White Paper

Tactical LTE

OCEUS NETWORKS

Background

Cellular communication systems provide an incredible capability to execute successful mission operations and represent an enormous savings to the Government in the development of advanced waveforms. The always connected and real-time dissemination of information improves a soldier's situational awareness, threat identification and mission execution. Leveraging commercial investments in research and development to benefit the warfighter is a sound proposition. Industry has invested billions in creating robust, reliable fixed networks.

Oceus Networks builds solutions that are tactically relevant in a Degraded, Intermittent, and Latent (DIL) environment. A tactical environment is distinct from a traditional fixed network where Wide Area Networks (WAN) are not guaranteed and equipment is on-the-move, including all the cellular infrastructure and services. And equally as important, Oceus Networks can create a secure, mobile, tactical broadband network without modifying COTS technologies to the point that future commercial investments cannot be leveraged.

Introduction

This paper discusses the different types of systems, the scalability of networks, deployment scenarios, testing, and management of the solution.

Size Matters – but it depends – Pico, Micro, Macro systems and Software Defined Radios (SDRs)

There are many different types of Long-Term Evolution (LTE) systems. An LTE system includes many subcomponents but some of the main components are: eNodeB (RF front end radio head and baseband processing unit) and Evolved Packet Core (EPC). There are many manufacturers and no single system type solves all deployment scenarios. Each system type has pros and cons and there are various things to consider:

- SDR system – small cell, flexible frequency agility, software interference filtering, range = meters, power output = typically 1W or less
- PICO system – small cell, frequency agility, frequency specific filtering, range = meters, power output = 250mW to 2W
- MICRO system – small cell, frequency agility, hardware filtering, range = meters to kilometers, power output = 5W to 10W
- MACRO system – Large cell, frequency agility, hardware filtering, range = kilometers to double digit kilometers, power output = 40W – 160W per radio head

SDRs and PICO systems are designed for indoor use with limited number of users, limited range, and tolerate very little RF environmental interference due in part to poor to non-existing RF front end components of the eNodeB. Adding power amplifier on the front of them to increase the range is a misconception. This approach also amplifies any noise in the environment and reduces the performance of the system. SDR systems use low powered general-purpose processors for LTE processing that limits the capabilities. In addition, as compared to commercial MACRO systems, SDR systems can't leverage the billions of R&D dollars spent by manufacturers to optimize performance nor leverage the improvements made from feedback from the massive number of fielded systems.

MICRO systems are designed for outdoor use and are typically designed to support 32 to 200 users, typically used for covering city blocks in an urban environment, and kilometers in a clear line-of-site environment. MICRO systems have dedicated hardware RF filters to deal with real world outdoor RF interference.

MACRO systems are designed for 200 to thousands of users, typically covering very large areas and have dedicated hardware RF filters. MARO systems are what commercial operators like AT&T use for their city-wide coverage. These systems use the highest quality of components and leverage the optimization and improvements made from feedback from the massive number of fielded systems.

Oceus Networks has thousands of man hours testing in a variety of outdoor environments and has proven with multiple customers that a MICRO system is the smallest system proven to work in an outdoor contested Electronic Warfare (EW) RF environment.

The throughput and range of a system is impacted by any interference in the RF spectrum. This interference can be any type of radio frequency in the spectrum, it doesn't have to be other LTE systems. Interference could be other communication systems or an intentional jammer. Systems that have high quality RF filters perform better than those that have software filtering.

Frequency agility can be accomplished in many ways. SDRs utilize software to adjust frequencies quickly but have limited RF filtering capabilities and therefore have lower performance in high interference environments. MICRO and MACRO systems use dedicated frequency radios with tuned hardware RF filters for higher performance. Systems that support simultaneous operation of multiple radios, each radio supporting a separate frequency, on a single system provides the same level of flexibility as an SDR but with increased RF performance in a contested RF environment composed of unknown or rogue emitters. Hardware RF filters are required for maximum RF performance. Commercial cellular operators like AT&T and Verizon depend upon robust equipment from TIER1 manufacturers such as Ericsson and Nokia and their equipment utilizes hardware RF filtering to guarantee the reliability and uptime their end customers demand.

