“Proof-of-Work” Proves Not To Work

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Summary

- Viewing “spam” as an “economic” problem
- Proof-of-work mechanisms
- How much proof do you want?
- Analysis from an economic viewpoint
- Analysis from a security viewpoint
- Conclusions

Is spam an Economics problem?

- Unsolicited Bulk Email is a major problem
- Some argue that problem is “Economics”
  - no charge for sending email
  - hence “one in a million” response is profitable
- Hence the fix is to charge for email ?
  - real money? 1p/email => $160 billion annually
    - phone companies would love this -- would we ?
  - eCash? doesn’t seem to have happened yet !

Proof-of-work schemes I

- Idea is to show that you care enough about your email to have expended effort in doing a (rather pointless) calculation first
  - there are ideas for useful calculations eg “Bread Pudding Protocols” (Jakobsson & Juels 1999) but generally just warms up the planet ☹
- Original idea: Dwork & Naor : Crypto 1992
  - used central server ☹☹☹

Proof-of-work schemes II

- Reinvented as HashCash (Adam Back, 1997)
  - compute HASH(destination, time, nonce) such that result has “n” leading zeros
  - 2^n hard for sender, but trivial check for receiver
- Dwork, Goldberg, Naor (Crypto 2003)
  - analyse a function limited by memory speed
  - small variation between systems (factor of 4)
  - so this is much better than using classic HASH

Email Statistics

- November 2003 (consistent stats available)
  - 2.30×10^8 Internet hosts (ISC)
  - 5.13×10^8 Internet users (Radicati)
  - 5.70×10^{10} emails sent daily (Radicati)
  - 56% of all email is “spam” (Brightmail)
- Hence the average situation is
  - 60 spam (& 50 real) emails per person per day
  - 125 real emails per host per day

What about “mailing lists” ?

- Expect to delegate proof-of-work analysis
- Lists common, but no published figures
- Inspected logs at large UK ISP (200K users)
  - this was after a spam filtering stage
  - consider identical source but >10 destinations
  - approximately 40% are of this form
- ie: reduce total to 75 emails per host per day
  - “back of envelope”, but only magnitude matters

How much work must we prove?

- Legitimate hosts must be able to send 75 emails per day (best case situation)
- Must reduce spam from 3.2×10^{10} per day
- Must allow for factor of 4 in capabilities
- Must assume spammers work 24 hours per day, but legitimate hosts may be switched off when not being actively used

… so all we need to do is to pick "n"

Economic analysis I

- Spammers charge 0.001 to 0.030¢ per email
  - survey in Goodman & Rounthwaite, 2004
- PC costs $500 / three years 50¢ per day
  - and pay electricity bill! 25¢ per day
- Spammer invests $50K and buys 100 PCs:
  - Salary $30K/annum 100¢ per day
  - So break-even at 35,000 emails/day/PC if can charge 0.005¢ each (ie: total 3.5 million /day)

[Scott Richter does 21 million/day @ 0.020¢]

Economic analysis II

- But spammers used to charge 0.1¢ per email (which leads to a break even rate of 1750)
- Spam response rates badly documented
  - Ms Betterly (WSJ Nov 2002) : 0.0023%
  - 0.0126% Iraqi Cards ("four times normal")
- If 0.003% and 0.1¢ then cost of ads is $33/sale. Only viable for some products
  - $50/mortage lead; $85/cellphone, $60/pills


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Economic analysis III

- Iraqi cards article (NYT 9 July 03) goes on:
  - best days: $5000 profit per million emails
    ie: half a cent per email in commission
  - printer ink: $500 to $1200 per million emails
    ie: 0.05¢ to 0.12¢ per email in commission
- Obviously wise to own more of value chain
- AND note that legitimate email response rates are expected to be 0.7 to 1.6%

Economic conclusion

- Good guys
  - 75 emails/host (best case)
- Bad guys
  - 1750 emails/host (if price returns to 0.1¢)
  - but this will exclude low margin products ☺
- BUT bad guys have “factor of 4” advantage
- So some headroom here, but not lots & lots

AT CURRENT RESPONSE RATES

Security analysis I

- Lots of ***0wned*** machines out there
  - SORBS: 1.2M HTTP, 1.4M SOCKS proxies
  - Recent viruses have hit million+ machines each
- Currently easy to spot ***0wned*** machines
  - they send a lot of email!
- But what if they computed "proof-of-work"
  - quietly giving results to sender systems
  - hard to spot and so likely to be long-lived

