무선랜 환경에서 AP 로드 밸런싱을 위한 AP-개시 플로우 리다이렉션 메커니즘☆

AP-Initiated Flow Redirection Mechanism for AP Load Balancing in WLAN Environments

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요 약

IEEE802.11 무선랜은 공항과 같은 공공의 장소에서 널리 사용되고 있으며 캠퍼스나 회사의 네트워킹 영역을 증대하고 있고, 최근 메쉬 네트워크나 다른 3세대 이동 통신 네트워크과의 통합 형태의 네트워크를 구성하기 위한 중요 기술로 주목 받고 있다. 무선랜 환경에서의 액세스 포인트 (AP) 간 로드 밸런싱 문제는 효율적인 자원 관리나 트래픽의 QoS 지원을 위해 중요한 문제이지만, 기존 연구들에서는 노드가 네트워크에 진입하는 시점이나 로밍 시점에 로드 밸런싱을 위한 AP 선택에 초점을 맞추고 있다. 본 논문에서는 AP의 가용성 모니터링을 통해 진정한 의미의 로드 밸런싱을 위한 AP-개시 플로우 리다이렉션 메커니즘을 제안한다. AP 자신의 가용자원이 거의 사용하게 되면, 즉 특정 임계치 이상 사용하게 되면, 자신이 서비스하고 있는 노드가 로밍 가능한 이웃 AP들에게 그들의 가용자원에 관하여 쿼리를 하여 entropy나 chi-square와 같은 통계적인 방법을 이용하여 AP 간 트래픽 분포도에 대해 계산하고, 리다이렉트할 플로우들을 결정하여 선택된 노드들을 트리거하여 플로우 리다이렉션을 수행한다. 시뮬레이션 결과, 제안된 플로우 리다이렉션 메커니즘이 다양한 측면에서의 성능향상을 입증할 수 있었다.

Abstract

IEEE802.11 Wireless LAN (WLAN) is being widely used in public space such as airport, and increases the networking boundary in campus and enterprise, and it has lastly attracted considerable attention for mesh network and converged network with other 3G mobile communication networks. In WLAN, load balancing among Access Points (AP) is an important issue for efficient resource management or supporting the Quality of Service (QoS) of traffic, but most researches focused on the AP selection in network entry or roaming of Stations (STA). In this paper, we propose an AP-Initiated Flow Redirection (FR) for AP load balancing by monitoring AP's availability in the true sense. When the AP's resource becomes almost saturated, that is used more than a specific threshold, the AP queries the roaming possible neighbor APs about their availability and calculates the distribution of traffic load with statistical methods such as entropy or chi-square. Finally, the AP decides flows and new APs for redirection and performs it. Our simulation results show that our FR mechanism increases the performance in the various views.

☞ Keyword : AP Load Balancing, WLAN, Flow Redirection.

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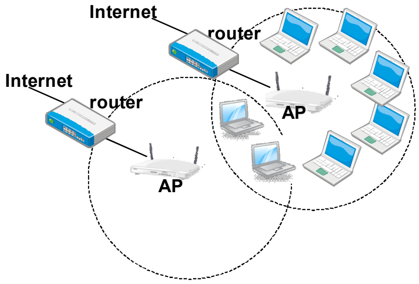
[2008/06/30 투고 - 2008/07/03 심사 - 2008/10/01 심사완료]
☆ 본 연구는 정보통신부 및 정보통신연구진흥원의 대학 IT연구센터 지원사업의 연구결과로 수행되었음 (IITA-2008-C1090-0801-0028)

1. Introduction

These days, IEEE802.11 [1] Wireless LAN, especially IEEE802.11a/g supporting 54Mbps transmission rate are broadly being used in campus, company, airport, bus/train station, and home, thus it increases the wired network boundary. Also, wireless mesh network by IEEE802.11 is assumed to address the market requirements for networks that are highly scalable and cost-effective, offering end users secure, seamless roaming beyond traditional WLAN boundaries and provide easy deployment.

In WLAN, cell planning is hardly performed, thus the resource management (e.g. radio) is important between neighbor APs. However, STA (Station) originally chooses an AP in case of the network entry according to the beacon strength of APs. However, this entry strategy could makes some APs congest even though neighbor APs have some resource to spare as shown in figure 1.



