LTraX – a „Maker Projekt“

Ultra-Low-Power Datalogger with GPS/LTE/2G and Bluetooth 5

Motivation

A relative of mine runs a trailer rental (small car trailers as "mobile advertising space" [1]) and the vehicles are often rented out for several years. So it would be good to know where they are. The problem is that trailers do not have their own power supply. A suitable device should therefore be able to transmit the position for several years with its own battery. We also tested some commercially available solutions, the result was absolutely sobering: all devices were unusable!

Since I was just getting acquainted with Bluetooth low energy, “LTraX” emerged as a hobby project (and someone who pursues his hobby has recently been called “Maker” [2]).

Results

It quickly became apparent that - with the right platform and the right tools - really impressive and absolutely professional results can be achieved without any problems. For questions, suggestions, etc., I look forward to your email, my contact details can be found at the end of the article [3].

Platform with BLE

Bluetooth has long been considered unsuitable for ultra-low-power applications. But at least since Bluetooth Low Energy (also known as "BLE") this is absolutely no longer true! And since BLE 5, the ranges that can be achieved have also been excellent.

In the meantime, almost all current browsers (Chrome, Opera, Edge, etc ...) are able to communicate with BLE devices directly via HTML / Javascript! And that works even with local HTML pages and it doesn't matter whether they run on a PC (Windows 10 or higher) or on an Android device! It is really very convenient and it can hardly be easier!

Javascript has also become a very powerful language and has been faster than comparable C ++ programs since Google’s V8 engine. Javascript can not only be used for browsers, it also runs perfectly on servers, can communicate with databases and send messages.

I strongly believe that BLE, especially in combination with Javascript, will become one of the key technologies for local communication in the next decade!

Hardware

For devices with BLE, it is highly recommended to use certified modules from renowned providers! I have tested a number of certified and non-certified modules and there have been some aha experiences. And even for a hobby project I would definitely recommend a high quality module! In our case, we chose the NINA-B3 (u-Blox) [4]: It is pleasantly small, uses an extremely powerful Nordic nRF52840 with a 64MHz Cortex-M4F core with a floating point unit (FPU) and 1MByte Flash and 256kB RAM [8]. Almost all I/Os can be assigned flexibly, e.g. as an analog input for monitoring the battery voltage.

The range of the NINA-B3 is not so important in our case, but I think the specified 1400 mtr is quite realistic.

For software development, Nordic provides Segger's “Embedded Studio” (“SES”) [5] free of charge. The EVAL kit for the NINA-B3 contains the right J-Link emulator. The software development with it is very fast and really fun!

The choice of the network for mobile internet is currently still somewhat problematic in Europe, since in many countries 2G is likely to have the best area coverage for a long time, but in some countries LTE-M1 is already possible (and in some cases even exclusively).

Therefore, a SARA-R412 (u-Blox) [6] was used as the modem. It is pleasantly small and (almost) usable worldwide.

The Embedd antenna was a special challenge: Due to the different frequency bands of LTE-M1 (700 MHz) and 2G (in Europe GSM 900/1800) and the narrow design sought, there are only a few possibilities. The Fractus RUN mXTEND ™ [7] antenna used is quite small and can be dragged exactly to the desired areas using an adaptation network.

LTraX is equipped with two internal sensors: a temperature / humidity sensor (Sensirion SHT30-DIS [9]) can determine whether water has entered the housing: if the internal humidity rises above a

critical value (e.g. 80% rH), the Notifies users and then has enough time to take care of the problem before damage can occur due to condensation. Based on the temperature value, the system can, for example, decide whether Internet transmissions will be delayed until it is warmer again (standard SIM cards are often only permitted down to -25 °C).

