

# **lumenradio Wireless Mesh Decoded User Guide**

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**lumenradio Wireless Mesh Decoded** 



#### **Product Information**

- Wireless mesh networks have revolutionized connectivity by extending wireless range through interconnected nodes.
- They are ideal for IoT ecosystems and smart city projects, providing reliable, flexible, and cost-effective connectivity over large areas.

### **Product Usage Instructions**

- Wireless mesh networks allow each node to relay data to the next, creating a vast, interconnected web.
- This structure enhances reliability and simplifies deployment compared to traditional cabled networks.
- Place nodes strategically to ensure optimal coverage.
- Power on each node and configure them to join the mesh network.
- Verify connectivity between nodes to ensure proper data relay.
- Consider technologies like Cognitive Coexistence for improved reliability.
- Ensure nodes are updated with the latest firmware for enhanced performance.
- Regularly monitor network performance and troubleshoot any connectivity issues promptly.

### **FAQ**

- Q: What is the benefit of Cognitive co-existence in wireless mesh networks?
- A: Cognitive Coexistence allows the network to operate in crowded wireless spaces without interference, ensuring reliability by dynamically adjusting transmission channels.

### **About the Author**

- Niclas Norlén is the founder of LumenRadio and a pioneer in the field of wireless technology.
- He has more than 25 years of experience delivering business-critical wireless connectivity, ranging from major
   Hollywood productions to large-scale IoT systems.
- Niclas won E&Y's Entrepreneur of the Year 2023 award in West Sweden for Best International Growth.

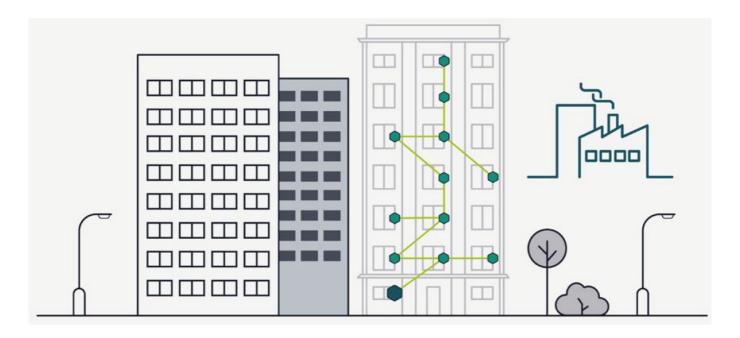


- "Mesh is a real buzzword these days in the wireless industry and is much vaunted in the fields of industrial IoT and smart infrastructure. I've been working with meshing technology for many years and have been instrumental in developing LumenRadio's own MiraMesh.
- Done right, meshing technology can be transformative for a wireless product.
- Paired with our best-in-class wireless range and Cognitive Coexistence, MiraMesh outperforms other technologies. It covers vast areas, even meshing through reinforced concrete in the most crowded wireless spaces.
- This translates to minimal effort needed for planning, installation and maintenance, whereas other competing
  meshing technologies often cause frustration and require extra work, contradicting the promise of user-friendly
  tech.
- In this paper, I'll delve into why MiraMesh is a cornerstone for some of our products and why we've opted out for others. It's a behind-the-scenes look at our technology and why we confidently say we deliver Wireless Without Worries."

