TELEMETRY NETWORK SYSTEM (TMNS)
LINK MANAGEMENT MODELING AND SIMULATION

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ABSTRACT

The TmNS system employs a novel channel access approach to achieve efficient use of the available spectrum while still providing a reliable bi-directional telemetry link. At the heart of this process is the Link Manager which performs real time adjustments to the transmission windows of radios as it senses changes in network connectivity, transmit queue loading, and network management input. Dynamic network capacity control based on radio queue loading is presented as an example of an operation to be verified by modeling and simulation.

KEYWORDS

Link Management, TDMA, TmNS, iNET

I. INTRODUCTION

The TmNS uses a TDMA based channel access architecture to provide reliable links for test articles communicating with ground stations. Traffic from ground-to-air (upstream) and air-to-ground (downstream) is time multiplexed on an allocated frequency channel as shown in Figure 1 for a network containing two active test articles. The TmNS network provides bidirectional network capability using much of the same communications infrastructure already present in Serial Streaming Telemetry networks.

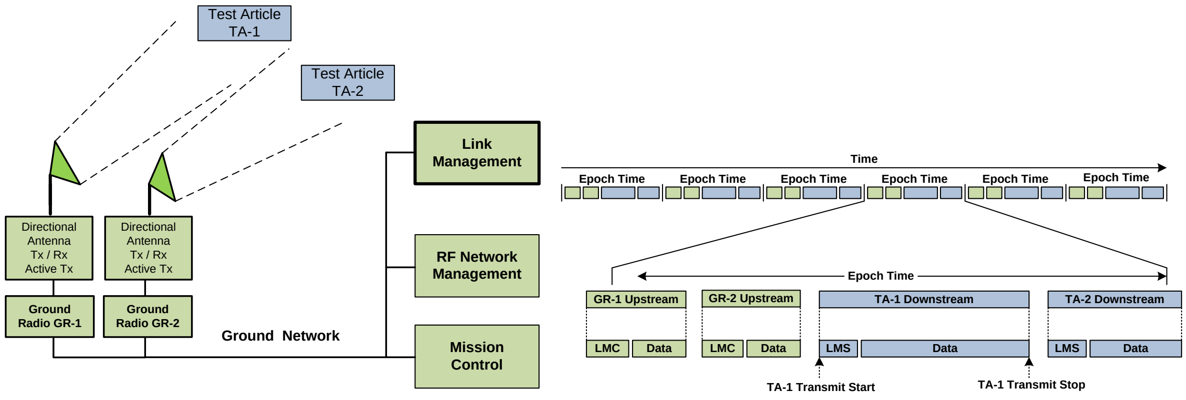

Figure 1: TmNS TDMA Channel Access

In the TmNS network ground radios receive Link Manager transmission control messages over the range ground network. These messages define the start and stop times of upstream transmissions to the test articles. The airborne test articles receive their link manager transmit control messages from the ground radio during upstream transmissions. These messages define the transmission start and stop times for test article data sent to the ground radio. The downstream traffic messaging process is shown at a high level in Figure 2.