(Figure 1) Inequality in AP load

Thus, many researches for AP load balancing have been performed [2,3,4,5]. However, most of them considered AP load balancing in the only network entry process of STAs. Hence, the change of used resource in STAs could not be controlled by them.

In this paper, we propose an AP-initiated flow redirection mechanism, considering the change of used resource. It need not a server, and is performed using statistical methods as distributed process. Also, because the only few nodes, APs, are monitoring and controlling for FR, most end devices perform the only general re-entry process following the FR initiation of AP. Above all, because our mechanism pursues the higher utilization for the availability of whole network than general AP selection method on IEEE802.11, it can provide the high quality service even though FR operation may incur a little delay.

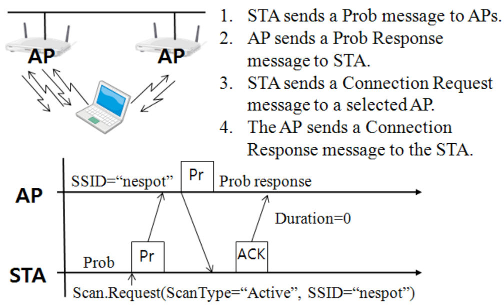
This paper is divided into five sections. In Section 2, we explain the AP selection methods on WLAN. We introduce in Section 3 our AP-initiated flow redirection. And next, we analyze our mechanism through simulation in the various views, and finally a brief conclusion is presented.

2. AP selection on WLAN

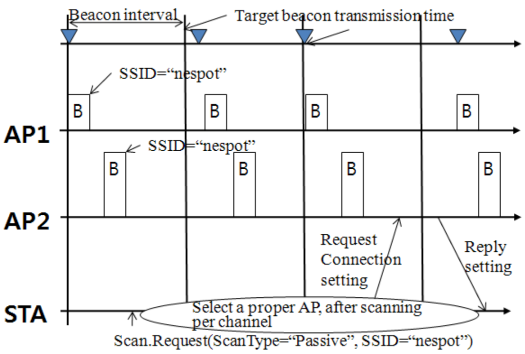
2.1 AP selection on IEEE802.11

Originally, IEEE802.11 WLAN provides two scanning methods for AP selection; Active and Passive Scan mode. On the Active mode, STA sends a Prob message to APs in order to enter a WLAN. APs receiving the Prob message respond with a Prob Response message. After comparing the Response messages, the STA selects a proper AP. Finally, the STA sends a Connection Response message to the selected AP, and then the AP responds with a Connection Response message.

On the other hand with Passive mode, STA scans per channel on the physical network, thus it selects a proper AP according to the strength of beacon from APs. After the STA selects a proper AP, it sends a Connection Response message to the selected AP. Finally, the AP responds with a Connection Response message.



(Figure 2) Active Scan mode in IEEE802.11 WLAN



(Figure 3) Passive Scan mode in IEEE802.11 WLAN

However, mostly STA decides its AP according to only the signal strength of AP.

2.2 AP selection methods for load balancing on IEEE802.11

As a result of AP selection in IEEE802.11 WLAN with a simple metric such as beacon strength, the traffic load among APs could be unbalanced as shown in figure 1. To overcome such problem, there are two approaches. One is centralized way proposed in [2]. In [2], a server is used to control STAs' association and works as admission controller. In fact, IEEE802.11 does not standardize any specific servers to control STAs' association. Moreover, if specific servers are needed to control STAs' association, latency taken during the HO (Hand-Over) procedure will increase. To reduce latency in HO, it is better for STA to select an AP.

From these reasons, decentralized approaches were proposed in [3] and [4] and they focused on AP selection mechanisms implemented in STAs. In [3] and [4], AP selection mechanisms were proposed for load balancing among APs. Their proposed algorithms considered RSSI (Received Signal Strength Indicator) and the number of STAs connecting to an AP. However, their traffic loads should be considered rather than the number of STAs. Therefore, it is difficult to control the load balancing to the true sense on IEEE802.11 networks. Moreover, they assumed that STAs could use the same transmission rate even when they connected to APs that were very far from it. However, in general, if a STA communicates with an AP that is far from it, it needs to use low transmission rate. Therefore, to take into account only the number of STAs for load balancing results in increasing the number of STAs that use low transmission rate. Consequently radio resource is inefficiently utilized and throughput of WLAN networks declines. Moreover, they considered a load balancing only at the network entry process of STAs, thus they are not the load balancing to the true sense, because they did not take a consideration of used traffic amount after network entry. We discuss and propose an AP selection mechanism for load balancing and the efficient use of radio resource, reflecting such a point. It considers channel load in an AP for load balancing, thus redirects the served STAs to the proper APs, considering with the location of STAs.

