Defending Against Derandomization Attacks

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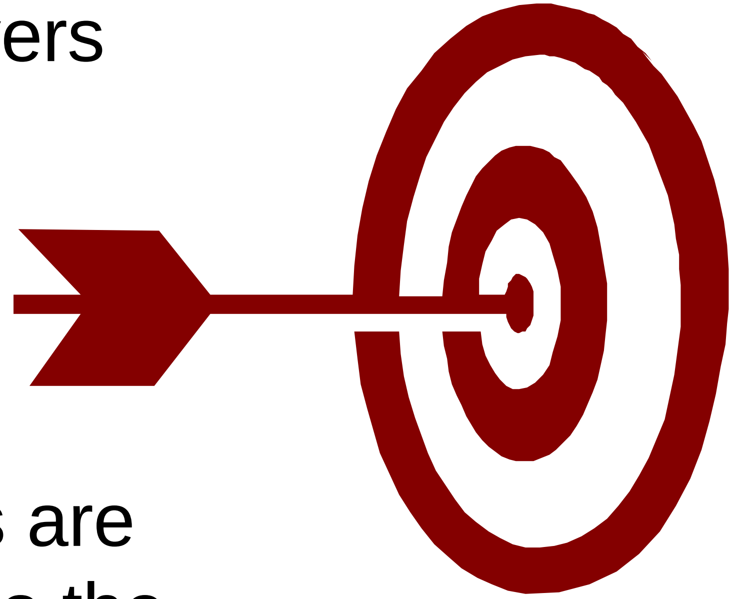
Motivation: Meet Jane Whitehat

- Jane’s servers provide a critical service
  - If service is interrupted for more than a few minutes at a time, Bad Things happen:
    - Business may grind to a halt
    - Fortunes may be lost
    - Careers may be ruined…
    - Lives may be in jeopardy?

Jane's services

- Jane's servers are a juicy target
  - Maybe Jane's employers have enemies…
  - Maybe the data on Jane's servers is very valuable…
  - Maybe Jane's servers are just a way to break into the company's network and go for the big score



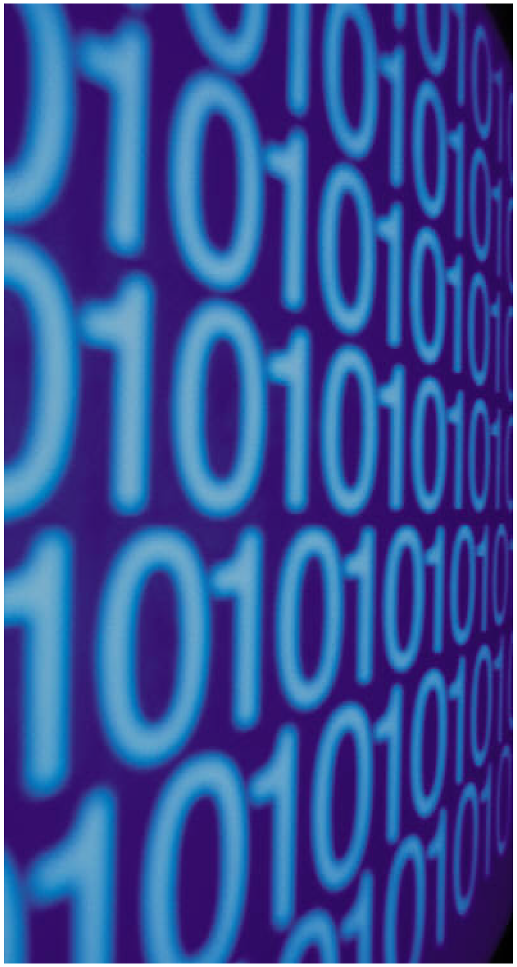
Know thy enemy

- Meet John Blackhat, l337 h4x0r
- John wants into Jane's network
  - He has motivation
  - He knows his trade:
    - Stack smashing attacks
    - Return to libc attacks
    - …
  - He has corporate/national backers???

