# Defending Computer Networks
## *Lecture 9: Worms*

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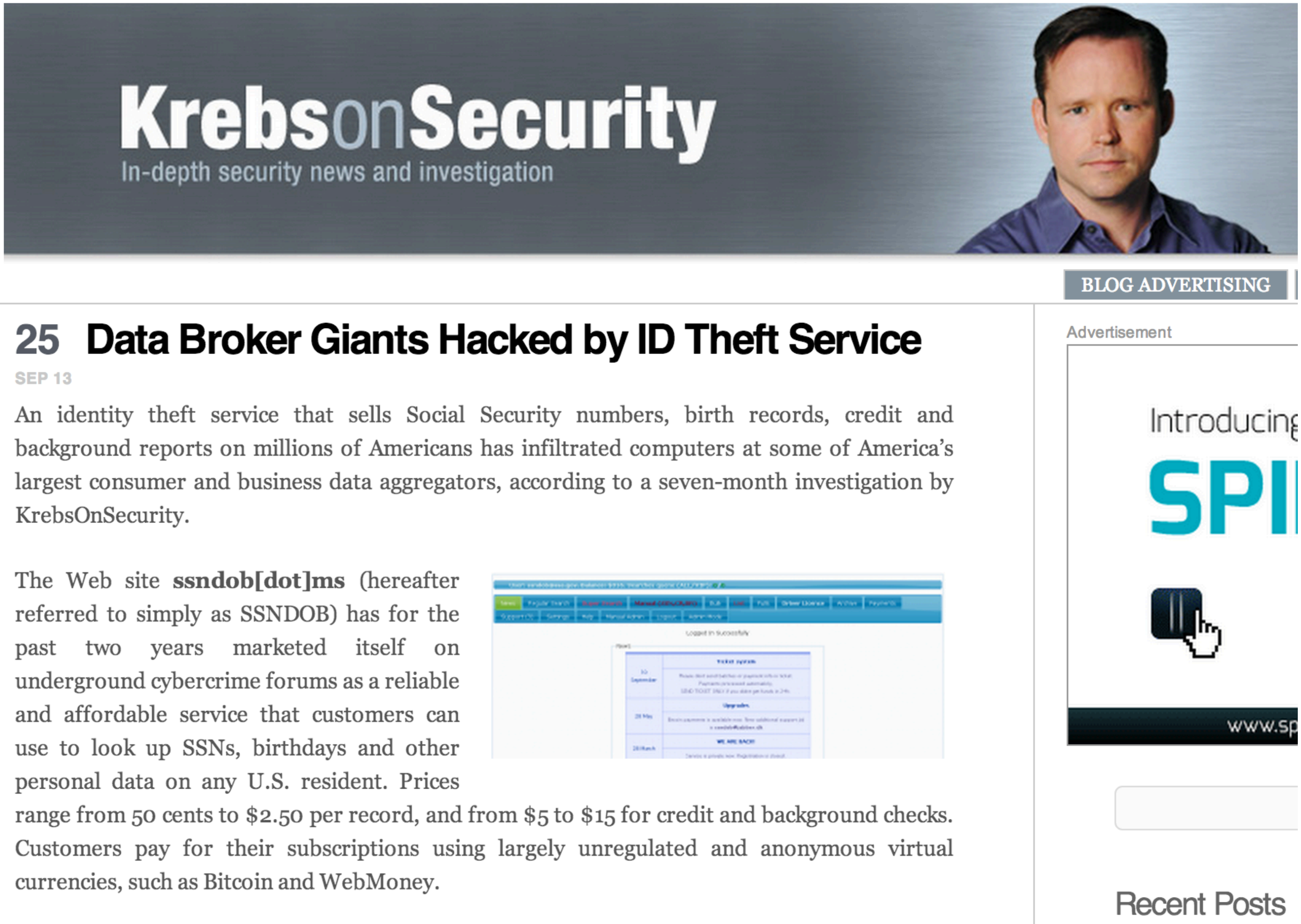
# Logistics

- HW2 up on website.
- Upcoming guest lectures
  - October 1st: Z (first half of lecture)
  - October 8th: Cornell ITSO office
    - Wyman Miles/Glenn Larratt/Dan Valenti
- Reminder that guest lectures are part of syllabus and may be quizzed on.

