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D17.2

Base Hardware platform with 5G communication

Abstract:

Within the context of the Augmanity project, sensing must be done from different perspective. This includes sensing the state and location of machinery, workers, and vehicles as well as the surrounding environment. For that, the Augmanity project envisions the development of a 5G IoT End Device and a 5G tag that shall be performing the desired sensing and shall provide the support to the communication technologies considered in the defined use cases. This deliverable presents the base hardware for these artifacts, and also presents initial insights into the software related to the Intrusion Detection Reporter, that adds a extra layer of security to be implemented in the 5G IoT End Device.

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Document relating to:

Activity	**A17**	Component Development for 5G IoT end devices, 5G tag, and Smart Wearables
Task	**A17.T1**	Development of base Hardware module
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Project Team Leaders		Fraunhofer Portugal (Waldir Júnior, Carlos Resende, André Pereira, Filipe Sousa) Globaltronic (Sérgio Silva) IT-Aveiro (Georgios Zachos, Joaquim Bastos, João Prata, Jonathan Rodriguez)

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1. Introduction

The Augmanity project proposes the development of a 5G IoT End Device and a 5G Tag. The end device is coupled with different sensing and communication technologies to allow for use cases related to predictive maintenance and energy management. On the other hand, the tag also includes sensing and communication technologies with the purpose of providing accurate location of workers, vehicles, and machinery in the shop floor. Moreover, to introduce an extra layer of security on the 5G IoT End Device, an Intrusion Detection Reporter (IDR) is to be implemented.

This deliverable is focused on presenting relevant information on the development of the base hardware for both the 5G IoT End Device and the 5G Tag. It also includes initial insights into the software the comprises the proposed IDR.

With the definition of the base hardware, we expect to provide support to the different sensing and communication requirements envisioned for the defined use cases. Once with the base hardware, the future work shall follow with the implementation communication modules to be included in the design of the final hardware of the 5G IoT End Device and the 5G Tag.

2. 5G IoT End Device: base hardware

As described in deliverable *D14.3 - Architectural design for the 5G IoT End Device and 5G Tag*, the core of the base hardware for the end device is the Kallisto module. This module contains a powerful microcontroller which is capable of processing all the data provided by the multiple sensors and may transmit such data through the different available communication media (natively it supports Bluetooth, ANT+ and NFC). For operation in non-time critical scenarios, Kallisto possesses the means to store data. Thus, it becomes more energy efficient (since it can transmit data aggregated bundles instead of a single sensor value) as well as more resilient (since it can deal with communication failures by later sending stored data when communication is re-established).

Within the scope of the project, the mezzanine board (Printed Circuit Board – PCB) being developed (i.e., the customized board to where Kallisto is to be attached) includes not only the addition of extended sensing capabilities which can be used at industrial scenarios, but it is also settling the foundations for the future tasks which include the inclusion of a new communication medium, a 5G NR module.

Additionally, the support to different-voltage relays is considered. This feature shall enable the proposed 5G IoT End Device to actuate in different equipment in the shopfloor according to the different use cases foreseen in the project. Readily available air quality sensors increase the pool of data extracted from the settings' atmosphere where the device is installed. These metrics include not only air quality index, but also estimation of CO_2 present in the air.

The hardware of the 5G IoT End Device is being designed based on a modular mindset. Thus, it is also considered the support for connecting low-power flow meters, from where precise liquid volume flows can be measured. Finally, the hardware may also include in its design an impulse meter circuitry, which shall enable the device to sense the consumption of energy/water/gas power meters.

Figure 1 shows the first setup of the 5G IoT End Device which consists of a Kallisto (1), a NB-IoT radio development kit (2), a high precision ambient sensor (3) and a relay (4).

