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An Experiment for Estimating Database Latency for Mobile Systems*

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Abstract: As ubiquitous computing begins to become a reality, the problem of estimating database performance metrics, such as database latency between mobile systems or database latencies among fixed and mobile systems, will become an ever more important issue for network engineers. The problem of estimating database performance metrics, especially latency for mobile systems, is of particular concern to military forces. This paper discusses an ongoing project for building a test bed for estimating database latencies among distributed systems that have fixed and mobile components. We are using a commercial network modeling tool, OPNET Modeler and a new module for OPNET, the Application Characterization Environment (ACE) Module to (1) build a model of a portion of a distributed network, and (2) characterize database operations for applications using the network. Our goal is to understand how the performance of distributed database processes affect the military processes of interest. This paper will: (1) describe the test bed (2) describe the status of building an OPNET model of a military network from network traffic data, and (3) provide initial results in building a model of squad-level mobile network components.

THE PROBLEM

Future command and control (C2) systems of Joint Task Forces (JTFs) will be a network of applications running in a distributed environment. These applications, such as the Advanced Field Artillery Tactical Data System (AFATDS), will depend, in part, upon timely distribution of data stored in the Joint Common Data Base (JCDB). This project aims to create an initial capability for conducting metrics-based experiments concerning performance of distributed applications under a variety of operational conditions. By modeling portions of the Army tactical local area network (LAN) or the JTF network using Army-developed models of the 4th ID network and the OPNET Modeler commercial network-modeling tool, The United States Military Academy's (USMA's) Information Warfare Analysis and Research (IWAR) Laboratory will assess network-level attacks against command and control systems such as AFATDS. Using real-world Army Fire Support C2 and Communications equipment, experiments are being conducted to estimate database latency metrics for mobile call-for-fire events. The network model can then be used to estimate database latencies for distribution of the data throughout the larger tactical internet. By using OPNET to control the synchronization of distributed applications using timed events, it may be feasible to estimate latencies in a larger distributed context. Answering such questions as: "What is the database access time for AFATDS to obtain item X from the JCDB?" or "What is the change in the database access time for AFATDS to obtain item X from the JCDB when change Y occurs in the network?" are the first steps needed to determine whether delays in database access times are "normal," due to equipment failures, or potentially deliberate interference with information system operation.

THE TEST BED

Concept

The Next Generation Performance Model (NGPM) of the Communication-Electronics Command (CECOM) Research Development and Engineering Center (RDEC) is being implemented using extensions to OPNET modules to provide the ability to model elements of the Force XXI environment at the network level. We intend to use a new module available for OPNET Modeler, the Application Characterization Environment (ACE), together with elements of the NGPM to support application assessments at the platform layer or network layer. For example, OPNET can be used to model portions of the Army tactical local area network (LAN) or the joint task force network and assess network-level attacks against command and control systems such as the Advanced Field Artillery Tactical Data System (AFATDS).

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As indicated above, future command and control systems of Joint Task Forces (JTFs) will be a network of applications running in a distributed environment. During execution of a JTF operation, we expect that some of these applications will be used to monitor the status of the operation and support comparison of current state of the force with the expected state based upon the current plan – that is that we will have a clear understanding of the current operational picture (COP). One view of this situation is to assert that we will know (1) the current location of friendly forces, (2) the current locations of enemy forces, and (3) the current activities of enemy forces. These applications, such as AFATDS, will depend, in part, upon timely distribution of data stored in the Joint Common Data Base (JCDB).

One technique use by commanders to compare the current state of the force to the expected state is the *synchronization matrix,* which is also called an *execution matrix*. The synchronization matrix is simply a look-up table with phases or key events of an operation across the top, units or activities down the side, and descriptions of unit or activity missions during the phases or key operational events as entries in the table. Thus, as an operation unfolds, commanders and staffs can quickly determine what units and activities should be accomplishing during different phases or key events of an operation. Comparison of the current state of the force to the expected state can then be accomplished by enumerating which units and activities are "on track" with the plan and which are not. For purposes of our project, we will initially focus on processes which support initiation and execution of "call for fire" events from infantry squads as the distributed processing problem of interest. We will start with modeling the mobile network being implemented at the squad level and move later into the connection of the faster-moving mobile networks at the squad, platoon and company levels into the slower-moving LANs found in the tactical operation centers (TOCs) at battalion, brigade and division levels.

