# UNIVERSAL MULTI-RAT TESTER FOR MMTC APPLICATIONS

**[1]Radovan Juráň, [2]Radek Možný**
Doctoral Degree Programme ([1]1st year, [2]2nd year), FEEC BUT
E-mail: [1]xjuran15@vutbr.cz, [2]xmozny03@vutbr.cz

Supervised by: Petr Mlýnek, Pavel Mašek
E-mail: mlynek@feec.vutbr.cz, masekpavel@vutbr.cz

**Abstract**: While the IoT has made significant progress along the lines of supporting its individual applications, there are many massive Machine-Type Communication (mMTC) scenarios in which the performance offered by any single Radio Access Technology (RAT) available today might be insufficient. To address these use cases, we introduce the concept of multi-RAT tester, which implies the availability and utilization of several RATs within a single IoT device. We begin by offering insights into which use cases could be beneficial and what the key challenges for mMTC implementation are. We continue by discussing the potential technical solutions and employing our own prototype of a multi-RAT device capable of using different Low-Power Wide-Area (LPWA) communication technologies. It is assumed that use of multiple radios simultaneously will lead to overall improvement of communication parameters by leveraging the synergy between RATs. The novel vision enabled by the multi-RAT concept in this work could be impactful across multiple fields and calls for cross-community research efforts in order to adequately design, implement, and deploy future multi-RAT mMTC solutions.

**Keywords**: LPWA, Multi-RAT, Industrial Internet of Things, SmartGrid, massive MTC

## 1 INTRODUCTION

The Internet of Things (IoT) growth gave rise to many wireless communication technologies operating in both licensed and unlicensed bands, which are applicable also for the wireless machine-to-machine (M2M) communication. As stated in [1], the M2M is mainly characterized by low data rates, limited bandwidths, and relatively simpler radio devices with very low energy consumption, which contrasts with the needs of human-to-human (H2H) cellular networks, focused on high data rates interchanged between rather complex devices.

In spite of that, the telecommunication providers tend to utilize their existing infrastructures when considering M2M, because not only do they already cover considerably large geographical areas, thus eliminating the need to build new infrastructure, but they also work in the licensed bands, which brings predictable environment properties and especially controlled interference – a parameter not always achievable in unlicensed bands [1].

Reliability of the service goes hand in hand with its security and flexibility – the key issues to address in any general radio communication system, especially one that includes a large number of connected devices, referred to as massive Machine Type Communication (mMTC) [2]. A typical example of the mMTC use case can be any smart-grid application, such as electricity meter data reading, power line monitoring, or demand management [1]. Another example is public transport tracking. One of the ways to enforce the technical performance requirements defined by [2] for reliability-demanding applications can be combining existing technologies in one device together – approach known as Multiple Radio Access Technology (Multi-RAT).

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## 2 UTILIZATION OF LPWAN MULTI-RAT FOR MMTC APPLICATIONS

In general, LPWA technologies have proven to be an ideal and efficient choice to satisfy mMTC applications' needs. Thus sporadic delay-tolerant data transmission for long distances ensures extended coverage and, at the same time, ensures high cost and power efficiency [3, 4, 5].

Each LPWA technology presents unique features, as observed from the comparison Table 1. As was addressed by authors already in, e.g. [3, 4], those technologies utilizing unlicensed spectrum such as Sigfox and LoRaWAN benefits from low operational expenses (OPEX). On the other hand, there is a drawback in limited time-on-air (ToA) due to the duty cycle or need for infrastructure deployment, thus increasing capital expenditures (CAPEX). On the other hand, mobile technologies like NB-IoT or LTE Cat-M provide almost unlimited service with already well-built infrastructure. However, with a trade-off in the form of extended OPEX due to the charge for the amount of transmitted data.

