MALWARE: VIRUSES

CMSC 414

FEB 08 2018

MALWARE

Malicious code that is stored on and runs on a victim's system

- How does it get to run?
  - Attacks a user- or network-facing vulnerable service
  - Backdoor: Added by a malicious developer
  - Social engineering: Trick the user into running/clicking/installing
  - Trojan horse: Offer a good service, add in the bad
  - Drive-by download: Webpage surreptitiously installs
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Potentially from any mode of interaction (automated or not), provided sufficient vulnerability

MALWARE: WHAT CAN IT DO?

Virtually anything, subject only to its permissions

- Brag: “APRIL 1st HA HA HA HA YOU HAVE A VIRUS!”
- Destroy:
  - Delete/mangle files
  - Damage hardware (more later this lecture)
- Crash the machine, e.g., by over-consuming resources
  - Fork bombing or “rabbits”: while(1) { fork(); }
- Steal information (“exfiltrate”)
- Launch external attacks
  - Spam, click fraud, denial of service attacks
- Ransomware: e.g., by encrypting files
- Rootkits: Hide from user or software-based detection
  - Often by modifying the kernel
  - Man-in-the-middle attacks to sit between UI and reality

MALWARE: WHEN DOES IT RUN?

Some delay based on a trigger

- Time bomb: triggered at/after a certain time
  - On the 1st through the 19th of any month…
- Logic bomb: triggered when a set of conditions hold
  - If I haven't appeared in two consecutive payrolls…
- Can also include a backdoor to serve as ransom
  - "I won't let it delete your files if you pay me by Thursday…"

Some attach themselves to other pieces of code

- Viruses: run when the user initiates something
  - Run a program, open an attachment, boot the machine
- Worms: run while another program is running
  - No user intervention required

SELF-PROPAGATING MALWARE

- Virus: propagates by arranging to have itself *eventually* executed
  - At which point it creates a new, additional instance of itself
  - Typically infects by altering *stored* code
  - User intervention required

- Worm: *self*-propagates by arranging to have itself *immediately* executed
  - At which point it creates a new, additional instance of itself
  - Typically infects by altering *running* code
  - No user intervention required

The line between these is thin and blurry

Some malware uses both styles

MALWARE: TECHNICAL CHALLENGES

- Viruses: Detection
  - Antivirus software wants to detect
  - Virus writers want to avoid detection for as long as possible
  - ***Evade*** human response
- Worms: Spreading
  - The goal is to hit as many machines and as quickly as possible
  - ***Outpace*** human response

VIRUS
DESIGN

VIRUSES

- They are **opportunistic**: they will *eventually* be run due to user action

- Two *orthogonal* aspects define a virus:
  1. How does it **propagate**?
  2. What else does it do (what is the "**payload**")?

- General infection strategy:
  - Alter some existing code to include the virus
  - Share it, and expect users to (unwittingly) re-share

- Viruses have been around since at least the 70s

HOW VIRUSES INFECT OTHER PROGRAMS

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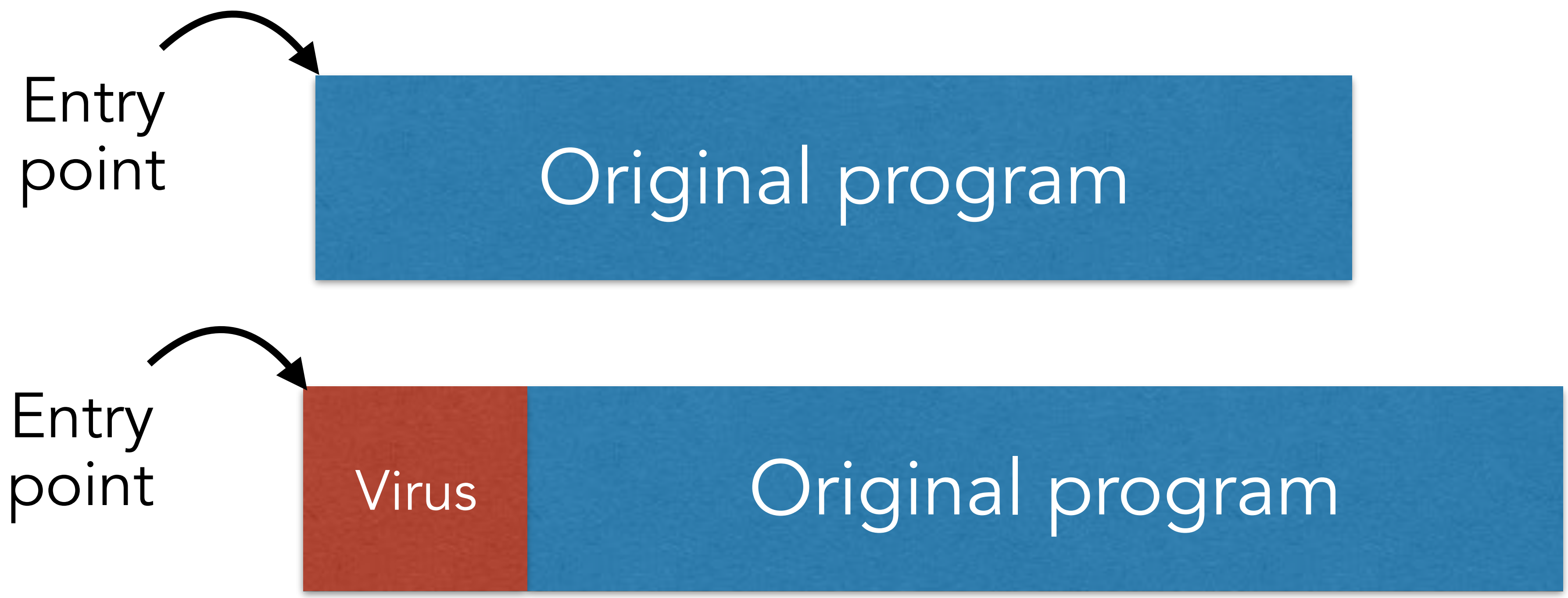

Take over the entry point

VIRUSES ARE CLASSIFIED BY WHAT THEY INFECT

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  - Implemented within a formatted document
  - Word documents (very rich macros)
  - PDF (Acrobat permits javascript)
  - (Why you shouldn’t open random attachments)

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  - Boot sector: small disk partition at a fixed location
  - If the disk is used to **boot**, then the firmware loads the boot sector code into memory and runs it
  - What's *supposed* to happen: this code loads the OS
  - Similar: AutoRun on music/video disks
  - (Why you shouldn't plug random USB drives into your computer)

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- Memory-resident viruses
  - “Resident code” stays in memory because it is used so often

VIRUSES HAVE RESULTED IN A TECHNICAL ARMS RACE

The key is ***evasion***

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Want to be able to claim wide coverage for a long time

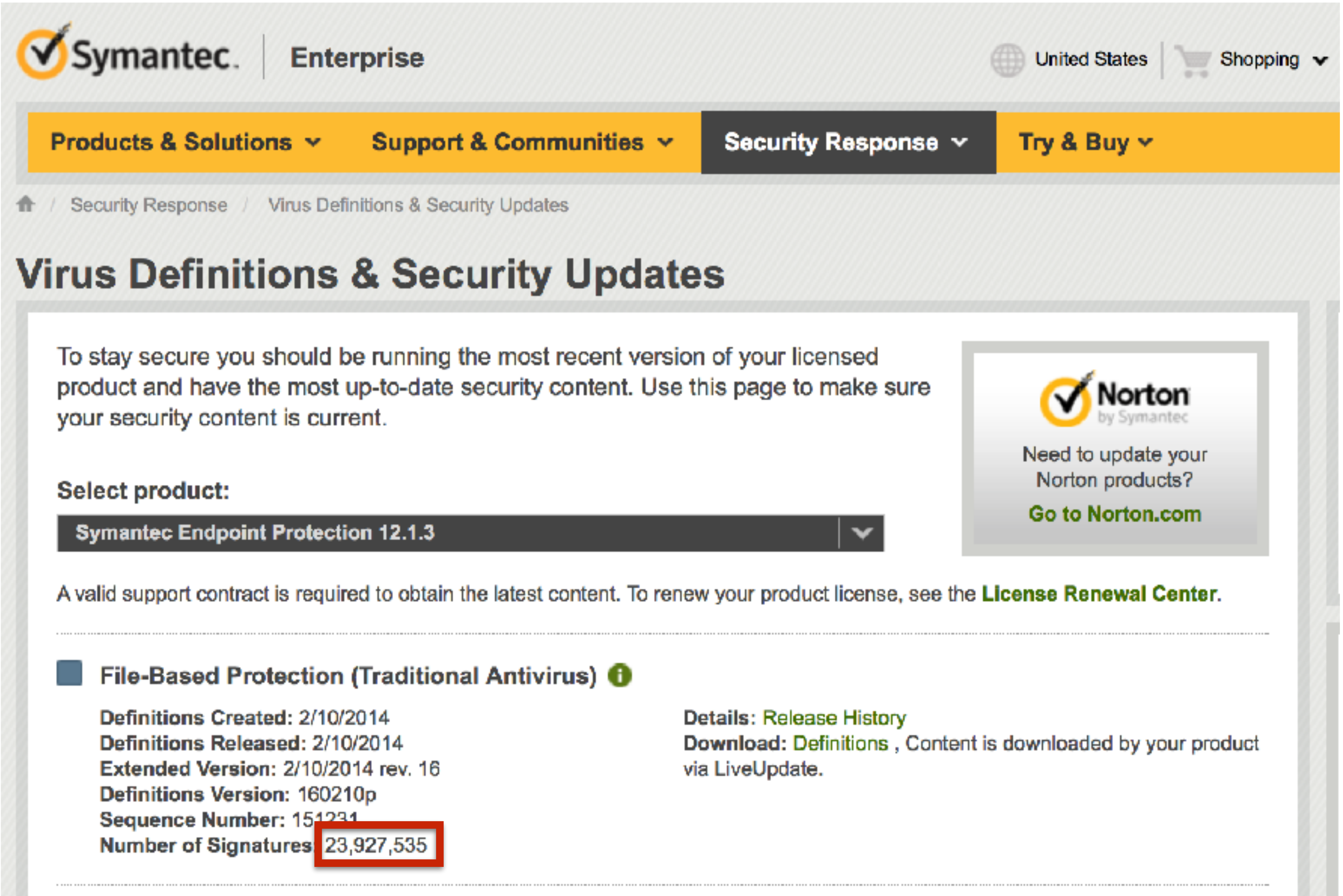
Want to be able to claim the ability to detect *many* viruses

HOW VIRUSES PROPAGATE

- First, the virus looks for an **opportunity to run**. Increase chances by attaching malicious code to something a user is likely to run
  - autorun.exe on storage devices
  - Email attachments
- When a virus runs, it looks for an **opportunity to infect** other systems.
  - User plugs in a USB thumb drive: try to overwrite autorun.exe
  - User is sending an email: alter the attachment
  - Viruses can also proactively create emails ("I Love You")

DETECTING VIRUSES

- **Method 1: Signature-based detection**
  - Look for bytes corresponding to injected virus code
  - Protect other systems by installing a recognizer for a known virus
  - In practice, requires fast scanning algorithms
- This basic approach has driven the multi-billion dollar antivirus market
- #Recognized signatures is a means of **marketing** and competition
  - But what does that say about how important they are?


Symantec.
Enterprise
United States
Shopping
Products & Solutions
Support & Communities
Security Response
Try & Buy
Security Response / Virus Definitions & Security Updates
Virus Definitions & Security Updates
To stay secure you should be running the most recent version of your licensed product and have the most up-to-date security content. Use this page to make sure your security content is current.
Norton by Symantec
Need to update your Norton products?
Go to Norton.com
Select product:
Symantec Endpoint Protection 12.1.3
A valid support contract is required to obtain the latest content. To renew your product license, see the License Renewal Center.
File-Based Protection (Traditional Antivirus)
Definitions Created: 2/10/2014
Definitions Released: 2/10/2014
Extended Version: 2/10/2014 rev. 16
Definitions Version: 160210p
Sequence Number: 151231
Number of Signatures: 23,927,535
Details: Release History
Download: Definitions , Content is downloaded by your product via LiveUpdate.

Um.. thanks?

FEATURE

Antivirus vendors go beyond signature-based antivirus

Robert Westervelt, News Director

Share

This article can also be found in the Premium Editorial Download **"Information Security magazine: Successful cloud migrations require careful planning."**

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Security experts and executives at security vendors are in agreement that signature-based antivirus isn't able to keep up with the explosion of malware. For example, in 2009, Symantec says it wrote about 15,000 antivirus signatures a day; that number has increased to 25,000 antivirus signatures every day.

"Signatures have been dying for quite a while," says Mikko H. Hypponen, chief research officer of Finnish-based antivirus vendor, F-Secure. "The sheer number of malware samples we see every day completely overwhelms our ability to keep up with them."

Security vendors have responded by updating their products with additional capabilities, such as file reputation and heuristics-based engines. They're also making upgrades to keep up with the latest technology trends, such as virtualization and cloud computing.

