Radiocrafts
Embedded Wireless Solutions

WP022

Reliability in RIIM

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Introduction

There is no doubt that LPWANs (Low Power Wide Area Networks) have proven themselves as a worthy enabler for a huge sector of IoT networks. Specifically, LPWAN-enabled WSN (Wireless Sensor Networks) show potential to be a reliable enabler for critical IoT applications. But the question is, how can the user guarantee the most reliability out of his LPWAN?

Reliability simply describes how much can the user trust his network to always deliver packets correctly. It can also refer to how much of the time is the network available for communication. Probably the first thing that comes to some peoples' minds when looking for the most reliable network would be LTE networks. Especially that LTE providers now offer some networks designed specifically for IoT applications. However, a number of reasons may steer users away from this option. For example, since in LTE-enabled IoT networks each node must be equipped with a SIM card, and a subscription fee must be paid, this makes it expensive. Moreover, given their complete reliance on the LTE network coverage, nodes will not work unless the area is already covered with an LTE network. Thus, nodes cannot be deployed in hard-to-reach places or remote fields. Most importantly, since we are now discussing WSNs, battery lifetime is a key metric to consider, and LTE networks are not the best option in this aspect.

Therefore, wireless mesh networks are witnessing an increased recognition as an excellent enabler of many key industrial IoT applications. Currently, many new deployments in the fields of, smart irrigation, street lighting, and industrial sensor networks, are using some sort of a mesh network. This is due to the fact that mesh networks provide an excellent alternative to tackle much of the practical RF issues while maintaining reliability.

This white paper aims to explain the different RIIM features which contribute to its high reliability. After a brief introduction about RIIM, each feature will be presented along with explaining its effect on the network operation.

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 always ensure maximum possible reliability. For more information about RIIM™, read more in here https://radiocrafts.com/products/riim-network/riim-parts-and-tools/

Network topology: Mesh vs. Star

One of the most basic means by which RIIM maintains its reliability is by using the mesh architecture. Mesh architectures provide numerous advantages over its peers such as dynamic self-formation, automatic self-reconfiguration, possible large coverage, low power consumption, and easy scalability. However, the most important feature for the scope of this document is the increased reliability.

As seen in figure 1, assuming the purple node is the gateway, the star network architecture provides only one RF link possibility from each node to the gateway. This means that if, for any reason, one of the RF links is broken, the child node would have no way of connecting to the gateway and the node will be disconnected. Thus, network reliability will be drastically reduced.

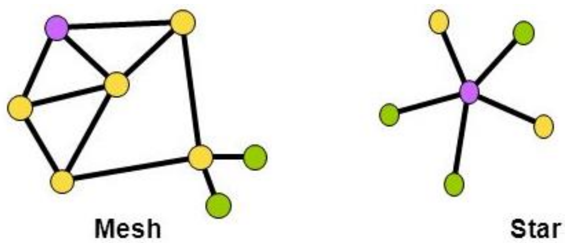

Figure 1. Example mesh architecture (left) and example star architecture (right)

On the other hand, as seen in the mesh architecture illustration, nodes are interconnected. This means that if the same incident happens and an RF link is broken, the RIIM algorithm would automatically reroute that child node's data through a different path. Therefore, this would save the network's reliability and allow for more resilience against single points of failure.

Perhaps a deeper advantage of mesh architectures over star can be observed in cases where long RF range is required. In a typical star architecture, to extend the range of a node, the data throughput might need to be reduced, to maintain same link budget over constant receiver sensitivity. This might not always be enough since link budgets are limited, and this also might mean radios have to stay more time on air, thus increasing the chances of packet collisions and packet loss. Obviously, this negatively affects reliability.

On the other hand, in the case of a mesh network, a very easy solution to extend range is to simply add an extra mesh router. Given that RIIM supports up to 28 hops, and more than 10 km in LoS range for the HP variant, extending range has never been easier, while maintain network reliability and ensuring that all packets reach their destination.

Operating Frequency: 2.4 GHz vs. sub 1 GHz.

Sub 1 GHz refers to wireless solutions operating on different locally regulated bands, typically at 433 MHz, 865-870 MHz and 902-928 MHz Whereas 2.4 GHz refers to the famous ISM band which is also license-free. But then, what's the difference between the two options?

Laws of physics tells us that attenuation or path loss increases with increasing frequency. The formula for free space path loss is $Path\ loss = DtDr\left(\frac{\lambda}{4\pi d}\right)^2$ and this shows that double the frequency = half the range. In addition, for indoor settings, the lower the frequency the better it penetrates walls. Therefore, to ensure the best link budget for safe packet transmissions, sub 1 GHz solutions, such as RIIM, are the more reliable option than 2.4 GHz-based solutions.

In addition, due to the widespread and the common laws making the 2.4 GHz band license-free nearly worldwide, this makes this band specifically congested. Therefore, it poses more danger to packets in terms of noise and interference. Such phenomena very well might degrade link quality, thus, severely degrading reliability.

