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A New Model for Network Valuation

Rod Beckstrom

Introduction

What is the value of a network? This has remained a question in economics for decades. This research piece presents a new model for answering that question.

In seeking to develop a model for cybersecurity risk management, it became apparent that having such a model depended on answering another question first, namely, "what is the value of the network we are protecting?" This line of fresh inquiry led to a new proposed model for valuing network.

Previous models for valuing networks sought to estimate value based on the size or structure of the entire network. Metcalfe's Law, the most popular version, proposed that the value of a network was proportional to the square of the number of nodes on a network. In this exponential growth model, the value of the network rises with the number of users, regardless of size. [1] Reed's Law built on Metcalfe's insights but focused on the number of sub-groups which can form within a broader network.

Both of these conceptual models provided some useful insights, but were limited by focusing on the network as a whole, observed from a central perspective. Being largely conceptual, these models were not generally applied to actual, applied network valuation problems, although Metcalfe's Law was used to verbally justify lofty valuations for new Internet technology companies until the stock market bubble burst in March of 2000.

This piece presents a new economic model of networks (Beckstrom's Law) that is based on a completely different perspective – looking at the edge of the network and the value that it adds to users transactions. It applies a user centric perspective.

Beckstrom's Law solves the valuation problem by looking at how valuable the network is to each user. The value to each user is determined by calculating the net benefit value the presence of the network adds to all transactions conducted by the user over that network. The model can be used to value any size of network, whether it has two users or billions.

Any type of network can also be valued with the model: social networks, phone networks, train networks, texting networks, support groups, private clubs or even the entire Internet itself.

The model is simple, fine grained, additive, and scalable yet divisible through set theory.

Derivatives of the core model can be created to solve various network economic problems, such as risk management, hacker economics, supply chain intrusion economics, and deterrence economics.

Beckstrom's Law can contribute to solving disparate network related economic problems, such as public policy formulation, information sharing incentives, and business model analysis.

A user can be any entity that uses the network, including individuals, companies, governments, and non-governmental organizations (NGOs). Each user's relationship to a network is an implied, and normally voluntary, contract, whether explicit or implicit. Networks provide platforms for many types of transactions, and the presence of a network can affect the price, value and nature of transactions. The added value generated by the network on all transactions conducted by that user can then be assessed using traditional economic and accounting methods. The network provides services to participating parties, and those services can be valued by an accounting of the costs and benefits of all transactions that are enabled by those services.

Let us use a simple example to illustrate the concept. If you buy a business book by your favorite author on Amazon.com for $16 (including shipping) and your lowest cost alternative is to drive to the store and pay a total of $26, including the cost of gas and time, then the net benefit to you of that transaction is $10. Amazon.com may also make money selling you the book for $16. If Amazon costs the delivered transaction at a total of $15, Amazon will enjoy a net benefit of $1 in the transaction as well. These numbers represent the net benefit value added by the availability of the network to each of the parties. If you tally all of your transactions over that network for a year, you could calculate the total net benefit of that network to you. If you tally the net benefit to you, Amazon.com and all other parties, you would have a value of that network. Since net benefits are calculated from the unique standpoint of each party, when the total is added for an entire network, there is no double counting.

A Transaction Based Network Valuation Model

To specify the model, the future benefits of transactions must be discounted to net present value terms. It is also important to recognize that transactions are not always simple and paired as an online book purchase, where you deliver money and receive a book. Some transactions, such as licensing anti-virus software, occur annually, but most benefits are derived on a usage basis over that period of time. Over a year you may send thousands of emails. Each of these is a transaction that has value, or you would presumably not engage in it. But these transactions are not paired. They are part of a bundle of transactions you conduct within the context of your relationship with a network.

