CSCI 1800 Cybersecurity and International Relations

Economics of Cybersecurity

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What is Cyber Economics?

• It is the study of the economics of computer and network security.
  – Understanding incentives
  – Learning from market failures
  – Appreciating the important of externalities
  – The value of intermediaries
  – Formulating policy and remedies
Why Should CS Talk about Economics

• Conventional CS approach failed to
  – Identify and correct all the threats

• CS needs help from economists to exercise control over vendors, markets and users
  – Incentives/penalties for human behavior are essential

• Situation is different for encryption
  – The problem is contained and well defined
  – Good encryption methods have been identified
Outline¹

• Since many cybersecurity problems are economic, modest incentives can significantly improve security.

• Four areas are examined
  – Online identity theft, industrial espionage, critical infrastructure protection, and botnets.

• Three economic challenges:
  – Misaligned incentives, information asymmetries, and externalities.

Some Cybersecurity Application Areas

• Data breaches
  – The primary way that information lost on individuals

• Industrial cyber espionage
  – Trade secrets remotely stolen; theft not detected.

• Critical infrastructure protection
  – Industrial control systems vulnerable & not protected

• Botnets
  – Common and involved in many types of attack.
Data Breaches

• In 2017 Ponemon Institute study
  – Average cost of a breach was $3.62 M
  – Probability of a material data breach ~ 28%
  – Average of 191 days needed to discover a breach and 66 days to contain it.
  – Source: Criminals (47%), Glitches (25%), Error (28%)
  – Existence of incident response team reduces cost
Industrial Cyber Espionage

• Operation Aurora launched in 2009.
  – Google revealed attack from China and eventually stopped offering its search service there.
  – The attack targeted repositories of Google and more than 30 other companies.
  – It received a great deal of press and government attention.
  – Were files just stolen or were they modified?

• Mandiant 2013 APT1 report shows this was tip of the iceberg. https://www.fireeye.com/content/dam/fireeye-www/services/pdfs/mandiant-apt1-report.pdf
Critical Infrastructure Protection

• Example:
  – 2007 Idaho National Lab experiment (also called Aurora) that destroyed a power generator. https://www.youtube.com/watch?v=rTkXgqK1l9A&feature=player_embedded

• US government has identified 16 critical infrastructure sectors.

• SCADA$^1$ systems are involved in almost all sectors. They are considered poorly protected.

1. SCADA: Supervisory Control and Data Acquisition
Economic Barriers to Cybersecurity

• Misaligned incentives
  – E.g. If those responsible for protecting a system don’t pay for security violations, no incentive to keep it safe.

• Information asymmetries
  – Absence of critical information can lead to poor decisions that alter markets.

• Externalities
  – Costs incurred by others not party to transactions.
  – E.g. air pollution reduces a manufacturer’s cost but increases cost to society.
Misaligned Incentives

• If those acquiring systems, don’t pay a price for failure to meet specs, failures are more likely.
  – E.g. Electricity companies save money by replacing atomic clocks with GPS.
  – When a solar flare wipes out GPS, the public pays the price.
Misaligned Incentives

• There is a natural tension between efficiency and resiliency in design of IT systems.
  – Critical infrastructures used to be operated on separate networks. E.g. ATT network (SS7), SCADA systems
  – Efficiency drives us toward network convergence. We are now heavily dependent on Internet.
  – Who is concerned about the unintended consequences?
    • See https://sm.asisonline.org/Pages/GridEx-IV-Tests-The-North-American-Power-Grid.aspx

• Efficiency often trumps security.
• When security fails, cost often borne by the public.
Information Asymmetries

- Incident data is essential but hard to obtain.
  - Unless incident can’t be ignored, such as Target POS attack
  - Reputations (and stock prices) are on the line.
  - Companies don’t want to reveal vulnerabilities.
Information Asymmetries

• Asymmetric information can be deleterious:
  – Akerlof (2007 Nobel) explained pricing of auto “lemons”
  – If market has 50 “good” used cars @ $2K and 50 lemons @$1K but customers can’t tell them apart, price drops well below $2K. Owners of good cars will not sell. Market gets filled with lemons.
  – Buyers won’t pay premium for quality that can’t be measured
Information Asymmetries

• Secure software is a market for lemons
  – Because buyers can’t tell which software is more secure, they have no incentive to pay more for one product versus another
  – This disincentives vendors to spend on security

• Robust cyber incident data is missing
  – Unless required by law, breach notifications not done
  – Without good loss measurements, resources cannot be allocated properly.
Externalities

• Positive network externality:
  – First-mover advantage results in market dominance
    • Think Facebook, Windows, etc.

