Technology Transfer & Smart Solutions Lab

Low Cost Sensor Node for Monitoring River Floods

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1. Introduction

River floods occupy a respectable percentage among all natural disasters, are presenting high risk, and usually cause great damage. Important tools in managing and preventing river floods are the Early Warning Systems (EWS), which are usually consisted both by a hardware (sensors, communication network) and a relevant software infrastructure (data logging, signal processing, modeling, risk detection). References 1-6 include related previous studies.

In the current work we are presenting a novel, low-cost and low-power hardware system, part of an EWS aimed for river floods. This system consists of multiple embedded electronic devices that utilize sensors, microcontrollers (MCUs), discrete and/or module type components, and have their own firmware and functionality.

2. System Description

System consists of two types of devices, the peripheral sensing nodes (SN), and a head node (HN). The data collected through this system is uploaded in a web server for logging and further processing. A photo of the system is depicted in figure 1.

2.1. Head Node

Initially the main idea was to implement the LoRaWAN specification in our private network. Although our design was focused at lowering the power demands of each device type, preliminary lab tests proved that the LoRaWAN Gateway demanded a minimum and constant power of 1.25 Watts. This power is much higher than a small, autonomous, and low-cost device can provide. Accordingly we decided to proceed with the raw LoRa specification, and thus we are not referring to our head node as "Gateway" because this term relates to the LoRaWAN specification.

Our head node actually is a single channel LoRa RX/TX, using the HopeRF RFM96W module which utilizes the Semtech SX1276 integrated circuit (IC). The MCU used is an Arduino pro-mini working at 8 MHz and at 2.9 to 4.2 Volts directly from a nominal 3.7 V Li-Ion battery. The battery is charged via a 1 W solar panel with the aid of a small charge controller/protection board. The head node has also a GSM interface based on Simcom's SIM800L module. Finally the head node uses Maxim's DS3231 real time clock (RTC) IC. The latter is mandatory for synching all devices of our system, as well as for precisely timing the firmware routines at the head node. The head node is equipped with a low-cost, hand-made, dual, omni-directional oriented, bi-quad antenna.

2.2. Sensing Nodes

Hardware-wise, the sensing nodes remained the same at the transition from LoRaWAN to raw LoRa design. They are almost identical to the head node, except that they do not have GSM interface, and that they are equipped with a smaller solar panel (½ W) and of course the water level sensors. The latter are the MaxBotix MB7066-100 ultrasonic precision rangefinders, capable of reading distance from an obstacle at up to 10 m. Their very narrow detection lobe makes the measurements very precise even in a harsh outdoor environment such as that off our application. Since each SN transmits only to a predefined HN, we used low cost, hand-made bi-quad directional antennas, which will improve the link budget of each LoRa link by several dBs.

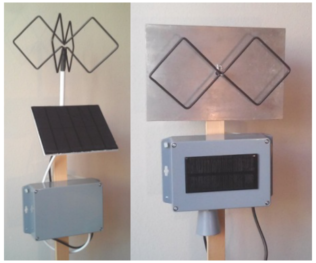

Figure 1. Flood EWS HN (left) and SN (right).

2.3. Communication Logic / Custom LoRa Protocol

The Logic of the communication is based in asynchronous data transmission to a web server, here chosen to be a MathWorks account. The term asynchronous indicates that during a predefined data collection period (T) the HN collects data from all SNs (which also transmit data at a period T but at different timings) and posts them once all together to the web server. The HN knows when to listen for each node by learning the exact time for each SN transmittance during a detection mode procedure that runs at the very beginning of the system installation or on a system restart (fig. 2, top). During the web server post procedure the user can pass commands to the HN in order to control some system parameters. One of these parameters is the period T which can take any value between 20 and 120 minutes in steps of 10. At the SNs side, the number as well as the precision in bytes of each measurement obtained during the period T can be also user adjusted, and can take integer values from 1 to 20, and from 1 to 4, respectively, offering an effective sampling period from 1 to 120 minutes. All parameter adjustments can be done in an active system. The LoRa payload design used in our custom communication protocol is presented in Figure 3. Figure 2 (middle and bottom part) shows two examples of the packet transaction timings between the HN and an SN. The block diagram of the systems is shown in fig. 4.

