Performance Simulations of Wireless Grid Communication Networks

Ibraheem Read ABDULSAM*, Se Mog Kim**, Jong Myung RHEE***

요 약

위성 통신은 지상 무선국과 위성 사이의 통신으로, 지상 무선국을 유기적으로 활용함으로써 효율적인 위성 통신이 가능하다. 무선 통신은 이동성, 지형 및 방해 신호가 중요한 성능 결정 요인이며, 그리드 네트워크의 한 요소이다. 따라서 그리드 네트워크의 지속적인 연구 성과를 차기 위성 통신에 적용할 수 있을 것이다. 군 통신은 무선 시스템을 기반으로 사용하기에, 군 통신에서 많이 사용하고 있는 라우팅 프로토콜, OSFP (Open Short Path First) 를 적용하여 그리드 네트워크의 성능 향상을 위한 시뮬레이션을 실시하였다. 본 논문에서는 BER (Bit Error Rate) 및 라우터 수에 따른 성능 변화와 그에 의한 네트워크의 MSS (Maximum Segment Size) 를 연구하였으며, 그 결과를 제시하였다. 연구 결과를 통하여 다양한 BER 및 라우터 수에서 최적의 MSS를 확인할 수 있었다.

Key Words : MSS, BER, grid network, military tactical communications, OSPF.

ABSTRACT

Satellite communications consist of communications between base stations of the ground and satellites. For efficient satellite communications, ground networks should be organically utilized. Grid networks are frequently used in and outside the country for wireless communications. The performance of wireless communications is determined by mobility, topography, and jamming signals. Therefore, continuous studies of grid networks are necessary for the utilization of next period satellite networks. Since military communications are used based on wireless systems, they can be considered as a sample of utilization of grid networks. Therefore, this paper presented the results of simulations conducted for the improvement of the performance of the grid networks used in military communications that employing the OSPF, a popular routing protocol for military applications. First we investigate the effects of changing the bit error rate (BER) and number of routers. Then we discuss the effects of maximum segment size (MSS) on network behavior and stability. In this way, we can determine the appropriate MSS for a grid network under various values of BER and number of routers. Such results can be also applied to commercial grid network evaluations

Ⅰ. Introduction

Grid networks have been widely used for military wireless communications in two ways, namely in tactical deployments or in stationary base installations. Typical examples are the US warfighter information network - tactical (WIN_T) and the tactical information communication network (TICN) for the Korean armed forces [1, 2]. Grid topology offers always-on physical connectivity by providing more than one link. Therefore, if any link goes down, the grid network can use alternative paths to the destination, which requires that the nodes of the network equip a routing algorithm to determine the correct path. The open short path first (OSPF) is a popular routing algorithm for determining the best route in military communication networks. As described in [3], Dean L. mentioned that the OSPF is a dynamic protocol that performs real-time calculations and reacts to topological changes within a network, making OSPF one of the most logical interior gateway protocol (IGP) choices for military networks today.

For military communications, wireless is widely used instead of wired for many reasons: for example, ease of installation and field geographic independence. Furthermore, wireless can provide an easy connection among mobile units [4]. However, the performances of wireless communications are often significantly degraded by their environments, which results in a greatly increase in the bit error rate (BER) to the traveling information signal. A few studies have been carried out with a view to enhance the network performance [5, 6]. In [5], Neil B. Buchanan et al. provided experimental evidence showing

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※ 이 논문은 2013년도 명지대학교 교내연구비 지원사업에 의하여 연구되었으며, 이에 감사드립니다.

*,**명지대학교 정보통신공학과 Ubiquitous&Convergence 연구실 (ibrahimgate@gmail.com*, kimsemog@empal.com**),
***명지대학교 정보통신공학과 (jmr77@mju.ac.kr), 교신저자 : 이종명

접수일자 : 2014년 4월 29일, 수정완료일자 : 2014년 5월 21일, 최종게재확정일자 : 2014년 5월 23일

that enhanced BER performance is possible using a retro-directive array operating in a dynamically varying multipath. Other work presents a method for controlling the BER, Specifically a study on the impact of clustering on the performance of an ad hoc wireless network [6]. These two techniques require either a hardware redesign or aligning a system setup, which may lead to considerable difficulty in a critical situation. Therefore, these solutions are hardly applicable for military communications, which should usually be real-time, easy to implement or apply, and available at all times.

The focus of this paper is enhancing wireless communications performance by reducing BER effects. In this paper we investigate how to mitigate the effects of BER on OSPF gird networks by changing the MSS of the travelling packets. This approach can be done in real time by using a command line interface (CLI) configuration for a device or a number of devices, rather than by developing some hardware equipment. We have implemented the wireless grid networks that contain routing nodes, sender, receiver, and also wireless links between them, using OMNET++ and INET network simulators [7]. We have looked into the impacts of various parameters, such as the number of routers and BER offered by the links on the network throughput. Further, we have studied the performance characteristics of the network by varying the MSS of the packets.

