Simulation of Tactical Communications Systems by Inferring Detailed Data from the Joint Theater Level Computer Aided Exercises

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Abstract - In this paper, a new scheme for the simulation of tactical communications systems is introduced where the mobility, call and availability patterns for the communications equipment are generated by using the data inferred from the joint theater level battle simulations. In this technique, the mobility, strength and posture data related to military units are stored in a database by a military constructive simulation system during computer-aided exercises. Then, the mobility, call and availability patterns for the communications equipment are derived from these data in the required detail and time resolution by our models. The data structures and the statistical data used in these models, the description of a tactical communications system studied by using our technique, and example results from this study are also presented.

Keywords - Military Communications, Tactical Communications, Constructive Simulation, Combat Models, Joint Theater Level Simulation, Highly Aggregated Combat Modeling, Computer Aided Exercise, Mobile Communications.

1. INTRODUCTION

Realistic tactical communications simulations [16, 17] require complex and detailed mobility [7-9], call [16] and availability [15] models. Some stochastic processes such as random walk, random waypoint, random drunken can be used to model mobility for tactical communications [17] where a process assigns the movement directions and speeds to the mobile terminals (MT) randomly at each time interval or at an event. Similarly, call-inter arrival times [16] can be modeled by well-known distributions such as exponential. The simulation tools for tactical communications, e.g., Global Mobile System Simulation (GloMoSim), Tactical Communications Model Server (TCMS), are often based on this approach.

GloMoSim [17] is a library-based sequential and parallel simulator for wireless networks. It is a set of library modules, which simulate a specific wireless networking protocol. In GloMoSim, mobility is simulated by the random waypoint, random drunken and trace-based techniques. TCMS, which links a distributed simulation environment with an existing standalone communications modeling toolkit, is introduced in [16]. In TCMS, the communications events are modeled as consecutive, independent and mutually non-interfering transceiver/receiver pair connections.

The models used in these simulation systems are often not detailed enough to simulate the communications in a joint theater because the mobility and call patterns for the tactical communications equipment are based on many parameters including the mission and the posture (e.g., attack, defend, move, in contact, etc.) of the related unit, availability of the equipment, and the terrain/weather conditions. Models for the availability of the tactical communications equipment have to consider also hostile battlefield environment apart from the given failure rates [15]. Moreover, these models must adapt the changes in tactical concepts and new weapon systems, which directly affect the mobility and attrition patterns of the units in a battlefield.

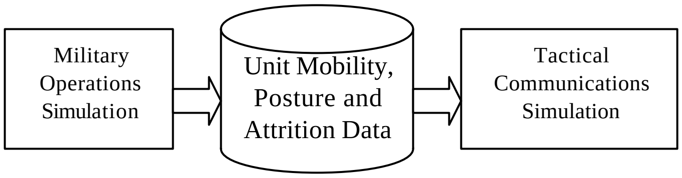

Figure 1. Reuse of constructive military simulations for the simulation of tactical communications.

Instead of using complex stochastic processes to produce the unit mobility, posture and attrition data for the simulation of the tactical communications systems, we can use the data recorded by constructive military simulations (CMSs) in computer aided exercises (CAXs) as shown in Figure 1, and build a more detailed simulation system for tactical communications on the data products of another CMS system. In our technique, more realistic and simpler models determine the availability of the communications equipment, and assign calls and mobility patterns to the available equipment based on the data provided by the CMS systems.

In the following section, the CMS systems are categorized and explored. In Section 3, our new technique and the simulation system developed based on this technique are explained. The major algorithms and models used in our simulation system, namely computer aided exercise interacted tactical communications simulation (CITACS), are also explained in the same section. In Section 4, the results from the performance study of a tactical communications system carried out by using CITACS are provided. We conclude our paper in Section 5.

2. CONSTRUCTIVE MILITARY SIMULATIONS

CMS systems [1, 11, 14] have been developed to provide computer aid for computing the possible outcomes of the courses of actions taken during the military computer aided exercises (CAXs). In CAXs, the staff officers in the military headquarters and the unit leaders are trained and evaluated by using some realistic or generic scenarios. The audience (i.e., the officers that attend the exercise) uses the most up-to-date tactical concepts, and the latest weapon systems are simulated in these exercises. The decisions of the officers, and the results produced by CMSs are carefully examined, verified and corrected if needed by the experienced directing staff. Hence, the mobility and event patterns obtained for the units in these exercises are realistic and up-to-date. CMSs are also used to analyze military operational plans.

CMSs are composed of detailed mobility and attrition algorithms. These algorithms, and the data used by them are carefully verified and validated. We can classify the CMS systems, which are often named combat models, into two broad categories: high-resolution and highly aggregated [2]. The detail level of a high-resolution CMS may be as high as an aircraft, a battleship, a tank or even a single troop. On the other hand, highly aggregated CMSs are developed to simulate the operations of units generally higher than battalions.

