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Private Networks for Refinery Industry - Commercial Deployment

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***Abstract*—The use-case like energy, mining, oil and gas moving towards industrial IOT (IIOT) applications for their day to day activities and this demands wireless connectivity every where. The Wi-Fi solutions are good for indoor but its hard to cover large outdoor areas with less Wi-Fi access points (APs), this leads to more APs deployment, cabling and infrastructure cost. On the other hand, public cellular networks offer an alternative, their limited proximity to refinery sites introduces difficulties. Mobile Network Operator (MNO) deployments are often situated far from refineries, and their base stations struggle to penetrate metal pipes, resulting in unreliable network connections and frequent disruptions to applications. To address these challenges, our approach involves deploying a private network on the Citizens Broadband Radio Service (CBRS [1]) spectrum, specifically in the 3.5 to 3.7 GHz mid-band range, within the refinery premises. This is the *first measurement based commercial deployment* ensures a robust signal footprint, even within metal pipes, thereby enabling employees to seamlessly utilize their devices and carry out daily tasks without encountering connectivity issues.**

I. Introduction

The use-case like energy and mining and their deployment scenarios concerning their corresponding challenges. Most of the Oil and Mining operations occur in rural places with poor network coverage and require heavy machinery to run 24 hours daily. The number of sensors on a refinery's pumps, tanks, and pipes can overwhelm radio systems (as shown in Fig. 1). Automation has been embraced by these roughnecks, with most large outdoor projects covered by LTE technology already. As more spectrum options and 5G devices become available, the market will move toward using LTE/5G for almost all of their wireless needs.

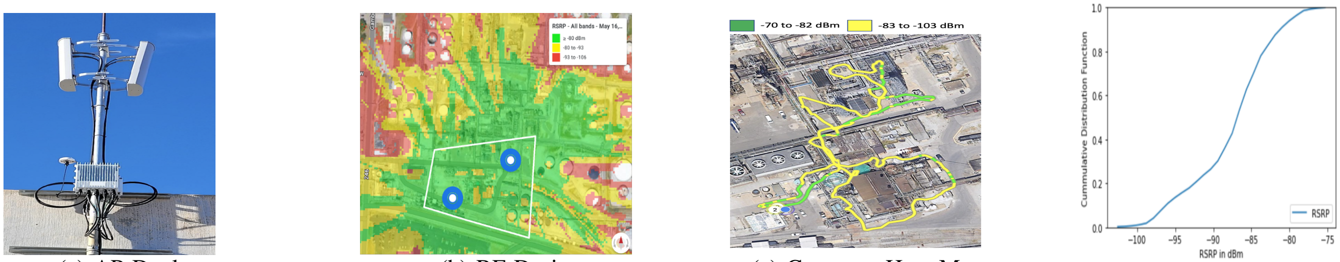
Fig. 1: Refinery - Industry 4.0 Use Cases.

Known Customer Deployments: Oil and gas companies have started to embrace LTE technology, including Origem Energia in Brazil, the Posiva plant in Finland, and Tampnet in the Gulf of Mexico. At least 15 energy companies have implemented Private LTE in drilling, extraction, refining, and downstream applications. Similar levels of investment are happening in the mining industry, with the number of autonomous haul trucks at mines growing to more than 1,000 during 2023, according to PwC.

Challenges faced by plants due to poor connectivity. In the refinery scenario, the employees carry the devices for inspections and routine check-ups. In most cases, they need prior approval to enter certain areas of the site. Depending upon the location and equipment involved, they need to get rigorous paperwork done prior to entering the site. The employees must go back and forth from the main office to each checkpoint to complete routine check-ups. Similarly, for inspections, they need to monitor specific areas and add information and data to the systems respective to the monitoring areas. In order to make this process simple and easy, refineries plan to move from manual paperwork to online approvals. For this change, the refineries need wireless connectivity throughout the premises.

Until now, Wi-Fi has been the default choice for wireless connectivity, but at these inspection sites, the reality is that the Wi-Fi signal is nonexistent or spotty at best. A large outdoor area (4000-5000 acres) in a harsh, metal-heavy environment is not conducive to Wi-Fi, as shown in Fig. 2. The number of Wi-Fi APs and infrastructure for copper, fiber, and switch ports are also very expensive. In addition, Wi-Fi operates on the unlicensed spectrum, and dense deployment of Wi-Fi APs demands more spectrum, eventually leading to more contention and collision on the wireless medium. Ultimately, this lowers the performance of mission-critical applications drastically.

