Untethering PLCs in industrial manufacturing with Private 5G

celona

DISCUSSION PAPER

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Introduction

In industrial manufacturing, the efficiency, reliability, and speed of data transfer are critical determinants of productivity and operational excellence. Traditional infrastructures, often dependent on wired networks and legacy systems, provide stability but constrain both the mobility and scalability essential for modern operations. With the advent of Private 5G, private wireless networks are poised to revolutionize the connectivity and management of critical equipment within the factory setting, including Programmable Logic Controllers (PLCs).

Private 5G is delivering a new connectivity solution – ready to resolve the long-standing connectivity issues in industrial environments, and supporting the use of PLCs to enhance overall operational efficiency.

What are Programmable Logic Controllers (PLCs)?

A Programmable Logic Controller (PLC) is a resilient computing system designed specifically for industrial automation. Unlike personal computers, PLCs are engineered to withstand harsh industrial environments and ensure uninterrupted control of machinery. Their ability to execute real-time decisions make them the true workhorses of the manufacturing sector, ensuring the seamless operation of industrial processes.

PLCs take on tasks such as:

Process control

Their versatility means they are able to manage tasks ranging from simple machine sequences to complex processing operations.

Machine control

PLCs can control the functions of machines, such as start/stop operations, speed control, and monitoring machine states.

Assembly lines

They can manage the coordination and timing necessary for production lines, ensuring efficient and error-free assembly processes.

PLC applications in industry

PLC applications are vast and diverse, with each use case benefiting from their capacity to enhance operational efficiency, precision, and productivity.

For example:

- In medical manufacturing, PLCs ensure precision and repeatability by controlling and monitoring the production of devices that must meet stringent regulatory standards.
- Automotive manufacturing relies heavily on PLCs for tasks ranging from the assembly line to paint shops and robotics. In particular, PLCs ensure that cars are assembled precisely and with a high degree of customization.
- When it comes to robotics in manufacturing, PLCs are used for motion control, material handling, and complex assembly tasks. When integrated with robotics, PLCs are productivity multipliers, enabling the rapid execution of complex manufacturing tasks with high precision.

How do PLCs communicate with various devices and systems?

PLCs communicate using several protocols that facilitate high-speed data exchange and enhance connectivity and integration capabilities, including but not limited to:

PROFIBUS & PROFINET: Widely used in automation for their ability to provide rapid data exchange between PLCs and devices

Modbus: A serial communication protocol that has been a de facto standard due to its openness and ease of deployment.

EtherCAT: Known for its high precision and synchronization, EtherCAT is particularly useful in robotic control.

Ethernet/IP: This industrial Ethernet protocol allows PLCs to exchange data over a network, further enhancing connectivity and integration within the manufacturing environment.

The connectivity challenges in PLC-driven manufacturing

Today, PLCs have become the central nervous system of manufacturing operations, controlling both the sequence of operations and ensuring process integrity. But, as with any technology, there are challenges and limitations that must be addressed to harness their full potential.

Manufacturers must have low-latency and high reliability

Manufacturing processes demand real-time control and decision-making, where every millisecond counts. Therefore, low-latency and high reliability in network connectivity are non-negotiable for synchronizing complex tasks and maintaining operational continuity.

But traditional connectivity methods often fall short.

For a start, Wi-Fi's application for real-time control tasks in industrial automation is limited due to challenges in delivering consistent latency and connection stability. This means wired networks - usually Ethernet-based, or utilizing fieldbus systems like Modbus or PROFIBUS - have been the de-facto choice.

Limitations of wired networks

While wired connections have been the mainstay for decades due to their stability and reliability, there are inherent limitations that make them less than ideal:

- First, wired networks are not easily scalable or adaptable. Changes in the manufacturing layout or process can require significant downtime and manual reconfiguration of the network infrastructure. The installation of physical cables, conduits, and the associated labor can be expensive.
- Additionally, it is not always feasible to install cable everywhere, and doing so could result in significant downtime. For example, a clean room or manufacturing area that is inaccessible to a scissor lift.
- Then there's the maintenance side of things which can add to the operational costs - especially in harsh industrial environments when costs can quickly start to stack up. And if a problem crops up, identifying and resolving issues in a vast network of physical cables can be time-consuming and require specialized personnel.