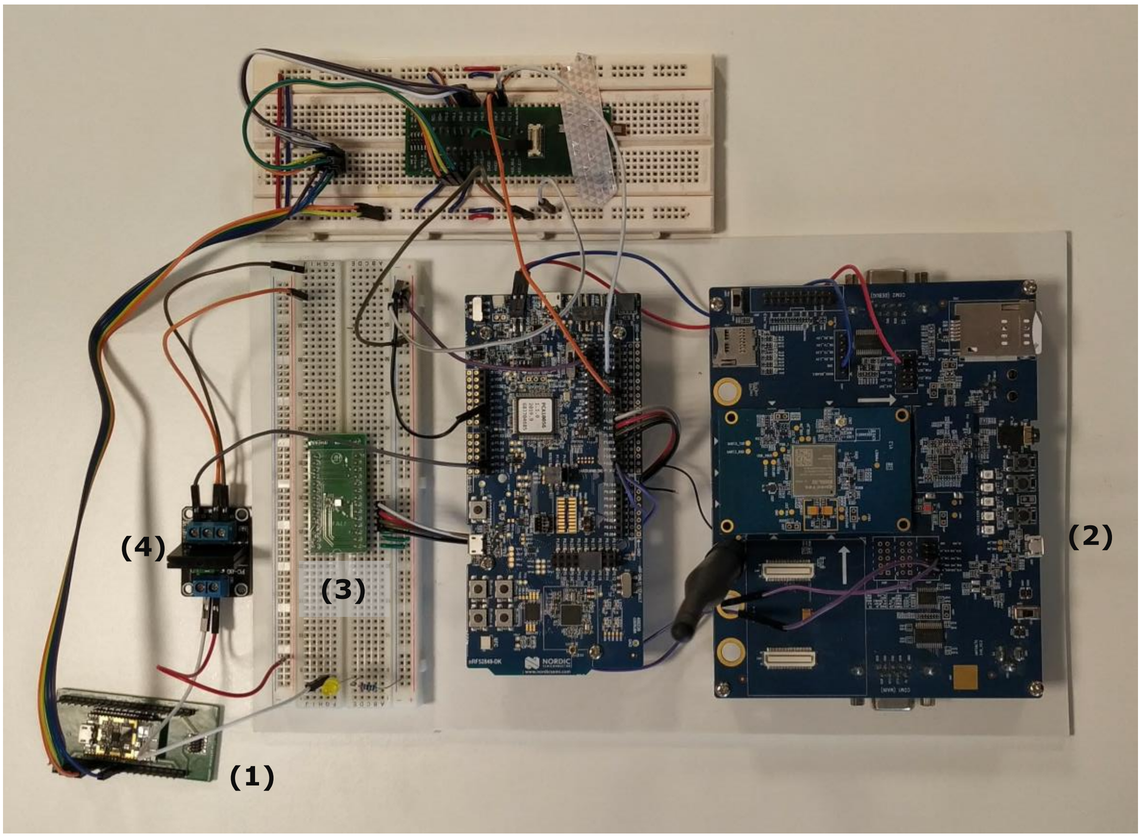


Figure 1 – First setup of 5G IoT End Device.

Despite very simple, this setup already illustrates how the base hardware is flexible enough for the realization of the different use cases considered in the Augmanity project. An example of application scenario could be the control of an HVAC system in an industrial setting. This control would be based on the readings of the ambient sensor. Such readings would be relayed, through the NB-IoT medium, to a central server where algorithms could decide to trigger the different operations of the HVAC system through the relay incorporated in the solution.

This base hardware will evolve with the next tasks concerning the communication, sensing and actuation modules for the 5G IoT End Device. These tasks go towards the support to 5G communication as well as further sensing and actuation capabilities to allow the realization of the different Augmanity's use cases.

Annex 6.1 illustrates a high-level block diagram of the 5G IoT End Device. In this diagram, it is possible to observe the power line distribution of the system, the communication lines available to communicate with different peripherals, the sensors and actuators to be added as well as the future 5G radio to be added later on in this project.

As the project evolves, so will this block diagram as to allow us to follow with the design of the electrical schematics and of the mezzanine board for the 5G IoT End Device.

3. 5G Tag: base hardware

Deliverable D14.3 presented a description of the 5G Tag under Section 3.2. From this detailed description, a base module was developed and produced by Globaltronic. The module incorporates the features described in the mentioned deliverable.

The processing unit is the ISP3010 featuring the nRF52832 chipset from Nordic Semiconductor 2.4GHz wireless System on Chip (SoC). It integrates a 32-bit ARM Cortex™ M4 CPU, 512 kB flash memory, 64 kB RAM as well as analog and digital peripherals.