# New Assigned Reading

- Staniford et al *How to 0wn the Internet in Your Spare Time*. http://www.icir.org/vern/papers/cdc-usenix-sec02/
- Falliere et al. *W32.Stuxnet Dossier*. http://www2.gwu.edu/~nsarchiv/NSAEBB/NSAEBB424/docs/Cyber-044.pdf

# Latest News



## 25 Data Broker Giants Hacked by ID Theft Service

SEP 13

An identity theft service that sells Social Security numbers, birth records, credit and background reports on millions of Americans has infiltrated computers at some of America's largest consumer and business data aggregators, according to a seven-month investigation by KrebsOnSecurity.

The Web site **ssndob[dot]ms** (hereafter referred to simply as SSNDOB) has for the past two years marketed itself on underground cybercrime forums as a reliable and affordable service that customers can use to look up SSNs, birthdays and other personal data on any U.S. resident. Prices range from 50 cents to $2.50 per record, and from $5 to $15 for credit and background checks. Customers pay for their subscriptions using largely unregulated and anonymous virtual currencies, such as Bitcoin and WebMoney.

https://krebsonsecurity.com/2013/09/data-broker-giants-hacked-by-id-theft-service/

# Main Goals for Today

- Worms.

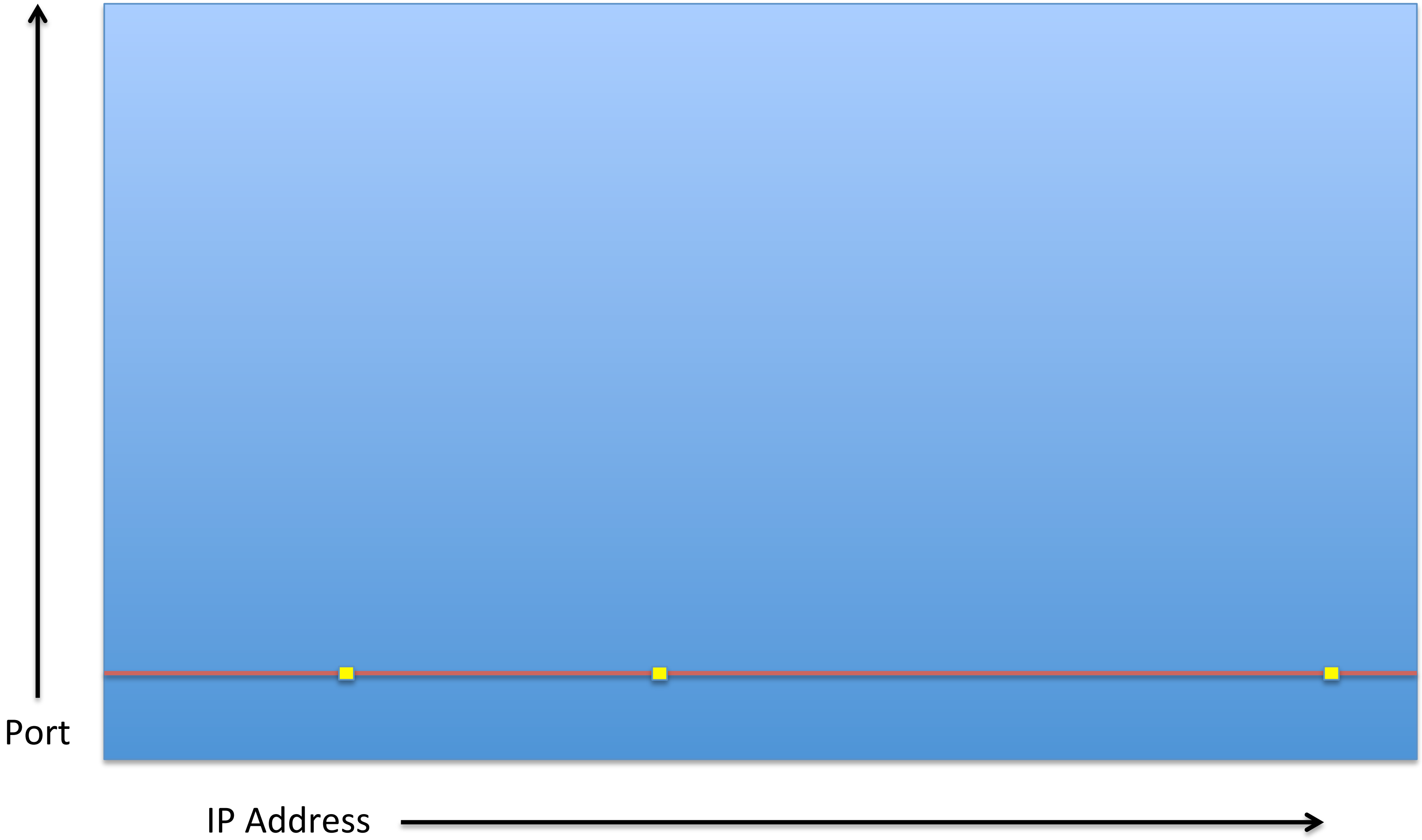
# Definitions

- Worm: A malicious program capable of infecting and running on other systems across the network via security weaknesses in that system in order to spread.
- Virus: Malicious code capable of infecting and attaching itself to other executables in order to spread.
  - Was more important in the PC/floppy drive era.

# Ancient History

- 1988 Internet Worm (first serious worm problem)
  - Infected BSD Unix systems
  - Robert Morris Jr – Cornell student at the time.
  - Exploited vulnerabilities
    - Stack overflow in finger
    - Unauthenticated debug functionality in sendmail
    - guessing weak passwords.
  - Looked on host for info about other hosts.
    - Topological worm.
  - "disrupted normal activities and Internet connectivity for many days"
    - http://spaf.cerias.purdue.edu/tech-reps/823.pdf

# Random Scanning Worms



# Scanning Worms Huge in the 2000s

- 2001 Code Red (I and II), Nimda
- 2003 Slammer and Blaster/Welchia
- 2004 Sasser
- 2008 Conficker