This project aims to create an initial capability for conducting metrics-based experiments concerning performance of distributed applications under a variety of operational conditions. The test bed will use Army-developed models of the 4th ID network and the OPNET Modeler commercial network-modeling tool to achieve a capability to evaluate performance characteristics of distributed applications. Implementation of the test bed will depend upon use of a new capability for OPNET Modeler, the Application Characterization Environment (ACE) module. We will use the ACE module to build an OPNET to model of a military network from network traffic. In the Information Warfare Analysis and Research (IWAR) laboratory we have two Single Channel Ground-Airborne Radio Systems (SINCGARs), one of which is connected to an Advanced Field Artillery Tactical Data Systems (AFATDs) and the other to a hand-held device for entering calls-for-fire. The hand-held device would be appropriate for use at the squad level for conducting a "call for fire" mission. These items establish an environment for conducting experiments to estimate database latency metrics for mobile call-for-fire events into an AFATDS. The network model can then be used to estimate database latencies for distribution of the data throughout the larger tactical internet. In addition to the ACE module for characterization of application behavior, OPNET has a module that implements the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA) which supports explicit control of synchronization of distributed applications using timed events. Thus, we expect that, at some point, it will be feasible to use DMSO simulations to estimate latencies in a larger distributed context. As indicated in the introduction, we expect to answer questions such as: "What is the data base access time for AFATDS to obtain item X from the JCDB?", or "What is the change in the data base access time for AFATDS to obtain item X from the JCDB when change Y occurs in the network?" Answers to such questions are the first step in being able to answer security-related questions concerning whether delays in database access times are "normal" or might be due to equipment failures, or might be due to deliberate or inadvertent interference with information system operation.

In that regard, we do **not** expect that the models we develop will represent **actual** conditions to be experienced in a given situation (e.g. our database latency numbers are not expected to be the "real" latencies that one might encounter for an operation). However, we **do** expect that the **trends** that we observe for a given set of equipment distributed over a given variability of terrain and weather conditions will experience under a given load and set of failure modes of system components (e.g. our percent of change of selected latencies under a given set of conditions for a given set of components degradations or failures should be valid for actual units given similar circumstances).

The Joint Common Data Base (JCDB)

The Joint Common Data Base (JCDB) will be the primary mechanism for sharing information between and within echelons of a future force structure JCDB data distribution between Tactical Operation Centers is summarized in Figure 1. The concept is that Battlefield Functional Areas (e.g. fire support, maneuver, …) will replicate and distribute BFA data between echelons and the JCDB at each echelon (i.e. in a given Tactical Operation Center (TOC) at a given echelon) will contain the common tactical picture at a given echelon for a given unit.