Jane’s defense

- Jane protects her services by deploying instruction set randomization
  - Or maybe StackGuard…
  - Or address space randomization...
  - Or maybe all of the above…

Randomization defenses



- Any of these techniques work by randomizing some part of the running system
  - Attacker must guess a key before an attack succeeds
  - In ISR on Jane's Intel Heptium-based servers, this is a 16-bit value XORed with the instruction stream

Keys can be guessed at

- Remember *War Games*? After enough guesses you too could start WWIII…

CPE1704TKS

- Conclusion:

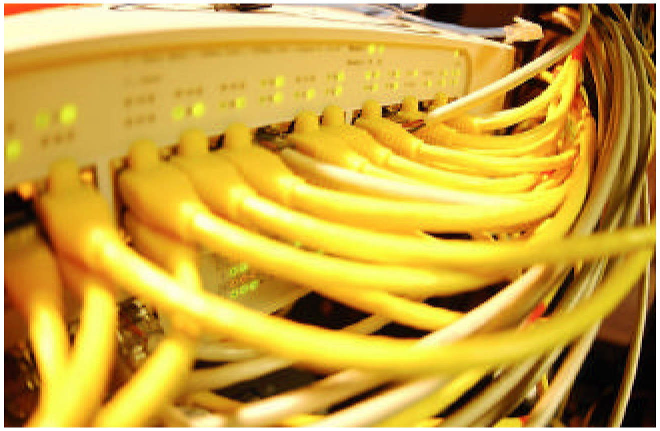
Jane Needs Our Help!

Sometimes failure is good

- Randomization defenses share some characteristics that may help us help Jane:
  - Any given attack attempt is likely to fail
  - Any failed attempt is likely to crash the system
- Why is this good?
  - Because it gives us a way to identify attack attempts (After the fact, though)

Can we find the attacker?

- Thought: maybe we can identify the attacker's IP address and block it
  - Easy to implement; minimal impact on users
  - What about spoofing?
    - If Jane's services require a full TCP connect, it is hard (but not impossible) to spoof the address…
  - But there are other problems…

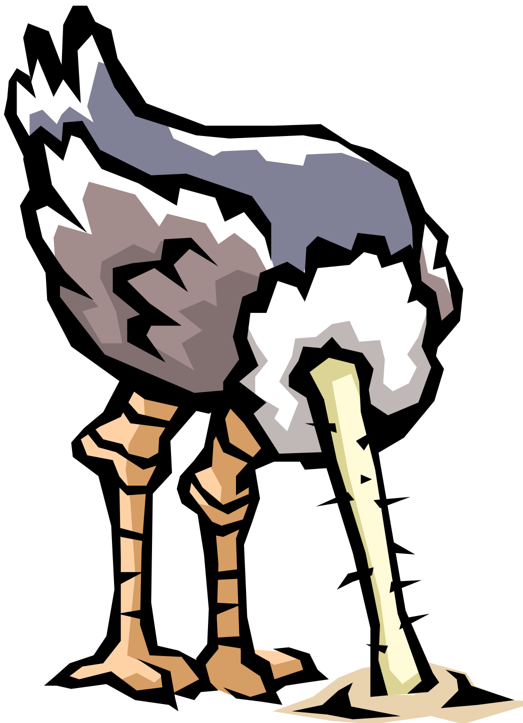


Problems with blacklisting…

- What if John has written a worm?
  - Attacks could be coming in from > 2^{14} compromised hosts at the same time…
- What if John employs a zombie network?
  - Ditto
- What if the attacker has access to the intranetwork wiring?
  - Could pretend to be a legitimate client…

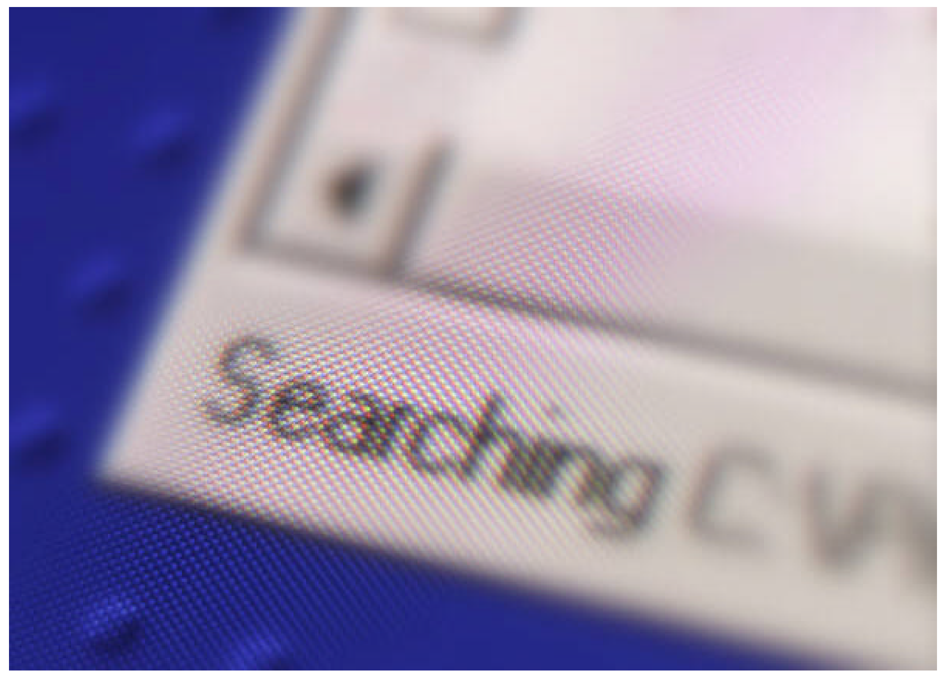
Maybe we can duck and cover?

