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Private Wireless Deployments

Market Requirements, Solution and Case Studies

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PRIVATE LTE (PLTE) / 5G

The demand for increased capability and control over enterprise wireless networks has led to the accelerating adoption of private LTE/5G networks as the primary IT network infrastructure. These systems offer a range of benefits beyond the deployment of unlicensed Wi-Fi networks or reliance on public mobile data services. These benefits include better operational control in a secure environment, efficiently covering outdoor and indoor spaces, support for low latency services, and better coordination of network hand-offs.

In a survey of 216 CIOs from the UK, US, Japan, and Germany, examining the industry challenges around the implementation and adoption of private 5G, there was significant interest in private 5G networks, with 90% of executives expecting that private 5G will become the standard network choice (Economist Impact, Dec 2021).

In March of 2022, Network Computing observed that Private 5G service providers were targeting enterprises that currently use wired Ethernet LANs (hard to install and manage) and Wi-Fi (which presents coverage and security issues) in their corporate networks. A private 5G network service can solve these challenges while providing ultra-low latency. (Network Computing, March 2022)

We agree that Private LTE/5G can significantly improve existing enterprise wireless networks. However, while these networks deliver dramatically improved customer experience and operational control, they cannot autonomously monitor and adapt to the wireless environment, a requirement to support the **mission-critical nature** of these networks and the increased performance that will accompany their deployment. Further, deploying these networks in lightly licensed spectrum bands (e.g., CBRS) requires RF Environmental Awareness to support more effective spectrum sharing between enterprises.

The current sharing mode, described below, doesn't resolve the interference and spectrum sharing problems that arise as the number of networks and users scale due to the availability of this low-cost spectrum. Within CBRS, spectrum allocation is made based on allotments of channels, which means the spectrum isn't really shared but rather allocated. This allocation methodology is also challenged since it isn't dynamic and doesn't react automatically to environmental changes (e.g., interference), resulting in suboptimal utilization of the available spectrum. Innovative spectrum management techniques, including Dynamic Spectrum Sharing, are expected to accelerate globally as regulators and network operators struggle to keep up with the 40% increase in data traffic occurring annually[1]. Mobile data traffic has become the wireless network equivalent of Moore's Law, while current spectrum allocation methodologies have yet to respond.

After a brief discussion of DGS's CLEARSITE™ technology, this paper focuses on two central values delivered: spectrum management and network performance.

DGS CLEARSITE™ TECHNOLOGY

DGS CLEARSITETM Technology

Solving Next Generation Wireless Network Challenges

The motivations for Private Wireless deployment center around network performance and economics. DGS ensures our RF Awareness solution improves the value model pursued by the enterprise. In a single platform, the CLEARSITE™ solution provides several unique capabilities:

Radio Frequency Data Capture

- Captures signals in multiple dimensions: space, time, frequency, and signal characteristics, aligned with customer goals
- Distributed nodal network capability allows DGS to sectorize and aggregate captured data
- CLEARSITE™ software integrates into existing RAN networks

Radio Frequency Data Analysis at the EDGE

- Multidimensional analysis enables detection, classification, identification, and geolocation of signals of interest
- Includes both blind and AI-aided capabilities
- Provides **true environmental awareness in near-real time**

Actionable Data Extraction at the EDGE

- Customer goals are applied at the edge to extract and present relevant data from the RF environment
- Minimizes backhaul and increases the speed of actionable knowledge dissemination
- Supports integration of 3rd party datasets for broader analytics

Process Optimization

- Improves operational performance of deployed resources

[1] Dynamic Spectrum Management System; Market Requirements, Solution and Case Studies, Dr. Armando Montalvo; https://digitalglobalsystems.com/news/

- **Enables ultra-reliable and low-latency** services and dynamic spectrum sharing
- **Coverage and capacity** models are significantly enhanced (>20%, use case dependent)
- Supports a high volume of users with low-to-moderate data rates (e.g., IoT)

5G Numerology

5G numerology allows for greater control over individual services. Flexible numerology in 5G is much different from numerology found in LTE, as it introduces new challenges with how waveforms are built and managed. You must consider subcarrier spacing, UL/DL configurations, and bandwidth. To fully exploit 5G's capabilities, RF Awareness is needed to support the dynamic optimization of RAN resources and their spectrum usage for each service in the network.