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    1. **Give them a harder signature to find**

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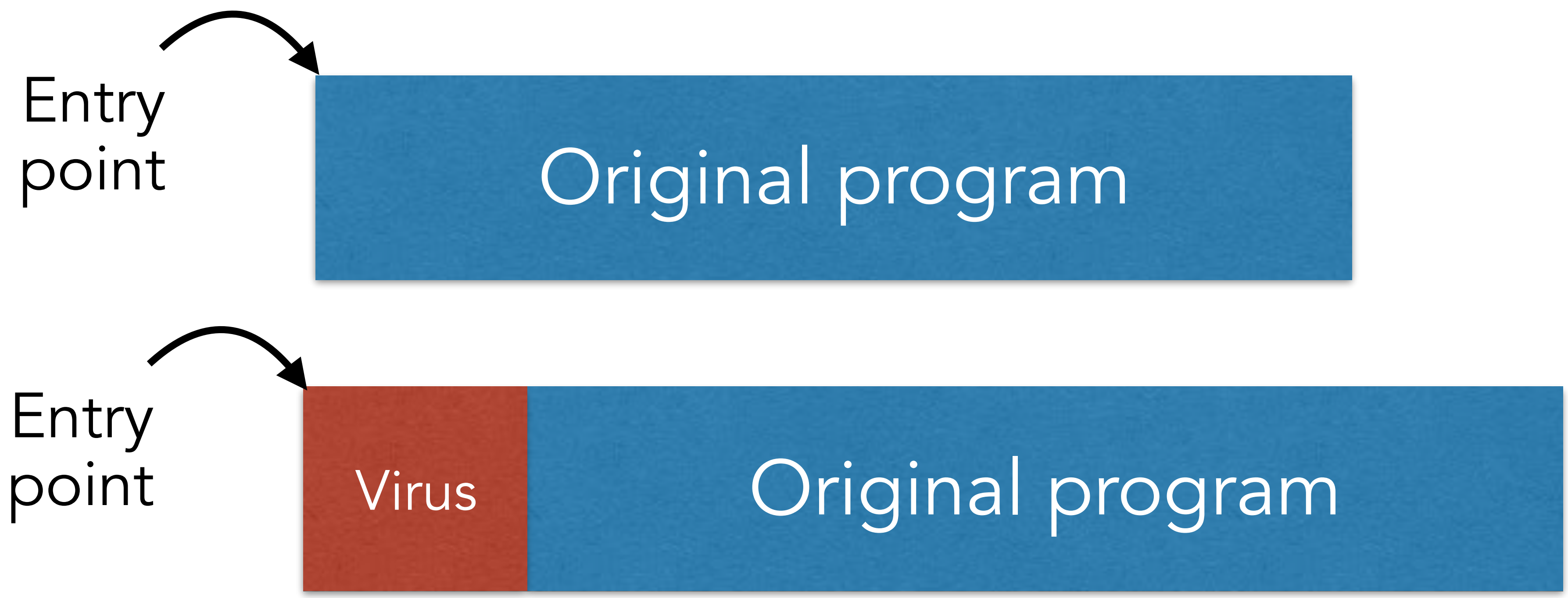
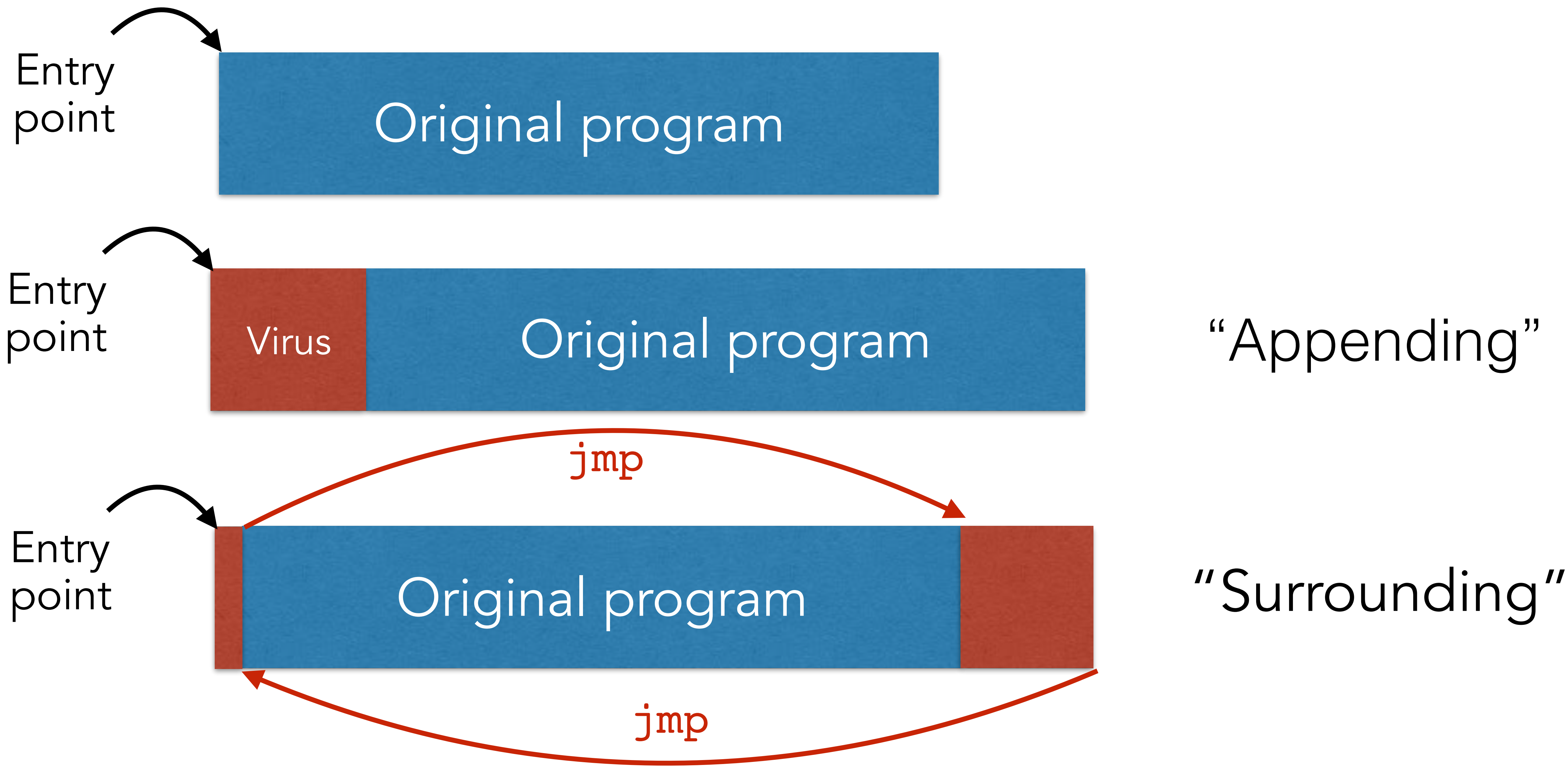


"Appending"

HOW VIRUSES INFECT OTHER PROGRAMS



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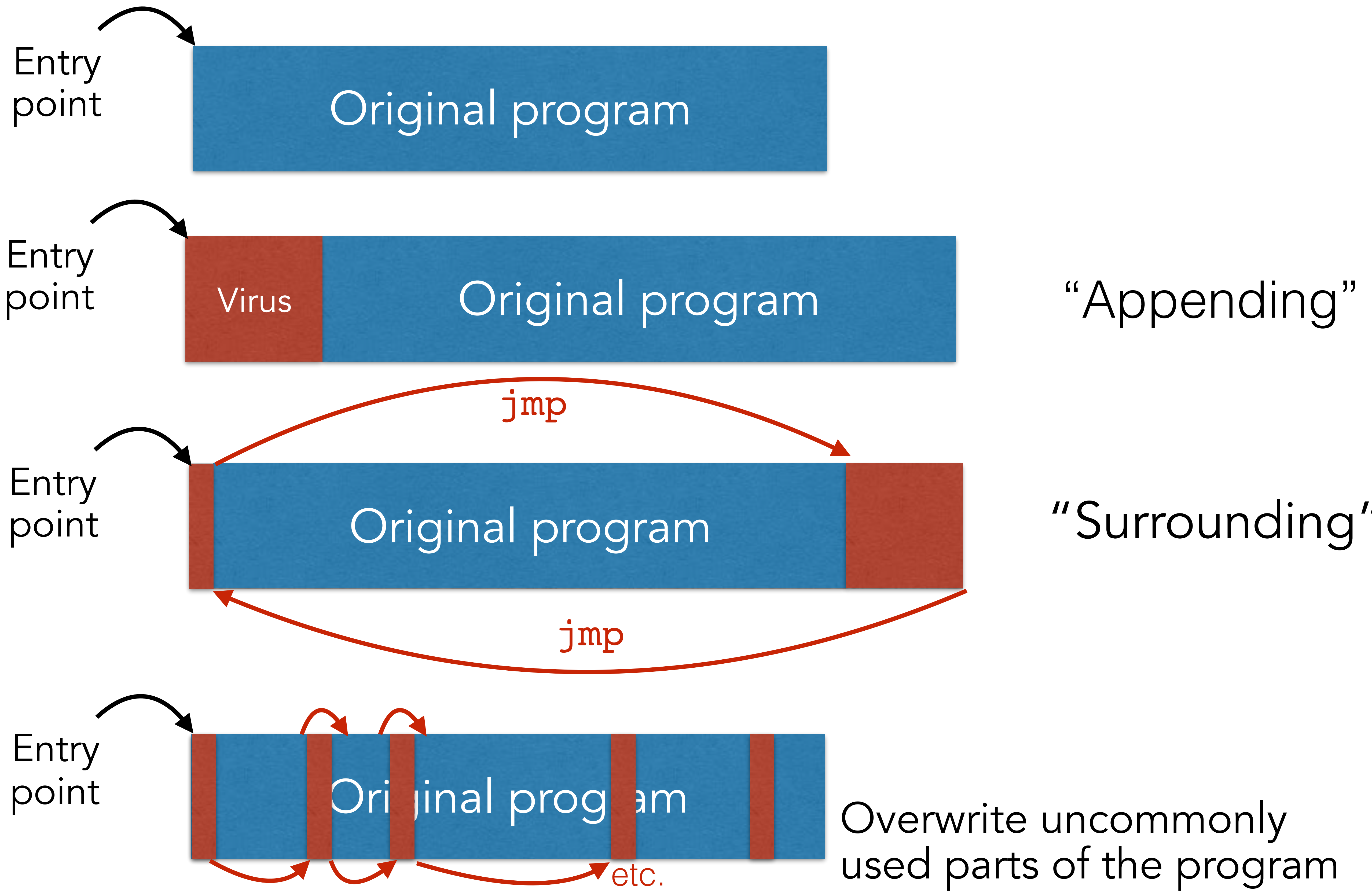

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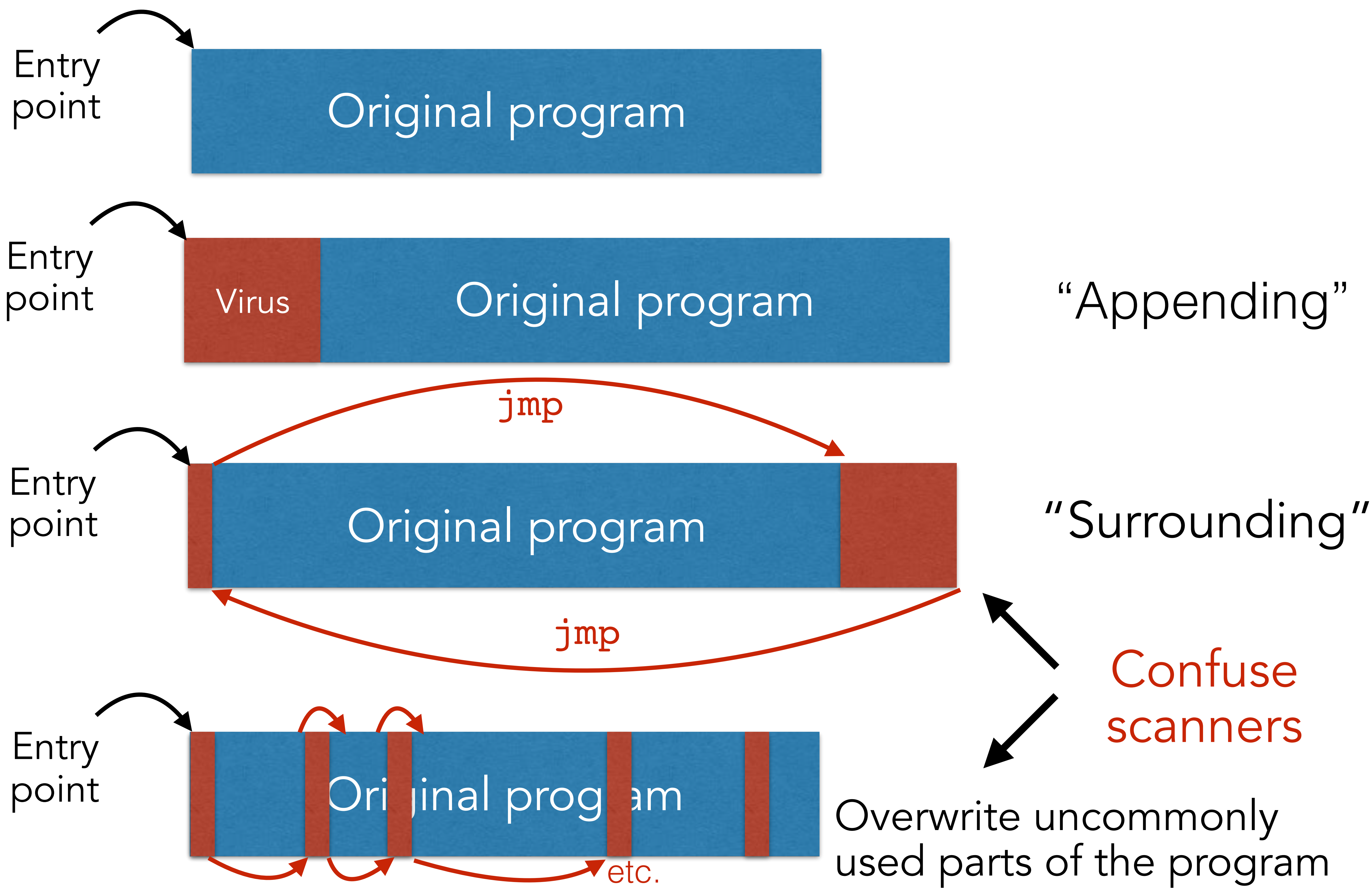