- In some we can detect an attack and suspend service until the sysops can react…
  – Could take an eternity … maybe even minutes ☺
  – Bottom line: Jane doesn't have the luxury of being able to do this



When all else fails…

- Maybe we can learn something about the requests themselves
  - If we could find a pattern in the requests that cause crashes, we could block attacks as they happen

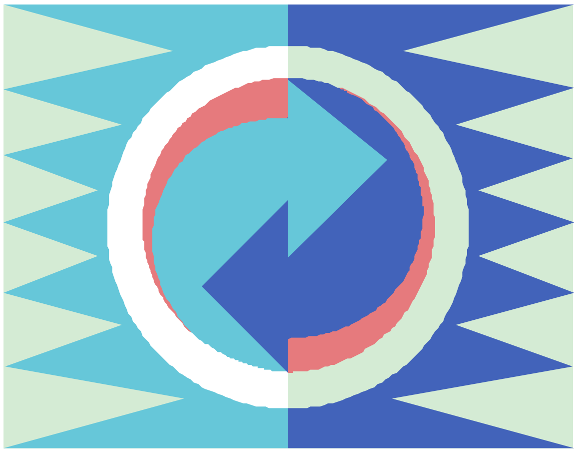


Assumptions I’ve made

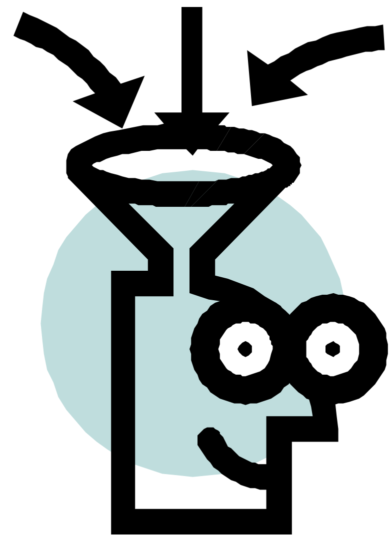
- Jane’s service receives requests as binary blocks over the network and sends one reply to each
- Jane’s service is written in C/C++ and has a buffer overflow hole (oops!)
- John has access to the code for the software Jane uses

More assumptions…

- Jane is willing to make modifications to the server software at the source level
  - Maybe we could do this at the OS level, but we'll cross that bridge when we get there…
- Jane's servers are configured to reboot the server software when it crashes



Knowing when to learn…



- We modify Jane's software so that:
  - Before accepting a request,
    it checks against known attack signatures and saves the incoming request as a 'suspicious' request file
  - After servicing a request, it marks the suspicious request as good instead
  - When it starts up, it looks for a suspicious request file—if it's there, the process must have crashed, and the file contains the request that crashed it

Finding the patterns

- We can look for areas of a request that match other known attack requests
  - First, sort a pair of requests by byte values
  - Look at each matching pair of bytes in turn:
    - Are they part of a matching regions in the unsorted request streams? If so, take as big a region as we can get…