• Negative network externalities:
  – Firms ignore security to achieve dominance
  – When firms dominate, individuals lose control over some issues, such as privacy.
Other Negative Externalities

• Underinvestment in security may impose burden on others:
  – Botnets proliferate
  – The power grid is insecure
  – National security is put at risk

• Free riding
  – If investment in security by others protects you, why would you invest in your own protection?
  – Consequence: security is likely to decline
Addressing Externalities

• Some solutions effective only when widely used
  – The Border Gateway Protocol (BGP), which is employed to announce new IP addresses, is insecure
  – Access to YouTube lost in 2008 for 2 hours
    • Pakistan Telecom used BGP to redirect access to YouTube

• Secure BGP (‘96) doesn’t offer immediate value and this is not widely used.

• Secure Shell (SSH) does offer immediate value and is widely used
Is Regulation the Solution?

• Topics we examine:
  – Ex Ante Safety Regulation vs Ex Post Liability
  – Information Disclosure
  – Cyber-Insurance
  – Indirect Intermediary Liability
Ex Ante Safety Regulation vs Ex Post Liability

• Ex ante goal: prevent accidents in advance.
  – 1999 Gramm-Leach-Bliley Act – repealed Glass-Steagall Act of 1933 & allowed affiliations between commercial banks and securities firms. (See Crash of 2008!)

• Ex post liability: threat of monetary damages
  – Would this push Microsoft to make code more secure?
    • They are making progress without it. Or are they aware of cost?
  – Ex post liability has a negative externality – it would reduce pace of innovation.
  – Without changes in coding techniques, software security may not increase.
Ex Ante Safety Regulation vs Ex Post Liability

• Unfortunately, security errors are unavoidable.
• Would results be better if vendors were held to a higher standard of coding and testing?
• In some sectors, best to use both approaches.
  – However, ex ante regulation doesn’t work well when regulator lacks information about harms or is uncertain about minimum standards.
  – Also, ex post liability doesn’t work when firms not always held responsible or they can’t pay.
• These conditions often hold in cybersecurity.
Information Disclosure

• Since information asymmetries are barrier to cybersecurity, info disclosure may be the answer.
  – “Sunlight is the best disinfectant” – Justice Brandeis
  – Community has a right to know.

• Law requires disclosure of toxic chemicals released into the environment.
  – This law has reduced the amount of such chemicals.
  – The Whitehouse-Kyl Cyber Security Public Awareness Act of 2011 might have done the same for cyber.

See http://www.gpo.gov/fdsys/pkg/BILLS-112s813is/pdf/BILLS-112s813is.pdf
Information Disclosure

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• Failure to publicize breaches exposes others.

• Information sharing and analysis centers (ISACs) are industry groups set up by DHS to protect the critical infrastructure. Effective! They don’t publicize data.
Risk Management Approaches

• Acceptance
  – Pay for loss through fees

• Mitigation
  – Install better technology (increases security cost)

• Avoidance
  – Impose customer requirements (lost business?)

• Transfer
  – Buy cyberinsurance (must pay premiums)
Cyber-Insurance

• Coverage provided for data breaches, business interruption, and network damage.
• Offers incentives to take precautions
• Rewards investment by lowering premiums
• Encourages data collection, dealing with informational asymmetries.
• Smooths out financial outcomes – small fixed present cost offsets future large losses.
Cyber-Insurance

• Cyber-insurance market small for a long time.
• What is wrong with cyber-insurance industry?
  – On supply side: Hard to measure security levels
• Needed are partnerships between forensics firms and insurance companies to better assess and reduce risk and price insurance products.
  – E.g. Arceo Analytics
Indirect Intermediary Liability