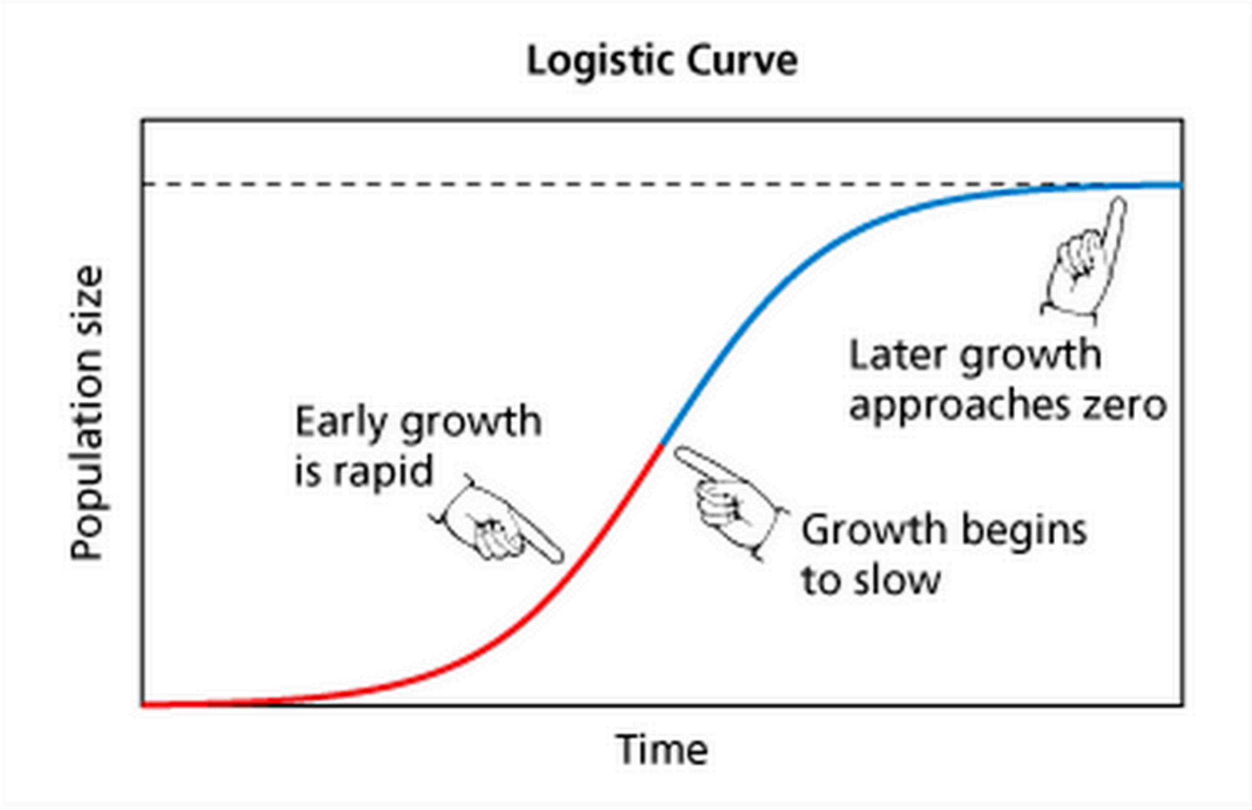
# Let's Do Some Calculus

- For a whole-Internet random scanning worm
  - Let v be fraction of addresses that are vulnerable to worm exploit
  - Let S be average scanning rate (syns/hr).
  - Then K = Sv is number of new compromises/hr/ already infected machine.
  - N = $2^{32}$v is the total number of machines
  - Fraction of machines comprised at time t is a(t)