**Table 1:** Technical parameters comparison of widely used LPWA technologies in Europe [3, 4].

| | **Sigfox** | **LoRaWAN** | **LTE-M**[1] | **NB-IoT**[1] |
|---|---|---|---|---|
| **Coverage (MCL)** | 159 dB | 155 dB | 155.7 dB | 164 dB |
| **Spectrum** | Unlicensed | Unlicensed | Licensed | Licensed |
| **Max. ERP** | 14 dBm | 14 dBm | 23 dBm | 23 dBm |
| **Modulation** | DBPSK (UL)<br>GFSK (DL) | LoRa (CSS)<br>FSK | QPSK,<br>16QAM | $\pi/2$ - BPSK, $\pi/4$ - QPSK,<br>QPSK (DL) |
| **Module cost** | 2 $ | 6 $ | 20 $ | 8 $ |
| **Restrictions** | 140 (UL), 4 (DL)<br>Mess. per day | Duty Cycle | Charged data | Charged data |
| **UL datarate** | 100 bps | 0.3 – 50 kbps | 1 Mbps | 0.3 – 62.5 kbps |
| **DL datarate** | 600 bps | 0.3 – 50 kbps | 1 Mbps | 0.5 – 27.2 kbps |
| **Max. app. payload** | 12 B / 8 B (UL / DL) | 51 – 242 B | 1600 B[2] | 1600 B[2] |

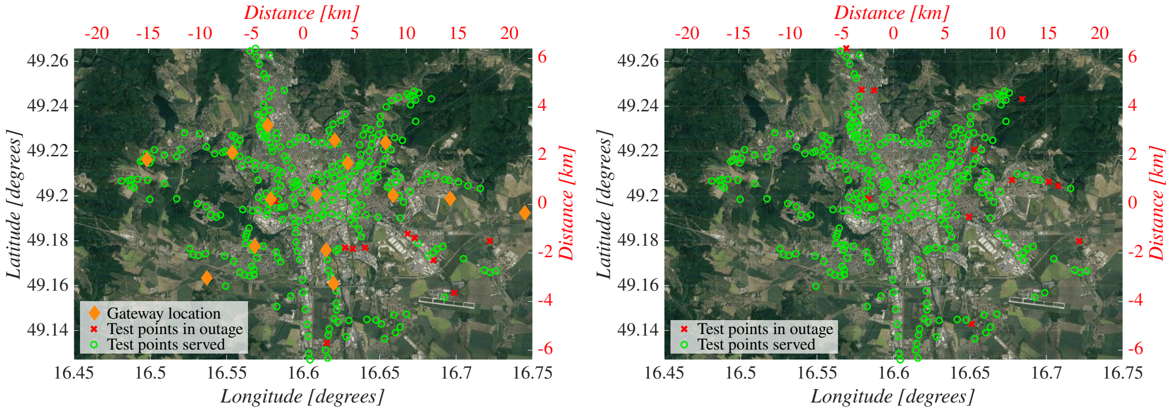
[1] According to the 3GPP Release 13.

[2] The maximum size of a Packet Data Convergence Protocol Service Data Unit (PDCP SDU).

Another comparison angle could be signal coverage. As cellular technologies provide almost ubiquitous availability in urban and rural areas, there might be specific cases like mines and ships where mobile technologies' deployment is difficult. Here the provision of continuous connection calls for Multi-RAT usage [3]. It is certain that for many use-cases, a single RAT is sufficient or even required to meet the application requirements. However, there are also cases like those mentioned above that point out that Multi-RAT solutions also have their momentum. Moreover, for certain can be said that there is no single RAT for all mMTC use cases.

In our previous works [3, 6, 7], the large single RAT coverage measurement campaign was thrown with an aim to evaluate coverage for Sigfox, LoRaWAN, and NB-IoT in the Brno, Czech Republic as an example of a mid-sized European city in terms of single RAT or possible Multi-RAT usage. The obtained results are depicted in Fig. 1. The goal was to find out the service availability at the tram stations and overall coverage for possible use cases such as public transport tracking or smart-meter deployments. It is important to note that the NB-IoT map is not included as all the points were served, which indicated omnipresent NB-IoT service availability with average reference signal receive power (RSRP) $-85$ dBm (good radio conditions). According to the results, it can be said that NB-IoT provides flawless coverage but with charged data trade-off. On the other hand, there were several signal outage areas in the case of Sigfox and LoRaWAN. See more information about the measurement campaign in [3, 6, 7].