The true cost of downtime

Recent studies highlight significant challenges and costs associated with wired networks in manufacturing. A major issue is the lack of scalability and adaptability, which can substantially contribute to downtime costs.

Uptime Institute, 2022 Outage Analysis Report

- Over **60%** of failures result in at least **$100,000 in total losses**, a significant increase from **39%** in 2019.
- The share of outages costing upwards of **$1 million** increased from **11% to 15%** over the same period.

Oden Technologies | Downtime in Manufacturing: What's the True Cost?

- Reactive maintenance strategies, which are more prevalent in less flexible wired setups, lead to an **average of 8.43%** unplanned downtime annually.
- In contrast, predictive maintenance strategies, enabled by more adaptable and connected networks, reduce unplanned downtime to an **average of 5.42%** annually.

How Private 5G overcomes modern manufacturing challenges

Private 5G is a local area network based on cellular technology tailored specifically for enterprise use. It offers the high-speed, low-latency benefits of 5G technology, including increased bandwidth and reliability, but within a controlled and secure environment. This makes it ideal for sensitive, high-stakes industrial operations that demand data privacy and immediate connectivity. Let's take a look at some of the challenges being addressed by Private 5G in manufacturing:

Latency and bandwidth limitations

Industrial operations often require real-time data processing and feedback to maintain process integrity. Private 5G can offer lower latency based on location relative to AP when compared to Wi-Fi and other wireless technologies.

Mobility restrictions

Wired connections inherently limit mobility, as equipment must be physically connected to communication networks. This can inhibit the reconfiguration of production lines and mobile robotics. Private 5G eliminates these restrictions, allowing for greater flexibility and mobility in industrial environments.

Interference and reliability

Manufacturing environments can be harsh for signal transmission due to interference from large metal surfaces and electronic noise. Private 5G networks are designed to be robust in diverse environmental conditions, ensuring consistent and reliable connectivity in even the harshest industrial settings.

How Private 5G supports PLCs

PLCs are the backbone of many automated processes in manufacturing. They traditionally rely on wired communications to ensure stability and speed. However, integrating PLCs with Private 5G networks brings several advantages:

Flexibility in operations

Equipment connected wirelessly to PLCs can be moved and reconfigured within the network without the need for complex cabling rework. This flexibility is particularly ideal for agile manufacturing environments that need to quickly change production lines based on new product requirements or improvements in process design.

Scalability

As manufacturing processes scale up, the underlying network infrastructure can also easily expand in a Private 5G setup without the proportional increase in complex wiring or disruption to existing operations.

Enhanced data integration

PLCs connected over Private 5G networks can seamlessly integrate with other industrial IoT devices. This integration facilitates better data analytics, machine learning implementations, and real-time monitoring across the factory floor, leading to improved predictive maintenance and operational efficiency.

Enhanced security

Security is an obvious concern in any industrial setting. Private 5G networks offer advanced security features that are essential in a manufacturing environment. For example, these networks bring strong device-level identification and authentication capabilities and include app-level segmentation over the air and network access. Celona's Private 5G or 5G LAN solution also supports a zero-trust strategy with APIs for extensibility and integration, providing enterprises with tools to address strict compliance requirements - and eliminating the need for costly and cumbersome overlay systems to manage authentication, network segmentation, and access rules.

