Algorithm development with LoRaWAN for monitoring system

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Abstract. This article presents the developed algorithm with LoRa specification. Based on it is achieved LoRaWAN for monitoring application in industrial systems. There is no universal solution for using LoRa Media Access, in such cases. The combination of low power hardware and radio communication is an advantage of the work. The developed algorithm ensures a new and modern network structure for monitoring in control systems. The real time observation is conducted in TTN. The experiments verified the algorithm applicability in the frame of systems of new digital industry.

1. Introduction
Nowadays are widely used networked devices, to achieve information in variety of applications. There is growing interest in such solutions in almost each area. Many systems need low power consumption, task distributions and collect data remotely using media access. There is no universal solution for monitoring and control using low energy and low cost networked devices. The aim of this work is to present the developed algorithm for monitoring in networked system using LoRa specification [1]. Applying network in industrial applications is widely popular, but complex, responsible, and sometimes dangerous task. More difficult case is when there is no power supply or electricity and a strict requirement for low power consumption, and long-range operation and protection. The work is devoted on algorithm development for industrial system purpose in the case of missing 220V supply using LoRaWAN.

LoRa means Long Range modulation which is suitable for the purpose of recent case, figure 1. LoRa is a proprietary spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation (CSS), which was developed for radar applications in the 1940’s.

Traditionally is applied in a number of military and secure communications applications; over past years this technique has seen increased adoption in a number of data communications applications. Due to its relatively low transmission power requirements and inherent robustness from channel. It trades data rate for sensitivity within a fixed channel bandwidth. It implements a variable data rate, utilizing orthogonal spreading factors, which allows the system designer to trade data rate for range or power, so as to optimize network performance in a constant bandwidth [3]. It is evident that a PHY layer of LoRa is modulation to higher-layer implementations, figure 2. This allows coexisting and interoperating with available network architectures.
Thus can be noted some of the basic concepts of LoRa modulation and the advantages. The modulation can provide when deploying both fixed and mobile low-power real-world communication networks.

2. System configuration

Classical control system consists: plant (target), connected with feedback to the controller and predefine reference. Figure 3 shows the overall control scheme with single loop. The difference of recent case is in the use of network connection between plant, controller and variety of devices for monitoring and reference set up. The Media could be used between: control device and plant, reference value and control, between each element, as is depicted with dashed circle line on the draw.

It is evident that the data and another type of information in the system loop can be transferred in between, marked with ellipse using media, figure 4. The developed solution covers the connections between End Nodes (in recent case it is BME 680, figure 7) and the developed LoRa Gateway, figure 7.

The figure shows that there are a variety of capabilities and tasks, on the one hand, a variety of different input devices are observed, with LoRa via Gateway being transmitted to many custom-defined applications. The network can contain thousands of nodes. If a new extension or addition is required for LoRaWAN, it is necessary to add the Gateway where there is no network coverage of an existing one. In the presented work, such a gateway has been designed and implemented with a freeze-dried spectrum. For Europe this is 868MHz frequency. This is an advantage and a contribution to this development, figure 7, LoRaWAN™.
Figure 5. The developed Application with LoRa and shifting to the LoRaWAN

2.1. Gateway design
The developed Gateway supports the links, depicted on figure 4 with dashed lines. It relates and corresponds to the feedback in control scheme on figure 3. Furthermore, it can cover and apply to all positions, denoted with dashed circle at the same figure. The data from (so called) end devices are transferred through CMWX1ZZABZ-091 LoRa® module made by MuRata to the Gateway or many Gates. It forwards received from Air packets to a public LoRa server, in our case TheThingsNetwork using Semtech packet-forwarding protocol. Hence, it is created LoRaWAN for industrial system purpose. The developed Application with LoRa and shifting to the LoRaWAN is given on figure 5.

3. Algorithm development
On the figure 6 is given the structure of the developed algorithm for system operating. It consists of 6 sub algorithms, depicted with ALGORITHM 1-5. The advantage of the presented solution is the programming in free text editor. It is used Arduino environment 1.8.7.

3.1. Algorithm
As it is shown on the algorithm block structure, figure 6, it has 5 main parts.

3.2. Programming of the algorithm
For algorithm programming is used ST-Link programator STM32L0. Part of the program code for the
ALGORITHM 1 and 2, follows:
#include <bme680.h>
#include <bme680_defs.h>
// I2C scanner by Nick Gammon. Thanks Nick.
#include <Wire.h>
void setup() {
  Serial.begin (115200);
  //****** make sure serial monitor baud matches ******
  // Leonardo: wait for serial port to connect
  while (!Serial)
    {
    }
  Serial.println ();
  Serial.println ("I2C scanner. Scanning ...");
  byte count = 0;
  Wire.begin();
  for (byte i = 1; i < 120; i++)
    {
    Wire.beginTransmission (i);
    i
    if (Wire.endTransmission () == 0)
      {
      Serial.print ("Found address: ");
      Serial.print (i, DEC);
      Serial.print (" (0x");
      Serial.println (i, HEX);
      Serial.println (")");
      count++;
      delay (1);  // maybe unneeded?
    }
  // end of for loop
  Serial.println ("Done.");
  Serial.println ("Found ");
  Serial.println (count, DEC);
  Serial.println (" device(s). ");
  }
  // end of setup
  void loop() {}
}