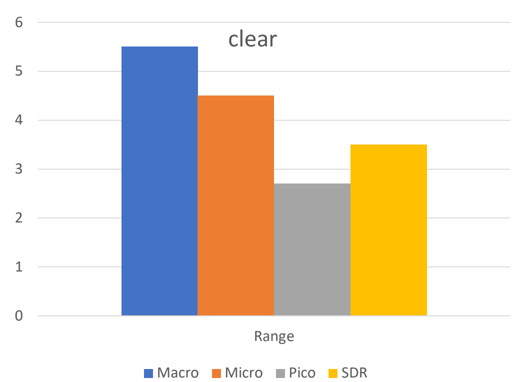
Mobile cellular links are typically uplink limited due to the lower transmit power levels associated with UE. Receiver sensitivity at the base station is a critical factor in determining maximum cell range. Receiver sensitivity is primarily influenced by the quality of the base station RF front end consisting of Low Noise Amplifier (LNA) and band pass filters. LNA Noise Figure sets the baseline Signal to Noise ratio for the entire receiver subsystem. Band pass filters determine the desired signal selectivity and unwanted noise rejection for the receiver subsystem.

LTE Macro and Micro systems have very good (low value) noise figures and have dedicated hardware filters with high attenuation to signals outside of the desired radio band. SDR systems typically have a lower LNA noise figure. SDR systems lack dedicated band filters since they attempt operations across wide frequency ranges. Operations across wide frequency ranges allow in unwanted emissions such a noise from adjacent channels.

Decreased cell range and reduced concurrent users are results of lower LNA performance. For example, Table 1 shows the expected uplink cell range for Macro, Micro, Pico, and SDR system types. Suburban cell ranges are calculated using link budgets with identical uplink parameters other than the referenced noise figures.

The Figure 1 clear graph below shows the improved Receiver Sensitivity and Uplink Range for each type of system in clear spectrum.

The Figure 1 interference graph shows the degradation in range from interference. This represents normal system level interference from neighbor cells, not jammer interference. Jammer interference would be significantly worse.



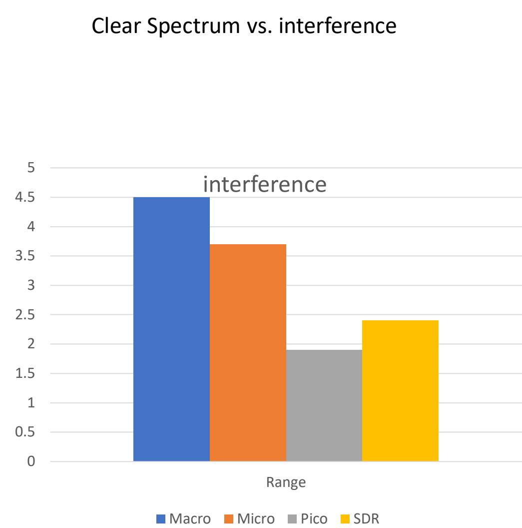


Figure 1: Clear vs Interference Range

	Noise Figure	Receiver Sensitivity (dBm/360 kHz)	Uplink Range (km)
Xiphos Macro	2	-121	5.5
Xiphos Micro	5	-118	4.5
Pico	13	-110	2.7
SDR	9	-114	3.5

* Xiphos Macro noise figure comes from Ericsson radio documentation.
** Pico noise figure reference comes from 3GPP TR 36.931.
*** SDR noise figure reference comes from Sidekiq™ X4, High-Performance, Multi-Channel SDR Transceiver

Table 1: Expected Uplink Cell Range

Table 2 below shows the effects of RF filter hardware on each system type. Macro and Micro systems have RF filters dedicated to the desired band of operation. SDR systems use software to simulate digital filters which often results in unwanted aliasing and additional latency. The impact of latency becomes more critical as LTE systems move towards 5G applications. Table 2 shows an expected 4 dB negative impact on Signal to Noise performance for SDR systems compared to Macro or Micro systems due to lack of dedicated hardware filters.

	Interference Impact (dB)	Receiver SINR* (dBm/360 kHz)	Uplink Range (km)
Xiphos Macro	3	-118	4.5
Xiphos Micro	3	-115	3.7
Pico	7	-104	1.9
SDR	7	-108	2.4

*SINR – Signal-to-interference-plus-noise-ratio

Table 2: Degradation in Range from Interference

Scalability

LTE systems On-The-Move have unique requirements that require creative solutions when based on Commercial Off the Shelf (COTS) Systems. COTS LTE solutions developed for the commercial sector won't meet basic tactical requirements without some additional functionality. Commercial cellular solutions lack capabilities to make them tactically relevant. Operation in a Degraded Intermittent and Latent (DIL) environment, for example, requires decentralized control and dynamic adjustments which are beyond the ability of the commercial, centralized solutions provided by traditional cellular networks. Within a contested environment, frequency agility enables the system in and around intentional and unintentional interference whereas traditional cellular solutions are statically configured. Commercial LTE deployments utilize a centralized model for user admission and authentication. Tactical operation requires a distributed model to support autonomous operation. COTS systems are designed for the mobility of user equipment between fixed LTE systems and require highly reliable system to system IP connectivity. To address LTE system mobility, Oceus Networks Advanced Network of Xiphos (ANOX) functionality synchronizes the user authentication databases (Home Subscriber Server (HSS)) across all systems to allow disconnected autonomous operation of a single stand-alone system as well as a multi-system network where a single user can attach and authenticate to any Xiphos system in the network. This HSS synchronization is a basic capability required for tactical LTE networks.

