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Telecom Modeling with ChatterBell

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Telecom Modeling with ChatterBell

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Abstract

This document provides a description and user manual for the ChatterBell voice telecom modeling and simulation capability. The intended audience consists of network planners and practitioners who wish to use the tool to model a particular voice network and analyze its behavior under varying assumptions and possible failure conditions.

ChatterBell is built on top of the N-SMART voice simulation and visualization suite that was developed through collaboration between Sandia National Laboratories and Bell Laboratories of Lucent Technologies. The new and improved modeling and simulation tool has been modified and modernized to incorporate the latest development in the telecom world including the widespread use of VoIP technology. In addition, ChatterBell provides new commands and modeling capabilities that were not available in the N-SMART application.

ACKNOWLEDGMENTS

Funding for this work was provided by the Department of Homeland Security (DHS) Office of Cyber and Infrastructure Analysis (OCIA). OCIA provides innovative analysis to support public and private-sector stakeholders' operational activities and effectiveness and to inform key decisions affecting the security and resilience of the Nation's critical infrastructure. All OCIA products are visible to authorized users at HSIN-CI and Intelink. For more information, contact OCIA@hq.dhs.gov or visit http://www.dhs.gov/office-cyber-infrastructure-analysis..

This authors wish to acknowledge and thank Nancy Brodsky for contributions she made to this Report.

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NOMENCLATURE

Abbreviation	Definition
AT	Access Tandem
ATM	Asynchronous Transfer Mode
BIRRDS	Business Integrated Routing and Rating Database System
CLLI	COMMON LANGUAGE Location Identifier
DHS	Department of Homeland Security
DSL	Digital Subscriber Line
FCC	Federal Communications Commission
GETS	Government Emergency Telecommunications Service
IP	Internet Protocol
ISP	Internet Service Provider
LATA	Local Access and Transport Area
LE	Local Exchange
LERG	Local Exchange Routing Guide
LT	Local Tandem
MSC	Mobile Switching Center
NANP	North American Numbering Plan
NGN	Next Generation Network
NISAC	National Infrastructure Simulation and Analysis Center
NPA	Numbering Plan Area (also known as Area code)
OCIA	Office of Cyber and Infrastructure Analysis
PBX	Post Branch Exchange
PPD	Presidential Policy Directive
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RSM	Remote Switching Module
VoIP	Voice Over Internet Protocol
WPS	Wireless Priority Service

1. INTRODUCTION

ChatterBell is an event-based modeling and simulation tool that was developed by Sandia National Laboratories to simulate telecom networks and their performance under different threat and/or failure levels. The modeling is based on real data that we are able to obtain from actual databases of the switches and connectivity in any given area within the USA.

ChatterBell is part of the NISAC voice communication modeling and simulation Capability. ChatterBell is based upon previous work that was done by Sandia National Laboratories in collaboration with Bell Laboratories.

The scope of this document is to describe the methodology used in modeling the voice telecom networks and the types of threats that can be modeled and analyzed. In addition, we will study an example network to show some of the results that can be obtained and analyzed.

2. BACKGROUND

The Department of Homeland Security (DHS) has identified 16 critical infrastructure sectors whose assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.

The communication sector is one of the prominent sectors that is of great importance to the overall security and national interest of the United States.

In February of 2013 the White House issued a presidential directive “Presidential Policy Directive 21 (PPD-21)” [1] on the importance and advancement of security and resilience of the critical infrastructure. This directive also identifies energy and communications systems as uniquely critical due to the enabling functions they provide across all other critical infrastructure sectors.

In recent years and in support of the United States Department of Homeland Security (DHS), Sandia National Laboratories through the Office of Cyber and Infrastructure Analysis (OCIA)'s National Infrastructure Simulation and Analysis Center (NISAC), has endeavored to create and maintain a leading-edge modeling and simulation capability for the telecommunication sector throughout the United States. It is the aim of this work to ensure our capability of evaluating the readiness and vulnerability of the communications sector in general and more specifically the potential impact of threats and attacks on the performance and resilience of communication networks anywhere in the US.

In support of this mission and capability Sandia National Laboratories has developed methodologies and procedures as well as simulation capabilities that enable us to assess the impact of threats and attacks on the communications sector in general and voice communication (telecom) in particular.

3. ELEMENTS OF VOICE COMMUNICATION MODELING

Voice communication starts when a person or entity initiates a call to another. If we trace the path of the call, then all potential paths and nodes along the path make up the critical elements of the voice communication model. In order to understand this, we must show the path between the various users and subscribers of the communication network.

3.1. Switches and Trunks

To support the communication sector the service providers install switches and connect them via logical paths that can carry communication which are called trunks. The switches are categorized by the function that they serve and are layered in a layered hierarchy in which they all play a critical role.

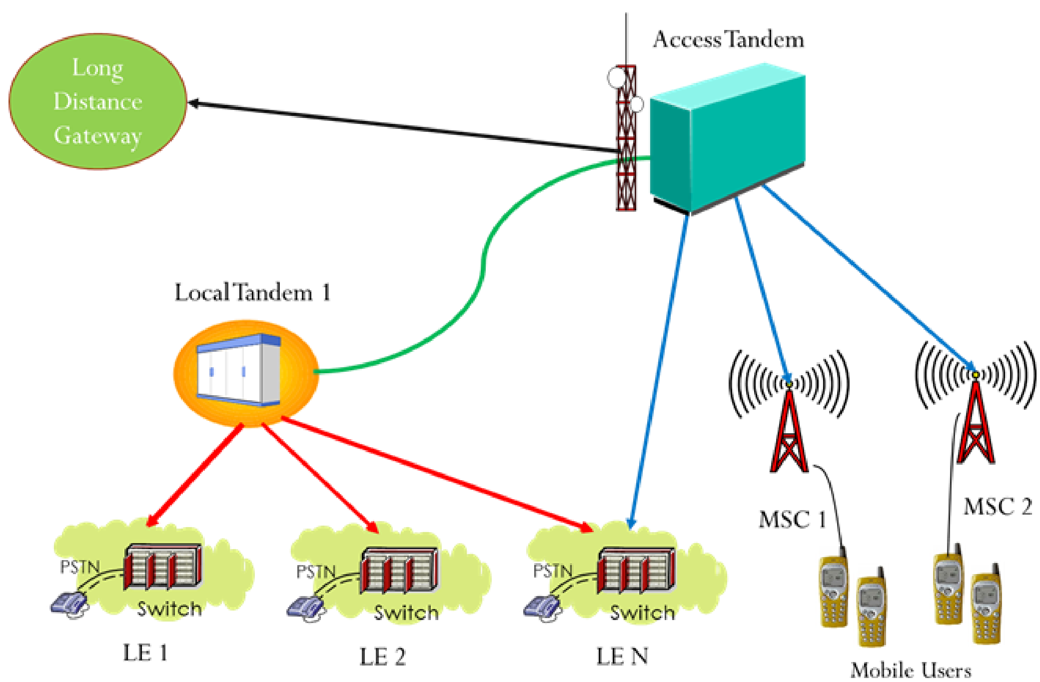


Figure 1. Elements and Hierarchy of Telecom Switches.