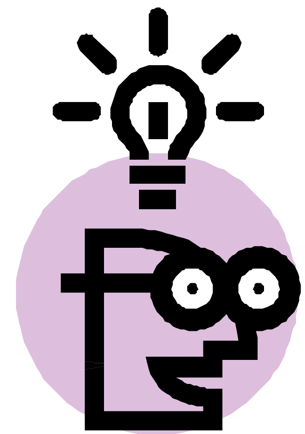
  - Basically, this is what grep does…

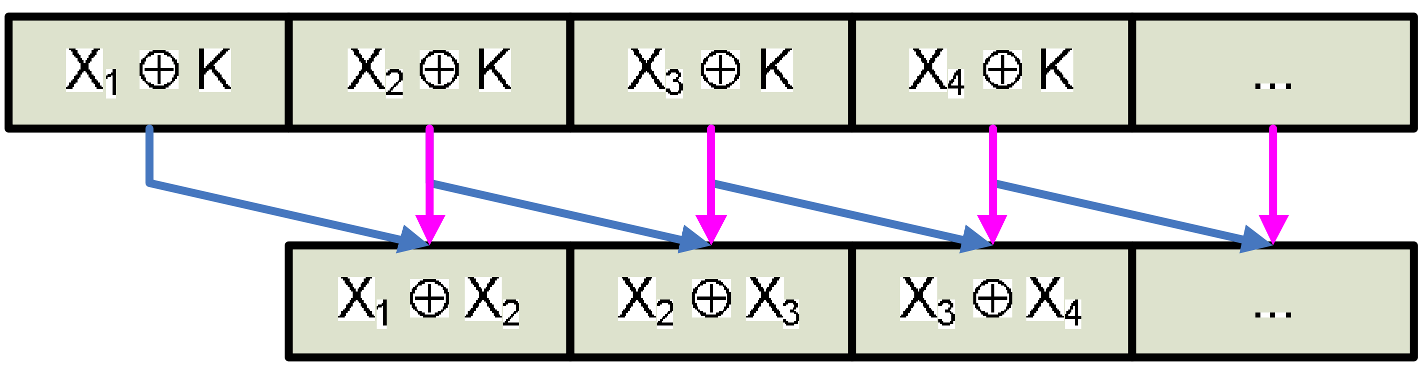
Finding too much

- It is possible to find too big a pattern
  - We want patterns that are general enough to catch all similar attacks but specific enough not to generate false positives…
  - We can solve this by finding patterns in the patterns

Doesn’t ISR pose a problem?

- Not really, you just need to do two scans for signatures:
  - The first is the normal scan, and it picks up unencrypted things like static strings and the target buffer address
  - The second is on a special de-ISR’d version of the requests:





Yeah, yeah, but does it work?

- Well, sort of…
  - Tested using:
    - 4,388 randomly generated 64-to-512 byte ‘good’ requests (512 byte buffer, did 1,000 at startup),
    - 275 simple buffer-overflow attacks straight out of *Smashing the Stack for Fun and Profit* tweaked for 16-bit XOR ISR, and
    - 337 attacks of my own devious design
    - A minimum of 6-byte keys

And???

- The good news:
  - The algorithm detected all but 4 of the stack smashing attacks and blocked them, and
  - Not one false positive!

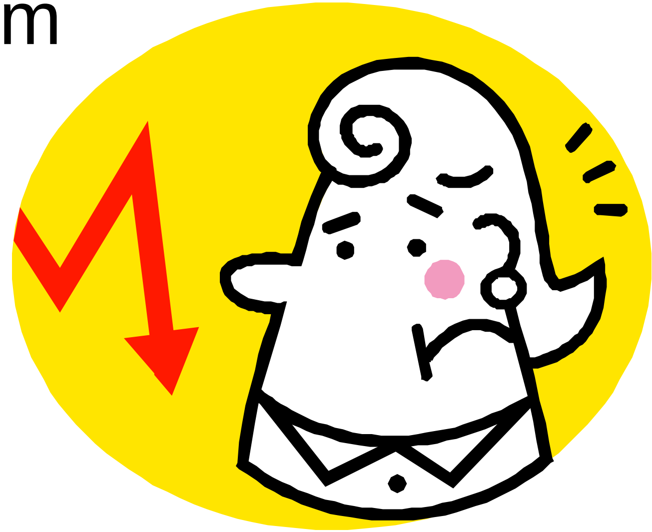
- The bad news:
  - My devious test was a bit too devious—the algorithm failed to block a single instance

How devious is devious?