• Liability doesn’t have to be placed on the party directly responsible for harm.
• Usually 3 players: bad actor, victim, third party.
  – E.g. Employers responsible for actions of employees
• Works when
  – Bad actor inaccessible, can’t be identified, or can’t pay if caught.
  – Too costly to design contracts that assign blame fairly.
  – Third party can detect or prevent harm and can internalize negative externalities by reducing # bad acts.
Indirect Intermediary Liability

• Lichtman and Posner (2004) argue that these conditions apply to ISPs as third parties*.
  – For what types of behavior could ISPs play this role?
• ISPs exempted from liability for defamatory content of subscribers (1996 Communications Decency Act)
  – Gave license to ISPs to monitor posts by users.
• DMCA exempts ISPs from copyright violations if they comply with “notice-and-takedown” requests.
• To stop online gambling, credit card companies are made 3rd parties.

* https://chicagounbound.uchicago.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1235&context=law_and_economics
Indirect Intermediary Liability

• The FCC announced in 2012* that ISPs representing more than 90% of US Internet users have agreed to take voluntary action against the following cyber threats:
  – Anti-bot Code of Conduct
  – DNS Best Practices
  – IP Route Hijacking Industry Framework

Indirect Intermediary Liability

• Credit card fraud makes bank the intermediary when fraud occurs at brick and mortar establishments but makes the merchant the intermediary for online transactions.
  – The reason apparently is that online transactions are considered more risky.
  – This treatment of fraud could change over time
Botnets Becoming Major Threat

- Mirai botnet became major threat in late 2016
  - ~600mpbs against Brian Krebs
  - ~1.2 terabit/sec against DYN
- Infected hundreds of thousands of devices:
  - Cameras, some printers and routers
- Located in
  - Vietnam (13%), Brazil (12%), US (11%), China (9%), Mexico (8%), Taiwan (5%), Russia (4%), etc.
- 2018 ~1.3 terabit/sec against Github*

* [https://www.wired.com/story/github-ddos-memcached/](https://www.wired.com/story/github-ddos-memcached/)

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Recommendation #1: Infected Bots

- **Tyler Moore’s program for malware remediation**
  - Require ISPs to act on notification of customer infection by helping to clean up customer computer. In return, ISPs exempted from liability. Else, liable.
  - Share cost of cleanup between ISPs, government, software vendors and consumers.
  - Publicize infections (report ISP, OS type, infection vector, time to remediation, and fix.)
  - Make software vendors pay for cleanup in proportion to number of reported infections of their software.
  - Cap the consumer contribution. They cannot be disconnected if they cooperate in cleanup.
Cleaning Up Infected Bots

• Situation unsatisfactory. What should be done?
  – Can encourage ISPs to help customers – very weak.
  – Can use DMCA as model. Give immunity to ISP if they help cleanup infected computers. Make them responsible if they don’t.

• Must have a) fair distribution of cost of cleanup, b) transparency via mandatory disclosure of infections, and c) protection of consumer connections.
Recommendation #2: Disclosure

• Regularly publish aggregated losses due to online banking and payment cards.
  – Incident figures
  – Victim demographics
  – Attack vectors
  – Business category

• Such info can help decide security measures.
Disclosure

• FBI runs Internet Crime Complaint Center (IC3)
• Financial services ISAC data kept in closed circle.
  – Because ISACs have voluntary disclosure systems, financial services industry does not internalize the cost of insecurity.
• Users also need to know where fraud occurs.
• Disclosure would help decide if more secure credit card technologies should be used.
Recommendation #3: SCADA Incidents

- Make disclosure of control system incidents and intrusions mandatory to the relevant ISACs who then publicly disseminate them.

- Intelligence officials say that Chinese and Russians are regularly intruding into US electrical grid.
Recommendation #4: Espionage

• Aggregate and report cyber espionage and report to WTO.

• Industrial espionage is a significant problem for American companies.

• They don’t report intrusions for fear of damaging their reputations.
  – Did the Google Aurora caper signal a change?
Conclusion

• Economic perspective essential to understand cybersecurity today and to improve it.

• Principal recommendations:
  – Get ISPs to take more active role in ridding malware
  – Collect and publish data on a range of security incidents
  – Raise awareness of the issues and assign responsibility for action