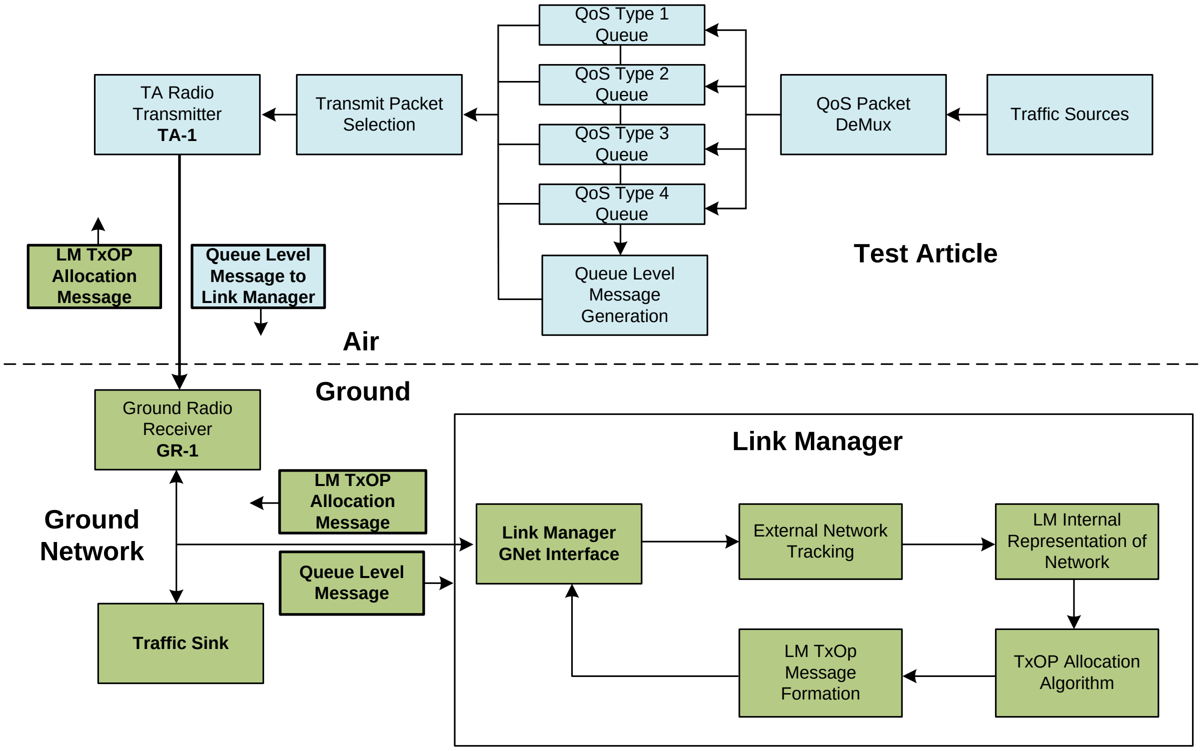

Figure 2: High Level Downstream Traffic and Control Flow in TmNS

Traffic received from sources on a test article are sorted by QoS markings and queued for transmission. Using a quality based servicing process, packets are selected from the QoS queues for transmission by the test article radio filling the transmit window which it is currently allocated by the Link Manager. The queue level information contained in the test article radio is relayed to the Link Manager on the ground. The combination of queue level messages to the Link Manager and the transmit window control messages to the Test Article represent a dynamic control loop. At a rate up to the TDMA epoch time, the spare capacity of the network is distributed in the form of extra transmit time to each of the test article radios. In addition to the capacity allocation effectiveness when servicing multiple test articles, of additional interest is how effectively can the quality of service be maintained for traffic flows under various network scenarios.

II. DYNAMIC NETWORK CAPACITY CONTROL

The central control of radio transmit start and stop times by the Link Manager gives the TmNS network the ability to share the limited data capacity resource for frequencies allocated on a test range. This approach allows traffic burst to be serviced with lower delay and reduced probability of messages loss due to buffer overflow conditions. The alternative to dynamic control is to have each link provisioned with its peak capacity rate leading to limited support for multiple simultaneous tests. Using a centralized Link Manager to compute and distribute the dynamic transmission windows, also avoids the inherent delay issues when each node arbitrates individually for transmit opportunities usage. The control loop consists of feedback to the Link Manager in the form of queue levels and a control output based on the amount of time allocated to the radio for transmit. In Figure 3 the path between the feedback and control messages are shown at a high level.

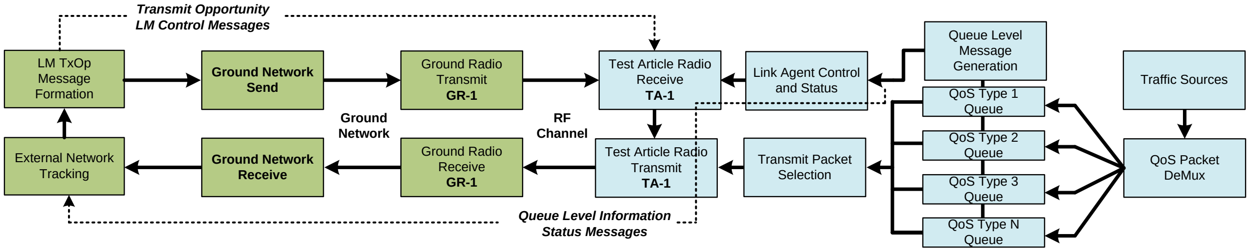

Figure 3: TmNS Dynamic Network Downstream Capacity Control

There are multiple delay blocks that need to be considered between the source and destinations of queue level status and transmit control messages. When a radio experiences a burst traffic increase, the rise and fall in queue levels will lag the increase in traffic capacity given to the radio as shown in Figure 4 for low and high rate updates. Some of the factors which determine the response to queue levels are: 1) the size and duration of increase in traffic beyond what can be handled by the currently allocated capacity, 2) the amount of dynamic capacity that the Link Manager can allocate to the radio, 3) the delay from queue level sensing to adjustments in the radio transmit window. These factors should be investigated under test scenarios which are representative of traffic, mobility, and link conditions typically found on a test range.