SPECTRUM MANAGEMENT

CBRS and Private Networks

In 2015, the FCC adopted rules allowing federal and non-federal/commercial users to share the 3550- 3700 MHz (3.5 GHz) frequency bands. They established the Citizens Broadband Radio Service (CBRS) and created a 3-tiered access and authorization framework to accommodate sharing between federal and commercial users. This established primary users, secondary users, and third-tier levels of users.

Within CBRS, access and operations are managed by an automated frequency coordinator known as the Spectrum Access System (SAS). When managing spectrum access, the SAS can incorporate information from an Environmental Sensing Capability (ESC) – a sensor network that detects transmissions from Department of Defense radar systems and transmits that information to the SAS. This establishes a mechanism for coordinating access between federal and commercial users, with the latter including both preferential licenses (PAL) and shared users (GAA).

CBRS third-tier user spectrum allocation is widely used to provide low-cost spectrum access for Enterprise Private Wireless and Fixed Wireless applications, leveraging LTE and newer 5G technologies. Independent research shows that over 50% of companies surveyed plan to deploy private 5G networks within the next 6 to 24 months. This is a dramatic market shift and is forecast to deliver much of the value expected from 5G.

While Mobile Operators plan to take advantage of this market shift through network slicing in the future, companies across the globe are already deploying private networks in unlicensed and lightly licensed bands like CBRS. As these private networks continue to scale, current approaches to spectrum grants are encountering challenges. Additionally, performance monitoring becomes critical because enterprise customers will rely on these private networks to support mission-critical applications, including those requiring low latency and high reliability.

The CBRS grant process does not ensure optimized use of the spectrum. Devices (CBSDs) accessing CBRS bands must be pre-registered with the SAS. The SAS does not monitor real-time data on other users of the spectrum. It relies solely on pre-registration and data provided by the ESC, which is built using propagation models, not real-time environmental data. Because of this static nature, the SAS cannot handle the growing number of devices or effectively manage changes in the RF environment (e.g., interference) or any cases where network devices or interference sources are moving.

DGS SOLUTION

DGS CLEARSITE™ can significantly improve the existing process by providing the SAS with real-time visibility of spectrum utilization, allowing grants to be made based on actual spectrum activity. Our patented solution, which utilizes advanced machine learning to provide actionable knowledge at the point of intercept, offers several benefits:

- The spectrum grant will be made based on current RF signal activity detected across the entire frequency band, not based on registrations that may not reflect the actual signal activity.
- Interference can be detected automatically, and replanning recommendations for existing allocations can be policy-driven. This will facilitate the coexistence of several third-tiered users in the band with minimal or no interference among them.
- Because CLEARSITE™ can provide a clearer picture of active signals, the number of access points able to share the spectrum increases. Currently, solutions do not exist to share channels based on the characterization of the active signals.
- Allows for the location and tracking of all active signals, thus quantizing possible interactions and interference between each other.
- Operators will have the ability to share channels and not just specific allocations of the spectrum. The current process is not true Spectrum Sharing. It’s better defined as Spectrum Allocation.

CLEARSITE™ provides these capabilities by embedding software directly in the 5G infrastructure or by deploying an independent sensor network. This strategy allows a portion of the CLEARSITE™ analytics to be integrated into every node in the network supporting dynamic optimization of the entire network. DGS solves the problem of scaling and performance limitations in private LTE and 5G networks by providing real-time knowledge directly to the SAS and network operators.

NETWORK PERFORMANCE

Resource Allocations

Typically, signal processing that exists in radio access networks is dedicated to establishing communication links according to defined protocols. Through rudimentary organizing actions, it is easy to see how this system can be enhanced based on different traffic types and a priori conditions (e.g., static policy). This is how most networks attempt to support mission-critical services. Unfortunately, these techniques do not address a central problem in today's complex RF environment. Interference from competing signals associated with different services and environmental sources must be managed. Typical functions in ISR systems are needed to provide effective and reliable awareness of the RF environment, including detection, classification in the time and frequency domains, and signal characteristics.