Put in economic terms, the net present value (***V***) of any network (***j***) to any individual (i) is equal to the sum of the net present value of the benefit of all transactions less the net present value of the costs of all transactions on the network over any given period of time (***t***), as shown in the following equation.

$$V_{i,j} = \sum_{k=1}^{n} \frac{B_{i,k}}{(1+r)^{t_k}} - \sum_{l=1}^{n} \frac{C_{i,l}}{(1+r_l)^{t_l}}$$

Where

$V_{i,j}$ = net present value of all transactions of k = 1 through n to individual $_{\mathbf{i}}$ with respect to network $_{\mathbf{j}}$

$_{i}$ = one user of the network

$_{j}$ = identifies one network or network system

$B_{i,k}$ = the benefit value of transaction $_{\mathbf{k}}$ to individual $_{\mathbf{i}}$

$C_{i,l}$ = the cost of transaction $_{l}$ to individual $_{\mathbf{i}}$

r_k and r_l = the discount rate of interest to the time of transaction $_{\mathbf{k}}$ or $_{\mathbf{l}}$

t_k or t_l = the elapsed time in years to transaction $_{\mathbf{k}}$ or $_{\mathbf{1}}$

To simplify subsequent derivations of the equation, the net present value benefit and cost terms will be simplified without the discount function and be italicized as simply $B_{i,k}$ and $C_{i,l}$. Other terms italicized will also express net present values of those terms, and a simple sigma will represent the relevant series of transactions over any defined time period.

Thus the equation is simplified to:

$$V_{i,j} = \sum B_{i,k} - \sum C_{i,l}$$

Valuing an Entire Network

The above equation represents the value of the Internet to one user. The value of the entire Internet or any network Nj is the summation of the value of that network to all individuals or entities, i through n, engaged in transactions on that network. Thus a summation term is now added before $V_{i,j}$.

$$\sum_{i=1}^{n} V_{i,j} = \sum B_{i,k} - \sum C_{i,l}$$

The Sum Value of All Networks

Similarly, to value all networks to all users in the world simply requires a summation of all networks j = 1 through n.

$$\sum_{j=1}^{n} \sum_{i=1}^{n} V_{i,j} = \sum B_{i,k} - \sum C_{i,l}$$

The total net value of all networks in the world is equal to the total value of net benefit of all networks to all users.

This total value is presumably less than total Gross Domestic Product (GDP) and greater than zero. Global GDP for 2008 is estimated to be 70.6 trillion dollars.[1] Worldwide telecom revenues are estimated to be $1.7 trillion for 2008, including both wire-line and wireless communications, amounting to $4.6 billion per day in telecom gross revenues and in total representing about 2.4 percent of global GDP. Global telecommunications industry revenues are estimated to grow to nearly $5 trillion by 2011.[2]

These figures on the estimated size of the global telecom industry represent a significant underestimate of the value of networks enabled by telecom capabilities. Due to advanced technologies and economies of scale, telecom service capabilities continue to expand while the real cost of service continues to fall. The value added by network access and usage yields a vastly larger economic impact. Moreover, there are many other networks whose value is not reflected in these telecom revenues, including television networks and social networks, among others. The global net value added of all networks may well be somewhere between 1 percent and 10 percent of global GDP, or between $700 billion to $7.0 trillion per annum. Just think of how much the internet is worth to you and remember that 1.3 billion other humans use it too, and this is but one network.

How does one begin to determine the value generated through network transactions. As a starting point, consider the different forms of value that are provided through transactions among networks enabled by electronic media. Transactions in this context can be defined as interactions that provide value to participants. Initially, one can consider dividing participants into two groups – individuals and organizations.

Benefits and Costs of Networks

The benefit value of a transaction on a network is bounded with a lower and upper limit. The benefit value should be higher than the cost of that transaction, or the user would presumably not execute that transaction. Also the benefit value of a transaction is equal to or less than the cost of conducting the same transaction through another service.

In a simple transaction like buying a book, where one delivers money and receives a book, the benefit is assumed to be higher than the cost. One should not pay more for a book than one values it at. Regarding the upper limit, the benefit should not be greater than the all-in cost of conducting the transaction through an alternative means. If instead of buying a book online one purchases it from a bookstore for $26 (including one's time), then that is the maximum benefit.