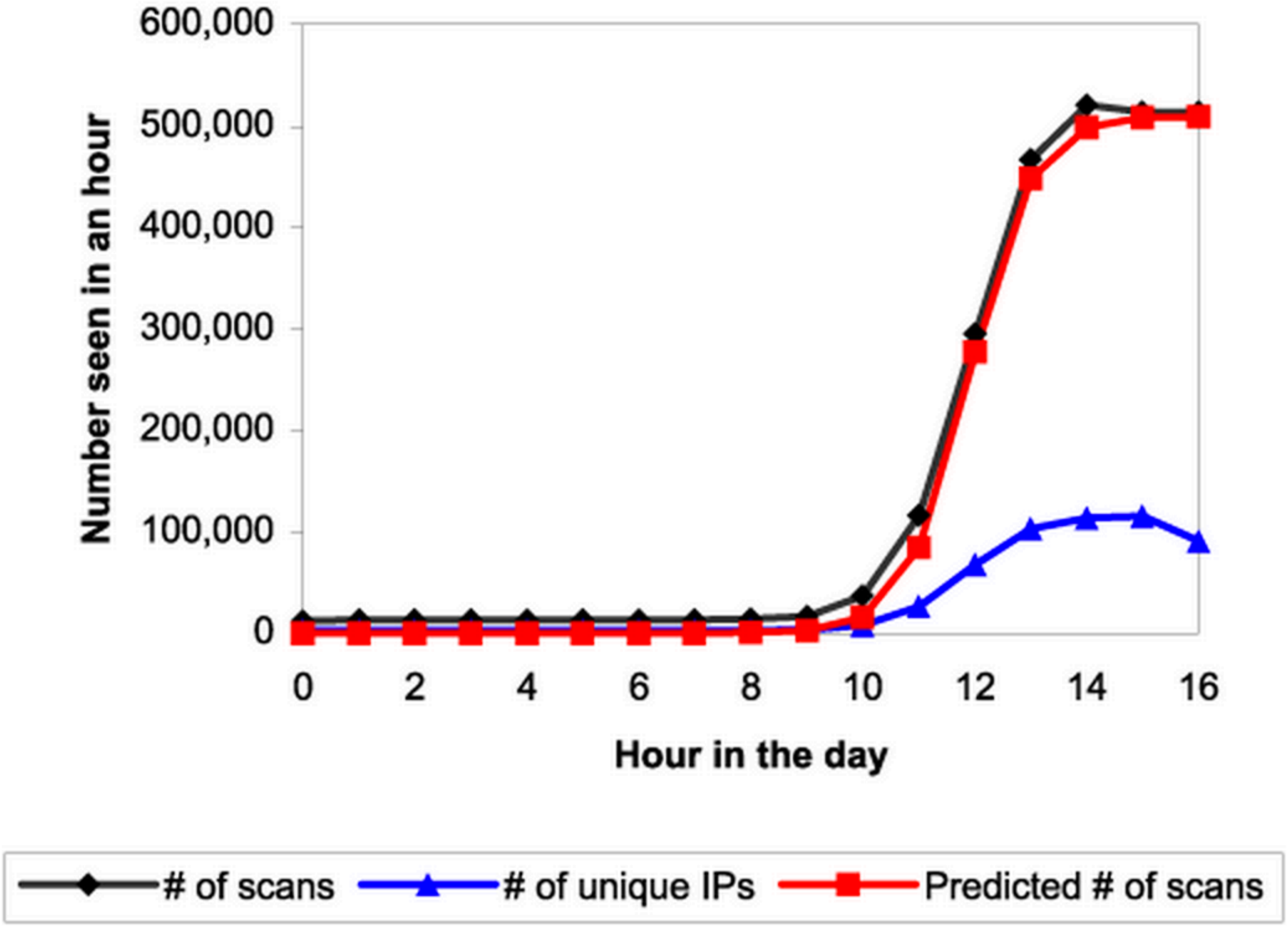
# Then…

- How many more machines will be compromised in next dt interval?
  - – Nda = NaK(1-a)dt
    - Assumes only infect once ("SI model" of epidemiology)
  - – da/dt = Ka(1-a)
  - – $a(t) = e^{K(t-T)}/(1+e^{K(t-T)})$
  - – Sigmoid or Logistic curve
    - Pierre Verhulst, 19th C.

