Run Copy Run

4) ADC 4 : ☐ Invert ☐ Alarm L ☐ Alarm H , Alarm Delay: 0 h, 0 m, 0 s ☐ Event Disable ☐ Admin  
LOW Event:  LOW Direct:  Low Level 0  
OK Event:  OK Direct:   
HIGH Event:  HIGH Direct:  High Level 0 Run Copy Run

**Invert** - inverted scale (100%-x) of the ADC input

**Alarm L** - Activation of the option to generate an alarm when the value drops below the min. threshold

**Alarm H** - Activation of the option to generate an alarm when the value exceeds the max. threshold

**Alarm Delay** - Alarm delay time. If the input status returns to the "OK" level before the time elapses, the alarm will not be activated.

**Event Disable** - Blocking event execution

**Admin** - admin flag enabling the change of the measurement input configuration

**LOW Event** - description of the event performed when the low threshold was exceeded

**LOW Direct** - event code to be executed after lowering the value below the lower threshold

**LOW Level** - Level of the lower threshold (min)

**OK Event** - Description of the "OK" event

**OK Direct** - event code to be executed after entering the "OK" range

**HIGH Event** - Description of the event for the upper threshold

**HIGH Direct** - event code to be executed after exceeding the upper threshold value

**HIGH Level** - Level of the upper threshold (max)

**Run** - running the configuration event (change of ADC Ad-Hoc configuration)

**Update Settings** - saves the initial configuration for the ADC inputs

### 3.6. Dimmers Configuration PWM/0..10V

Dimmers:

1) Dimmer 1 : ☐ Invert ☐ Admin ☐ Disable ☐ Once , Value Min: 0 , Value: 0 , Mode: N/A , Step: 0 , Value Max: 0 Run Copy Run

2) Dimmer 2 : ☐ Invert ☐ Admin ☐ Disable ☐ Once , Value Min: 0 , Value: 0 , Mode: N/A , Step: 0 , Value Max: 0 Run Copy Run

3) Dimmer 3 : ☐ Invert ☐ Admin ☐ Disable ☐ Once , Value Min: 0 , Value: 0 , Mode: N/A , Step: 0 , Value Max: 0 Run Copy Run

4) Dimmer 4 : ☐ Invert ☐ Admin ☐ Disable ☐ Once , Value Min: 0 , Value: 0 , Mode: N/A , Step: 0 , Value Max: 0 Run Copy Run

RGBW Dimmer: Mode: N/A Continuous Mode: ☐ Red ☐ Green ☐ Blue ☐ White Advanced: ☐ Red ☐ Green ☐ Blue ☐ White Run Copy Run

Update Settings

All Controllers Settings Change Names Scheduler Write Config Upgrade Firmware Reset Controller Reset Controller - Copy Logout

**Invert** - Dimmer polarity reversal (100% - x)

**Admin** - An administrative flag that allows you to change critical options

**Disable** - Blocking the dimmer output

**Once** - Change dimmer settings once (then stop dimmer)

**Value Min** - minimum value of dimmer settings

**Value** - dimmer's target value

**Mode** - Dimmer setting mode (Stop/-/+ /Set)

**Step** - Step of changing the dimmer level value

**Value Max** - the maximum value of the dimmer setting

**Run** - Runs the dimmer event

**Copy** - Copy the event to the clipboard

**The RGBW dimmer retrieves the setting values from individual colors.**

In addition, it allows you to activate the continuous color change mode using the presets of single dimmers.

**Update Settings** - saves the startup configuration for all settings

**Buttons:**

**Update Settings** - saving the configuration in the @City system

**All Controllers** - a list of all controllers

**Settings** - settings of the current controller

**Change Names** - change the name of the current controller

**Scheduler** - the scheduler-calendar editor of the current controller

**Write Config \*** - sending a command to download the configuration by the controller

**Firmware Upgrade \*** - sending a command to download the firmware by the controller

**Reset Controller \*** - sending reset command to download by the controller

**Reset Controller - Copy** - copy of the controller reset event to the clipboard

**Logout** - logout of the user (for security reasons, you should also close all open instances of the web browser that can store the login parameters in the cache).