Acknowledgments and Retransmissions

Now taking a deeper dive into the stack, RIIM offers acknowledgements over two layers, the application layer and the link layer. Acknowledgement packets are an absolute necessity to guarantee reliability. Given the very unpredictable nature of the RF realm, something as simple as a bus driving by close to an antenna, can cause a momentary drop in link quality which might result in packet loss. Therefore, RIIM ensures maximum reliability and the best packet success rare by implementing, not only one, but two layers of acknowledgments.

The first layer of acknowledgments is in the link layer. This refers to any message exchange happening between two neighboring RIIM nodes. Link Layer acknowledgments happen on hop-to-hop basis, no matter what messaging protocol is used, be it UDP or CoAP. In either way, link layer acknowledgments exist, and the receiver always informs the transmitter when the packet is received. Tat way, if a transmitter does not receive an ack back from the receiver, it will be aware that its original message was not received and then it will retransmit it.

Moreover, RIIM also utilizes end-to-end acknowledgments. This type of acknowledgements happen only between two ends of a message, and its an exclusive option only for CoAP messages. This means that this type of ack messages are not exchanged on hop-to-hop basis. This type of end-to-end ack acts as an extra layer of security exclusive between the original sender and the intended end receiver, to ensure the best reliability and that all packets are successfully received by their end receiver.

TSCH: Frequency Hopping

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.

Being a frequency hopping technique, TSCH allows RIIM nodes to transmit packets on different frequencies from a pre-set frequency list. This means that with TSCH reliability is ensured as interference on a certain channel would not bring down the service entirely. This ensures RIIM radios have plenty of safe margin in case of the presence of jamming or interference noise.

Polite Spectrum Access Techniques

As specified in ETSI's EN 300-220 standard, which governs the operation of SRDs, Polite Spectrum Access is a technique which ensures radios use the available spectrum politely, thus, allowing a radio to exceed the 1% duty cycle restriction. To break it down, Polite Spectrum Access consists of two parts, Listen Before Talk (also known as Clear Channel Assessment) and Adaptive Frequency Agility.
LBT (Listen Before Talk), as its name implies, is a technique where the radio scans the channel, assigned to it by the TSCH algorithm, before transmitting on it. If the channel is found to be noisy, the radio waits and does not transmit on it. This dramatically increases the radio's resilience to noise, which directly reflects on the packet

error rate, boosting the network's reliability. LBT listens for a short time window before transmitting. The listening operation is mainly for other transmissions and possible sources of interference on that channel.

Adaptive Frequency Agility works on top of LBT by scanning all channels and 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 best channels with the least noise.

By the use of Polite Spectrum Access techniques, RIIM ensures that the radio listens before transmitting on a channel, and if a channel is frequently found to be noisy, it is dropped from the channel hopping list. This ensures the maximum reliability for radio transmissions.

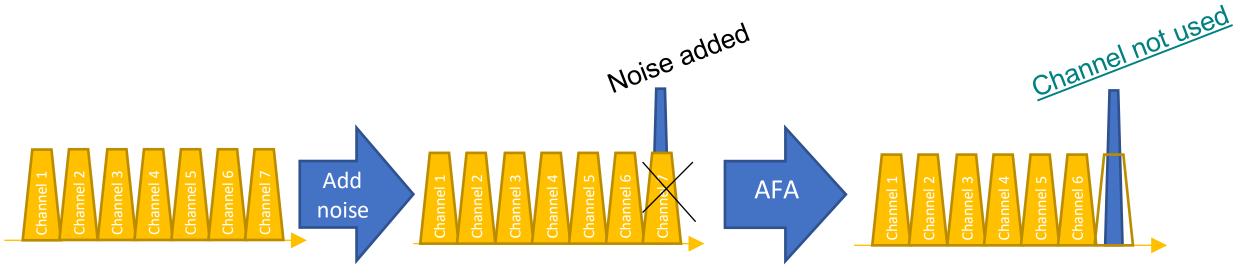

Figure 2. AFA illustrated

Summary

RIIM is designed to provide an industrial grade mesh network, able to cater for a different variety of IoT use cases. One of these use cases is critical IoT applications. Such applications require high network reliability and availability. Which means the network must ensure very high packet success rates and must also ensure available network at all times.

To best tackle this, RIIM offers multiple layers of reliability over much of its stack. Starting from the top, RIIM operates using a mesh architecture, which ensures multiple alternative RF paths in case on is broken. Then, RIIM utilizes two layers of acknowledgments, to ensure lost packets are recognized and retransmitted.

Moreover, RIIM uses TSCH which enables two very important features, frequency hopping and polite spectrum access techniques. Frequency hopping ensures that packets are sent over multiple frequencies, to avoid noise and jamming. Whereas polite spectrum access techniques ensure that noisy channels are determined early before transmission and are avoided. Such features ensure that RIIM offers users the most reliability while keeping cost, complexity, and power consumption low.

Document Revision History

Document Revision	Changes
1.0	First release

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