Figure 1 shows the switches involved in establishing voice communication as well as the layered hierarchy of these switches. There are Local Exchanges (LEs) which support landline telephones also names POTS (Plain Old Telephone Service). These LEs are supported by Local Tandems which provide alternate routes for calls in case the primary route is blocked. There are also Mobile Switching Centers (MSCs) which support mobile subscribers. The mobile service is also supported by Access Tandems which provide connect the various MSCs as well as providing communication between the LEs and MSCs. Finally, the Access Tandems also support the communication needs between the local calling area and other far calling areas via the long-distance gateways.

3.2. Sources of Data

When we model a communication network, we typically model a homogenous local calling area. These local areas are called Local Access and Transport Area (LATA). By identifying the main switches within a LATA we are able to make accurate representation of what the switches and trunks are as well as the hierarchy of these switches.

There are several sources of data which we use to identify the elements that we use in modeling a communication LATA. Chief among those is the Local Exchange Routing Guide (LERG) database which is issued on a monthly basis and is available to Sandia National Laboratories. The LERG tells us a lot about the switches within a LATA as well as the hierarchy of theses switches. From it we can generally determine the main traffic switches called Local Exchanges, as well as any remote switches which are dependent on any one of these local exchanges. In addition, we can determine the main MSCs and their operating service providers. Moreover, we can identify the local operating tandem switches as well as the access tandems and their connectivity (hierarchy) with respect to the LEs and MSCs. Finally the LERG tells us about the number of users and subscribers that are supported by each of its traffic switches.

Once we identify the above switches, this is when the real modeling work begins. For one thing, the LERG does not tell us anything about the connectivity between the LEs or the MSCs. Nor does it tell us directly about the amount of traffic that flows between any two switches in the network. To determine this information, we must rely on our network planning expertise to compute the amount of traffic generated at every switch and map out an entire communication network capable of supporting this traffic under normal operating conditions.

In addition to the LERG Sandia National Laboratories also has access to other databases that provide us with added information about the distribution and location of wireless base stations as well as the geographic coordinates of the various switches and the boundaries of the geographic regions that they support.

4. CREATING THE COMMUNICATION MODEL

There are several essential steps in creating a communication model for any given LATA. These can be summarized as follows:

1. Reading the LERG database and gleaning the information needed about the basic building blocks of the LATA.
2. Importing other relevant databases to support and augment the LERG data.
3. Generating a traffic demand matrix that describes the traffic communication between the main traffic generating switches within the LATA as well as the distribution of this traffic throughout the LATA and beyond its boundaries (i.e. long distance traffic)
4. Use well established and accepted traffic planning guidelines and engineering principles to determine the overall connectivity of the switches and alternate routes. These are the same principles and guidelines that are used by the actual service providers to do the network planning of their respective networks.
5. When all the numbers have been generated the model input files are determined and they are fed into the ChatterBell modeling tool to generate the actual communication model that can used to do traffic simulation and analyze various stress and failure studies.

In the following sections, we will take a look at the above steps and show how they work synergistically to create the communication model and prepare for eventual studies that are desirable to perform on it.

5. LERG AND OTHER DATABASE INPUTS

5.1. LERG Overview

The LERG (Local Exchange Routing Guide) is a large database containing information on the communication resources and capabilities within the states and localities of the US. The LERG Routing Guide (referred to as the LERG throughout the rest of this document) provides routing data obtained from the iconectiv Business Integrated Routing and Rating Database System (BIRRDS) into which data is entered by service providers and/or their agents. The LERG is a snapshot of information contained in BIRRDS at a point in time.

With the technological advances in Telecom and the advent of newer and diverse service providers such as wireless carriers, Completive Local Exchange Carriers (CLECs), Internet Service Providers (ISPs), etc., the LERG is used by all service providers within the NANP (North American Numbering Plan) to report to other service providers their routing and numbering information, especially planned changes, in a common and accepted manner.

5.1.1. Overall LERG Organization

The LERG database is published in Microsoft Access format and it contains within it several individual database files that must be read and deciphered on their own terms.

We will examine three essential tables from the LERG that are essential in creating the telecom model. These are named LERG 7, LERG 7 SHA and LERG 6.

In addition to the above database tables the LERG database contains several other tables that provide important information about the hardware types of switches and the service provider which owns and operates these switches.

5.1.1.1. LERG 7 Database

The switching entities are found in the LERG 7 table. This table contains the switch names and associated location symbols also called COMMON LANGUAGE Location Identifier (CLLI 11) which should be used in the modeling except for cases where the switch may need to be modified for a proper network topology file. For example, in some cases a switch may need to be simulated as two virtual switches if it is serving two separate and independent functions. In such cases the switch names that are used in the simulation model are derived from the original CLLI 11 names.

Table 1. LERG 7 Switches and Types

Switch type	Switch functional description
LE (Local Exchange)	This is a landline central office and it plays a central role in the enabling and operation and all landline telephones.

RSM (Remote Switching Module)	This is a remote switch which is typically dependent on a host switch to become functional. If the host should fail, the RSM is generally unable to serve any traffic even though it may not have suffered any local failure.
MSC (Mobile Switching Center)	These are the equivalent of the LEs but for the mobile subscribers instead of the landline telephones.
LT (Local Tandem)	LTs support the completion of the LEs Local traffic calls and provide an overflow path for calls that are blocked on their direct route (if such a route exists).
AT (Access Tandem)	ATs support LE to MSC, MSC to MSC and long distance traffic routing and overflows.