Another common criterion to classify CMSs is the operational areas. According to the operational areas, they can be categorized into three classes as shown in Figure 2. The simulation systems that can serve more than a single service, e.g., army and navy or army, navy and air forces, are the joint systems. A single joint simulation system can simulate joint operations or the service systems can interact with each other by using the distributed simulation techniques such as High Level Architecture or Aggregate Level Simulation Protocol [2] to simulate a joint operation. The later type of joint simulation systems is called confederations. There are also special purpose simulation systems developed to simulate a certain aspect of the battlefield, such as logistics or intelligence.

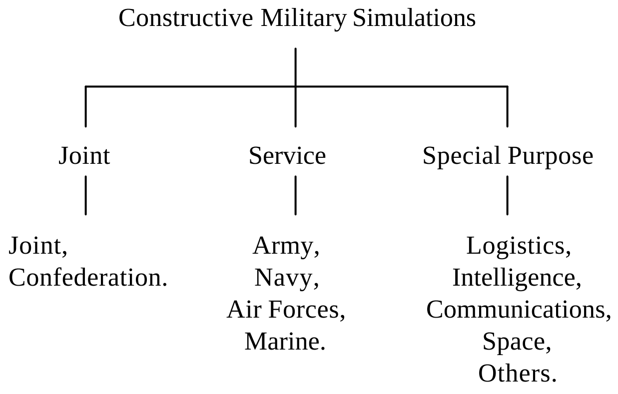

Figure 2. The classification of combat models.

Since the highly aggregated joint CMS systems model the interaction of the entities in a large joint theater, their outcomes are the results of the models that consider a wider range of the joint battle force components than the other categories of the CMS systems. Joint Theater Level Simulation (JTLS) [1, 18] is a highly aggregated joint CMS. It can simulate the army, navy and air forces operations, logistics, command, control and communications in the theater level. Since JTLS is the system that supports almost all of the joint CAXs in NATO, we have many virtual joint battles, which are digitally recorded by JTLS. These recorded battles can be used to generate realistic mobility, posture and event patterns for the simulation of the tactical communications systems by using "*replay*" utility. "Replay" means running a simulation with the previously entered commands.

Although JTLS can provide us with the most realistic mobility, posture and event data, the resolution of these data is not enough to evaluate the performance of a tactical communications system. In the following section, we introduce CITACS, which interacts with JTLS and uses its outcomes in the detailed mobility, call and availability models for the tactical communications simulation.

3. CAX INTERACTED TACTICAL COMMUNICATIONS SIMULATION

The architecture of CITACS is shown in Figure 3. In this architecture, JTLS provides the mobility, combat strength and tactical posture data for the simulated units. The commands entered during a previous CAX are replayed and a translator converts the results of this simulation into the format needed for CITACS. Then, a simulation manager reads the collected data, and forwards these data to the generators that generate the call, availability and mobility patterns in the required resolution. The resolution of the data generated by JTLS is in the company, battalion and brigade levels for each minute. This resolution is enhanced to radios for each second. The simulation manager runs the implemented algorithms according to the generated data and stores the data related to the predefined performance metrics into a database. A post processor, which runs after the simulation, analyzes the stored performance data and writes the results to a final database.