On a first phase, a prototype was developed to allow the development of the UWB driver and SDK, that will expose the sensors and features described under the deliverable D14.3. One of the 3 prototypes batch can be seen in Figure 2.

Figure 2 – 5G Tag first prototype.

These prototypes allow the SDK development in order to facilitate the works of task T17.4 - Development of communications and location software (M17-M25).

The natural evolution of the 5G Tag was to be a miniaturized PCB as described in D14.3. Therefore, the above prototypes were miniaturized to feature the hardware specification necessary to the use cases. Figure 3 shows the digital version of the miniaturized PCB.

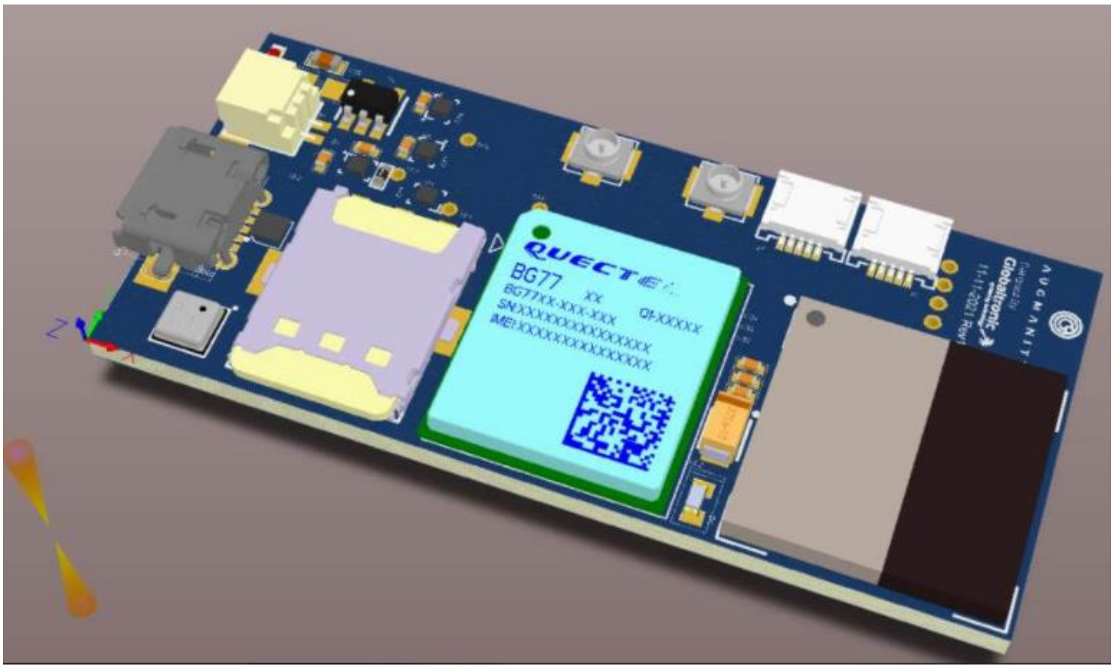


Figure 3 – 5G Tag's miniaturized PCB (digital version).

In the developed PCB, we can see that it features a BG77, an LTE Cat M1/Cat NB2 Module that will expose the 5G and NB-IoT communication capabilities to the tag.

This way, the 5G Tag, features ultra-low power consumption by leveraging the integrated RAM/flash as well as the ARM Cortex A7 processor supporting ThreadX. It is fully compliant with 3GPP Rel-14 specification and provides maximum data rates of 588 kbps downlink and 1119 kbps uplink, allowing the transfer of data between the 5G Tag and 5G Gateway.

Besides designing the above hardware, currently the hardware modules are under prototyping, and Figure 4 shows the PCB of the 5G Tag.

Annex 6.2 presents the schematics for the 5G Tag.