In [5], AP selection strategy in IEEE802.11e WLAN was proposed, reflecting upon channel load of AP and provided transmission rate. However, it also just takes into account AP selection in the network entry of nodes, thus it could not control the traffic amount change of STAs.

3. AP-initiated load balancing

Our flow redirection for AP load balancing consists of three processes;

- Decision of flow redirection
- Selection of STAs and new APs for flow redirection

- Execution of the flow redirection

3.1 Decision of flow redirection

For the load balancing of true sense, each AP monitors its own availability (e.g. the amount of available radio resource). However, the other metrics for the decision of flow redirection could be used, for example, average throughput or delay, and performance metrics of flows requiring the high quality of service. If the AP discovers the used resource amount is more than the specific threshold α for example 80% or 90%, it requests the availability to the neighbor APs to that serving STAs can roam. Thus, it calculates the traffic distribution using the availabilities through statistics methods; entropy or chi-square.

Hence, the entropy H defined at [6] can be computed on availabilities, as following equation 1:

$$H = -\sum_{i=1}^{n} P_i \cdot \log_2 P_i$$
$$P_i = \frac{Ava\_AP_i}{\sum_{j=1}^{n} Ava\_AP_j} \qquad (1)$$

The value *Pi* is calculated with the division of *APi*'s availability (*Ava_APi*) by the total of the availability of its own AP and neighbor APs(*Ava_APj*). The value *n* is the number of neighbors APs including its own AP.

Thus, comparing the value for entropy with the specific threshold β provides a mechanism for deciding whether the AP performs flow redirection, because entropy presents the traffic distribution. The threshold β might be decided by the average traffic distribution of AP zones in the severe traffic situation. Also, the thresholds α and β could be regulated as the frequency of flow redirection.

On the other hand, pearson's chi-square (X^2) test can be used for distribution comparison in cases where the measurements involved are discrete values. For example, it could be used to test the distribution of traffic load. Each AP counts the number of received packets from STAs during a specific time. Let *n* be the number of neighbors APs including its own AP. Define *Ni* as the number of packets served at the *APi* and *ni* as the expected number of packets served at the *APi* under the typical distribution. Then the chi-square statistic is computed as equation 2:

$$x^2 = \sum_{i=1}^{n} \frac{(N_i - n_i)^2}{n_i} \qquad (2)$$

3.2 Selection of STAs and new APs for flow redirection

After the AP decides to do flow redirection, it should select which STAs among serving STAs are flow-redirected, and where they are flow-redirected, that is, new APs. Based on the availability of neighbor APs, the AP simulates the flow redirection as shown in figure 4. At first, the AP queries the serving STAs about the beacon strength for neighbor APs and groups the serving STA according to AP with the biggest strength, except the AP. For example, if STA1 has 1 for AP1, 2 for AP2 and 5 for AP4 as the beacon strength, and then STA1 is included in STA_4.

Then, the AP sorts the availabilities of neighbor APs and its own availability. The AP selects a neighbor AP (APb)with the biggest availability, and chooses a STA in a set STA_b. If IEEE802. 11e is used for QoS support, STA with flows requiring high quality can be taken preference for FR. The AP recalculates entropy H or chi-square X2 assuming that the STA is flow-redirected, and compares the statistics value with the specific threshold β. This procedure is repeated until the statistical value of traffic distribution is β.

However, for the STAs requiring critical service time such as STAs not enduring FR delay, the AP measures the average delay by FR operation, thus it can exclude those STAs at FR selection step.

Also, if there are STAs that cannot perform FR by AP-initiation, the AP can manage the STAs additionally, thus it can exclude those STAs at FR selection step.

