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A New Perspective on Internet Security using Insurance

Jean C. Bolot
Sprint, California, USA
email: bolot@sprint.com

Marc Lelarge
INRIA-ENS, Paris, France
email: marc.lelarge@ens.fr

***Abstract*—Managing security risks in the Internet has so far mostly involved methods to reduce the risks and the severity of the damages. Those methods (such as firewalls, intrusion detection and prevention, etc) reduce but do not eliminate risk, and the question remains on how to handle the residual risk.**

In this paper, we take a new approach to the problem of Internet security and advocate managing this residual risk by buying insurance against it.

Using insurance in the Internet raises several questions because entities in the Internet face correlated risks, which means that insurance claims will likely be correlated, making those entities less attractive to insurance companies. Furthermore, risks are interdependent, meaning that the decision by an entity to invest in security and self-protect affects the risk faced by others. We analyze the impact of these externalities on the security investments of users using a simple 2-agent model. Our key results are that *there are sound economic reasons for agents to not invest much in self-protection*, and that *insurance is a desirable incentive mechanism which pushes agents over a threshold into a desirable state where they all invest in self-protection*. In other words, insurance increases the level of self-protection, and therefore the level of security, in the Internet. Therefore, we believe that insurance should become an important component of risk management in the Internet.

I. INTRODUCTION

The Internet has become a fundamental component of modern economies, and it provide services, starting with connectivity, that are strategic to companies, governments and individual users. As a result, it has become crucial to the various entities (operators, enterprises, individuals,...) that deliver or use Internet services to protect the Internet infrastructure and the services delivered through that infrastructure against risks.

There are typically four options that individuals or organizations can take in the face of risks and the associated damages: 1) avoid the risk, 2) accept the risk and the loss when it occurs, 3) self-protect and mitigate the risk, and 4) transfer the risk to another party.

Most entities have so far chosen a mix of options 2 and 3. This has led to the development and deployment of a vast array of systems to detect threats and anomalies, and to protect the network infrastructure and its users from the negative impact of those anomalies. In parallel, most of the research on Internet security has similarly focused on issues related to option 3, with an emphasis on algorithms and solutions for threat or anomaly detection, identification, and mitigation.

Unfortunately, self protecting against risk or mitigating risk does not eliminate risk and despite all the research, time, effort, and investment spent in Internet security, there remains a significant residual risk. *The question then is how to handle this residual risk.*

One way to handle residual risk which has not been considered in much detail yet is to use the fourth option mentioned above, namely transfer the risk to another entity. A widely used way to do this is through insurance. The risk is transferred to an insurance company, in return for a fee which is the insurance premium. Insurance allows individuals or organizations to smooth payouts for uncertain events (variable costs of the damages associated with security risks) into predictable periodic costs. Using insurance to handle security risks in the Internet raises several questions: *does this option make sense for the Internet, under which circumstances? Does it provide benefits, and if so, to whom, and to what extent?* Our goal in this paper is to consider those questions.

We focus here on risks such as those caused by propagating worms or viruses, where damages can be caused either directly by a user, or indirectly via the user's neighbors. Specifically, we consider risks that are *correlated*, meaning that the risk faced by an entity increases with the risk faced by the entity's neighbors (e.g. I am likely to be attacked by a virus if my neighbors have just been attacked by that virus) and *interdependent*, meaning that those risks depend on the behavior of other entities in the network (such as their decisions to invest in security). Thus, the reward for a user investing in security depends on the general level of security in the network.

We analyze the impact of these characteristics on the security investments of the users with and without insurance being available. Users can decide whether or not to invest some amount c in security solutions to protect themselves against risk, which eliminates direct (but not indirect) damages.

In the 2-user case, it is known [9] that, in the absence of insurance, there exists a Nash equilibrium in a "good" state (where both users self protect) if the security investment cost c is low enough. We build upon this result to add insurance to the 2-user case. Our main result is that *if the premium is a "good" premium then insurance is a strong incentive to invest in security.* A "good" premium is a premium negatively related to the amount invested by the user in security; it parallels the real life situation where homeowners who invest in a burglar alarm and new locks expect their house theft premium to

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decrease following their investment.

