Get Smart with Your Cold Chain Monitoring:

How Wireless Monitoring Ensures Food Safety

Introduction

Monitoring and controlling food storage temperatures at all stages of the cold chain is a critical aspect of food safety. Any break in the chain can lead to food waste, the risk of foodborne illnesses, and a failure to adhere to standardized regulations. Thanks to the robustness of LoRaWAN technology, wireless sensors are now better able to handle the performance requirements of demanding environments located in food service organizations including commercial restaurants, warehouses, transport vehicles, and every other stage of the food cold chain. This white paper discusses how the right LoRaWAN system can ensure the most effective cold chain monitoring.

Ensuring Food Safety Compliance Through Wireless Sensing

For health and economic-related reasons as well as to ensure FDA-compliance, restaurants and the food service industry in general have very strict guidelines for food safety. According to the **Centre for Disease Control & Prevention (CDC)** an estimated 48 million Americans (about one in six people) get sick from foodborne illness each year. Studies done by the Food and Agriculture Organization (FAO) of the United Nations showed that an estimated one-third of all human food (approximately 1.3 billion tons) world-wide is lost or wasted somewhere along the supply chain that ranges from farms to processing plants, warehouses, retailers, restaurants, and our own homes (from farm to fork).

There are strict guidelines outlined by the **HACCP (Hazard Analysis and Critical Control Points)** management system. The HACCP is a globally recognized risk-based preventative approach that, according to the **FDA (US Food & Drug Administration)**, addresses food safety by analyzing and controlling "biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution, and the consumption of the finished product." These guidelines apply to all stages of the food service supply chain – from raw materials to shipping to the finished product.

One of the five major risk factors identified in the **FDA's Food Code** is improper holding temperatures. In addition (and alarmingly), the FDA has found that **91% of full-service restaurants have no FSMS (Food Safety Management System).**

Monitoring and controlling food storage temperatures throughout the supply chain or, in this white paper's case, the cold chain, is a critical (and regulated) aspect of food safety. Both raw ingredients and cooked products must be maintained at certain temperatures to ensure they're safe for consumption, and breaks in this chain is one of the biggest reasons for food waste. When proper temperatures are not maintained, food must be discarded or risk the spreading of foodborne illnesses. Considering the number of foodborne illnesses and the massive amount of food waste each year, the need for and enforcement of strict, standardized food safety guidelines is obvious.

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Monitoring Methods and Associated Challenges

There are two methods for measuring and monitoring temperature – manually and automatically via wireless sensor technology. Both methods present challenges.

Traditionally, temperature monitoring has been done manually; someone uses a thermometer to check the temperatures and then logs those temperatures. Not only is this manual process time-consuming, it is also potentially inconsistent and unreliable. An individual must be relied on to actually complete the task in a timely manner, complete the task correctly, properly store the data (whether it be a paper/hard copy log or a computer spreadsheet), and know what to do/ how to respond if the temperature is too warm or too cold. Human error is one of the largest factors in HACCP-related noncompliance.

Even when manual monitoring is done consistently and correctly, it only considers the current temperature at the time it was recorded. It doesn't provide real-time data. It also likely does not account for patterns such as when/if the temperature spiked (or dropped), how much it spiked/dropped, and for how long.

Having access to real-time data and understanding potential patterns is also crucial to maintaining a proper cold chain.

More recently, temperature monitoring is commonly automated by way of wireless sensor technology to monitor, measure, and record real-time temperatures. This automatic method can substantially improve food safety by providing a continuous and consistent data stream of temperatures 24/7, every day of the year. Once collected, this data can be stored in the cloud and accessed from any internet-connected device allowing the retrieval of these temperatures anytime and from anywhere. This enables more immediate action when there is a temperature-related issue allowing companies to be more proactive in solving the problem and decreasing the potential amount of food waste.

