Paper Title: Radio Network Automation for Operational Testing. A Practical Resource for Radio Network Planning

Robert Cox	Carlos Leon-Barth, Patricia Wright	Thomas Mitro	Scott Nix, Robert E. Carpenter
Army PEO STRI	Athena-Tek	AIT Engineering	General Dynamics
Orlando, FL	Orlando, FL	Orlando, FL	Orlando, FL
Robert.M.Cox14.civ@mail.mil Author2@email.com	Carlos.Leon-Barth@athena-tek.com Patricia.Wright@athena-tek.com	Thomas.Mitro@aitengineering.com	Scott.Nix@gd-ms.com Robert.E.Carpenter@gd-ms.com

ABSTRACT

This paper summarizes the research conducted by General Dynamics in cooperation with the United States Army Program Executive Office for Simulation, Training and Instrumentation (PEOSTRI) in the development of a Radio Network Planning application that leverages Scalable Network Technologies (SNT) Radio Frequency (RF) modelling combined with the visualization power of National Aeronautics and Space Administration (NASA) Web WorldWind open source virtual globe Application Programing Interface (API). The resultant product delivered to the U.S. Army at Ft. Hood Operational Test Command (OTC) site permits Test Officers with no previous Radio Frequency (RF) training to identify the optimal network coverage automatically for different selected test range locations. The simulation considers terrain features using Digital Terrain Elevation Data (DTED), tower location, uplink and downlink transmission, environmental and ground effects, using pre-configured radio models for Cubic Army Mobile Instrumented Training System (AMITS) and Saab Interim Range System (IRS). The final product supports the Home Station Instrumentation Networks and Test Center networks while promoting an interactive user interface experience with graphical network coverage heat-map overlays displayed via open source products utilized throughout the Integrated Live-Virtual-Constructive Test Environment (ILTE) product line. The methods, models and research results summarized in this paper shall be of interest to the radio networks simulation software design and development community with interest in a practical approach to Radio Network Planning.
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ABOUT THE AUTHORS

Dr. Robert Cox, is a member of the US Army PEO STRI Program Manager for Instrumentation, Targets and Threat Simulators (PM ITTS) Instrumentation Management Office (IMO) and is the program manager for the Integrated Live Virtual Constructive Test Environment (ILTE) and Test Modernization (TNM) programs. Dr. Cox has an earned Doctorate in Atmospheric Sciences and Meteorology from Texas A&M University and has over 60 publications.

Dr. Carlos Leon-Barth, is the Chief Systems Engineer at Athena-Tek with 20 years of expertise in simulation and training. He is actively supporting the Integrated Live Virtual Constructive Test Environment (ILTE) program at General Dynamics. Dr. Leon-Barth holds a Bachelor of Science. in Electrical Engineering from University of Florida, a Master of Science and Doctor of Philosophy in Computer Engineering from the University of Central Florida. Dr. Leon-Barth has numerous publications in areas of bandwidth optimization, modeling & simulation.

Patricia Wright is the Senior Radio Frequency Engineer for Athena-Tek is supporting the Integrated Live Virtual Constructive Test Environment (ILTE) program at General Dynamics. She has 19 years' experience in commercial telecommunications. She has experience with Nextel, Sprint, and Shentel using various Samsung, Ericsson, Lucent and iDEN radio systems. She specializes in Radio Frequency engineering with a strong emphasis on propagation modeling and simulation, in-building systems and spectrum planning. Mrs. Wright has extensive experience with RF network design and mobile communications in narrow and wide band technologies. She earned a Bachelor of Science in Electrical Engineering from the University of South Florida.

Tom Mitro is a Staff Software Engineer at AIT Engineering in Orlando, Florida. He has over ten years' experience in both the defense and commercial industry having previously worked for Lockheed Martin, Nova Technologies, Universal Orlando and Electronic Arts. Mr. Mitro holds a Bachelor of Science degree in Computer Information & Sciences from Ohio State University and a Master of Science degree in Modeling & Simulation from The University of Central Florida.

Scott Nix is the current General Dynamic's Program Manager of the ILTE effort. He has been developing or managing development of tactical and live, virtual and constructive training products for the US Armed Forces for the last 25 years.

Robert Carpenter is the General Dynamics Mission Systems (GDMS) Lead Engineer on the PM-ITTS project: Integrated Live-Virtual-Constructive Test Environment (ILTE). Mr. Carpenter is licensed Professional Engineer (PE) with over 30 years of experience in systems engineering, project management, and team leadership. He has a Bachelor's a degree in Electrical Engineering and a Bachelor's degree in Music from Northwestern University.