The rest of the paper is organized as follows. In Section II, we describe related work. In Section III, we introduce the classical expected utility model for a single user and present the standard results about risk premium and the interplay between self-protection and insurance. In Section IV, we describe the 2-user model, present the results for self-protection in the absence of insurance, then build on those results to include insurance and prove our main point. Section V concludes the paper.

II. Related work

A vast amount of research has been published on protection against risk in the Internet (including anomaly detection, mitigation, etc) on one hand, and on insurance against risk on the other hand [7]. Comparatively little has been carried out or published at the intersection of insurance and the Internet. We can divide relevant contributions in two areas, namely *cyberinsurance* or insurance of computer risks in general (without much focus on network effects), and *insurance of correlated or interdependent risks*.

Using *cyberinsurance* as a way to handle the residual risk after computer security investments have been made was proposed more than 10 years ago [10] but popularized only recently [12]. The authors in [8] make the economic case for insurance, arguing that insurance results in higher security investments and that it solves a market failure, namely the absence of risk transfer opportunity.

The market for cyberinsurance [11] started in the late 90's with insurance policies offered by security software companies partnering with insurance companies as packages (software + insurance). The insurance provided a way to highlight the (supposedly high) quality of the security software being sold, and to deliver a "total" risk management solution (risk reduction + residual risk transfer), rather than the customary risk reduction-only solution; see for examples solutions offered by Counterpane/Lloyd's of London [5]. More recently, insurance companies started offering stand-alone products (e.g. AIG's NetAdvantage [1]).

A challenging problem for Internet insurance companies is caused by *correlations between risks*, which makes it difficult to spread the risk across customers; a sizeable fraction of worm and virus attacks, for example, tend to propagate rapidly throughout the Internet and inflict correlated damages to customers worldwide [13]. Furthermore, entities in the Internet face *interdependent risks*, i.e. risks that depend on the behavior of other entities in the network such as whether or not they invested in security solutions to handle their risk. Thus the reward for a user investing in security depends on the general level of security in the network. Correlated and interdependent risks have only very recently started being addressed in the literature. References [2], [3] consider insurance with correlations in the extreme case of a monoculture (a system of uniform agents) with correlated Bernouilli risks and argue that the strong correlation of claims in that case may hinder the development of a cyberinsurance industry.

Reference [9] considers the situation of agents faced with interdependent risks and proposes a parametric game-theoretic model for such a situation. In the model, agents decide whether or not to invest in security and agents face a risk of damage which depends on the state of other agents. The authors show the existence of two Nash equilibria (all agents invest or none invests), and suggest that taxation or insurance would be ways to provide incentives for agents to invest (and therefore reach the "good" Nash equilibrium), but they do not analyze the interplay between insurance and security investments. Our work also builds on the model of [9], and considers a single insurance market but it differs from [9] because it models all three desirable characteristics of an Internet-like network, namely correlated risks, interdependent agents, and a general model of a network (although we consider the 2-agent case in this paper), and it derives general results about the state of the network and the behavior of the agents, with and without insurance being available.

Next, we describe the classical expected utility model for a single agent and present the standard results about premium computation and the interplay between self-protection and insurance.

III. Insurance and self-protection: basic concepts

A. Classical model for insurance

The classical expected utility model is named thus because it considers agents that attempt to maximize some kind of expected utility function u. We denote by $u[X]$ the value of the utility function at X. In this paper, we assume that agents are rational and that they are risk averse. For example, consider an agent given the choice between i) a bet of either receiving \$100 or nothing, both with a probability of 50%, or ii) receiving some amount with certainty. A risk averse agent would rather accept a payoff of less than \$50 with probability 1 than the bet.

We denote by w_0 the initial wealth of the agent. The *risk premium* π is the maximum amount of money that one is ready to pay to escape a pure risk X, where a pure risk X is a random variable such that $\mathbb{E}[X] = 0$. The risk premium corresponds to an amount of money paid (thereby decreasing the wealth of the agent from w_0 to $w_0 - \pi$) which covers the risk; hence, π is given by the following equation:

$$u[w_0 - \pi] = \mathbb{E}[u[w_0 + X]]$$

The risk premium plays a fundamental role in the theory of insurance and we refer to [7] for a detailed account of the economics of insurance. We will focus in the rest of this section on the interplay between insurance and self-protection investments in networks. To simplify our analysis, we consider simple one-period probabilistic models for the risk, in which all decisions and outcomes occur in a simultaneous instant;