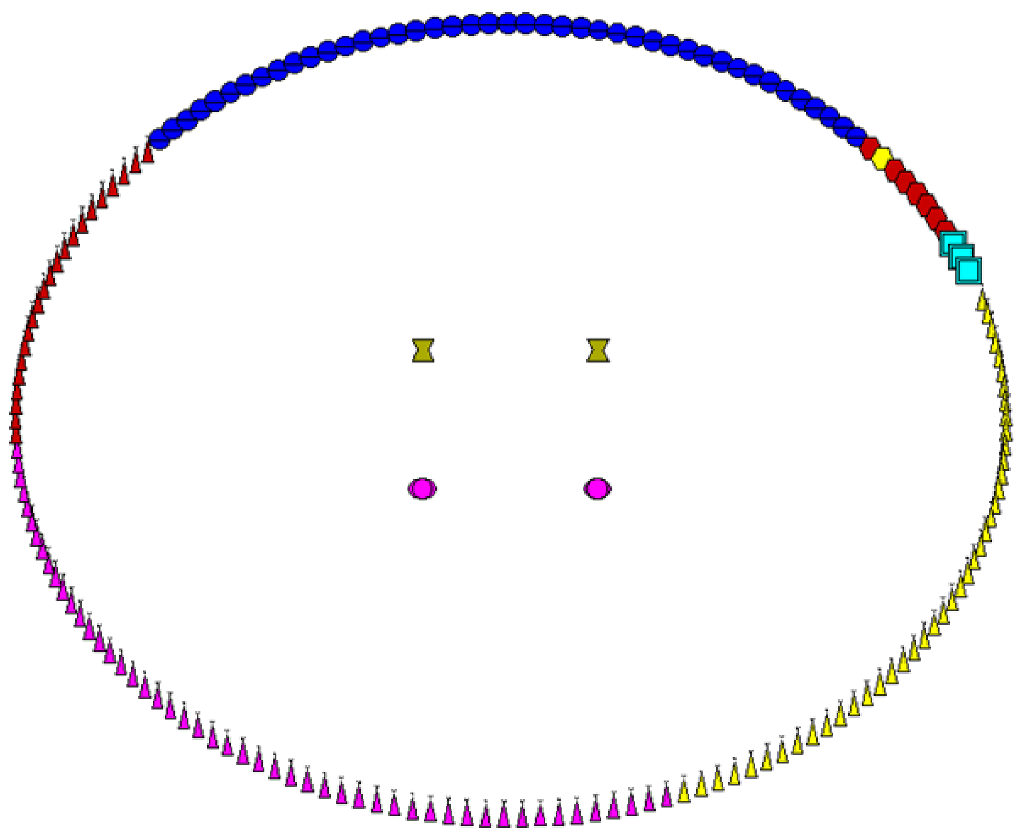


Figure 2. Telecom Switches in a communication Model.

If we take an example network, and by the end of this first step, the network might look as shown in Figure 2. Figure 2 shows the typical switches in a given LATA (in this case Georgia LATA 440). Note that the switches in the middle are the LTs (oval Shape) and ATs. All the other switches are the actual traffic generating switches including LEs (blue), MSCs (red and yellow hexagonal shapes) and the triangular switches are all modeled as remote switches. Traffic generating switches serve end customers directly, while non-traffic generating switches serve other functions in support of the overall communication switching and delivery.

5.1.1.2. LERG 7 SHA Database

The LERG 7 SHA table provides specific information about the hierarchy of the switches that play important roles in the communication model. This information includes the hierarchy between remotes and their supporting hosts. A host may support multiple remote switches, however a remote can only have a single host supporting its functionality.

The LERG 7 SHA also provide information about the hierarchy between the LEs and their supporting Local Tandems as well as between the LEs, MSCs and their corresponding Access Tandems.

5.1.1.3. LERG 6 Database

Having determined the switching entities of the network above, it is essential to find out the number of installed lines on each of the line-supporting exchanges. The line-supporting exchanges are all the switching entities except for LTs and ATs. These tandem switches typically do not support subscriber lines directly.

The LERG 6 table provides critical information on the number of subscribers that are supported by each of the traffic generating switches as well as the localities of these service numbers. This table typically shows several entries (or one) per switch. These entries can be used to determine the number of installed lines on the switch. The procedure also entails finding all the NPA and NXX code combinations and the number of lines supported under each of these combinations. In addition, the LERG 6 provides other critical information about the type of lines that are installed and their possible function within the communication model.

It is important to note that The North American Numbering Plan (NANP) governs the management of telephone numbers for the Public Switched Telephone Networks in North America (Canada, USA, Caribbean, and territories) within the international country code prefix '+1'. According to this plan all North American phone numbers are in the format of NPA-NXX-XXXX (where N is any digit from 2-9, and X from 0-9). NPA identifies the 3-digit Numbering Plan Area (Area Code) NXX identifies the Central Office (aka. Exchange) within the NPA. XXXX identifies the destination Station (home or office) within the NXX.

Figure 3 below shows our example network where the connections show dependencies and support between hosts and remotes as well as LT and AT connectivity.

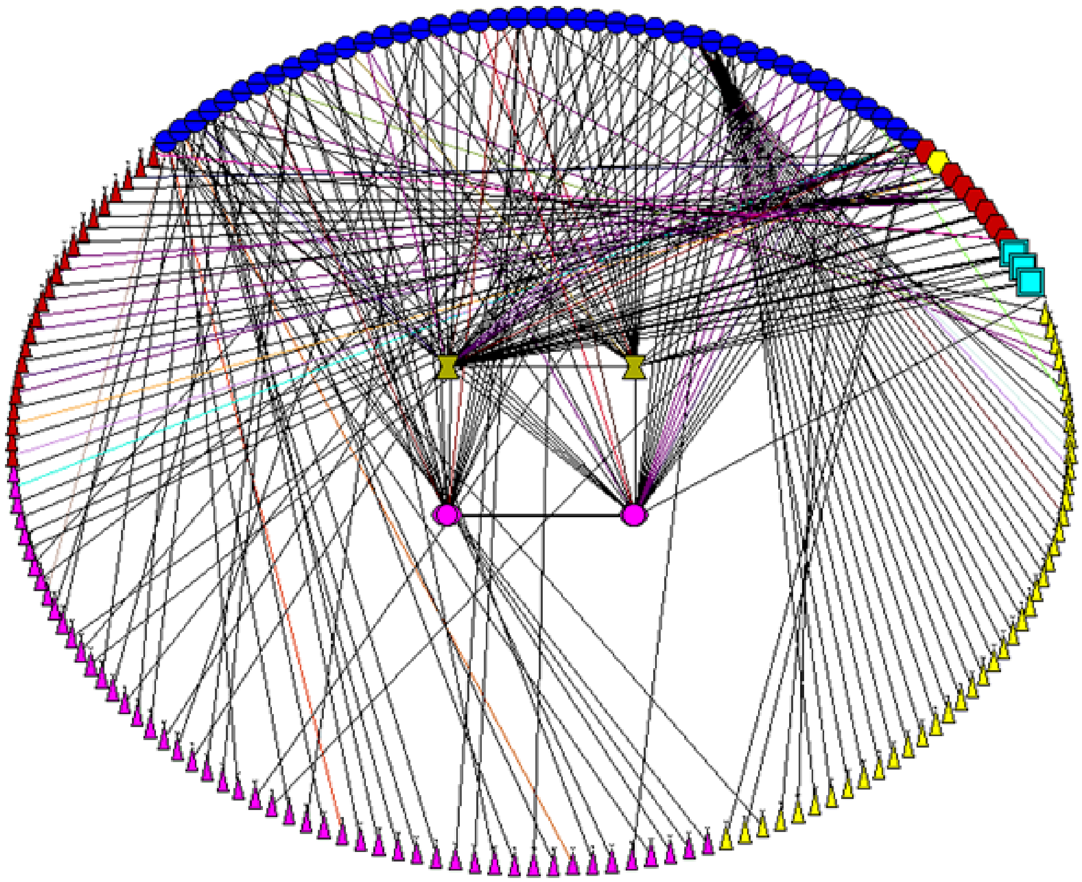


Figure 3. Switches and LERG Based Hierarchy.

5.2. Other Databases and Input Files

Besides the LERG database there is a number of other important databases and input files that play an important role in the creation of a communication model. These include ArcGIS mapping files that are utilized in mapping the topology and geographic location of the various switching nodes. This information is often critical in determining how a given switch may be affected by a potential threat.

