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Design of LoRa Service Infrastructure Solution for D2D Communication over Physical 433 MHz Wireless Link

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***Abstract* - In this work, we present results from wireless link performance evaluation of LoRa-based low-cost devices operating in the 433 MHz unlicensed band. Diffie Hellman key exchange method is used to allow two devices, having no prior knowledge of each other, to establish a shared secret key over an insecure channel. The proposed solution is tested in various conditions and channel states, showing acceptable performance, reliability and scalability to serve higher number of networked IoT devices, without running standardized protocol stack as LoRaWAN.**

I. Introduction

Nowadays, significant research and development efforts are undergoing by the academia and industry on the study, analysis and finding new solutions related to high-dense sensor networks as part of the IoT (Internet of Things) concept [1,2]. LoRa (Long Range) is a modulation technique that enables long-range transfer of information with a low transfer rate and high energy efficiency. LoRaWAN from the other side is a protocol stack (Fig. 1) designed on top of the LoRa physical layer by LoRa Alliance. It uses unlicensed radio spectrum in ISM bands to provide low power, wide area communication between remote sensors and gateways connected to the IoT network. It is obvious that the intention of such standards-based approach is efficient and faster set up of public or private IoT networks using hardware and software which is secure and interoperable. The end-devices and gateways are connected with links within ISM radio bands with single hop, while the gateways and network servers are connected using wired IP back-haul infrastructure or 3G/4G/5G wireless broadband connections. Nowadays, rapid development of mission-oriented IoT applications [3-9] is possible using affordable and easily accessible hardware platforms and development kits which do not employ standard-based protocol stacks. Moreover, the limited signal- and data processing resources of such development platforms, based on widely available microcontrollers such Arduino etc., make them unsuitable to process complex multi-layer protocol stacks.

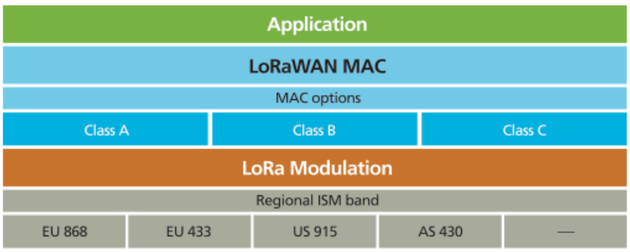

Fig. 1. LoRaWAN Protocol Stack

Naturally, a question arises from the above facts: "Is it possible to realize IoT infrastructure with similar LoRaWAN full stack functionality application with standard devices equipped with LoRa radio interface, with software-defined API-assisted upper layer functionalities, such MAC, device function classification security and scalability?". The results from practical system design, performance analyses and tests in various operational conditions in this work, prove that fully functional IoT service and node-gateway communication infrastructure could be successfully realized with low-cost devices and carefully designed low-complex software functions, allowing real-time data exchange between resource-constrained IoT nodes.

II. DESCRIPTION OF THE LORA NODES

Fig. 2. LoRa devices used in the development

The IoT devices/nodes (Fig. 2) are equipped with SX1278 chip which is based on ESP32 for frequency of 433 MHz. The nodes have 16 MB on board flash memory and 0.96-inch blue OLED display, lithium battery, charging circuit, and highly-integrated CP2102 USB-to-UART bridge controller providing a simple solution for updating RS-232 designs to USB using a minimum components and PCB space. The CP2102 includes a USB 2.0 full-speed function controller, USB transceiver, oscillator, EEPROM, and asynchronous serial data bus (UART) with full modem control signals in a compact 5 x 5 mm MLP-28 package.