Each agent faces a potential loss ℓ, which we take in this paper to be a fixed (non-random) value. We denote by p the probability of loss or damage. There are two possible final states for the agent: a good state, in which the final wealth of the agent is equal to its initial wealth w_0, and a bad state in which the final wealth is $w_0 - \ell$. The amount of money m the agent is ready to invest to escape the risk is given by the equation:

$$pu[w_0 - \ell] + (1 - p)u[w_0] = u[w_0 - m] \quad (1)$$

We can actually relate m to the risk premium defined above. Note that the left hand-side of Equation (1) can be written as $\mathbb{E}[u[w_0 - p\ell - X]]$ with X defined by $\mathbb{P}(X = \ell(1 - p)) = p$ and $\mathbb{P}(X = -p\ell) = 1 - p$. Hence we have $\mathbb{E}[w_0 - p\ell - X] = u[w_0 - p\ell - \pi[p]]$ where $\pi[p]$ denotes the risk premium when the loss probability equals p. Therefore: $m = p\ell + \pi[p]$.

The term $p\ell$ corresponds to what is referred to as the fair premium, i.e. the premium which exactly matches expected loss. On the left hand side of the equation, m corresponds to the maximum acceptable premium: if an insurer makes a proposition at a cost of $\wp$, then the agent will accept the contract if $\wp \leq m$. From the insurer's perspective, the premium $\wp$ depends on the distribution of the loss (here p and ℓ).

B. A model for self-protection

Investments in security involve either self-protection (to reduce the probability of a loss) and/or self-insurance (to reduce the size of a loss). For example, intrusion detection and prevention systems are mechanisms of self-protection. Denial-of-service mitigation systems, traffic engineering solutions, over-provisioning, and public relations companies are mechanisms of self-insurance (over-provisioning to reduce the impact of overloads or attacks, PR firms to reduce the impact of security attack on a company stock price with crafty messages to investors). It is somewhat artificial to distinguish mechanisms that reduce the probability of a loss from mechanisms that reduce the size of the loss, since many mechanisms do both. Nevertheless, we focus on self-protection mechanisms only.

We first look at the problem of optimal self-protection without insurance. We denote by c the cost of self-protection and by $p[c]$ the corresponding probability of loss. We expect larger investments in self-protection to translate into a lower likelihood of loss, and therefore we reasonably assume that p is a non-increasing function of c. The optimal amount of self-protection is given by the value c^* which maximizes

$$p[c]u[w_0 - \ell - c] + (1 - p[c])u[w_0 - c] \quad (2)$$

Consider the simple case where the loss probability is either one of two values, namely $p[c] = p^+$ if $c < c_t$ or $p[c] = p^-$ if $c > c_t$, with $p^+ > p^-$. The optimization problem (2) above becomes easy to solve: indeed, the optimal expenditure is either 0 or c_t.

In the rest of the paper, we assume that the choice of an agent regarding self-protection is restricted to a binary choice: either the agent does not invest, or it invests c_t which will be denoted c for simplicity. If the agent does not invest, the expected utility is $p^+u[w_0 - \ell] + (1 - p^+)u[w_0]$; if the agent invests, the expected utility is $p^-u[w_0 - \ell - c] + (1 - p^-)u[w_0 - c]$. Using the derivation in the subsection above, we see that these quantities are equal to $u[w_0 - p^+\ell - \pi[p^+]]$ and $u[w_0 - c - p^-\ell - \pi[p^-]]$, respectively. Therefore, the optimal strategy is for the agent to invest in self-protection only if the cost for self-protection is less than the threshold

$$c < (p^+ - p^-)\ell + \pi[p^+] - \pi[p^-]. \quad (3)$$

C. Interplay between insurance and self -protection

We now analyze the impact that the availability of insurance has on the level of investment in self-protection chosen by the agent.

Consider first the case when Equation (3) is satisfied, namely it is best for the agent to invest in self-protection. We assume that the agent can choose between insurance with full coverage and self-protection. Clearly if the agent chooses full coverage, he will not spend money on self-protection since losses are covered and the utility becomes $u[w_0 - \wp]$. In the case of optimal self-protection, the utility has been computed above: $u[w_0 - c - p^-\ell - \pi[p^-]]$ since Equation (3) holds. Hence the optimal strategy for the agent is to use insurance if

$$\wp - p^-\ell - \pi[p^-] < c \quad (4)$$

Note that because of Equation (3), we must have

$$\wp < p^+\ell + \pi[p^+]. \quad (5)$$

If Equation (3) does not hold, then it is best for the agent not to invest in self-protection, and the choice is between insurance and no self-protection. It is easy to see that if Equation (5) holds, then the premium is low enough and the optimal strategy is to pay for insurance.