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Robert Cox
Army PEO STRI
Orlando, FL
Robert.M.Cox14.civ@mail.mil
Author2@email.com

Carlos Leon-Barth, Patricia Wright
Athena-Tek, Inc.
Orlando, FL
Carlos.Leon-Barth@athena-tek.com
Patricia.Wright@athena-tek.com

Thomas Mitro
AIT Engineering
Orlando, FL
Thomas.Mitro@aitengineering.com

Scott Nix, Robert E. Carpenter
General Dynamics
Orlando, FL
Scott.Nix@gd-ms.com
Robert.E.Carpenter@gd-ms.com

INTRODUCTION

The US Army PEO STRI sponsors the Integrated Live, Virtual, Constructive (LVC) Test Environment (ILTE) program, on a mission to build new Operational Test Command (OTC) capabilities; ensures that the ILTE requirements for upcoming operational tests are satisfied. The program leverages the Common Training Instrumentation Architecture (CTIA) reusable software and services to create novel capabilities that support of the Army Combat Training Centers (CTC) needs. Training and Instrumentation (PEOSTRI) in the development of a Radio Frequency Network Planning, leveraged Scalable Network Technologies (SNT) Radio Frequency (RF) software modelling tool. SNT developed radio models for EXata to represent OTC radios, however immature to model radios from Cubic Army Mobile Instrumented Training System (AMITS) and Saab Interim Range System (IRS). The program leveraged tool was a good candidate for predicting OTC radio communications, but did not have a visualization tool that would permit Test Officers with no previous RF training to identify the optimal RF network coverage automatically for different selected test range locations.

Following program requirements the team drafted a plan to leverage SNT work as a baseline for a radio network planning tool that abstracts the underlying complexity of RF communications theory, and permits Operational Test Personnel to perform RF network performance studies within pre-determined geographic areas. Most importantly, the design had to include a user interface that allowed the OTC user to position the network elements over the terrain using heuristics learned in the field. The tool using color regions overlaid on a map would describe intuitively the effects of the radio communication network interaction with the selected terrain.

The RF Network Automation Tool fielded to the United States Army and described in this publication generates holistic results that conduct to a reliable communications RF network layout. The software tool leverages existing transmitter and receiver mathematical models for different radios used at OTC. Modeling considers antenna radiation patterns, ambient effects, terrain topology within other RF characteristics explained further on this document to automatically generate visual color graded effects of the radio network propagation overlaid on maps integrated using USGS terrain data, National Aeronautics and Space Administration (NASA) WorldWind and GeoServer open source applications. The fielded Radio Networks Planning provides the ability to create realistic what-if scenarios as a basis for analysis for a chosen network layout. The resultant network propagation studies obtained prove that different scenarios can be used to optimize the network layout for a specific geographic area. The data saved, can be revised ensuring that the simulated results correlate with active network measurements further providing final information regarding the optimal layout for the network. The following sections provide information to the scientific community about the tools used, the integration devised and the results obtained.

Radio Networks Propagation Study

The SNT EXata network simulation software, licensed to the ILTE program, is comprised of radio model algorithms that are used as a base to preset a communications network and predict its propagation performance mathematically as the radio signals interact with Digital Terrain Elevation Data (DTED) collected from United States Geological Survey (USGS) site (Earth Explorer Home, n.d.). However; SNT communications network resultant prediction lacks the display of the RF communication effects on the selected terrain. The RF network prediction tool default wave radios models are enhanced by the radio wave parameters for the radio equipment used during the operational tests. The radio models updated behavior reflect operating conditions such as weather, location and terrain topography for the geographic areas selected.

The RF network prediction tool provides great data results thousands of times a second that can't be studied on a map. Working together with SNT and the authors of this publication, we leveraged the CTIA/ILTE existing situational awareness tools built around NASA World Wind (NASA Ames Research Center, 2019) and GeoServer (Open Source Geospatial Foundation, 2014) and delivered a network propagation map layer over a GeoTIFF (GeoTIFF Format Specification Revision 1.0, 2019) terrain map layer that displays typical radio communication coverage for selected Operational Test Center areas. Therefore, Operational Test Personnel without RF theoretical knowledge of the underlying network, can apply heuristics and position network elements on the map as they observe the radio coverage results. Minutes later, the visual outcome of the RF prediction allows the rehearsal of the test operation communications to ensure feasible and truthful communications based on the location of the transmitting towers.

Wihl pointed out in his experiments that most modeling and simulation systems assume perfect communication conditions (Wihl, Lloyd, 2015). The fielded CTIA based propagation application considers imperfect communications by inserting in the model parameters air density, temperature and the effects of foliage on the terrain that provide a visual performance study of the RF communications networks that is closer to reality. The visual results obtained are an enhancement to the existing SNT application tools.

A radio frequency propagation study provides the necessary tools for computing the strength of a given signal transmission at the various locations in the network, compute coverage patterns and thus provide good coverage where needed. Typically, these propagation tools are challenging to configure and require a Radio Frequency (RF) Engineer to model the antennae, radios, technology and modulation. Other parameters normally considered for a RF network prediction are transmit/receive frequencies, channel bandwidth, up/down link calculations, budgets and weather conditions.