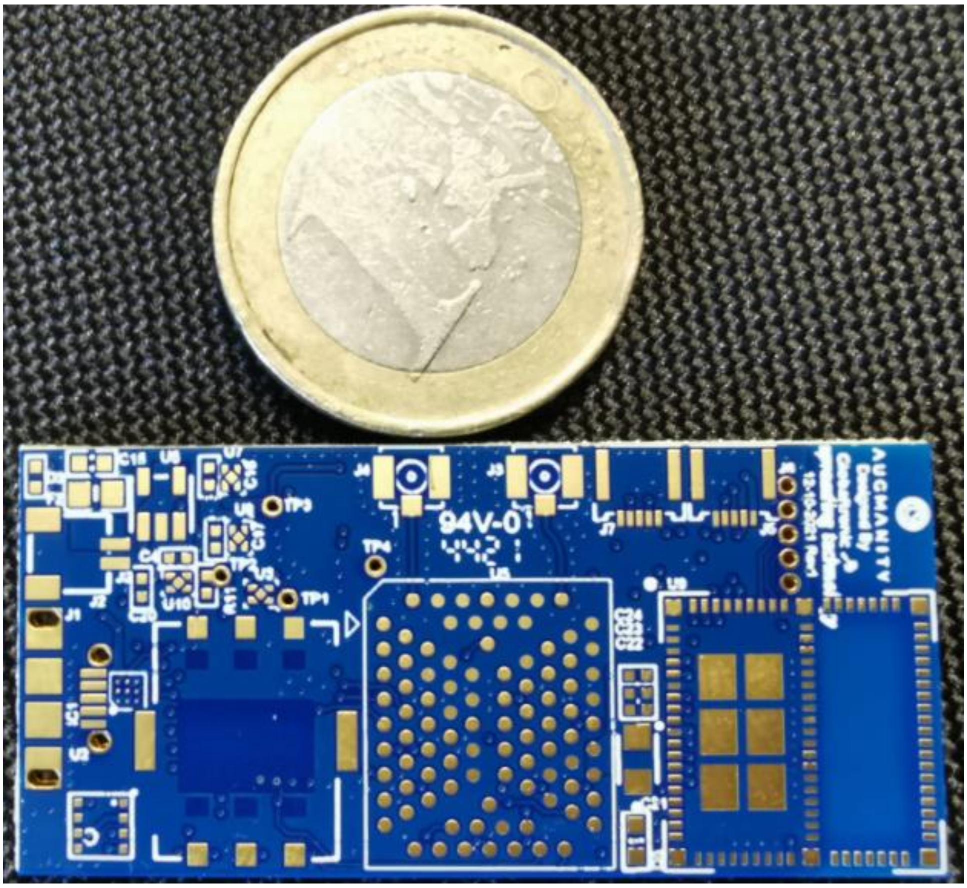


Figure 4 – 5G Tag's PCB.

In the image, we can see the small size of the 5G Tag that is 49mmx22mm.

The hardware features 3D accelerometer and 3D gyroscope with ultra-low power performing at 1.25 mA (up to 1.6 kHz ODR) in high performance mode and enabling always-on low-power features for an optimal motion experience and free-fall support. The system allows event-detection interrupts, enables efficient and reliable motion tracking and contextual awareness, implementing hardware recognition of free-fall events, 6D orientation, tap and double-tap sensing, activity or inactivity, and wakeup events.

An ultra-low power high-performance 3-axis magnetometer was also included as recommended in D14.3.

On the sensor side, the BME680 from Bosch integrates high-linearity and high-accuracy gas, pressure, humidity and temperature sensors including Air Quality Index (IAQ Index).

To correctly maintain the time, a precise RTC was implemented.

One of the most important features is to be able to track the movements, for that the system implements a UWB precise position technology, allowing ultra-low-power positioning using anchors as location reference.

UWB communication is compliant to IEEE802.15.4. and allows precise location using the internal antenna up to 50 meters.

The 5G Tag can also implement BLE, Bluetooth Low Energy protocol stacks, ANT/ANT+ and NFC-A for OOB pairing.

The 5G Tag supports communication at 2.4 GHz and 6.5 GHz.

4. Intrusion Detection Reporter for 5G IoT End Device

Deliverable D14.3 presented a description of the Intrusion Detection Reporter (IDR) which is a software component that is meant to be deployed on the 5G IoT End Device to increase its level of security. The IDR gathers data from the 5G IoT End Device and provides them to the Intrusion Detection Engine (IDE) software component which runs on the 5G Gateway and is responsible for detecting any abnormal behaviour of each connected 5G IoT End Device. Deliverable D14.2 provides a description of the IDE component. Figure 5 shows the IDR component in the 5G IoT End Device, the IDE component in the 5G Gateway and the communication between the two components.

