Radiocrafts
Embedded Wireless Solutions

WP020

RIIM™ for Street Lighting

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Smart Street lighting

Some might think that a street lighting network is merely a switch to turn streetlights on and off, this is very far from the truth. In fact, an efficient and reliable street lighting network is a key enabler in any smart city design. A smart street lighting network is a large-scale network which incorporates a variety of monitoring devices, such as sensors or even cameras, which serves to make the city more safe, smart, and sustainable.

At the heart of any street lighting network, lies the light management functionality. Which is an essential functionality as smart management of light directly translates to more efficient usage of power resources, which helps in saving money and preserving the environment. On top of that, street lighting networks can also be used to monitor the weather, pollution, and several other environmental factors.

Therefore, an optimum street lighting network should support massive deployments, which allows for controlling several light poles by the same control system. It would benefit from a dynamic architecture, allowing it to mitigate deployment challenges, in terms of range and obstructions. In addition, it should be secure, as undesired parties tapping into the control system of a street lighting network could cause safety concerns. Moreover, the RF aspect of the network should support high throughputs, to provide connectivity for the various potential applications built on top of the street lighting application. Last but definitely not least, to ensure the most efficient utilization of resources, the network should support addressing and synchronization schemes which allow synchronous events and precision control.

Smart Street Lighting Network Requirements:

- Time Synchronous events
- Large Coverage Area
- Reliable Communication
- Security
- High Throughput data = High Duty Cycle with polite spectrum access
- Easy integration to cloud = SLIP+IP
- Future Proof=IP

In this document, the performance of RIIM™ will be discussed in the light of the above-mentioned requirements.

Introduction to RIIM

Radiocrafts Industrial IP Mesh (RIIM™) is Radiocrafts' unique end-to-end IP mesh network, designed to cater for a variety of massive and industrial IoT use cases. RIIM™ is best suited for applications which require industrial-grade reliability, long range, easy scalability, and easy setup. Being a mesh network, RIIM™ is a self-forming and self-healing network, which means that setup is easy and automatic. It also means that poor or broken links are replaced automatically, to ensure maximum possible reliability at all times.

One of RIIM™'s target application area is smart city applications. Enabling efficient, synchronized, and highly reliable street lighting networks has been the main driver in RIIM™ development recently. A vital element in any smart city design is a smart and robust street lighting network. In this document, the features which place RIIM™ at the top of the list of street lighting enablers are explained, in addition to the benefits the user achieves with RIIM™. For simulation results on how RIIM™ behaves in street lighting networks with 100 and 1000 nodes, please check application note 38.

RIIM™ in a nutshell

The building block in a RIIM™ network is the RC1882-IPM module. This module is versatile and can be used for three different roles: as a border router, a mesh router node, and as a leaf-node. A Border Router lies at the edge of the network and manages the network operation and its connection to the outside world. A Mesh Router can be connected to sensor nodes, it also acts a router, pushing data up and down the mesh structure. Leaf nodes can also be connected to sensors, they support Sleep Mode, thus they can't act as routers.

RIIM™ nodes are controlled and programmed by using Radiocrafts' ICI (Intelligent C-Programmable interface). In RIIM™ terminology, they are called ICI applications, which are high-level C programs written on any editor and uploaded to a RIIM™ node via the UART/Serial port. ICI applications are based on a powerful API which allows users access to a number of vital functionalities, such as network setup, timers, and much more. With an ICI application, the user can configure key network parameters, define read and write sensor functionalities, and configure the module's hardware.

Some of the main features of RIIM™ include:

- A Global sub-1 GHz solution

RIIM™ Operates in the 868 MHz or 915 MHz frequency band. (Contact sales@radiocrafts.com for 433 MHz inquiries)

- Link Layer Security & DTLS/TLS
- Multicast
- Supports both CoAP and UDP protocols
- Supports up to a thousand nodes organized in a mesh network-topology
- Line of Sight (LoS) range of up to several hundred meters in normal low power module and more than 10 km in the high-power module
- 2-way symmetrical communication with OTA (Over the air) updates.
- Very short network delays for near real time applications.
- Cloud application compatible via IP packets to each mesh router

Mesh Structure

One of the key features of RIIM is its mesh structure. In general, LPWANs are enabled by using one of three options: Star Networks, Mesh Networks, or Cellular LPWANs. Each of which has its own architecture, and hence, its own advantages and disadvantages.