#### THE RISE OF MESH

### A transformative technology

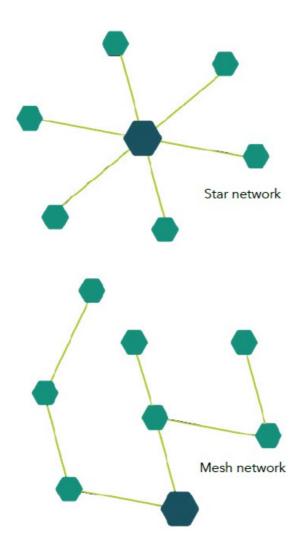
- Wireless mesh networks (WMNs) have revolutionized the way we achieve reliable, flexible and cost-effective connectivity over large areas.
- This has made them particularly suited to providing the infrastructure necessary to support the huge number of connected devices in IoT ecosystems. And they are equally integral to the development of smart city projects, enabling city-wide connectivity for various applications like surveillance, traffic management and public Wi-Fi.
- Mesh networks extend wireless range by allowing each node to relay data to the next, effectively creating a vast, interconnected web. This structure not only enhances reliability but is also much simpler to deploy than the traditional cabled alternative, not to mention cheaper to install and maintain.
- In this piece of knowledge content, we're going to be looking at the fundamentals of wireless mesh, before lifting the lid on how LumenRadio has succeeded in taking meshing technology to the next level.



### What is Wireless Mesh

#### An introduction to mesh networks

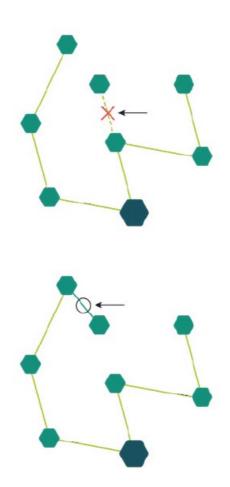
- To explain what a wireless mesh network is, it's helpful to first look at what a star network is.
- In a star network, each device (or node) is connected to a central device (or hub). The hub controls the network and there is a single path for data to travel from the hub to a node.
- It's technically simple and very reliable but the network can be affected when devices are added or removed, and it is completely dependent on the central hub.
- In a mesh network, each device is directly or indirectly connected to every other device in the network.
- Each node can act as a repeater for the signal and there are multiple paths for the data to travel. The network gets its name from the mesh structure which is created as a result.
- So, in simple terms, a wireless mesh network (WMN) is a cooperative system where each device helps spread the connection, making it stronger and more reliable as a whole.



# Key features of wireless mesh

# Self-healing

- The beauty of wireless mesh is that it is self-healing if one link fails, the network still carries on working and it does so without manual intervention.
- When a node becomes unreachable, the network can dynamically reroute traffic through alternate paths to maintain connectivity. Any node can send information to any other node making wireless mesh extremely flexible and resilient across a large area as there is no single point of failure.

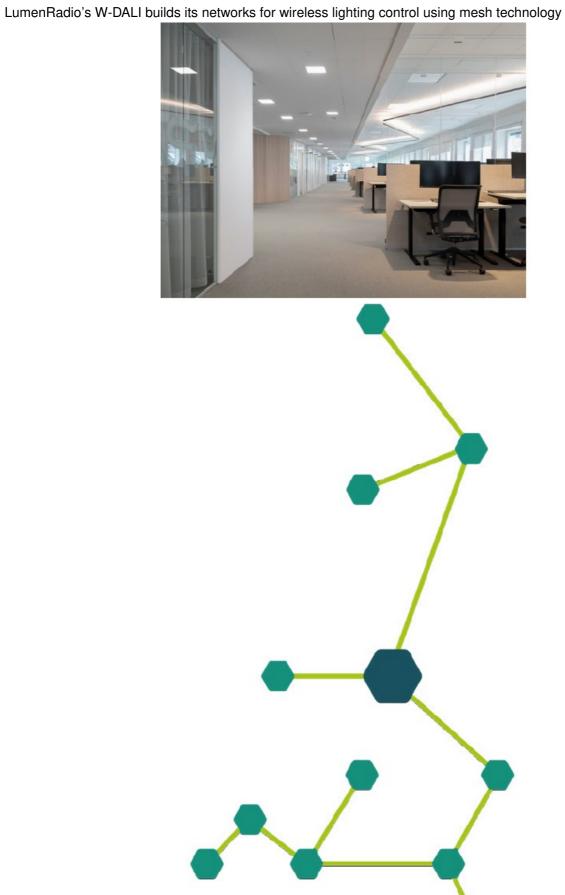


### **Self-configuration**

- Another useful property of a mesh network is self-configuration. Self-configuration means that the network of
  devices sets itself up, adjusts itself and maintains itself without needing someone to manually configure each
  connection.
- As a result, the network is incredibly flexible and simple to deploy, especially in places where manual setup
  would be difficult or time-consuming. This also makes mesh a solution that scales extremely well since any new
  nodes that are added automatically join the network.