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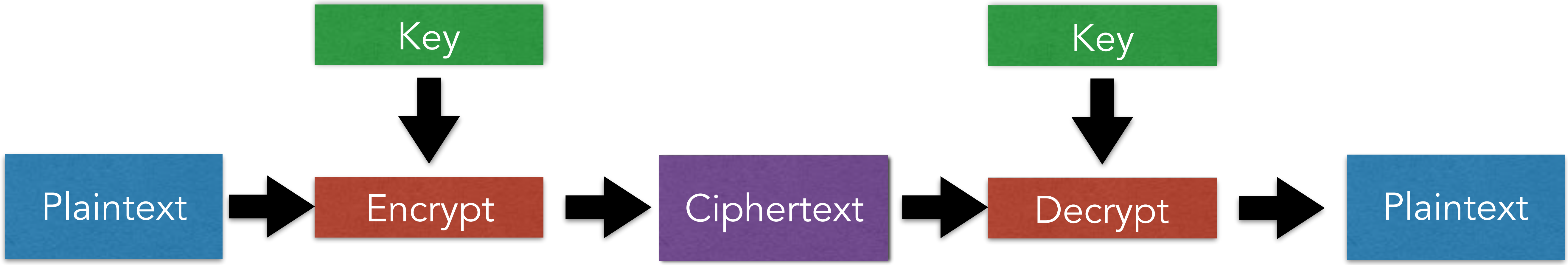
Mechanize code changes:

Goal: every time you inject your code, it looks different

BUILDING BLOCK: ENCRYPTION



Symmetric key: both keys are the same

Asymmetric key: different keys

Important property: the ciphertext is ***nondeterministic***
i.e., "Encrypt" has a different output each time

but decrypting always returns the plaintext

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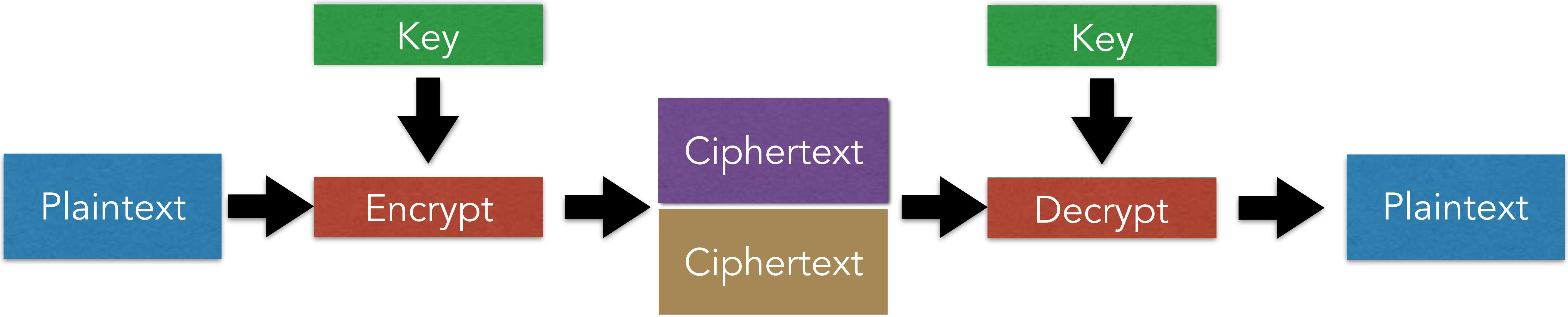

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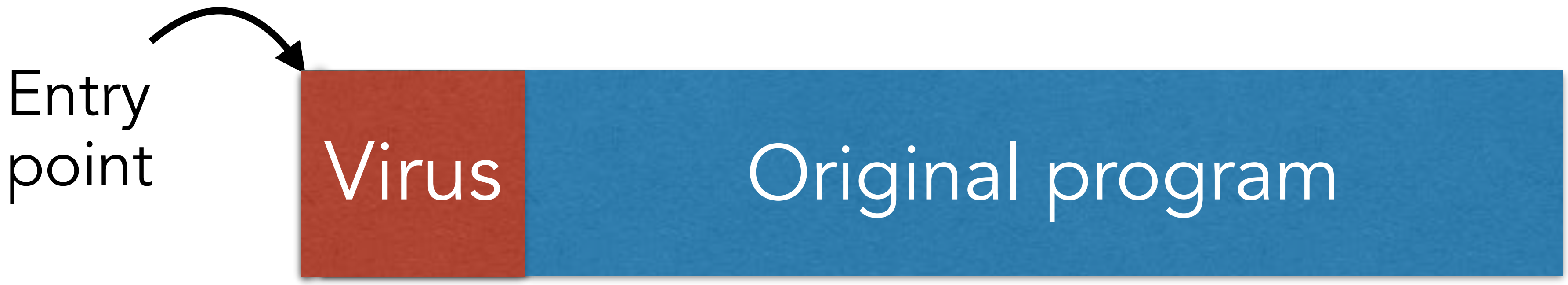
POLYMORPHIC VIRUSES



Take over the entry point

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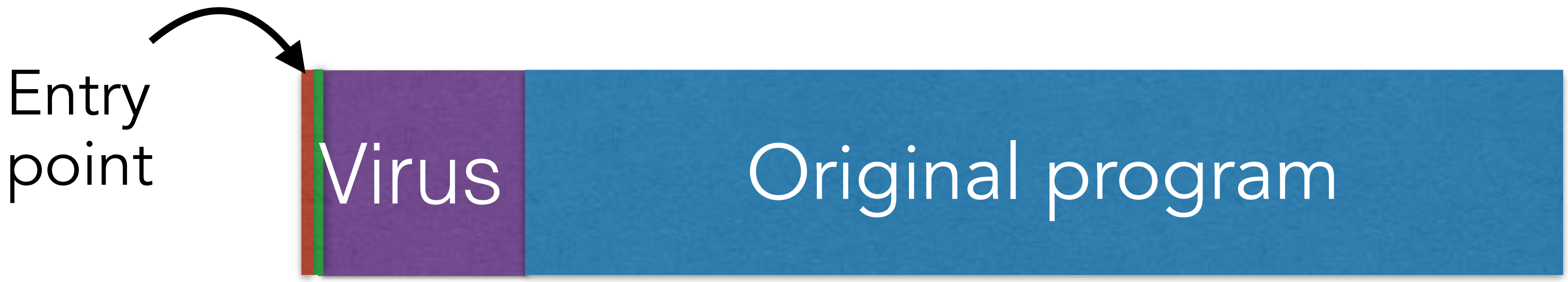

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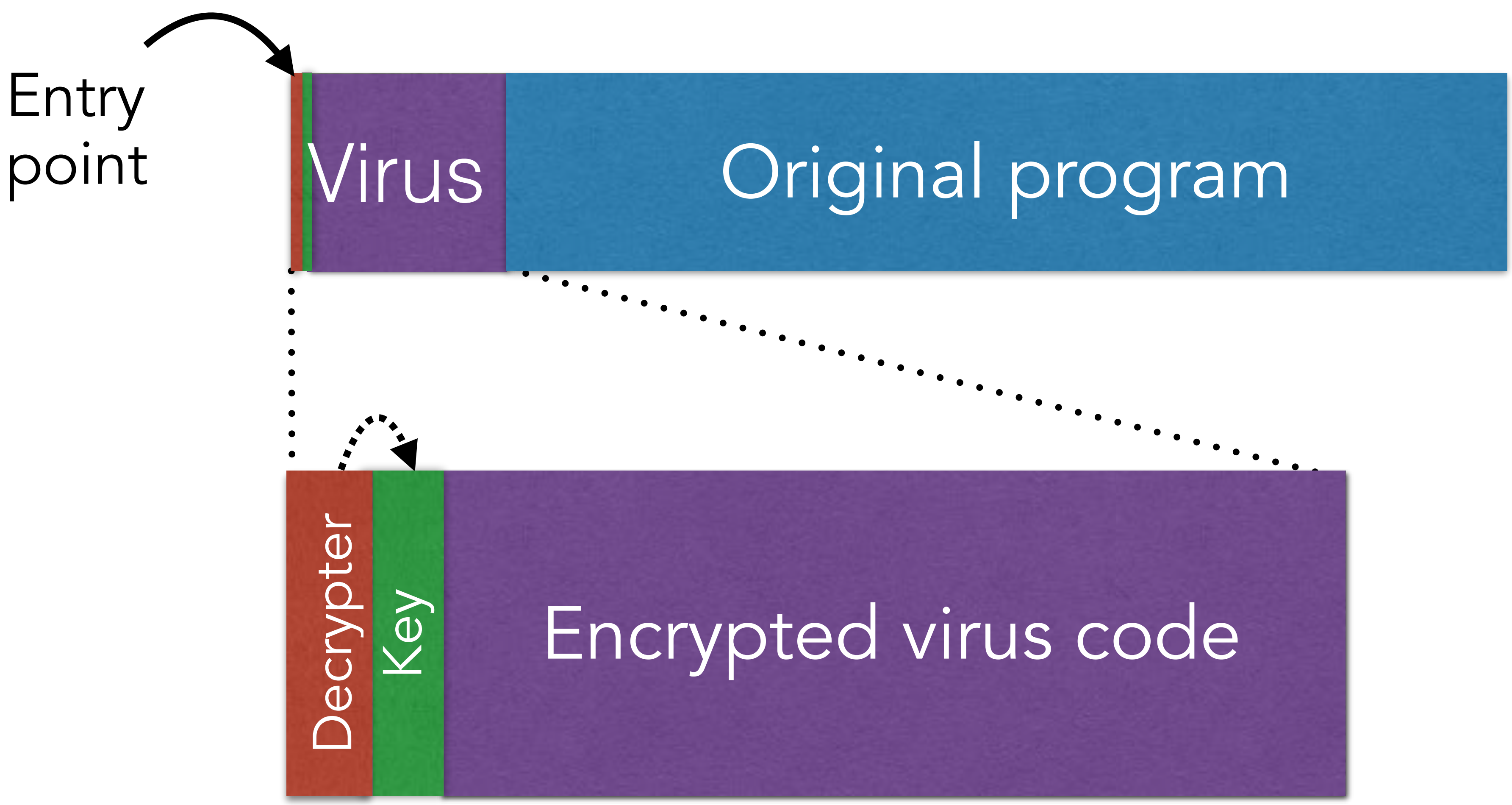

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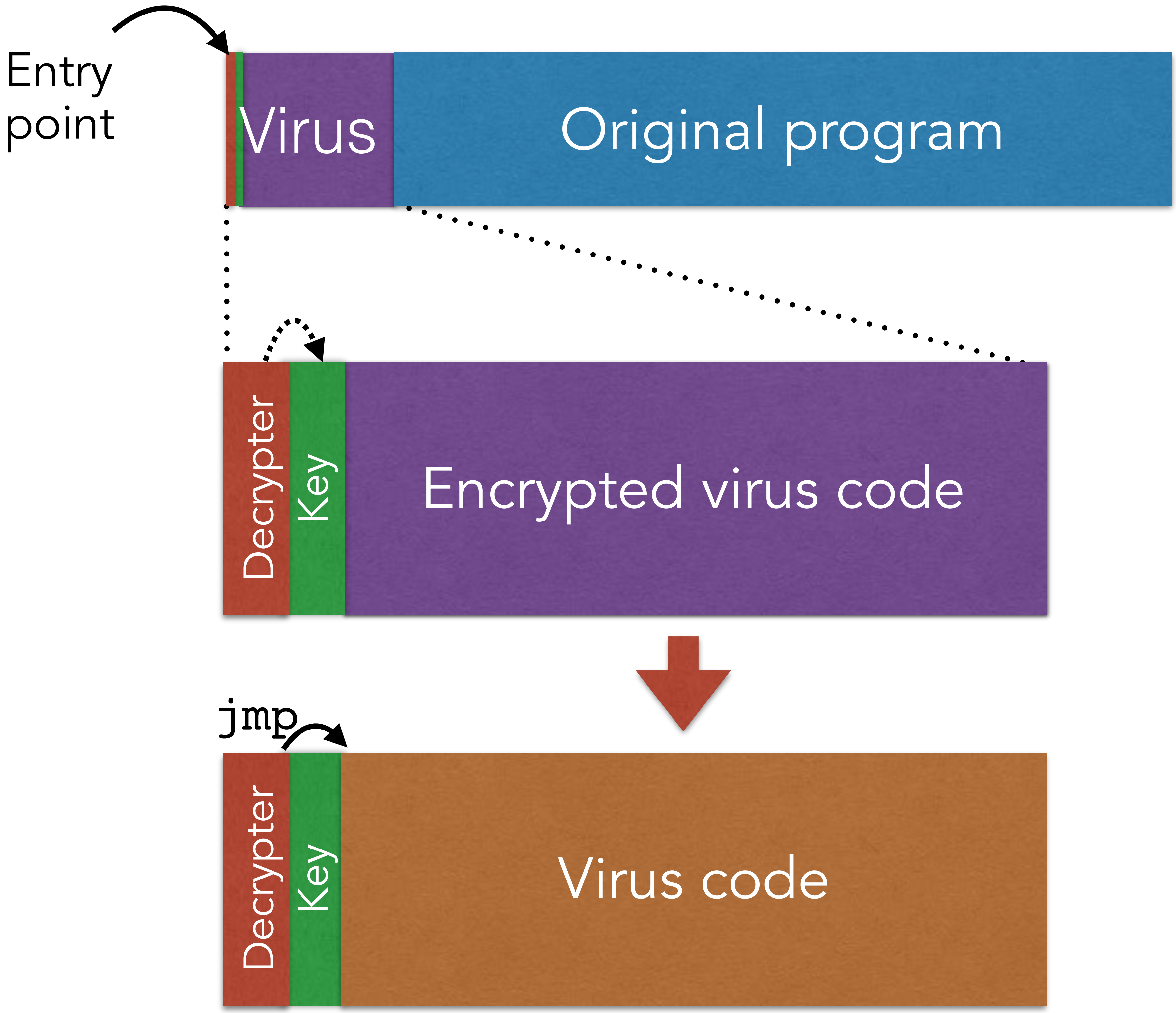