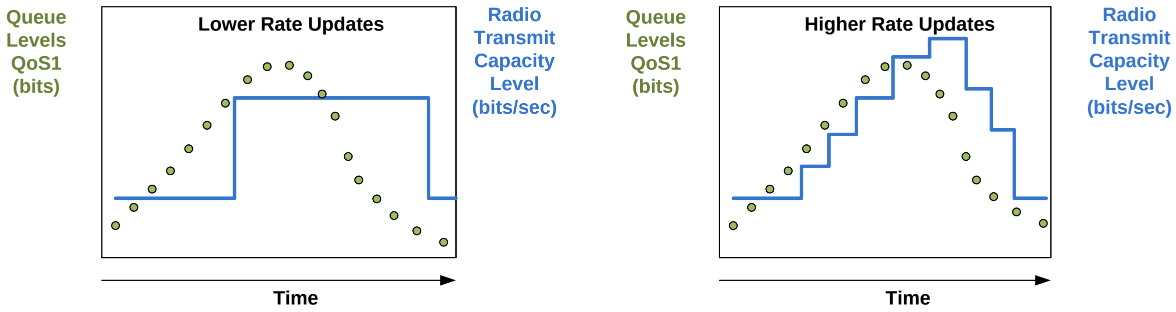

Figure 4: Queue Level Response vs. Radio Capacity Changes from the Link Manager

III. MODELING AND SIMULATION

As a shared-code software system deployable in the OPNET simulation environment, the Link Manager Software will natively execute within OPNET, providing the developer full control and visibility into the execution of core Link Manager protocol algorithms. Deployed together with OPNET models representative of TmNS RAN networking elements, OPNET simulations can be run in accordance with TmNS concept of operations (CONOPS) and system goals to verify network system performance and scalability.

The developed shared-code Link Manager OPNET model serves as a tool during software development to validate and verify key design choices and address any potential faults in the system design and/or CONOPS.

A. LM Node Model

The TmNS Link Manager has been designed to run on top of existing, OPNET supplied workstation class IP node models. Facilitated by the Link Manager OPNET OS Abstraction Layer, the native LM software is able to execute seamlessly within the OPNET simulation environment as a shared-code process as shown in Figure 5.

