Electronic Design

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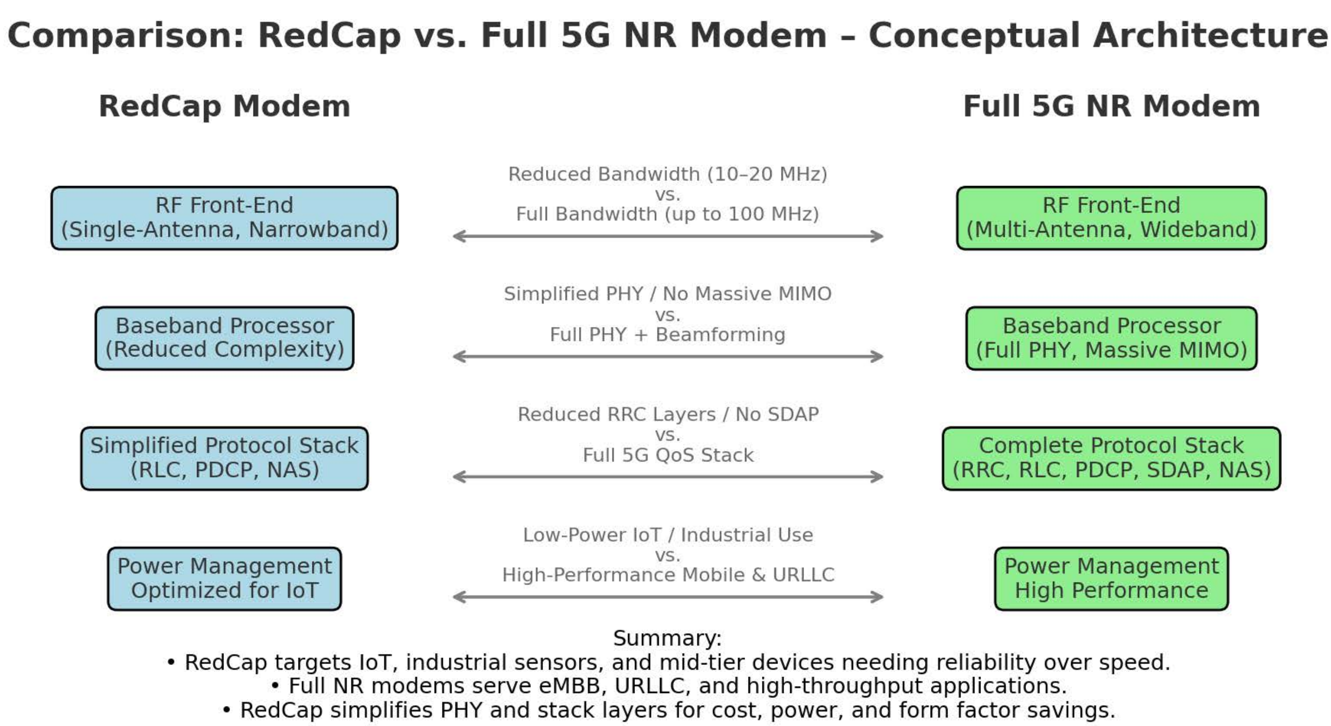
Finding a Path to 5.5G and 6G Adoption in Process Control

The next steps beyond 5G promise great advantages in terms of bandwidth and latency, making possible many new process-control functions.

5G has been around for years and has seen some adoption in process applications. Now on the horizon, likely with [extensive use of optical transmission](), is 6G and in the near term, 5.5G.

Sometimes called "5G-Advanced," 5.5G is being positioned as a bridge between today's 5G and full 6G. In process control and industrial automation, it unlocks some specific use cases because it combines ultra-reliable low-latency communication (URLLC), enhanced uplink capacity, high device density, and integrated AI/ML support. In short, 5.5G enables process industries to go beyond monitoring and use wireless for *control* — something that standard 5G struggled to guarantee consistently.

For example. closed-loop control of distributed actuators and sensors without relying on long wired connections can make a big difference in real-time distributed control. With



This comparison diagram illustrates how a RedCap modem differs from a full 5G NR modem. It highlights key contrasts in bandwidth, MIMO complexity, protocol depth, and power management.

latency below 1 ms and reliability >99.999%, 5.5 G allows wireless PID or even model predictive control loops across machines or production lines.

Similarly, mobile robots and automated guided vehicles (AGVs) can benefit from 5.5G for network slicing and low-latency connectivity. This will enable precise trajectory synchronization, collision avoidance, and dynamic task reassignment to coordinate fleets of robots in warehouses, refineries, or process plants.

Adopting 5.5G can further support massive wireless sensor networks. Such networks consist of thousands of vibration, temperature, pressure, and chemical sensors spread across a refinery or power plant. The higher device density made possible with 5.5G can support up to millions/km^2, and better power efficiency extends sensor lifetimes while maintaining reliable coverage.

Tracking critical assets (valves, mobile equipment, hazardous material containers) indoors with sub-meter accuracy can be accomplished with high-precision positioning through 5.5G. With the integrated positioning enhancements made possible with 5.5G, plants are able to reduce reliance on separate RFID or UWB systems.

