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Agent-based system simulation of wireless battlefield networks

Younes Regragui, Najem Moussa*

LAROSERI, Department of Computer Science, Chouaib Doukkali University, El Jadida, Morocco

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ABSTRACT

Mission-critical military operations with dismounted soldiers are frequently characterized by high battlefield dynamics. In such scenarios a mobility model can manage soldiers' movements dynamically especially under enemy attacks. This paper presents a group mobility model simulating realistic soldier and leader battlefield behaviors. Our model analyzes communication between a group of dismounted soldiers deployed in a mobile ad hoc network (MANET) and their leader under several perturbation factors (e.g., noise and enemies attacks) which affect movements and topology connectivity. Results show that the dismounted soldiers' collective movement improves the capacity of communication channels, whereas noise uncertainty may dramatically destroy the network. Moreover, the enemy's presence, another disorder parameter, changes qualitatively and quantitatively the army's wireless communication topology. Enemy numbers decrease almost linearly the throughput at the sink node (commander). A discussion of results follows, using distributions of path lifetimes, path lengths, packet delivery and group sizes in the communication soldiers' network.

1. Introduction

Recently, the army has been interested in developing new skills and competencies such as making soldiers more connected [1] in the battlefield based on modern soldiers' electronic equipment and computer technologies by using mobile wireless ad hoc networks (MANETs)[2,3]. The utilization of dismounted soldiers is one of the major strategies being adopted in the Army which makes tactical operations on the battlefield much easier to control. In a military environment, the dynamics of such missions may change rapidly, so the dismounted soldier would need to incorporate several new technologies to exchange information consisting of surveillance and tactical operations in order to prevent intrusion and detect enemies[2].

In the context of military operations, autonomous dismounted soldiers may interact simultaneously with the environment (battlefield) and with each other so as to complete an assigned mission such as a sweep operation of houses or buildings in a wide area, containing features such as mountains, forests, or rivers. The group of soldiers may be divided into a number of battalions with each one having its own mission, especially in some critical situation (e.g., searching and attacking the enemies during a sweep operation or escaping from an unexpected enemy attack). This stressful overcharge of interactions, in conjunction with the geographically variable nature of the battlefield area and the unpredictable behavior in terms of wireless network topology state.

* Corresponding author.
E-mail addresses: regragui.y@ucd.ac.ma (Y. Regragui), moussa.n@ucd.ac.ma (N. Moussa).

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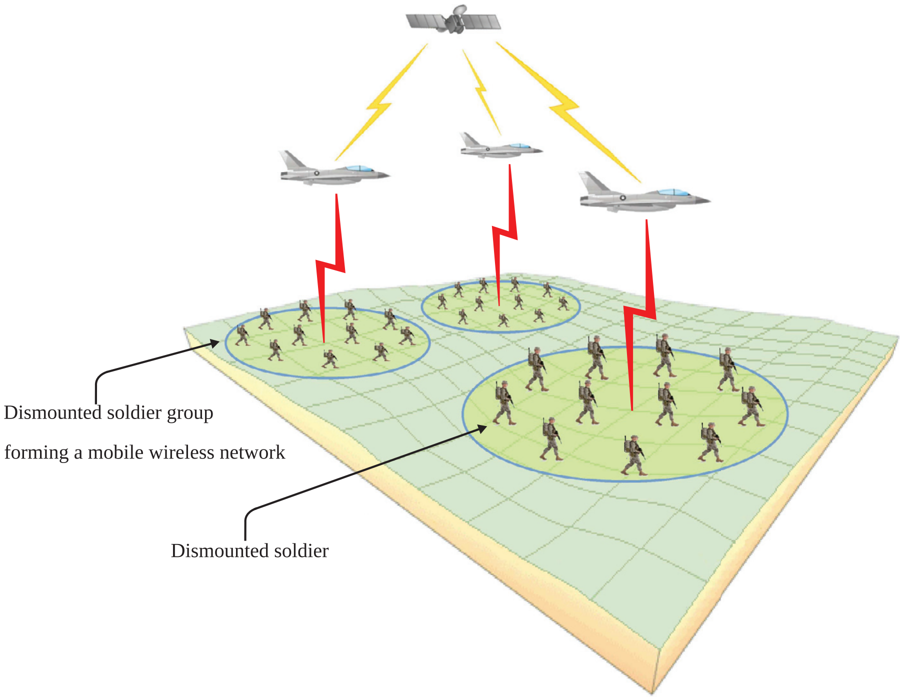

Fig. 1. Illustration of dismounted soldier group in military modern communications infrastructure.

The network connectivity is worsened due to topology changes driven by wireless links and unpredictable mobility of soldiers. The highly dynamic in nature of dismounted soldiers' mobility on the battlefield and node failures are considered among the main reasons for this challenging problem. Therefore, the evaluation of the network performance during the execution of a tactical military scenario for such situations in the real world setting is in many cases not feasible since the cost can be too high and it is impossible to test in real world deployment of soldiers in the battlefield with the presence of enemies. Therefore, a simulation environment is very attractive for evaluating and studying the impact of soldiers' behaviors on the performance of the network and topology condition during military operations. Typically, the utilization of a simulation environment is intended to reflect and assess real-world scenarios accurately such as modeling the mobility and wireless communication of soldiers on the battlefield as realistically as possible. After the deployment of soldiers on the battlefield, the destination direction of each soldier is done via a mobility model in the simulation, including the velocity of each one and their interaction with one other (see Fig. 1).

In the literature, various group mobility models have been proposed for studying and simulation of MANET in a real-world scenario. Among them the reference point group mobility (RPGM)[4], which is one of the most commonly used Group Force Mobility Model (GFMM). [5] focuses on group interaction and movement, but also provides the capability to incorporate obstacles into a simulation area and give the groups the ability to maneuver around them. However, in most of the existing group mobility models, the authors did not focus explicitly on more complex situations such as investigating the effect of enemies' attacks on the battlefield. They focused in the most cases on communication in battlefields with the presence of geometric obstacles in the form of buildings or inter-vehicular communication. To the best of our knowledge, this study is the first one that proposes a modeling approach for a military scenario based on the presence of enemies on the battlefield in mobile ad hoc networks (MANETs).

In summary, the aim of this paper is to introduce a group mobility model to simulate wireless communication on the battlefield of a dismounted soldier group with and without the presence of enemy attacks as realistically as possible. For our purposes, we were interested in studying our model as follows:

- Evaluation of network performance of dismounted soldiers with the presence of perturbations factors (noise) used as a flexible modeling of obstacles.
- Network performance analysis in terms of tactical dynamics of dismounted soldiers on the battlefield in the presence of enemies. Moreover, we provide statistical evaluations based on the connectivity of soldier groups on the battlefield, especially when soldiers are trying to escape from enemy attacks in which unexpected network topology change may occur.

This paper introduces a group mobility model, in order to realize a performance study of a collective motion of dismounted soldiers in a MANET network with the commander (leader) defined as a sink node. This study is evaluated through

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