The radio frequency propagation tool uses a mathematical model to statistically describe the signal strength on the path from transmitter to receiver. There are several mechanisms which affect fundamental modeling of signal strength. Some of which are distance sensitivity, local variability also called local mean and changes around the local mean. The average power loss is a monotonically increasing function of the distance between the base station and the mobile user (IEEE, 1993). The plane wave incident on the mobile receiver changes slowly due to different scattering mechanisms and the surrounding terrain structure as the mobile user moves from one location to another. Thus, superimposed on the path loss are slow variations in the mean signal strength and over a period of time, which is short in comparison to the periods of the slow channel variations, so that the mean signal level appears essentially constant. It is assumed that over this short period of time the prominent features are the same and that although mobile radio channels are non-stationary, mobile radios can in practice be modeled over short-time intervals, as stationary.

Many scenario combinations of the RF propagation tool were analyzed to determine the optimal and best fit path loss calculation. The signal strength, as stated above should fall off as a function of distance and considering the radial calculation distance was set to 10 km, we would expect to see very low predicted signal levels at the edge of the coverage area. The area near the edge of coverage would typically expect to see transmit power values dip to -127 dBm and into the noise floor. Each iteration and improvement in the RF propagation tool predicted model will provide more accurate path loss values so the calculations can be optimized, and the predicted coverage plots will be closer fit to measured signal levels in the field. A radiating element (transmitting antenna) causes a distribution pattern of radiated power and the receiving antenna collects the electromagnetic energy as the radiated power crosses its aperture.

This brings the following Free-Space Path Loss Equation:

$$\frac{P_r}{P_t} = \left[e_t \, e_r (1 - |\Gamma_t|^2)(1 - |\Gamma_r|^2) \left(\frac{\lambda}{4\pi d} \right)^2 \right] \times [D_t(\theta_t, \varphi_t) D_r(\theta_r, \varphi_r) |\boldsymbol{a}_\mathrm{t} \cdot \boldsymbol{a}_r|^2]$$

Equation 1. Free-Space Path Loss

This equation considers the transmitter and receiver components for the system. It takes into account an impedance mismatch between Γ_t and Γ_r and represents the polarization unit vectors of the antennae as $\boldsymbol{a}_t$ and $\boldsymbol{a}_r$. In the remainder of this text we will assume reflection coefficients $[(1-|\Gamma_t|^2)(1-|\Gamma_r|^2)] = 0$ at both ends (no mismatch losses), no efficiency losses ($e_t\, e_r = 1$) at both ends, and the dot product of the polarization unit vectors = 1 (no polarization losses). We can comfortably make these assumptions knowing the equipment has gone through rigorous testing to comply with military standards (U.S. Government Department of Defense, 1996).

The Antenna directivity is the value of the directive gain in the direction of its maximum value at the transmitter and receiver is expressed by $D_t(\theta_t, \varphi_t)D_r(\theta_r, \varphi_r)$. We replace directivity with antenna gain $\boldsymbol{G_{0t}G_{0r}}$ to account for the non-isotropic (ideal) antenna. Then, the Free-space path loss written as a ratio of received-to-transmit power ($\frac{P_r}{P_t}$)is now Equation 2 (Ulaby, 1997), the Friis Transmission Equation that represents the power transmitted, with gains, from one antenna $\boldsymbol{G_{0t}}$ to another receiving antenna, with gains, $\boldsymbol{G_{0r}}$ when operating at wavelength λ and separated by a distance *d*.

$$\frac{\boldsymbol{P_r}}{\boldsymbol{P_t}} = \boldsymbol{G_{0t}G_{0r}}\left(\frac{\boldsymbol{\lambda}}{\boldsymbol{4\pi d}}\right)^{\boldsymbol{2}}$$

Equation 2: Friis Transmission Equation

A simplified calculation allows us to discuss the component pieces of path loss. From the Friis equation to the simplified equation below, we rearrange the equation and solve for Received Power, $\boldsymbol{P_r}$. Recall, logarithmic identities transform the equation into a sum and difference resulting in Equation 3.

$$Received\ Power = Transmit\ Power - Path\ Loss + Fading + Shadowing$$

Equation 3: Simplified Power Received Equation

Free-Space Path Loss means implies that no physical obstructions are present. In telecommunication, the free-space path loss (FSPL) is the attenuation of radio energy between the feed points of two antennas that results from the combination of the receiving antenna's capture area plus the obstacle free, line-of-sight path through free space (usually air) (Islam & Haider, 2010). The "Standard Definitions of Terms for Antennas", IEEE Std 145-1993, defines "free-space loss" as "The loss between two isotropic radiators in free space, expressed as a power ratio." (IEEE, 1993). Despite this name and definition, the FSPL includes a receiving antenna aperture component in the total attenuation (Islam & Haider, 2010). It does not include any path loss associated with hardware imperfections, or the effects of any antenna gains. It is an unusual name in that free-space is not radio signal transmission in a vacuum but terrestrial propagation without the effects of ground clutter, vegetation, and terrain and must have line-of-sight between a transmitter and a receiver. Essentially, empty physical space for wave propagation.