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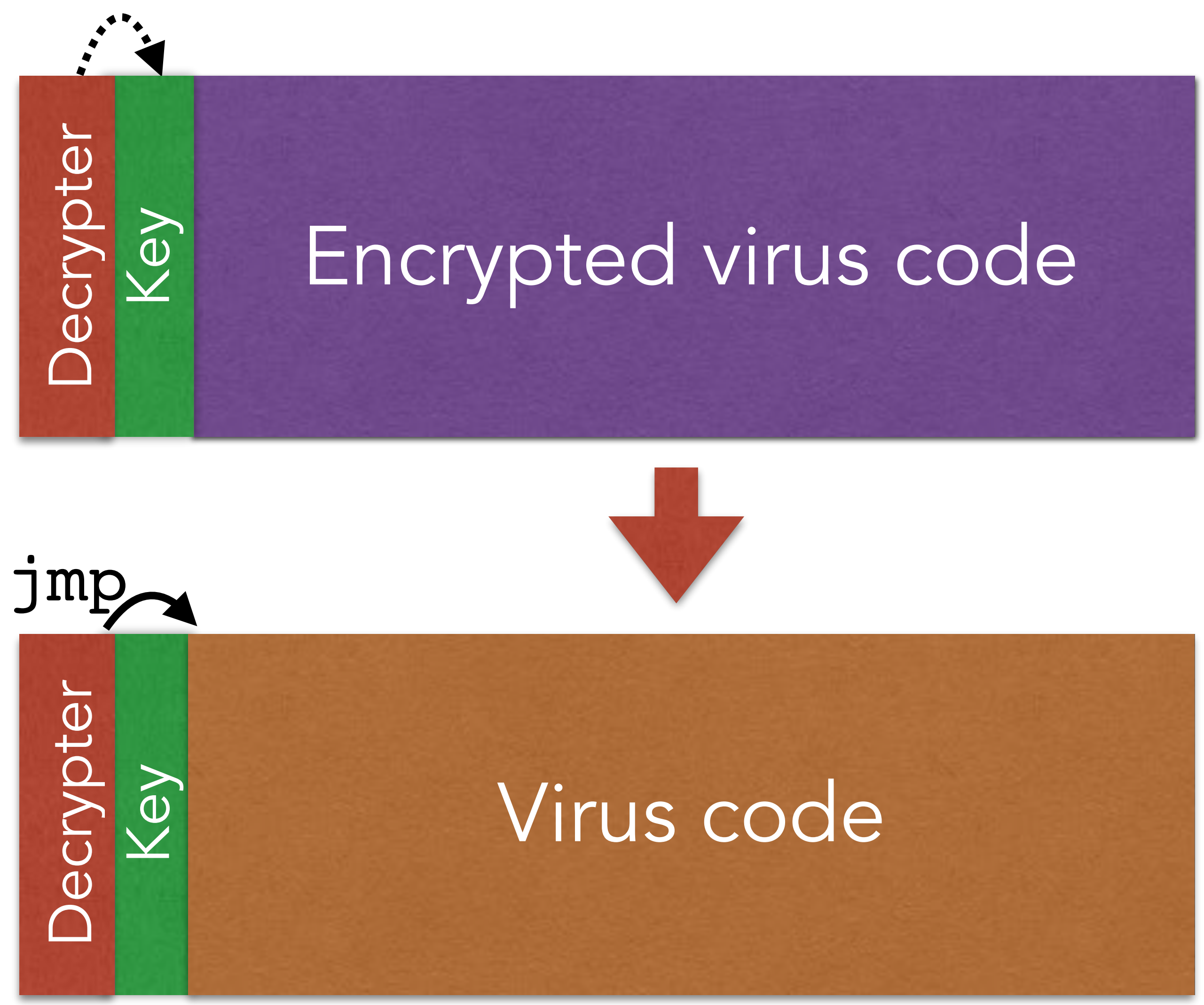

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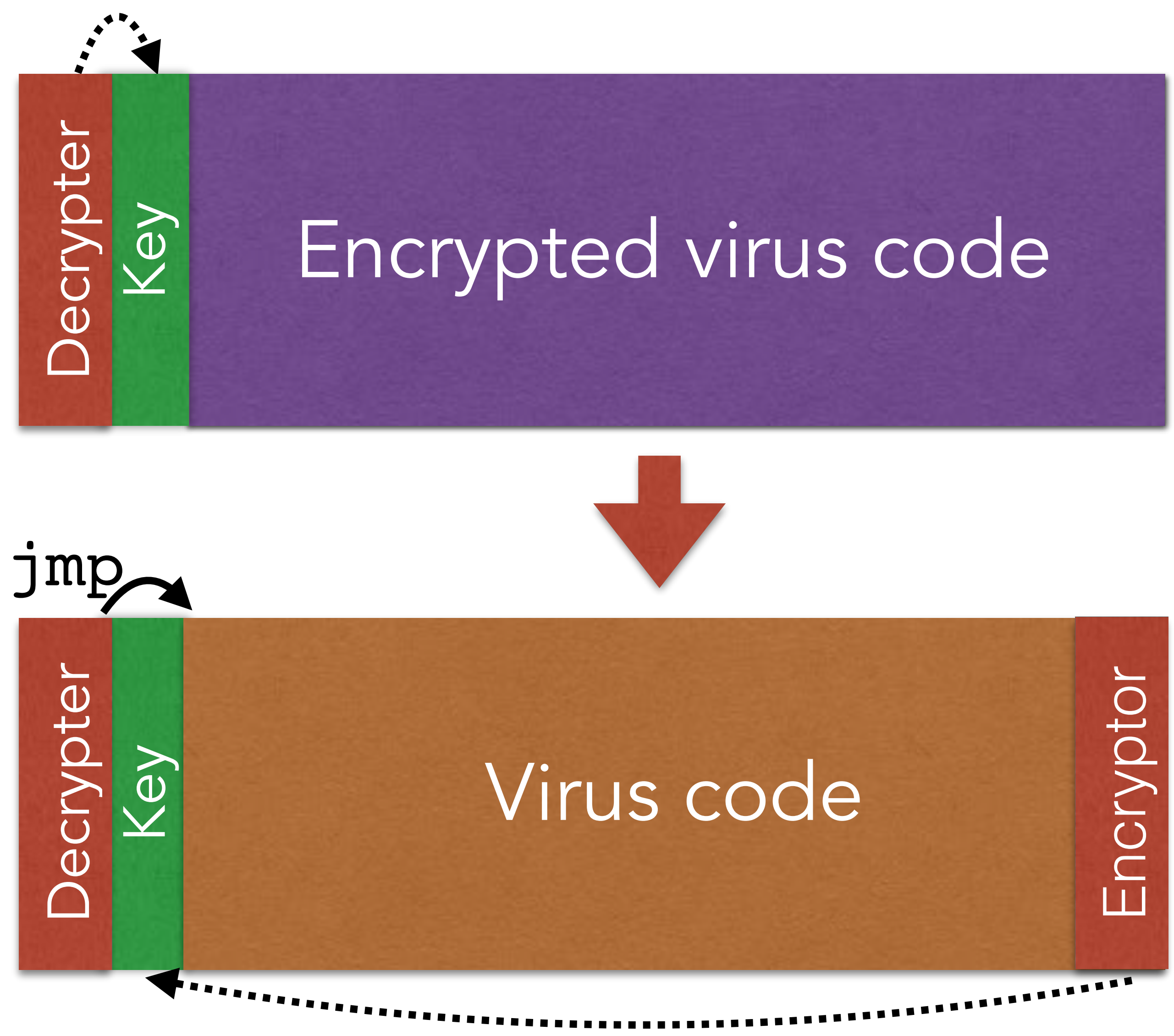

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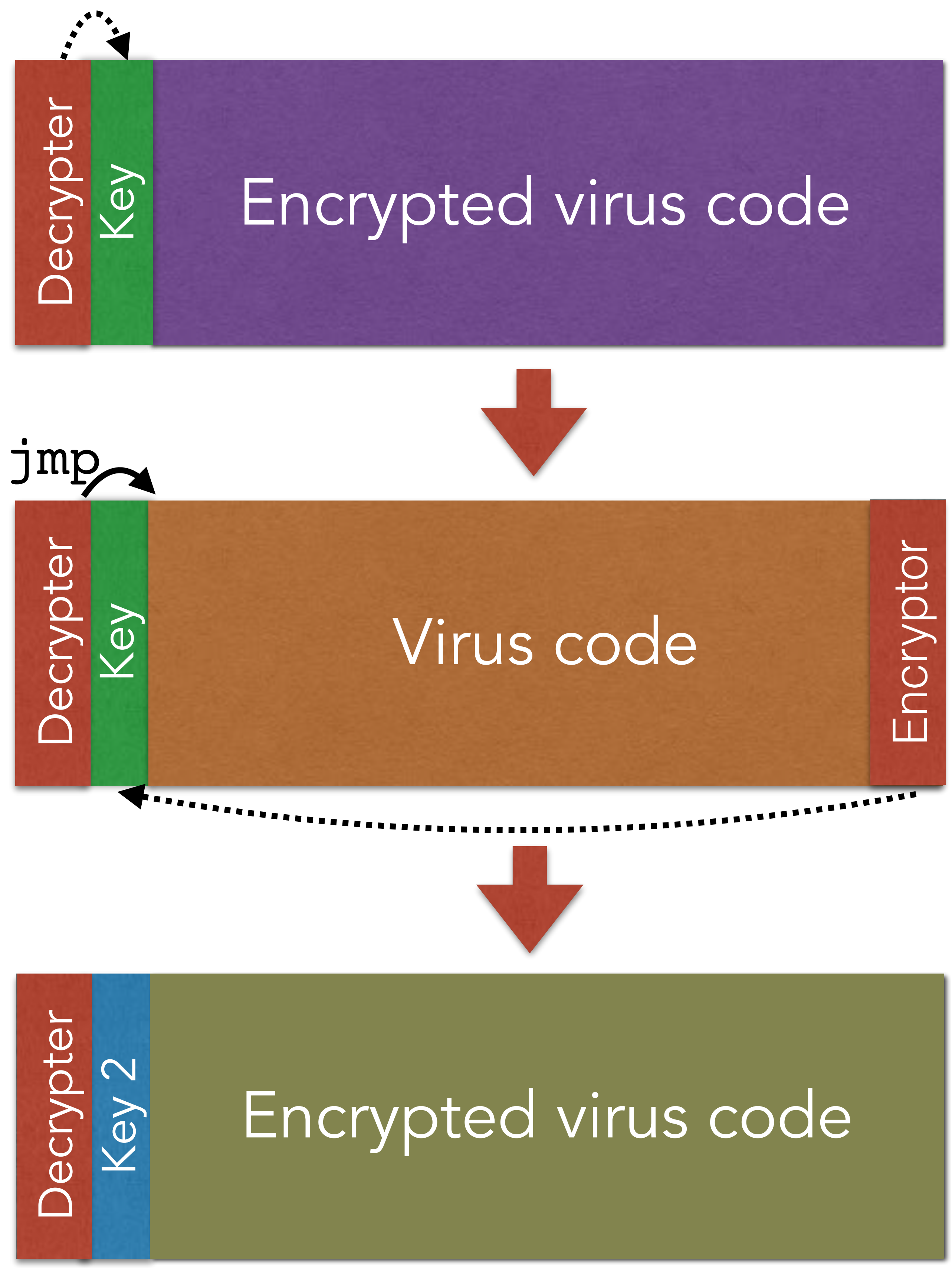

Encryption will yield a different output upon each invocation

POLYMORPHIC VIRUSES: ARMS RACE

Now you are the antivirus writer: how do you detect?

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Now you are the antivirus writer: how do you detect?

- Idea #1: Narrow signature to catch the decrypter
  - Often very small: can result in many false positives
  - Attacker can spread this small code around and jmp
- Idea #2: Execute or statically analyze the suspect code to see if it decrypts.
  - How do you distinguish from common "packers" which do something similar (decompression)?
  - How long do you execute the code??

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POLYMORPHIC VIRUSES: ARMS RACE

Now you are the *virus writer* again: how do you *evade*?

- Idea #1: Change the decrypter
    - Oligomorphic viruses: one of a fixed set of decrypters
    - True polymorphic viruses: endless number of decrypters
- Idea #2: Change the decrypted code itself

METAMORPHIC CODE

METAMORPHIC CODE

- Every time the virus propagates, generate a *semantically different* version of the code
  - Higher-level semantics remain the same
  - But the way it does it differs
    - Different machine code instructions
    - Different algorithms to achieve the same thing
    - Different use of registers
    - Different constants….