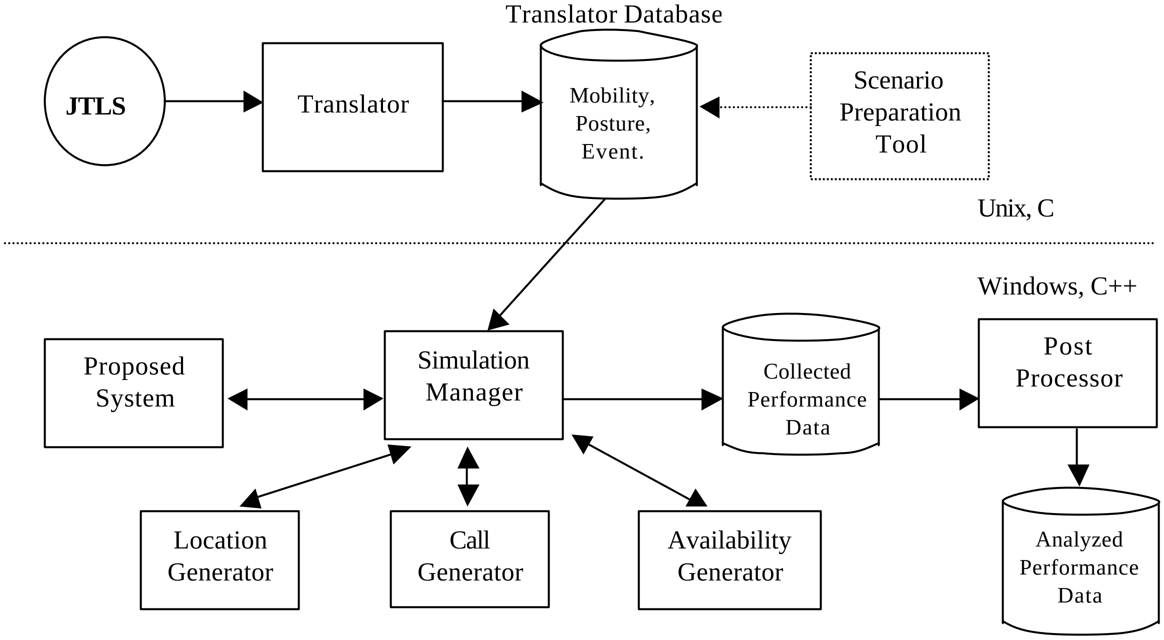

Figure 3. The architecture of CITACS.

3.1. Translator

Translator interacts with JTLS, converts the results of a CAX run with JTLS into the format defined for CITACS and stores them in a database. Each record in this database has nine fields, which are shown in Table 1. These fields and the values that can be assigned to them are selected based on the available data in JTLS and the data needed by our models.

Each unit has a separate record for each minute in this database. The simulation time information is inserted in the separator records with minute resolution. Between two time records, the records related to each unit for that minute is saved.

The deployment data for units is also fetched from JTLS and appended to the translator database. The deployment data is a single record that includes which portions of a unit is deployed in the front (p_f), in the left flank (p_{fl}), in the right flank(p_{fr}), and in the rear (p_r) of the area covered by the unit.

The translator database is a text file, which can be read and edited by a text editor. This helps to see and interpret the database, which is actually a scenario for the tactical communications simulation. It allows to edit or to create scenarios by using a text editor. We also developed a scenario preparation tool, which creates a scenario by using mobility models such as random waypoint. The location and the strength of a number of military units at certain times are entered as input, and the scenario preparation tool creates a translator database based on this input.

Table 1. The translator database.

Field	Definition	Example
Unit name	9 character long unit names.	1stTnkBtl, 2ndCvlCoy.
Unit type	One of the 10 unit types.	Non-applicable, headquarter, infantry, artillery, armor, special-force, squadron, support unit, signal unit, others.
Unit size	One of the 10 unit sizes.	Squad, section, platoon, company, battalion, regiment, brigade, division, headquarter, others.
Latitudes	The latitude of the units in degrees.	28.567343
Longitudes	The longitude of the units in degrees.	41.345671
Posture	One of the ten unit postures.	Attack, defend, delay-withdraw, move, air-operation, amphibious, formation, incapable, inactive, wiped out.
Current combat strength	The current to the full combat strength ratio.	0.98
Direction	One of the six directions.	North, north-east, south-east, south, south-west, north-west.
In-combat	Whether the unit is in contact with the opposing forces or not.	In-contact, not in-contact.