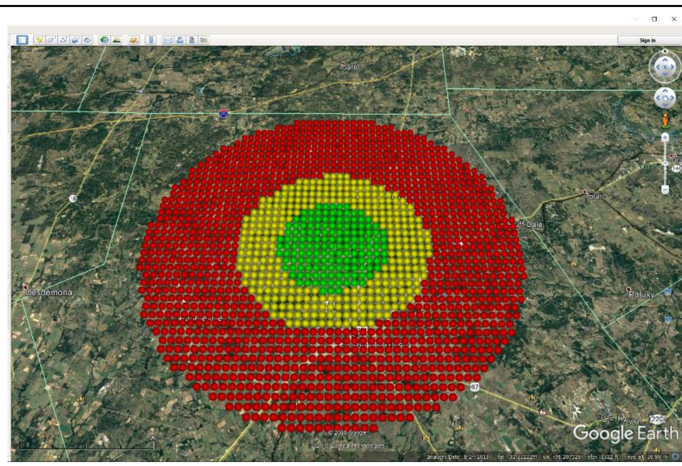

Figure 1. Free-Space Pathloss Coverage Plot

Figure 1 is an example of the data when RF transmission is isolated for one transmitter not accounting for terrain variation. RF Signal coverage does not propagate concentric rings therefore we should expect there to be more signal level variation as the signal passes over the terrain, ground clutter or land use and through the foliage. For Radio Signal communication, the free space assumption is far from being realistic and the terrain is always present. In reality, the simplified path loss model represents an “average” and we need to represent the difference between the average and the actual path loss.

Long-term fading is a random process caused by shadowing and the statistics of the slow variation of the mean level caused by signal shadowing of the radio signal by buildings and hills (Dowla, 2004). Most propagation tools refer to shadowing as long-term fading but this particular RF propagation tool prefers to use shadowing. Short-term fading is the process of rapid, random fluctuations of the power level around the local mean. The mechanisms that change the “short-term” characteristics change over as little as a quarter wavelength, while the “long-term” statistics remain constant over about sixty wavelengths. In addition to long and short-term fading, there is multi-path which is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies, to name some of the causes (Dowla, 2004).

Figure 2 Path Loss, Shadowing and Multi-Path shows the path loss alone as the solid line, with shadowing and path loss and the large dots, dotted line and finally the combination of path loss, with shadowing (fast and short-term) losses and multi-path losses plotted vs the ratio of received to transmit power on a logarithmic scale. The small dotted sinusoidal wave is the predicted path of the radio signal as it moves away from the transmission point to the edge of coverage. Note the oscillatory behavior of the signal as it moves along the path of both the path loss alone line and the shadowing and path loss summed dotted line. So now we have a graphical view of the variations around the local mean of the radio signal.

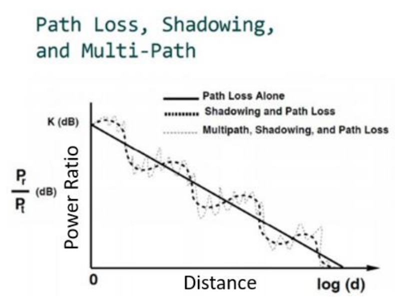

Figure 2. Path Loss, Shadowing, and Multi-Path

Many scenario combinations of the RF propagation tool were analyzed to determine the optimal and best fit path loss calculation. The planar earth model transforms spherical coordinates into planar coordinates, basically a flat earth model. The two-ray method is a geometric method which predicts the path losses between a transmitting antenna and a receiving antenna when they are in Line of Sight (LOS) and calculates a reflected signal for the second ray. Longley-Rice is also known as the Irregular Terrain model (ITM) that has two parts: a model for predictions over an area and a model for point-to-point link predictions (Scalable Network Technologies, Inc, 2018). The ITM was selected as the propagation model for the reason that it is a better fit for the areas of interest for this project. The signal strength, as stated above should fall off as a function of distance and considering the radial calculation distance was set to 10 km, we would expect to see very low predicted signal levels at the edge of the coverage area. The maximum calculation distance of 10 km was chosen after many propagation iterations and a review of the signal strength versus receive sensitivity of the four radio systems of interest. For example the receive sensitivity of one radio system was -102 dBm and another was -105 dBm. The area near the edge of coverage, we would typically expect the transmit power values to dip to -127 dBm and into the noise floor. Each of the radio systems require the signal to fall off enough so the interference levels can be estimated by the edge of usable coverage for that particular radio system. Ten kilometers was chosen because the radio signal of this study achieved the fall off required at that distance. Knowing this initial deployment, is omni antennae rather than directional, we can add that the calculation distance is twice the radial distance as well. The additional challenge for this RF Network Coverage Tool was the wide range of frequencies used by the radios. Some of the radio networks would be adequate to cover the area with 3-5 towers while some may need up to eight towers for the same given area. We had to factor in frequency usage germane to each radio system from 225 MHz to 1.3 GHz. Interestingly, ITM is method for predicting the attenuation of radio signals for a telecommunication link in the frequency range of 20 MHz to 20 GHz (Scalable Network Technologies, Inc, 2018), our frequency range. This large variation in the spectrum range is problematic for distance with respect to signal penetration through foliage and signal speeds.