In summary: if Equation (4) holds, the optimal strategy is to pay for full coverage insurance and not invest in self-protection. Otherwise, the optimal strategy is to invest in self-protection and not pay for insurance.

The combination of insurance and self-protection raises the problem of what is referred to as moral hazard. Moral hazard occurs when agents or companies covered by insurance take fewer measures to prevent losses from happening, or maybe even cause the loss (and reap the insurance benefits from it). Indeed, if the premium does not depend on whether or not the agent invests in self-protection, then insurance becomes a negative incentive to self-protection. A known solution to the problem is to tie the premium to the amount of self-protection (and, in practice, for the insurer to audit self-protection practices and the level of care that the agent takes to prevent the loss) [6]. Note that this condition is necessary to avoid moral hazard: if the premium is not designed as above, then self-protection will be discouraged by insurance and we would observe either a large demand for insurance and a small demand for self-protection, or the converse.

A natural candidate for such a desirable premium proposed in [6] is the fair premium:

$$\wp[S] = p^-\ell, \text{ and, } \wp[N] = p^+\ell.$$

With this premium, insurance co-exists with an incentive to invest in self-protection [6]. To agents that do not invest in prevention, the insurer may offer a premium $\wp[N] + \gamma$, where $\gamma \geq 0$ denotes a premium penalty (loading). To agents that invest in prevention, the insurer may offer a premium $\wp[S]-\gamma$, where γ denotes a premium rebate.

The utility for all possible cases is summarized in Table I. The first column denotes the choice made by an agent. It is denoted by the pair (U, V), where $U = I$ means that the agent pays for insurance and $U = NI$ otherwise, and $V = S$ means that the agent invests in self-protection and $V = N$ otherwise.

TABLE I
UTILITY WITH INSURANCE AND SELF-PROTECTION - SINGLE USER CASE

(I, S)	$u[w_0 - c - p^- \ell + \gamma]$
(I, N)	$u[w_0 - p^+ \ell - \gamma]$
(NI, S)	$u[w_0 - c - p^- \ell - \pi[p^-]]$
(NI, N)	$u[w_0 - p^+ \ell - \pi[p^+]]$

Note that for any non-negative value of γ, the strategy (I, S) always dominates the strategy (NI, S). Now for (I, S) to dominate (I, N), we need

$$c < (p^+ - p^-)\ell + 2\gamma.$$

For (I, S) to dominate (NI, N), we need

$$c < (p^+ - p^-)\ell + \gamma + \pi[p^+].$$

This concludes the description of results from classical insurance theory. Next, we consider a 2-agent model with correlated and interdependent risks.

IV. Interdependent Security and Insurance: The 2-Agent Case

Recall that interdependent risks are risks that depend on the behavior of other entities in the network (e.g. whether or not they invested in security solutions to handle their risk). In the presence of interdependent risks, the reward for a user investing in self-protection depends on the general level of security in the network.

A. Interdependent risks for 2 agents

Reference [9] was the first to introduce a model for interdependent security (IDS), specifically a model for two agents faced with interdependent risks, and it proposed a parametric game-theoretic model for such a situation. In the model, agents decide whether or not to invest in security and agents face a risk of damage which depends on the state of other agents. As in Section III above, the decision is a discrete choice: an agent either invests or does not invest in self-protection. We assume that loss can happen in two ways: it can either be caused directly by an agent (direct loss), or indirectly via the actions of other agents (indirect loss). We assume that the cost of investing in self-protection is c, and that a direct loss can be avoided with certainty when the agent has invest in self-protection.

The cost of protection should not exceed the possible loss, hence $0 \le c \le \ell$. Four possible states of final wealth of an agent result: without protection, the final wealth is w_0 in case of no loss and $w_0 - \ell$ in case of loss. If an agent invests in protection, its final wealth is $w_0 - c$ in case of no loss and $w_0 - c - \ell$ in case of loss.