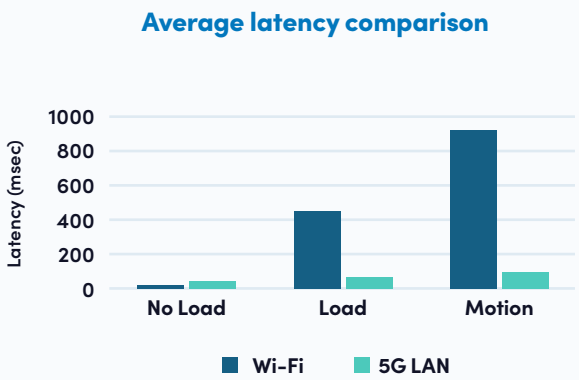
MicroSlicing™

A unique and patented technology developed by Celona, MicroSlicing offers significant benefits for PLCs in manufacturing environments. By creating virtually isolated zero-trust networks within the same physical infrastructure, MicroSlicing enables dedicated lanes for critical communications, ensuring reliable, low-latency service level agreements (SLAs) for manufacturing-critical PLC traffic. This capability dramatically reduces latency and packet errors, providing the necessary performance and reliability for real-time industrial applications.

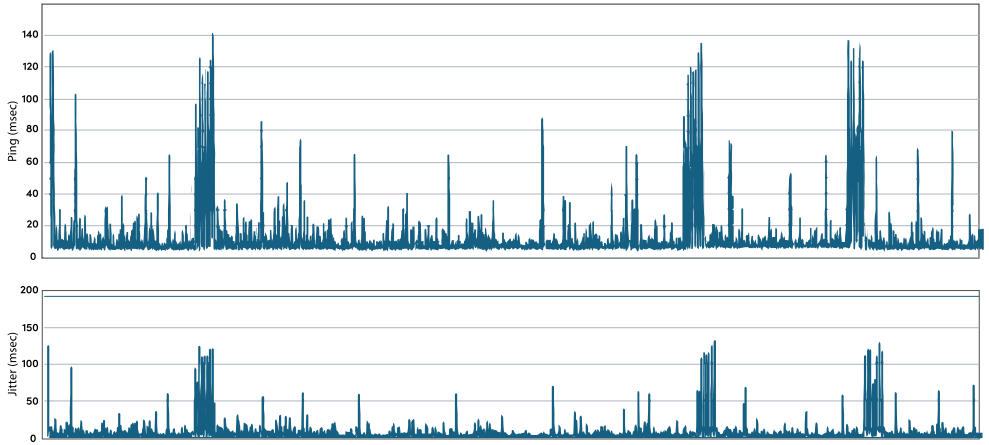
Other benefits include:

- Increased operational efficiency via the ability to configure flow priority, packet delay budget (PDB), and packet error rate (PER).
- Seamless integration with existing Local Area Network (LAN) policies.
- Data privacy with full data path control and centralized encryption - giving IT/OT teams visibility and control over all private cellular devices.
- No need for costly and cumbersome overlay systems to manage authentication, network segmentation, or access rules.

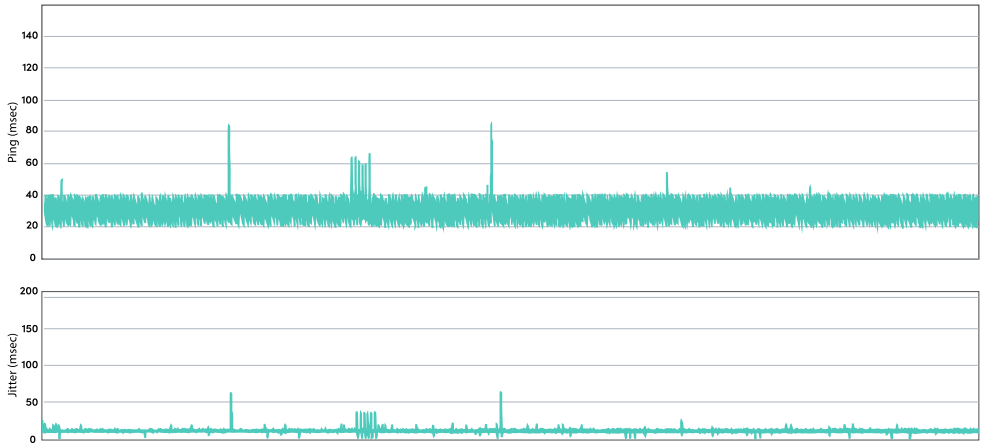
Comparing the performance of Wi-Fi vs 5G LAN



Wi-Fi



Celona 5G LAN (Private 5G)



How Private 5G is deployed in greenfield versus brownfield facilities

Private 5G and greenfield

In new, or "greenfield," manufacturing facilities, there is a unique opportunity to build infrastructure from the ground up. Here, cutting the cables and implementing wireless solutions such as Private 5G can lead to substantial cost savings and enhanced flexibility. The absence of physical cabling means that manufacturing layouts can be designed and re-designed with minimal constraints, allowing for innovative process configurations and rapid adaptation to production demands.