Famous examples of star networks are LoRa and Sigfox. Given their star structure, they do not support routers/repeaters. Hence, they are required to support wide coverage in their single-hop structure, this dictates the use of very low data rates. Moreover, since they are optimized for sensor readings, their links are asymmetrical and optimized for uplink, which makes them a poor fit for street lighting applications which are mainly downlink oriented.

Another serious drawback of star networks when comparing to mesh networks is that star networks are mostly immobile and do not support any flexibility in the topology. Which means that in a street lighting network, if a new building is built which blocks the LoS, it would require a re-design to relocate the gateway and try to re-establish the broken link. On the other hand, with mesh networks, this issue is easily solved just by adding a mesh router. Therefore, mesh networks have a very clear advantage over star networks for street lighting applications.

On the other hand, cellular LPWANs such as NB IoT have their own advantages in terms of wide coverage. Though, they still have their own drawback when it comes to street lighting, in terms of price and network life. Firstly, cellular LPWANs require a subscription fee, which when multiplied by the total number of nodes in a street lighting network, might result in a huge overhead cost. Second, as you might have noticed already, cellular technology is one of the fastest technologies in terms of advancements. 10 years ago, 3G networks were widely used everywhere, while now, they are history as 5G networks are already being rolled out. This might cause issues in streetlight networks which usually have a lifetime of 10-15 years, as the user might find the technology he is using is becoming obsolete and he needs a new subscription.

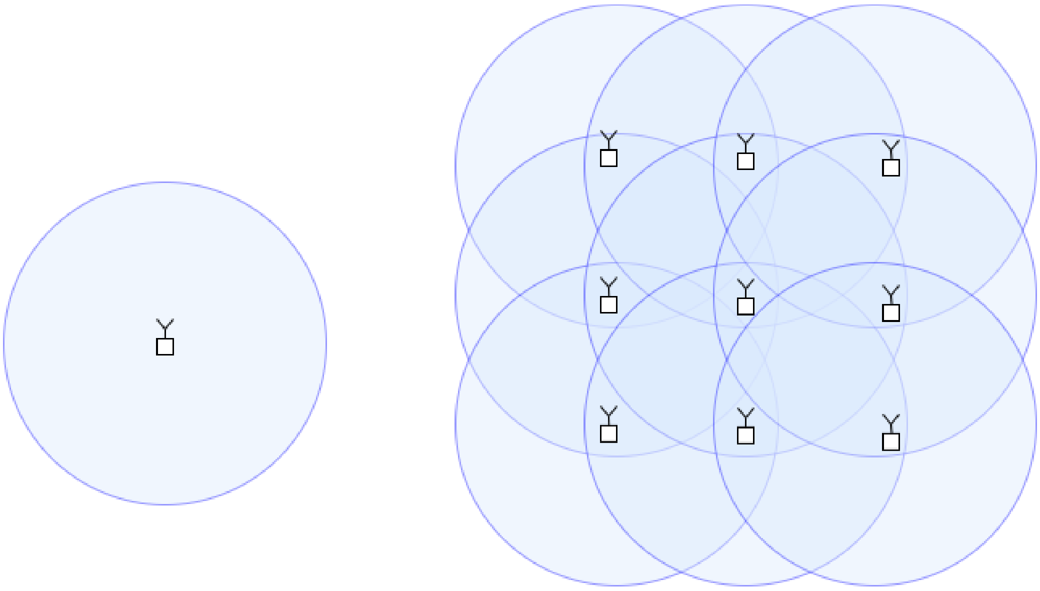

Figure 1. Coverage of one device (left) and coverage of a mesh with 9 devices (right)

Symmetrical Links

Symmetrical links, being a weakness point in competing technologies, is a crucial differentiator for RIIM™, especially in street lighting applications. For control purposes, street lighting networks require a heavy load on the downlink. To achieve this, RIIM™ provides a 50-kbps link on both uplink and downlink, which gives the user the ability to use the downlink efficiently.

