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INJECTING SIMULATION AND MODELING UPSTREAM IN THE SYSTEM ENGINEERING PROCESS

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ABSTRACT

This paper describes the application of simulation and modeling to enhance the understanding of a communication networking solution for the Trucking Locator Control System (TLCS) case study at the Johns Hopkins University Masters Program in Technical Management. The four major steps in this process were: developing a model of the TLCS system; generating assumptions about the TLCS system; selecting a simulation tool using a trade-study; and implementing the selected simulation tool. The selected simulation package, COMNET III, was used to establish common understanding about the system under consideration, to provide insight into its performances, and to generate data for further analysis. The same process can be utilized in other System Engineering applications, not only for educational purposes, but also to provide tools for conceptual system design and to enhance the design and integration phase in the System Engineering life-cycle.

1 INTRODUCTION

The traditional roles of simulation and modeling were to conceptualize thoughts, to define alternatives, and to evaluate and predict the performances of complex systems. Until recently, most of the simulation tools, that were used to achieve these goals, were developed in high level languages (e.g., FORTRAN) and required high level of user expertise. Therefore, these simulation tools could not be used, in a timely manner, as helpful educational tools.

The introduction of new powerful and user-friendly simulation tools, such as COMNET III and ARENA, provided the means to expand the use of simulation and modeling beyond its traditional roles. For example, it has been suggested to use discrete event simulation tools to teach and motivate statistics students, and to help to present interdisciplinary case studies more effectively (Romeu 1995). This paper describes the application of communication networking simulation to enhance a System Engineering scenario that is used at the Johns Hopkins University Technical Management Masters Program in the Whiting School of Engineering.

The technical management masters program instructional methodology employs a mixture of lectures on theory and practice and realistic scenarios. One of these scenarios is the Trucking Locator Control System (TLCS) scenario, in which students assume the role of system engineers in a company that was awarded a contract to develop an information system for a trucking company.

2 THE TLCS SCENARIO

2.1 The TLCS Case Study

The TLCS scenario is part of a *System Design and Integration* course. In this course, competing teams of students are required to develop a TLCS design, based on a the following high-level requirements:

1. Present the truck location to the driver on an on-board display system
2. Send location and status updates from the trucks to a central control center
3. Present the trucks location at the control center
4. Send messages from the central control center to the trucks
5. Support a fleet of 10,000 trucks that operates all over the continuos 48 states and parts of Canada and Mexico

2.2 The TLCS Architecture

The TLCS consists of Mobile Truck Systems (MTS) that will be mounted on the trucks, a Central Control Center (CCC), and a communication service. The MTS unit consists of a navigation sub-system, a communication sub-system, an onboard computer that provides user interface to the truck driver, and an application software that include a digital map. At the CCC, a LAN of workstations loaded with a digital map and application software will be operated by a team of dispatchers. The MTSs will send location and status updates from the CCC. Using this information, the dispatchers will track loads, reroute trucks, maintain a database of trucks and drivers performances, and disseminate weather, traffic advisory, and other relevant information to truck drivers as required.

2.3 Networking Solutions for the TLCS

According to the TLCS scenario, the communication between the CCC and the MTSs will be provided by a commercial communication service. The requirement to provide full coverage of the continuos 48 states implies that this service must be provided by a mobile satellite communication system. Several mobile Satellite communication systems were considered: The American Mobile Satellite Corporation (AMSC) circuit-switched mobile satellite SKYCELL telephony service, the QUALCOMM packet-switched mobile satellite messaging service, and the ORBCOMM packet-switched mobile satellite messaging service. The simulation model that was developed to enhance the TLCS scenario is based on the SKYCELL mobile satellite service. This model can be modified in the future to represent other mobile satellite services.

2.4 The Need for a Communication Network Simulation

One of the key TLCS design issues is the selection of a communication network for the system. Due to the technical complexity and cost that are associated with communication system of that scale, it has been decided to select a commercial communication service rather than to develop an independent communication sub-system. The selection of an optimal communication networking service was identified as an area where the application of a discrete-event simulation may significantly improve the understanding of the system engineering aspects of the problem. The following requirements for a simulation and modeling tool were identified:

1. Model the TLCS users profile
2. Model candidate networking solutions
3. Develop Quality of Service (QOS) parameters
4. Evaluate the performances of candidate networking solutions
5. Assess changes in the users profile
6. Provide data for further analysis

3 SIMULATION TOOLS

3.1 Selecting a Simulation Tool

Four categories of simulation tools were considered: special-purpose Commercial On The Shelf (COTS) communication simulation packages, general-purpose COTS simulation packages, general-purpose simulation languages and libraries, and developing a simulation tool using a standard programming language.