\* - sending the command means adding to the event queue. On connecting controller to the @City system, the controller downloads these events.

### 3.7. Calendar-scheduler Configuration

The calendar-scheduler allows autonomous triggering of repetitive or scheduled events (commands). An example would be, for example, turning on the street lamp at 17 o'clock and switching off at 7 o'clock (in winter).

**Del (Delete)** - completely deletes the schedule item.

**En. (Enable)** - Activate schedule item (only those positions will be executed that have the Enable flag set)

**Name** - Event name (you can describe the event in a recognizable way)

**Event Code** - event code in hexadecimal code (copied from the clipboard when creating commands)

**Month fields (Ja, Fe, ..., No, De)** - months January ... December in which the event will be started

**Day** - Day. You can select any day of the month or "\*" for any (running the event every day).

**Weekday fields (Mo, Tu, .. Su)** - you can select the days of the week on which the event will be performed.

**Hour** - The hour. You can choose any hour or "\*" for everyone (running the event every hour).

**Min** - Minute. You can select any minute or "\*" for everyone (running the event every minute).

Logical **"and"** algorithm is implemented between all fields (except **Name**), so they must all be met for the event to be executed.

E.g. Turning on street lamps (**November, December, January, February**) at **17.01** without **Sundays**.

**En** - selected

**Event code** - 00002101010000000000 // run of the 1st binary output

**Months fields** - only **No, De, Ja, Fe** are marked

**Day** - selected "\*" for each day of the month

**Hour** - selected time is **17**

**Min** - selected minute **01**

**Weekday fields** - all but **Su** selected

## 4. LoRaWAN Network Infrastructure Configuration

*This chapter only applies to LoRaWAN communication. In the case of systems working using other transmission methods, it can be omitted.*

According to the LoRaWAN network specification, the controller connects to the @City cloud indirectly through:

- LoRaWAN gateway (e.g. Kerlink) with the Semtech Packet Forwarder (SPF) installed to send all LoRaWAN packets bidirectionally via UDP protocol to the LoRaWAN Network Server.
- LoRaWAN Network Server - for communication between the LoRaWAN gateway and the application server.
- Application server for uploading data to the @City cloud

### 4.1. LoRaWAN Gateway Configuration.

There are many LoRaWAN gateways on the market that can simultaneously contain a number of additional options:

- LoRaWAN Communication Gateway
- SPF package (Semtech Packet Forwarder)
- LoRaWAN Network Server (**NS**)
- LoRaWAN Application Server (**AS**)
- Database
- LTE Communication Module

#### 4.1.1. Basic configuration of LoRaWAN gateway

**The LoRaWAN gateway should be accessible from at least one configuration station.**

When installing via Ethernet/WiFi and configuring only from a local LAN/WLAN, the gateway's security is not very critical (unless we provide access to the gateway from outside, i.e. the Internet).

In the case the LoRaWAN gateway is connected only via GSM/LTE, it is necessary to secure the gateway against access and various types of attacks.

- If we want to be able to connect to the LoRaWAN gateway remotely, it must have a public + static IP address

and SSH service available. Otherwise, you will need to physically connect to the gateway via an Ethernet or WiFi interface.

- it is necessary to set complicated access passwords for all users on the device.
- disable all unused services such as Telnet, FTP, POP, SMTP, IMAP, WWW etc. that may be the target of attacks "occupying" the gateway with other processes such as login attempts.
- you can limit the possibility of logging in, only from stations with selected static IP addresses, which is quite effective protection against hacking. This also applies to seemingly insignificant services such as ICMP (ping), HTTP, FTP, etc.
- after full configuration and many weeks of system tests, we can block all external services and remote access, which, however, will hamper the service, search and check the gateway logs.

### 4.1.2. Semtech Packet Forwarder (SPF) Configuration

The SPF's task is to send LoRaWAN packets to the LoRaWAN network server through the IP network (UDP protocol) to the required address of the LoRaWAN network server.

LoRaWAN Gateway with SPF is transparent and passes all packets in both directions.

It does not process or authorize data packages in any direction.

Configuration of SPF is very simple and involves "directing" it to the required LoRaWAN network server.

Log in via SSH to the LoRaWAN gateway using the username and password specified by the device manufacturer.