The main challenge with automatic monitoring is that launching an automated system can be complicated and expensive for a variety of reasons. The food storage/restaurant industry is an especially difficult environment for wireless connectivity due to the overall environment being challenging for RF communications – stainless-steel surfaces, insulated and concrete walls, and a variety of other radio signal obstacles. Pair these with possibly harsh temperatures and moist environments that are typical inside insulated coolers and freezers. And,

as if these conditions are not already complicated enough, the potential distance between sensors and the equipment to which they transmit data can add another element of connectivity stress.

Temperature Monitoring Challenges:

- **Manual temperature monitoring:** Potentially inconsistent and unreliable, time-consuming, and lacks real-time data.

- **Automatic temperature monitoring via wireless sensors:** Expensive and complicated to set up and maintain.

Aside from harsh and complicated environments, to utilize the full benefits of wireless sensors, a complete end-to-end solution is necessary which requires technology expertise and potential development for your particular cold chain monitoring environment – ranging from the sensors to bridging data via gateways to the cloud and finally the cloud analytics and server pieces to make use of the sensor data itself.

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Cold Chain Management Solutions

Despite some challenges, it's clear from the overall benefits that utilizing a wireless sensor system is the better option for monitoring cold chain temperatures. With their reliable record-keeping capability and ability to provide real-time data in a variety of ways, a system utilizing wireless sensors makes it far easier for restaurants and other food service organizations to minimize loss and comply with applicable regulatory agencies. As already stated, wireless sensors provide real-time data that is stored in the cloud, making it accessible at all times to the company's managers/decision-makers and in whatever display format is required.
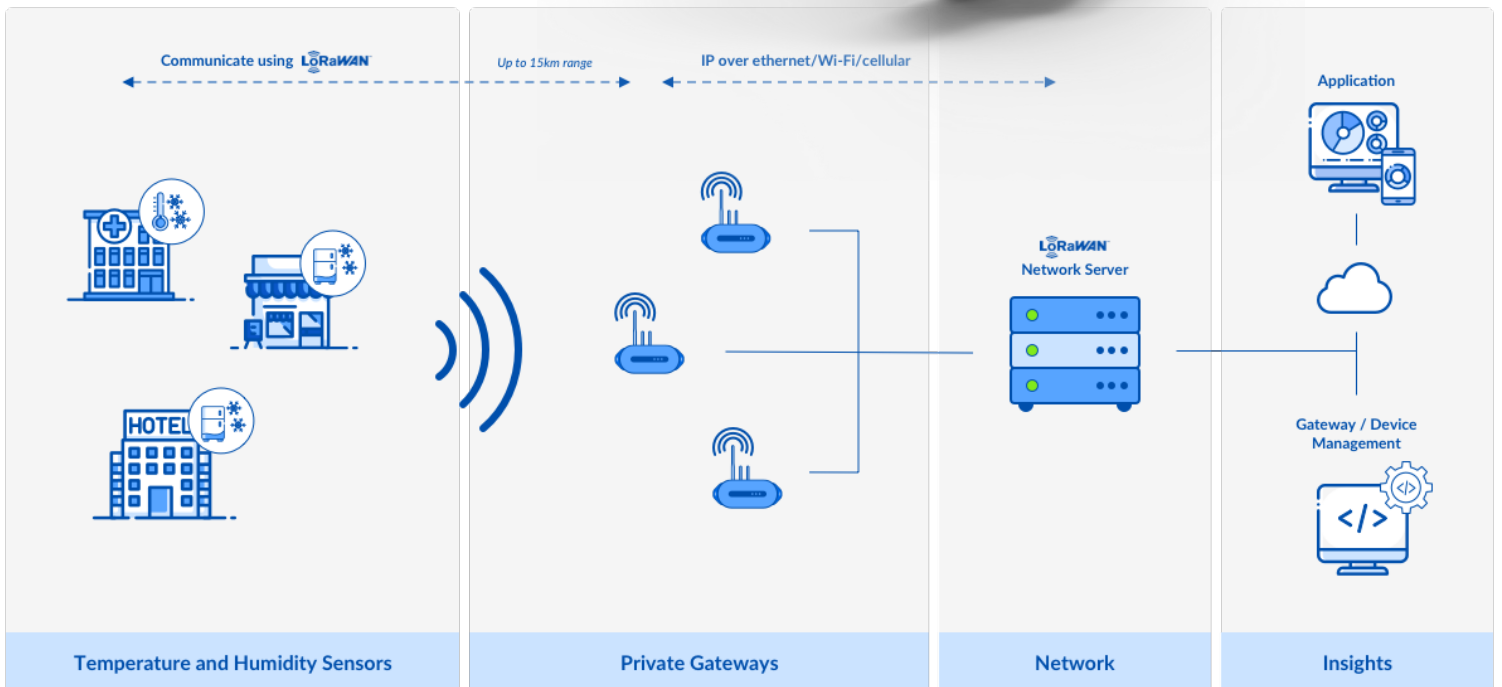
There are several factors to consider when initiating a cold chain temperature management system. A full solution involves industrial-level hardware such as wireless sensors and base stations called gateways, monitoring software and applications, effective connectivity that functions well in a harsh environment, and a network service provider partner with a good go-to-market strategy. We'll look at each of these factors in this paper.