3.3 Execution of the Flow Redirection

After the AP chooses the STAs for flow redirection, it informs them a new AP, in order that they can request the connection setting to the new AP. If needed, the AP buffers the traffic during the flow redirection of STAs, and retransmits it to the new AP in order to minimize the performance decrease by flow redirection.

```
Makes STA_i (1≤i≤n)
/* Groups serving STAs as the AP with biggest
beacon strength */

Do {
      Sorts Ava_APi  (1≤i≤n)
      Selects   AP_b
/* Selects a neighbor AP (AP_b) with the biggest
availability*/

      Chooses a STA in a set STA_b

      Updates Ava_APi (1≤i≤n)

      Recalculates statistics
  /* Calculates entropy H or chi-square X^2 assuming
that the STAs are flow-redirected*/

}While (Statistics > β)
```

STA_i : Set of STAs that beacon strength of APi is biggest among its reachable APs, except the querying AP.

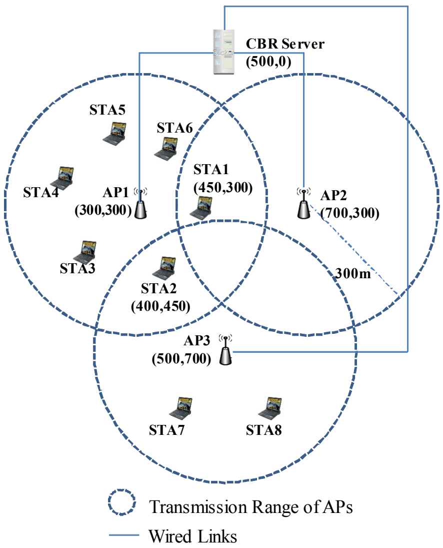
(Figure 4) Algorithm for choosing STAs and new APs of flow redirections

4. Performance Analysis

The entropy H or chi-square X^2 statistics are generally known as good analysis methods for the calculation of traffic distribution, thus many research used them especially for differentiating attack case and normal case [7]. Hence, in order to give proof that they are good choices for deciding the flow redirection according to the traffic load of the neighbor, we simulate our mechanism, comparing with general AP selection mechanism in the various views, with GloMoSim (Global Mobile Information Systems Simulation Library) that provides a scalable simulation environment for wireless and wired network systems [8].

4.1 Simulation Environments

We simulate our mechanism with the following simulation environments as figure 5 and table 1.



(Figure 5) Simulation Network

(Table 1) Parameter values of simulation

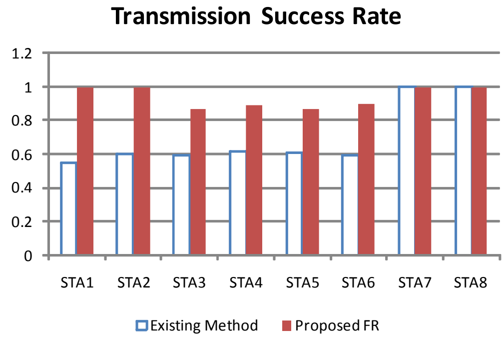
Parameters	Values
Terrain	1000m X 1000m
WLAN between Station(STA) and AP	IEEE 802.11b, 11Mbps
Wired Link between AP and CBR Server	100Mbps
Basic CBR(Constant Bit Rate) Traffic from each STA to CBR Server	Packet size: 512Bytes, interval : 5msec
Transmission Power of APs	10 dBm
Transmission Radius of APs	300m

4.1.1 Performance Comparison with Existing Method

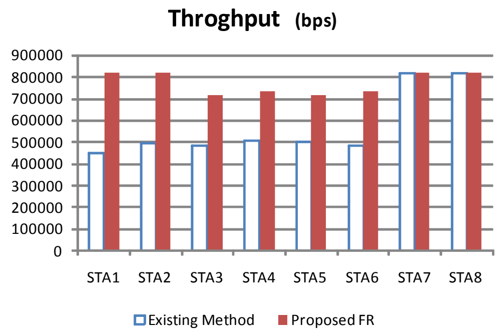
At first, we simulate our FR mechanism in order to compare with existing method that just chooses AP according to the received signal strength from APs. At the existing method in the simulation network as figure 5, STA1 and STA2 choose AP1 as access node toward CBR server because AP1 is the nearest. On the other hand, our FR mechanism of AP1 triggers STA1 to redirect its traffic toward AP2, and STA2 toward AP3, because AP1 is overloaded. In results, the load distribution of our mechanism improves transmission success rate, throughput and end-to-end average delay of each station including STA1 and STA2, as shown in figure 6, 7 and 8.