Costs of networks include the cost of joining or maintaining access to a network, such as paying for Internet access, and all costs associated with conducting transactions over that network, including labor time, electricity, the cost of products or services, and any other costs. The Internet as a network is interesting in that once access is secured, there are many services such as Skype calls, Wikipedia information, search services, etc., that are offered for free, which generates significant benefits.

Considerable conceptual and empirical work needs to be done in a new field of network value accounting that can utilize the model to gain a better understanding of this increasingly important component of modern economies. One could envision that several techniques could be applied, depending on the nature of the transaction. One approach would be to estimate the positive value added in such transactions as online purchases, time saved through information access, or productivity gains emanating from corporate information technology networks. Another approach would entail examining the net costs of alternative transaction modes (e.g., costs of telephone calls and mail as an alternative to VOIP and email). Still another method would be to calculate the negative effects of network disruptions (e.g., sales or efficiency losses, temporary cessation of operations, etc.). In addition to estimating the direct benefits and costs through various means, it would also be appropriate to estimate the indirect impacts, utilizing relevant economic multipliers to capture spillover effects.

Extending the Model to Network Security

This model was discovered while attempting to answer the question of "what function are we trying to optimize in network security?" The model can be explicitly extended to incorporate security investments and losses.

To accomplish this, it is simply necessary to break out the costs C in greater detail for the sake of clarification. Let us define a new term C prime or C'. C' is equal to all costs, except security costs which we will define as S and security related losses which we will define as L. Also, to further simplify the equation, we will now drop the sigma as assumed. The fundamental value equation becomes:

$$V_{i,j} = B_{i,k} - C'_{i,l} - SI_{i,o} - L_{i,p}$$

Where $C'_{i,l}$ = the cost of all transactions except security related investments and losses

$SI_{i,o}$ = the cost of security investment transaction $_o$ to the individual $_i$

$L_{i,p}$ = the cost of security loss $_p$ to the individual $_i$

In other words, the net benefit value of a network is equal to the summation of all transaction benefits, less all transaction costs, less security costs, and less security related losses to a user.

The Security Cost Function

To drill down more specifically on security costs, the security cost function becomes,

$$SC_{i,j} = \quad SI_{i,o} + L_{i,p}$$

Where $SC_{i,j}$ = net present value of all Security Costs to individual $_i$ with respect to network $_j$

In other words, security is a cost and security losses are also a cost. This now provides a clear economic function to optimize (in this case, minimize).

Core Security Risk Optimization Function

$$\text{Minimize } SC_{i,j} = \quad SI_{i,o} + L_{i,p}$$

Security costs (investments plus losses) are optimal when they have been minimized. This leads to an important insight. One dollar of security investments is only a benefit when it reduces expected losses by more than a dollar. In other words, security dollars should be invested where they produce the greatest drop in expected losses, and security investments should increase just until they reduce a dollar in expected losses, and no more.

Economically, this introduces a new important trade-off: security dollars versus loss dollars. The question for any organization then becomes, how does the expected loss function drop with increases in security dollars?