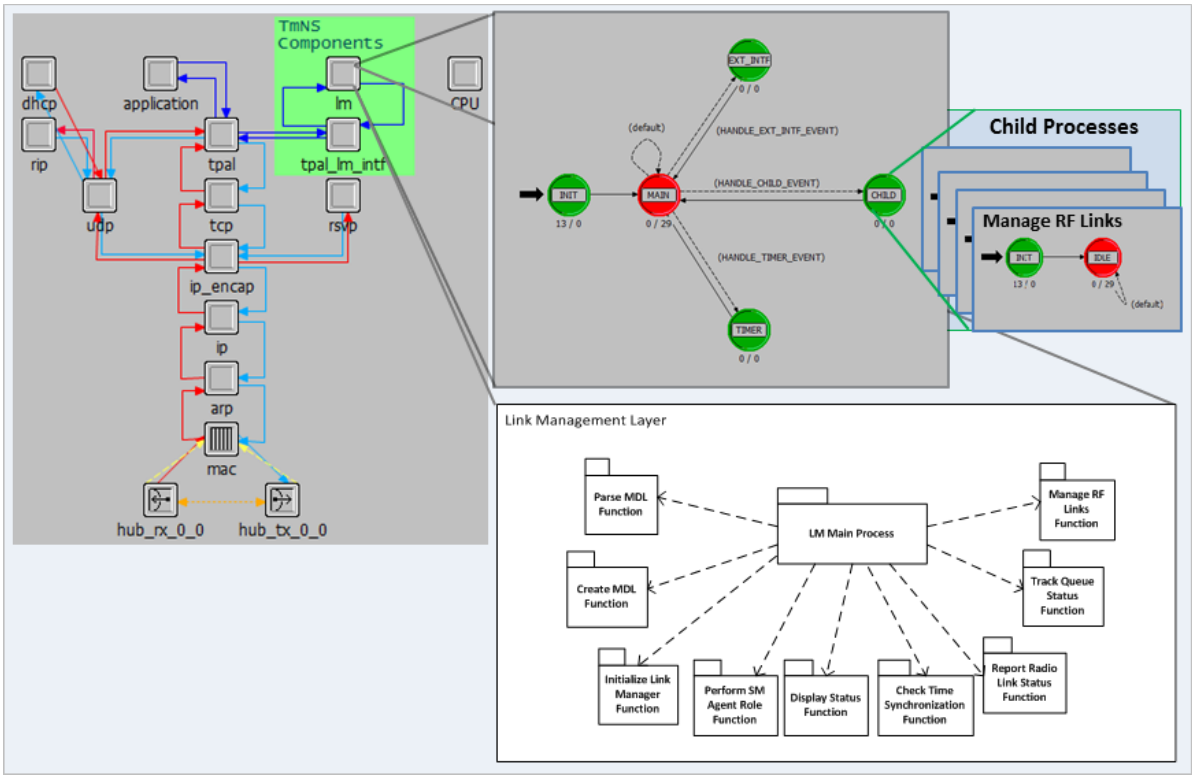

Figure 5: TmNS Link Manager Node Model (Update)

To enable the Link Manager software to execute within OPNET, the LM OS Abstraction Layer provides a unified and flexible interface to the Link Manager for accessing key system facilities and resources.

As shown in Figure 5, Link Manager specific modules are contained within the illustrated green block. The module “tpal_lm_intf” provides the necessary message transform logic to enable the Link Manager process to embed link management protocol messages within OPNET formatted TCP/UDP/IP packets, hence enabling it to exchange messages with other nodes in the network.

The module “lm” in the green block is the actual Link Manager component. As depicted in Figure 5, at initialization, the Link Manager process spawns a number of child processes where appropriate to simulate the parallel processing effect of critical Link Manager events and messages. With this organization, the Link Manager main process communicates with its child processes via shared-memory blocks. As designed, each one of the Link Manager functionality may be exercised during the course of a simulation. Generally, the model Link Manager main process monitors and handles events related to IPC with its child processes, timer events, and handling of messages from/to its external interface.

B. Radio Node Models

The Ground and Test Article radio OPNET models provide functional models of the TmNS radio systems to the extent needed to support the simulation goals. The models implement each of the major functional components present in the Ground and Test Article radios such as the RF Transceiver, Ethernet Transceiver, Link Agent Functionality, Radio Agent Functionality, Link Management Functionality, Queue Management Functionality, the RF Network Management Functionality, and general simulation support functions. The Ground and Test Article radio models are custom designed and built to meet the functional requirements of the actual TmNS radio systems with the highest fidelity.