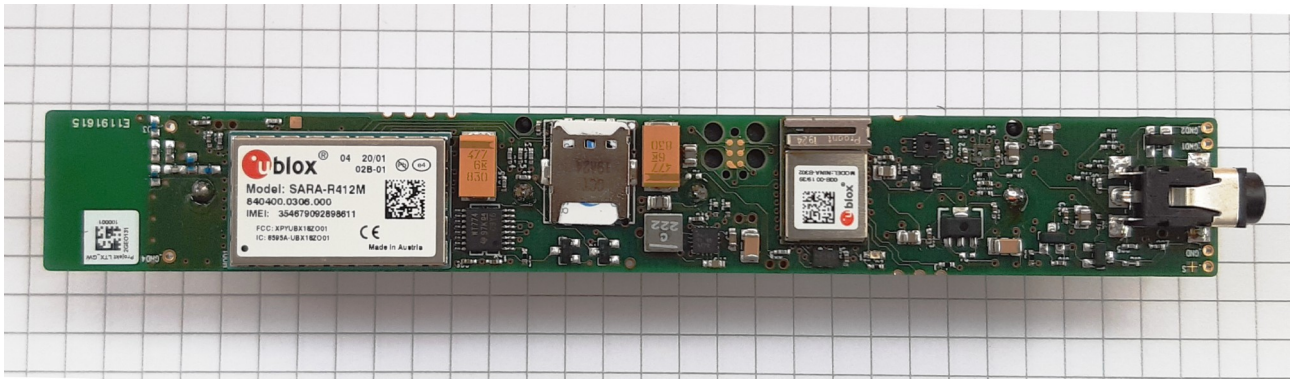
The second internal sensor is a combined acceleration and magnetic field sensor LSM303AGR from ST [10]: It can measure the 3-dimensional position of the device in space in a very energy-saving manner, plus accelerations (including motion and free-fall detection) and also a external magnetic field. The magnetic field can be the earth's magnetic field, or it can also be a nearby magnet that can be used e.g. Sabotage sensor function.

As an interface to external sensors, LTraX is equipped with a universally programmable, 4-pin interface. Drivers for I²C, 1-wire interfaces (various temperature sensors), counters, etc. are available (purely technologically, up to 4 of these interfaces are possible and provided in the drivers and up to 100 sensor channels are possible).

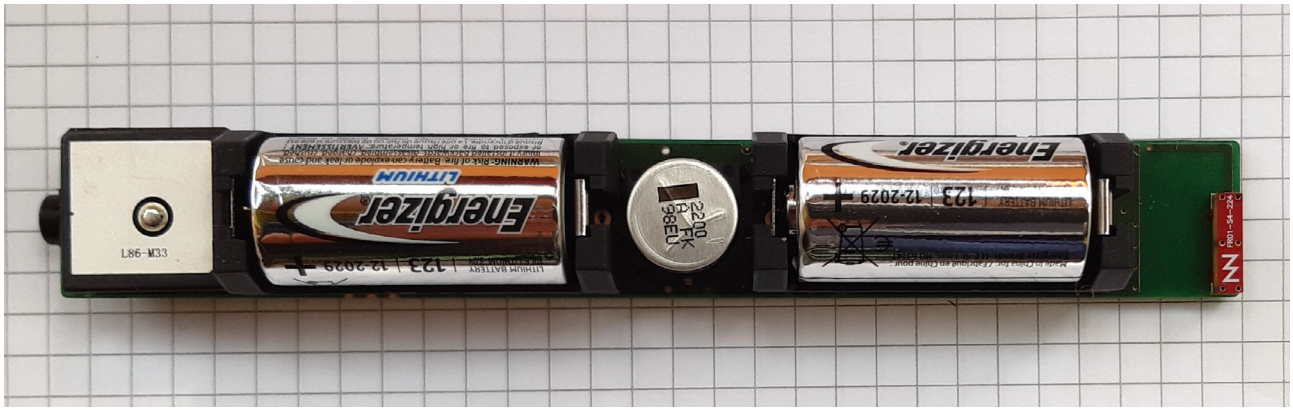
The last sensor is a GPS / GLONASS module (GPS is operated by the USA, GLONASS by the Russian Federation), here only referred to as "GPS".

However, it is not always necessary to use GPS (and sometimes not at all, since GPS requires a fairly clear view of the sky and also consumes valuable energy). In simple cases, it is often sufficient to know the position of the radio mast of the cell. LTraX automatically sends this to the server. In urban areas, the radius of a radio cell is usually less than 1 km, in the countryside rarely larger than 5-10 km and the server can still activate GPS if necessary).