# Logistic Curve



# Code Red



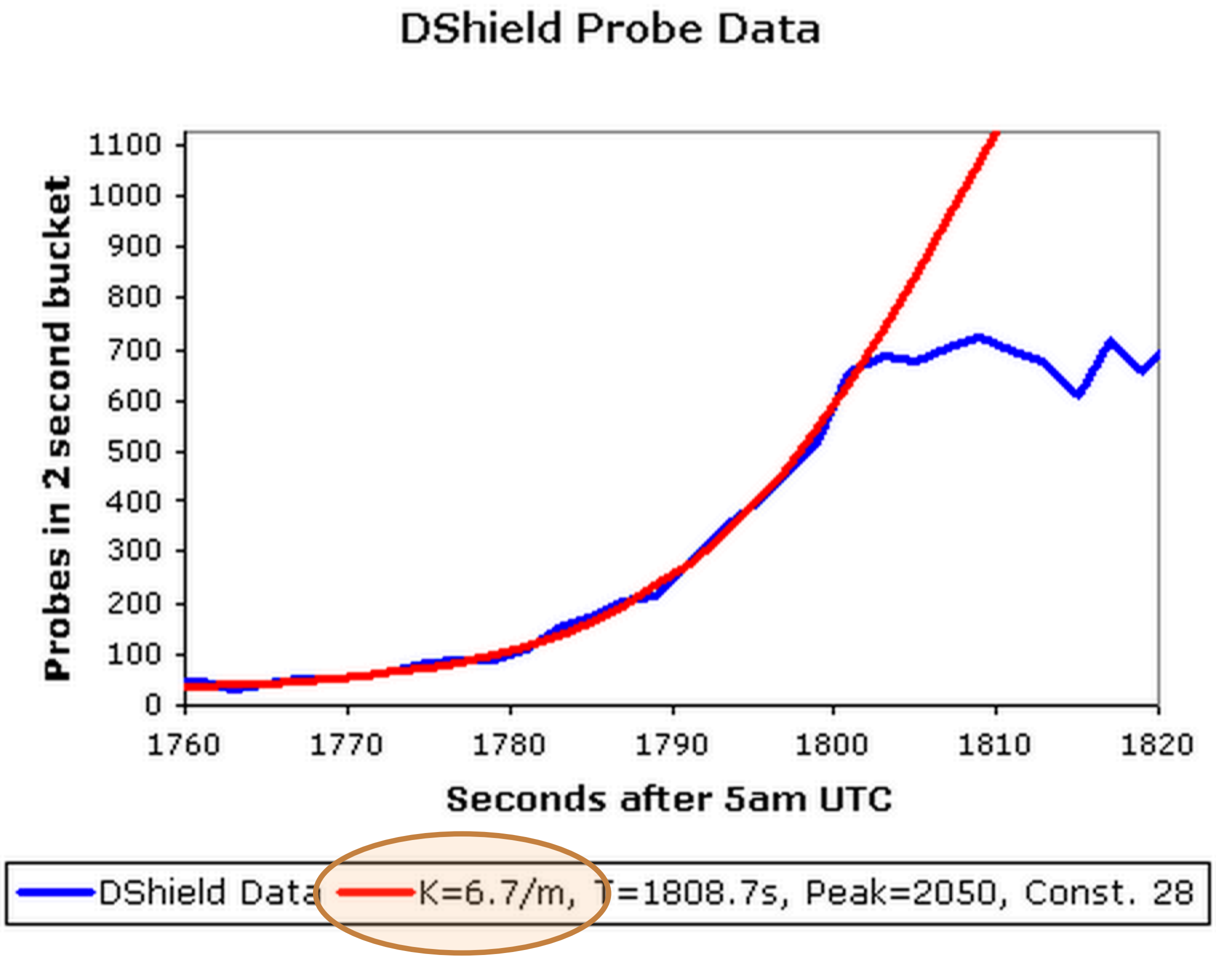
K = 1.8/hr

# Code Red Spread

- Vulnerability in IIS Web Server
  - http://www.youtube.com/watch?v=v6GnX3ZhuAg

# 5 Minute Break

# We thought Code Red was fast, until…



http://www.caida.org/publications/papers/2003/sapphire/sapphire.html

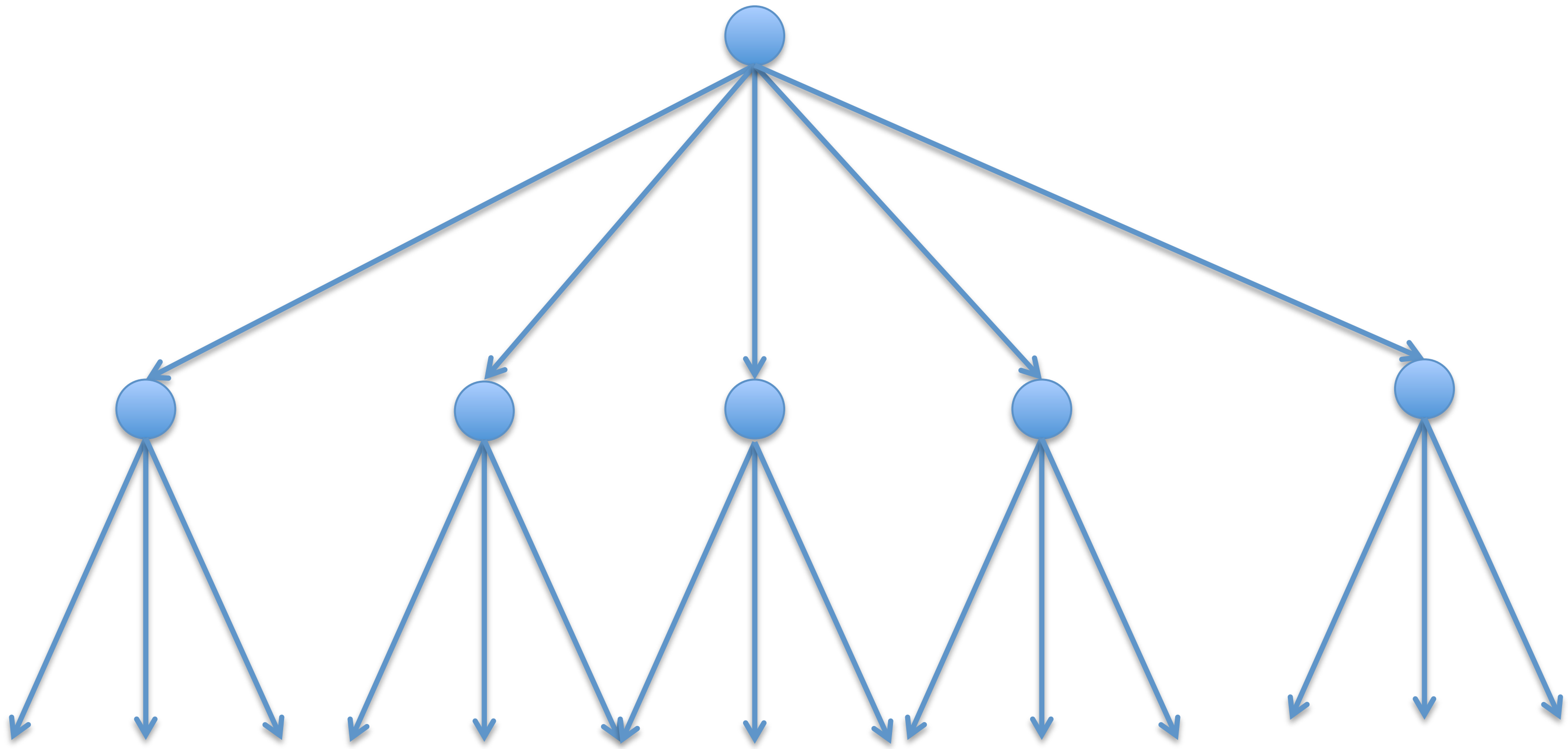
# How Slammer Did It

- Occurred in 2003.
- Exploited a vulnerability in MS SQL Server.
- Worm data was only 376 bytes!  Fit in one packet.
- Handcrafted machine code contained:
    - Data to overflow buffer and gain control
    - Code to find the addresses of needed functions.
    - Code to initialize a UDP socket
    - Code to seed the pseudo-random number generator
    - Code to generate a random address
    - Code to copy the worm to the address via the socket
- Could spew out hundreds or thousands of worms per second from each infected machine.

