



Best Practices for Technology and Protocol Selection in Industrial Wireless Applications

Clarifying Application Requirements

The initial and perhaps most crucial step in selecting wireless technology for industrial applications is a thorough understanding of the specific communication needs and use cases. This means identifying the type of devices to be connected, the nature of the data they generate, and the operational context. For instance, connecting mobile devices such as tablets often demand high bandwidth and moderate latency, while fixed industrial assets involved in critical process control may require ultra-reliable, low-latency communication. Defining these parameters clearly ensures the selected technology will support the application effectively without unnecessary complexity or cost.

Different industrial operations impose various demands. Applications might range from high-speed data transfers to simple status updates with infrequent reporting. Some scenarios require real-time monitoring and control, such as robotics on a factory floor or autonomous guided vehicles (AGVs), which necessitate robust, low-latency wireless connections. Others, like tank level monitoring or valve position reporting, often involve low data rates and tolerate higher latency, allowing for use of low-power protocols. Understanding these application-specific requirements helps narrow down wireless technologies that best fit the operational goals and regulatory considerations.

Evaluating the Working Environment

Industrial environments are particularly challenging due to their harsh and often unpredictable conditions. These may include extreme temperatures, high humidity, exposure to dust and chemicals, mechanical vibrations, and interference from heavy machinery emitting electromagnetic noise. Wireless devices and protocols designed for industrial settings must, therefore, be ruggedized and certified to withstand these physical stresses. Devices with high Ingress Protection (IP) ratings, conformal coatings, and compliance with industrial standards are often critical to ensure longevity and reliable operation.



In addition to physical conditions, electromagnetic interference (EMI) is a significant concern. Industrial facilities frequently have numerous wireless and wired electrical systems operating in proximity, leading to potential radio frequency (RF) interference. Selecting protocols with strong anti-interference features, frequency agility, and robust error correction mechanisms helps maintain stable communications. Proper site surveys and RF spectrum analysis also form part of the environment evaluation to mitigate potential signal degradation and avoid deployment failures.

Matching Performance Parameters to Needs

Industrial wireless solutions must balance multiple performance metrics, such as data throughput, signal coverage, latency, and reliability, tailored to the application demands. For real-time control or safety-critical operations, ultra-reliable low-latency communication (URLLC) is paramount to ensure instantaneous response and system stability. In contrast, monitoring functions like asset tracking or environmental sensing may prioritize energy efficiency and long battery life over high data rates.

Signal range and penetration are equally important, especially in dense manufacturing facilities with metal structures and reflective surfaces that can impede wireless signals. Technologies offering mesh networking or multiple antenna diversity can enhance coverage and reduce dead spots. Error rates and retransmission mechanisms also impact overall system reliability, and these factors must be aligned with acceptable performance thresholds for each use case. Through this careful matching of technical parameters, industries can achieve effective communication without over-provisioning or sacrificing operational continuity.

Considering Power Supply and Consumption

Power consumption is a critical factor in industrial wireless technology selection, especially for battery-powered or remote devices where frequent battery replacement is impractical. Many industrial applications rely on sensors and actuators that operate on batteries for extended periods, sometimes spanning years. Technologies like WirelessHART and LoRaWAN are designed specifically to optimize energy use, employing techniques such as time-synchronized communications and low-duty cycling, which allow devices to remain in low-power sleep modes for most of the time, waking only to transmit essential



data. This balance between data transmission frequency and energy consumption directly impacts device longevity and maintenance schedules.

In contrast, protocols such as Wi-Fi or cellular technologies like 4G/5G generally consume significantly more power, making them less suitable for battery-operated devices unless continuous power sources or Power over Ethernet (PoE) are available. However, these technologies offer advantages in bandwidth and range, supporting applications requiring high data throughput or mobility. Therefore, power consumption considerations must be weighed against communication needs. Energy-efficient wireless technologies enable the deployment of truly wireless networks that reduce cabling costs and increase flexibility, but the power profiles of each technology must be carefully matched to the device's expected operational lifetime and application data requirements to avoid premature failures and frequent battery replacements.

This extended focus on power management is fundamental to designing sustainable and cost-effective industrial wireless systems, where the reduction of maintenance overhead and downtime can translate into significant operational savings.

Ensuring Robust Security

Given the sensitive nature of control and operational data, security is a critical factor. Suitable wireless protocols must incorporate strong encryption, identity verification, and access control. This protects industrial networks from cyber-attacks, unauthorized access, and data breaches, thereby safeguarding both equipment and data integrity.