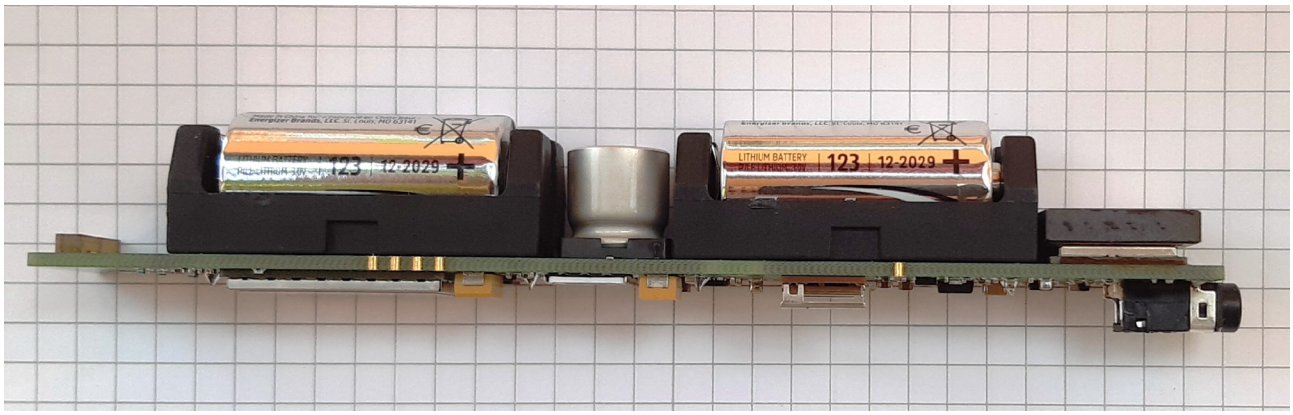
For the battery supply, 2 standard CR123a batteries (3V, approx. 1600 mAh capacity, operation from -40 ° C to +70 ° C) are provided, which can be procured cheaply anywhere.



LTraX – Component side, the 4-pin jack plug is optional for external sensors



LTraX - Top side with GPS module, right side the embedded antenna with feed



LTraX - Side view

Das 3D printed enclosure

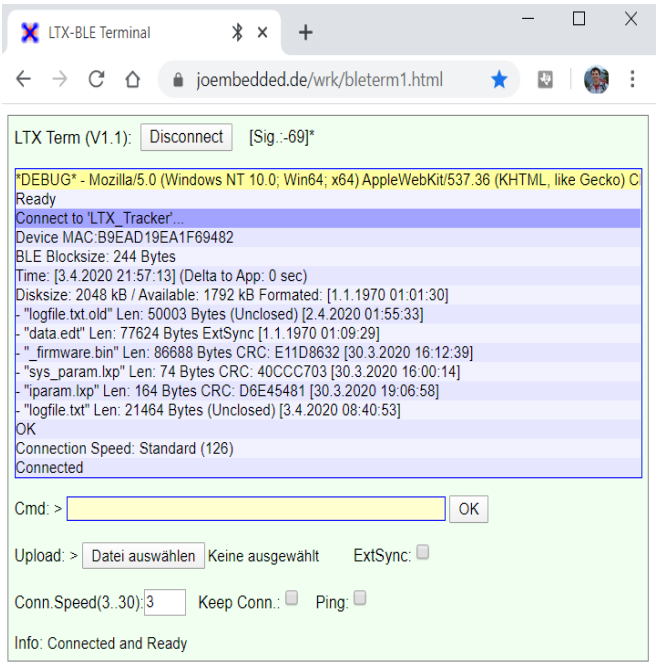
I made the first housings on my son's small 3D printer from the easy-to-process material "PLA". For later use, the housing made of robust "ABS" is printed by an online provider for little money. The housing is primarily only splash-proof, but if it is installed appropriately, this is also sufficient for outdoor use: a small packet of desiccant in the housing moderates the penetrating (and diffusing) moisture and the user is informed by the server if the moisture values are too high. It is very important that no over- or under-pressures can form in the housing, because this leads to so-called pump effects, where condensation water collects in the housing.

There is also the option of deliberately opening the housing so that the internal temperature / humidity sensor can be used, for example, to monitor the humidity of a storage area (as one of the many alternative application scenarios for the LTraX).

Embedded-Software with JesFs

Many “maker projects” fail because a certain task has been solved, but the flexibility for professional use is lacking.

At first, the use of a real file system on a “so small device” may seem exaggerated, but for exactly the above reason I used the (free) JesFs file system [11] (with the associated boot loader JesFsBoot) for LTraX and for that ported nRF52 CPUs. JesFs makes it possible, for example, to completely separate functionality and parameters or to access the files of the saved data, log files or settings very easily using BLE.



The BLE-Terminal, in HTML/Javascript for easy file transfer and firmware upload

JesFs has been designed in such a way that it can synchronize itself with a virtual file system of a server with minimal communication overhead. This process takes place automatically with every Internet transmission. Very convenient!

Parameter or firmware updates are automatically transferred to the LTraX, while the latest data are automatically transferred from the LTraX to the server.