For example, if we consider a potential flooding threat to the communication network, then it is of great importance to know where the switches are located to see if they fall within the floodplain or if they are located outside of its bounding region.

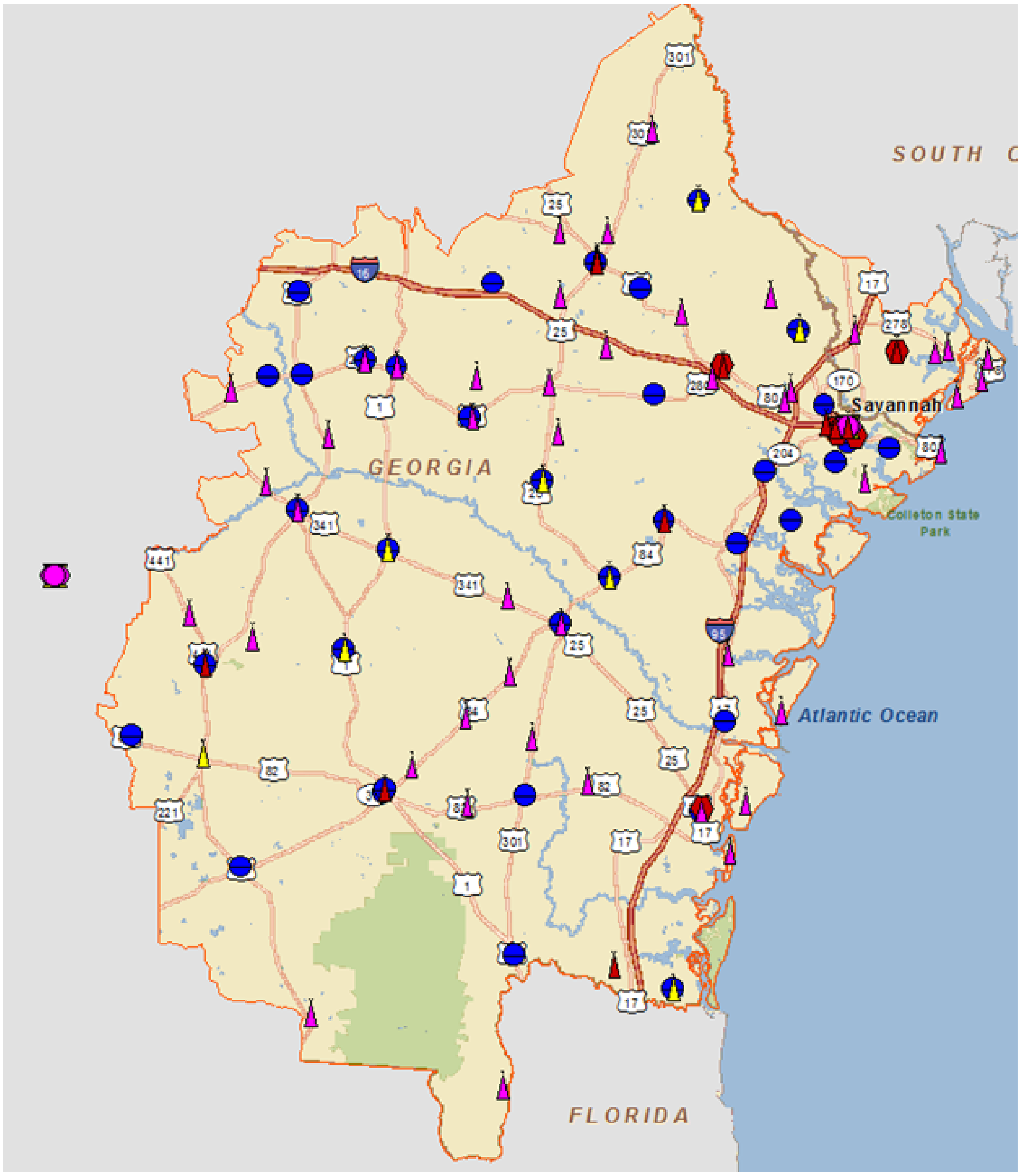


Figure 4. Switches Showing their Geographic Location.

Figure 4 above shows the resulting view once we combine all the data that we obtain from the LERG and non-LERG databases that we have access to at Sandia National Laboratories.

5.3. Mobile Area Coverage Data Modeling

In modeling mobile communication, we cannot consider the mobile lines to be statically located since we know that mobile users will likely carry their devices with them when they travel to work or even to other cities or countries. Therefore, it is not realistic to consider the areas of coverage to be the static addresses of the various mobile subscribers.

In order to be more realistic we have identified a modeling technique that takes into account the actual radio tower locations in modeling the mobile subscriber locations. For example Figure 5 shows a LATA where the actual tower locations have been mapped. In order to model the location of the mobile users, we assume their distribution to follow the distribution of these radio towers. Furthermore, we subdivide the LATA into service boundaries for these operational towers and then we make the simplifying but reasonable assumption that these towers are serviced by the nearest MSC (Mobile Switching Center).

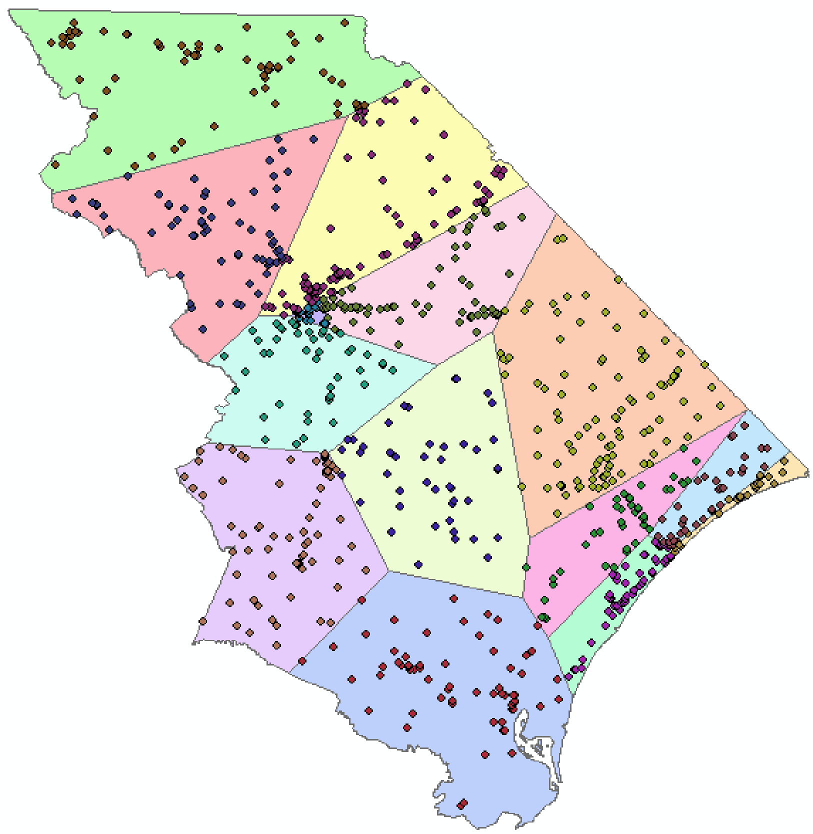


Figure 5. Mobile Coverage Areas Showing Radio Tower Locations.

