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Bluetooth Meets Seafood: BLE Sensors Transforming Seafood Traceability

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ABSTRACT

Seafood is one of the most heavily traded and most fraud-prone food commodities in the world, moving through fishing vessels, processors, cold stores, distributors, and retailers before it reaches a consumer's plate. At every one of these handoffs, information about the product's origin, temperature history, and handling can be lost, altered, or falsified. This article examines how Bluetooth Low Energy (BLE) sensor technology is emerging as a practical, low-cost tool for closing these traceability gaps. Unlike static RFID tags that must be manually scanned, BLE sensors broadcast identity and environmental data continuously to any nearby smartphone or gateway, making it possible to reconstruct a near-continuous, item-level history of a seafood shipment's journey. Drawing on recent research in wireless sensor networks, cold-chain logistics, and blockchain-enabled food traceability, the article explains how BLE works, why it is well suited to the seafood cold chain, where it is already being deployed, and what challenges remain before it becomes a mainstream traceability tool. The discussion is aimed at a general audience, seafood industry professionals, supply chain managers, and technology-curious readers rather than specialists in wireless protocol design.

KEYWORDS

Bluetooth Low Energy (BLE); seafood traceability; cold chain monitoring; IoT sensors; food supply chain; blockchain; fisheries logistics

Introduction

A piece of shrimp on a supermarket shelf may have travelled through a dozen hands before it reached the customer: a fishing crew, an on-shore processor, a cold-store operator, a freight forwarder, a customs inspector, a distributor, and finally a retailer. Each of these steps is an opportunity for the product's story to become murky. Studies of the global seafood trade have repeatedly found that a significant share of seafood sold to consumers is mislabelled or cannot be reliably traced back to its point of catch, undermining both food safety oversight and consumer trust (Ferrari, 2023; Bhat et al., 2021). Illegal, unreported, and unregulated (IUU) fishing compounds the problem, since fraudulent paperwork can disguise the true origin of a catch as it moves through a fragmented, multi-party supply chain (Alabi & Mondragon, 2023).

Digital tools such as barcodes, RFID tags, GPS trackers, and increasingly blockchain ledgers have been proposed as solutions, and each has found a place in seafood logistics. But most of these tools share a common weakness: they only record information when someone actively scans a tag or logs a data point. Between those scans, a shipment's real condition is essentially invisible. Bluetooth Low Energy (BLE) sensors are gaining attention precisely because they remove this blind spot. A BLE-tagged crate of fish does not wait to be scanned; it continuously "shouts" its identity and sensor readings into the air, ready to be picked up by any compatible device that happens to be nearby (Surgere, 2024). That shift from occasional, deliberate scanning to continuous, passive sensing is what makes BLE a genuinely different proposition for seafood traceability, not just a cheaper version of RFID.

The Traceability Problem in Seafood Logistics

Seafood is unusually hard to trace for three structural reasons. First, it is highly perishable; quality begins degrading from the moment of catch, and safety depends on maintaining a narrow temperature band throughout transport, processing, and storage. Second, the supply chain is fragmented across many independent actors like small-scale fishers, processors, exporters, and distributors who often keep records in incompatible formats or on paper. Third, seafood is frequently transformed along the way (filleted, frozen, repackaged, mixed with other catches), which breaks the simple one-to-one link between a "batch" and its original source.

Recent systematic reviews of digital traceability technologies in fish supply chains conclude that no single technology addresses every stage of this journey. Instead, the strongest systems combine several tools, sensors for real-time environmental data, RFID or barcodes for batch identity, and blockchain for tamper-resistant record-keeping layered on top of one another (Bhatt et al., 2025). Within that combination, BLE sensors are increasingly positioned as the "sensing" layer: the component that continuously captures what is actually happening to the product physically, as opposed to what a paper or digital record claims happened.

What BLE Sensors Actually Do?

Bluetooth Low Energy is a wireless communication standard built for devices that need to run for months or years on a small battery while sending small amounts of data frequently. Unlike classic Bluetooth, which was designed for high-bandwidth uses like audio streaming, BLE trades bandwidth for extremely low power draw, making it well suited to small sensor tags. Foundational engineering studies of the protocol have shown that, depending on how the connection parameters are configured, a BLE device powered by a small coin-cell battery can theoretically operate for anywhere from a couple of days up to well over a decade, with a single master device able to communicate with thousands of peripheral sensors (Gomez, Oller, &Paradells, 2012).

In a seafood logistics context, a BLE sensor is typically a small, rugged tag attached to a crate, pallet, or shipping container. It carries one or more miniature sensors, most commonly temperature, but sometimes also humidity, light exposure, shock, or door-opening detection — along with a tiny radio chip. Rather than waiting for a handler to scan it with a dedicated reader, the tag periodically broadcasts an "advertisement" containing its identity and latest readings. Any BLE-capable device nearby a warehouse gateway, a delivery driver's smartphone, even another BLE tag acting as a relay can pick up that broadcast and forward it to a central database (Wiliot, 2025). Because reading a BLE tag requires no line-of-sight and no deliberate scanning action, data can accumulate throughout transport rather than only at fixed checkpoints.

Why This Matters for the Cold Chain

Temperature control is the single most important variable in seafood quality and safety. A short break in refrigeration- a truck door left open too long, a delayed transfer between cold stores can accelerate spoilage and create food-safety risk long before any visible sign of decay appears. Traditional monitoring approaches often rely on either a single logger placed somewhere in a container, which cannot capture variation between individual pallets, or manual temperature checks at scheduled intervals, which cannot catch a brief excursion that happens between checks.