Install SPF according to the LoRaWAN gateway manufacturer's instructions.

The SPF configuration directory is „**/user/spf/etc/**“ however, depending on the LoRaWAN gateway manufacturer, it may be located in other locations.

The main configuration of SPF is in the file "**/user/spf/etc/global\_conf.json**", which should be edited with the available editor (e.g. vi or nano). We change the value of the parameter: "server\_address" by entering the fixed IP address of the network server or the domain name (Requires an additional properly configured DNS client service).

The default return communication port is **1700** (if you plan to change them, you must do the same on the LoRaWAN network server) by entering identical values.

Logs of the SPF package are located in the „**/user/spf/var/logs/**“ directory in the **spf.log** file and its archive copies.

The network configuration of the LoRaWAN gateway on linux OS is normally in the directory `"/etc/"`, where you can enable/disable standard network services and secure the server.

You should also change the passwords of all users available on the system with the **passwd** command to secure against unauthorized access by unauthorized persons. You must also change the user password for web-based support.

It is also best to disable WiFi communication, as intruders may try to use attacks via this transmission medium.

After completing this configuration, reset the gateway with the **reboot** command.

## **4.2. LoRaWAN Network/Application Server Configuration**

There are many solutions for network and application servers (including free ones). Each of them has its own way of integration with external services and systems (e.g. clouds like **@City**). For this reason, the **@City** system must have an interface for integration with the installed LoRaWAN NS/AS server.

In the case of a production system, we can use the free service "The Things Network", as long as we are within very large daily limits defined for each device {especially "On The Air Time" (30s \*\*) and a small number of commands sent to the device (10 \*\*)}.  
*\*\* indicative current daily device limits may change.*

If you need to load new firmware and configuration, it is necessary to use your own LoRaWAN server (network + application).

This gives us several options:

- using TTN to work in a production environment and a dedicated physical server only for configuration updates and new firmware (\*).
- use of a dedicated physical server for all of the above activities.
- using two dedicated physical servers (one for the production environment and the other for software updates and configuration) (\*)

On some systems, the firmware+configuration is fixed (for all available controllers in the system) and initiated at the stage of initial system configuration, which simplifies the selection.

(\*) - in these cases it is necessary to have a second LoRaWAN gateway set on the second server for configuration and firmware update in order for the production environment to work continuously. For low-critical applications, you can change the configuration of one LoRaWAN gateway dedicated LoRaWAN server,

which, however, will result in loss of communication with the production environment and incorrect operation of these devices.

It should be realized that the software update of a single LoRaWAN controller takes about an hour, with good range ( $DR \geq 4$ ), so it is worth using an additional gateway to upgrade the firmware and configuration. At low coverage ( $DR < 4$ ), firmware configuration and update is not possible and requires a Gateway with LTE communication near the updated devices.

### 4.2.1. LoRaWAN Network Server Configuration

On the LoRaWAN network server, add the LoRaWAN communication gateway (the address is located on its cover, or in the file "`/user/spf/etc/local_conf.json`", or displayed in the logs "`/user/spf/var/log/spf.log`"). Check in the web server logs that the communication gateway connects to the server.

The next steps are the configuration of the application server (it is usually located on the same device as the network server).

The next steps to be performed, depend on the application server solution used, and the availability of the Back-End/Front-End interface. The interface simplifies "first steps" and system configuration.

**Generally, you should:**

- Add an application with a specific ID for the production environment
- generate „API KEYS” for linking for the application and adding "right-application-link" permissions (you must copy the automatically generated key).
- generate „API KEYS” for integration via webhook (giving the name of the application and webhook) with the rights: "right-application-traffic-down-write" "right-application-traffic-read" "right-application-traffic-up-write" (copy the automatically generated key). This key is used for communication on the @City website along with the name "webhook".
- create an integration webhook for the application with the @City server specifying:
  - Application ID
  - Webhook ID
  - destination address **`http://*.*.*./IoT/`** and **`up.php`** paths
- Manual or script addition of all @City LoRaWAN devices (with a unique DEV EUI) giving additionally the same values for each field:
  - Application ID

