

AN APPROACH IN THE ANALYSIS OF COMMUNICATION-INFORMATION SYSTEM MODEL IN MILITARY OPERATION

Saša M. Devetak*

University of Defense in Belgrade, Military Academy

Samed M. Karović

Educons University – Sremska Kamenica

Miroslav R. Terzić

University of Defense in Belgrade, Military Academy

This paper describes an approach to the analysis of performance of the modelled communication-information system (CIS) in military operations using RIVERBED simulation package. The basis of military operations concept and the CIS model to meet the needs of command and control (C2) have been discussed. In order to analyze the possibilities of the CIS for transfer of information the methods of analysis, modelling, operational research and simulations have been applied. The graphs of dependence on load links, the amount of transmitted information (packet) and packet loss depending on the duration of a simulated military operation are shown. The importance of the applied methods of modelling and simulation is represented by the possibility of the CIS modelling, and an analysis of its performance without using a real system due to high economic costs. The only limitation in the paper is the assumed network connectivity between the CIS elements (the effects of relief, vegetation, weather conditions, etc. on telecommunications have not been considered). In a broader sense, the paper is designed for everyone involved in modelling and simulation in order to evaluate an approach to practical application of methods of solving specific problems, and in a narrower sense to persons engaged in the CIS design and telecommunications planning in various types of operations in order to analyze the possibilities and optimize the CIS elements.

Key Words: model, simulation, telecommunications, communication-information system, military operation

Introduction

The communication-information system (CIS) is an association of functional elements that include collection, transmission, protection, electronic processing, presentation, storage and distribution of information for the system of command and control in military operations. The CIS architecture is determined by the structure of the

* sasa.devetak@va.mod.gov.rs

Army forces, which are used in carrying out various tasks. This paper has modelled the forces of three levels of command (battalion-brigade-operationalgroup) in a defensive operation.

The modelled CIS is characterized by mobility, ability to work in field conditions and the provision of telecommunications capacity and customer service to meet the needs of command and control in an operation. The elements of the telecommunications system include access and network nodes (Mobile Switching Center – MSC) linked by radio-relay links. The nodes consist of ATM (Asynchronous Transfer Mode) switches that implement TDM (Time-Division Multiplexing) and IP (Internet Protocol) component in the ATM system of transmission and switching. The access nodes of all three levels of command provide various customer services (voice, file, email, data, video streaming, etc.). The methods of operational research and simulation have been applied in order to analyze the performance of the CIS model for the purpose of C2 (Command and Control) in military operations. The theory of mass service is applied to determine a capacity for voice traffic whereas the software package Riverbed Modeler 17.5 Academic Edition has been used to simulate capacities of the CIS model in IP data transfer. The simulation scenario defines the network elements, the traffic types (services and applications), as well as the mode of operation of various user profiles and their needs for service. The target performance of the model has been followed with a special emphasis on the commitment of the most critical links in terms of the maximum traffic load. The results of the simulation scenario are presented by the adequate graphs in order to analyze packet data transmission by the described network. The analysis of the system performance using simulation software is very significant because it provides a simpler, more efficient and cost-effective consideration of the possibilities of the system and optimization of telecommunications network in an operational use.

Military operations

A military operation is a specific social phenomenon that can solve armed conflicts by application of different content of warfare. Modern management theories enable definition of an operation as a single project (enterprise, process), which fulfills the unique general objective by a variety of combat and non-combat activities engaging human and material resources under the single command, in certain space and at certain time. The application of the project management concept establishes an effective organization, which enables the best use of the available methods of planning, organizing, managing and supervising in order to implement the project effectively. [1]

In principle, military operations have the following phases: preparation, conduct, stabilization and disengagement. The operations planning, forces organization, provision of the required resources, training and operational development of forces are conducted in the preparation phase of an operation. The execution of a military operation involves the organization of command and control, action and counteraction, logistics, maneuver, combat support, force protection and civil-military cooperation. In the last phase, the gradual disengagement of forces is done after reaching the objective of the operation and elimination of consequences of a military operation. [2]