- The devious requests need only 6 non-random bytes:
  - Two bytes of code: EB FE
  - Four bytes of data: the location of the injected code, partially randomizable
  - The rest of the attack buffer can be completely randomized—no patterns to find!
  - Note: this only tells you what the randomization key is, it doesn't get you in

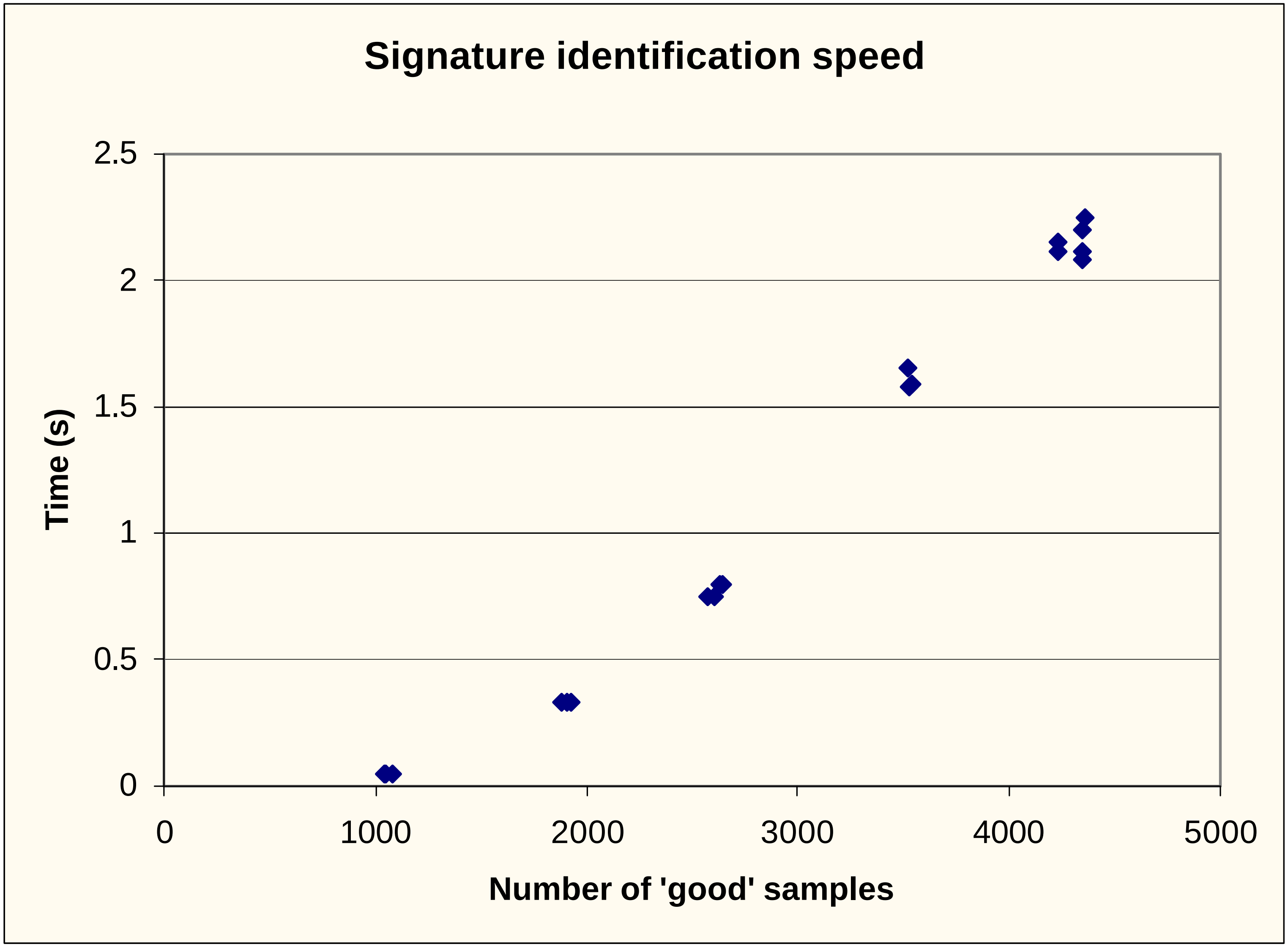
Can we block the devious case?