CTIA Leveraged Capabilities

The Common Training Instrumentation Architecture utilizes a Service Oriented Architecture (SOA) to support multiple applications in the Live Training Transformation (LT2) product line. CTIA and the LT2 product line were developed under PM TRADE and PEO STRI to support Army live and joint training exercises and, additionally, interoperability in LVC environments (Lanman, Linos, Barry, & Alston, 2016). The CTIA SOA platform is built upon loosely-coupled software components that are designed for a separate, individual functionalities (Service-oriented architecture (SOA), 2019). Examples of such services are locational translation, Battle Damage Assessment (BDA) models, and training exercise entity services. CTIA SOA services communicate through the Streaming Text Oriented Messaging Protocol (STOMP) and Representational State Transfer (REST) Abstract Programming Interfaces (APIs) exposed to LT2 components. A new CTIA SOA service and LT2 component were developed to enable network planning functionality for ILTE in order to interface with the SNT EXata Commercial Off The Shelf (COTS) software based on RF configurations provided by the NASA Web WorldWind User Interface (UI).

EXata is an RF network prediction platform, as explained in the sections above that uses Software Virtual Networks (SVNs) to emulate network antennas and other RF devices. The software provides data via multiple RF protocol layers to interface with differing devices to provide the ability to connect to real-time applications through network emulation (EXata Network Emulator Software, 2019). When integrated into the CTIA environment, this data is used to provide the LT2 map implementation with network planning data. The LT2 map implementation was developed using NASA Web WorldWind open source software using GeoServer as the terrain tile server for the visual application.

Web WorldWind is an open-source JavaScript library provided by NASA and is the map implementation for ILTE, which interfaces with necessary LT2 components and CTIA SOA services (NASA Ames Research Center, 2019). While the default Web WorldWind application utilizes map data, such as imagery and terrain assets, hosted openly by NASA, in this particular case this is hosted by a GeoServer instance for the ILTE system given the computational enclave requirements within a closed network that ILTE operates within (Features-WWSK/NASA WorldWind, 2019). The local GeoServer is able to provide standard imagery data to WorldWind client applications, such as GeoTIFFs, Shapefiles, and Geospatial Data Abstraction Library (GDAL), and also provides hosting of terrain formats such as DTED and Band Interleaved by Line (BIL) (Features-WWSK/NASA WorldWind, 2019). Web WorldWind and GeoServer live in virtual machines inside the ILTE environment.

Figure 3 demonstrates the user interaction with the LT2 User Interface (UI) to invoke the CTIA SOA network planning service, which handles communication between the SNT EXata software and LT2 framework. When an OTC loads the map, any imagery or terrain data that has been imported into the GeoServer instance is served to the web client

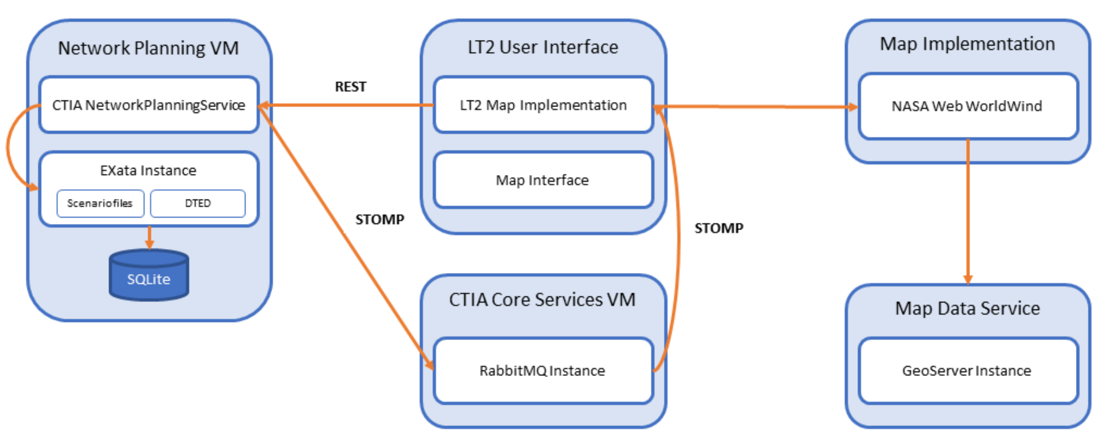

Figure 3. ILTE Networking Planning CTIA/LT2 Implementation

application. The LT2 map component, which is agnostic of the map implementation, then queries instrumentation and exercise-specific CTIA SOA service(s) to retrieve network planning data as it is represented in the CTIA data model. Once the map has initialized with map imagery and SOA services, the user can interact with antennas and network towers in the LT2 UI and invoke the request to calculate network coverage for the network towers. The network planning CTIA SOA service then passes the network tower data to the EXata application, which it uses in conjunction with DTED data to create a SQLite database dump file containing the calculated coverage data. The CTIA SOA network planning service is alerted when the database dump file is created, mines the EXata SQLite database to map to the CTIA data model representation, and sends the mapped data via STOMP 1.2, an HTTP modeled framed based protocol (Github Inc., 2012). The LT2 network planning component handles this data once it receives the STOMP message and calls on to the LT2 map implementation to render.