The first step of operational planning is creation (formation) and development of an operational model. It is the result of a thought process, which has carried out the analysis of the operational environment and set their own and the enemy forces in a logical relationship. In other words, it represents visualization of the basic commander's ideas for the conduct of an operation, which relates tasks of the forces and the end state. "The operational model in all cases should be a reflection of the commander's understanding of the operational environment displayed textually and/or graphically". [3]

Formulation of an operational model is done by definition of the operational environment, defining, identifying and solving a problem operationally. On the basis of the operational model, the concept (draft) of a military operation is produced, which defines the specific objectives and activities and actions that have to be undertaken in order to reach each of the defined objectives, that is reaching the defined objective.

Modelled forces in the Army operation conduct defense operation in the area of 100x150 kilometers. The analysis of the telecommunications system for the purpose of command and control in these conditions was processed for a three-level command (battalion-brigade-operational group). Each of them has specifics in terms of the number of people that require communications services and bandwidth.

Communication-information system model

Telecommunications-information support of military operations is a process in which communication-information system is planned, organized and implemented for transmission, protection, electronic processing, storage and presentation of information. This creates the necessary conditions for functioning of command and control of the engaged forces in military operations. An optimal model of communication-information system is found by planning, organizing and implementing telecommunications-information support, an organizational structure is created, the CIS elements in the area of operations are set in the single technical-technological structure, and telecommunications and user services are established, maintained and used. [4]

Modelled forces in an operation determine the model of telecommunications system. The important characteristics of the system are that it enables operation in the field conditions (climatic-mechanical properties of the device), that it is movable (mobile) in the sense that the elements of the system enable monitoring commands and units in the area of an operation and it provides the necessary telecommunications capacity and user services. [5] An approach in modelling telecommunications systems for needs of forces in a military operation in support of civil authorities is shown by Karović and Pavlović. [6]

The CIS model consists of an integrated radio-relay network (transport network) that connects nodes, that is mobile switching centers (MSC). The access nodes are deployed at command posts of modelled forces in an operation, and network nodes (level one and two) in the area of an operation. The services that are discussed in this paper are voice communication and data exchange through the IP part of the network. Although they are enabled through the same transport network in switching, they are separated.

The radio-relay component has the function of interconnecting the switching nodes per each type of interface. The radio-relay component is composed of TADIRAN GRC-408E 8Mb/s devices, connected in a ring structure, which have the following interface: G.703 E1, G.703 E2 and V.11. V.11 interface rate 8192 kb/s was used in the model. The link flow is 8192

kb/s including 512 kb/s reserved for voice applications and 7680 kb/s for data transfer. The codec that is used for voice applications is G.711 and 8 simultaneous calls can be established per link. The quality of service in MSC nodes is defined in such manner that voice services and service data are completely separated by the bandwidth reserved for them.

MSC consist of MTIS (Military Tactical Internet Switch) switches, which are essentially ATM switches with a special IPC (Internet Protocol Card) intended for routing IP traffic. MTIS stations enable circuit voice service to be switched through ATM connection and IP traffic through IPoATM. [7] Besides digital and analog telephones that provide voice service, Local Area Network (LAN) for data is set at command posts (access nodes). All devices are networked via MSC. Local area networks contain 34, 19 and 10 users, depending on the level of command. The exchange of data through the IP part of the network consists of two types of services, e-mail and web (http) service.