3.2. Simulation Manager, Location, Call and Availability Generators

The algorithm of the simulation manager is illustrated in Figure 4. It reads the records related to each unit minute by minute from the translator database. After reading the data of the next minute, the speeds and the lost power in the next minute are calculated for each unit, and the simulation is run until reaching the time read.

```
1. Read the time for the new period and calculate the time difference with the last period.
2. Read the translator database for each active unit for the new period.
     Read the information for each unit into the simulation manager data structure.
     Calculate the speed and the bearing of each unit according to the location in the last period.
          Calculate the speed and the bearing of each component according to the speed and the bearing of the unit that owns the component.
     Calculate the lost combat strength in the last period.
3. Repeat until the simulation time reaches the time of the current period.
     Add the time interval (the required time resolution) into the simulation time.
     Calculate the location of each component according to its speed and bearing (location generator).
     Calculate if the components initiate a call or a call initiated in the previous intervals will last one more interval (call generator).
     Make the calculator carry the required calculations for the new situation for each component (proposed system).
4. When the next time period is reached, calculate which components are destroyed or failure in the last period according to the lost combat strength of the unit (event generator).
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Figure 4. The simulation manager algorithm.

3.2.1. Location Generator

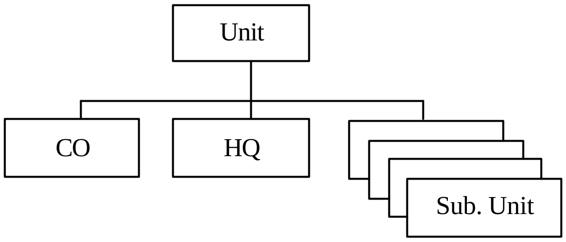


Figure 5. The generic unit organization for infantry.

Since the resolution of the data created by the translator is in unit level, the location manager should enhance this resolution up to the radio level. A generic unit organization similar to the one shown in Figure 5 is used to determine the number of radios (*m*) within a unit. This organization depends on the branch of the unit. For instance, Figure 5 represents an infantry unit. It is assumed that each infantry unit has one radio for the commanding officer (CO), four radios for the headquarter, and four subordinate units, which have the same organization. This standard organization is the same down to the squad level where there are three radios in total. These radios are deployed to the area whose center is determined from the translator database. The depths and widths of units in different postures are given in Table 2. The unit depths and widths are determined according to the generic unit organizations.

Table 2. The fronts and depths of the simulated generic units in meters.

Unit	**Branch**	**Attack**		**Defense**		**Withdraw**		**Move**		**Other**	
		Front	**Depth**	**Front**	**Depth**	**Front**	**Depth**	**Front**	**Depth**	**Front**	**Depth**
Company	Infantry	1000	500	1500	1000	2000	2000	400	400	1500	1000
	Artillery	500	250	500	250	500	250	500	250	500	250
	Tank	1000	500	1500	1000	2000	2000	400	400	1500	1000
	Special	1000	500	1500	1000	2000	2000	400	400	1500	1000
	Support	500	250	500	250	500	250	500	250	500	250
	HQ	50	50	50	50	50	50	50	50	50	50
Battalion	Infantry	1500	1000	3000	2500	6000	5000	400	2000	3000	2500
	Artillery	3000	1000	3000	1000	3000	1000	3000	1000	3000	1000
	Tank	1500	1000	3000	2500	6000	5000	400	2000	3000	2500
	Special	1500	1000	3000	2500	6000	5000	400	2000	3000	2500
	Support	1500	1000	1500	1000	1500	1000	1500	1000	1500	1000
	HQ	100	100	100	100	100	100	100	100	100	100
Regiment Brigade	Infantry	4000	3000	8000	16000	16000	20000	1000	7000	8000	16000
	Artillery	3000	1000	3000	1000	3000	1000	3000	1000	3000	1000
	Tank	4000	3000	8000	16000	16000	20000	1000	7000	8000	16000
	Special	4000	3000	8000	16000	16000	20000	1000	7000	8000	16000
	Support	1500	1000	1500	1000	1500	1000	1500	1000	1500	1000
	HQ	200	200	200	200	200	200	200	200	200	200
Higher	HQ	200	200	200	200	200	200	200	200	200	200

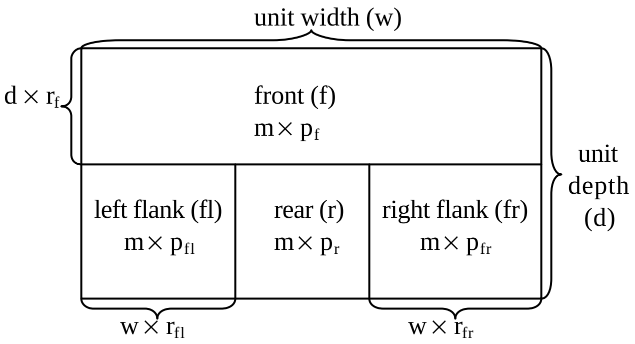


Figure 6. The distribution of radios among the regions covered by a unit.