### **HELPFUL DEFINITIONS**

- WMN wireless mesh network; a decentralized structure with interconnected devices or nodes that can all communicate with each other.
- Node any device which is part of the mesh network.
- Gateway a node that provides an interface between the mesh network and external networks, such as the
  Internet. Gateways route traffic between the internal mesh network and outside networks, allowing for broader
  connectivity.
- **Mesh Router** a specialized node that primarily manages network traffic. Routers facilitate communication by forwarding data packets between nodes, ensuring that information can travel through the network efficiently.
- **Mesh Client** an end-user device, such as a laptop, smartphone or tablet, that connects to the mesh network to access services.
- Repeater a node with the primary function of extending the network's range by receiving and retransmitting signals. Repeaters help in areas where direct communication between nodes is not possible due to distance or obstructions.



**Taking Wireless Mesh to the Next Level** 

#### How to realize the full potential of mesh

- Mesh does have its downside even though it is self-healing, it is not invulnerable.
- In fact it can be considered sensitive to interference.
- Take Thread in an office, for example.
- Turning on a microwave can be enough to block all the nodes in that room creating a dropout large enough to collapse the entire network.

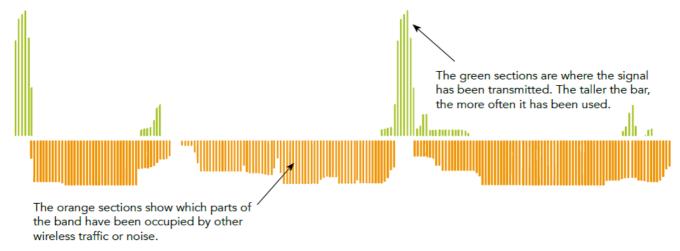


### **Introducing MiraMesh with Cognitive Coexistence**

- LumenRadio's own mesh network platform, MiraMesh, removes this Achilles heel thanks to patented Cognitive Coexistence technology a feature unique to MiraMesh networks.
- Cognitive Coexistence ensures the reliability of a network by scanning the 2.4GHz band and avoiding areas being used by other wireless devices.
- As a system with only a few pre-defined rules, it has the freedom to be completely flexible and react to changing conditions in real-time, hopping to the optimal channel for transmission whenever needed.
- In this way, it allows a MiraMesh network to operate in the crowded 2.4GHz space with other wireless technologies without causing interference or being interfered with.
- For a deeper dive into the merits of Cognitive Coexistence and what makes it such a game-changer in the world of wireless, you can download this Insider's Guide.

#### **GET YOUR COPY**

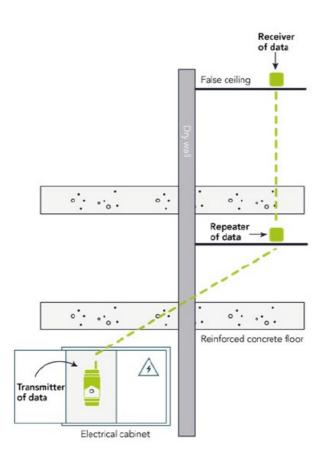
• This diagram represents Cognitive Coexistence in action within the 2.4GHz band. Each bar represents a specific 1MHz frequency in the frequency spectrum 2.402GHz – 2.480GHz.



 Cognitive Coexistence skillfully utilizes the free sections and adapts to changing conditions to always find the best way through.