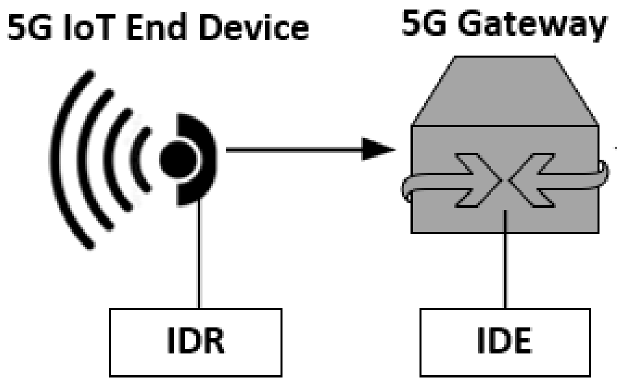


Figure 5 – The IDR and the IDE components and the communication between the two components.

The IDR component includes three software blocks, which are presented in Table 1 and Figure 6, along with their inputs, outputs, and brief descriptions.

Table 1 – Software blocks of the IDR component.

Software block	Input argument(s)	Output(s)	Brief description
Data acquisition	monitored features, sampling period of monitored features	record	Collects data for the specified features of the 5G IoT end device itself during the sampling period and creates a record.

Logging	record, max size of a log file	log file	Writes a record in a log file.
Sender	log file, max number of log files in a report, device id, 5G Gateway IP address and port	report	Creates a report including a set of log files and transmits it to the IDE running on the 5G Gateway.

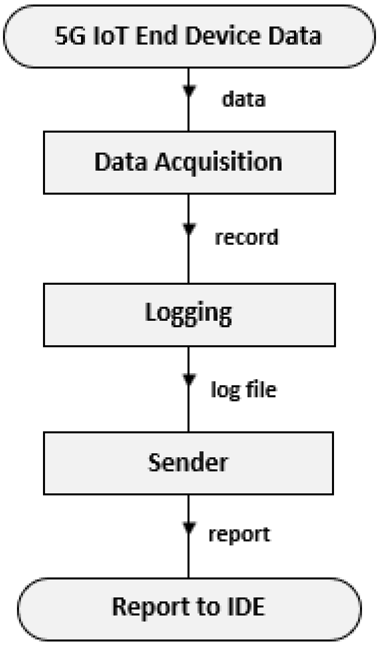


Figure 6 – Software blocks of the IDR component.

The parameters regarding sampling period of monitored features, maximum size of a log file, maximum number of log files in a report and the 5G Gateway IP address and port are operational parameters that are required to be configured on the 5G IoT End Device before the start of the normal operation of the IDR component. Additionally, the device ID is assumed to be provided internally by the 5G IoT End Device to the IDR component. At this point, it is worthwhile to mention examples of features that the IDR component may need to monitor:

- Time that the system spends in a specific mode (e.g., user mode, system mode, idle mode).
- CPU usage as a percentage.
- CPU frequency.
- Number of currently running processes.
- Internal memory statistics:
    - Available internal memory as a percentage or number of bytes.

- Used internal memory as a percentage or number of bytes.
- External memory statistics:
  - Available external memory as a percentage or number of bytes.
  - Used external memory as a percentage or number of bytes.
- External memory input-output statistics:
  - External memory reads as a counter or a number of bytes.
  - External memory writes as a counter or a number of bytes.
- Network input-output statistics:
  - Number of bytes or packets sent through the Network interfaces.
  - Number of errors that occurred during the transmission of bytes/packets.
  - Number of bytes or packets received through the Network interfaces.
  - Number of errors that occurred during the reception of bytes/packets.
- Network interface cards (NICs) information:
  - Name of the network interface card (e.g., Bluetooth, Wi-fi).
  - Whether it is up and running.
  - Speed of the network interface card in bits (or kilobits or megabits).