Private 5G and brownfield

Contrasting with greenfield projects are "brownfield" facilities – and the challenge here lies in retrofitting or upgrading legacy systems with minimal disruption to ongoing operations. The transition to a more flexible network like Private 5G involves careful planning and execution to integrate with the old systems without causing significant downtime or production losses.

In both greenfield and brownfield scenarios, the evolution toward wireless connectivity, specifically Private 5G networks, presents a compelling solution to the problem statement. Private 5G networks promise to overcome the limitations of wired connections, offering low-latency, high-reliability communication with the added benefits of flexibility and reduced cabling costs. The switch to 5G enables manufacturers to reimagine their production lines and prepare for the future of industrial automation where PLCs and other control systems can communicate seamlessly, irrespective of their physical location within the facility.

> *A dedicated cellular-enabled Industry 4.0 solution – like Private 5G - could potentially deliver a return on investment (ROI) of 10x to 20x over five years, while contributing to operational cost savings of about 8.5%. This translates to USD 200 to USD 600 per square meter per year for a factory or industrial site.*
> ABI Research | How to improve ROI for industry 4.0 user case

PLCs, Private 5G and the role of industrial mobile gateways and routers

One of the defining characteristics of PLCs is their lifecycle. These systems are known to last upwards of 40 years, thanks to their design for long-term durability and ease of updates. This longevity is paramount in industries where consistent operation and time-tested reliability are so critical.

But to harness the benefits of Private 5G networks in manufacturing, PLCs must be adeptly integrated into this wireless infrastructure. This is where industrial mobile gateways and routers come into play, serving as critical conduits for connectivity.

Industrial mobile gateways and routers are specialized devices that facilitate the connection between PLCs and a Private 5G network. They translate the communication protocols used by PLCs to ones compatible with 5G, effectively bridging the gap between the factory floor and the digital communications network.