#### Giving mesh a superior range

- In a mesh network, nodes can work as repeaters, sending data across the network. Consequently, multiple paths exist between each two nodes. This redundancy enhances network resilience because if one route fails, an alternative path can be found.
- With nodes acting as repeaters, even nodes not directly within range of each other can communicate via
  intermediate router nodes. This is a major advantage of mesh networking in IoT applications because it allows
  a user to extend the range of the network.
- Couple this with Cognitive Coexistence which significantly extends the range of a wireless product and you
  have a world-beating solution. You can also read more about this in our Insider's Guide to Cognitive
  Coexistence.





Heritage buildings typically have thick, stone walls so building automation retrofits can only be carried out using a wireless control solution – and mesh is the best option.

### Choosing the right tool for the job

- LumenRadio specializes in providing winning wireless alternatives to a range of different cable protocols.
- In the building and industrial automation world, this includes wireless solutions for the BACnet, Modbus and DALI protocols. All of these solutions use meshing technology to create a wireless network.
- But in another field entertainment lighting where LumenRadio provides CRMX, the industry-leading solution for wireless DMX a star network is preferred to mesh. If mesh works for the other products, why not here? The answer is latency.
- Latency is the time it takes a signal to travel from point A to point B. The lower the latency, the faster the signal has completed its journey. This is important to technical professionals in the entertainment industry because they do not want audiences to experience any form of lagging or out-of-sync lighting effects.
- They expect a latency of 5 milliseconds or less when controlling lighting for film and concerts1. For wirelessly controlling street or office lighting, this type of speed is not mission-critical.
- What the entertainment lighting industry wants can be described as "deterministic latency" where there is no randomness involved. Here a star network is ideal as it gives lighting technicians controlled latency which they can be guaranteed will not exceed their limit of 5ms.
- Mesh cannot make the same assurances, since every time a data packet hops from one node to another, latency is added. Meshing has automated hopping,

Mesh is not suited for all applications – Wireless DMX, which is widely used in the entertainment lighting industry, uses a star network configuration.



- so the number of hops made cannot be influenced and the exact time it takes for the signal to be received cannot be known in advance.
- Mesh also requires a certain amount of bandwidth to operate. For wireless DMX, all the available bandwidth is required to transmit the lighting control data so using mesh in this case is too costly.

Cable protocols	Application area	LumenRadio's wireless options	Type of network
DMX	Entertainment lighting control	CRMX	Star
DALI	Lighting control	W-DALI	
BACnet	Building automation and control systems	W-BACnet	Mesh
Modbus	Industrial automation and control systems	W-Modbus	

<sup>1</sup>Research from various universities (MIT, Parma and St. Andrews) would suggest that the human eye cannot perceive movement quicker than 13ms. With a latency of 5ms you can be assured that no human being will notice a lag!

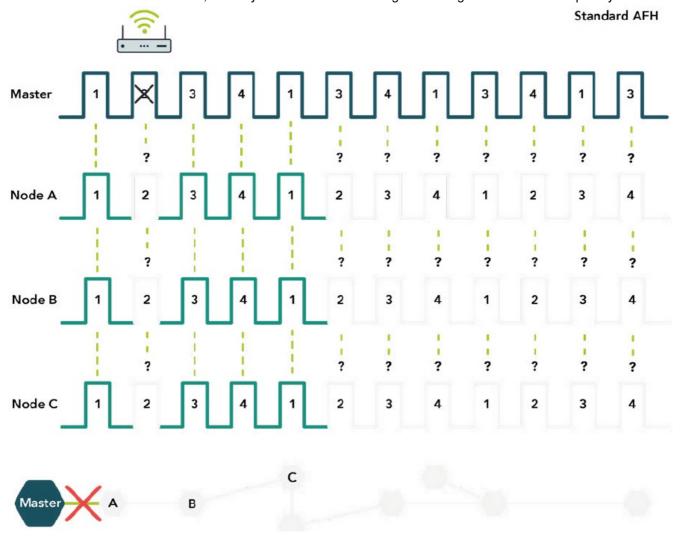
# Frequency synchronization creates mesh network stability

- The beauty of Cognitive co-existence is how effective it is at making use of the gaps on the narrow 2.4GHz frequency by optimizing adaptive frequency hopping (AFH).
- When a standard wireless system uses AFH, it cycles through a static list of frequencies and blocks a section of the 2.4GHz band where there is already noise.
- But as it continues to hop, the predefined sequence no longer syncs up and the receiver expects to hear a signal on a different channel. This increases the likelihood of data loss and network failure.
- Mesh networks are particularly sensitive to this loss of synchronization as it can cause the whole network to fail.