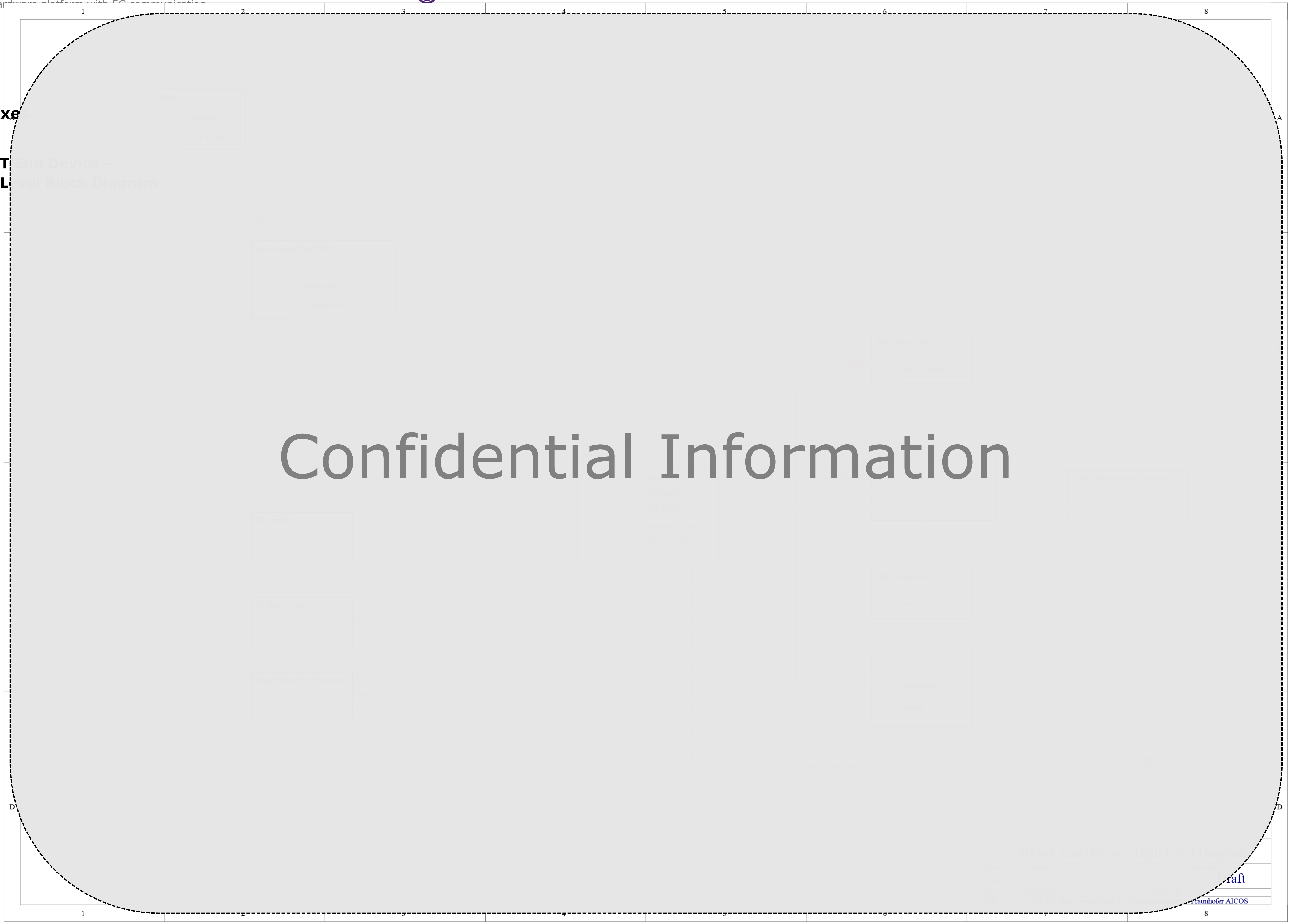
5. Conclusions and Remarks

This deliverable introduces the base hardware for the 5G IoT End Device and 5G Tag. The document also presents block diagrams and first setups and prototypes for these artifacts. Moreover, the document elaborates on the Intrusion Detection Reporter software that is expected to increase security of the proposed 5G IoT End Device.

With the base hardware, the efforts towards the end device and tag shift to the development of the different communication modules that compose these solutions as part of activity *A17 – Component Development for 5G IoT end devices, 5G tag, and Smart Wearables*.

6. Annexes

6.1 5G IoT End Device – High-Level Block Diagram



6.2 5G Tag – Schematic