E-mail is exchanged through the network in two ways, continuously throughout the period of preparation and conduct of an operation (exchange of smaller messages) and in discrete time intervals when different levels of command exchange typified orders and reports (messages of mostly higher memory value). WEB service consists of searching various data on servers continuously during preparation and conduct of an operation. Network elements, which are interconnected in a mobile telecommunications system is shown in Figure 1. [8]

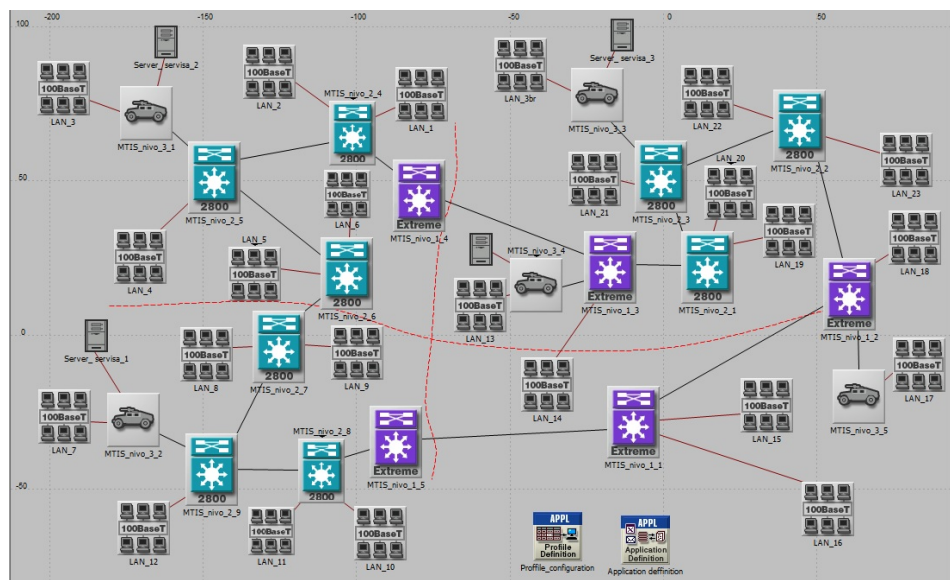


Figure 1 – Topology of communication-information system (CIS)

The network nodes of the level one are displayed in purple, the level two nodes in blue color and the access nodes of all three levels of command (battalion-brigade-operational group) as combat vehicles. All access nodes have the LAN segment with a corresponding number of users. In the network there are four redundant servers at the command posts of the level two and three. Servers enable applications in the telecommunications system.

Application of RIVERBED simulation package in the analysis of the communication-information system capabilities

Riverbed Modeler 17.5 Academic Edition is used for the simulation of telecommunications system. It is designed to simulate different types of computer networks. Academic Edition software has the following limitations: there is no support for LTE, UMTS and WiMAX; the total number of nodes in the simulation is 80, including 20 interconnected with the other elements (routers and switches); the number of events in the simulation is 50,000,000, which significantly limits the duration of the simulation. The software package meets structural and replicative validity, veracity and adequacy of its application. The development and establishment of the CIS, checking network connectivity and verification of network and C2 services has been carried out on the simulation without affecting the environment (relief, vegetation, weather conditions), as well as the electronic warfare of an enemy. An experiment on the real system would require huge costs.

Computer simulation has been performed through several phases and activities: definition of a scenario (defining nodes, LAN, links, servers, applications, user profiles, connection of LANs, service and profiles, definition of telecommunication traffic), determination of the target points of measurement (definition of the measurement of nodes, links, applications), simulation of the process of information transmission and display of the simulation results. In order to define the telecommunications traffic, empirical data on the type and amount of information – documents (operational orders, additional orders, reports, other information) to be exchanged between the elements of three levels of command in a military operation have been collected. Operational orders have been contemplated with the scheme of an operation on a topographic map (without and with compression). Five different e-mail services and a Web service for the preparation phase and execution phase of a modelled military operation have been defined in the simulation model as shown in Table 1. [8]

Table 1 – Summary of service in the simulation model

Type of service	The runtime service	Number of PC to perform service in the LAN segment	Stored value service
Mail of additional orders	Continuously throughout the duration of an operation	One terminal in the LAN	100 kB
Background mails	Continuously throughout the duration of an operation	Whole LAN	2 kB
Operational order level 1	1 minute after starting the simulation (in preparation of an operation)	One terminal in the LAN	4MB / 1,2MB
Operational order level 2	3 minutes after starting the simulation (in preparation of an operation)	One terminal in the LAN	3,5MB / 0,75MB
Operational order level 3	5 minutes after starting the simulation (in preparation of an operation)	One terminal in the LAN	3,2MB / 0,3MB
Report 1	After the first phase of execution of an operation	One terminal in the LAN	80 kB
Report 2	After the second phase of execution of an operation	One terminal in the LAN	80 kB
WEB (http) servis	Continuously throughout the duration of an operation	Whole LAN	Searching (default)