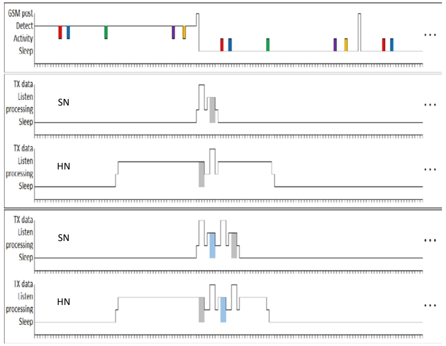

Figure 2. Examples for network timing logic for five SNs, T = 1 h, grid = 1 m (top), simple data TX (middle) data TX with command (bottom), grid = 1 s.

Serves as	HN SN ID & Type	TX counter	Battery	TX period	N sample & X	Payload	Payload
Posit. in Payload	0	1	2	3	4	5	6
bit number	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
Description	HD ID: 0 - 3; SN Type: 0 - 3; SN ID: 0 - 15	TXcnt: 0 - 255	Reserved; Battery level: 0-100 %	T: 10 - 240 minute	Reserved; 0=data, 1=ACK; 0=1 B, 1=2 B, 2=3 B, 3=4 B; N sample: 1 - 10	Payload byte XxN	Payload byte XxN-1

...	Payload	Payload	PL Checksum	PL Checksum	Checksum	Checksum
...	5 + XxN -2	5 + XxN -1	5 + XxN	5 + XxN + 1	5 + XxN + 2	5 + XxN + 3
...	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
...	Payload byte 2	Payload byte 1	High Byte	Low Byte	High Byte	Low Byte

Serves as	HN SN ID & Type	TX period	N sample & X	FEC	FEC	Checksum	Checksum
Posit. in Payload	0	1	2	3	4	5	6
bit number	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
Description	HD ID: 0 - 3; SN Type: 0 - 3; SN ID: 0 - 15	T: 10 - 240 minute	0=ACK, 1=RST; 0=ACK, 1=CMD; 0=1 B, 1=2 B, 2=3 B, 3=4 B; N sample: 1 - 10	FEC High Byte	FEC Low Byte	High Byte	Low Byte

Figure 3. LoRa payload design for SN (top) and HN (bottom). Payload bytes omitted of SN sends back an ACK packet.

3. System Innovations

To the authors' knowledge a complete design of a personal LPWAN based on the LoRa protocol implemented in such low cost and in such high energy autonomy scheme is not yet available. The extremely low power profile of our HN, the innovative time framed design protocol, and the in-short-future publicly available hardware and software libraries of our system make our design truly unique. Power autonomy on the SNs is expected to reach 3-4 months, and in the HN about 30 days, based on a 10 minute TX period and with no solar charging at all. Cost wise, both HN and SN (excl. sensors) stay under the €50 margin. The custom antenna designs is another major innovation, while such antennas are not commercially available. An upgrade to the wireless link quality in a great extent is expected. Preliminary tests indicate successful LoRa links at ranges up to 20 km with no Line-of-Sight conditions.

Counteracting on these benefits, working on a single band and having the possibility of random packet collision are drawbacks of our system, especially when comparing to extensive and trusted specifications, like the LoRaWAN.

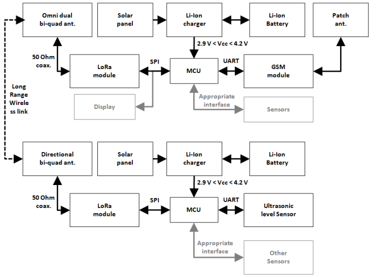

Figure 4. Block diagram of the proposed system, HN (top) and SN (bottom).

4. Conclusions

Lab tests have proved our design to be fully functional, yet, due to major issues (i.e. covid-19 pandemic) we were unable to make our first installation in Evros river at northern Greece, to evaluate our system in real conditions. Results and collected data, as well as system's tests will be publically available (contact the authors).

5. References

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EGU2020-20175