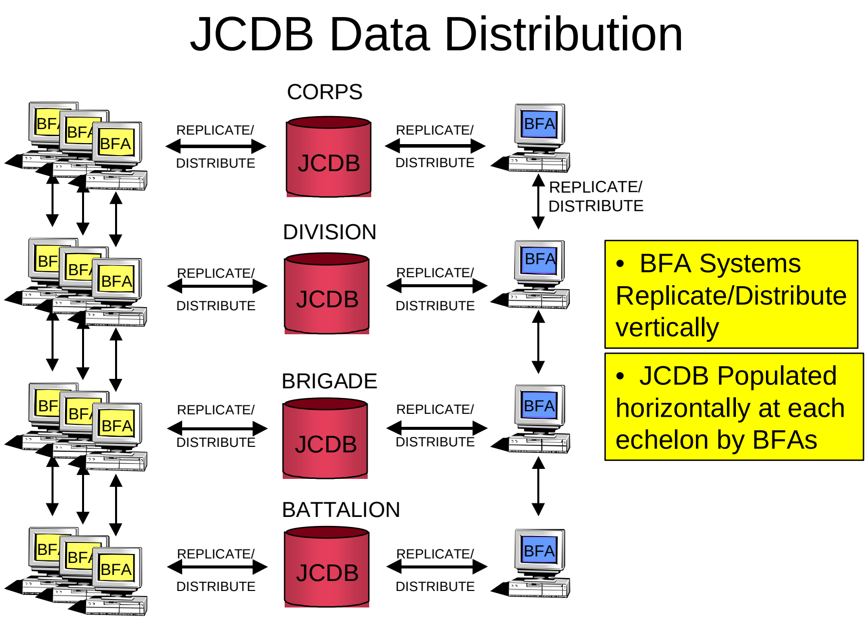

Figure 1. JCDB Data Distribution

We have completed a first step in the process outlined above by building an initial OPNET model of squad mobile data communications shown in Figure 2. In this model we follow current doctrine of squad leader control of his squad through use of two team leaders who each subsequently control the soldiers in their respective teams. The squad leader shares data with the team leaders through use of a mobile node that also serves to provide a path for data flow with the higher platoon leader and platoon sergeant. The mobile node data server could be a function of the squad leader's equipment or one of the team leaders or all three sets of equipment could be configured as mobile nodes with two of them being backup at any one time. These kinds of questions are the subject of the Land Warrior development effort and for purposes of this series of experiments we will expect that all three of the soldiers are expected to be able to support the connectivity of the squad with the platoon.

The issue then is to begin to approximate battlefield processes in our model by creating appropriate flows over time of data by type through the network. OPNET has models of typical loading patterns of different types of users (e.g. database users, web surfers, engineering users, …) but these are not expected to match the usage patterns of a squad. Indeed, we expect that the usage patterns of a squad would vary by type of squad mission and that, even for a given mission, these patterns would vary for different environments.

The OPNET program can accept packet traces of a network over time and construct a model that approximates the network configuration and data flow between components. As data becomes available, we will be able to improve the accuracy of our Figure 2 model through use of actual packet trace data. Given the configuration of components shown in the OPNET model of Figure 2, we can investigate different metrics available for use in studying different network configurations.

MODELING OF THE NETWORK AND APPLICATIONS

The network model

We have received a version of the NGPM that contains models of the fixed and mobile components of the unit networks. We will use NGPM models to include portions of the fixed and mobile communications components such as the Near Term Digital Radio (NTDR), the Future Battle Command Brigade and Below (FBCB2), the Single Channel Ground and Airborne Radio System (SINCGARS), and the Mobile Subscriber Equipment (MSE).

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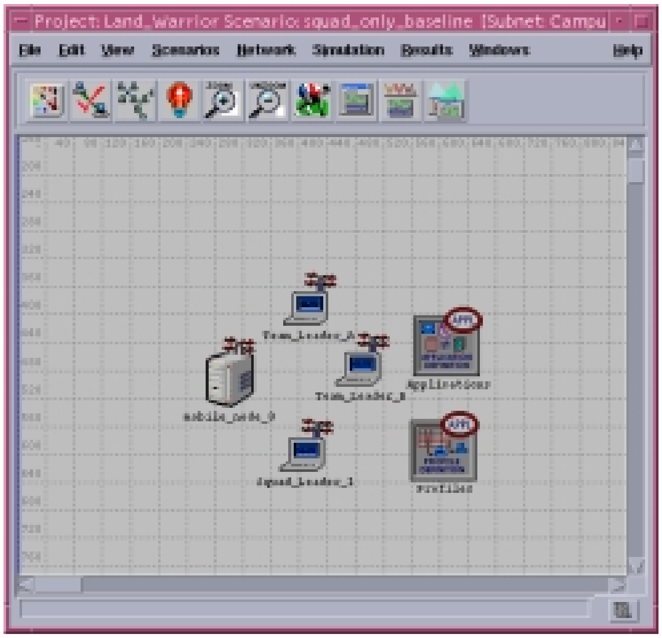

Figure 2. Land Warrior OPNET Model

Thus, consider the results shown in figure 3 where, although no bits were dropped, the wireless LAN delay varied from approximately 1millisecond over most of the simulation period to more than 6 milliseconds for the peak LAN load of less than 1500 bits per second. This may be absolutely acceptable behavior.