Planning for Compatibility and Scalability

In industrial wireless systems, ensuring compatibility with existing infrastructure and standards is vital. Industrial environments often have multiple legacy systems alongside newer technologies, and wireless solutions must seamlessly integrate without causing disruption. Standards such as ISA-100.11a, WirelessHART, and IEEE 802.15.4 provide frameworks for interoperability between different devices and manufacturers. By selecting technologies compliant with these widely accepted standards, facilities can avoid vendor lock-in, simplify maintenance, and facilitate smoother upgrades or expansions.



Scalability is equally important to accommodate future growth and evolving operational needs. Industrial wireless networks should support adding new devices or expanding coverage areas without requiring complete system redesigns. Scalable solutions allow the network to grow horizontally (more devices) and vertically (higher data loads or additional services) while maintaining performance and reliability. Designing with scalability in mind also helps optimize costs over the system's lifecycle, ensuring that investments remain effective as technology and business processes change. Employing standards-based solutions that emphasize flexibility, and modularity enables industries to adapt quickly to new requirements and emerging technologies, future-proofing their wireless infrastructure.

How this process works

Example 1

For this scenario, we are choosing a secure OT wireless technology for tablets and handheld devices on a heavy industrial factory floor with moderate to heavy 2.4 GHz interference and significant local IT use of 5 GHz Spectrum.

1. **Application Requirements:** Maintenance engineers use tablets and handheld devices to access machinery schematics and manuals, with the added need for real-time remote assistance from machine vendors. The wireless technology selected must support moderate to high data throughput for downloading technical documents and streaming video or augmented reality remotely, while providing seamless roaming across the extensive factory floor. Security features, including WPA3 encryption and enterprise authentication (e.g., 802.1X), must protect sensitive operational data and vendor communications.
2. **Environmental and Spectrum Challenges:** The factory environment presents moderate to heavy interference in the crowded 2.4 GHz band due to multiple wireless systems and industrial electromagnetic noise. Furthermore, local IT heavily uses the 5 GHz spectrum, reducing available channels and increasing contention. The OT wireless solution must therefore avoid both 2.4 GHz interference and the congested 5 GHz band, maintaining reliable connectivity under harsh conditions and coexistence challenges.
3. **Technology and Spectrum Selection:** The optimal choice for wireless technology in this industrial OT use case would be either **Wi-Fi 6E or Wi-Fi 7**, leveraging the 6 GHz spectrum. Both standards address interference and congestion issues present



in legacy bands and bring enhanced performance, security, and efficiency suitable for demanding industrial environments.

3.1 Wi-Fi 6E extends Wi-Fi 6 into the 6 GHz band, which offers additional clean spectrum for high-throughput, low-interference wireless communication. It supports up to 9.6 Gbps speeds, 160 MHz-wide channels, and includes features like OFDMA, MU-MIMO with up to 8 spatial streams, Target Wake Time (TWT) for power efficiency, and WPA3 security. Wi-Fi 6E devices are backward compatible with 2.4 and 5 GHz bands, providing flexibility for legacy device support while offloading high-bandwidth traffic to 6 GHz.

3.2 Wi-Fi 7 (802.11be) further advances capabilities, doubling the channel width to 320 MHz in 6 GHz and supporting data rates up to approximately 46 Gbps with 4096-QAM modulation and up to 16×16 MU-MIMO streams. Importantly, Wi-Fi 7 introduces Multi-Link Operation (MLO), allowing devices to simultaneously send and receive across multiple bands (2.4, 5, and 6 GHz), which dramatically improves reliability, throughput, and latency. MLO and enhanced TWT improve device power management and network efficiency, especially beneficial in dense industrial settings.

3.3 Practical Considerations

3.3.1 Range and Coverage: Higher frequencies in 6 GHz reduce range compared to 2.4 GHz but deliver greater bandwidth and less interference. Industrial deployments must plan dense AP placement with robust antenna designs to overcome physical barriers and metallic obstructions typical on factory floors.

3.3.2 Device Compatibility: Wi-Fi 6E is mature with a growing ecosystem; Wi-Fi 7 adoption is emerging with new compatible devices entering the market. For future-proofing and cutting-edge applications like AR/VR remote assistance, Wi-Fi 7 offers clear advantages.

3.3.3 Security: Both standards implement WPA3 and enterprise-grade security which are essential for OT environments handling sensitive machinery data and vendor communications.