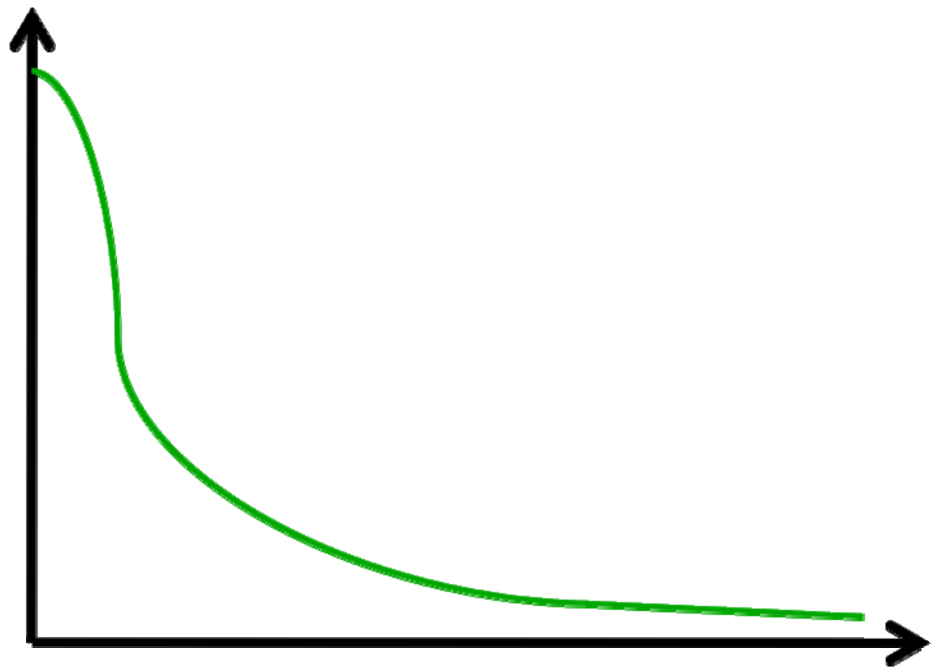
While calculating the expected losses is extremely difficult, it is nonetheless vital, for without it, investments in security lack an economic basis. Recent discussions with private sector and governmental Chief Information Security Officers have confirmed the need for such an economic model and analysis.

It can also be argued that the short term loss value functions may be greater than the steady state value added of a network. In other words, while the presence of a network may normally only contribute $10 billion in economic value each day to a country, the complete shut down of that network may have a higher short term cost. This latter value is a “disruption value losses” and several economic pieces have been drafted on this topic. For example, at the individual company level, losses have been estimated at $2 million per incident.[3] If numerous companies are involved in a systemic network disruption, the losses would be substantial. In short, the disruption cost is equal to the economic loss of a network being suddenly shut off, as opposed to how much it adds on a normal periodic basis.

While in the short term a disruption value could be greater than the conventional value added of the network, in the long term, the two should converge in that over time the lost value add would lead to an equal and offsetting investment in replacing the network functions with a new network.