(Table 2) Average of STAs for performance factors

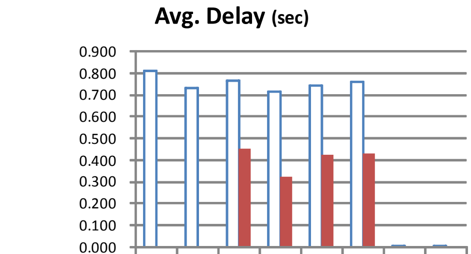
Performance Factors	Existing Method	Proposed FR
Transmission success rate	0.69475	0.9421875
Throughput (bps)	569592	772296
Avg. Delay (sec)	0.5659847	0.2064015



(Figure 6) Transmission success rate of each station



(Figure 7) Throughput of each station

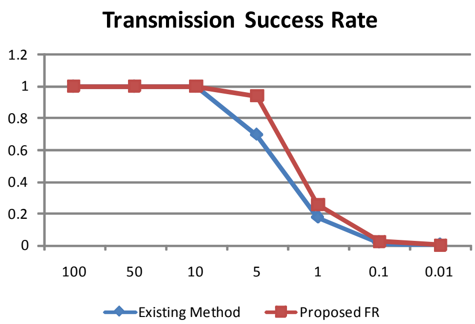


	STA1	STA2	STA3	STA4	STA5	STA6	STA7	STA8
Existing Method	0.812	0.733	0.763	0.713	0.742	0.757	0.004	0.004
Proposed FR	0.004	0.002	0.454	0.327	0.425	0.430	0.005	0.005

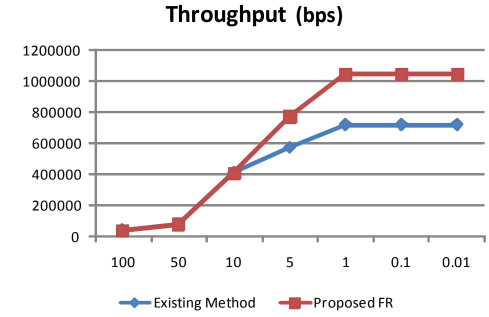
(Figure 8) End-to-end average delay of each station

4.1.2 Performance Comparison as Traffic Load

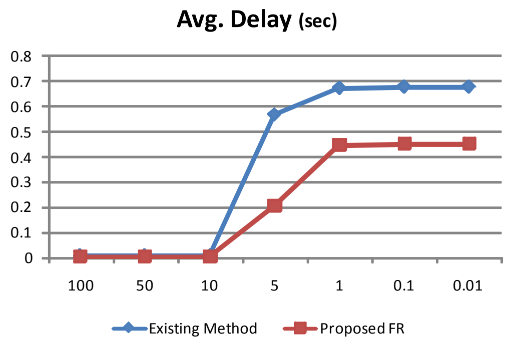
Also, we compare our mechanism with existing method as traffic load changes. We vary CBR interval of each STA from 100msec to 0.01msec. That is, CBR traffic with interval 0.01msec generates the most severe traffic. In results, as shown in figure 9, 10 and 11, AP1 can cover six STAs in the traffic environment with interval 100, 50, and 10msec, but the performance of transmission success rate decreases and average delay increases when traffic is more serve at existing method, and the increase of throughput stops at a degree level. However our FR distributes the traffic to other APs, thus performance decrease of transmission success rate and average delay is mitigated and throughput is increased.



(Figure 9) Transmission success rate as CBR interval (msec)



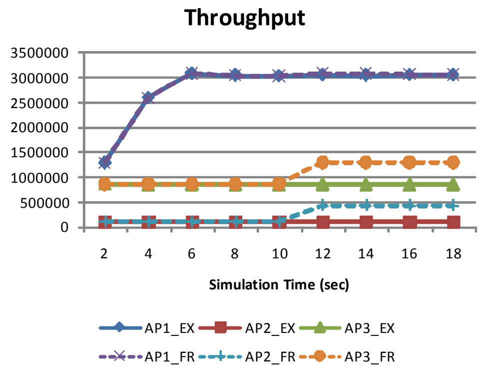
(Figure 10) Average throughput of all flows as CBR interval