To deploy the radios, we first distribute them among the regions of a unit according to the deployment data in the translator database as shown in Figure 6. The area covered by a unit is divided into four regions, namely front (*f*), left flank (*fl*), right flank (*fr*) and rear (*r*). The multiplication factors for the depths of the front region (r_f) and the flanks (r_{fl} , r_{fr}) are passed to the system as parameters according to the tactical doctrine. The number of radios in each of these regions is given by

$$m_k = \begin{cases} m \times p_f & \text{for } k = f \ (\text{front region}) \\ m \times p_{fl} & \text{for } k = fl \ (\text{left flank}) \\ m \times p_{fr} & \text{for } k = fr \ (\text{right flank}) \\ m \times p_r & \text{for } k = r \ (\text{rear region}) \end{cases} \qquad (1)$$

Then the radios are uniformly distributed within their regions. The Equations (2) through (8) are used to find out the geographic coordinates of the radios in the front region. Similar equations are used for the other regions. We first find how far a radio is from the center of the owner unit in x axis (d_x) and y axis (d_y). These two variables, d_x and d_y, are random variables which have the following distributions:

$$p(d_x = a) = \begin{cases} \dfrac{m_f}{w} & \text{for } -\dfrac{w}{2} < a \le \dfrac{w}{2} \\ 0 & \text{otherwise} \end{cases} \qquad (2)$$

$$p(dy = a) = \begin{cases} \dfrac{m_f}{d \times r_f} & for\ \dfrac{d}{2} - (d \times r_f) < a \le \dfrac{d}{2} \\ 0 & otherwise \end{cases} \quad (3)$$

When we determine d_x and d_y for a radio, we can find its geographic location (x_r, y_r) by using Equation (7) and Equation (8), knowing that the central location for the owner unit (x_u, y_u) is read from the translator database.

$$h = \sqrt{d_x^2 + d_y^2} \qquad (4)$$

$$a = \arctan\left(\frac{dx}{dy}\right) \qquad (5)$$

$$q = \begin{cases} 90 - a & \text{when the unit is facing north} \\ 45 - a & \text{when the unit is facing north} - \text{east} \\ 315 - a & \text{when the unit is facing south} - \text{east} \\ 270 - a & \text{when the unit is facing south} \\ 225 - a & \text{when the unit is facing south} - \text{west} \\ 135 - a & \text{when the unit is facing north} - \text{west} \end{cases} \quad (6)$$

$$x_r = x_u + (h\ ´\ \cos q) \qquad (7)$$

$$y_r = y_u + (h\ ´\ \sin q) \qquad (8)$$

After the initial deployment, the simulation manager reads the data for the next time period. According to the locations that the units will be in the next period and their current locations, the covered distance d_u and the direction of movement j_u for each unit for the next time period are calculated. Based on these calculations, the covered distance d_r and the direction of movement j_r for each component are determined for that period by using Equations (9) through (12) as shown in Figure 7. Then the simulation is forwarded second by second, and in each second location manager adds the speed of each radio (location change in a second) into its previous location.

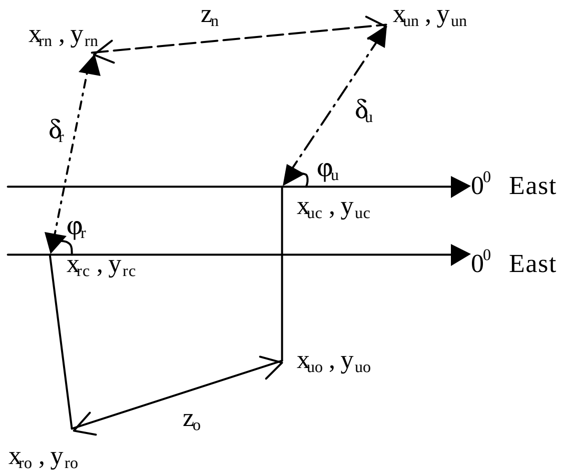
$$d_r = d_u + b_d\ ´\ s_d \qquad (9)$$
$$j_r = j_u + b_j\ ´\ s_j \qquad (10)$$

In Equations (9) and (10), b_d and b_j are random variables that have the following distribution.

$$b = \begin{cases} -1 & with\ probability\ \frac{1}{2} \\ 1 & with\ probability\ \frac{1}{2} \end{cases} \qquad (11)$$

In Equations (9) and (10), s_d and s_j are also random variables. The distribution and mean values for these variables are passed to the system as parameters according to the user scenario. Based on these variables, the radios and the access points of a unit move on the directions and with the speeds, which may be different than the direction and the speed of the unit that they belong to. However, we prevent the radios and the access points from changing their distances relative to the center of the owner unit more than a threshold value t according to the original relative positions by applying Equation (12). If this constraint is not satisfied with the values determined for the random variables, new values are tried with the same distributions and mean values until it is satisfied. Hence, the components of a unit move with a common drift based on the direction and speed of the unit.

$$½z_n - z_o½\ £\ t \qquad (12)$$



x_{uo}, y_{uo}	original location of a unit
x_{ro}, y_{ro}	original location of a radio
x_{uc}, y_{uc}	current location of a unit
x_{rc}, y_{rc}	current location of a radio