6. GENERATING A TRAFFIC DEMAND MATRIX

We have previously identified all the traffic generating switches as well as the number of subscribers supported by every switch. In this step, we compute the total traffic load per switch and then derive the overall traffic matrix which shows how much total traffic is flowing from every switch to every other switch.

The unit for call traffic we use is the centum call second (CCS or 100 call-seconds). (Erlang is another unit of traffic, 1 erlang is equivalent to one 60 minute call-hour per hour). We can think of Erlang as the call occupancy of a line. So a line generating 0.50 erlangs is idle 50% of the time and generating traffic the rest of the time. The formula to convert from Erlang to CCS is to as follows:

$$traffic_{in\ CCS} = traffic_{in\ Erlang} * 36$$

The total call traffic in a network is computed by taking the total number of subscribers for every switch and multiplying that by the expected traffic to be generated per subscriber. Once that is completed we have the total traffic generated per switch.

The next step is to divide the total traffic per switch among all the available switches. We use a certain percentage to compute the intra-office traffic (the diagonal of the traffic matrix). We also use a percentage to compute the total long distance generated by a given switch. Once that is done we use a gravitational model to distribute the remaining traffic from any given switch to all other available switches.

6.1. Types of Traffic Generated

Since ChatterBell simulates real telecom networks, it is also designed to support the various types of communication that exist all around us. Of particular interest, ChatterBell supports both residential as well as business traffic types for landlines. It also supports mobile traffic subscribers, and Modem traffic if needed. In addition, as more and more service providers are migrating from traditional PSTN lines to VoIP lines, we have endeavored this year to add the capability of supporting VoIP lines anywhere in the telecom network.

6.1.1. PSTN Communication

Traditional PSTN lines are being reduced by all service providers in favor of the newer VoIP technology. Having said that, the traditional PSTN line is still by far the most reliable form of communication available to consumers. This is directly related to the fact that PSTN lines do not require an electric power source at the end user premises. In fact PSTN lines draw their power directly from the switch which is provided and used by the phone company.

Since these switches are considered a critical part of communication, the service provider typically ensures continuity of service despite any potential failures and external threats. Because of this the subscriber can continue to initiate and receive calls despite any local failures that they may encounter including wider disruptive power failures.

6.1.2. Wireless Traffic

Wireless traffic here refers to voice traffic that is initiated or received on a mobile communication device. This type of traffic has its own model within ChatterBell and is governed by different priorities and assumptions with respect to its potential failure.

Since the mobile communication devices are battery operated, the mobile subscriber can potentially continue to make and receive calls when they encounter a local failure or power outage. However, since the mobile switches and mobile infrastructure in general is typically less reliable than the PSTN counterparts, the mobile subscriber is typically more susceptible to potential failures and outages as compared to the PSTN landlines.

6.1.3. VoIP communication

As previously mentioned, we have added the capability to model VoIP lines in ChatterBell this year. There are several considerations in modeling VoIP lines. For one thing, there are two types of VoIP lines, and they are not all identified as VoIP lines in the LERG file. These types of VoIP lines are:

1. True VoIP lines, characterized by having to use a special VoIP-capable telephone device in order for them to work properly.
2. VoIP lines that have been modified by the service provider at the point of the device to accept regular telephone devices. Such lines use additional equipment at the end user site to deal with the requirement of converting from voice traffic to IP traffic. These constitute the majority of VoIP lines; however, the LERG still shows these as normal lines since they use a normal telephone device at the other end.

It is important to note that both of the lines above are vulnerable to power outages since they rely on the router communication from the end user to the switch, and that communication link is likely to fail as soon as a power failure occurs, and in some cases shortly thereafter. The end user may choose to install at their own expense a battery backup device that can keep the phone operational for one or two hours after a power failure.

Irrespective of which type of line we model, we must take into consideration that these lines are more vulnerable to failure than either PSTN or even mobile telephones in cases of power outages.

7. GENERATING THE INPUT FILES FOR CHATTERBELL

Once all the above steps have been completed we generate the traffic input files that are used by ChatterBell to size the appropriate connection links between all the switches and run the actual traffic simulations.

A high level view of the ChatterBell modeling and simulation tool is shown in Figure 6. This shows the steps that are typically involved in running a simulation scenario and going from input files to output data that is ready to be analyzed.

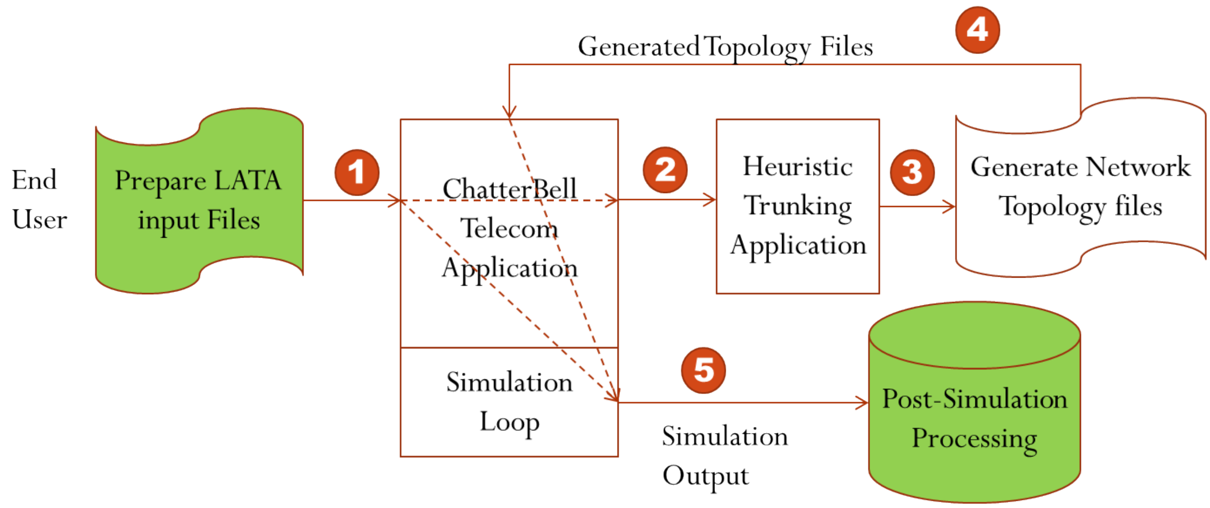


Figure 6. High Level View of ChatterBell.

In order to illustrate this process more clearly, it is best that we show the steps using an example test case. Such a test case will be presented in the next Section.

8. SAMPLE TEST CASE

This section shows the step by step process to run the test case traffic model using ChatterBell. The user must have an operational copy of the ChatterBell executable windows application. This is typically named “ChatterBell.exe”.

8.1. Running ChatterBell

In order to prepare for this operation it is best to unzip the contents of the file Test_Case.zip and place those in a known directory on your computer. For our purposes we should assume that those files are place in the directory path “C:/ChatterBell/TestCase”.