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        - Different machine code instructions
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        - Different use of registers
        - Different constants….
- How would you do this?
    - Include a code rewriter with your virus
    - Add a bunch of complex code to throw others off (then just never run it)

```
5A              pop  edx
BF04000000      mov  edi,0004h
8BF5            mov  esi,ebp
B80C000000      mov  eax,000Ch
81C288000000    add  edx,0088h
8B1A            mov  ebx,[edx]
899C8618110000  mov  [esi+eax*4+00001118],ebx

58              pop  eax
BB04000000      mov  ebx,0004h
8BD5            mov  edx,ebp
BF0C000000      mov  edi,000Ch
81C088000000    add  eax,0088h
8B30            mov  esi,[eax]
89B4BA18110000  mov  [edx+edi*4+00001118],esi
```

Figure 4: Win95/Regswap using different registers in new generations

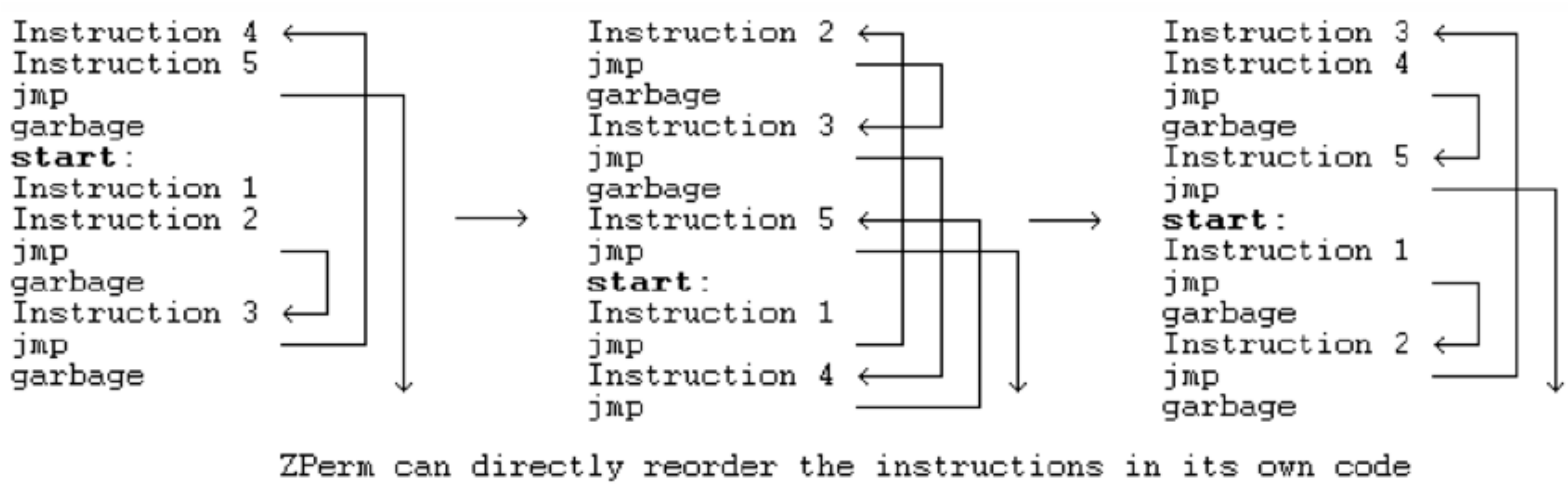
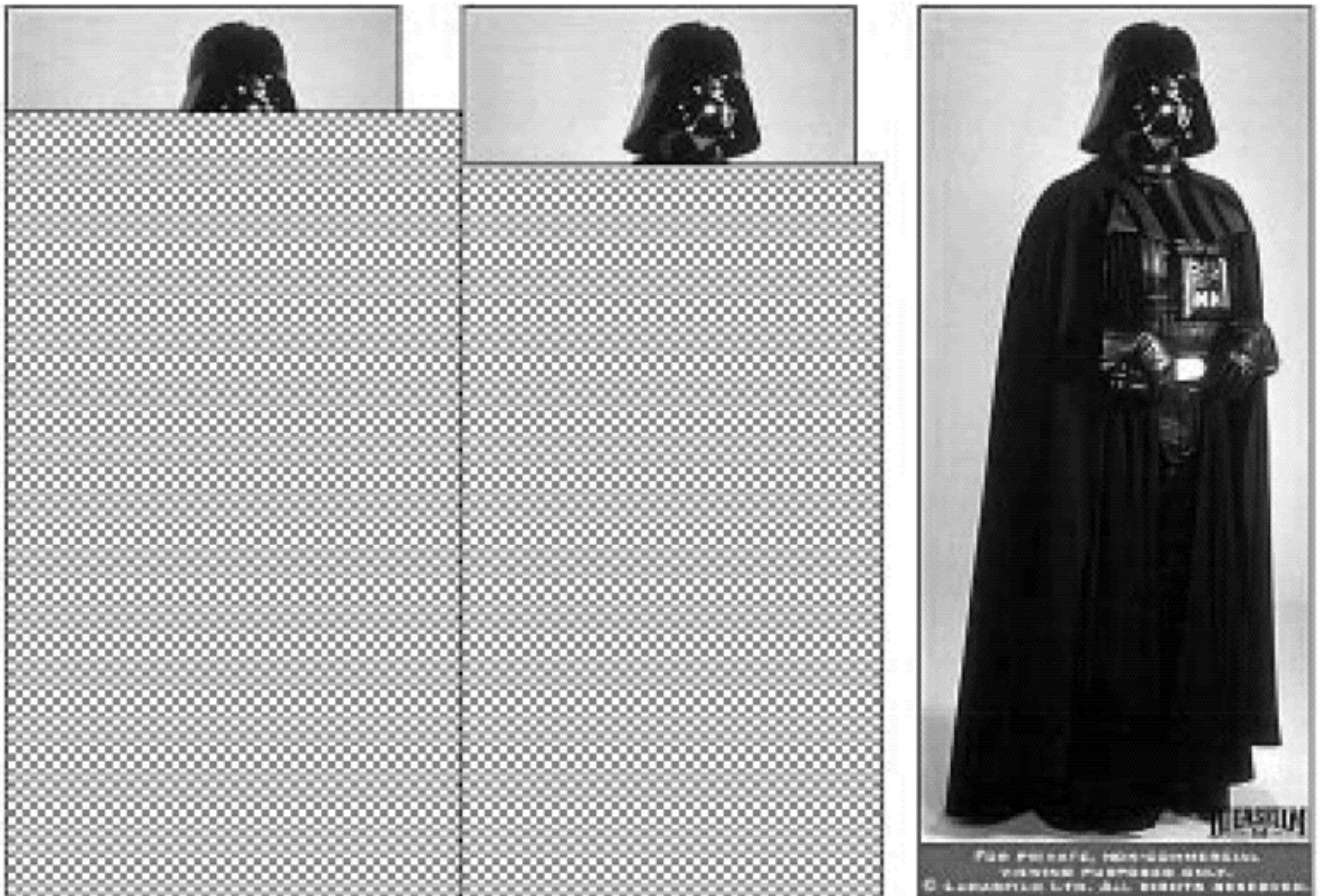


Figure 7 Zperm.A inserts JMP instruction into its code

```
a. An early generation:

C7060F000055   mov      dword ptr [esi],5500000Fh
C746048BEC5151 mov      dword ptr [esi+0004],5151EC8Bh

b. And one of its later generations:

BF0F000055     mov      edi,5500000Fh
893E           mov      [esi],edi
5F             pop      edi
52             push     edx
B640           mov      dh,40
BA8BEC5151     mov      edx,5151EC8Bh
53             push     ebx
8BDA           mov      ebx,edx
895E04         mov      [esi+0004],ebx

c. And yet another generation with recalculated ("encrypted") "con-
stant" data.

BB0F000055     mov      ebx,5500000Fh
891E           mov      [esi],ebx
5B             pop      ebx
51             push     ecx
B9CB00C05F     mov      ecx,5FC000CBh
81C1C0EB91F1   add      ecx,F191EBC0h ; ecx=5151EC8Bh
894E04         mov      [esi+0004],ecx
```

Figure 6: Example of code metamorphosis of Win32/Evol

Polymorphic



When can AV software successfully scan?

Figure 8: A partial or complete snapshot of polymorphic virus during execution cycle

Metamorphic

When can AV software successfully scan?

Figure 10: T-1000 of Terminator 2

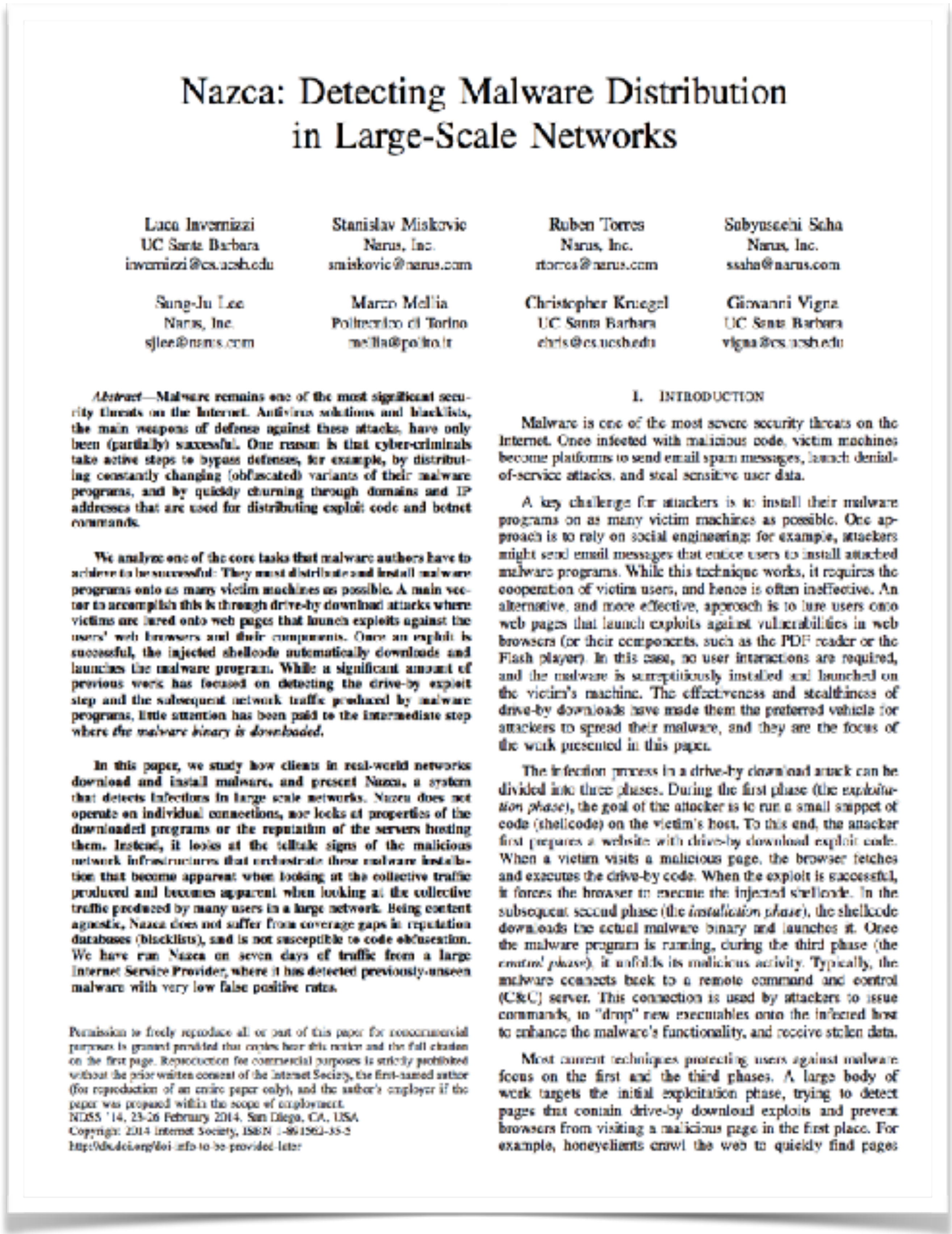
DETECTING
METAMORPHIC VIRUSES?

DETECTING METAMORPHIC VIRUSES

- Scanning isn't enough: need to analyze execution behavior

- Two broad stages in practice (both take place in a safe environment, like gdb or a virtual machine)
  1. AV company analyzes new virus to find behavioral signature
  2. AV system at the end host analyzes suspect code to see if it matches the signature

NAZCA



Nazca: Detecting Malware Distribution in Large-Scale Networks

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Stanislav Miskovic, Narus, Inc., smiskovic@narus.com
Ruben Torres, Narus, Inc., rtorres@narus.com
Sabyasachi Saha, Narus, Inc., ssaha@narus.com
Sung-Ju Lee, Narus, Inc., sjlee@narus.com
Marco Mellia, Politecnico di Torino, mellia@polito.it
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Giovanni Vigna, UC Santa Barbara, vigna@cs.ucsb.edu

Abstract—**Malware remains one of the most significant security threats on the Internet. Antivirus solutions and blacklists, the main weapons of defense against these attacks, have only been (partially) successful. One reason is that cyber-criminals take active steps to bypass defenses, for example, by distributing constantly changing (obfuscated) variants of their malware programs, and by quickly churning through domains and IP addresses that are used for distributing exploit code and botnet commands.**

We analyze one of the core tasks that malware authors have to achieve to be successful: They must distribute and install malware programs onto as many victim machines as possible. A main vector to accomplish this is through drive-by download attacks where victims are lured onto web pages that launch exploits against the users' web browsers and their components. Once an exploit is successful, the injected shellcode automatically downloads and launches the malware program. While a significant amount of previous work has focused on detecting the drive-by exploit step and the subsequent network traffic produced by malware programs, little attention has been paid to the intermediate step where *the malware binary is downloaded*.

In this paper, we study how clients in real-world networks download and install malware, and present Nazca, a system that detects infections in large scale networks. Nazca does not operate on individual connections, nor looks at properties of the downloaded programs or the reputation of the servers hosting them. Instead, it looks at the telltale signs of the malicious network infrastructures that orchestrate these malware installation that become apparent when looking at the collective traffic produced and becomes apparent when looking at the collective traffic produced by many users in a large network. Being content agnostic, Nazca does not suffer from coverage gaps in reputation databases (blacklists), and is not susceptible to code obfuscation. We have run Nazca on seven days of traffic from a large Internet Service Provider, where it has detected previously-unseen malware with very low false positive rates.