In addition to the time and frequency domain, signal characteristics are required (i.e., how all signals interact in the environment) along with geolocation. This information can be integrated into the RAN with dynamic and static policies associated with the provision of each service to extract actionable data that can be used to ensure the **optimization of resource allocations** (frequency, power, error correction, modulation schemes, etc.) required to establish efficient connectivity for all services in an automated manner. This is fundamental for efficiently managing existing services and inserting new emerging services and applications.

An example of emerging services requiring optimization of resource allocations is ultra-reliable and low-latency communications (URLLC). This is a crucial value element of 5G networks and is expected to support applications ranging from transport automation to robotic surgery. For the metaverse and more modest VR applications, effectively managing latency is critical to avoid creating a nauseous consumer. As the Enterprise continues to pursue the economics of leveraging cloud-based compute and storage, low latency becomes critical to ensure positive application experiences are maintained while accessing lower-cost resources. For these types of services, fast optimization of network resources based on relevant RF environmental information is a requirement.

Through multi-dimensional RF Awareness, the resource allocations necessary to support these services at a given time can be ascertained without making assumptions regarding the RF environment. “Knowing” the environment removes a significant variable in the computations necessary to guarantee a given service level and allows these services to be delivered effectively, automated, and cost-efficiently.

Network Slicing

Carriers can provide the same private wireless services through a cloud-native 5G standalone (SA) core network with network slicing services. This may involve less organizational disruption since on-premise equipment is moderated, but significant complexity is involved in the Carrier network. Network slicing promises to establish a virtual private wireless network with the same performance and security benefits as a dedicated private wireless network delivered on the carriers' spectrum.

The arrival of network slicing is one of the expected 5G capabilities that has lagged. The availability of the SA Core and the complexity of delivering and managing the service have delayed broad market adoption. This has created an opportunity for dedicated private wireless networks, which have seen solid market traction recently.

Allocating the spectrum in the Network Slicing model is less complicated since the same operator manages all the access points. However, the same motivation for efficient spectrum usage remains. Since the carrier has invested significant capital in acquiring the spectrum, every reasonable effort will be made to extract as much value from the spectrum as possible. In many cases, they will be competing for customer networks that may have free spectrum as an option, driving the carrier to be as efficient as possible in utilization of this resource. This creates a clear requirement for CLEARSITE™ RF Awareness.

Network slicing represents a significant opportunity for the carriers but managing the complexity associated with multiple networks and multiple SLAs will be challenging. CLEARSITE™ RF Awareness provides valuable environmental knowledge that will allow the RAN to adjust resource allocations to ensure SLAs are met in real-time, addressing a key complexity in managing these networks. SLAs will be difficult to maintain without visibility of the dynamic environmental conditions facing their networks.

CASE STUDY

Port operations are receiving more attention globally as supply chain disruptions have exposed challenges in these critical logistics points. Before this focus, streamlining operations through various automation options was already well underway[2]. This focus on operational efficiency has exposed the challenges associated with legacy networks, including coverage, capacity, reliability, and latency. As a result, ports and inland logistics centers have become a key target for 5G private networks and the performance benefits that can be realized.

In our example, we highlight the case of a private wireless network with multiple mission-critical communications applications leveraging low-cost shared spectrum. Our example

[2] https://www.wired.co.uk/article/rotterdam-port-ships-automation

reflects a port where a large number of mission-critical sensors (cameras, AGVs, identifying tags, etc.) are deployed, demanding high throughput of 25 Mbps per service (UL and DL) as well as services to support AR/VR applications that require high reliability and low latency (at least less than 10 ms). This port includes significant autonomous connectivity (M2M) as well. Figure 1 is a pictorial representation of such a port.