The capabilities of 5.5G also helps with adoption of digital twinning and augmented reality (AR) for operators. 5.5G's higher uplink speeds and reduced jitter support real-time video streaming and AR overlays without lag, meaning that plant workers can effectively use AR glasses for maintenance, remote expert guidance, or real-time digital-twin overlays.

The enhanced uplink capacity of 5.5G supports massive streams of machine data, while AI/ML at the edge (supported by 5.5G's architecture) allows for near-real-time analysis. Thus, it becomes practical to adopt and use digital twins and predictive maintenance; for example, continuously updating a digital twin of a chemical plant or wind farm for optimization and fault prediction.

Finally, 5.5G can supercharge cyber-physical safety systems—for instance, if an emergency shutdown triggers, there's hazardous gas detection, or safety interlocks are transmitted wirelessly. In short, 5.5G enables process industries to go beyond monitoring and utilize wireless for control, which is something that standard 5G struggled to guarantee consistently.

Concrete Steps to Prepare the Way

As process industries evolve toward smarter, more autonomous operations, the arrival of 5.5G and eventually 6G wireless networks promises to reshape how control systems communicate. These technologies extend far beyond faster download speeds — they introduce deterministic latency, AI-enhanced reliability, and native integration with industrial time-sensitive networking (TSN).

But to unlock these benefits, plants must begin engineering their infrastructure today. Preparing for next-generation wireless isn't a matter of waiting for carriers. It's about architectural readiness, edge intelligence, and device compatibility. Preparation steps include:

1. Establish a Private Network Framework

Design or modernize a private 5G or non-public network (NPN) that can evolve into 5.5G. In practice, this means securing local spectrum — often through shared or licensed bands — and deploying on-premises base stations (gNBs) connected to a local 5G core.

Choosing a standalone private core (SNPN) allows full control of quality of service (QoS), data routing, and security. It also ensures low-latency breakout at the edge — crucial for closed-loop control. Plants integrating public carriers (PNI-NPN) should insist on network slicing agreements that guarantee deterministic latency below 1 ms for time-critical traffic. These steps lay the foundation for controlled, certifiable connectivity.

2. Integrate Edge Computing and Local User Plane (UPF)

Future wireless control depends on edge-centric architectures. A local user plane function (UPF) within the plant routes process data without leaving the facility, while multi-access edge computing (MEC) platforms host analytics, condition monitoring, or even soft PLC logic.

To prepare, plants should consider virtualizing control and monitoring applications into containerized services that can migrate easily between local servers and edge nodes. The goal is to treat the network and compute fabric as one distributed platform. Therefore, when 5.5G introduces enhanced uplink capacity and 6G adds integrated sensing, the plant can absorb these capabilities without redesign.

3. Engineer TSN and Deterministic Interworking

Next-generation wireless isn't isolated from wired infrastructure. 5G TSN interworking — standardized in 3GPP Release 16 and enhanced in 5.5G — allows radio segments to join Ethernet-TSN domains with synchronized clocks and predictable delay.

Preparing now means auditing existing control networks for IEEE 802.1AS (gPTP) support, deploying TSN bridges, and planning NW-TT (Network Translator) nodes at 5G ingress points. This ensures that motion or batch controllers relying on microsecond-level determinism can safely extend their loops over wireless.

4. Develop a RedCap-Ready Device Strategy

Device connectivity will diversify under 5.5G. Reduced Capability (RedCap) modules *(see figure)*, offering mid-range performance and low power, will connect sensors, mobile terminals, and AGVs economically. The main components of a RedCap modem typically include an RF front-end and baseband processor and a simplified protocol stack, power management, and interface layers (SIM/eSIM and host).

RedCap modems are simplified 5G devices that deliver reliable, low-latency connectivity with reduced bandwidth and power consumption. They omit complex features like massive MIMO, making them cost-effective and energy-efficient.

In process industries, RedCap enables direct wireless links to sensors and actuators, supporting real-time monitoring and control with less overhead. Process equipment vendors should begin embedding M.2 or mini-PCIe slots for modular 5G/6G radios, ensuring forward compatibility as silicon evolves.

5. Adopt AI-Driven Network Management

Finally, AI-native optimization — a hallmark of 6G — relies on continuous telemetry. Implement network data collectors and intent-based controllers now to manage QoS, predict congestion, and adjust slices dynamically. The sooner that operators start curating these datasets, the more intelligent their networks will become when 6G's learning loops mature.

Some final thoughts: Preparing for 5.5G and 6G in process control isn't a single upgrade — it's an ecosystem transformation. By securing spectrum, localizing compute, synchronizing TSN domains, and modularizing devices, industrial operators can ensure that when ultra-reliable wireless finally arrives, their plants are ready to make every microsecond count.

References

FCC Technology Advisory Council 6G Working Group Report (PDF), August 5, 2025.

6G Networks and the AI Revolution—Exploring Technologies, Applications, and Emerging Challenges.