See all 5G LAN certified gateways >

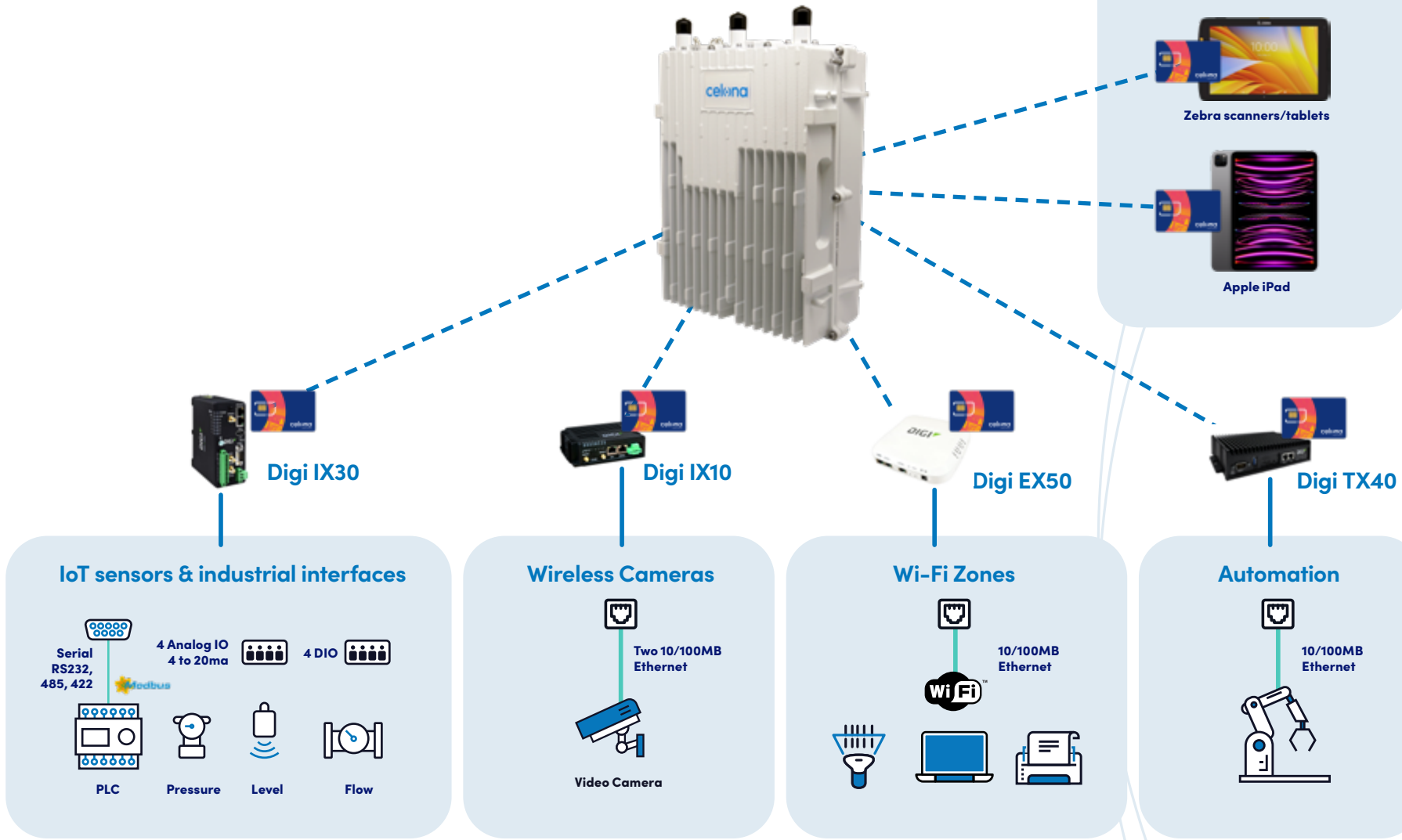
5G Private Device Mandatory Requirements:
5G NR SA Mode Support
Frequency Band support by region / regulatory domain
Band n48 support for USA with FCC certification
Band n77 for support EU with CE certification
Band n78 for support EU with CE certification
Band n79 for Korea & Japan
Ability to restrict device to a specific frequency band.
10/20/40 MHz carrier support in n77/78; 40 MHz carrier support in n48
Configuration for IPv4 service
2x2 MIMO support for downlink as minimum
PLMN ID MCC support (315- US, 999- EU/UK)
Support for log collection and debugging (e.g. QXDM, or an interactive login shell)
Support for multiple 5QIs (1 and 3 for GBR; 82 for Delay Critical GBR; 69, 6, and 7 with non-GBR)
QoS for LAN traffic

5G Private Devices Desirable Capabilities:
eSIM support for devices (if applicable)
NAT disable on WAN for CPE routers.
DHCP relay for CPE routers (Required for supernetting)
WAN pass-through for CPE routers
UE should be configurable to respond to ICMP echo packets.
Gap free inter-frequency measurements for connected mobility.
4x4 MIMO support for downlink
2x2 MIMO support for uplink
256-QAM support downlink and uplink
Ability to select 5G connection as higher priority over Wi-Fi
If applicable - Support for external GPS antenna on CPE routers
If applicable - Explosive Certification - C1D2 for USA, ATEX Zone 1 for EU

Celona: 5GLAN Certified gateways include

BEC TECHNOLOGIES · cradlepoint · DIGI · SIEMENS · SIERRA WIRELESS

Example of connecting PLCs and industrial equipment to Private 5G via Digi gateways



A new era of intelligent Private 5G powered factories

As 5G technology continues to evolve, its integration into industrial manufacturing is expected to deepen. The ability to untether PLCs and other critical manufacturing equipment from fixed network connections opens up new horizons for smart manufacturing practices, where flexibility and efficiency are continuously optimized.