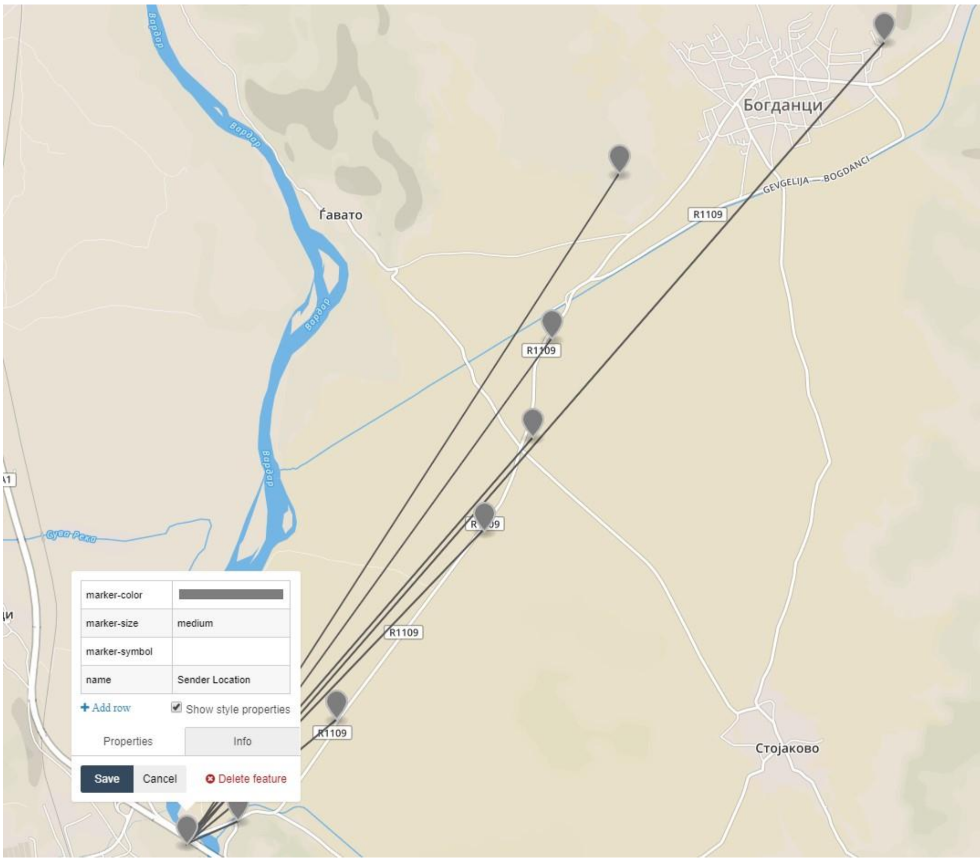

Fig. 3. Test results from non-urban environment

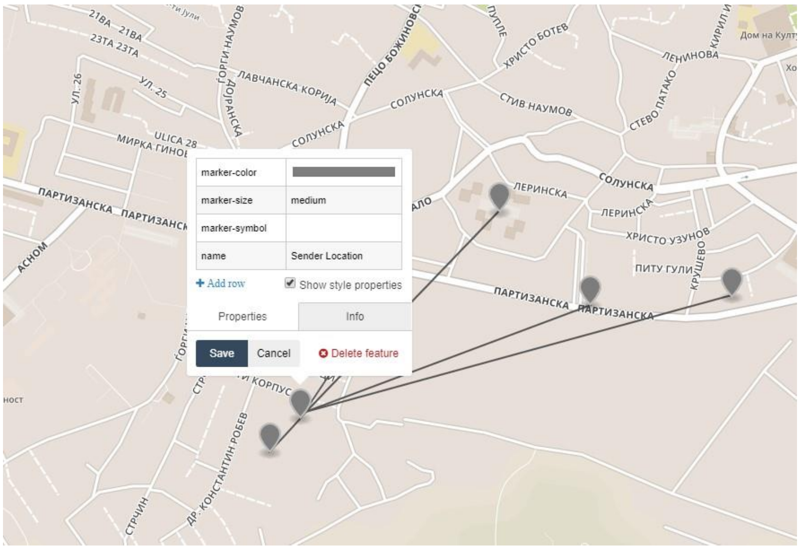

Fig. 4. Test result from urban environment

III. TESTBED

1. LoRa Sender – IoT device (Fig. 2) - get data from a sensor, generates Diffie-Hellman key, encapsulate packet and send packet over 433MHz D2D radio communication.

2. LoRa Reciever – IoT device (Fig. 2) that get data from 433MHz D2D radio communication, reads packet data and display on screen packet data and the current RSSI

3. Batteries – 3.7v 8800mAh to power LoRa devices

4. Battery Charger

5. Vehicle – To achieve desired distance

IV. DATA FLOW AND LORA ARCHITECTURE

The data flow architecture from the sender node to receiver node is designed as follows:

A. LoRa Sender

1. Generates Diffie-Hellman encryption key. Values used to generate this key are hardcoded into each device
2. Get the measured parameter from temperature sensor device (other sensors can be added easily). Constructs JSON string with hardcoded data like: LoRaID, measured temperature and the generated encryption key.
3. Send the data as JSON string via 433 MHz radio link.

This process is repeated on every sender device for n seconds that is hardcoded into each node. For synchronization, both (sender and receiver) devices use the previously defined sync word. This approach guarantee that receiver device will reject all of the packets not using identical sync word. This data later could be processed, visualized and analyzed from various aspects depending from the usage model.

B. LoRa Receiver

1. Receive the data packet
2. Read/Decode data packet
3. Measure RSSI
4. Display data and RSSI on screen

The communication between the sender and the receiver (gateway) is connectionless, similar to the concept of UDP-based communication where no acknowledge regarding the successfully received packet is sent back to the transmitter. For non-mission critical applications this approach is acceptable and in favor of bandwidth efficiency and energy conservation while in the same time support the scalability of the solution when increasing the number of IoT devices using the service architecture proposed.

V. Wireless Link Performance Evaluation

For testing in non-urban environment, Vardarski Rid region was selected - close to the city of Gevgelija (municipality of Bogdanci). The road from Gevgelija to Bogdanci is almost a straight line, and Vardarski Rid is always in the line of sight, for any part of the road. The sender LoRa device was placed on the hill where it has the most beautiful field of vision all the way, more precisely in the coordinates of 41 ° 08 '57.0 "N 22 ° 31'17.6" E.

For testing in urban environment, we realized the measurements the city of Bitola. The sender device was placed coordinates 41 ° 01'15.4 "N 21 ° 19'24.2" E.

In an urban environment where large distortion of the signal is expected due to many obstacles, the most distant successful transfer achieved is 900 meters with the RSSI of -120. This result is very acceptable considering the environment in which the test was performed. In non-urban environment the longest distance achieved is 8800 meters with RSSI of -125.

VI. Conclusion

Considering the low-cost devices used, equipped with standard LoRa-based 433 MHz radio interface without higher-gain antenna configurations, the reliable application of such devices for non-mission-critical applications as transfer of sensor data is achievable. The functionalities of the upper layers as those in LoraWAN certified devices, for such applications could be replaced by simple software operating high on the application layer. With the data-flow architecture, proposed in this work, also the security expectations of the application are achieved, which is crucial for such non-standardized low-cost and low-complex development approach.

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