- 4 **Network Design and Interference Mitigation:** A detailed site survey and RF spectrum analysis guide deployment to optimize access point locations and select channels in the 6 GHz band. Features such as band steering encourage capable devices to operate on 6 GHz, reducing 2.4 GHz and 5 GHz congestion. Industrial Wi-Fi solutions may



incorporate Multipath Operations and advanced antenna diversity to combat interference from metal structures and heavy machinery. Network segmentation ensures OT traffic isolation, while Quality of Service (QoS) mechanisms guarantee priority for maintenance and remote assistance communications.

- 5 **Power and Device Considerations:** Tablets and handheld devices equipped with Wi-Fi 6E support power-saving mechanisms extending battery life without sacrificing performance, essential for mobile OT applications demanding continuous connectivity and responsiveness.
- 6 **Security and Scalability:** WPA3 security protocols combined with robust enterprise authentication protect wireless OT data. Network micro-segmentation and continuous threat monitoring create a hardened OT zone separated from IT traffic. The highly scalable Wi-Fi 6E architecture supports future growth in connected devices and emerging industrial applications, ensuring long-term investment protection.

Summary of Recommendations

For a secure, high-performance OT wireless network supporting machine maintenance tablets and handhelds in challenging RF environments, Wi-Fi 7 is the best forward-looking choice if compatible devices and infrastructure deployment schedules allow. Wi-Fi 6E remains a robust and widely supported option that balances performance and ecosystem maturity well. Both leverage the 6 GHz spectrum to bypass congested legacy bands, provide high throughput and low latency necessary for document access and remote assistance, and offer strong security for industrial operations.

This recommendation aligns deployment technology with the latest in wireless standards, balancing cutting-edge features with practical industrial considerations.

Example 2

Selecting Appropriate Wireless Technology for Level Sensors in a Tank Farm Connecting Remote IO to a Central PLC

1. **Application Requirements:** The wireless technology must connect multiple level sensors and remote IO devices located at various tanks in a tank farm to a central PLC controller for processing. Communication requires reliable data delivery with low to moderate bandwidth since sensor data typically consists of periodic analog or digital readings. Depending on process criticality, latency requirements may range from moderate to low, allowing efficient monitoring and control. Battery-



powered sensors will benefit from low power consumption solutions, especially if tanks are widely dispersed and difficult to wire.

2. **Environmental Conditions:** Tank farms typically have wide physical separations between tanks, challenging line-of-sight communications. Wireless signals may suffer from obstructions, reflections, and environmental factors like weather conditions. The industrial environment may generate electromagnetic interference, but typically less intense than heavy factory floors. Wireless communications must also comply with safety regulations governing petrochemical or hazardous areas.
3. **Technology Selection:** Based on these factors, low-power wide-area network (LPWAN) technologies such as WirelessHART or ISA100.11a are ideal candidates. Both are designed specifically for process industries, offering mesh networking capabilities that provide robust, self-healing communications over large areas and challenging environments. WirelessHART and ISA100.11a support deterministic latency suitable for PLC control loops and offer proven security features including encryption, authentication, and integrity checks critical for industrial process safety.
4. **Network Design and Reliability:** The mesh network topology enables multiple redundant communication paths, improving reliability and fault tolerance. Network devices act as repeaters, extending coverage without additional infrastructure. Centralized network management allows easy integration with PLCs and use of standard protocols (like HART or Modbus) for seamless data processing. Proper antenna placement and potentially the use of industrial gateways ensure strong signal quality even in complex layouts.
5. **Power and Maintenance Considerations:** These sensors and remote IO typically have constrained power sources, so protocols that support low duty cycles, energy-efficient sleep modes, and predictable transmission schedules maximize battery life, reducing maintenance overhead and increasing uptime.
6. **Security and Scalability:** WirelessHART and ISA100.11a provide end-to-end security tailored for OT environments, including multi-layer encryption and device authentication. The scalable mesh architecture supports adding sensors or IO modules as operations grow, future-proofing the network for additional process monitoring or control points.

Summary of Recommendations

For level sensors in a tank farm connecting remote IO with a central PLC, WirelessHART or ISA100.11a are optimal wireless technologies. They provide secure, reliable, low-power



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mesh networking with proven industry adoption and interoperability, addressing range, environmental, and safety requirements typical of tank farm automation. This approach ensures seamless integration into process control systems and maintains operational safety and efficiency.