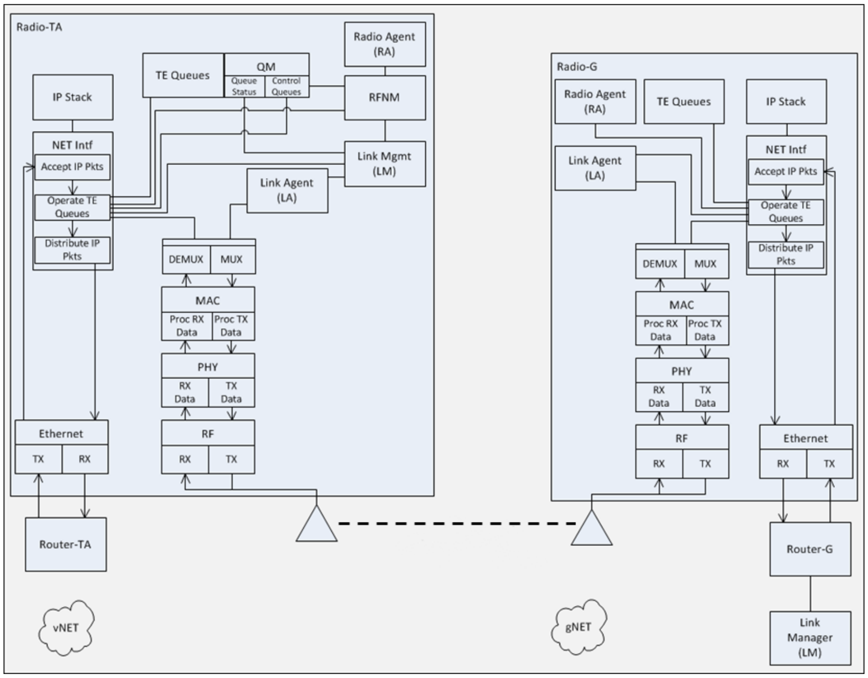

Figure 6: TmNS Ground and Test Article Radio Node Models

C. Simulation Framework

This Link Manager OPNET modeling and simulation effort focuses on the Radio Access Network portion of the TmNS, with specific emphasis on the link management functionality of the network system. The goal of the simulation is to verify and validate system-level use cases and design choices pertaining to scalability and performance. Figure 7 provides an overview of the simulation framework, capturing each participating component in the TmNS RAN segment, as well as supporting simulation components related to system configuration, traffic generation, statistics collection, and node mobility management.

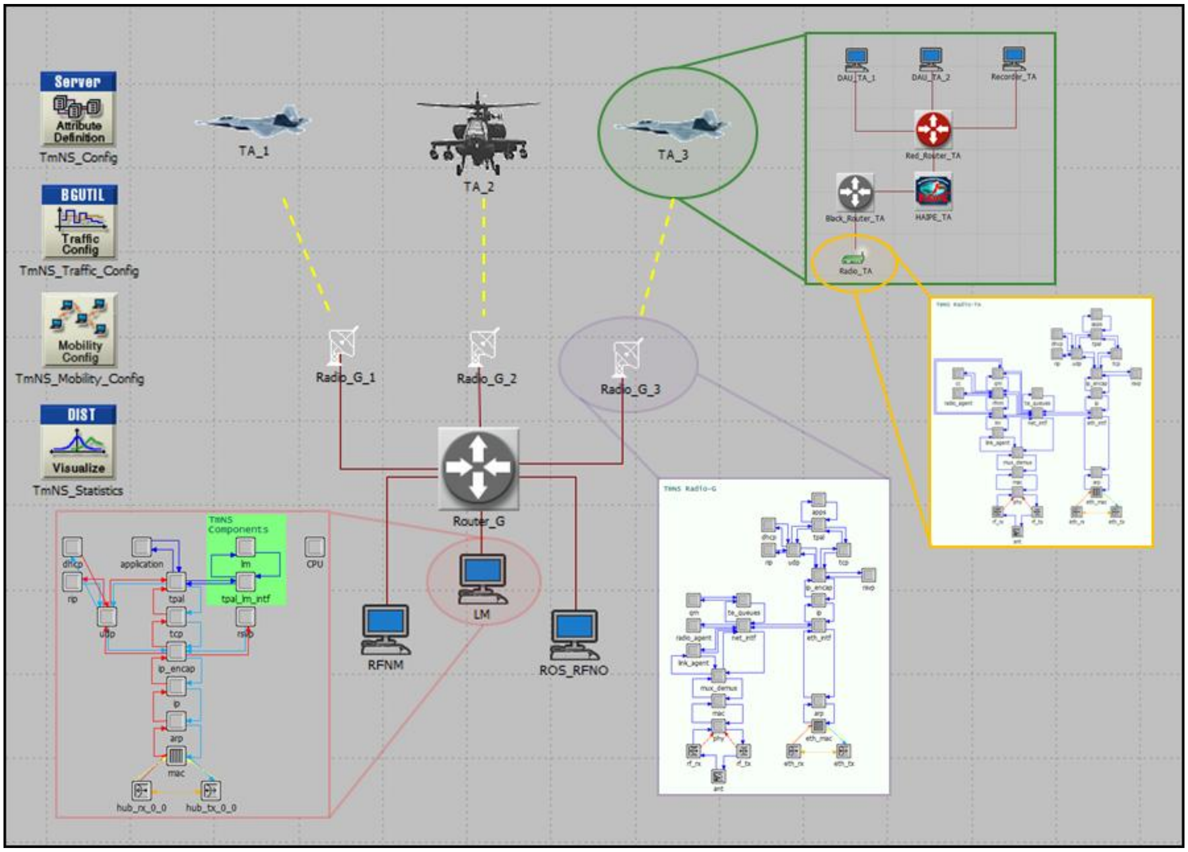

Figure 7: TmNS Simulation Framework

As a critical component in the TmNS RAN, the Link Manager is responsible for the control and coordination of radio operations in the network. The Link Manager relies on information received from network and link management entities pertaining to uplink and downlink RF links and queue status of ongoing tests to dynamically allocate channel capacities. To simulate the flow of application traffic from the vehicle network to the ground network and vice-versa, the simulation framework provides a Traffic Generator component that can be configured to generate representative traffic flows from DAUs and flight recorders onboard Test Articles, as well as command and query messages from the ground network.