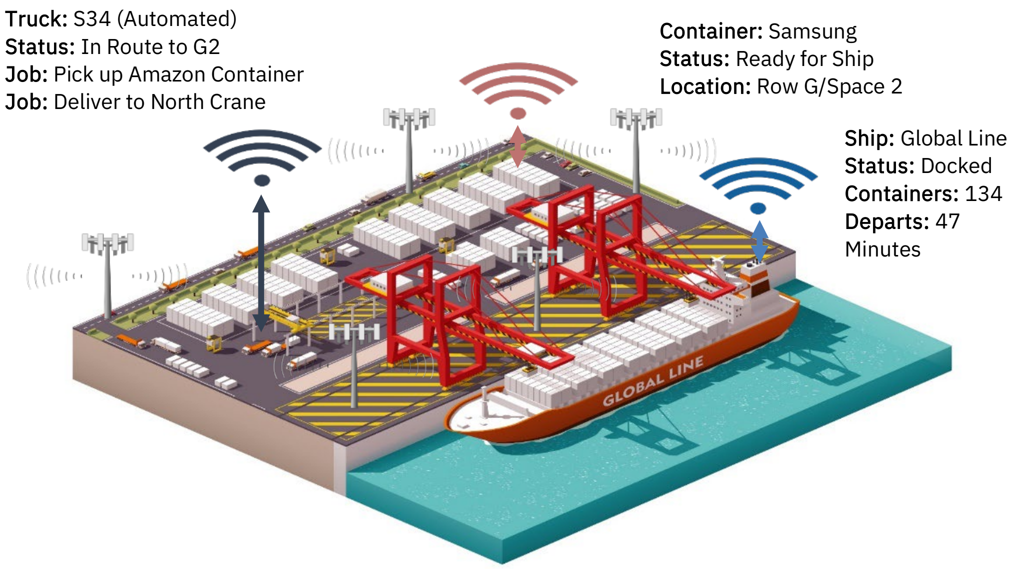

***Figure 1**: Private Wireless Network*

This example also represents a congested RF environment with multiple unrelated signals from ships and other port services in the environment, as well as port operations and security service signals, all utilizing a large portion of the spectrum in multiple bands (low-band, mid-band, and perhaps some lower portions of the high-band). It is expected to serve around 150 devices per square kilometer (data extracted from the Port of Hamburg RFI) and be able to support all services mentioned above and depicted in Figure 1.

Using the Hamburg port as an example, a typical coverage and capacity analysis (using a typical design methodology) is highlighted below:

- Delineated coverage area
- Define network configuration per service (frequency band, bandwidth, transmit power, antenna gains, etc.)
- Find average throughput requirement per service
- Calculate demand density of sites
- Calculate required range per service (using link budgets calculations for UL and DL, thus defining the expected coverage range)
- Calculate capacity range based on average device/cell spectral efficiency used for communications and available bandwidth

Because we require throughput of 25 Mbps with latency of less than 10 ms, we need to use relatively simple modulation schemes (with simple error correcting capabilities) and robust-to-low SNR and/or SINR (e.g., bpsk, QPSK, M-QAM, N-PSK, etc.), that are supported by the main protocol the network is using (LTE, Advanced LTE, 5G, etc.). Using LTE protocols, where you wish to support mission-critical service and the average service in the coverage area of interest suggests over 80 conventional sites, using a minimum of 40 MHz of spectrum, and some sites with 16-element antenna arrays and UEs with four antenna elements, or to support multiple directional layers. For high throughput mission-critical operations (autonomous uploading/downloading and tracking and transporting cargo), we can supplement the LTE protocol with advanced techniques in the physical layer that, based on the RF environmental measurements (such as SINR, SNR, latency, signal detected directionality, etc.) and customer priorities, can optimize the spectrum utilization through optimizing network parameters such as modulation (bits/Hz/s), available bandwidth, power usage, and propagation directionality, among others.

Depending on the density of signals in this RF environment, this will result in an increase in focused spectrum utilization that is equivalent to an increase in spectrum efficiency of 0.25 to 1.5 bits/Hz/s. This results in a reduction in the infrastructure required (sites) to support mission-critical services. For this example, an improvement equivalent to 0.5 bits/Hz/s can translate to an 11% reduction, while a 1 bit/Hz/s improvement will result in a 20% reduction, and a 1.5 bit/Hz/s improvement could result in a 28% reduction in the number of sites required to support the aforementioned mission-critical operation.

SUMMARY

CLEARSITE™ enhances the value of any private wireless deployment and represents a fundamental requirement where spectrum sharing and elevated network performance are necessary. The RF Awareness capabilities target specific obstacles facing these networks and ensure the Enterprise can extract full value from these deployments.

- **Scalability** through Dynamic Spectrum Sharing support
- **Economics** by improving RAN coverage and capacity
- **Network Performance** through support for URLLC
- **Sustainability** by promoting efficient resource allocations

As the RF Awareness delivered by CLEARSITE™ is integrated into Private Wireless solutions, the benefits across the industry will transform today's communications networks and support the promise of future 5G services.

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