Network Propagation Visualization

Initially we had to analyze the data that was being captured by EXata and visualize the results for comparison. The generated data by EXata was stored in a SQLlite database; it contained thousands of records generated every second. We created a new service to read the data stored in SQlite to quickly observe the power of the transmitters as radiated in free space.

Upon receiving the STOMP message from the CTIA SOA network planning service, the LT2 Map Component creates a new WorldWind Layer in which to render an image of the coverage data (WorldWind: Class: Layer, 2019). This data from the SOA service contains the latitude, longitude, and average signal strength to create an image containing a gradient of points based on the three fields. Figure 4 represents the signal strength ranges used when determining the gradient of the image, which is then used to create a WorldWind Placemark containing the gradient and is then added to the WorldWind Layer to be rendered (WorldWind: Class: Placemark, 2019). Figure 4 shows the initial visualization of network coverage data exported by EXata in Google Earth. It can be noticed how the red dots provide information where the RF reception is weak. More importantly it depicts areas where the RF reception is theoretically unavailable. Figure 5 depicts the final visualization of the data in the ILTE environment displayed on the web client with the geographic antenna locations. The dots are now replaced by the heat map layer in WorldWind, which represents the areas of radio reception considering effects for a fixed power source. It can also be noticed that the green areas in low mountain areas provide good coverage, however decreased by terrain obstructions such as hills and foliage. The comparison of images verifies the accuracy of displaying network coverage data by Google Earth and the LT2 WorldWind map.

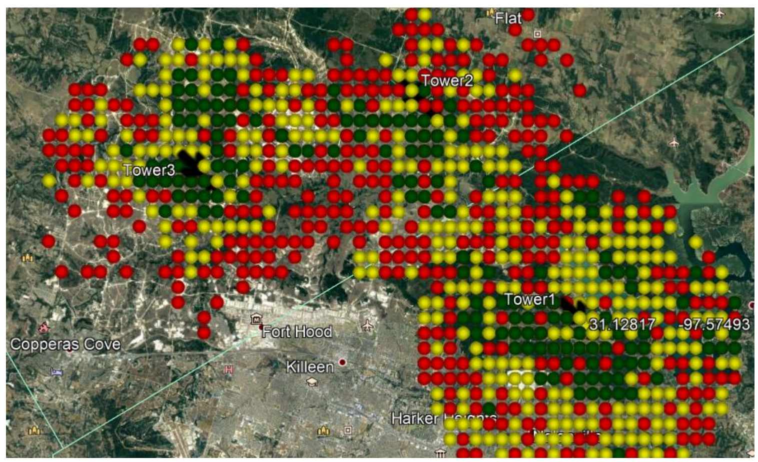

Figure 4. Initial EXata Output Visualization.

The table below depicts the network coverage strength as it relates to the aforementioned visualizations. Received signal level bands were determined by industry standards for TDMA narrow band networks. Green being greater that -85 dBm is considered to guarantee in "comms" with a nine-dB fade margin. Yellow signal levels between -85 dBm and -95 dBm are placed into a "good but not guaranteed" with a nine-dB fade margin. Lastly, the received signal between -95 dBm and -105 dBm are in a class considered to be marginal in which the radio could be "in and out of comms" due to a variety of reasons from terrain to distance or foliage.

Table 1. RF Network Signal Power Legend

Signal Bands	Average Signal Power (dBm)	Color Display
Good	Greater than or equal to (-85)	**Green**
Marginal	Less than (-85) and greater than (-95)	**Yellow**
Poor	Less than (-95) and greater than or equal to (-105)	**Red**

Challenges

The EXata RF propagation tool does not predict co-channel interference and to resolve that challenge, a geographical grid was used to determine the areas likely to experience co-channel interference from tower to tower. While that method is inaccurate, the risk was assumed knowing that if the path loss was greater than predicted the result could be dead zones or if the path loss was less than predicted the result could be areas of co-channel interference. The next challenge was that there is no uplink component to the prediction. The RF path from the radio to the tower was not modeled and path balance between the downlink and uplink was calculated, not predicted. An additional shortcoming to this project was the lack of noise floor analysis. Again, this could be problematic if the predicted signal strength varies significantly greater than or less than. And lastly, to determine required capacity, uplink predictions are needed which is described above.