The next step is to run ChatterBell. This is done by double clicking on the executable file “ChatterBell.exe”.

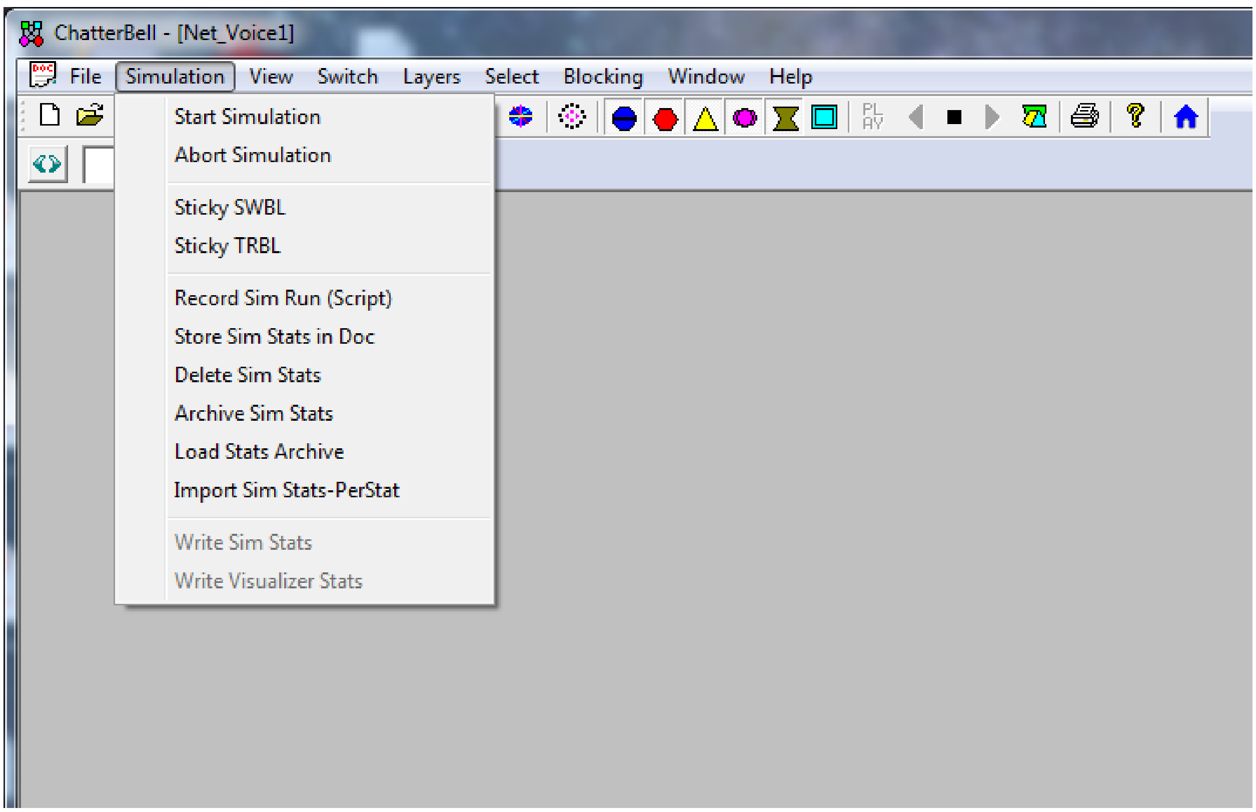


Figure 7. ChatterBell Application Main View.

Figure 7 shows the main view of ChatterBell. This is the interface that allows the user to run voice model simulations and prepare the output data. In order to run the TestCase simulation the user should select the “Simulation” menu. From the drop down list they get they should select the “Start Simulation” Command. This command brings up a dialog box designed to start a voice communication traffic simulation.

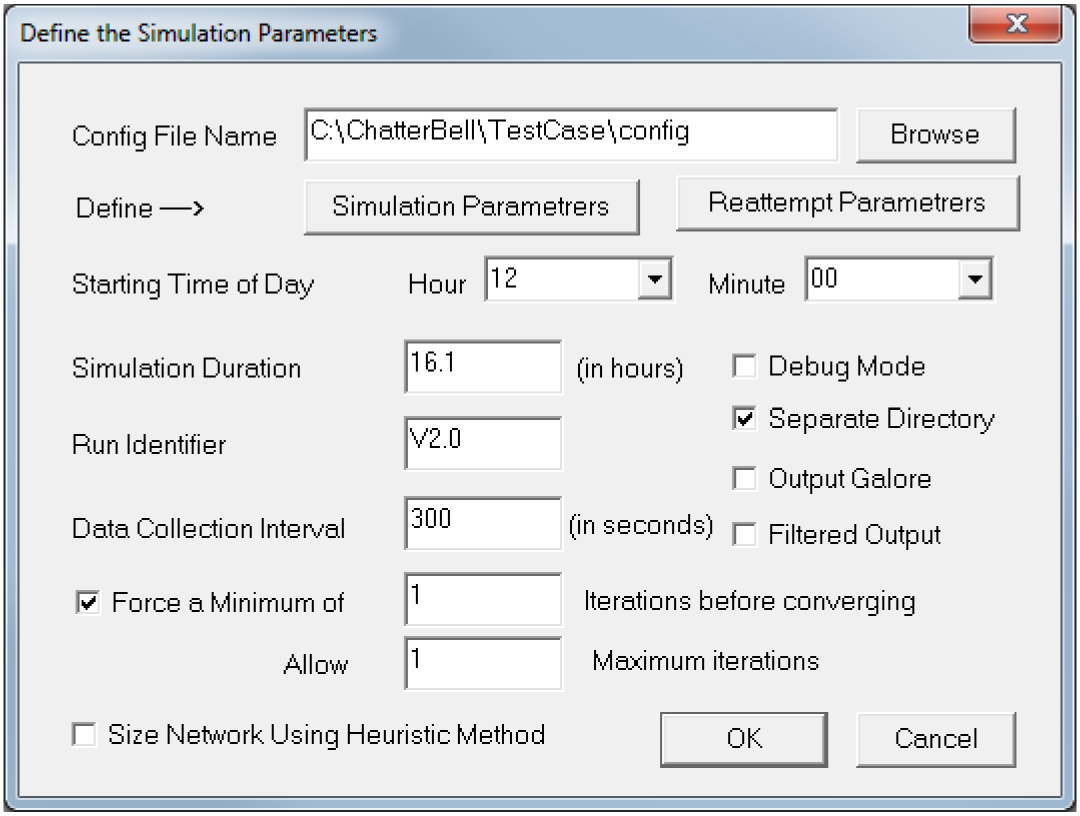


Figure 8. Voice Simulation Dialog Box.

Figure 8 shows the voice Simulation Dialog Box. The path for the TestCase directory and specifically the config file within that directory should be entered in the “Config File Name” area. You can click the browse button on the right to find another config file if you so desire. Since we are running the TestCase default scenario in this case, we can just click on “OK”. All the default values in the dialog box are acceptable at this satge.