Consider now a network of 2 agents sharing one link. There are four possible states denoted by (i, j), where $i, j \in \{S, N\}$, i describes the decision of agent 1 and j the decision of agent 2, S means that the agent invests in self-protection, and N means that the agent does not invest in self-protection. We examine the symmetric case when the probability of a direct loss is p for both agents, where $0 < p < 1$. Knowing that one agent has a direct loss, the probability that a loss is caused indirectly by this agent to the other is q, where $0 \le q \le 1$. Hence q can be seen as a probability of contagion. To completely specify the model, we assume that direct losses and contagions are independent events. The matrix $p[i, j]$ describing the probability of loss for agent 1, in state (i, j), is given in Table II.

TABLE II
PROBABILITY OF STATES

	S	N
S	$p[S, S] = 0$	$p[S, N] = pq$
N	$p[N, S] = p$	$p[N, N] = p + (1-p)pq$

We now derive the payoff matrix of expected utilities for agents 1 and 2. If both agents invest in self-protection, the expected utility of each agent is $u[w_0 - c]$. If agent 1 invests in self-protection (S) but not agent 2 (N), then agent 1 is only exposed to the indirect risk pq from agent 2. Thus the expected utility for agent 1 is $(1 - pq)u[w_0 - c] + pqu[w_0 - c - \ell]$ and the expected utility for agent 2 is $(1 - p)u[w_0] + pu[w_0 - \ell]$. If neither agent invests in self-protection, then both are exposed to the additional risk of contamination from the other. Therefore, the expected utilities for both agents are $pu[w_0 - \ell] + (1 - p)(pqu[w_0 - \ell] + (1 - pq)u[w_0])$.

Assuming that both agents decide simultaneously whether or not to invest in self-protection, there is no possibility to cooperate. For investment in self-protection (S) to be a dominant strategy, we need

$$u[w_0 - c] \ge (1-p)u[w_0] + pu[w_0 - \ell] \text{ and}$$
$$(1 - pq)u[w_0 - c] + pqu[w_0 - c - \ell] \ge$$
$$pu[w_0 - \ell] + (1-p)(pqu[w_0 - \ell] + (1 - pq)u[w_0])$$

With the notations introduced earlier, the inequalities above become:

$$\begin{aligned} c &\le p\ell + \pi[p] =: c_1, \\ c &\le p(1-pq)\ell + \pi[p + (1-p)pq] - \pi[pq] =: c_2. \end{aligned}$$

In most practical cases, one expects that $c_2 < c_1$, and the tighter second inequality reflects the possibility of damage caused by other agent. Therefore, the Nash equilibrium for the game is in the state (S, S) if $c \le c_2$ and (N, N) if $c > c_1$. If $c_2 < c \le c_1$, then both equilibria are possible and the solution to the game is indeterminate. Overall, we have the following:

- if $c < c_2$: the optimal strategy is to invest in self-protection;

TABLE III
PAYOFF MATRIX WITH INSURANCE AND SELF-PROTECTION

	agent 2: S	agent 2: N
(I,S)	$u[w_0 - c - pq\ell + \gamma]$	
(I,N)	$u[w_0 - (p + pq(1-p))\ell - \gamma]$	
(NI,S)	$u[w_0 - c]$	$(1-pq)u[w_0 - c] + pqu[w_0 - c - \ell]$
(NI,N)	$(1-p)u[w_0] + pu[w_0 - \ell]$	$pu[w_0 - \ell] + (1-p)(pqu[w_0 - \ell] + (1-pq)u[w_0])$

- if $c_2 < c < c_1$: if the other user in the network do invest in self-protection, then the optimal strategy is to invest in self-protection;
- if $c_1 < c$: then the optimal strategy is to not invest in self-protection.