An efficient downlink is also important for OTA updates, which is heavily used by street lighting applications. For examples, the user might regularly need to update their lights On/Off schedules, instead of uploading these instructions to each node individually, OTA can be used. But, with technologies with poor downlink links, OTA are not possible. While with RIIM™, OTA have never been easier.

End-to-end IP

RIIM™ natively supports end-to-end IP communications, as all internal communications inside a RIIM™ network between the Border Router and end nodes are achieved using IPv6 addressing. Therefore, if the infrastructure supports IPv6, a RIIM™ node can communicate with an external cloud service or an external server by using IPv6.

This allows for a number of benefits. First, with end-to-end IP connectivity, comes end-to-end security. This is basically due to the fact that no protocol translation is needed, hence, encryption is maintained all through the way from the end node, passing through the Border Router, till reaching the external cloud or server. Second, when all RIIM™ end nodes have IPv6 addresses, this enables global addressing and allows for seamless scalability. Lastly, achieving IPv6 links all the way mitigates the need for extra switches and routers which would make the system more complex.

Despite being optional, some street lighting users prefer connecting their RIIM™ network to the internet by using a cellular modem. The resulting setup is shown in figure 2 below. For more information about Radiocrafts' SLIP interface and different means of connecting RIIM™ to the internet, please refer to application notes 46 and 47.

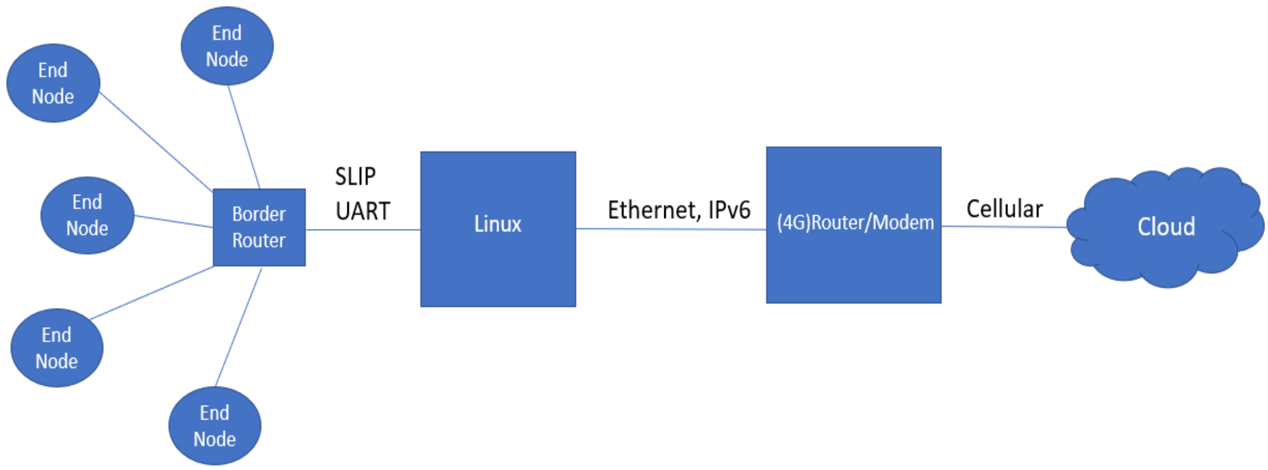

Figure 2. Connecting RIIM to a cellular modem.

Time Synchronized Channel Hopping (TSCH)

TSCH (Time Slotted Frequency Hopping) was introduced in IEEE 802.15.4-2015 and is a combination of Time division multiple access and Frequency-division multiple access. This means that transmissions are done at several frequencies and at different time slots in a synchronized manner.

In TSCH, nodes form a globally synchronized network. The network broadcasts beacons which contain timing information to let other nodes synchronize and join. Child nodes continuously correct their relative clock drift to their parent through timing information in acknowledgement packets. The airtime is divided into a continuously repeated set of slots and a node is only allowed to communicate during its assigned slot(s). Within a slot there is time to transmit and receive an acknowledgement from the destination. Communication happens on different channels for each repetition of the same slot, and therefore if a packet is lost due to RF interference, its retransmission is more likely to succeed in the next slot repetition since it will be sent on a different channel.