While the Simulation is running you will see a progress box that shows the progress of the simulation along with some key indicators therein. This is shown in Figure 9 below.

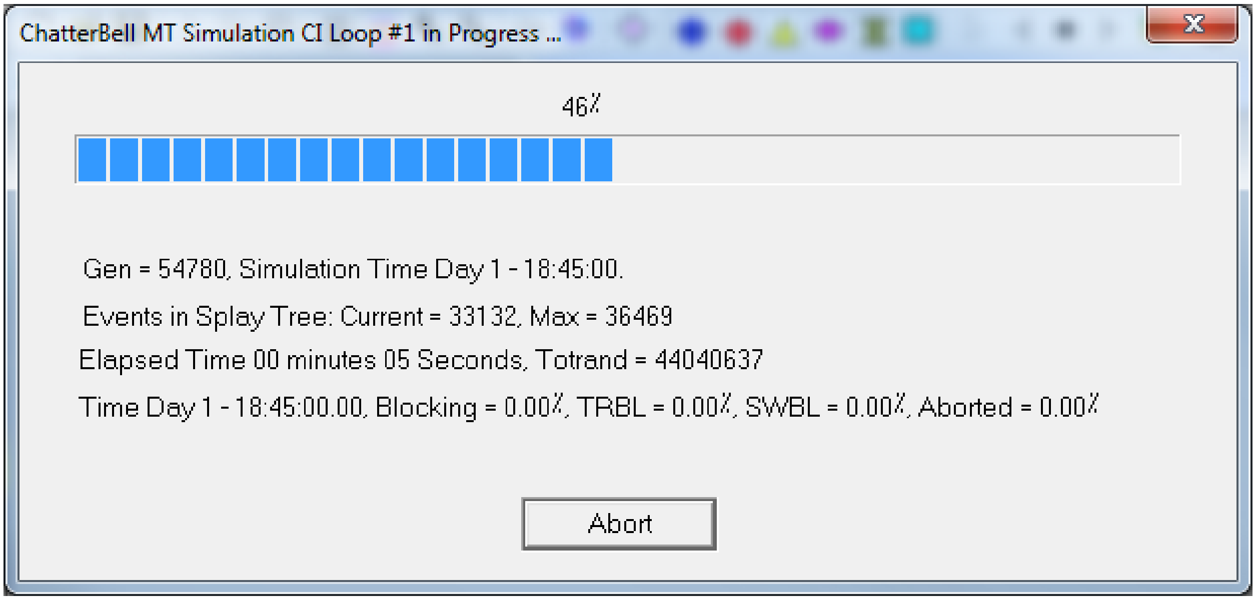


Figure 9. Simulation Progress Dialog Box.

If for some reason you wish to abort the simulation before it is complete you can do so by clicking on the “Abort” button.

Once the simulation is finished, ChatterBell will show an indicator box with the main statistics from the overall simulation as shown in Figure 10.

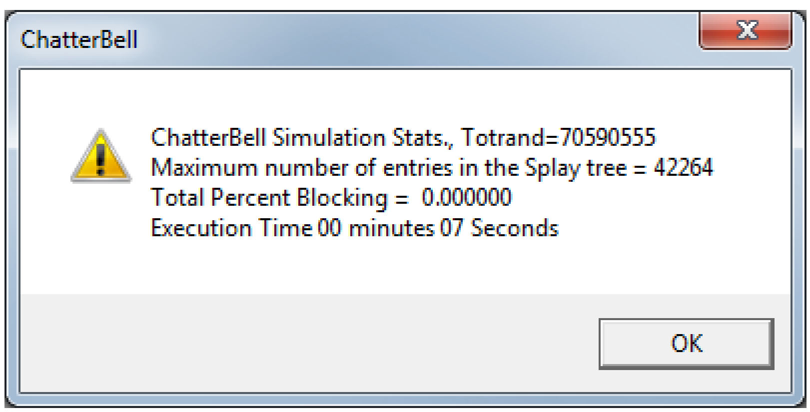
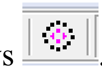


Figure 10. End of Simulation Dialog Box.

Now that the simulation is completed, the next step is to store the results so that it can be later retrieved and displayed for conducting analyses on the data and producing desired graphs and charts. To do so, the user must first select the command from the simulation drop down menu once more, “Store Sim Stats in Doc”. This command actually creates switch visual objects to represent all the switches within the testCase network simulation. You can view these switches in the main view window by rearranging them. To do so you click on the icon showing a number of switches arranged in circles. This icon appears as follows .

Once that is done, the switches are arranged in a logical circular view as shown in Figure 11.