# How Fast Could a Worm Be?

- Flash worm strategy
  - Do the scanning ahead of time
    - Map entire network/Internet for vulnerabilities
    - (We know intelligence agencies do this)
  - Then precompute spread tree.
    - Each worm instance carries part of address list with it
    - Takes on infecting its part

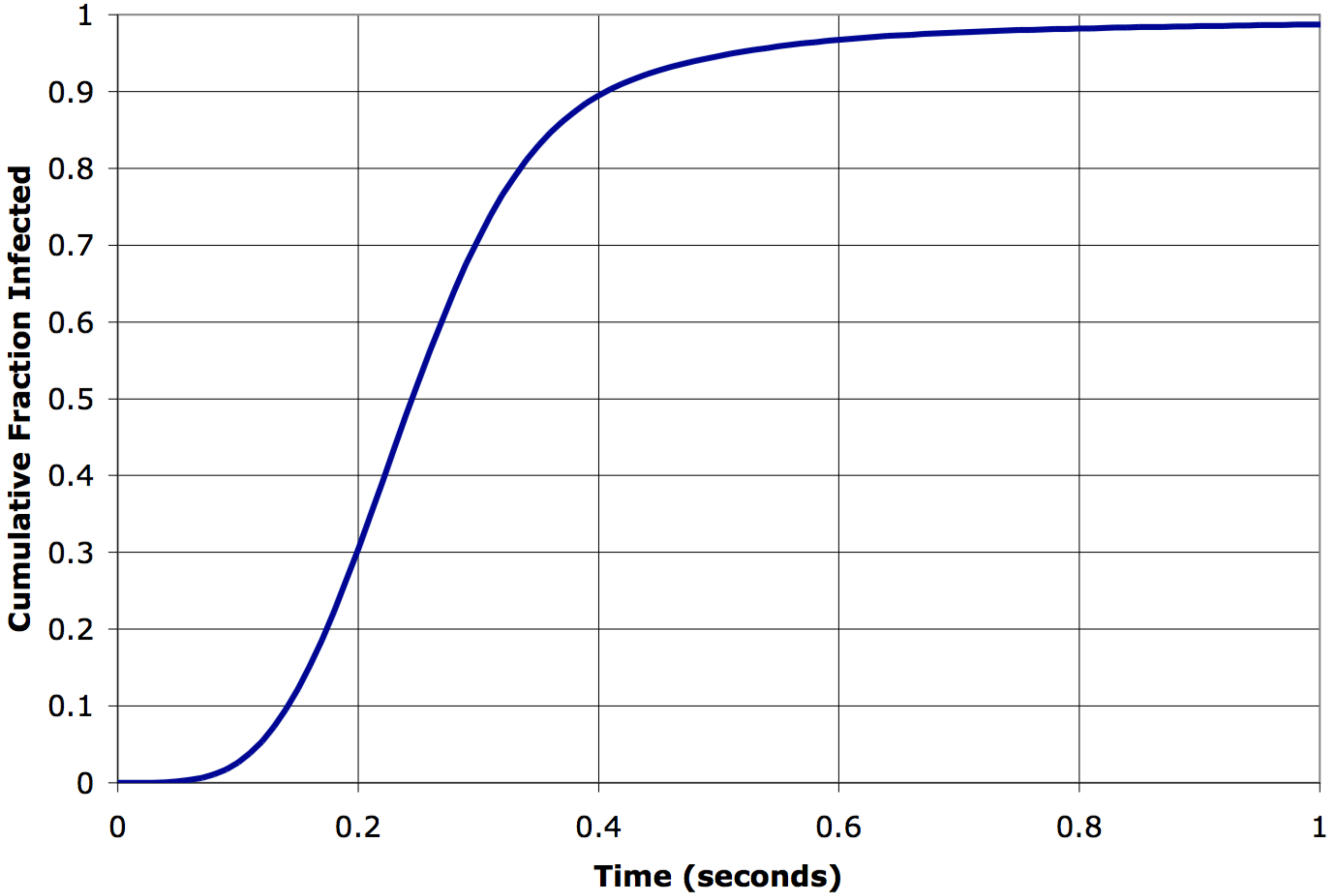
# Flash Worm Spread Tree



# Strategy

- Pick a very fast node to start on
  - Then a shallow tree
  - Secondary node address lists can fit in one pkt
- Simulation used observed Slammer packet delivery speed distribution
- Observed Internet latency distribution
- Optimum was 9260x107 to infect 1m hosts
- http://www.caida.org/publications/papers/2004/topspeedworms/topspeed-worm04.pdf

# Single Packet Flash Simulation



Fraction of a million Internet hosts infected

http://www.caida.org/publications/papers/2004/topspeedworms/topspeed-worm04.pdf

# Ultimate constraint

- Speed of light in fiber
  - To go half way around world as crow flies:
    - 6370000*3.14159/3x10$^8$/(2/3)
    - about 100ms
- Plus time to infect each host

# Defenses for Scanning Worms

- Host-level:
  - ASLR/DEP/Canaries/etc
  - Limit outbound connections
- Network level
  - Detect/block scanning
    - Firewalls
    - Packet filtering in routers
    - Intrusion prevention systems
    - In-switch security measures

# Overall Dynamic

- Suppose each worm finds r children to infect
  - Total before containment/remediation.
- Successive generations:
  - 1, r, $r^2$, $r^3$,…
  - $1 + r + r^2 + r^3 + \ldots = 1/(1-r)$ if $r<1$
  - Eg if $r = 0.9$, total is $1/(1-0.9) = 10$
  - If $r > 1$, series diverges.
- So must ensure each worm instance finds on average less than 1 child
  - Epidemic peters out
  - Known as "epidemic threshold"
  - Similar to critical mass in nuclear explosions

# Email Worms (1999)

- Mostly scourge of late 90s/early 2000s
  - Melissa – Microsoft Word Macro "Worm"
    - Word document attachment to email
    - Used a large variety of enticing subject lines to emails to try to get users to open attachment.
      - Very first version claimed to have passwords to porn sites.
      - Various 'social engineering' hooks to get you to open it