If there is a node that hasn't received a signal, then it cannot repeat that signal. Frequency synchronization is lost but it still takes time for the network to realize this and once it does register, it takes even more time as the entire network resets itself.

- Packet loss is a reality and even the best networks have to live with this. This does not have to be fatal for a star network, but for mesh, it is catastrophic, which is why most companies do not even attempt to do wireless mesh using AFH.
- LumenRadio, however, can give you the advantages of AFH in a mesh network thanks to Cognitive Coexistence.

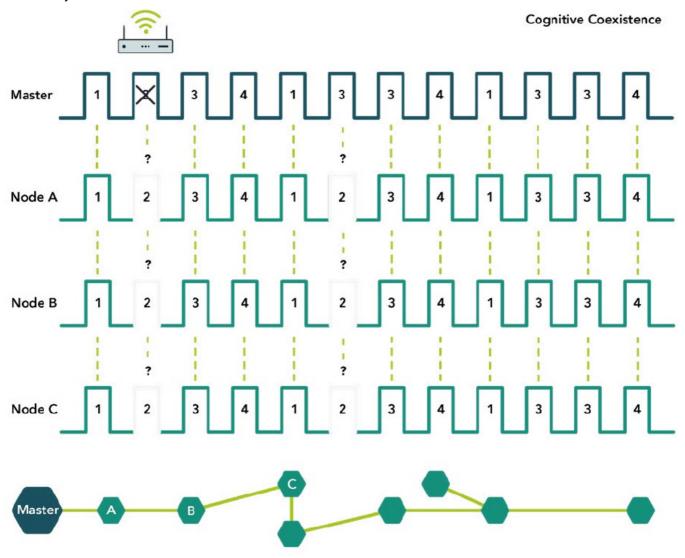
Mesh networks rely heavily on frequency synchronization. A loss of alignment due to interference can disrupt data flow and cause network-wide failure, as unsynced nodes are no longer listening on the correct frequency.



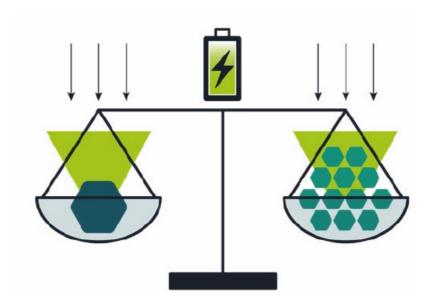
#### How it works

- Cognitive Coexistence improves upon the weaknesses of standard AFH systems by employing "smart blocking" technology. Essentially it replaces the blocked channel with a good channel on the list, so the rest of the sequence is maintained and only a small piece of data is lost. This ensures that the transmitter and receiver remain sufficiently in sync to avoid a system failure.
- This is why the marriage of Cognitive Coexistence with LumenRadio's mesh is so important as it ensures a vastly more stable and reliable network.

Cognitive Coexistence minimizes data loss in mesh networks by intelligently adapting to interference and keeping



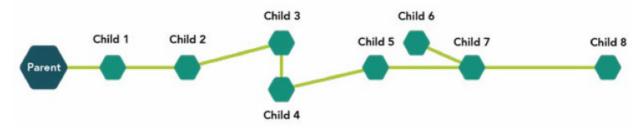
# **Balancing the Data Flow**



# LumenRadio's wireless mesh takes a balanced approach to decision-making

Imagine you want to have a mesh network made up of 200 nodes. Conventional wisdom says that you would require a "super node" – one that is designated as the ultimate decision maker for the whole network and works out the frequencies for all the other nodes. This super node would have to handle a large flow of data and therefore require a larger CPU. This creates an issue not least in terms of energy usage.

