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## AN060: Low Power and Deep Sleep for RIIM

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# Low Power and Deep Sleep for RIIM

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## Background

Radiocrafts Industrial IP Mesh (RIIM) is a power efficient and robust mesh network supporting up to 1000 nodes in a single network. RIIM has from the ground up been optimized for low power and is capable of very low power consumption while still retaining robust and reliable operation.

When designing a wireless system for battery operation and maximum battery lifetime there are several aspects to consider.

- What different states can a product be in: Storage, transport, installation, normal operation, “alarm” operation, connection loss/failure and more.
  - o All states above must be considered by the development engineer. If a battery is inserted during installation the battery drain during storage and transport can be neglected. But if a battery is inserted from manufacturing, then it is critical to minimize current draw during storage and transport.
- How to set up network to behave optimally
  - o Network behaviour dictates current consumption in normal operation. This is always a trade-off vs. other parameters such as latency, throughput, and network size. There exists no solution that optimize for all parameters at once.
- How to setup each device/module to prevent unwanted battery drain.
  - o For each device it is also important to set the I/O pins and to disable unused peripherals in order to get the correct low power performance.

This application note describes what needs to be done to achieve the lowest possible power drain and which choices that can be made when it comes to performance vs power consumption.

## Platform selection

Platform selection is important to power consumption. RIIM comes in two main versions, Time Slotted Channel Hopping (TSCH) and Single Channel (SC).

TSCH will in general be more suited for an active network where data is transferred frequently. This is because the radio will only be on in predetermined timeslots when the node expects to receive data, and off otherwise. This happens automatically and is synchronized throughout the network.

SC is more suited for very sleepy networks, where nodes can be put to sleep for extended periods of time without the need to receive data. During this “sleep” time, the nodes will be deaf and not able to receive any packets. They must be explicitly put to sleep and woken up using ICI.

## Node types

TSCH supports the following node types:

- Border Router / Border Router Standalone (BR)
- Mesh Router (MR)

Single Channel supports the following node types

- Border Router / Border Router Standalone (BR)
- Mesh router (MR)
- Leaf (LEAF)

BR uses quite a bit more power than the MR and LEAF (see datasheet), but only one BR is needed for every RIIM installation. We will focus on lowering power consumption for the MR and LEAF in this document.

## Software support for low power

Radiocrafts' Intelligent C-programmable I/O (ICI) includes functions to control the behaviour of the RIIM module. The main power control functions are described in the following chapters. ICI also controls other functions and peripherals that may increase power consumption, such as frequent timers and the activation of peripherals such as the UART.

### Turning on and off the radio

For SC nodes, the functions **Network.Radio\_On()** and **Network.Radio\_Off()** can be used to disable listening. Even if radio is turned off, it will keep an active connection alive by sending/receiving control packets.

Also, the node will try to connect to a network if not part of one already. This is important, as the joining process is power intensive, and it will not give up until it is part of a network. This can lead to unacceptable power drain. To mitigate this, it is also possible to use the function **Network.stop()** to completely stop the radio. Using this function disconnects the node from the network and ensures no traffic on the radio whatsoever.

### Setting TSCH parameters

TSCH can be setup in several different modes. The available predefined modes are

- TSCH\_LOW\_POWER
- TSCH\_BALANCED
- TSCH\_LOW\_LATENCY
- TSCH\_HIGH\_THROUGHPUT\_SENSOR\_DATA

These are optimized for different scenarios. It is also possible to change these on-the-fly in a live network. This makes it possible to save power during certain periods and prioritize performance in other periods. These modes can be set using the ICI function **Network.setTSCHParameters()**, or by setting it in only the root node and let the settings automatically propagate down the network. Use **Network.autoupdateTSCHParameters()** to use this feature.

In TSCH, it is also possible to adjust the Enhanced Beacon (EB) rate. The higher the EB rate, the faster the network will form, and new nodes will join. However, this also uses more power. Increasing EB rate temporarily can therefore help bring down the total power consumption because nodes stay in the power-hungry join state for shorter amounts of time.

## Reduce the data amount.

In the world of 4g/5g and Wi-Fi, the amount of data sent is huge. In IoT the rules are different and every byte counts. This makes it important to minimise the data traffic.

In each RIIIM packet approximately 80 bytes of user data can be added. This is in addition to an overhead of about 40 bytes per packet. Therefore, it takes less energy to transfer 50 bytes every 100 seconds, than transferring 5 bytes every 10 seconds as packet overhead is then only transferred once.

## Mist computing

Using ICI, applications can benefit from the computational capabilities of the RIIIM modules and thereby avoid or limit data transmission when it is not necessary. This can for instance be to do signal processing locally on the module, or avoid transmission altogether given that some value is within a limit.

## Hardware considerations

Without proper connections to the module, a good power design, peripheral connections, and good antenna matching, it can be hard to achieve the lowest power.

## Power supply

A stable power supply will help power efficiency, stability, and RF performance.

As the voltage gets higher, the current drain drops and vice versa. However, the total power consumption (given by the formula  $P=UI$ ) is lowest when voltage is lowest, albeit not as much as one might expect.

## GPIOs

GPIOs that are not in use or that is configured as inputs will potentially leak current if left floating. This happens if the input pin is not a logic low or high, but something in between. To fix or avoid this problem two things can be done.