- Probably not with this algorithm
  - Tried reducing the minimum key size to 4 bytes
  - Algorithm blocked 150 of 347 attack attempts (that's 43% and its still better than nothing)
  - BUT at the cost of a false positive
    - 0.02% false positives, but may still be too much

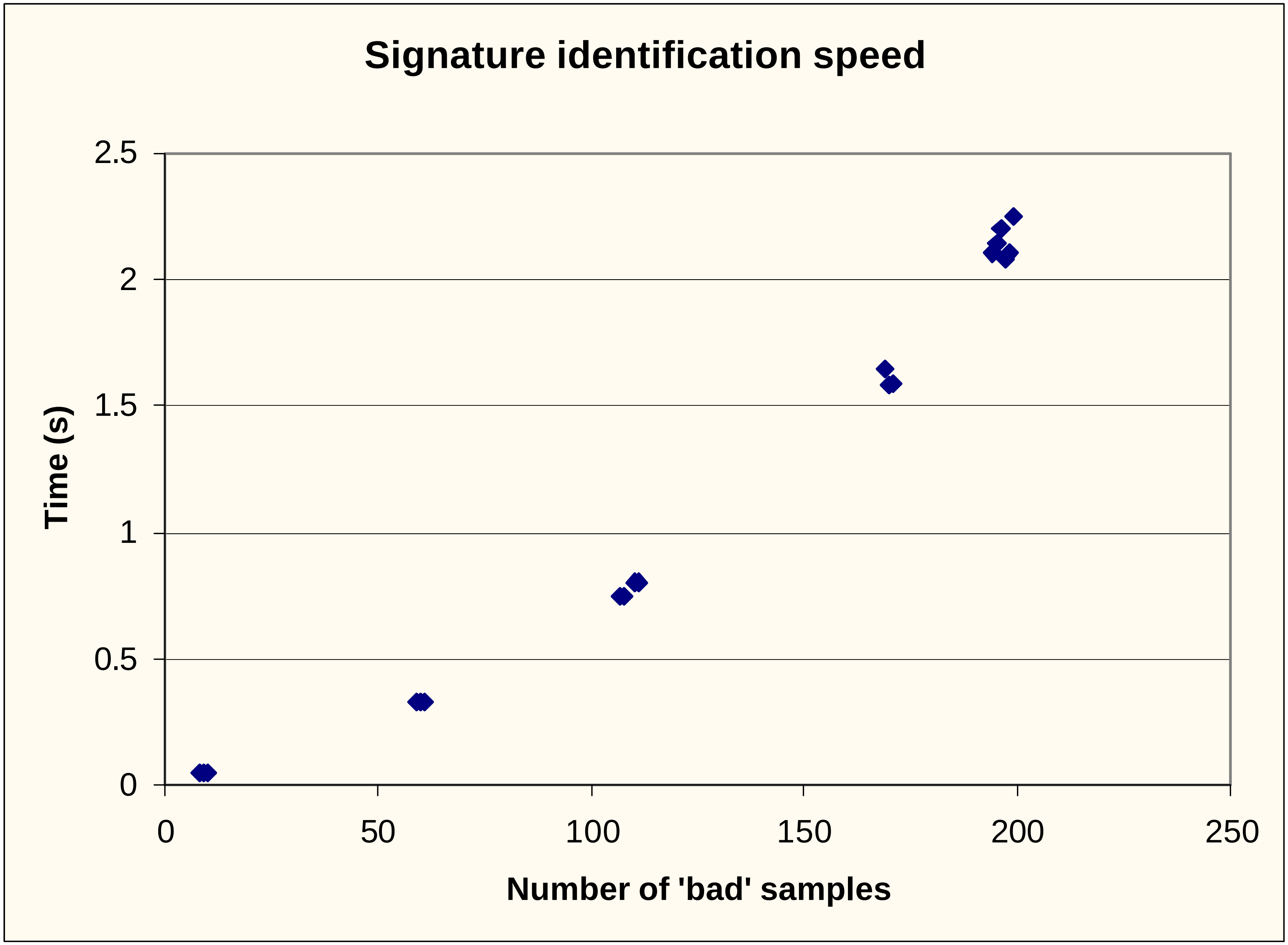


Any performance impact?