During the TmNS RAN Link Manager modeling and simulation, network performance statistics will be collected at the system, node, and local process levels. Statistics related to system health, status, throughput and latency of application and background traffic flows, uplink/downlink capacity assignments, queue loading and servicing, and delivery of time critical control messages will be collected and made available for post-simulation analysis. In addition, a live simulation monitoring and capturing support application will facilitate rendering of in-process simulation data, providing information corresponding to link tables, bearer tables, and queue fullness tables.

A configuration model provides the interface necessary for setting system level configuration parameters that globally affect the behavior of nodes in the network. Example of global parameters affecting radio models are RF channel settings related to bandwidth, center frequency, transmit data rate, default transmit power, and receiver sensitivity level. Node specific configuration interfaces such as for setting MAC addresses, static IP addresses, and traffic filtering settings will be provided at the node-level or via external input files to uniquely configure each node to match the elements in the TmNS network.

To simulate the physical movement of Test Article models, the simulation framework will provide a Node Mobility Manager component that will facilitate definition and provision of node trajectory commands to independently control the movement of each node in the simulation environment.

D. TmNS Verification Scenarios

When verifying the system-level use cases and network scalability and performance qualities related to dynamic control and coordination of radio operations, the TmNS Link Manager modeling and simulation effort will utilize networking scenarios configured specifically to stress the capability of every critical component involved in fulfilling the Link Manager's roles.

A baseline scenario will be provided to verify the process of network device discovery, topology verification, and nominal traffic injection to simulate network commands, queries, and response message delivery performance. This baseline scenario will also serve to verify the proper functioning of the link management algorithms.

A typical network usage scenario will be used to ascertain the system's ability to perform under nominal conditions. The scenario will be designed to import real capture data for its traffic generation and capture statistics for later comparison to actual system traffic statistics data.

Worse-case scenarios will be developed to stress the system beyond its steady state operation. These scenarios will include conditions where the system experiences sudden and sustained simultaneous surge in various bursts configurations. The burst conditions include: long bursts, random bursts, and periodic bursts of traffic. These conditions will place a high demand on the dynamic allocation of available transmit channel capacity. The scenarios should provide insights into the ability of the Link Manager to efficiently allocate prioritized traffic in the range network.

IV. CONCLUSION

The TmNS RAN Link Manager Modeling and Simulation framework was presented with a focus on the Link Manager portion of the TmNS. The Link Manager software under development provides a layered architecture with an operating system abstraction layer that enables the Link Manager software to natively execute within the OPNET simulation environment. As a shared-code OPNET model, the Link Manager provides a high degree of fidelity to the network simulation. Subjected to different networking scenarios, the Link Manager model is designed to operate very similarly to the Link Manager platform software in development. The ground and Test Article radios have been modeled at the functional level, whereby key functionalities of the actual radio system are implemented in the model. To verify the scalability and reliability of the TmNS network, three specific OPNET simulation scenarios have been proposed. A baseline/verification scenario is intended to simulate network device discovery, topology verification, and other basic system operations. Typical network usage scenarios are designed to test the TmNS under normal network usage and traffic conditions, ultimately using actual lab/captured network traffic data as input for verification purposes. Worse-case scenarios aim to stress the network system beyond its steady state operation. Abnormal and sustained sporadic traffic bursts will be introduced from multiple sources to test the Link Manager’s ability to react and respond to changing network conditions in a timely manner.

In addition to the dynamic capacity sharing process outlined in this paper, the model can be used to investigate other key technical performance measures. One example is maintaining channel capacity efficiently across two ground radios when handoffs occur. During a ground radio handoff upstream traffic is depleted from the current ground radio while the network begins to route traffic to the new ground radio. During this time the Link Manager assumes the role of providing an efficient allocation of the available channel capacity across the radios involved in the handoff as well as other radios in the network.

The simulation model described here is currently being designed and implemented along with the Link Manager Reference model. Some of the results from the modeling process will be included in this paper presentation at ITC in October 2011.

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