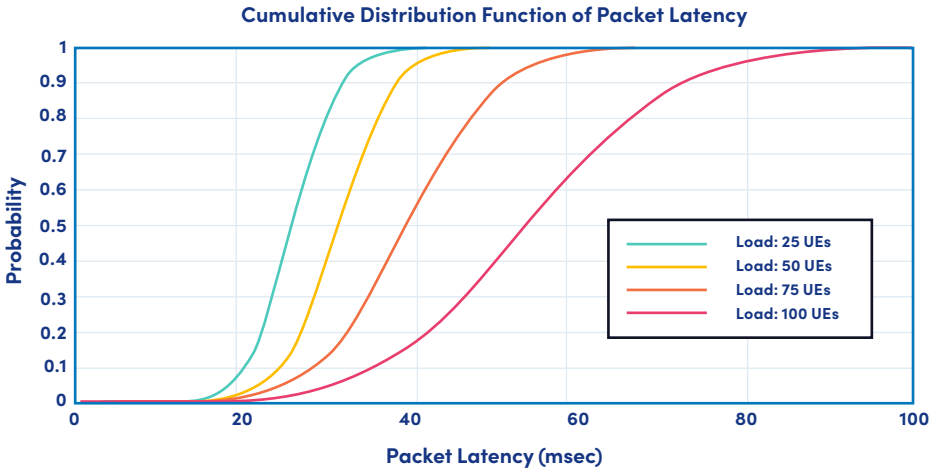
There is little doubt that Private 5G networks represent a significant technological leap in industrial manufacturing. By enabling wireless connectivity for PLCs and equipment, Private 5G delivers on its promise of a more flexible, scalable, and efficient manufacturing process.

Private 5G real world applications

Celona's complete turnkey enterprise private wireless solution is currently being implemented and tested by several leading manufacturers and retailers globally.

Max latency spike vs probability chart for an unloaded vs loaded network situation

Y-axis - probability from 0-99.99%
X-axis - max latency spike in milliseconds measured on your system.



Average RTT latency in a loaded and unloaded network

On a loaded network, the latency is expected to increase by approx. 5ms

- RTT Latency on an unloaded network: <20ms
- RTT Latency on a loaded network with PLC traffic in a micro-slice: 20-25ms

Highest RTT latency spike in 99.9% of the time for critical traffic in both a loaded and unloaded Private 5G network.

- RTT Latency on an unloaded network: <35ms
- RTT Latency on a loaded network with PLC traffic in a micro-slice: <100ms

Assumptions and number of clients connected for loaded & unloaded.

- The standard deviation is +/- 5%, latency is the RTT latency between PLC and enterprise network.

Key assumptions:

- 50% of the load is assumed to be PLC with critical communications requirements
- PLC connected to 5G Router, CPE in a GBR micro-slice (5QI3)
- PLC duty cycle at 100% with periodicity of 10ms
- Traffic profile with 100 Kbps per PLC

When or in what situation / client density would the Private 5G network not be able to maintain sub 100ms latency for the PLCs?

- We can guarantee < 100 msec for when client density is below 100 per Access Points
- Latency will increase when total throughput of all devices exceeds the AP's specifications.
- Radio interference from non-Celona network will impede latency.

Learn more about 5G LAN for manufacturing and explore our case studies >

Start your journey with Celona today >

ABOUT CELONA

Based in Silicon Valley, Celona is a pioneer and leading innovator of enterprise private wireless solutions. The company is credited with developing the industry's first 5G LAN system, a turnkey 4G/5G system that enables enterprises and mobile network operators to address the growing demands for more deterministic wireless connectivity for critical business applications and vital use cases not met by conventional wireless alternatives.

Celona's products and technology have been selected and deployed by a wide range of customers including Verizon, NTT, SBA Communications, Standard Steel, and Haslam Sports Group. To date, the company has raised $135 million in venture funding from Lightspeed Venture Partners, Norwest Venture Partners, NTT Ventures, Cervin Ventures, DigitalBridge and Qualcomm Ventures.

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