Configured LAN segments are defined by a corresponding number of PC terminal and associated user profiles, which have the implemented applications with various modes of operation. Thus traffic characteristics are defined and the simulation model is described in a given network, there are also four redundant servers that enable applications listed in Table 1. Servers operate for segments in their part of the network. However, they are also redundant. It means that in case of failure of a server, other servers take over the functionality of its services.

The objective of a simulation is to determine whether such network of major links with capacity 7680 kb/s and the predefined traffic, can respond to the demands that are set in terms of telecommunications services. The parameters that are monitored are clogging of the busiest links, load time of e-mail application and the total packet loss in the system.

Results of simulation

When establishing links of MTIS nodes the capacity is defined separately for voice service and data service. Reserving the link capacity for voice service has been done by application of operational research method – the queuing theory. Bolch and associates have further analyzed Erlang distribution. [9, 10]

On the basis of the empirical data on voice traffic between the elements of three levels of command the intensity of voice traffic ($\alpha < 5$) is defined. By using Erlang formula for sufficient probability of servicing ($p_{op} > 0.9$) and availability ($k_s \approx 1$) it is necessary to provide 512 kb/s (8 telephone channels of 64 kb/s) for voice traffic on link. The remaining capacity of 7680 kb/s is used for IP transmission. Figure 2 shows the analysis of the dependence of the parameters: service probability (p_{op}), the intensity of voice traffic (α) and availability (k_s) for the channel number $n = 8$. [8]

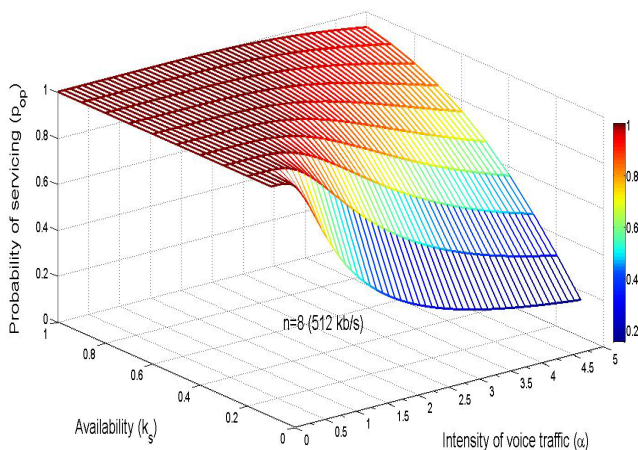


Figure 2 – The dependence of the parameters of voice traffic

The results of the measurement of target points after the simulation of the information transmission in the scenario are shown in the following figures.

Figure 3 shows the results of the analysis of the utilization of the most loaded link (the link between MTIS nodes of the level one command) for e-mail service and the bulk e-mail service and web service in the preparation phase and conduct of an operation. The figure clearly shows peaks of the link load when operational orders are handed over in the preparation phase of an operation between the different levels of command in the telecommunications system (Figure 3 left). Then the load of the link comes up to 100%, i.e. the link is fully occupied. For other e-mail and Web services in a given duration time of simulation (particularly during the conduct of an operation) the capacity of the most loaded link enables completely smooth transfer of information (Figure 3 right).