The products in the first category , special-purpose communication simulation tools have built-in modules that represent communication network building blocks, such as nodes and links. Two COTS products were considered in this category: COMNET III by CACI and OPNET by MIL 3.

The products in the second category, general-purpose simulation tools, provide means for quick model building using graphical user interface. Some of the COTS products in this category are: ARENA by Simulation Modeling, EXTEND by Imagine That, and Workbench by SES.

The third category, Simulation Languages, consists of a large variety of languages and libraries that vary in their capabilities and level of complexity. Two of the products in this category are Mathematica by Wolfram Research and SIMSCRIPT by CACI.

The fourth category, standard programming language, was excluded from being a viable solution due to the typically long development time and high risk that are typically associated with it (Canitz 1994).

The Measures of Effectiveness (MOEs) that were used to compare between the candidate simulation tools and their relative weight are presented in table 1. These MOEs cover both the level of performance (effectiveness) and the required amount of effort (cost).

Table 1: MOEs for the Trade-Study

MOEs	Weight	Alt. 1	Alt. 2	Alt. 3
Built-in functions	1			
User friendly	3			
Easy to modify	2			
Easy to interpret	3			
required training	2			
Hardware req.	1			
Software cost	2			
Total score				

3.2 COMNET III

After completing the trade-study and after prototyping the TLCS simulation tool with both COMNET III, ARENA, and EXTEND, it has been decided to use the COMNET III simulation package. COMNET III is a discrete-event communication networks simulation environment that contains pre-defined hardware and protocol objects and built-in graphics and reporting. This enables fast and simple prototyping. COMNET III runs on both PC and UNIX workstations (Law and McComas 1995, Jones 1995).

4 ASSUMPTIONS

The following assumptions about the communication networking service were made prior to the development of the simulation model:

1. The mobile satellite service users are represented using "user groups" based on the system topology. For example, the SKYCELL system "user groups" represent users that have the same incoming calls profile that are located in geographical coverage zones that correspond to the four time zones.
2. Situations where users cross geographical coverage borders shall be ignored.
3. The of out-of-band communications can be excluded from the simulation - The out-of-band communications are the command and signaling transmissions that are used to manage the communication service, and they should never utilize more than 5 percent of the communication system resources.
4. Blockage by building and vegetation, rain attenuation, and other RF disturbances shall be represented by a simple MTBF/MTTR model
5. The candidate networking systems have pre-existing communication load that represent other users. For example, the SKYCELL system already provide telephony services to subscribers in rural areas.
6. Call inter-arrival time has a negative exponential distribution with mean λ
7. Call duration has a negative exponential distribution with mean μ

5 THE SIMULATION MODEL

5.1 The Communication Network Model

The TLCS communication network model consists of a model of the communication network and a model of the TLCS system user profile. The TLCS communication network model is shown in figure 1. The initial model of the TLCS users profile is based on the following assumptions: only 40% of the trucks are on the road at any given time, on the average each MTS sends 10 messages per hour to the CCC, and the CCC send two messages per hour to each MTS. This initial TLCS users profile is given in table 2.

Table 2: The initial TLCS users profile

	From trucks	From CCC
λ [seconds]	0.1	0.5
μ [minutes]	0.01	0.01

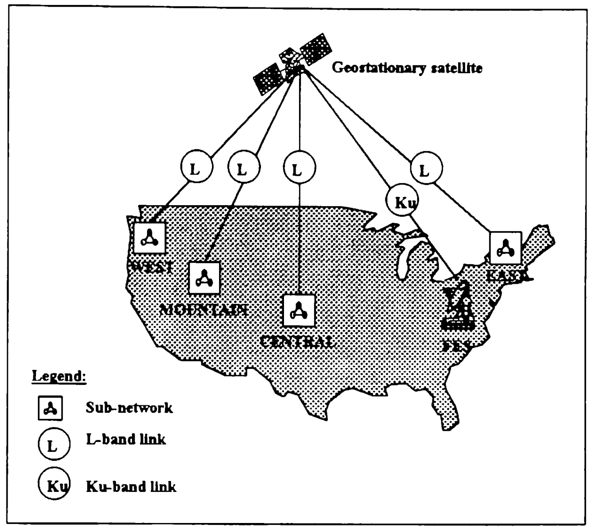

Figure 1: The TLCS communication network

5.2 Quality of Service (QOS)

A set of QOS parameters is needed to evaluate and interpret the simulation results. From the user perspective, the QOS parameters should represent the probability that a placed call go through and that it is completed successfully. From the provider perspective, the QOS parameters should represent the use of network resources. The following QOS parameters represent these requirements:

- The number of carried calls
- The usage of scared network resources
- The number of disconnected calls
- The number of preempted calls
- The blockage probability

6 A SUMMARY OF THE SIMULATION RUNS

The simulation model was run in class to evaluate the performances of a communication networking solution for the TLCS. The students actively participated in the simulation runs, by suggesting "what if" scenarios, by modifying the user profile, by trying to predict the simulation results, and by analyzing the meaning of the simulation runs output. Table 3 describes the input for a set of simulation runs: First, the simulation model was run without the TLCS users, and then it was run five more times with different TLCS users profiles. Figure 2 and Figure 3 show the resulting simulation output.