BLE changes this in two ways. First, because tags are cheap and low-power, they can be attached at the individual pallet or even case level rather than just once per container, giving a much finer-grained picture of where a cold-chain break actually occurred. Second, because BLE tags broadcast continuously rather than only when scanned, a temperature excursion is captured automatically by any gateway within range, rather than depending on a worker remembering to check a logger. Industry analyses of BLE-based cold-chain deployments note that this combination allows operators to demonstrate compliance at the level of an individual item, showing not just that a shipment arrived on time but that it stayed within safe temperature thresholds at every point along the route (Elain Innovation, 2025).

This item-level visibility is particularly valuable for seafood exporters trying to meet the documentation demands of importing countries and retailers, many of which increasingly require proof of cold-chain integrity, not just a final delivery confirmation, before a shipment can be accepted or certified.

BLE as Part of a Larger Traceability Architecture

BLE sensors rarely work alone. Recent reviews of digital fish-supply-chain traceability point to an emerging architecture in which BLE or similar wireless sensors form the data-capture layer, feeding information into a shared digital ledger, often blockchain-based, that other supply chain participants and, in some designs, consumers can query (Alabi & Mondragon, 2023; Ismail *et al.*, 2023). In this model, a BLE tag on a batch of tuna records its temperature history from the moment it leaves the vessel; that history is periodically uploaded to a blockchain ledger alongside catch location, processing dates, and chain-of-custody information, creating a record that is both continuous and difficult to tamper with after the fact.

This layered approach also helps address one of the seafood industry's persistent fraud problems: substitution, where a lower-value or illegally caught fish is relabeled and sold as a higher-value or legally caught species. A blockchain record alone cannot detect substitution if the underlying data entering it is unreliable; sensor-verified, time-stamped location and condition data from BLE tags makes it considerably harder to insert fraudulent information into the chain without leaving inconsistencies that automated checks can flag (Rahman et al., 2021).

Real-World Momentum

The direction of travel is visible in how seafood and cold-chain logistics providers are already experimenting with BLE. Passive, battery-free BLE tags, sometimes described as an alternative to conventional UHF RFID, are being trialled specifically because they combine RFID-like low cost and simplicity with BLE's ability to be read by ordinary smartphones rather than specialized readers, lowering the barrier for smaller processors and distributors to participate in a shared traceability system (Bottani et al., 2025). Meanwhile, newer BLE standard versions have improved the accuracy of location-related features, which researchers suggest could soon make it possible to pinpoint not just that a temperature excursion occurred, but roughly where in a warehouse or vehicle it happened (Elain Innovation, 2025).

For an industry where a large share of processing and first-mile handling is done by small operators with limited IT budgets, the appeal of BLE is as much practical as technical: the readers are smartphones people already carry, the tags are inexpensive relative to active satellite trackers, and no specialized scanning infrastructure needs to be installed at every checkpoint for basic visibility to improve.

Challenges

BLE is not a complete solution on its own, and researchers are candid about its limitations. Range is short compared with cellular or satellite tracking, so BLE data collection depends on gateways or smartphones being physically present along the route.A gap in coverage anywhere in the chain, such as during ocean transit or in a rural loading yard, means a corresponding gap in the record. Because BLE devices are designed to be easily discoverable, their transmissions can also be picked up by devices other than the intended reader; security researchers have documented weaknesses in how BLE's privacy features resist tracking by unauthorized parties, a concern that matters more as more valuable, item-level supply-chain data rides on the same broadcasts (Wu et al., 2024). Cost, while low per tag, still adds up across millions of shipped units, and battery-powered tags eventually need replacement or disposal, raising both maintenance and sustainability questions that battery-free designs are only beginning to address (Bottani et al., 2025).

There is also the broader systems challenge shared by every traceability technology: sensors can only be as trustworthy as the process for attaching them correctly and keeping them attached to the right batch. A perfectly accurate temperature log is of little value if a tag was swapped between crates, deliberately or by accident. This is precisely why current research increasingly treats BLE sensing as one verified input into a larger, cross-checked system rather than a stand-alone guarantee of traceability (Bhatt et al., 2025).

Future Scope

For all these open questions, the trajectory is clear. As BLE hardware gets cheaper and battery-free, energy-harvesting designs mature, tagging entire pallets or even individual high-value seafood items becomes economically realistic rather than a niche pilot project (Bottani et al., 2025). Combined with blockchain record-keeping and machine-learning-based anomaly detection approaches already being explored in academic fish-supply-chain research, BLE sensing is positioned to become a standard, largely invisible layer of the seafood cold chain: quietly recording condition and location data at every step, surfacing problems in near real time, and giving buyers, regulators, and consumers a far more continuous and verifiable picture of where their seafood has actually been.

Conclusion

Seafood traceability has long been limited by the gaps between deliberate checkpoints, the moments when someone actually scans a tag or checks a temperature log. BLE sensors close those gaps by turning every nearby smartphone or gateway into a potential data collection point, generating a continuous, item-level record of a shipment's condition and movement rather than a handful of snapshots. Paired with blockchain ledgers and other digital traceability tools, this approach offers a practical path toward a seafood supply chain that is not just documented after the fact, but genuinely visible as it happens, a meaningful step toward tackling fraud, improving food safety, and rebuilding consumer trust in seafood, from ocean to plate.

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