NDSS '14, 23-26 February 2014, San Diego, CA, USA
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http://dx.doi.org/doi-info-to-be-provided-later

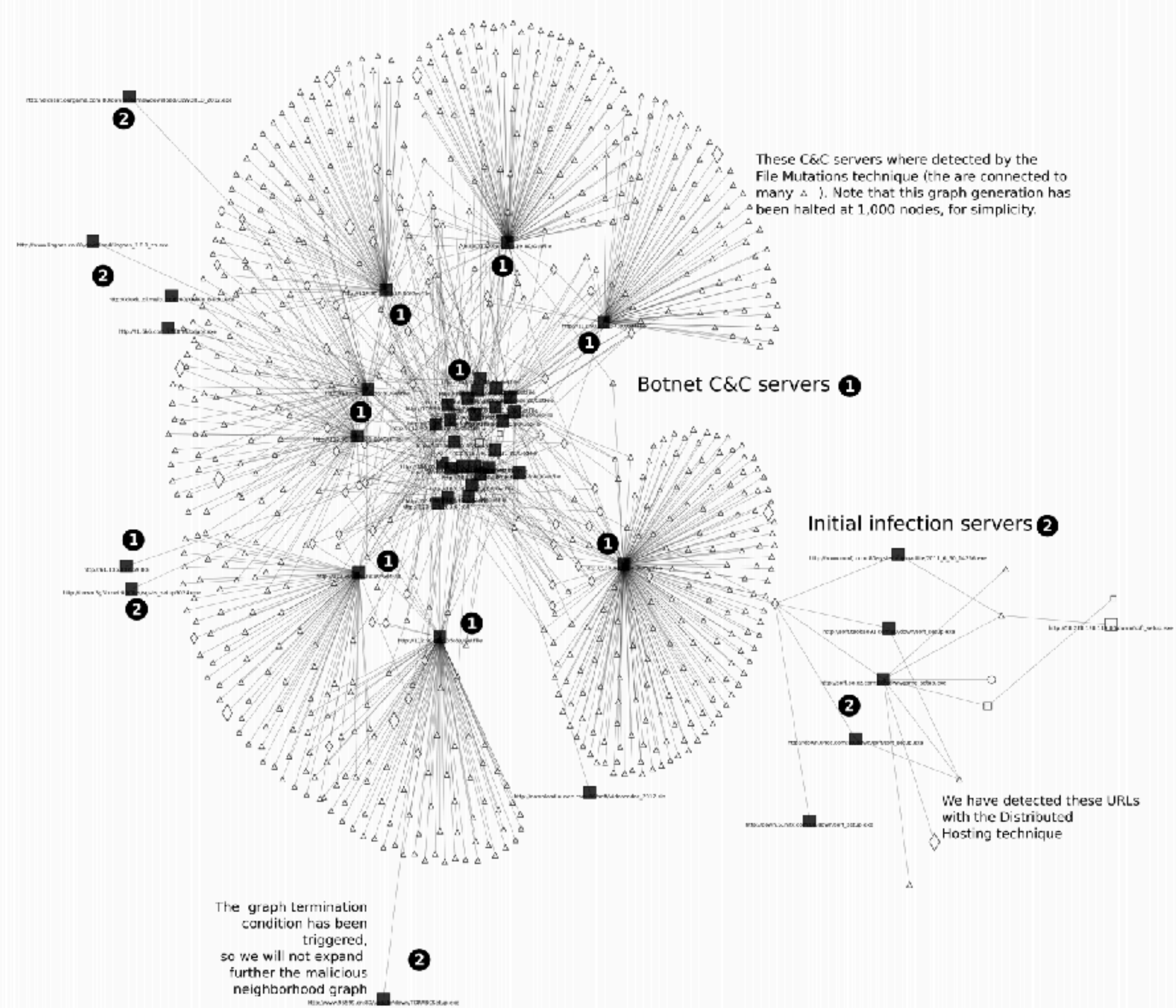
I. INTRODUCTION

Malware is one of the most severe security threats on the Internet. Once infected with malicious code, victim machines become platforms to send email spam messages, launch denial-of-service attacks, and steal sensitive user data.

A key challenge for attackers is to install their malware programs on as many victim machines as possible. One approach is to rely on social engineering: for example, attackers might send email messages that entice users to install attached malware programs. While this technique works, it requires the cooperation of victim users, and hence is often ineffective. An alternative, and more effective, approach is to lure users onto web pages that launch exploits against vulnerabilities in web browsers (or their components, such as the PDF reader or the Flash player). In this case, no user interactions are required, and the malware is surreptitiously installed and launched on the victim's machine. The effectiveness and stealthiness of drive-by downloads have made them the preferred vehicle for attackers to spread their malware, and they are the focus of the work presented in this paper.

The infection process in a drive-by download attack can be divided into three phases. During the first phase (the *exploitation phase*), the goal of the attacker is to run a small snippet of code (shellcode) on the victim's host. To this end, the attacker first prepares a website with drive-by download exploit code. When a victim visits a malicious page, the browser fetches and executes the drive-by code. When the exploit is successful, it forces the browser to execute the injected shellcode. In the subsequent second phase (the *installation phase*), the shellcode downloads the actual malware binary and launches it. Once the malware program is running, during the third phase (the *control phase*), it unfolds its malicious activity. Typically, the malware connects back to a remote command and control (C&C) server. This connection is used by attackers to issue commands, to "drop" new executables onto the infected host to enhance the malware's functionality, and receive stolen data.

Most current techniques protecting users against malware focus on the first and the third phases. A large body of work targets the initial exploitation phase, trying to detect pages that contain drive-by download exploits and prevent browsers from visiting a malicious page in the first place. For example, honeyclients crawl the web to quickly find pages


These C&C servers where detected by the File Mutations technique (the are connected to many △). Note that this graph generation has been halted at 1,000 nodes, for simplicity.
Botnet C&C servers 1
Initial infection servers 2
We have detected these URLs with the Distributed Hosting technique
The graph termination condition has been triggered, so we will not expand further the malicious neighborhood graph
1
2

DETECTING METAMORPHIC VIRUSES

- Countermeasures
  - Have your virus change slowly (hard to create a proper behavioral signature)
  - Detect if you are in a sandbox (or other safe execution environment, e.g., gdb) and act differently
- Counter-countermeasures
  - **Detect detection** and skip those parts
- Counter-counter-counter…. Arms race

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Attackers have the upper hand:
AV systems hand out signatures, thus serving as an *oracle*

CRYPTING SERVICES

Attackers have an informational advantage

Crypting service

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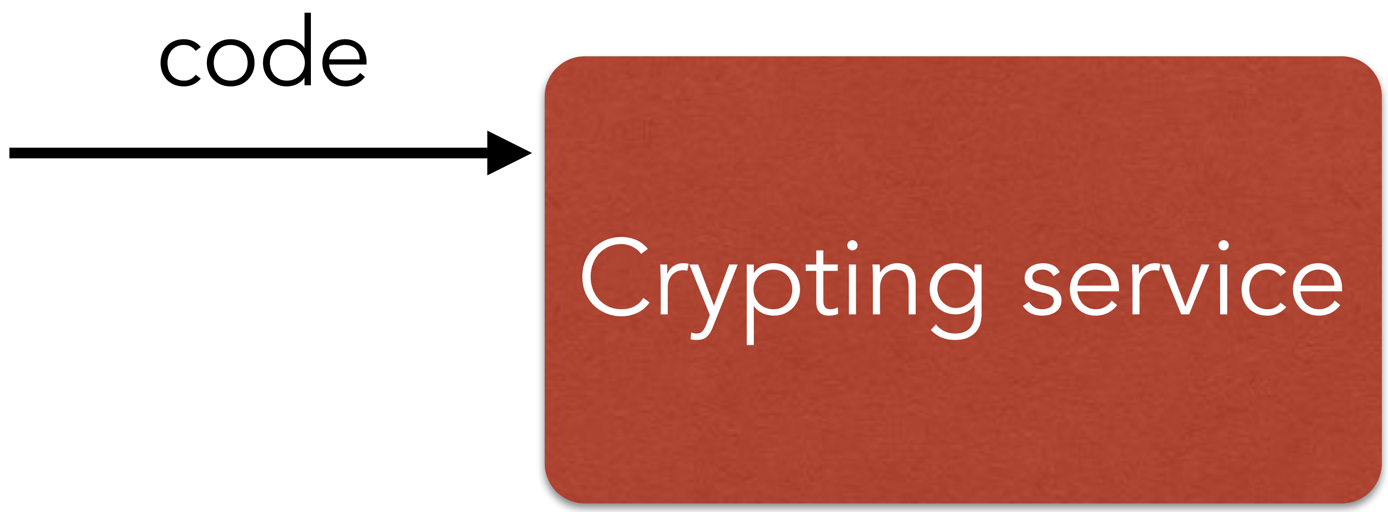

CRYPTING SERVICES

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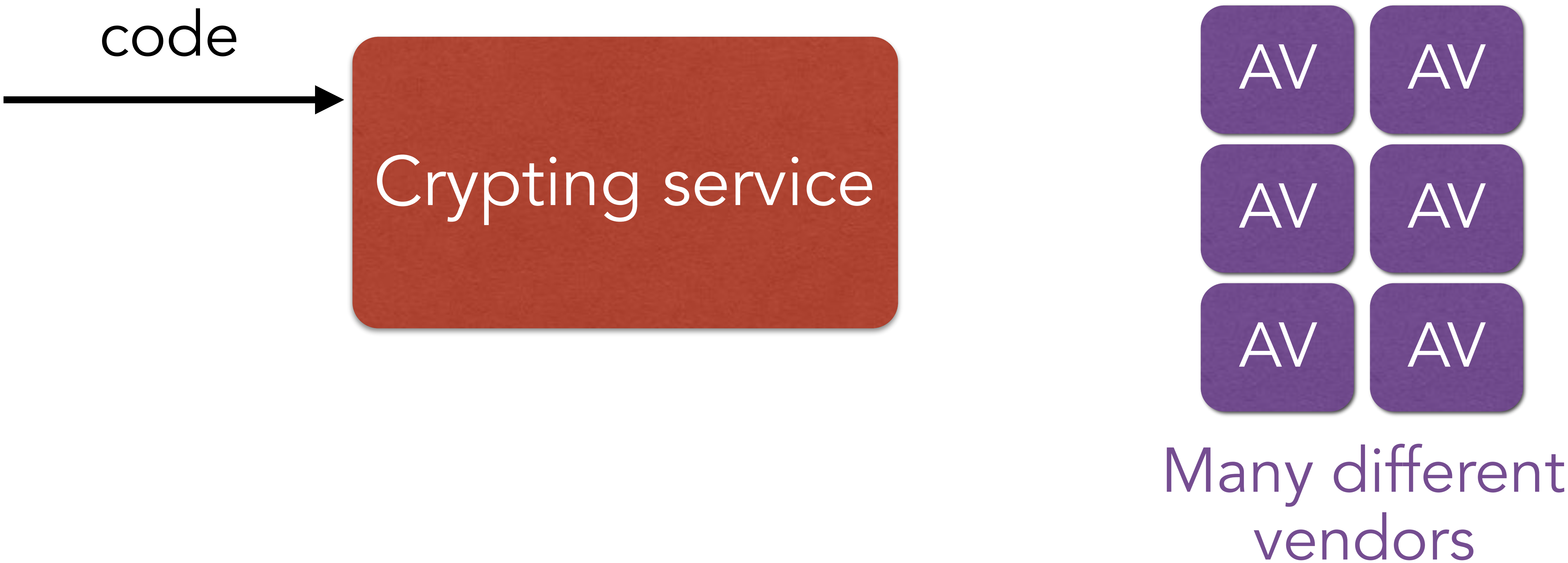

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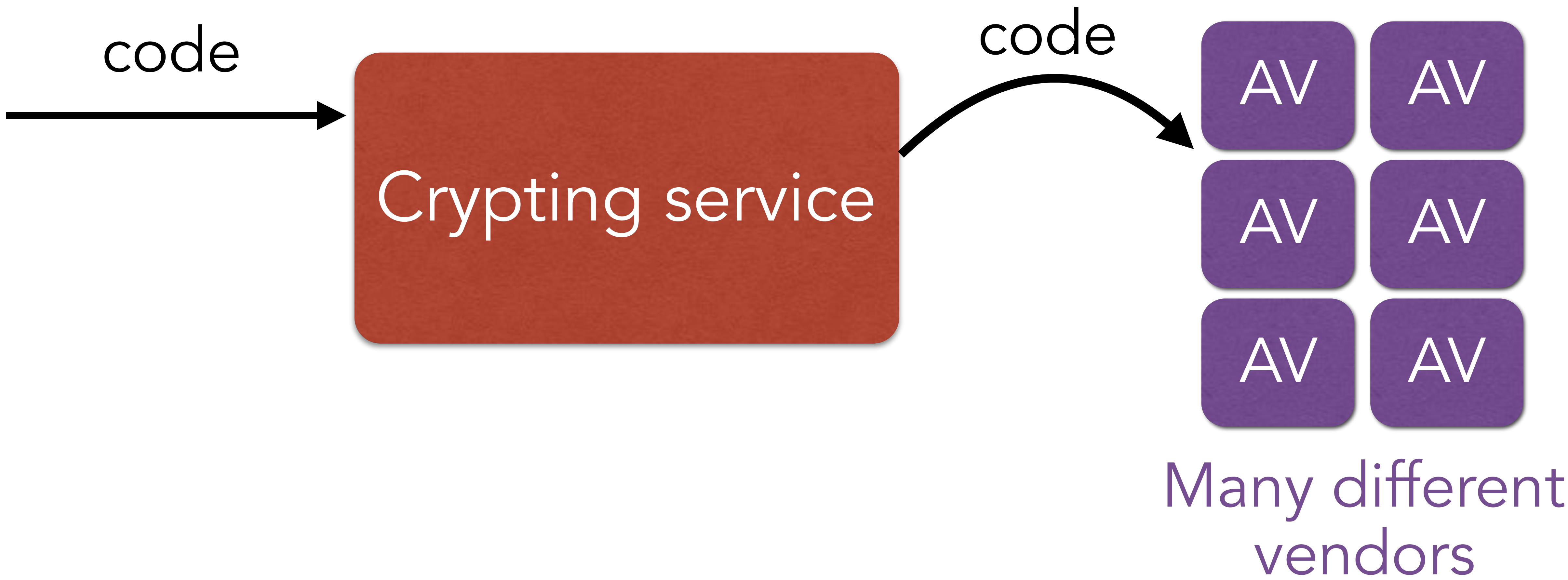