Internally, using ICI, it is possible to define the output to a logic high or low by either enabling a built-in pullup/pulldown resistor, or by setting the GPIO to output.

Externally, the GPIOs can be physically connected to ground or the supply voltage, possibly via a resistor if preferred.

## Antenna matching

A mismatched antenna can lead to increased power usage, among other things such as poor RF performance, or even lower power consumption. A good design practice is to implement a matching network between the module and the antenna for final adjustments to be done without redesigning the PCB. As the current consumption during transmit will vary with the antenna match it could be useful to measure the TX current.

## How to properly measure power consumption

Measuring power consumption in a dynamic, running system can be hard. To get a proper value, both current and voltage must be measured. Here, voltage is usually not a big problem, given that the power supply is stable and powerful enough. However, current consumption can vary by orders of magnitude between sleep and transmission.

This makes simple measurements using voltage drops over resistors hard. If the resistor has too large a resistance, the voltage drop will be significant during high loads and influence the measurement. On the other hand, a resistor with too small resistance will provide a very small voltage drop when current is low, which can be hard to detect and measure. One solution is to use a low resistance resistor and an amplifier. This can then for instance be connected to an oscilloscope as shown in the following figure.

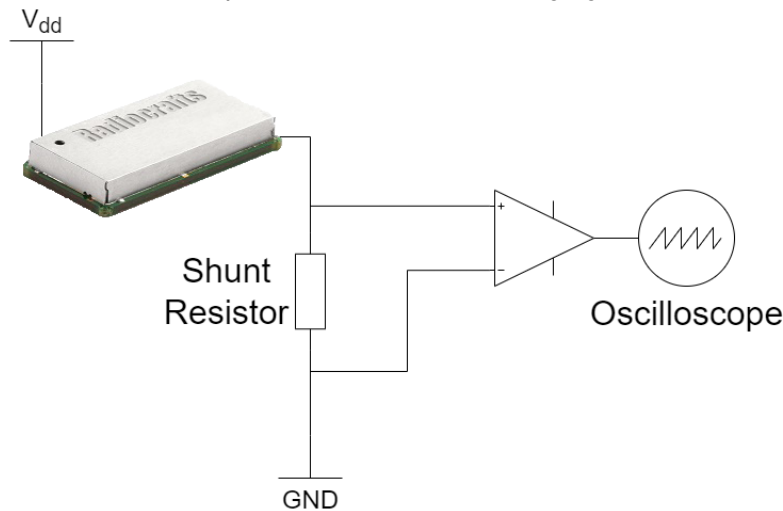


Figure 1. Schematic for measuring dynamic current as voltage over resistor

Also, since a running module is dynamic and changes power consumption fast, a simple multimeter can only give you an average, which may not even be accurate – depending on parameters such as the sampling rate of the multimeter.

Dedicated dynamic power meters exist and can be used as well, solving most of the practical problems and giving consistent results. Also, the software tools provided with these tools can help with measurement, analysis and capturing data. One very good low-cost tool is the PPK2 from Nordic Semiconductor.



Figure 2. Example screenshot with dynamic current consumption with PPK2

## Summary

- Change modes and network behaviour dynamically according to current use case and needs
- TSCH gives the possibility to save power in an active network
- Very sleepy devices might fare better using Single Channel
- Completely turning off the radio can make sense if:
  - o Module is inactive for extended periods (hours/days)
  - o Module is unable to connect to any existing network
  - o Module is in storage
- Do computation locally on the node to limit amount of data transmitted on RF
- Reduce number of transmissions – use larger payloads instead
- Keep voltage as low as possible
- Provide a solid, nicely decoupled power supply
- All unused and input GPIOs should be either:
  - o Not be allowed to float externally, and/or
  - o they should be pulled high/low using ICI
- Measuring power can be hard and needs proper planning
  - o Compare and calibrate measured power drain with known hardware, such as development boards from Radiocrafts
  - o Use a dedicated measuring device and setup suitable for your power scenario (dynamic, static, average...)

The following table summarizes some states of operation and suggestions to how to implement the behaviour of the module.

	Storage and Transport	Installation	Normal operation	Alarm operation	Connection loss/failure mode
<b>TSCH Mesh router</b>	Battery disconnected or deep sleep mode	Adjust up EB rate to accelerate joining.	Use TSCH Low power to minimize current consumption. Send as little data as possible.	Assuming little time spent in this mode can allow higher current consumption	Deep sleep and try to join infrequent
<b>Single channel leaf node</b>		As normal operation	Send as little data as possible. Poll if needed downlink	Do not use <b>Network.Radio_Off()</b>	

## Radiocrafts' RIIM Products and Services

Radiocrafts offers 3 modules running RIIM

- RC1882CEF-IPM has 14 dBm max output for 868 MHz
- RC1882HPCF-IPM has 27 dBm max output for 868 MHz
- RC1892HPCF-IPM has 27 dBm max output for 915 MHz

Visit [www.radiocrafts.com](http://www.radiocrafts.com) for details, datasheets and SDK.

Radiocrafts also offers a tool to estimate power consumption and battery lifetime for TSCH mesh routers. This is available on the Radiocrafts GitHub page: <https://github.com/radiocrafts/Battery-Lifetime-Estimation-Tool>

Please contact Radiocrafts sales or support to discuss any project that might need customization.

## Document Revision History

Document Revision	Changes
1.0	First release

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