x_{un}, y_{un}	new location of a unit
x_{rn}, y_{rn}	new location of a radio
φ_u	direction of a unit for the new period
φ_r	direction of a radio for the new period
δ_u	distance covered by a unit during the new period
δ_r	distance covered by a radio during the new period
z_o	original distance between a radio and the unit that it belongs to.
z_n	distance between a radio and the unit that it belongs to at the end of the new period.

Figure 7. The position of a radio relative to the unit that it belongs to.

3.2.2. Call Generator

The call generator generates the calls according to the unit type, the unit posture and whether the unit is in combat or not. The data related with these parameters come from the translator database. Using these data together with the average arrival rate coming from a statistical work, calls are generated. At each time interval, the call generator first decides for each radio whether the radio initiates a call or not. Then the destination, the type and the duration of the calls are determined.

Table 3. Call destination statistics.

The destination of a call	(%)
To a subordinate unit.	61.15
To the leading HQ or CO.	22.43
Other units attached to the same higher unit.	7.84
Neighbor units attached to other units.	4.64
Anyone, any unit.	3.94

We made a statistical study with 20 officers who have at least 10 years of experience on leading a combat unit. The average values obtained from the results of this study are given in Tables 3 through 5. In Table 3, the call destination statistics are summarized. As expected, the subordinate units or the COs of the leading units are called most of the time. This is very important because it indicates that the subscribers of a tactical communications system usually call the subscribers in their vicinity.

Table 4. The number of calls in an attack within one hour.

In-Contact	Yes			No		
Branch	**Min**	**Av**	**Max**	**Min**	**Av**	**Max**
Infantry	10	17	31	6	9	17
Artillery	12	18	27	5	8	12
Tank	19	21	30	7	12	17
Special Force	16	17	24	4	7	11
Signal	9	14	19	5	13	18
Headquarter	12	15	22	8	13	16
Other	9	13	18	8	12	16

To decide on the call rate l, the simulation manager provides the type and the posture of a unit, and whether it is in contact or not. Then the call manager looks up the call rate a_{bc} for the attack posture from Table 4 according to the unit type and in-contact information. This value is multiplied with the factor n_{pc} read from Table 5 according to the posture and in-contact information as given in Equation (13). The result is the call rate for that unit for that time period.

$$l_i = a_{bc} \text{ ´ } n_{pc} \qquad (13)$$

where

l_i is the call rate for unit i

a_{bc} is the call rate for branch b and contact situation c in attack posture

n_{pc} is the normalization factor for posture p and contact situation c.

Table 5. The factor to normalize the call rates for other postures.

Posture	In contact	Not in-contact
Defense	0.79	0.53
Withdraw-Delay	1.01	0.68
Move	0.73	0.53
Amphibious	1.05	0.76
Other	0.74	0.56

It is assumed that the call rate is following a Poisson process. The exponential distribution for the call inter arrival times is an acceptable approximation in a battlefield, because war fighters try to communicate with short time intervals in certain period of times, and if the time intervals between calls get larger than the mean interval, they get much larger than the mean. This is the same in call duration, too. We do not have any statistical data related to call intervals or call durations to derive the distributions. Based on experience, we assume that the exponential distribution can approximate both the inter arrival and the call duration times. However, we also factorize the call duration and the inter arrival time distributions in simulations.

Table 6. Call durations.

	Duration in seconds
Minimum	6.70
Average	19.33
Maximum	41.33

The expected call duration for the calls are generated according to the exponential distribution whose mean value is as shown in Table 6. The last thing to be determined about a call is the type of the call. We envision six types of multimedia calls, and distribute the calls among these types uniformly with the percentages shown in Table 7. Since multimedia is a new concept for tactical communications, we cannot complete a statistical study on the call type, and determine the rates intuitively. However, we factorize the ratio of the multimedia calls to the ordinary voice calls in simulations as illustrated in Table 7.