The measurement campaign results encouraged authors to work on a Multi-RAT solution, which addresses a few of the mMTC use-cases that are to be widely implemented utilizing the benefits Multi-



**(a)** LoRaWAN converage in Brno Czech Republic [7]. **(b)** Sigfox converage in Brno Czech Republic [6].

**Figure 1:** Coverage measurement campaings of LPWA technologies in Brno Czech Republic 2019.

RAT approach. The first use-case already being implemented is public transport tracking, where LPWA technologies are ideal for data transmission of position to a remote server. Here the challenge relies upon the continuous connection availability as addressed in our previous work [3].

The second and at the same time, the main intended use-case is, as was mentioned, smart-grid, more precisely smart metering. This aim in the case of the Czach Republic is crucial as the selective deployment of electricity smart-meters utilizing NB-IoT and secondary RAT by 2024 is set by legislation and currently deployed meters utilizing power line communication (PLC) and MESH technologies are not suitable for dense deployment. This only enhances the need for a solution such as the one presented in this work. In general, smart the key performance indicator (KPI) for smart meters is not on the side of power efficiency, but ensuring the service availability in remote areas and, e.g., delay tolerance with 10 s [2, 8]. Mentioned remote areas and places under the surface means signal dead-zones for legacy systems. As for the technology most suitable for the scenario, several works addressed this topic (such as [1]) with NB-IoT as the best choice. However, the secondary technologies could extend the versatility for this use case in the Multi-RAT scenario.

With all this in mind, together with the fact that each application has different demands, the need for more universal devices such as the one delivered in this work and addressed in Section 3 is clear. Now one device able to combine all mentioned prerequisites could provide enough versatility in the form of an all-in-one module for the applications mentioned earlier.

However, the Multi-RAT approach also brings certain drawbacks and challenges for sufficient and optimized use. The first downside is the device cost. The use of Multi-RAT requires a more complex device design with multiple communication modules. This inevitably increases the expenses. The second drawback to be addressed is the power efficiency and overall performance considering efficient RAT switching as was addressed in [3]. The machine-learning techniques provide an efficient way how to handle these optimizations [5]. Authors of [9] already elaborated on power-efficiency enhancements utilizing reinforced-learning (LA) that could be implemented even in constrained devices with promising results. Since the proposed design of the device considered batteryless operation, the power efficiency is not KPI as was already mentioned, but the work has proven that LA could be a way to go for the overall Multi-RAT operation optimization.

## 3 DESIGN OF MODULAR UNIT FOR DATA GATHERING AND TRANSMISSION UTILIZING MULTI-RAT APPROACH

The proposed communication unit is based on Raspberry Pi Compute module 3 (CM). As shown on overall block schematic diagram in Figure 2, the device consists of two main boards – motherboard for the CM and an extension communication board, which offers two miniPCIe slots for radio communication modules. The whole system seats in a compact housing with standard DIN rail mounting.