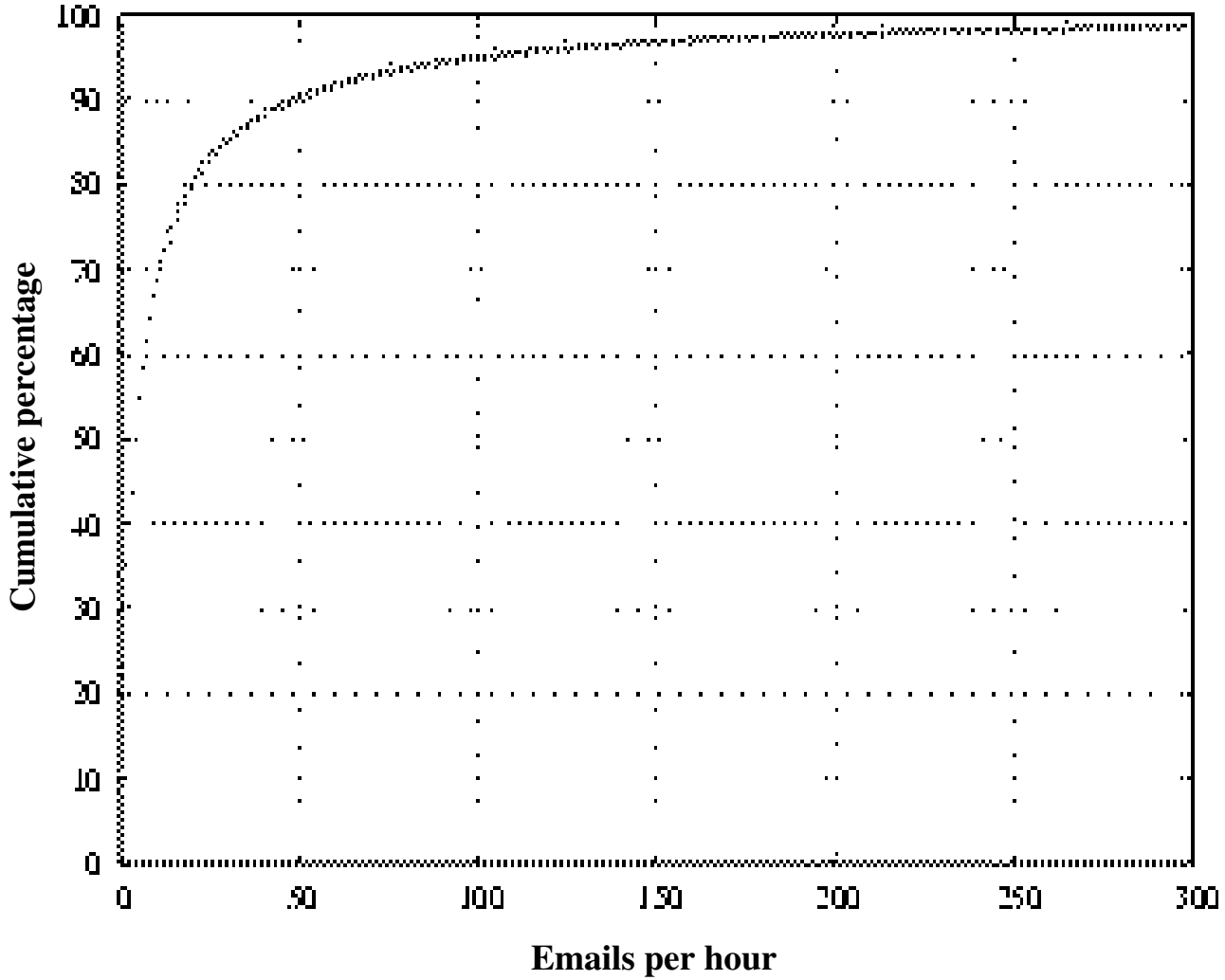
Security analysis II

- Nov 2003, 3.2 x 10^{10} spam emails
- Suppose one million machines hijacked for proof-of-work (spammers share them out!)
- So, they only need to do 32,000 each
  - consistent with ISP figures for abused hosts
- If want 99% of our mailboxes to be "real" then must restrict spam to 250/host per day
- & for just 0.1% to be spam, then 25 per day

Security conclusion

- Good guys
  - 75 emails/host (best case)
- Bad guys
  - 250 emails/host (if spam is just 1% of mailbox)
- No “factor of 4” advantage this time
  - unless spammers can choose *0wned* machines
- So **very** limited headroom
  - & impossible to reach “one in a thousand” level