Rather than start the discussion at the beginning with wireless sensors and gateways, we're going to jump first to the ideal wireless technology behind your cold chain monitoring network – LoRaWAN.

LoRaWAN (Long Range Wide-Area Network) is an extremely robust technology that outperforms alternative technologies for battery-operated devices in challenging cold chain environments. This technology enables low-powered, battery-operated devices to wirelessly communicate over long distances (2-3 km in urban settings and 6-10 km in rural settings). LoRaWAN achieves its robustness to interference and its long-range communication properties from the use of chirp spread spectrum radio modulation, used in military and space applications for decades. LoRaWAN is also unique in that it can be deployed on public or private networks. The ability to deploy on a private LoRaWAN network is advantageous for several reasons including:

- **Location –** The area/environment in which you plan to deploy your network may not have a public LoRaWAN network in place.
- **Remote or inaccessible sensor locations –** If you need to deploy sensors in extremely remote areas or in difficult to access areas (such as deep basements), a public network may not be accessible.
- **Large deployment area –** If your plan is to deploy a very large number of LoRa sensors, having your own LoRaWAN network can decrease the overall cost.
- **Security –** Avoiding a public LoRaWAN operator and using your own private network enables you to own your data end-to-end.

Communicate using LoRaWAN   Up to 15km range   **IP over ethernet/Wi-Fi/cellular**   **Application**

LoRaWAN Network Server

Gateway / Device Management

Temperature and Humidity Sensors   **Private Gateways**   **Network**   **Insights**

Sensors and Gateways

As we covered earlier, wireless sensors automatically collect the data you need to ensure proper temperature and/or humidity maintenance. To ensure accurate and ongoing monitoring, these wireless sensors can be configured to transmit data as often as required to meet your particular cold chain needs. Because they only transmit as needed, they're extremely power-conscious and can last for years on one set of standard AA batteries ensuring a minimal amount of maintenance on your part. With a combination of wireless sensors along with a LoRaWAN gateway and network, you can create an entire network to cover multiple cold chain locations. This network can be easily configured and monitored using a smartphone, tablet, or any other device that fits your needs.

A LoRaWAN gateway receives data from, and sends data to, your wireless sensors. Once the gateway receives data from the sensors via LoRaWAN, it uses high-bandwidth networks (such as Wi-Fi or cellular) to transfer that sensor data over IP to the cloud. A single gateway can serve thousands of sensors and, by combining these wireless sensors with an associated gateway (and LoRaWAN network), you can create a low-cost, easy, automatic plug-n-play system. Install the batteries, plug in the cables, and your system is up and running. With this ease of use, restaurant managers, food service workers, compliance employees, and any other associated personnel do not need to be sensor or wireless experts.