Figure 6. The Flow chart of the developed algorithm
Programming of the ALGORITHM 3

function kur(d,c,b,a) {
    var bytes = (a<<24) + (b<<16) + (c<<8) + d;
    var sign = (bytes & 0x80000000) ? -1 : 1;
    var exponent = ((bytes >> 23) & 0xFF) - 127;
    var significand = (bytes & 0x7FFFFF);
    if (exponent == 128)
        return sign * ((significand) ? Number.NaN : Number.POSITIVE_INFINITY);
    if (exponent == -127) {
        if (significand === 0) return sign * 0.0;
        exponent = -126;
        significand /= (1 << 22);
    } else significand = (significand | (1 << 23)) / (1 << 23);
    return sign * significand * Math.pow(2, exponent);
}

function Decoder(a) {
    var decoded = {};
    decoded.tmp = kur(a[0], a[1], a[2], a[3]) / 1;
    decoded.hum = kur(a[4], a[5], a[6], a[7]) / 1;
    decoded.pre = kur(a[8], a[9], a[10], a[11]) / 100;
    decoded.gas = kur(a[12], a[13], a[14], a[15]) / 1000;
    decoded.alt = kur(a[16], a[17], a[18], a[19]) / 1;
    return decoded;
}

4. Equipment
In this system is used as an End device, BME680, figure 8. It is an open-source hardware, made by Adafruit Industries. The library adafruit/Adafruit_BME, [4], provides gas, humidity, temperature and pressure measurements. The used Arduino library for BME680 version is 1.0.7.

Figure 7. The developed and assembled Gateway for LoRaWAN, and the End node device.

Figure 8. The developed system with LoRaWAN

5. Experiments and results
The programmed algorithm was ran and proved in real time experiment. On the next figure 9, the project in TTN is presented. On the figure 10 is shown the payload that is received from device test-device-bme680-02. The snapped picture shows only encrypted data in the frame of payload. This payload has to be decoded, as it explained in ALGORITHM 3. On figure 11 is shown the result of the applied ALGORITHM 3 for data decoding transferred via LoRa. The obtained information is presented on figure 12. The payload is presented in Json format. This is widely used but not so user-friendly data format.
Figure 9. The developed project In TTN with LoRaWAN

Figure 10. Visualisation of the received payload from device

Figure 11. The detailed view of the payload.

Figure 12. The decoded payload from the device via LoRa

6. Conclusion
The work is devoted to the industrial system application in the case of missing 220V supply using LoRaWAN. The main goal is the developed and programmed algorithm, ensures data monitoring in industrial systems with LoRa specification. An advantage is that it can be easy programmed in text environment. The presented solution with LoRa specification is a basement in LoRaWAN for monitoring and furthermore application in industrial environment. Due to the lack of universal approach for using such Media Access in industrial cases, this can be viewed as an effort to achieve new standard for LoRaWAN. From different point of view this solution can be assumed as an effort for future standardization to the new modern digital industry. The achieved results, security transferred, crypted and decrypted (figures 10-12) show the promising future work. It could be devoted on program development to ensure the Algorithm 4 and 5 for proper user interface, regarding to the process control tasks. Future works will improve the ALGORITHM 5, to ensure the control action with classical control low.

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References
[1] LoRa Alliance, LoRaWAN™ 1.1 Specification Kim J., J. Song, A Dual Key-Based Activation Scheme for Secure LoRaWAN. Wireless Communications and Mobile Computing Volume 2017, Article ID 6590713, https://doi.org/10.1155/2017/659071
[2] Semtech, Application Note, Revision 2, May 2015©, Corporation
[3] http://www.adafruit.com/products/3660
[4] Marais J., R. Malekian, A. Abu-Mahfouz, LoRa and LoRaWAN Testbeds: a Review, Conference: IEEE Africon 2017, South Africa, DOI: 10.1109/AFRCON.2017.8095703

[5] Durkop L., B. Czybik, J. Performance evaluation of M2M protocols over cellular networks in a lab environment, 18th International Conference on Intelligence in Next Generation Networks (ICIN), 2015, Paris, France DOI: 10.1109/ICIN.2015.7073809

[6] https://www.st.com/content/dam/technology-tour-2017/session-1_track-2_lora-enabling-low-power.pdf

[7] https://fenix.tecnico.ulisboa.pt/downloadFile/1689468335603030/LoRaWAN%20Introduction.pdf