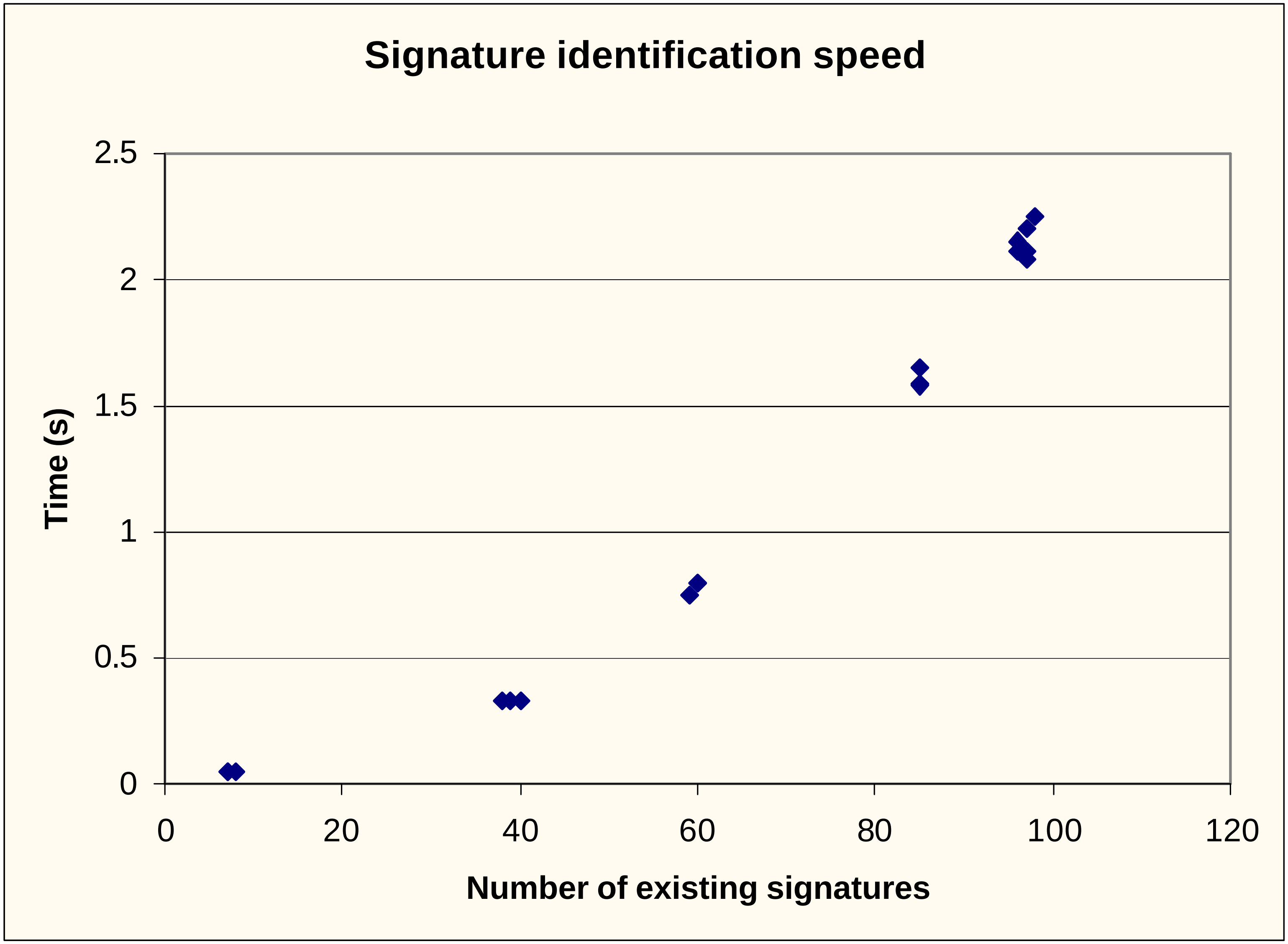
- Some:
  – Loading the data sets took ~15 ms and didn't seem to scale badly (and that's good)
  – Requests examined in no time at all (well, in no time that could be measured on my Wintel box…)
  – What about signature identification speed?



Signature identification speed
Time (s)
2.5
2
1.5
1
0.5
0
0
1000
2000
3000
4000
5000
Number of 'good' samples



Signature identification speed
Time (s)
Number of 'bad' samples
0
0.5
1
1.5
2
2.5
0
50
100
150
200
250



Signature identification speed
Time (s)
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Number of existing signatures

So what now?

- Well, the signature detection algorithm isn't perfect, but it may still be useful
  - Need to try this on other kinds of attacks
    - Should try a return-to-libc on a Fedora box…
  - Need to try this with real requests
    - Actual sever requests may be more or less similar to the attack patterns than my random generations
  - Need to experiment with techniques for managing the size of the good and bad sets

Any questions???

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