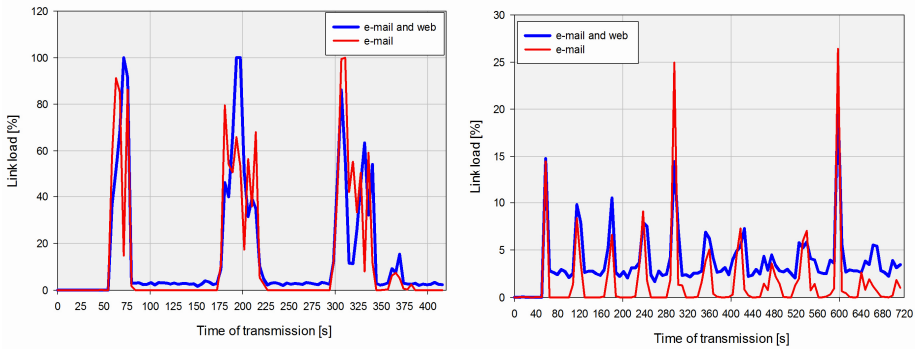


Figure 3 – Review of the most loaded link bandwidth in the network

The amount of information traffic, i.e. the total number of packets per second to be transmitted in the CIS model in the preparation phase of an operation is shown in the following figure.

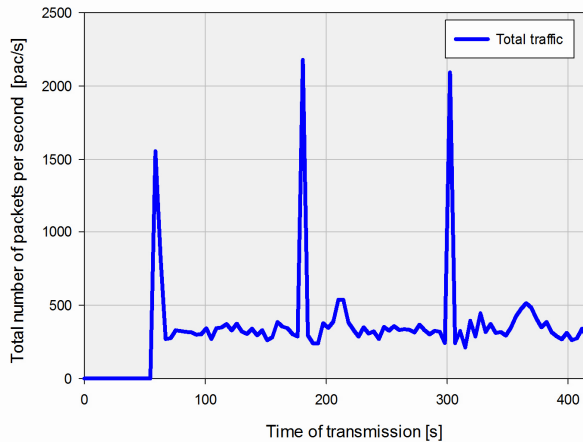


Figure 4 – The amount of information traffic during the preparation phase of an operation

Figure 5 shows the time required for the submission of e-mails of different sizes. The e-mail timings at the critical moments of submitting reports come up to 38 seconds.

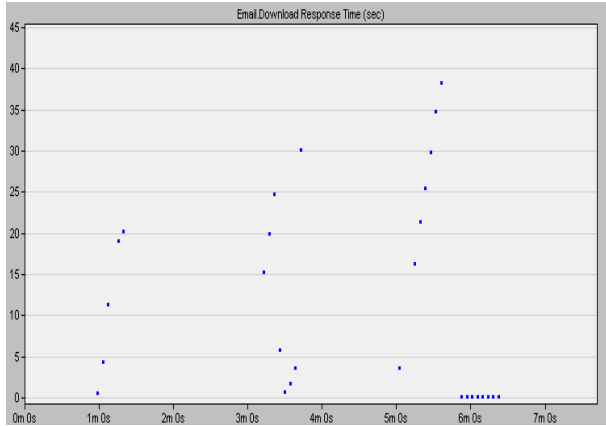


Figure 5 – Time of e-mail applications download in runtime operation

Figure 6 shows the results of comparative analysis of the packet loss per second for e-mail and the bulk e-mail and web services in a model of the telecommunications system (preparation phase and conduct of an operation).