When a lack of connectivity hampers digital solutions, refineries typically rely on labor-intensive solutions such as pen and paper or an offline computer to gather sensor data or images at the inspection site. Once back at the office, personnel uploads the data into SAP or similar platforms for consultations with on-site or off-site experts for the next steps. Considering that inspections occur 24/7, multiple times a day, these methods do not allow for any optimization or increases in efficiency - resulting in constantly increasing operational costs. They also introduce more possibilities for poor data-gathering practices and human error impacting the effectiveness of the work. Successfully addressing these connectivity challenges



(a) AP Deployment (b) RF Design (c) Coverage Heat Map (d) RSRP Distribution

Fig. 2: Performance Analysis interms of RF Prediction, Heat Maps and RSRP Distributions

opens up a myriad of possibilities for Industry 4.0 technologies, presenting the opportunity to enhance results and reduce costs significantly.

II. Comparing Connectivity Options

A. Public Cellular, Wi-Fi and Private Wireless [2]

In this section, we compare three different connectivity options for the refinery use-case **Spotty coverage:** Spotty wireless coverage indoors and especially outdoors causes delays in gathering and transmitting data, often resulting in a loss of productivity. In public cellular, the coverage depends on the location of macro towers, construction materials, landscape, and other external factors. Considering Wi-Fi, poor network coverage, especially outdoors, lowers transmission power susceptibility to spectrum noise - co-channel interference results in spotty coverage. However, in private networks [3], it is a more pervasive wireless solution due to higher transmit power, lower noise floor, and low wireless interference. **Unreliable QoS:** Mission-critical applications require definitive latency and throughput. Public Cellular is a best-effort-based solution and cannot guarantee QoS without expensive onsite installations. Wi-Fi does not guarantee throughput and latency as Wi-Fi does not support deterministic QoS with strict priority contention-based (CSMA-CA), requiring devices to "fight" for access, making prioritizing challenging. However, the private wireless network guarantees SLA for critical applications. 5G LAN features Microslicing technology that enables deterministic QoS with strict priority. Microslicing assures guaranteed bit rate and latency values for each device and application. **Mobility Issues** Autonomous vehicles and robotics often traverse expansive areas at speeds exceeding 25 mph. While mobility in public cellular networks is generally acceptable outdoors, it poses challenges indoors due to poor signal strength, contingent on the building materials used. On the other hand, Wi-Fi is not inherently designed for seamless mobility, as handover decisions are device-driven, requiring disconnection and re-connection to access points based on proximity. In contrast, private wireless networks facilitate seamless mobility within a company's indoor and outdoor facilities, and its infrastructure controls handover decisions and executes them with precision and timing [4]. **Constantly increasing costs** The total cost of providing wireless networks over a large area is prohibitive. Public cellular charges are based on consumption and are subject to overages and complex contracts. The Wi-Fi scenario requires more Wi-Fi APs due to the lower coverage range of Wi-Fi. Outdoor installs require expensive installation, trenching, and cabling. There are fewer APs in private wireless due to the higher coverage range of Private Wireless. Outdoor APs can be roof-mounted to provide significant outdoor coverage, avoiding the cost of trenching and cabling.

III. Performance Analysis & Conclusion

In this section, we discuss the RF prediction, coverage map and RSRP distribution for the dense metail refinery regions. Fig. 2 (a) shows the external environment of refineries with full of heavy metal pipe structure. Fig. 2 (b) shows the two AP RF design prediction model connectivity in those metal areas (which is represented by a white box). Fig. 2 (c), shows the device side coverage map. We used the professional rooted device QPOC to collect the Received Signal Reference Power (RSRP) coverage during the time of walk experiment. Fig. 2 (d) shows the RSRP distribution, we observed no coverage hole in the refinery premises. Only 3% of the users are in the edge of the coverage regions. We observed a smooth and reliable transmission of the refinery employee applications.

In our study, we performed the **first measurement on commercial deployment** of a private network within a refinery environment characterized by metal pipe structures. Our findings revealed that this deployment effectively delivers robust RSRP signals within the pipes, ensuring uninterrupted coverage and seamless mobility with dependable connections across the entire refinery. Notably, we did not encounter any areas lacking coverage within the premises.

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