- EUID for the application
- Root Key for the application
- Frequency plan (regional LoRaWAN band settings e.g. EU\_863\_870 for Europe)
- DEV EUI (individual address of each device assigned by the module manufacturer). If it is not on the cover, you should find in the application server logs the addresses of unknown devices trying to connect to the server.
- lorawan-version = 1.0.2, lorawan-phy-version = 1.0.2-b
- LoRaWAN OTAA authorization

## 5. Work condition of @City GSM / LoRaWAN devices

Temperature - 40C .. +65C  
 Humidity 0..80% r.H. no condensation (device)  
**GSM Power supply** 5VDC @ 2A  $\pm 0.15$  V (for PPM sensor and when connecting relays)  
 3.5VDC..4.2VDC @ 2A (in other cases)

**LoRaWAN power supply** 5VDC @ 300mA  $\pm 0.15$  V (for PPM sensor and when connecting relays)  
 3VDC..3.6VDC @ 300mA (in other cases)

### GSM+GPS Devices:

Antenna input 50ohm  
 SIM nano-SIM or MIM  
 (choice at the production stage - MIM imposes a network operator)  
 Modem Approval Orange (2G-CATM1), T-Mobile/DT (2G-NB-IoT), 2G Other operators

BANDS (Europe)	Class	Output Power	Sensitivity
B3,B8,B20 (CATM1 – 800MHz) **	3	+23dB $\pm 2$	< -107.3dB
B3,B8,B20 (NB-IoT – 800MHz) **	3	+23dB $\pm 2$	< -113.5dB
GSM850,GSM900 (GPRS) *	4	+33dB $\pm 2$	< -107dB
GSM850,GSM900 (EDGE) *	E2	+27dB $\pm 2$	< -107dB
DCS1800,PCS1900 (GPRS) *	4	+30dB $\pm 2$	< -109.4dB
DCS1800,PCS1900 (EDGE) *	E2	+26dB $\pm 2$	< -109.4dB

*When using an external narrow-band antenna frequency-matched for a given band.*

\* only for Combo modem: 2G, CATM1, NB-IoT

### Certificates:

- RED (EU)
- GCF (AU)
- PTCRB (NA)
- FCC, IC (NA/NV)
- RoHS / REACH

### GPS/GNSS:

operating frequency: 1559..1610MHz  
 antenna impedance 50ohm  
 maximum sensitivity \* -160dB stationary, -149dB navigation, -145 cold start  
 TTFF 1s (hot), 21s (warm), 32s (cold)  
 A-GPS yes  
 Dynamics 2g  
 minimal refresh rate 1 Hz

\* matched external narrow-band antenna

**LoRaWAN Devices 1.0.2 (8 channels, TX power: +14dBm) Europe (863-870MHz)**

<b>DR</b>	<b>T</b>	<b>modulation</b>	<b>BR bit/s</b>	<b>Rx Sensitivity</b>	<b>Rx Tests</b>
0	3min	SF12/125kHz	250	-136dB	-144dB
1	2min	SF11/125kHz	440	-133.5dB	
2	1min	SF10/125kHz	980	-131dB	
3	50s	SF9/125kHz	1760	-128.5dB	
4 (*)	50s	SF8/125kHz	3125	-125.5dB	
5 (*)	50s	SF7/125kHz	5470	-122.5dB	
6 (*)	50s	SF7/250kHz	11000	-119dB	
7		FSK 50kbs	50000	-130dB	

(\*) Parameters required to upgrade the firmware of the system via OTA

(DR) – Data Rate

(BR) – Bit Rate

T – The minimum period of data update to the @City cloud

**LoRaWAN practical coverage tests:****Test Conditions:**

**LoRaWAN Kerlink ifemtocell** Internal Gateway

passive outdoor broadband antenna placed outside at a height of ~9m above ground level Wygoda gm. Karczew (~ 110m above sea level).

LoRaWAN device with forced DR0 with an external broadband magnetic antenna placed 1.5m above the ground on the car roof.

Rural areas (meadows, fields with small trees and rare buildings)

The farthest result was Czersk ~10.5km (~200m above sea level) with RSSI equal to -136dB (i.e. with the maximum sensitivity of the LoRaWAN modem guaranteed by the manufacturer)