The remainder of this paper is organized as follows. In Section Ⅱ we present the network design assumptions including OSPF routers distribution, and also describes the link configurations for simulations. Simulation module design and implementation are presented in Section Ⅲ. Simulation results are included in Section Ⅳ. Section Ⅴ contains our conclusion and suggestions for future work.

Ⅱ. Network Design Assumptions

Fig. 1 shows a sample network topology that consists of 4 routers distributed over a grid network, in which the client and the server are set as the sender and the receiver, respectively.

For the sake of consistency, we need to specify the parameters for the network components. These parameters include OSPF router configuration, internet protocol (IP) distribution, interface connection type, and wireless link parameters, as well as the variable parameters such as the MSS and the BER.

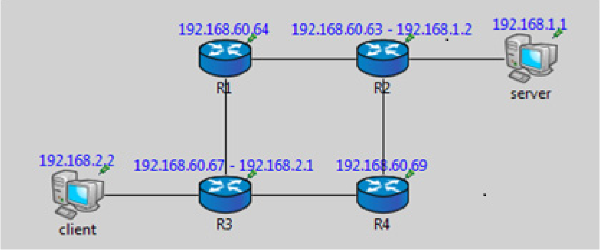


Fig. 1. Four routers grid sample network, built using OMNET++IDE

The routing configurations of the routers in the network are made to create a single area (area 0), with the network ID of 192.168.60.0. The reason for designing the network with a single area rather than multiple areas is that the OSPF expects all areas to inject routing information into the backbone [8], and that kind of dissemination will divert us from our goal.

Also, interface connection is assumed as point- to-point protocol (PPP) to avoid convergence time delay. The RFC 4938 defines a PPP-over-Ethernet based mechanism for integrating IP routers and mobile radios in ad hoc networks, enabling faster convergence and more efficient route selection [9].

To create a wireless connection environment, all the links between routers should be made to simulate a real radio channel. Each link is assumed to work wirelessly with a 50 μs time delay between the nodes and 45 Mbps data rate. Since the BER depends on the wireless medium, the BER value varies from 10^{-6} as the best transmission case to 10^{-4} as a noisy channel [10].

In our simulations, we considered several cases, each case contain different number of routers and will be simulated separately. The number of routers is set as 4, 9, 16, 25, and 100, distributed on a grid network. Arbitrary 10 MB data are sent from the client to the server, and we monitor the communication throughput at the server node. For simulation purposes we have changed the MSS value, although the default value is set as 536 bytes [11]. This enables us to investigate how to mitigate the effects of the BER according to the number of routers and the MSS.

Ⅲ. Simulation Modules Design and Implementation

In this section, we present simulation modules design and implementation. In Fig. 1, each link represents a wireless medium with a delay and the corresponding BER. The network shows a single area with the IP address of 192.168.60.0 and a subnet mask of 255.255.0.0 to avoid the limits of the number of clients.

1. Simulation modules design

a. Routers

OMNET++ has a variety of simulation modules that simulate the work of actual instruments. Fig. 2 shows the inner functions of the OSPF routing module. These functions are distributed in two types of blocks; the blocks connected with each other by arrows have a sequence of functions that interact directly with the information packet, while the blocks with no arrow have a logical function that does not interact with the packets directly.

Fig. 3 shows another example of a grid network with nine routers. In our simulations we have defined two router models, a boundary router and an interior router. The boundary router is used to connect to the outside by an external interface. External interfaces are configured with a static route to the client or the server. This module uses three interfaces. One is connected to the client or to the server, and the others are connected to the other routers. The interior router has no external interface and is connected by two to four interfaces depending on the router location in the network.

b. Client and server

Fig. 4 shows a screenshot of the functions and features that are offered by the OMNET++ simulator to resemble an ideal realistic sender or receiver. The overall module simulates multiple protocols such as TCP, UDP, SCTP, and ICMP. The red notation in Fig. 4 illustrates which protocol is used in sending and receiving; this module also has an embedded throughput meter function, which allows us to monitor the sending and receiving operations step by step.

An important part of the simulation is the transmitting of data. 10 MB of data were prepared to send from the client to the server using port 80 with MTU of 1,500 bytes. As soon as the routers exchange hello packets with one another, the shortest path is selected to the destination, and the data will then start to travel to the target node based on the IP address.