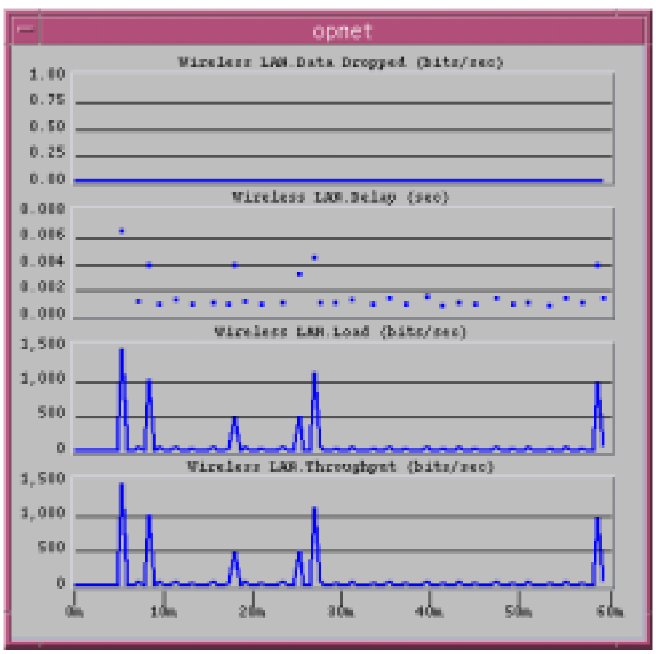

Figure 3. Typical Network Data Available from OPNET

However, it may also be the case that a delay of 6 milliseconds will be unacceptable under certain conditions. It may also be the case that the delay would be greater, or that packets might begin to be dropped, if one or more of the system components failed or if component performance became degraded.

Concerning the synchronization matrix discussed above, a commander's decision to alter the current plan might be the result of the operation failing to meet the timetables embedded in the relationships summarized in the synchronization matrix. The fire support plan is a key annex of an operations order and the activities of fire support units during different phases of an operation are a key portion of the synchronization matrix. A long-range goal of our experiment is to understand in more detail how network monitoring can be useful in estimating current system state in terms of its ability to support execution of an operation (e.g. for the current phase of the operation, are the network resources allocated to fire support processes sufficient to provide acceptable latencies in executing pre-planned and on-call fire missions?). The near-term goal is to understand in more detail the dependencies of hand-held devices for entering calls-for-fire, of network elements for relaying the calls-for-fire, and of C2 and unit elements in controlling and executing the calls-for-fire.

We are currently adding models of the Single Channel Ground and Airborne Radio System (SINCGARS) and the Future Battle Command Brigade and Below (FBCB2) components of the command and control system that are contained in the NGPM. The data loading of the network is being obtained from current Army field experiments.

There remains much to be done in this regard since we need to create an environment in the Information Warfare Analysis and Research Laboratory (IWAR) where the existing Advanced Field Artillery Tactical Data System (AFATDS) and Field Artillery Tactical Data System (FATDS) systems can communicate with IWAR computers that will be surrogates for other BFA systems. The next major step in the experiment will involve creation of an OPNET model of the military network from source network traffic and provide a top-level view of that model.

Modeling of AFATDS/JCDB applications on the network

Once activities such as a call for fire can be initiated over the IWAR laboratory network, the initial AFATDS/JCDB database modeling task will be to obtain a baseline of database access times for various queries. We will then use the ACE module to predict various outcomes, such as database access times under various communications failures, and then create the failure conditions to validate the ACE ability to provide useable estimates.

CONCLUSION

We have provided a statement of the modeling problem estimating database latency for mobile Army systems and described an experiment for making such an estimate. We have also provided a statement of the current status of the project. Our expectation is that this experiment focused on the call-for-fire event(s) at the lowest echelon of Army command and control will provide a reliable basis for gradually conducting similar experiments at progressively higher command and control levels.

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