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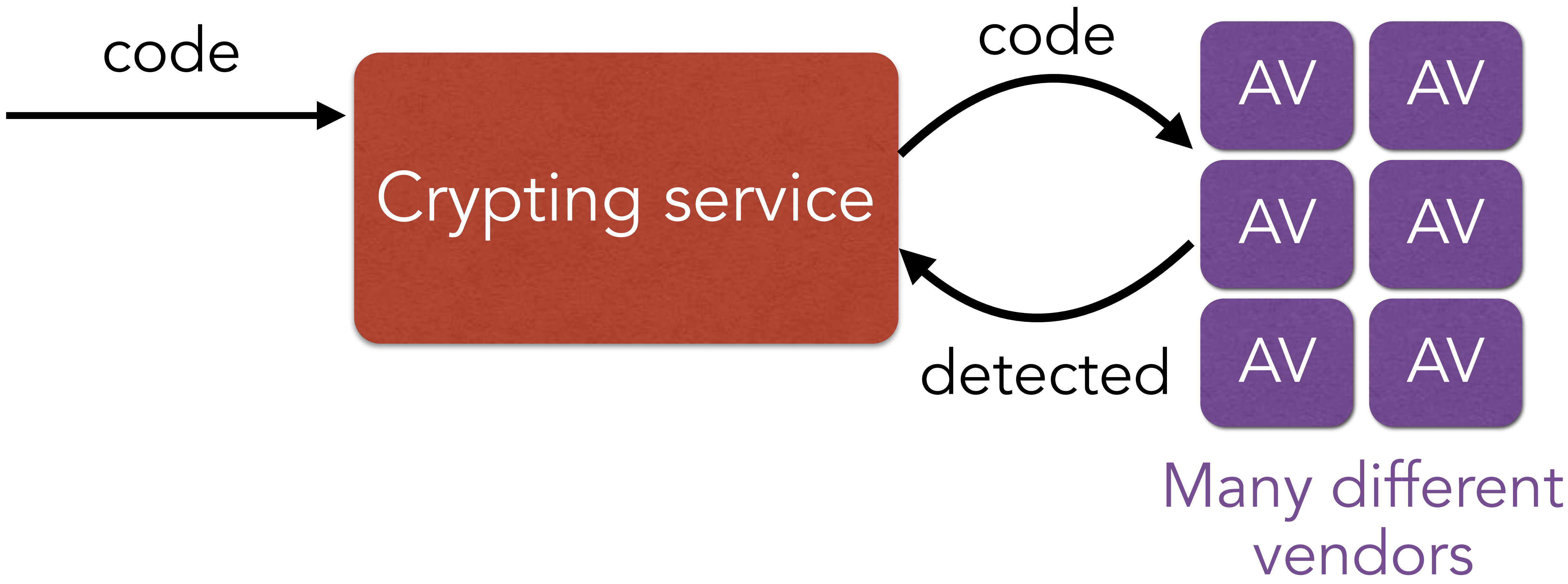

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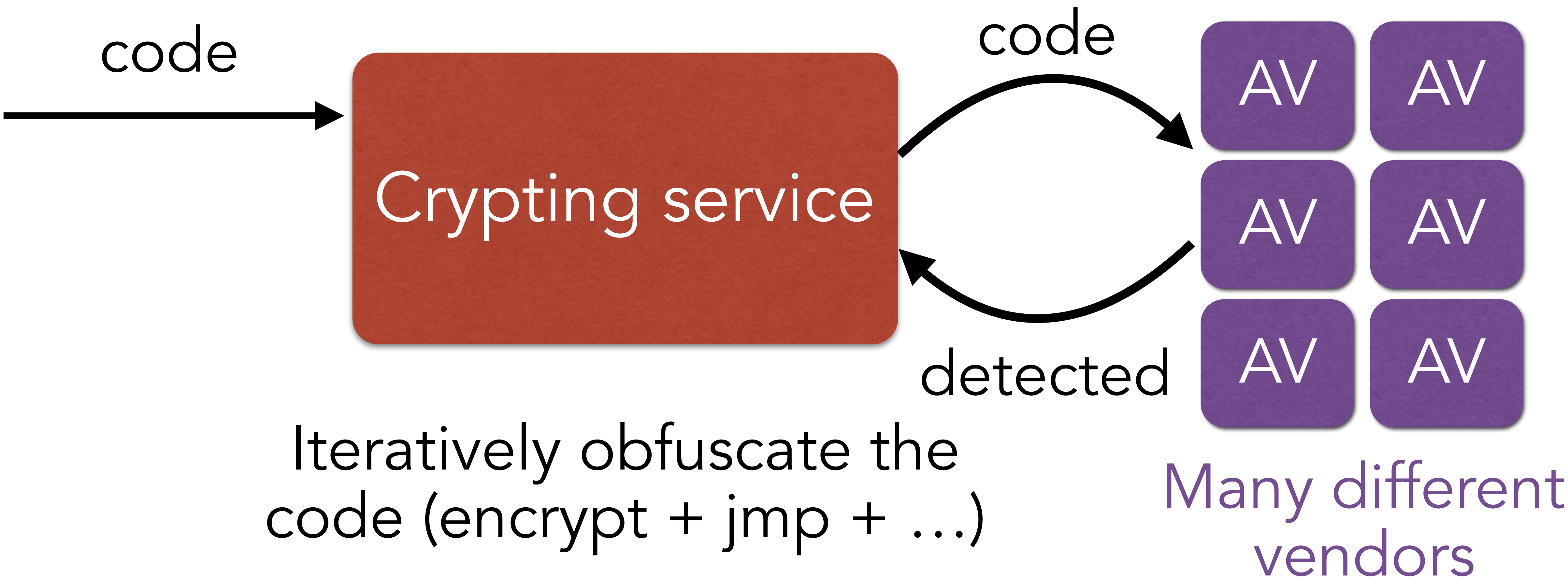

CRYPTING SERVICES

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code

Crypting service

Iteratively obfuscate the code (encrypt + jmp + …)

AV AV
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Many different vendors

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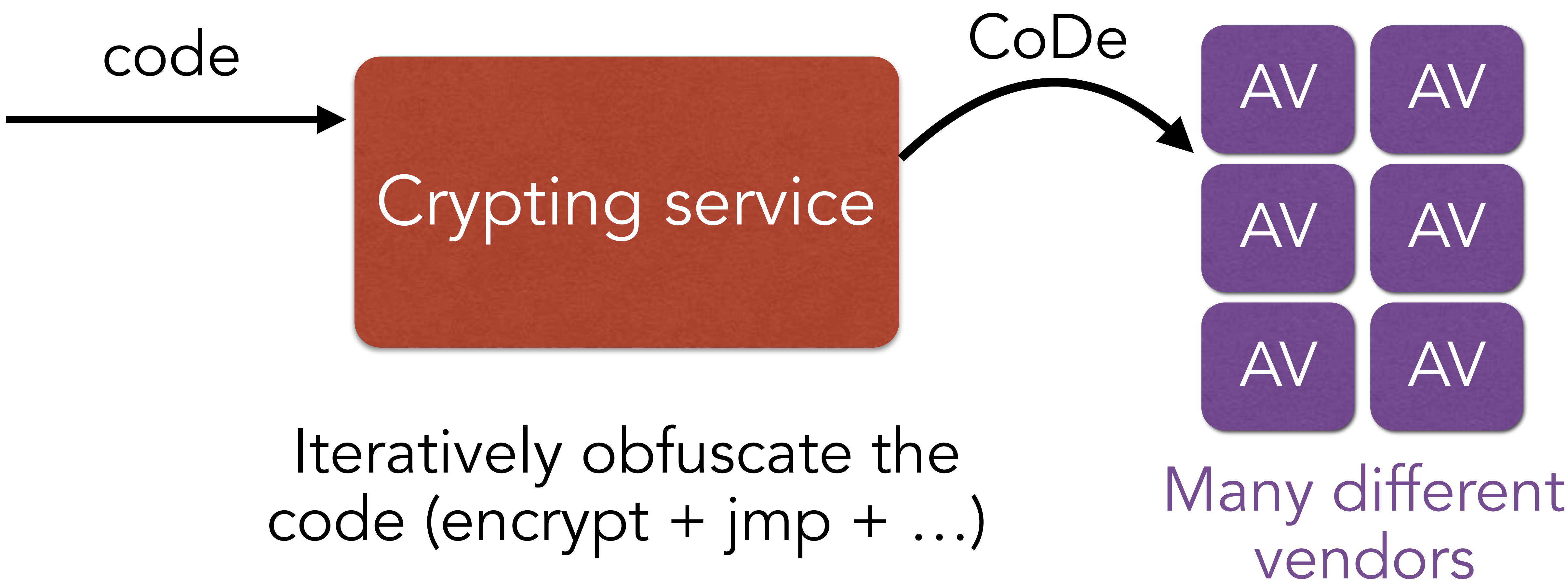

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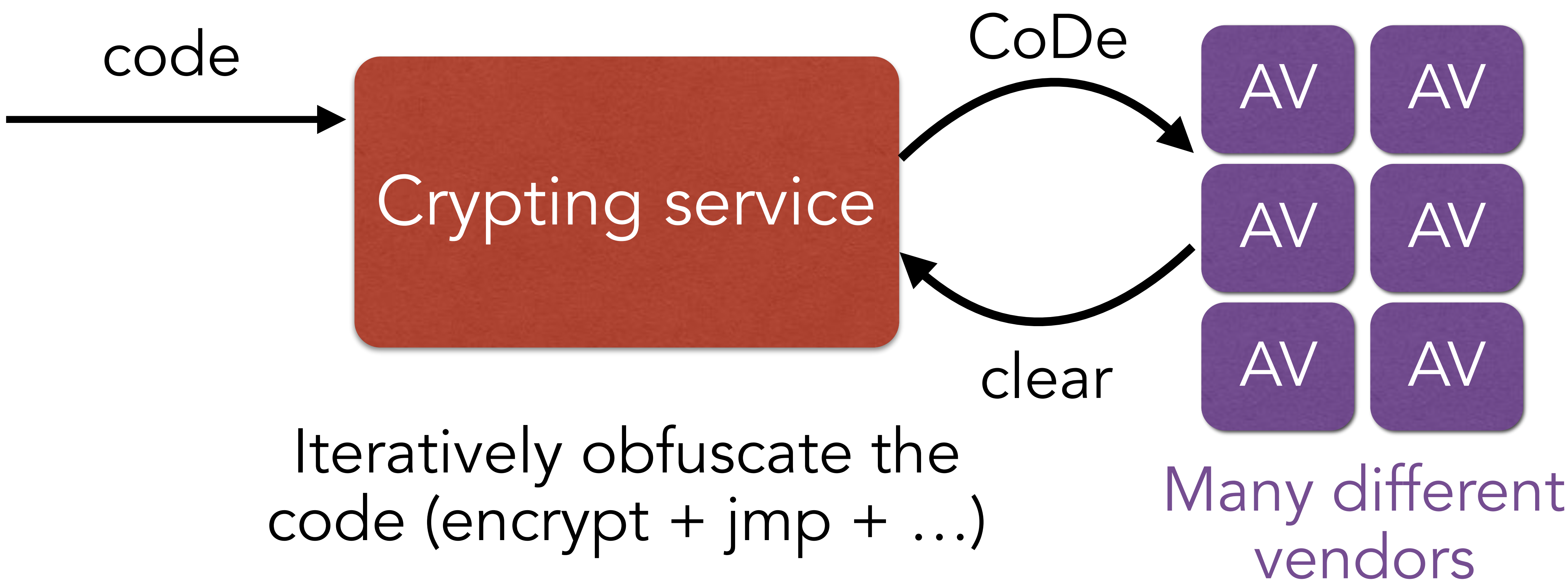