The challenges faced from the ILTE network planning implementation have mainly been related to communication between the CTIA SOA service and external EXata COTS software. While there is a RESTful interface provided by EXata, it's not sufficient an ILTE use case. Optimally, network planning data would be condensed and passed to the COTS software that computes the network coverage, but there were many challenges in sending the required information, monitoring of SQLite database file generation, and installation of the software in conjunction with the CTIA SOA services that had to be overcome.

RESULTS

The improved fidelity of the SNT radio models permit predictions of the RF network coverage in locations like Ft. Hood and Ft. Bliss. The resultant radio network studies can be used by OTC operators in these isolated locations to predict the optimal location of the transmitters for different operational tests. The results obtained using current antennae locations explain the signal loss in known areas. The derived conclusions are the basis for antenna transmitter relocation. Figure 5 shows the final results of two predictions, a two and three tower network prediction at Ft. Hood using different antenna locations and sorted by increased coverage. It should be obvious to the reader that green areas or transitions from green to yellow provide the best coverage. The increased color density indicates the best antennae distribution for the selected terrain. Red regions designate unreliable coverage and transparent regions indicate no coverage.

We demonstrate that the system design simplifies the Test Planner's tasks before an exercise begins by giving that Test Planner the tools to plan the radio network with confidence of the results. The simplicity of the color scheme, ease of tower placement and radio system flexibility empowers the Test Planner and removes doubt with respect to radio coverage. This will allow the Test Planner to troubleshoot radio issues with increased confidence.

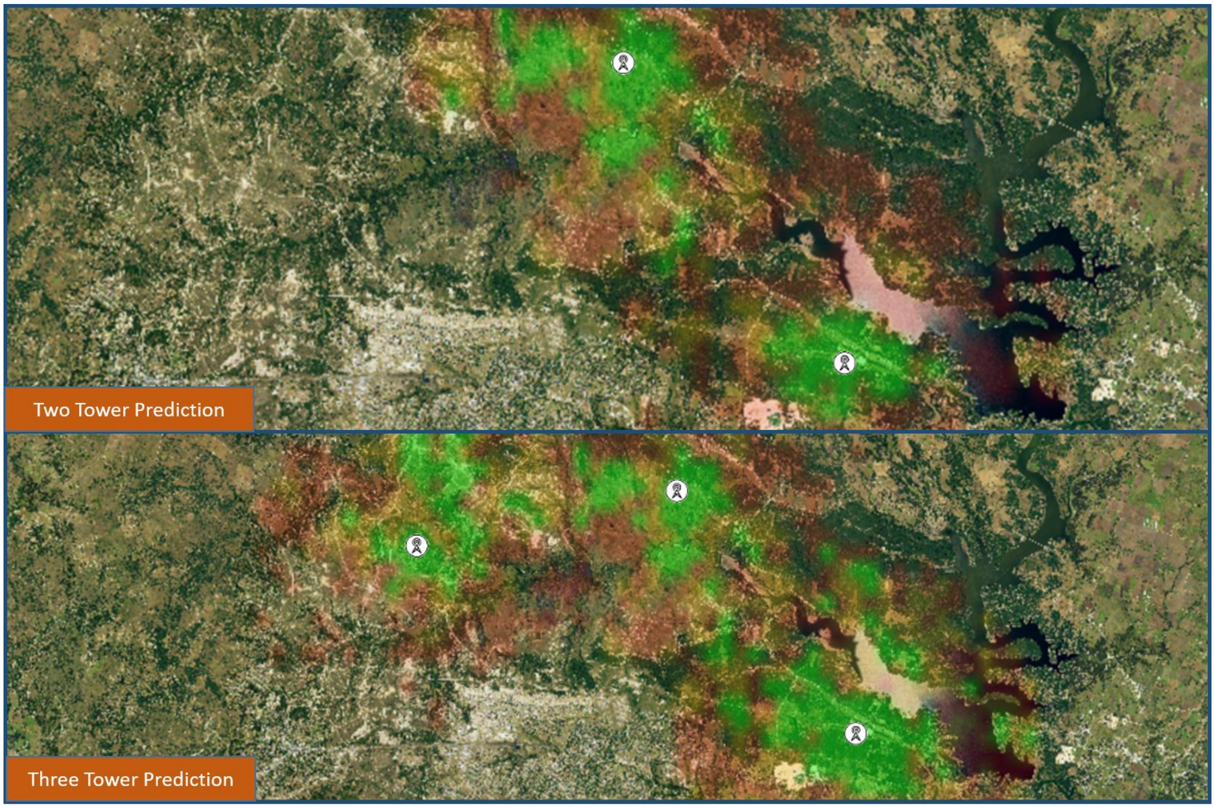

Figure 5. ILTE Plots of Received Power at Fort Hood

The integration of COTS tools such as Web WorldWind, GeoServer for maps display has maximized the use of funding and time for several projects. Leveraging CITA services and COTS software allow us not only to represent network coverage, but also to display network entities with MIL-STD 2525C icons, ability to draw tactical graphics and on the map as many other applications derived from this combination. We believe that the software community will benefit from these tools specifically in an enclave environment where web base servers are not available to reach out for data.