To receive your sensor's temperature and humidity readings in your application, you will need a central network service to manage your devices and securely route the data after it is received by the gateway. In the selection of the right network server, the following considerations play a role:

- **Ease of integration –** how elaborate and well defined are the server's APIs to connect with your application cloud of choice, for example Microsoft Azure or AWS?
- **Lock-in prevention –** how easy is it to switch vendors after deploying the services?
- **Flexibility and scalability of deployments –** do you manage your own infrastructure or rather go for a hosted service? Can you serve multiple regions and what are the availability requirements?
- **Pricing model –** do you rather pay per connected gateway or per registered device? How does the model scale along with your own pricing model, beyond 10s or 100s of thousands of devices?
- **Security –** what are your or your customer's security policies? Who are allowed to manage the security keys of your devices?
- **Service Level Agreements and support –** do the service levels enable you to achieve the SLA's you have in place with your customers?

Choosing the right network server provider is critical to your cold chain monitoring solution. For example, The Things Network is a free, well-documented service that provides the backbone for your LoRaWAN-based cold chain solution. They also offer an enterprise service tier for large and complex deployments with high availability requirements. They have an extensive track record in the cold chain monitoring domain.

Benefits of LoRaWAN Technology:

✓ **Outperforms other technologies in harsh cold chain environments**
Signals penetrate well through thick walls

✓ **Long range functionality**
Up to 10km (outdoor)

✓ **Low power use**
Devices can last years on a single battery

✓ **Low bandwidth**

✓ **Inexpensive**
(e.g. $75 for a temperature sensor)

✓ **Secure**
128-bit end-to-end encryption

The Take-Away (pun intended!)

As stated previously, it's obvious that monitoring and controlling food storage temperatures at all stages of the cold chain is a critical aspect of food safety. The fact that improper food holding (time and temperature) is one of the top non-compliances for both fast food and full-service restaurants further emphasizes this point. The robust LoRaWAN technology enables wireless sensors to better handle the performance requirements of demanding environments located in food service organizations at every stage of the food cold chain.

To gain the full benefits of your wireless sensors, you need a complete system to manage the data that your sensors provide... a system that includes data storage, analysis and visualization as needed.

In summary, to ensure the most effective cold chain monitoring system, you need the following:

- The best wireless sensors and gateway that can handle your harsh and challenging food storage environment
- The technology expertise or an experienced team to help develop, customize, and support your entire system
- The most robust technology to ensure connectivity and consistency in your challenging cold chain system
- A network service provider with a solid go-to-market strategy to make your task easier, less costly, and most effective

About Laird Connectivity's LoRaWAN Design Solutions

Sensors and gateways from Laird Connectivity are the ideal choice for cold chain applications. Our range of technology expertise includes high-performing and reliable LoRaWAN connectivity and decades of Wi-Fi and Bluetooth experience which delivers unmatched capabilities in the cold chain industry. Pair IoT sensors and gateways right out of the box or customize to meet specific design requirements.

Sensors

Our family of BLE-enabled sensors can be built to specific application needs. The Sentrius RS1xx is a battery-powered, long-range integrated temperature and humidity sensor equipped with LoRaWAN and BLE connectivity. Its small, rugged form factor contains superior performance and flexibility. It also works with the RG1xx series of LoRaWAN gateways for simple out-of-the-box integration and is compatible with 3rd party cloud providers such as AWS IoT and LoRa network ecosystem partners like TTN.

Gateways

Laird Connectivity IoT gateways are proven to work in the harshest environments like industrial kitchens and steel refrigerators and freezers without compromising cost or security. We make sure devices continuously provide edge intelligence to respond to real-world situations in real time. The RG1xx Series of LoRaWAN/multi-wireless gateways and IG60 IoT gateways give companies full ownership over their network, adding multi-protocol connectivity to sensors and devices to gather actionable IoT intelligence.

LoRaWAN network

The Things Industries (TTI) is a well-established LoRaWAN network server provider to connect your devices and gateways to the cloud. TTI provides a backbone to over 2,000 locations in US and EU for cold chain monitoring, comprising restaurants, hotels, hospitals, pharmaceuticals, transport and logistics. With an installed base of over 15,000 LoRaWAN gateways, and 150 enterprise customers globally, TTI assumes a leading role in the global ecosystem for private LoRaWAN networking.

lairdconnect.com/iot-platforms