As additional communication resources are deployed to the Area of Operations, advanced On-The-Move capabilities and peer system awareness are required. COTS LTE technologies are not designed for the systems to be On-The-Move. COTS LTE systems are designed to be fixed, and then highly tuned for optimal performance and user experience. Tactical systems require system-to-system communication to tune the network in near real-time. For example, as systems come together and have overlapping RF coverage the systems must communicate this information to each other in order to adjust parameters and settings to allow for capabilities like session continuity via handover. Without this near-real time tuning, the user equipment (UE) and systems can enter an errored state and won't change their connections to a better target system and could remain attached to a system with a less desirable RF signal. Degraded RF signals results in degraded throughput when, instead, user equipment could move to a system with a stronger RF signal and better performance.

As systems move away from each other and their RF coverage no longer overlaps, the systems must communicate this information to each other. As UEs move from RF coverage, to no coverage, then back into RF coverage of another system, the UE will perform a network selection and attach procedure. Without this near real-time tuning, UEs could become disconnected for an extended period of time as the UEs cycle through standard COTS algorithms for network selection and attachment. COTS Network selection and attachment could take several minutes until the device is successfully re-attached to a system. These COTS algorithms are embedded deep in the UE and modification of those is near impossible. The network must adapt to control the COTS behavior and augment functionality for tactical networks.

Oceus Networks' Secure Mobile Platform (SMP) software makes moving from system to system security enclaves seamless for the user. SMP is a secure container of multiple security profiles that are automatically initialized based on the system selected. Each profile can be uniquely tailored to the security requirements of each system. SMP also monitors the status of the VPN tunnels and will re-connect seamlessly without any end user interaction. This solution allows the user to focus on their mission without manually entering credentials for each system.

Making applications available when operating autonomously or within a tactical network is a major challenge. Scaling services and distributing the data across multiple systems must be considered when designing a solution. A thorough data model must be created to understand the capacity of each system, as well as the backhaul between systems. Federated Services in a tactical network and the data modeling requires a vast understanding of the systems and network capabilities, and the deployment scenarios.

Deployment Scenarios

Stand-alone system deployments are the easiest to deploy. The only major consideration is the performance of the RF between the UE and the system. All user admission and authentication, security enclave, and services are all provided locally.

As deployments become more complex and additional systems are introduced into the network, the complexity increases exponentially. For these deployments to be successful, advanced On-The-Move capabilities are required. Distributed HSS, near real-time system tuning, security enclave management, federated services, multiple backhaul technologies to interlink systems, and mission planning and execution management software are mandatory.

Testability

Third Generation Partnership Project (3GPP) is the international standards organization that defines LTE waveform specifications. 3GPP waveform compliance ensures interoperability between commercial LTE user equipment and LTE operator networks. 3GPP eNodeB standards define LTE equipment performance in areas of modulation characteristics, conducted and radiated emissions, frequency stability, and interference rejection. Hardware RF filters are especially vital in meeting LTE receiver requirements towards sensitivity, selectivity, dynamic range, and interference rejection. Oceus Networks has extensive experience in testing to LTE specifications both in-house and with LTE industry certification labs. Besides LTE interoperability, optimal emissions performance and interference control are crucial to meeting operational thresholds identified in the DOD spectrum certification process (DD-1494 / JF-12).