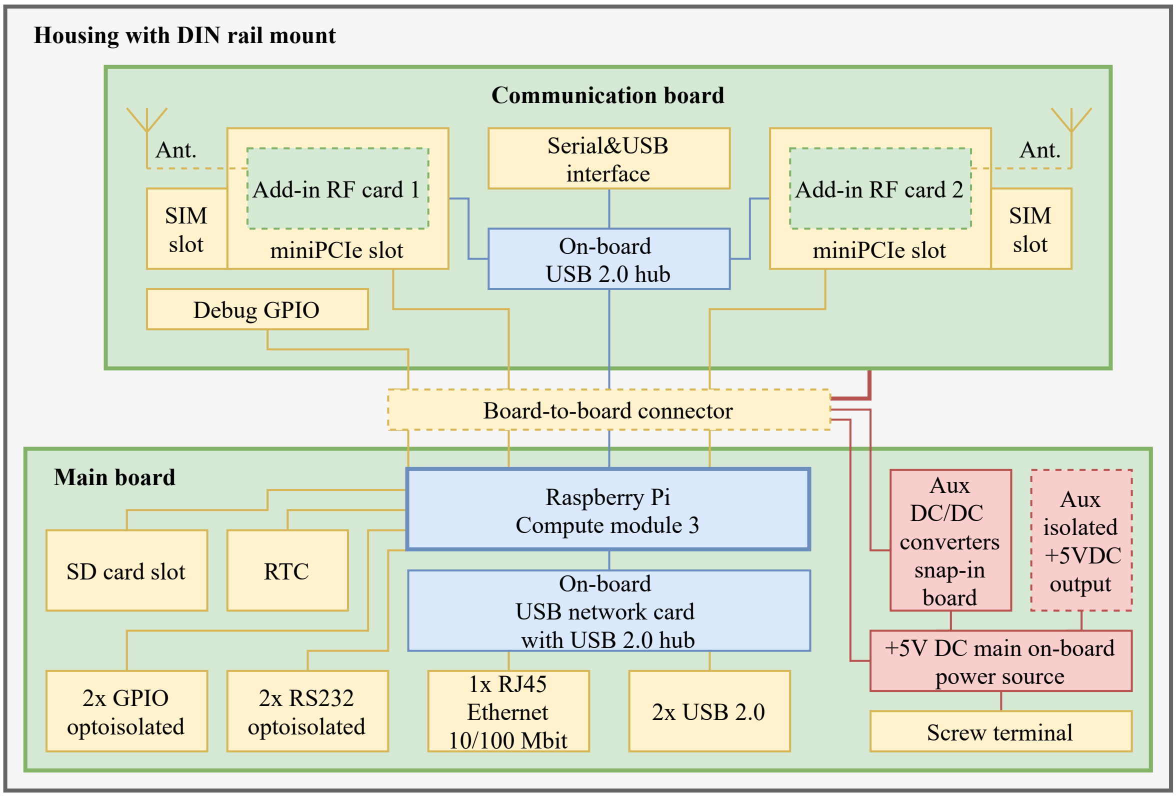


**Figure 2:** Block schematic diagram of the Multi-RAT communication unit.

The motherboard for the CM is flexibly designed to support mounting options for CM sub versions and to exploit potential of its interfaces. There is a custom-built on-board USB network card with integrated USB 2.0 hub build around Microchip LAN9514, which offers 1x 10/100 Mbit Ethernet and up to 4 USB 2.0 ports, of which two are used for external device connectivity and one is used as board-to-board connection with the RF board. The other interfaces were connected to separate screw terminals, namely two optically isolated RS485, two optically isolated GPIOs, and one +5 V DC supplementary isolated power source. The CM has been extended by an independent RTC with 12 mm coin cell battery holder and micro Secure Digital (SD) card slot.

The power is delivered via screw terminals from external power source (intended to use with auxiliary power source of electricity meter) to the on-board custom designed main power source, which the distributes the power to the main voltage +5 V DC branch on the board directly as well as indirectly via supplementary snap-in power board, which supplies lower voltage levels of +3.3 V DC and +1.8 V DC.

The detachable extension board offers two standalone miniPCIe slots, each supplemented by its own Subscriber Identity Module (SIM) card holder and LED indications as per miniPCIe spec. This brings the true universality to the proposed Multi-RAT solution as it allows to fit any add-in RF cards of various communication standards via one unified interface, either off-the-shelf cards or even custom-built. As the main bus utilized to use with miniPCIe cards is the USB, there is an on-board Texas Instruments TUSB4041I custom USB hub, which interconnects the miniPCIe slots with the main board and on top of that one serial to USB debug interface.

## 4 CONCLUSION

In this paper, we addressed the idea of Multi-RAT use for mMTC applications such as smart-metering or public transport tracking. It is clear that there is no killer app nor single RAT that could satisfy the demands for such a diverse set of mMTC use cases as might indicate the LPWA measurement campaign in Section 2. Thus the need for modular communication devices, as the one carried out in this work, capable of adopting a Multi-RAT approach is required.

Presented design in Section 3 provides flexible all-in-one solution supporting interfaces for external devices such as electricity meter or other sensors actuators. Modular RAT interfaces in the form of mPCIe slots enable custom setup tailored to the specific mMTC use-case needs. The above-mentioned proved the design suitable for the diverse mMTC applications of public transport tracking smart-meters.

The natural step in future work is to construct the device, verify its functionality with initial measurements, possibly optimize the device and subsequently deploy it with RATs according to the use-case demands. As smart metering is a hot topic now in the 2021 Czech Republic due to its intended deployment of smart electricity meters by 2024, the future test's main focus is in this area. Including possible optimizations (as were addressed in Section 2) such as the implementation of the machine learning technique. This approach might improve overall device performance in the form of predictive transmission according to the signal quality and changes for all RATs or to lower the operational expenses by optimized RAT switching.

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