It should be noted that the number of carried calls in case 2, case 3, case 4, and case 5 is by orders of magnitude larger than the number of carried calls in case 1, and yet the blockage probability in these four cases in significantly smaller than the blockage probability in case 1. These results are different from the intuitive expected results. The reason for this behavior is that the additional load in cases 2 through 5 is made of short calls, compared with the other users of the mobile satellite service (μ = 0.01 minutes .vs. μ = 3 minutes). Case 6, on the other hand, demonstrates a situation where the incoming calls overflow the communication network.

Table 3: Simulation runs summary

Run	User profile description
1	Without the TLCS users
2	With the initial TLCS users profile
3	Longer calls (0.1 minute) from trucks
4	With 60 calls/truck/hour
5	Case 3 + Case 4
6	Longer (1 minute) calls from CCC

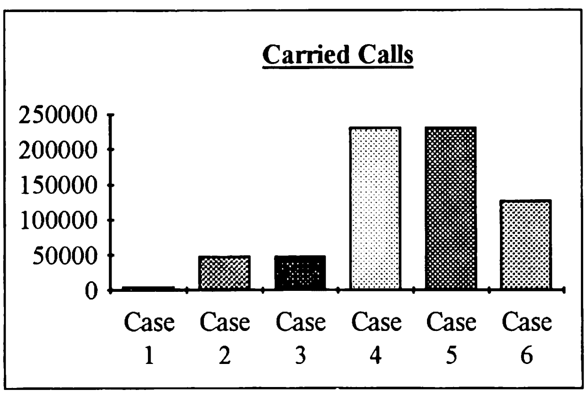

Figure 2: Number of carried calls

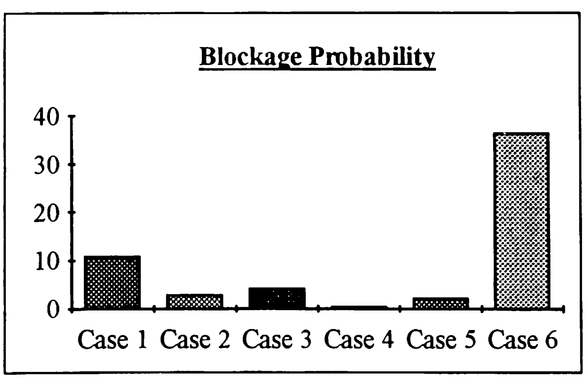

Figure 3: Blockage probability

7 CONCLUSIONS

This paper described the application of simulation and modeling to evaluate a communication network solution for the TLCS system, as part of a System Engineering case study at the Johns Hopkins University Masters Program in Technical Management.

The use of a powerful and user-friendly simulation tool (COMNET III in this case) provided an opportunity for student with no prior experience, to focus on the system under consideration, rather than on the simulation development environment. In fact, it took these students less than an hour to understand the TLCS simulation model. Although no quantitative data was collected about the use of Simulation and Modeling for this purpose, the overall response from the students who participated in this exercise was that using simulation and modeling improved their understanding of the TLCS scenario; facilitated better communication about the TLCS communication needs and the candidate solutions; and helped them to identify the TLCS communication sub-system constraints and un-used resources.

The introduction of powerful and easy to use simulation tools such as ARENA and COMNET III enables the use of Simulation and Modeling in the early phases of the System Engineering process. The use of Simulation and modeling in the early phase of the System Engineering process enhances the understanding of complex System Engineering problems, provide means to mitigate risks without having to build costly prototypes, and can also be used to generate data for further analysis (for example, cost analysis).

The System Engineering process of evaluating the performances of a communication networking solution for the TLCS consisted of four major steps: developing a model of the TLCS system; generating assumptions about the TLCS system; selecting a simulation tool using a trade-study; and implementing the selected simulation tool. The same process can be used in other applications, not only for educational purposes, but also to provide tools for conceptual system design and to enhance the design and integration phase in the System Engineering life-cycle.

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