Real hosts : daily rates



93.5% < 75

BUT

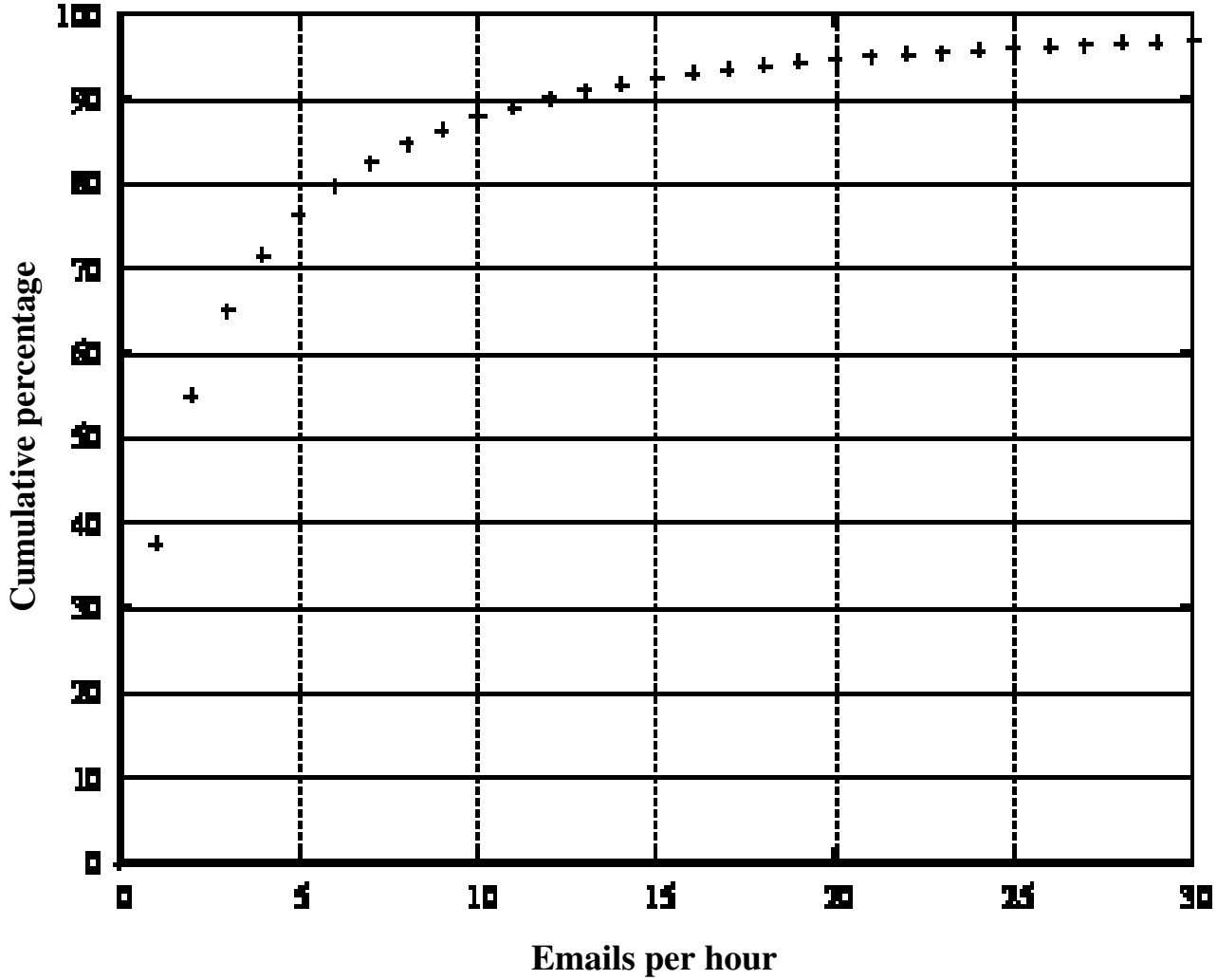
0.13% > 1750

1.56% > 250

viz: this impacts real senders

albeit some are just [exempted] mailing lists

Real hosts : hourly rates



Spammers run
24 hours/day,
real users don't!

1% > 73/hour
i.e.1750/day

13% > 11/hour
i.e. 250/day

viz: this impacts
lots of people

Conclusions

- HashCash payment for email is attractive
- BUT spammer profit margins per sale mean that some will be able to afford the PCs to do the proof-of-work required
- BUT hijacking of end-user machines means impractical to restrict them to 1% of email
- Simplistic proof-of-work just doesn't work!

“Proof-of-Work”

~~Proves~~ Not To Work
Proven

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& thanks to