The network calculation visualizations within Web WorldWind in the ILTE environment demonstrate how the CTIA SOA and LT2 environment were implemented for an operational testing environment. The results exemplify that, regardless of specification applications, in this instance SNT EXata, the CTIA SOA architecture can be used to interface with a multitude of functionalities in the simulation and training domain, such as medical simulations, weather forecasting, or integrated LVC training events. The results also identify that the LT2 product line posses the ability to interface with the CTIA architecture in isolated, configured environments to meet the functionality of the applied system. The challenges identified with third-party COTS applications, as depicted in previous section, is an example of how integration with external applications, regardless of functionality, may prevent issues to overcome, but it describes that the architecture is able to integrate additional functionality for the simulation and training industry uses cases.

FUTURE WORK

Co-channel interference analysis needs improvement for more accurate RF Network prediction. The SNT model does not consider the interference between two transmitters at the edge of their cell coverage when a receiver fights for a reliable signal. There is interference caused by the overlap of two transmitting towers not considered by the existing models. Improvements in this area are necessary for increased fidelity in the prediction of the Radio Coverage. In addition, capacity planning, also referred to as dimensioning, is critical to determine the break point for the number of instrumented entities the RF network can sustain. For dimensioning, the uplink (mobile to tower) path analysis and noise figure analysis is required.

The components of the ILTE system developed for network planning functionality can be leveraged for other use cases in the LT2 product line, chiefly different map applications and interactivity across training and simulation environments.

As depicted in Figure 3, NASA Web WorldWind is the current implementation used by ILTE, however a common LT2 map interface has been developed for abstraction a reuse by other web-based maps with limited client-side modification; this interface contains common map functionality such as panning and zooming so that different maps are able to be used for separate use cases that leverage CTIA and the LT2 framework. Different applications in the current LT2 product line, such as ILTE or Force on Target (FoT), have separate needs for map usages, e.g. Situational Awareness (SA) of live training exercises versus operational test planning, and, through a common map interface, have the ability to utilize map applications other than WorldWind. Such abstraction allows the LT2 framework to upgrade to future map versions as web technologies evolve as well.

The network coverage implementation for ILTE can also be integrated into distributed simulations with future development. While there is a CTIA SOA implementation for interaction with other real-time systems through the Distributed Interactive Simulation (DIS) protocol, DIS does not support the data model that is necessary for network planning communication between systems (Nan & Eusgeld, 2011). The High Level Architecture (HLA) would support this since it allows for this data, however all necessary interaction across distributed systems via the HLA Run-time Infrastructure (RTI) instance and corresponding Federation would have to interface through the appropriate Federation Object Model (FOM) (Nan & Eusgeld, 2011). The current CTIA SOA does not have an HLA gateway and would need to be developed to support such integration with other simulations.

In addition to support of different 2D map implementations other than WorldWind, coverage calculations could be visualized 3D virtual environments that implement a Common Image Generator Interface (CIGI) instance, which is a standard for Image Generators (IGs) to generically communicate with simulation systems and applications. Similar to an HLA gateway, as mentioned above, CTIA does not currently have a CIGI gateway implementation to convey this data, however this data is common for most Image Generation IG implementations to support, mainly positional data, 3D model mappings to DIS and HLA standards, etc. Coupled with the support for real-time integration, this would allow 3D environments to display network coverage data with real-time updates to be projected in virtual simulations.

CONCLUSION

Each iteration and improvement in the RF propagation tool predicted model will provide more accurate path loss values so the calculations can be optimized, and the predicted coverage plots will be closer fit to measured signal levels in the field. Our future role will be to obtain, review, and optimize for each of the testing facilities. Using log files and historical data, we can get a closer fit based on two sets of characteristics, the first being range location, weather and seasonality, terrain, ground clutter (land use) and vegetation. The second set of characteristics being the radio type and frequency used. As this RF Network Coverage tool develops, new radio systems and new technologies will be integrated into the RF profiles available for the testing community. As new technology becomes available; it would behoove the testing community to take advantage of the spectrum efficiency and spectrum gains from each new iteration of technological advances.

The latter half of this paper has shown the software implementation of the ILTE system in detail and how it leverages the CTIA training architecture, LT2 product line, COTS SNT EXata and the open source Web WorldWind map to provide network coverage visualization for ILTE uses cases. A new CTIA SOA service was developed for ILTE to support these use cases, and the paper presented why the CTIA SOA architecture was utilized for a loosely-coupled service to interface with RF network emulation applications. Similarly, the paper presented how the LT2 framework can integrate additional map implementations for different LT2 products without affecting other components of the system. These benefits were extrapolated upon to propose how integration with such a CTIA and LT2 configuration could be developed to interface with real-time systems and virtual simulations.

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