Table 7. The types of calls.

Multimedia to total call rate	%37	%63	%74	%98
Voice	63	37	26	2
Teleconference	18	30.6	36	47.7
Videophony	7.2	12.3	14.4	19.1
Videoteleconference	1.8	3.1	3.6	4.8
High priority data	1	1.7	2	2.6
Data	9	15.3	18	23.8

3.2.3. Availability Generator

The availability of a communications equipment is decided based on the mean failure rate m, the change in the combat strength y of the related unit, and the mean recovery time. We randomly select $m_{it}n$ of the communications equipments of a unit, which has n communications equipments. These equipments are made unavailable by the end of an exponentially distributed random recovery time. The failure rate m_{it} for unit i at time t is given by

$$m_{it} = \begin{cases} m + y_{t-1} - y_t & \text{for } y_t < y_{t-1} \\ m & \text{otherwise} \end{cases} \qquad (14)$$

where

m is the expected failure rate due to fatigue, and

y_t is the combat strength of the unit at time t.

3.3. Post Processor

The post processor runs on the data produced by the simulation manager, and prepares some summary statistics reports. Detailed information about the performance metrics related to calls, handoffs, the connectivity and the resource utilization are presented in these reports. CITACS can produce these reports starting from the desired minute in simulation for the required number of time periods defined by the user.

A large set of factoring parameters can be determined for the simulation studies. A separate simulation is run for the combinations of the factoring parameters by using CITACS according to the used design of experiment. Then, reports related to the determined performance metrics are generated by the post processor.

4. EXPERIMENTAL RESULTS

The first study carried out by using CITACS is the performance evaluation of an architecture that applies the third generation (3G) Personal Communications Services (PCS) technologies [4, 6, 12] to the mobile subsystem of the next generation tactical communications systems [5, 10, 12, 13]. This architecture utilizes a novel resource management scheme named Virtual Cell Layout (VCL) [3] to manage the scarce radio resources in a mostly terrestrial multi-tier network where both the cellular and ad hoc techniques are used.

Note that the aim of this paper is not to introduce VCL. VCL is explained here to give a better perception on the scope of CITACS. The detailed explanation of VCL and VCL based algorithms can be found in [3].

4.1 An Example Communications Architecture Studied by Using CITACS

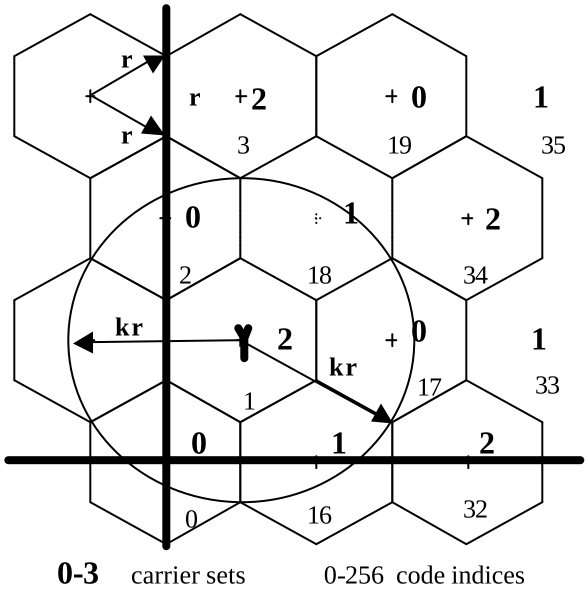


Figure 8. Virtual cell layout.

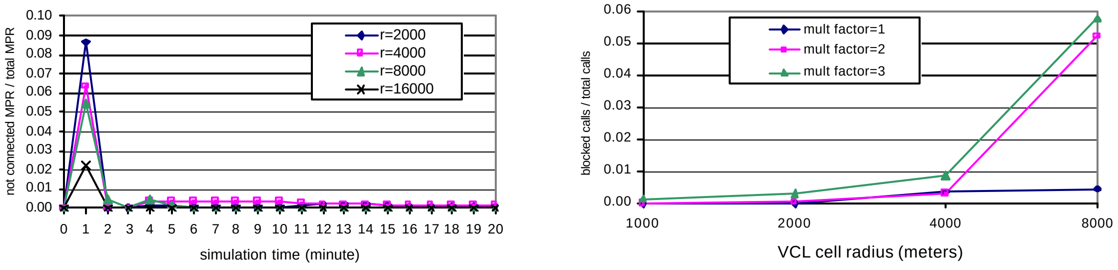
VCL is proposed for resource planning tasks, such as code division multiple access (CDMA) code and frequency carrier assignment [3]. CDMA is a multiple access scheme to share a transmission medium among multiple terminals. It is a conflict free technique based on the usage of the unique CDMA codes by every terminal. Frequency carrier is a bandwidth at a specific central frequency. With the aid of VCL, the CDMA code and frequency carrier assignment tasks can be carried in a distributed way and without relying on the existence of a central system or an accurate and timely topology database. In VCL, the communications area is tessellated with virtual cells, which are fixed size hexagons that are placed starting from a reference geographic location as shown in Figure 8. If an access point knows its geographic location, this location information can be mapped into a VCL cell index. This index can be used to determine the radio resources, which are a carrier set, and the CDMA codes assigned to the VCL cell.

The real cells are mobile and created by the mobile base stations, which are either radio access points (RAPs) or cluster head man packed radios (MPRs). The size of the real cells may be different from the size of the VCL cells. If the side length of a VCL cell is *r*, then the real cell radius becomes *kr*. We call *k* as the multiplication factor. When the multiplication factor is one, a real cell usually cannot cover the entire virtual cell where it is located because access points are not necessarily at the center of the virtual cells.