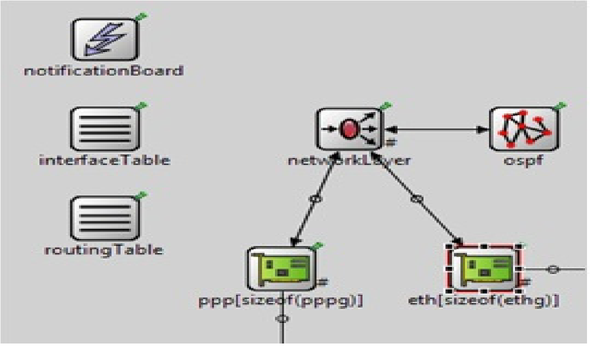


Fig. 2. Screenshot for a full-featured router node including the OSPF algorithm

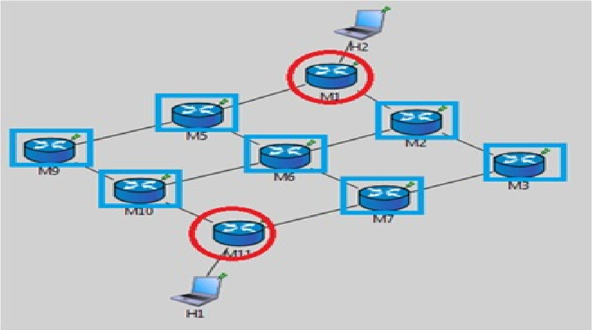


Fig. 3. A network simulation sample using nine routers, made by OMNET++IDE. The red colored circles denote the boundary routers, and the blue colored rectangles denote the interior routers.

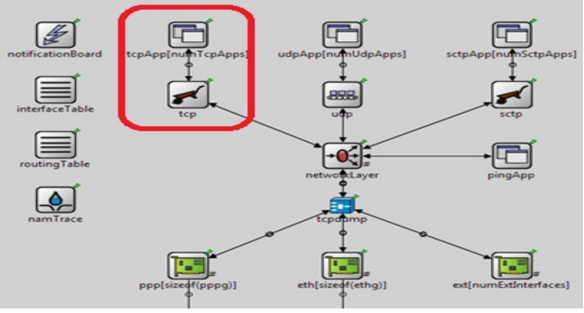


Fig. 4. Screenshot of full-featured client or server nodes running the TCP application

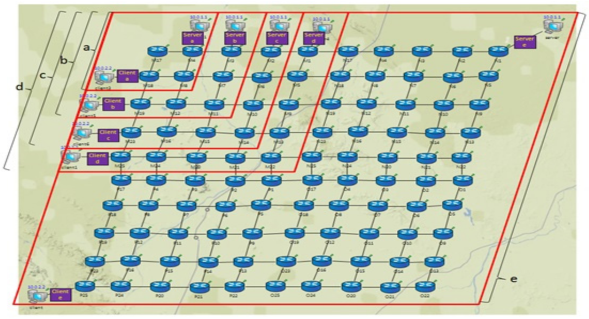


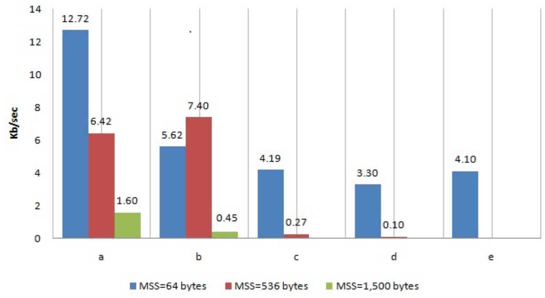
Fig. 5. Screenshots for our topologies; a, b, c, d and e refer to the squares that contain the number of issued routers.

2. Implementation

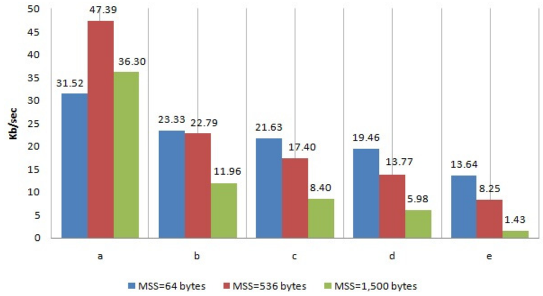
In order to investigate the grid network performances, we need to examine the throughput of the network due to the effects of the BER and how the throughput will be enhanced as a result of the change in the MSS. In addition, we need to examine the effects of adding more routers to the network.

The OMNET++ based simulation implementations have been used to make several cases depending on the number of routers. Fig. 5 shows the topology representation for all our cases. Each case has a different number of routers: 4, 9, 16, 25, and 100 routers are arranged for cases a, b, c, d, and e, respectively.