B. IDS and full coverage insurance

We now consider the situation where the choice is left to the agent as to whether to invest in self-protection and/or in a full coverage insurance. As noted in Section III-C, if we want to avoid a moral hazard problem, the insurance premium has to be tied to the amount spent on self-protection. Note that the probability of loss for agent 1 depends on the choice made by agent 2, however it seems necessary (at least from practical a point of view) to link the premium applied to agent 1 to the behavior of agent 1 only. A possible choice (which is profit-making for the insurance) is to choose for each decision of the agent the fair 'worst case' premium as follows,

$$\wp[S] = pq\ell, \quad \wp[N] = (p + (1-p)pq)\ell.$$

We summarize the payoff for agent 1 in Table III, depending on the investment of agent 2 and for the four possible choice of the agent (notations are the same as in Section III-C). We denote

$$c_4[\gamma] := p(1-pq)\ell + \pi[p + (1-p)pq] + \gamma.$$

Let us examine the situation depending on the behavior of agent 2. If agent 2 invests in self-protection (denoted by S_2), then for $c < c_1$, agent 1 chooses to invest in self-protection also and not otherwise. Consider now the case when agent 2 does not invest in self-protection (denoted by N_2). Then if $c < \min(c_3[\gamma], c_4[\gamma]) := c[\gamma]$, the optimal strategy is (I,S). Note that we have $c_4[\gamma] \geq c_2$ for all values of γ and we proved above that we can choose γ such that $c_3[\gamma] \geq c_2$. Therefore it is possible to tune γ such that $c[\gamma] \geq c_2$.

Note in particular that when insurance with discrimination is available, (S,S) becomes a Nash equilibrium for $c < c[\gamma]$ with $c[\gamma] > c_2$ for well-chosen values of γ. In such a case, insurance is an incentive to self-protection. The main features present in the single-agent are also present in the 2-agent case. However a new feature comes into play because of the interdependent risks, namely the existence of a new threshold c_2 which takes into account the externality modeled by the possible contagion via the other agent. We see that the externalities due to the interdependent risks tend to lower the incentive for investing in self-protection. However, we also see that the effect of the insurance (with discrimination) is unaffected by these interdependent risks. As a result the relative efficiency of insurance is higher in the presence of externalities.

V. CONCLUSION

One of our main contributions in this paper is to develop and solve a simple model which explains why economically rational entities would prefer a relatively insecure system to a more secure one, and which shows that insurance is an incentive mechanism which leads both users in our 2-user model to the desirable state where they all invest in self-protection. In reference [4], we have extended this work to the general case of n agents and show that the results in this paper still hold. In fact, we find that insurance is a powerful incentive mechanism for self-protection. Specifically, we show that the adoption of security investments follows a threshold or tipping point dynamics, and that insurance is an incentive mechanism which pushes entities over the threshold to the state where they all invest in self-protection.

To conclude, we believe that Internet insurance, in addition to providing the benefits shown in the paper, offers a fertile area of reflection and research. It is a timely area, as well, given the recent activities around clean-slate Internet design. We propose to add to the slate a broader definition of risk management, which includes the transfer of risk in addition to only the mitigation of risk.

REFERENCES

[1] American International Group, http://www.aignetadvantage.com/
[2] R. Böhme. Cyber-insurance revisited. *Proc. of Workshop on the Economics of Information Security (WEIS)*, 2005.
[3] R. Böhme and G. Kataria. Models and measures for correlation in cyber-insurance. *Proc. WEIS 2006*.
[4] J. Bolot and M. Lelarge. A New Perspective on Internet Security using Insurance. *INRIA Report RR-6329*.
[5] http://www.counterpane.com/pr-lloydssl.html
[6] I. Ehrlich and G. S. Becker. Market insurance, self-insurance, and self-protection. *The Journal of Political Economy*, 80(4):623–648, 1972.
[7] C. Gollier. *The Economics of Risk and Time*. MIT Press, 2004.
[8] J. Kesan, R. Majuca, and W. Yurcik. The economic case for cyberinsurance. In *Securing Privacy in the Internet Age*, A. Chander et al., Eds., Stanford University Press, 2005.
[9] H. Kunreuther and G. Heal. Interdependent security. *Journal of Risk and Uncertainty*, 26(2):231–249, 2003.
[10] C. Lai et al. Endorsments, licensing, and insurance for distributed systems services. *Proc. 2nd ACM Conf. Computer and Comm. Security (CCS)*, Fairfax, VA, Nov. 1994.
[11] R. P. Majuca, W. Yurcik, and J. P. Kesan. The evolution of cyberinsurance. *Information Systems Frontier*, 2005.
[12] B. Schneier. Insurance and the computer industry. *CACM*, vol. 44, no. 3, March 2001.
[13] C. Zou, W. Gong, D. Towsley. Code Red worm propagation modeling and analysis. *Proc. 9th ACM CCS'02.*, Washington, DC, Nov 2002.