Management

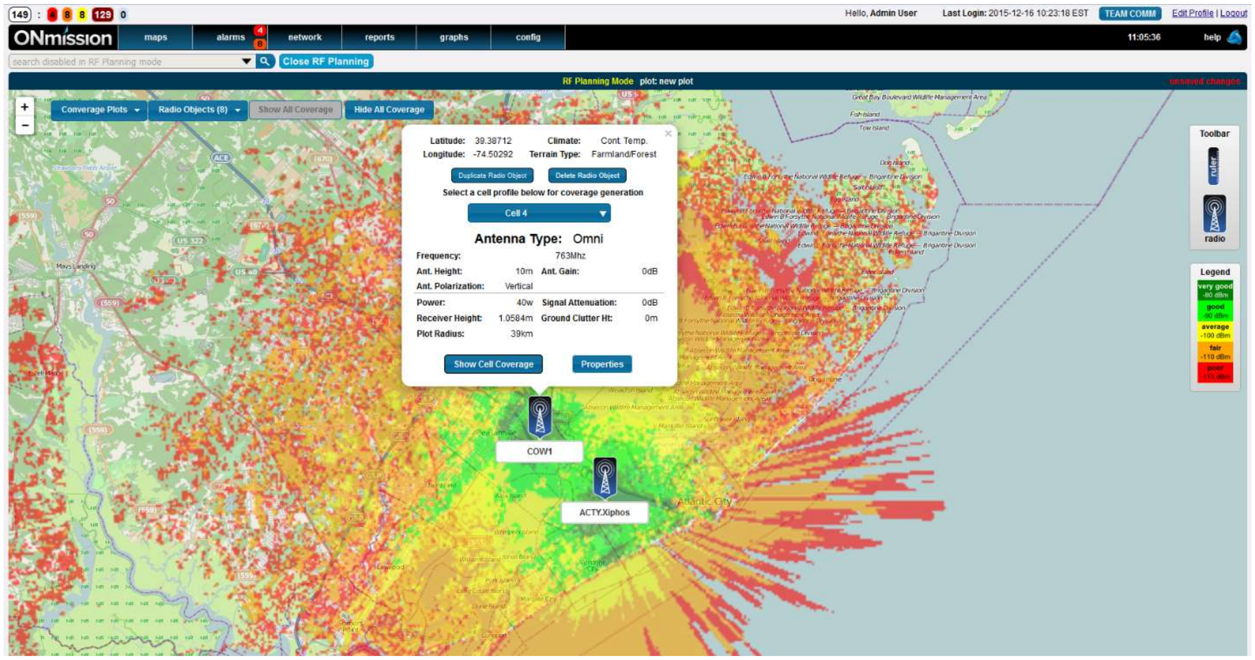
As part of an end-to-end Tactical On-The-Move solution, management of these networks is critical. Commercial tools can provide part of the solution, but not meet the near-real time requirement for successful planning, monitoring and execution of the mission. The distributed nature of a Tactical LTE deployment is also in conflict with the COTS centralized management approach. Custom management tools specialized for tactical networks are required.

Optimal situational awareness is essential to understand how information, events and actions will impact mission-critical goals and objectives.

Oceus Networks' ONmission is a network management software suite that includes SensorNet, RF planning, system provisioning, system monitoring, subscriber management, and Tactical mobile device management. ONmission has many features to plan, provision, manage, and troubleshoot mission networks.

ONmission SensorNet provides functionality to gather information from sensors in the network and Artificial Intelligence (AI)/ Machine Learning (ML) algorithms provide Situational Awareness (SA) across the entire network including the RF environment and backhaul links between systems. Sensors can include the UE, the LTE systems, backhaul products like MANET, SATCOM, and others.

ONmission RF planning is an RF coverage prediction map that is used for pre-mission planning. Below is a screenshot of ONmission RF Planning.



Summary

Tactical On-The-Move solutions are unique and require specialized functionality on top of COTS HW & SW.

Oceus Networks provides powerful solutions to tactical communication users. Oceus Networks has spent years designing, testing and deploying our products to provide an end-to-end-solution that works in this unique and dynamic environment. We were first to deploy Commercial Solutions for Classified (CSfC) security for cellular in a tactical environment for the 4G Afloat NAVAIR project. We were first to demonstrate handover from eNodeB to eNodeB in a tactical environment during NIE 13.2 with the Army's Warfighter Information Network-Tactical (WIN-T).

For more information, see our patents on these subjects:

Methods of Operating Wireless Parameter-Sensing nodes and remote host

U.S. Patent No. 9,055,163

Best Backhaul Available Link Quality

U.S. Patent No. 9,155,020

Mobile Cellular Networks (ONmission)

U.S. Patent No. 9,167,442

Mobile Cellular Networks (Xiphos)

U.S. Patent No. 9,198,221

Backhaul Optimization

U.S. Patent No. 9,924,427

Secure Network Enrollment

U.S. Patent No. 9,686,238

Target User Equipment-Base Station Comm Link

U.S. Patent No. 10,172,078

Secure Network Rollover

U.S. Patent No. 15,625,035

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