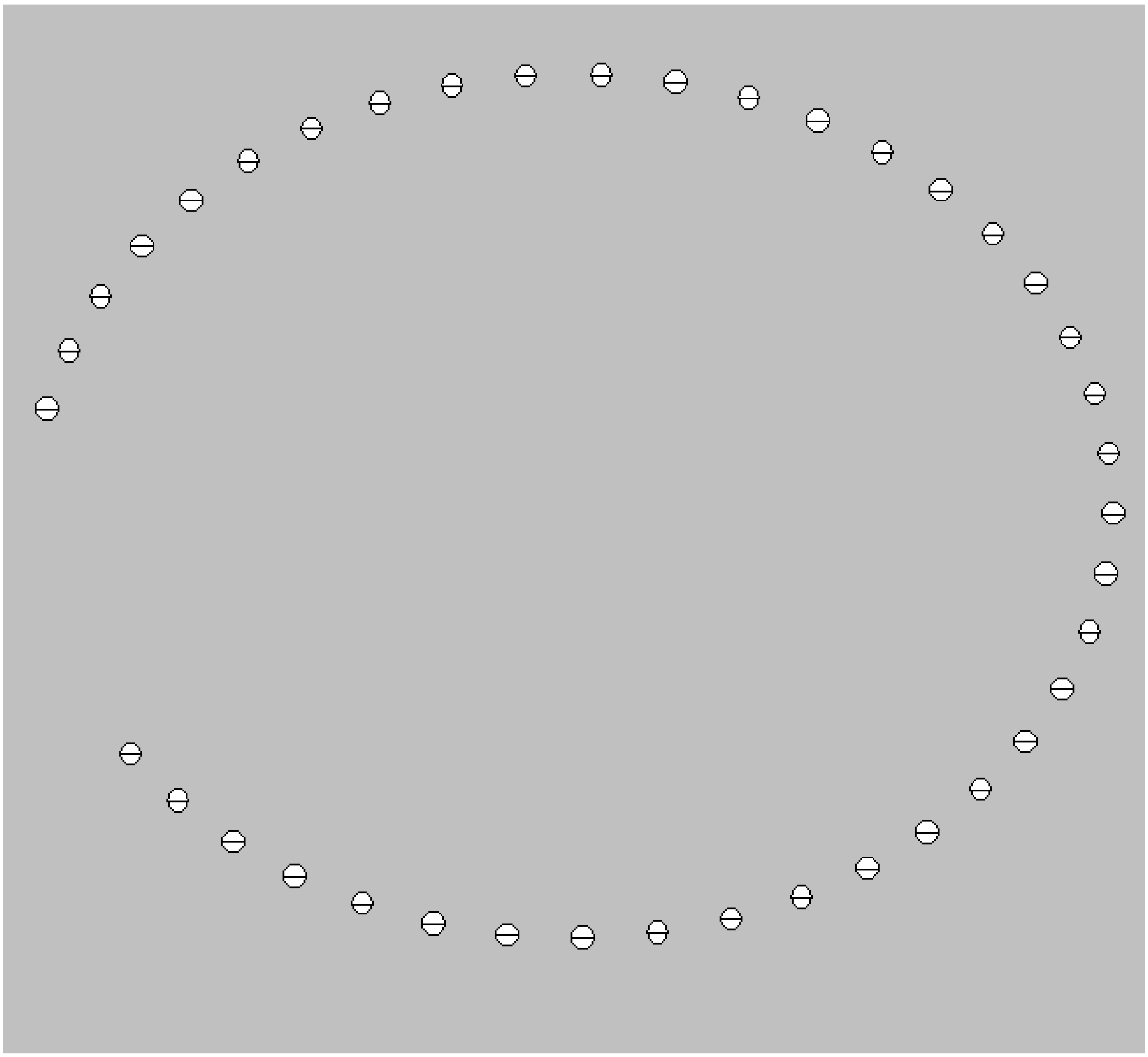


Figure 11. TestCase Switches arranged by ChatterBell.

The next step is to save the visual representation of the TestCase switches in a file that can be later loaded on demand. To do so, you select the “File” “Save As” command and type the file name “TestCase.nsv”.

The next step is to store the actual simulation results in its own archive that can be later retrieved to perform desired analyses and show visual representation of the results. This is done by Selecting the command “Record SIM Run (Script)”. Once this command is selected the user will be prompted to save the archive file “Archive.nsz”. This is the archive that contains all the simulation statistics that is of importance to the user. Please go ahead and save this file and remember where it has been saved. This file is associated with TestCase.nsv visual file which was saved earlier, and they must be used together in the future. After saving the nsz archive, the user will be prompted to save a file containing the overall statistics from the simulation run in a file called “DBlock.txt”. Go ahead and save this file and you can later open it in a text editor or in Excel (as a CSV file) and manipulate the pertinent data therein.

Once these files have been saved and the script is completed ChatterBell shows the completion dialog box as in Figure 12.

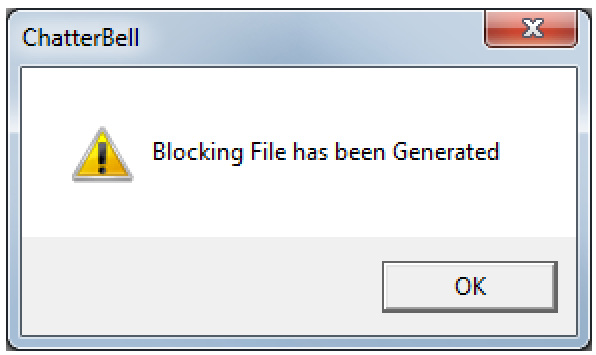


Figure 12. ChatterBell Completion Dialog.

Now that all the visual files and simulation statistics archive have been saved, ChatterBell can be closed, and later re-opened, and these files may be reloaded once more. (Load the nsv file first and then the nsz Archive).

However, before we close the application at this point, you can view a graphical representation of the simulation results. To do so, select the command “Blocking” and “Show Overall Stats”. Click Ok on the dialog box that is displayed, and the tool shows the following graph as shown in Figure 13 (or a similar figure if not identical).

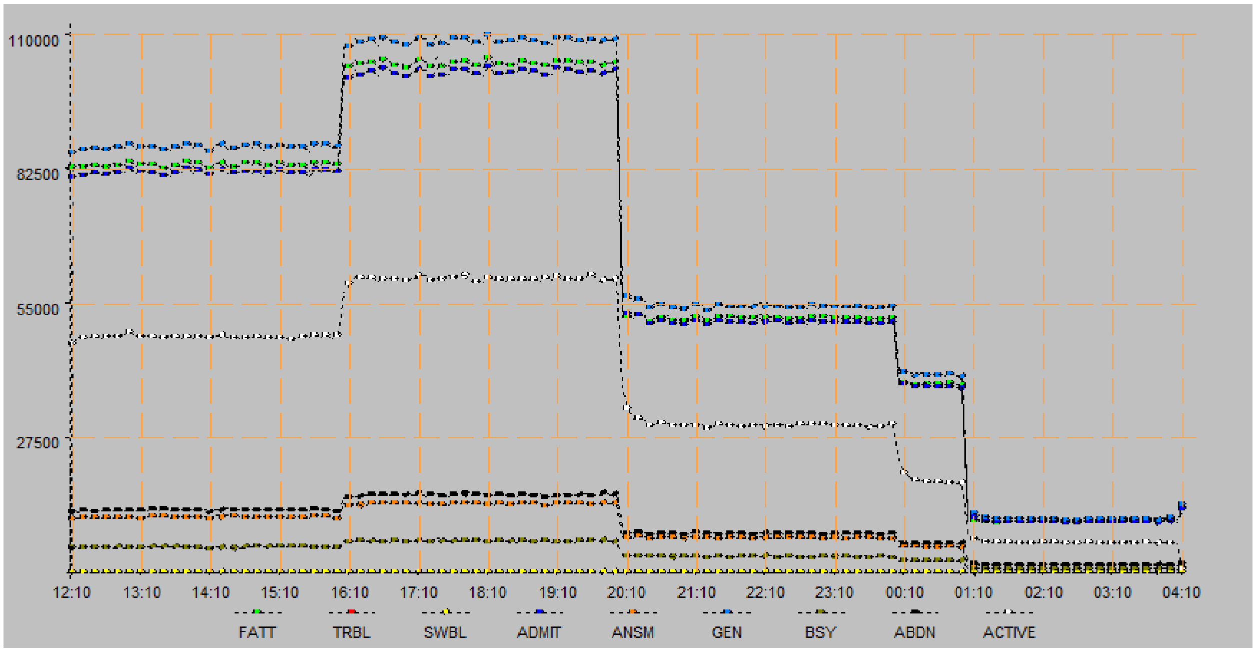


Figure 13. ChatterBell Graph Showing the Traffic Simulation Results.

9. CONCLUSIONS

Sandia National Laboratories has undertaken the critically important task of modeling the national infrastructure of communication against service disruptions, usage behavioral changes and network failures. In this report we have shown the main elements of a voice communication model and then illustrated how ChatterBell is used to simulate various types of disruptions and potential network failures as well as other failures that may also impact the telecom sector (for example power outages).

This year we have added many new capabilities to the voice communication modeling capability including the modeling of mobile area coverage as well as the addition of VoIP modeling capability to the ChatterBell modeling and simulation tool. We have also created a number of ready-to-use models for several LATAs within the USA that can be utilized for emergency preparedness for anticipated threats such as hurricanes, and other natural disasters as well as non-traditional threats of various sources and extents.

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