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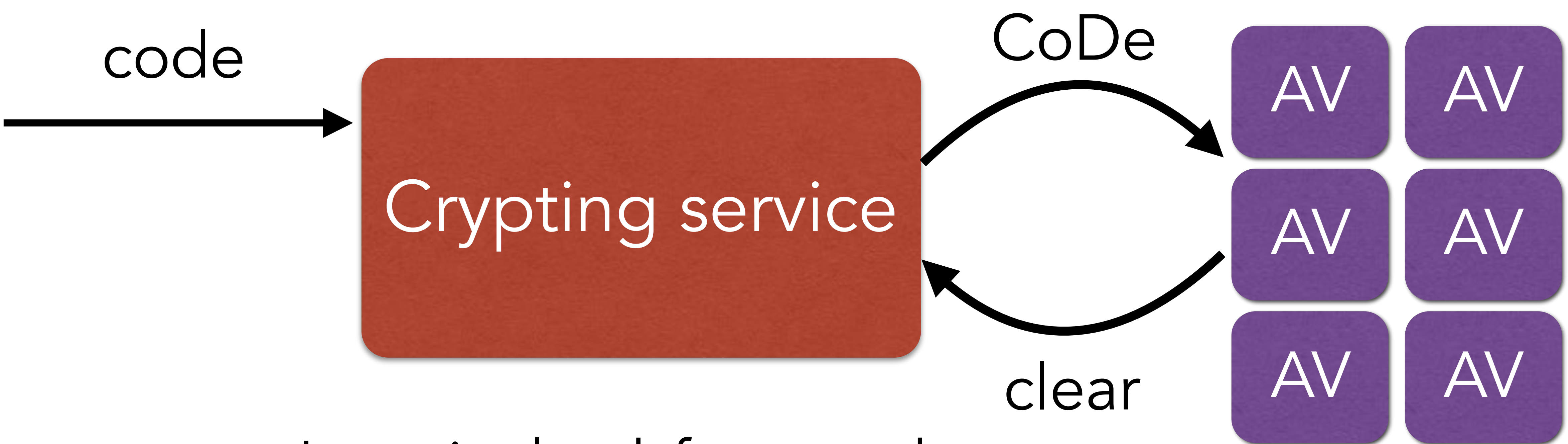

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Until the obfuscated code is "fully undetectable"

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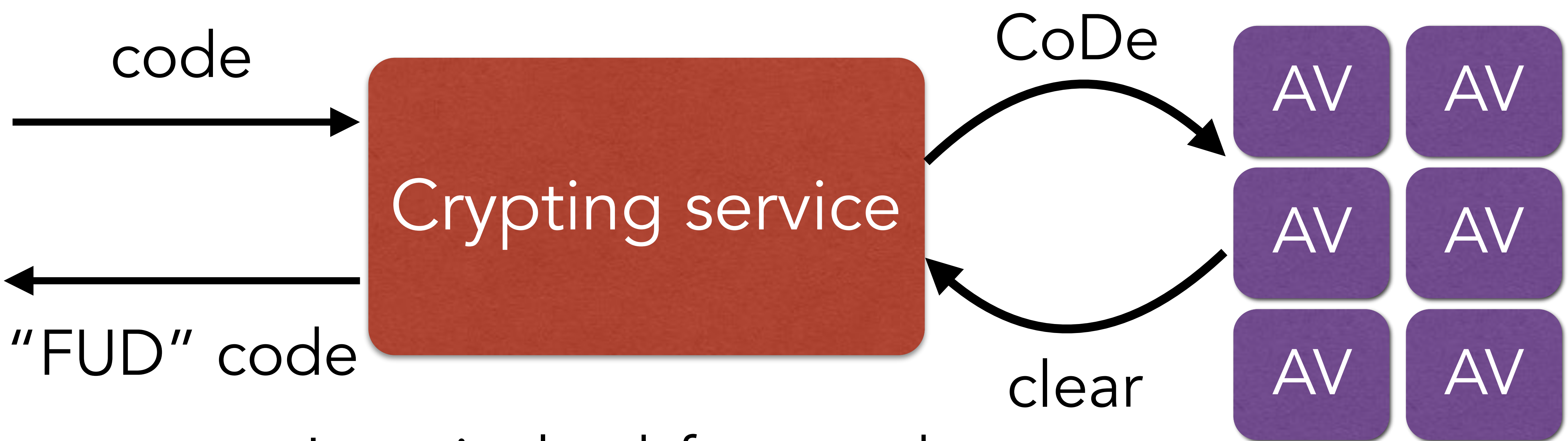

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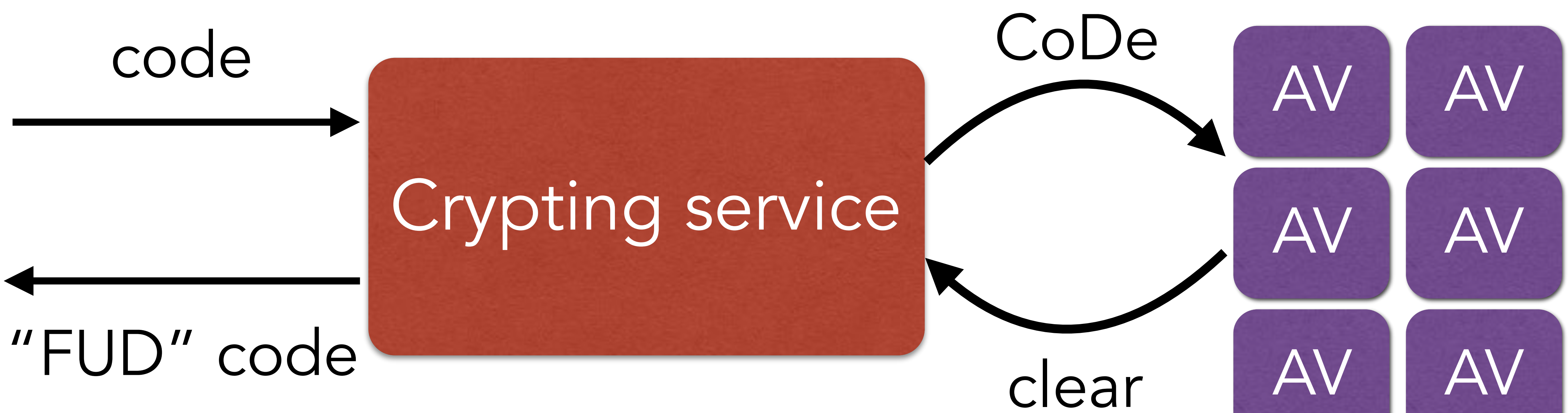

Many different vendors

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2013: Web-based crypting services

One charged $20 to "remain undetected for more than 7 days"

PUTTING IT ALL TOGETHER SOUNDS HARD...

- **Creating** a virus can be really difficult
  - Historically error prone
- But **using** them is easy: any scriptkiddy can use metasploit
  - Good news: so can any white hat pen tester

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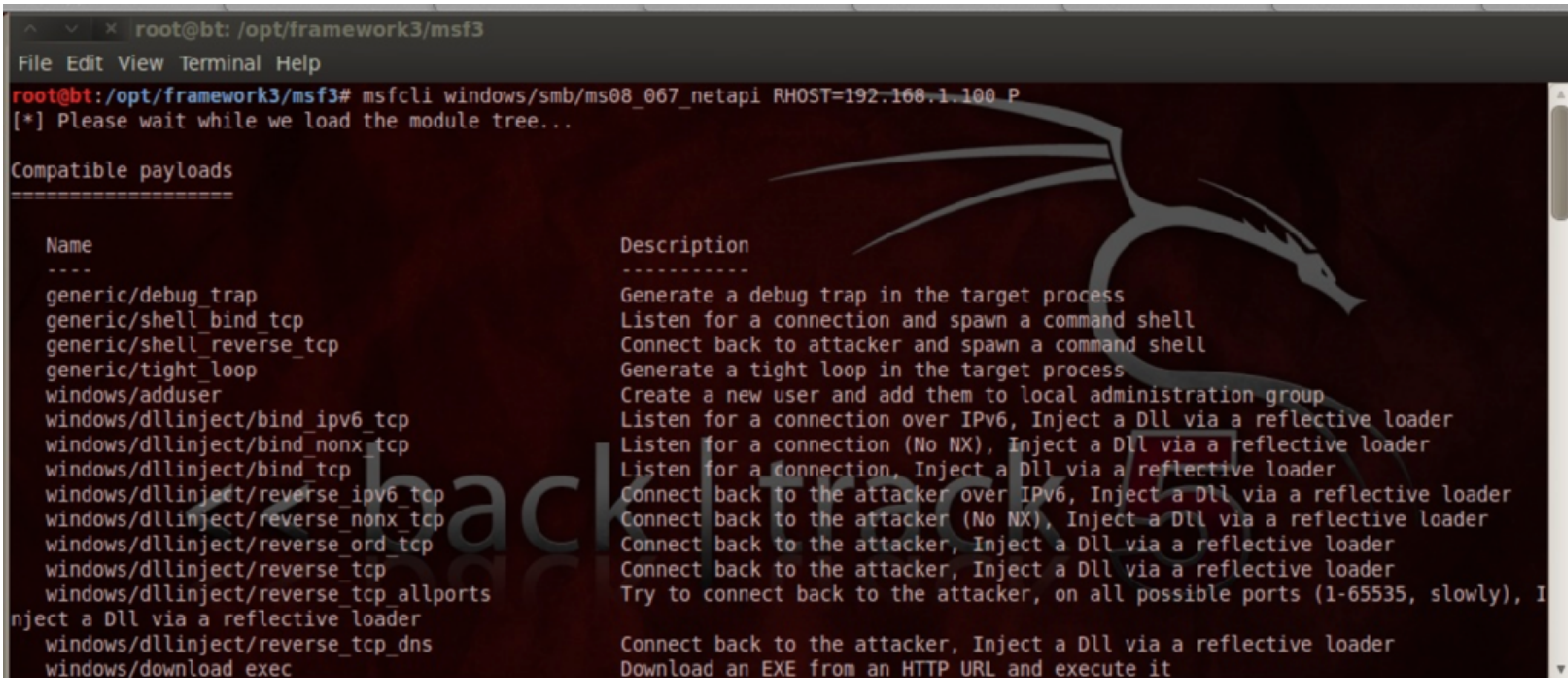
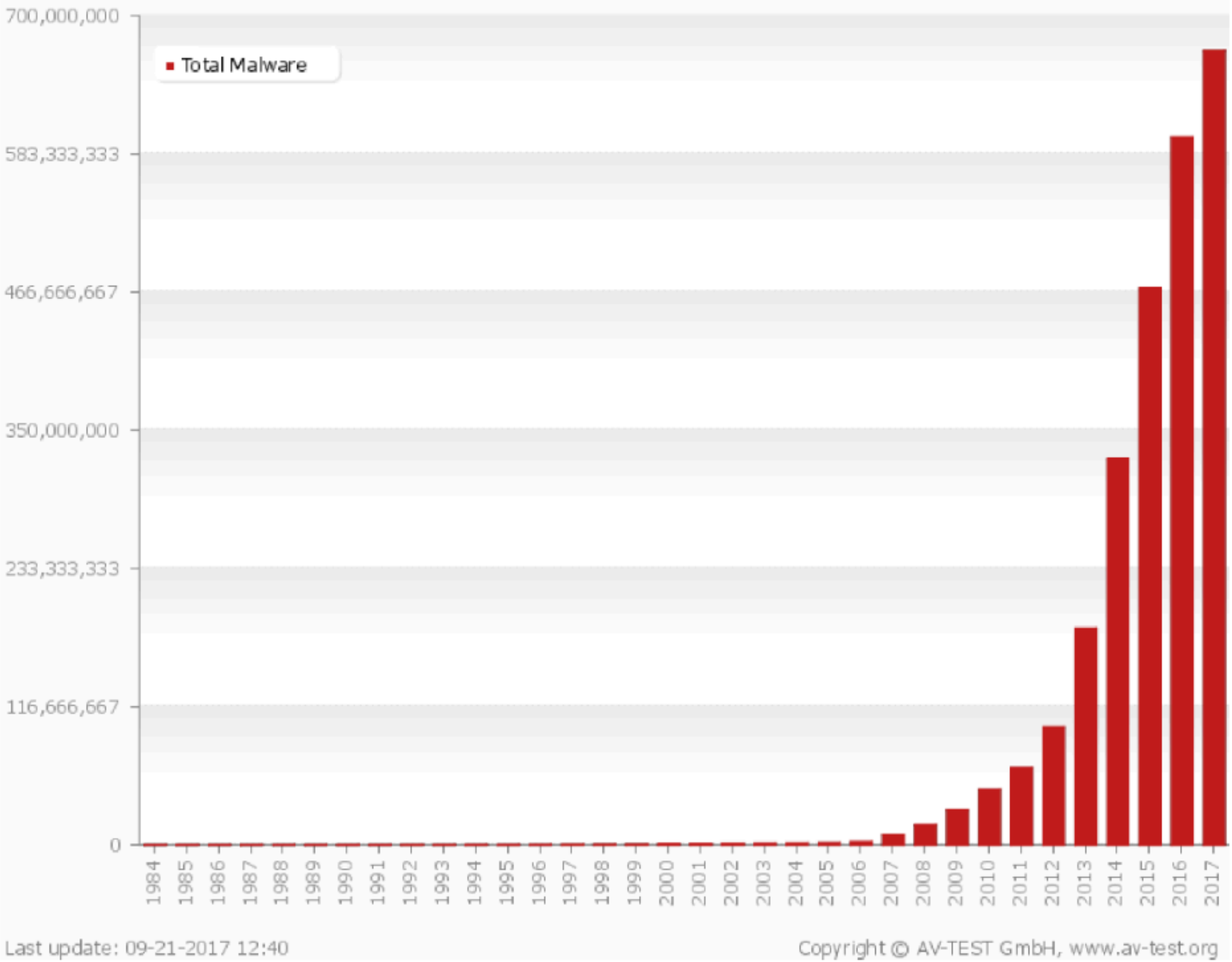


HOW MUCH MALWARE IS THERE?

- Polymorphic and metamorphic viruses can make it easy to *miscount* viruses
- Take numbers with a grain of salt
  - Large numbers are in the AV vendors' best interest



https://www.av-test.org/en/statistics/malware/

HOW DO WE CLEAN UP AN INFECTION?

An often overlooked question

- Depends what the virus did, but..

- May require restoring / repairing files
  - A service that antivirus companies sell

- What if the virus ran as root?
  - May need to rebuild the entire system

- So what, just recompile it?
  - What if the malware left a backdoor in your compiler?
    - Compile the malware back into the compiler
  - May need to use original media and data backups