    - Some say not a worm, depending on whether macro language is a "program" or not.
    - Stole address book and mailed itself out

# I Love You (2000)

- Subject ILOVEYOU
- Attachment “LOVE-LETTER-FOR-YOU.txt.vbs”
- Scoured address book, so appeared to come from someone you knew.
  - *Many* people opened.
  - Believed to have affected tens of millions of computers.

# Email Worms in General

- Are “topological” worms
  - Find their victims using the natural topology of a protocol communication graph
    - In this case email address books
- Use ‘social engineering’
  - Tricking human users into doing something they shouldn’t.
  - In theory could use exploit in mail client, but hasn’t been seen on a large scale.

# Email Worm Defenses

- Anti-virus scanning of attachments
- Anti-spam screening of inbound emails
- User education.
  - Including warnings when opening strange attachments.
- Email worms appear not to spread as much any more.
  - Defenses must keep below epidemic threshold.
  - Except…

# Storm Worm (2007)

- Used subject lines like
  - "230 dead as storm batters Europe"
  - And many, many others tied to current events
- Had an executable attachment.
  - Defeated AV by "repacking" the exe every 10 minutes.
- Successfully built a large botnet
  - Probably for Russian organized crime.
  - Millions, maybe tens of millions of infected IPs.
- So email worm probably not permanently dead.

# Stuxnet Worm

- Discussion today is focussed on spread, not payload.
- Likely target of worm:
  - industrial controllers for centrifuges in Iranian nuclear plant (goal: damage/destroy them).
- Need to
  - Get on internal corporate networks of Iranian entities
  - Get on air-gapped SCADA networks.
  - Find machines attached to right controllers
  - Execute real payload.
- Worm was used as the search strategy to find and cross the bottlenecks.
  - Apparently worked: caused extensive delay to Iranians.

# Stuxnet Strategies

- Propagate through any network shares identifiable on accounts of infected computer.
- Zero-day print spooler vulnerability.
- Target hard-coded password in Siemens WinCC (SQL database) product.
- Windows server service vulnerability.
- Ability to infect USB drives.
  - Targetted a Windows vulnerability when viewing the folder on the drive.