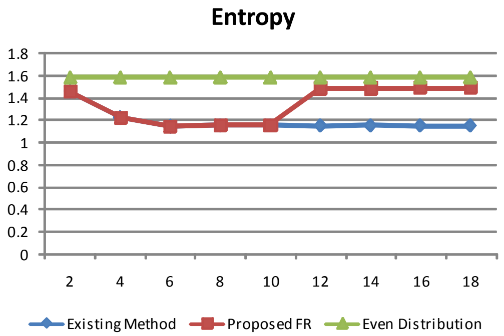
(Figure 11) End-to-end average delay as CBR interval

4.1.3 Performance Comparison as Time

Lastly, we show the performance change as the time is going on. For this simulation, we generate 3 CBR flows of 10msec interval toward AP1, 2 CBR flows toward AP2, and 1 CBR flow toward AP3 at the start of simulation. Then, we add 3 CBR flows toward AP1 every 2 seconds. And we assume our FR mechanism performs each 10 seconds. Figure 12 depicts the average throughput change of flows on each AP as time is going on. Notation '_EX' means that existing method is performed, and notation '_FR' means that our FR mechanism is operated. For example, 'AP1_EX' is the average throughput of flows passing on AP1 with existing method. In results, at 6 seconds, AP1 becomes saturated with increased flows every 2 seconds, though other APs is under-loaded. Thus, our FR mechanism chooses flows for FR until β becomes over 1.4, and performs it at 10 seconds. In results, our mechanism can increase total throughput of all APs with all flows as shown in figure 12. Figure 13 depicts the entropy change as the simulation time, and 'Even Distribution' means the entropy value (1.5849) in which three APs pass the flows of same amount. Thus we assume β is 1.4.



(Figure 12) Average throughput of flows as time



(Figure 13) Entropy change on AP1 as time

4.1.4 Overhead of our mechanism

As the overhead view, we can think that our mechanism require the selection and execution of FR. For the selection of STAs and new APs for FR, the operation on AP is required like figure 4, but statistical calculation like equation 1 or 2 is not complex, and the processing capacity of recent APs is sufficient for it. Also, the selection step requires the available resource of neighbor APs, but APs can periodically transmit the information to each other through the abundant steady resource of wired connection among APs.

Also, with due regard to the FR delay as the overhead of FR execution, our mechanism measures the average delay by FR operation, thus it can exclude the STAs requiring critical service time such as STAs not enduring FR delay, at FR selection step.

5. Conclusions

In this paper, we have suggested an AP-initiated flow redirection mechanism for AP load balancing in IEEE802.11 WLAN networks. Each AP controls the traffic load with neighbor APs, considering the normal and peak traffic situations. If needed, the AP buffers the traffic during the flow redirection of STAs, and retransmits it to the new AP in order to minimize the performance decrease by flow redirection.

We simulated our mechanism, comparing with existing method using received signal strength as AP choice criteria. We could show that our mechanism increased the performance in the various views. Also, our mechanism can easily apply to access nodes of other networks, such as mesh networks or converged networks.

References

[1] "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE Std 802.11 -1999 (Reaff 2003).

[2] A. Balachandran, P. Bahl and G.M. Voelker, "Hop-Spot Congestion Relief in Public-area Wireless Networks," WMCSA, June 2002.

[3] I. Papanikos and M. Logothetis, "A study on dynamic load balance for IEEE 802.11b wireless LAN," COMCON 2001, 2001.

[4] Y. Fukuda and Y. Oie, "Decentralized Access Point Selection Architecture for Wireless LANs -Deployability and Robustness," IEEE VTC2004, Sep. 2004.

[5] Shojiro Takeuchi, Kaoru Sezaki and Yasuhiko Yasuda, "Access Point Selection Strategy in IEEE802.11e WLAN Networks," WCNC2006.

[6] C.E. Shannon, and W. Weaver, "The Mathematical Theory of Communication," University of Illinois Press, 1963.

[7] Laura Feinstein, Dan Schnackenberg, Ravindra Balupari, and Darrell Kindred, "Statistical Approaches to DDoS Attack Detection and Response," DARPA Information Survivability Conference and Exposition, 2003.

[8] GloMoSim, available at http://pcl.cs.ucla.edu /projects/glomosim/ (last visited on June 27, 2008).

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