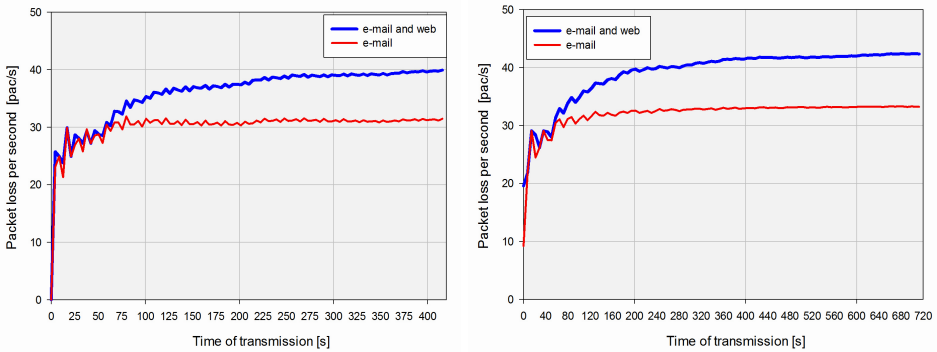


Figure 6 – Number of lost packets in the telecommunications system

We can conclude that the packet loss is small, constant and with a minimal difference in the use of both services. Loss of traffic relates primarily to packet losses of routing protocols (OSPF – Open Shortest Path First Protocol in the simulation). It results in minimal loss of user applications. Having in mind that these are TCP (Transmission Control Protocol) oriented applications, the losses had no impact on the performance of e-mail and Web (http) service.

Conclusion

It can be concluded that in order to have successful command and control it is necessary to connect all forces deployed in the area of a military operation by the CIS, which enables integration, transmission, delivery and presentation of relevant information and creates unique information dimension of operational environment. The simulation on the shown model has proved that the model provides the efficient flow of information and transmission of voice and IP data for C2 in military operations.

The simulation program has proven to be a good software solution for simulation of the telecommunications network in all its aspects: applications, user profiles, network elements, etc. The modelled telecommunications system enables the transmission of traffic that is defined and fully meets the requirements and performance services. The load of the main links of the level one and two of command is complete at certain moments. Moreover, the loading time of e-mail applications in these periods grows up to 38 seconds. However, the minimal total packet loss in the network shows that telecommunications system in the period of maximum traffic load will not be in failure.

References

- [1] Talijan, Miroslav, Mile Jelić & Rade Slavković. „Project management and modeling military operations“ *Project Management and Operations of the Army of Serbia: Thematic collection of scientific papers*. Belgrade: Military Academy, 2012: pp. 61-81.
- [2] *Doctrine operations of the Army of Serbia*. Belgrade: Serbian Army General Staff, Media Center „Defense“, 2012.
- [3] *operational planning, JP 5-0*. Washington DC: US MOD, Joint Headquarters, 2011.
- [4] Devetak, Saša & Samed Karović. „Telecommunication-information support in operations“. *Vojno delo* 2016, 6: pp. 123-135.
- [5] Devetak, Saša, Vladimir Suša, Radovan Dragović & Mladen Trikoš. „Application of the simulation program RIVERBED MODELER 17.5 in analyzing the performance data of functional telecommunication system“ *YU INFO 2016: Collection of scientific papers*. Belgrade: Association for Information Systems and Computer Networks, 2016: pp. 431-434.
- [6] Pavlović, Boban & Samed Karović. „The application of Bass Difussion Model in forecasting telecommunication services users in military assistance to civilian authorities“. *Defence Science Journal* 2015, Vol. 65, No. 2: pp. 144-149, DOI: 10.14429/dsj.65.6026.
- [7] Devetak, Saša, Jovan Bajčetić & Zoran Perišić. „Modular tactical switching system“ *3rd Scientific Conference of defense technologies OTEH 2009*. Belgrade: Military Technical Institute, 2009.
- [8] Devetak, Saša. *Model of telecommunication-information support forces of Army in the defense operation*. Doctoral dissertation. Belgrade: Military Academy, 2016.
- [9] Bolch, G., Greiner, S., de Meer, H. & Trivedi, K. *Queueing Networks and Markov: Chains Modeling and Performance Evaluation with Computer Science Applications*. New Jersey: John Wiley & Sons, 2nd edn, Inc., Publication, 2006.
- [10] Goyal, A., Lavenberg, S. & Trivedi, K. „Probabilistic modeling of computer system availability“. *Annals of Operations Research* 1987, Volume 8, Issue 1: pp. 285–306.
- [11] <http://riverbed-modeler-academic-edition.software.informer.com/17.5/> (accesseg 23 January 2017)

Acknowledgments

The paper is based on the research of the author's doctoral dissertation and the research conducted as part of the implementation of scientific research project under document number VA-TT/1-17-19, which is funded by the Ministry of Defense of the Republic of Serbia.