LumenRadio's MiraMesh solves this problem by removing the need for a super node altogether. It spreads the data workload over each of the nodes in the network so that there isn't one single node that requires a much higher level of computing power. Why does this matter? Because it means there is effectively no limit to the number of nodes a MiraMesh network can have.



Every child node in the network talks and contributes with data, but the closer a child is determines how important the parent rates that information.

### **Low Energy Mesh**



### The (un)official record holder

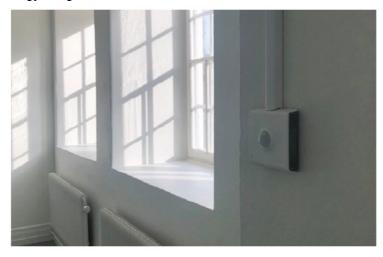
- In many circumstances, it is advantageous to utilize low-energy mesh for low-power, short-range communication between devices.
- Low energy mesh is ideal for applications where power consumption is critical and is a key enabler for batteryoperated wireless products used in industrial applications.
- LumenRadio holds the (un)official record for the lowest amount of energy used, having reduced the power consumption for meshing nodes to less than 16uA, which enables more than 15 years of operation in routing mode from an AA-sized battery.

#### The experts' choice

• This is significantly better than any other competing wireless technology. It enables battery-powered products to run on the same battery throughout their entire lifecycle and means that building-wide battery-powered

meshing connectivity is achievable.

- Many large companies such as SKF, Honeywell and Swegon have chosen LumenRadio because of this
  best-in-class energy usage. In lab tests, LumenRadio always performs the strongest. And in real-world
  conditions, it performs even better.
- This is because Cognitive Coexistence technology makes it incredibly likely that a data packet is delivered at the first time of asking. On average, other technologies will take more tries and resend the data more often, which results in higher energy usage.



For low-energy mesh, MiraMesh outperforms the competition making it best-in-class for power usage

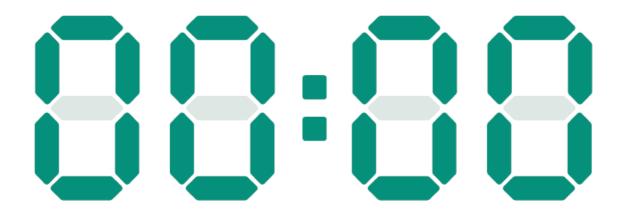
#### HOW LOW ENERGY MESH KEEPS POWER CONSUMPTION AT AN ABSOLUTE MINIMUM

Devices in a low energy mesh network are optimized to use minimal power, extending battery life so that they can operate for many years on a single charge. Here are some of the features they use to conserve power:

- **Sleep modes**: Devices often have sleep modes where they consume extremely little power when not actively transmitting or receiving data.
- **Duty cycling**: Devices can be configured to wake up periodically to check for data transmission needs and then return to a low power state, reducing overall energy usage.
- **Optimized communication**: Efficient routing algorithms and data packet management help minimize energy usage during communication.



### **Time Synchronization**



#### Keeping in sync with microsecond accuracy

- If a node in a wireless mesh network is powered by electricity, it can transmit and receive information all the time there are no issues with energy consumption.
- A battery-powered node, however, cannot be constantly "on" and must use features like sleep mode to ensure it isn't wasting battery life (see Chapter Three: Low Energy Mesh).
- In many real-world cases though, mesh must combine battery and electricity power sources in the same network. This is referred to as "mixed configuration". One typical example could be a battery-powered control switch on a wall that controls a node on a lighting fixture that is connected to the mains.
- To be able to run mesh on a mixed configuration network like this, everyone has to work from the same clock and this is where LumenRadio's MiraMesh excels.