Based on VCL, the self-configuration, mobility management and resource management schemes for two major tactical communications equipments, namely RAPs and MPRs are proposed in [3]. CITACS is used to evaluate the performance of these algorithms and schemes.

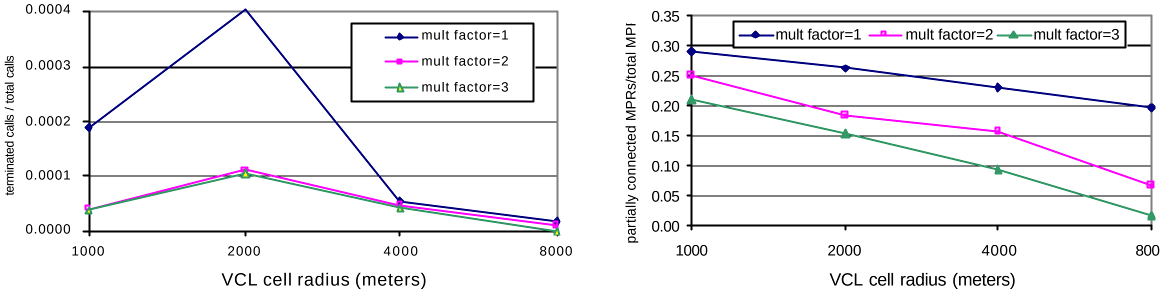
4.2. Simulations by CITACS

Some of the results obtained in these studies are illustrated in Figure 9. We examined the performance of the proposed VCL based tactical communications system according to some metrics such as the self organization time, the blocked and terminated call rates, the connected MPR rate and the handoff rate by using CITACS. Since the objective of our paper is not to examine the performance of VCL, we do not give the detailed VCL evaluation results. They can be found in [3].



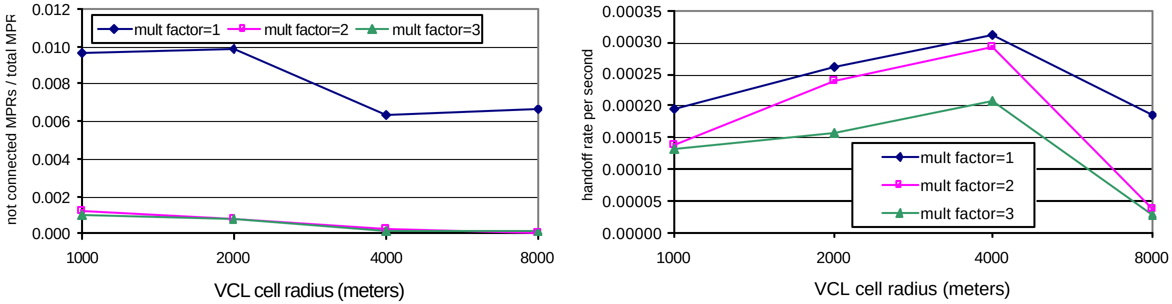
a. Self organization time.

b. Blocked call rates.



c. Terminated call rates.

d. Partially connected MPR rates.



e. Not connected MPR rates.

f. Handoff rates.

Figure 9. Example results from the simulations run by using CITACS.

During these simulations, CITACS used three different scenarios. The details about these scenarios are given in Table 8. Translator created two of these scenarios from realistic CAXs by interacting JTLS. The third scenario is a generic scenario created by the scenario preparation tool. In the first scenario, 153 units are simulated over an area of 115 km × 170 km. Location manager deployed 77 RAPs and 18529 MPRs for this scenario based on the unit types and sizes. The size of the area for the second scenario is the same as the first. The location manager deployed 30 RAPs and 5721 MPRs in the second scenario. In the generic scenario, 20 RAPs and 3452 MPRs are simulated for 28 military units over an area of 85 km × 40 km.

Table 8. Scenarios used in the simulations for VCL.

Scenario	Type	Area (km)	# of military units
1	Real	115×170	153
2	Real	115×170	49
3	Generic	85×40	28

CITACS can run the simulations for these scenarios 10 times faster than real time (i.e., every 10 minutes are simulated in one minute) on the average. Note that we simulate more than 18000 radios in a complex tactical communications architecture by using realistic mobility, call and availability models. This allows us to test a novel tactical communications system in a realistic and up-to-date (i.e., current tactical doctrines and weapon systems) virtual battlefield.

5. CONCLUSIONS

We have many virtual wars, which have been recorded by highly aggregated joint military simulation systems during CAXs. Hundreds of well-trained and experienced officers interact with these simulation systems to enter their carefully designed plans. The outcomes of the plans are examined and justified by the directing staff of the CAXs. Since the most up to date doctrines and combat systems are applied during these virtual wars, the recorded data can be used to produce very realistic mobility and attrition patterns. We propose to use this data in the performance evaluation of the tactical communications systems.

The resolution of highly aggregated joint military simulations is not high enough for the tactical communications simulations, because they are designed to simulate thousands of units deployed in a large theater. The higher resolutions cannot be handled by the audience of these exercises. The resolution of the mobility and attrition data recorded during highly aggregated joint CAXs must be enhanced to the required detail level in order to be used in tactical communications simulation.

In this paper, we introduce our new algorithms and models to enhance the resolution of the mobility and attrition patterns obtained during CAXs. By using these models, we deploy radios and other communications equipment to theaters, generate calls, decide on the call durations, the call types and the call destinations, and even determine the availability of the equipment. The implementation of the proposed architecture and models are used in the performance evaluation of the novel tactical communications architectures. In these studies, our architecture simulates thousands of tactical communications equipments efficiently by using realistic mobility, call and availability models.

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