Since the LTraX only has a maximum memory of 2 MB, the files work in ring memory mode and the memory can never overflow, but you can still have the history of the data via BLE if no internet is available. And 2 MB is a lot.

LTraX is designed to use as little energy as possible. As a "sign of life", he reports regularly (for example daily) to the server and optional sensors are recorded at an adjustable rate (1min - 24h). However, the GPS is only activated if the acceleration sensor detects movement (or the magnetic field sensor detects a significant change in position). The GPS is then additionally recorded every hour, for example.

Energie budget

With activated BLE, the NINA-B3 requires approx. 5-10 µA, in addition there are approx. 10 µA of quiescent currents. With a basic consumption of <20 µA, the 1600 mA of the batteries last for up to 10 years and the LTraX can still be addressed via Bluetooth at any time!

Transmission of the SARA-R412 via 2G and mobile internet takes approx. 15 seconds (with good network and little data) and requires an average of approx. 50 mA (LTE-M1 is significantly more economical). Ideally, 8000 transfers are possible with a single battery pack!

With daily transmission, this results in 6.8 years (mathematically and without self-discharge)!

The motion sensor actively consumes approx. 6 µA.

The GPS module used requires approx. 30 mA and, with a clear view of the sky, finds its position after approx. 10-60 seconds (the longer it was inactive, the longer it takes). The GPS module requires approx. 7 µA for its RTC, but can then find a signal faster. If movement is very rare and the battery life is long, it can make sense to deactivate the RTC asleep. The desired accuracy of the GPS position also affects power consumption. Thanks to JesFs, however, all of these parameters can be easily adjusted. In terms of rollover, you can count on about 0.4 mAh consumption with daily position determination.

In good conditions, 6 hours of movement every day, GPS recording every 2 hours and transmission to the server every 6 hours, about 2 mAh / day are used up, the batteries last about 2 years, but the server will notify the user in good time if they are renewed should.

SIM cards for "shelf goods"

There are now (for Europe) a wide variety of M2M SIM card providers, but most of them work on a contract basis. To my knowledge, there are currently only 2 providers of prepaid M2M SIM cards in Europe. These have the advantage that “shelf goods” can be produced with it and at the same time the risk of misuse is completely eliminated.

1NCE SIMs [12] contain 500 MB with a term of 10 years, the 1NCE SIMs are valid in over 100 countries and the SIM card only works in the temperature range -25 ° C to +85 ° C (the up to -40 ° C usable variant is an eSIM, which must be soldered).

Things-Mobile [13] only contains 100 MB, but the runtime is unlimited and Things-Mobile offers SIMs for the extended temperature range from -40 ° C to + 105 ° C as SIM.

Both SIMs are charged with EUR 10 as standard.

Apart from the fact that even with very intensive use with LTraX, hardly more than 5 MB per year can be expected, both providers offer the option of reloading the cards online.

In my view, this creates the conditions for the first time to expand the cloud to include “shelf goods” for free trade!

Thanks for your interest!

The development of the LTraX was a lot of fun and my relative can now monitor his trailers.

For questions, suggestions, etc., I look forward to your mail [3]!

Links

[1] „Mobile advertising space“: https://www.die-mobile-werbeflaeche.de

[2] Maker – Wikipedia: https://en.wikipedia.org/wiki/Maker_culture

[3] Contact me: joembedded@gmail.com and https://joembedded.de

[4] BLE-Modul NINA-B3 Open CPU: http://spezial.com/de/u-blox-kurzstrecken-funkmodule-bluetooth-module-nina-b3-series

[5] Segger Embedded Studio: https://www.segger.com

[6] LTE/2G-Modem SARA-R412: https://www.spezial.com/de/u-blox-sara-r4

[7] Embedded Antenne Fractus RUN mXTEND™: https://fractusantennas.com/mobile-antenna

[8] BLE-Soc Nordic nRF52840: https://www.nordicsemi.com/Products/Low-power-short-range-wireless/nRF52840

[9] Temperature/Humidity Sensor Sensirion SHT30-DIS: https://www.sensirion.com/en/environmental-sensors/humidity-sensors/

[10] Motion Sensor ST LSM303AGR: https://www.st.com/en/mems-and-sensors/lsm303agr.html

[11] JesFs – Jo‘s Embedded Serial File System: https://github.com/joembedded/JesFs

[12] 1NCE Prepaid SIMs: https://1nce.com

[13] Things-Mobile Prepaid SIMs: https://www.thingsmobile.com/de

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