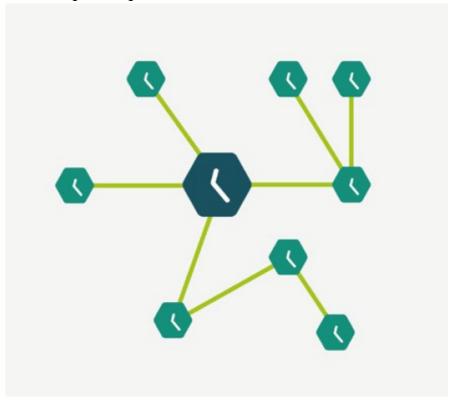
# The benefits of a precise internal clock

Accurate time synchronization is a key feature of MiraMesh. It allows nodes that are saving energy by sleeping, to wake up when it's time to receive a signal. The greater the accuracy, the more energy is saved, as the node does

not need to be active longer than is necessary.

Ideally, every node would wake up at exactly the same time, namely at the point when the signal is transmitted. But if this cannot happen simultaneously, then the "dead time" between the signal being sent and the signal being received, should be as minimal as possible.

In a 200-node network, for example, MiraMesh is tuned to make sure the internal clock in node 1 and the internal clock in node 200 are never out of sync more than 50 microseconds! The system regularly recalibrates to maintain this incredible level of accuracy and reduces dead time massively so that wireless mesh can be kept running for as long as a decade without having to change the batteries.



### What can you use high-precision timing for?

Here are a couple of real-world examples where super-accurate time synchronization is a real plus.

- 1. Have you heard of the "popcorn effect"? It refers to the phenomenon where multiple lights in a wireless network do not turn on or off simultaneously but instead activate or deactivate in a staggered, inconsistent manner. This creates a visual effect where the lights appear to pop on one after another, similar to the way popcorn kernels pop at different times in a popcorn maker.
  - With MiraMesh the popcorn effect is avoided entirely as the internal clock in each chip ensures synchronization between transmitter and receiver so accurately that all the lights will be perceived to turn on in unison.
- 2. Having wireless mesh with an accuracy to within 50 microseconds is also a great advantage when it comes to measuring and collecting data.

Swedish company, SKF, is the world's largest manufacturer of ball bearings and is at the absolute cutting edge of technology in that field. It can measure the minute vibrations in its bearings and accurately predict when those bearings need to be replaced.

As a result customers never have to experience any downtime in their production line because of faulty bearings. To correctly make these lifespan predictions, however, SKF needs to know that measurements from two vibration sensors on either side of an axel, for example, were taken at the same period.

Standard mesh networks are not only unstable but also lack accurate time synchronization, which is why SKF uses LumenRadio's wireless mesh for the job.

#### **Summary**

- Done right, you can achieve great things with mesh
- Wireless mesh networks have revolutionized the way we achieve reliable, flexible and cost-effective connectivity over large areas, making them integral to IoT ecosystems and the development of smart cities.
- They create a decentralized system where each node relays data to others, forming a self-healing, self-configuring network. But they are vulnerable to interference and collapse.
- Enter MiraMesh, LumenRadio's own mesh network platform, which removes this Achilles heel thanks to its unique Cognitive Coexistence technology.
- Cognitive Coexistence dynamically scans the 2.4GHz band to avoid interference from other devices, allowing it to operate in extremely crowded environments.
- This approach provides stable, synchronized communication with minimal packet loss, outperforming other wireless technologies in range and reliability.
- Together with extremely low energy usage and accurate network-wide synchronization, this has taken wireless
  mesh to a whole new level.

#### **Wireless Without Worries**

Want to learn more about frequency-friendly, rock-solid wireless technology? LumenRadio offers pre-certified radio modules ready for integration to give your devices the most reliable wireless connectivity. We also have end-user products which replace some of the most used cable standards with a more convenient wireless alternative – from Wireless DMX and W-DALI to W-BACnet and W-Modbus.

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### **Documents / Resources**



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#### References

User Manual

Manuals+, Privacy Policy