Illustration 1. Plotting Security Investments Versus Losses

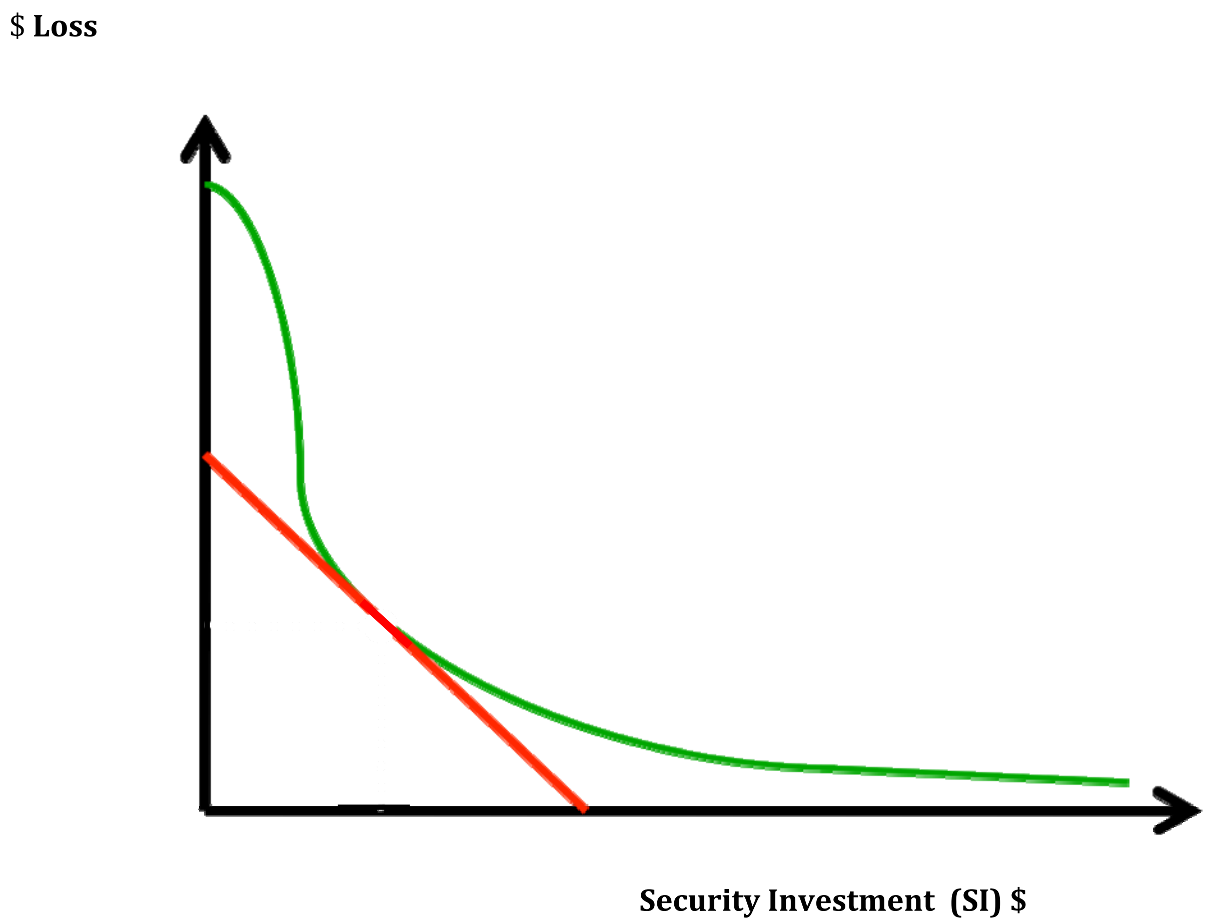
$ Loss



Security Investment (SI) $

In Illustration 1, as the security investment increases along the horizontal axis, the losses, represented by the green line, drop. Initially, the drop is very steep as the first dollars invested in security yield a significant decrease in losses. However, as the level of security dollars invested increases, at some point, there are diminishing returns. In terms of network security, this roughly conforms to the observed reality that a number of key security steps such as installing all software patches and the like tends to reduce 80% of the problems. In other words, the first easy investments have a relatively high payoff. To close the gap on the other 20%, however, becomes increasingly expensive for each 1% reduction in risk.[4]

Illustration 2. Optimal Security Investment



The optimal security investment occurs on the loss function line where it is tangent to a 45 degree line, or where one dollar of security investment equals one dollar decrease in expected losses. This point is represented by S' in terms of security dollars.

Summary

It is important and useful to have a simple and robust model for estimating the ongoing economic value of networks. Such a model makes it possible to calculate or at least estimate the value of the presence of networks. The framework presented in this article provides a simple model that is consistent with other primary economic models such as transaction accounting, cost accounting and net present value analysis. The model answers a very important question - what is the value of a network, while opening up new questions to be answered, such as how can we best value the benefit of transactions?

The model can be applied in many ways: to structure public policy, to analyze the economics of hacking, to analyze the economics of deterrence, and to calculate the value of network resilience, just to provide a few examples. The model can potentially serve as a foundation for future advances in the field of network economics.

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[1] Gross World Output, estimated on a Purchase Power Parity basis, 2008CIA World Factbook, https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html#Econ .

[2] Telecommunications Industry Association, as reported in TMC Net News, July 10, 2008, http://it.tmcnet.com/topics/it/articles/33591-global-telecommunications-revenue-almost-5-trillion-2011.htm

[3] "Internet Business Disruptions Benchmark Report," the Aberdeen Group, 2004.

[4] Based on a conversation on August 22, 2008 with Vincent Cerf, a founder of the Internet and Vice President of Google, and a key driver behind IPv6.

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