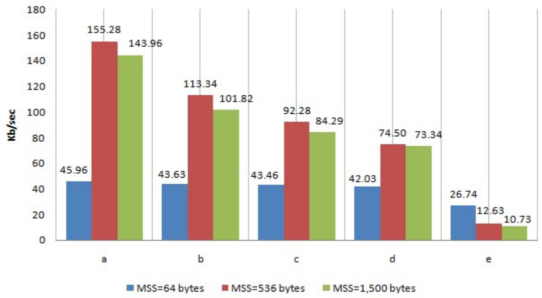
In addition, Fig. 5 shows five square notations. Each square covers the number of routers for our study.



(a) BER=10^{-4}



(b) BER=10^{-5}



(c) BER=10^{-6}

Fig. 6. Simulation results of sending 10 MB data for all our simulation cases, showing the data throughput for each case with BER value.

Ⅳ. Simulation Results

In this paper, we present a new algorithm called redundant logical paths (RLP), which is suited to any closed-loop network topology. This algorithm solves the unnecessary traffic problem in the standard HSR that is caused by duplication and random forwarding. The idea of our algorithm is to establish two logical paths between each HSR node and all the other nodes, which eventually will establish a logical, full-meshed network among all the nodes, except the Quadbox node type, which is used only for interconnecting purposes. Furthermore, the RLP algorithm can also be applied to a ring topology that has no Quadbox nodes, but it will be useful because the network performance will be the same of the standard HSR protocol and the Quadbox nodes will need bigger size of memory. Instead of using the standard HSR protocol, which depends on duplication and forwarding, these logical paths will be used for the unicasting traffic type. Thus the RLP algorithm will significantly reduce the frame traffic in HSR networks, which will result in enhanced traffic performance. For the sample network in this paper, simulation results show 62.5 - 80 % reduction in network frame traffic compared to the standard HSR as presented in tables 1, 2, 3 and 4.

Ⅴ. Conclusions and Future Work

In this paper, we present new performance simulations of military tactical grid communication networks employing the OSPF, a popular routing protocol for military applications. From our simulations, we have found a way of enhancing the OSPF-routed network that suffers high BER, i.e., wireless link. The method can be summarized as adjusting the MSS value of the sending frames according to the quality of the transmission link. The simulation results shown in Fig. 6 support our method. Thus, we conclude that the default MSS value, 536 bytes, does not serve the network well in a noisy wireless channel. Instead, 64 bytes of MSS is the better choice, as shown in Fig. 6(a). By contrast, in a low BER link, the default MSS provides better results. Figs. 6(b) and (c) show a good performance at an MSS of 536 bytes at the BER 10^{-5} and 10^{-6}. Therefore, when a good BER medium is offered to our network, we should use high MSS values, or we can say that the standard default MSS value is a good choice.

In the future, we need to develop a tool that detects or calculates the link BER value. After finding the BER, the sender can send a control frame telling the receiver to adjust its MSS values according to the link BER. Such a tool can help to enhance the performance of many military applications, for example, a military wireless sensor network and tactical on-the-move communication network.

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저자

Ibraheem Read ABDULSAM

- 2006년 6월 : Nahrain Univ., Iraq B.Sc in Laser and Optoelectronics Eng.
- 2010년 6월 : Nahrain Univ., Iraq M.Sc in Laser and Optoelectronics Eng Eng.
- 2010년~2012년 : Network Engineer in IDN(Iraqi Defense Network) for MOD(Ministry of Defense)
- 2012년 3월~현재 : 명지대학교 정보통신공학과 박사과정

<관심분야> : Military communications, ubiquitous networks and smart grid communications.

김 세 목 (Se Mog Kim)

- 1998년 2월 : 부경대학교 전자공학과 (공학사)
- 2013년 2월 : 명지대학교 통신공학과 (공학박사)
- 1998년~2001년 : ㈜네오디지틀 과장
- 2002년~2008년 : ㈜성원정보통신 부장
- 2009년~현재 : ㈜굿네트웍스 실장

<관심분야> : Military Communication, Fault Tolerant System, HFC network.

이 종 명 (Jong Myung Rhee) **정회원**

- 1976년 2월 : 서울대학교 전자공학과 (공학사)
- 1978년 2월 : 서울대학교 전자공학과 (공학석사)
- 1987년 12월 : North Carolina State Univ. ECE Dept. (공학박사)
- 1978년~1997년 : 국방과학연구소 책임연구원
- 1997년~1999년 : 데이콤 연구소 부소장
- 1999년~2005년 : 하나로텔레콤 CTO (부사장)
- 2006년 9월~현재 : 명지대학교 정보통신공학과 교수

<관심분야> : Military Communication, Fault Tolerant System, Ad-hoc, Data Link, Convergence, Smart Grid Communications