Benefits of TSCH include:

- Higher resilience to RF interference
- Higher network reliability
- Enabling battery-operated Mesh Routers

- Enabling Time Synchronization
- Enabling frequency hopping on 50 channels, which is a requirement for FCC certification to enter the US market
- Enabling frequency hopping on 10 channels, which is a requirement for certification to enter the Indian market
- Enabling frequency hopping on 14 channels, which is a requirement for > 500mW transmissions in Europe

Time Synchronization

Street lighting applications require a fair share of control. Efficient and elegant control over a visual application, such as street lighting, usually requires the implementation of synchronized events. Time synchronization, a feature enabled by the use of TSCH, allows for managing the exact start and stop times of certain events.

Time synchronization allows for a common understanding of time in RIIM™'s mesh network. When all nodes are aware of time, synchronizing events becomes possible. Synchronizing events might mean a number of things. For example, in a street lighting application, the user can program the light controller-through RIIM™- to automatically turn the lights on at 17:00, then off again at 07:00. When combined with RIIM™'s efficient and symmetrical link, regular OTA can be sent to light controllers with new lighting schedules to adapt to changing seasons.

Without the use of Time Synchronization, RIIM™ nodes would have no understanding of time, thus, time information would have to be manually fed to the nodes, to achieve synchronization and events starting at exact times. Timing information can be fed into a RIIM™ network through a number of ways. To learn more about Time Synchronization in RIIM™ and how it works, please check application note number 50.

Polite Spectrum Access

From a regulator's point of view, regulating the use of unlicensed frequency bands is essential to allow for a fair distribution of radio frequency use. On the other hand, this puts extra restriction on radio user's as they are only allowed to use radio channels under certain conditions. One of those conditions is the duty cycle, which simply means how much of the time is radio allowed to transmit in.

In Europe for example, under ETSI regulations, a radio's maximum duty cycle is 1%, which means, the radio is allowed to transmit only in 1% of the time. For instance, on the course of one hour, a radio is allowed transmission only for 36 seconds. This clearly reduces the amount of time the radio can stay on air, which by turn reduces the total radio throughput. This can be problem at times when there is a need for passing on much data through the network. In the example of street lighting application, this happens when using OTA for instance.

As part of Radiocrafts constant efforts to provide our users the best performance and the optimum utilization of resources available, RIIM's SDK 2.0.0 will implement a technique called Polite Spectrum Access, which would take the maximum duty cycle from 1% up to a staggering 37.8% in Europe. Polite Spectrum Access entails the use of multiple frequencies, which a specification in TSCH.

Polite Spectrum Access is a technique which ensures radios use the available spectrum politely. To break it down, this consists of two parts, Listen Before Talk (also know as Clear Channel Assessment) and Adaptive Frequency

Agility. LBT (Listen Before Talk) works just as its name implies, the radio scans the 14 available channels (in Europe a radio is allowed to transmit on 14 of the 16 available channels for channel hopping) before transmitting on any of them. If a channel is found to be noisy, the radio waits and doesn't transmit on it. This dramatically increases the radio's resilience to noise, which directly reflects on the packet error rate, boosting the network's performance.

Adaptive Frequency Agility works on top of LBT by marking the channels which are often found to be noisy, then it drops those channels from the hopping list, which ensures that the radio only uses the channels with the least noise. According to ETSI regulations, a radio implementing polite spectrum access can increase the time it can utilize a single channel from 1% to 2.76%, multiplied by 14 channels available in Europe, this means the whole system's duty cycle is now 37.8%.

This reflects on the system with very valuable benefits. Firstly, increasing the duty cycle by such a huge margin makes OTA updates and frequent transmissions much more efficient and faster. In street lighting applications, this can enhance the user experience a lot. Secondly, implementing such noise-sensing techniques ensures that noisy channels are avoided, which significantly reduces packet error rates and allows for more range per hop.

Summary

RIIM™ is considered by a lot of our customers as an industry-leading enabler for street lighting applications. This is far more than just a claim, each new feature introduced in RIIM™ aims to tackle a common challenge faced in the smart applications industry. For street lighting applications, RIIM™ has an arsenal of features to help users design a reliable, state-of-the-art network, with the best possible reliability, range, and intelligence, while maintaining fairly low system complexity.

Document Revision History

Document Revision	Changes
1.0	First release

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