OS Security
SELinux and Ethos

Radboud University Nijmegen, The Netherlands

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Next week's lecture

Guest lecture by Jordy Kersten and Frans Kollée
(Madison Ghurka)

31C3 Recommendations

- Tobias Engel: “SS7: Locate. Track. Manipulate.”
- Karsten Nohl: “Mobile self-defense”
- Daniel J. Bernstein, Tanja Lange: “ECCHacks”
- Jacob Appelbaum, Laura Poitras: “Reconstructing narratives”
- Starbug: “Ich sehe, also bin ich ... Du”

Videos of talks online at
http://media.ccc.de/browse/congress/2014/

A short recap

- Various programs to detect/prevent intrusion (IDS, IPS, AV)
- Different categories of malware:
  - Virus (self-reproducing, needs host program)
  - Worm (spreading routine, no host program)
  - Trojan (no spreading routine, usually comes with useful masquerading functionality)
- Correction: Viruses do *not* have to print their own source code!
- Self-reproducing programs and “quines” are still related
- Rootkits are used to hide the results of an attack
- Particularly dangerous: kernelspace root kits
- Even worse: bootkits infect the MBR
- Even worse: hardware/firmware malware
- Malware detection either signature-based or heuristic
- Code polymorphism (and self-modifying code) to counter signature-based AV
- AV can hurt security: larger attack surface, false positives, user perception of security

LSM

- Linux security traditionally follows the UNIX security model
- Around 2000, various projects worked on MAC (and generally stronger security) for Linux
- Linus Torvalds about inclusion of SELinux: “make it a module”
- Since Kernel 2.6: API for *Linux Security Modules* (LSMs)
- Hooks to module functions when accessing security-critical resources
- An LSM sets function pointers in a data structure called `security_operations`
- Global table of this type called `security_ops` defined in `include/linux/security.h`

Criticism of LSM

LSM is in the mainline kernel and various LSM implemetations exist, however, there is some criticism of the API:

- Small overhead even if no LSM is loaded
- LSM is designed for access control, but can be abused, for example, for bypassing GPL license
- “Because LSM is compiled and enabled in the kernel, its symbols are exported. Thus, every rootkit and backdoor writer will have every hook he ever wanted in the kernel.” (https://grsecurity.net/lsm.php)
- LSM provides hooks only for access control
- Systems like grsecurity and RSBAC need more than just access control
- “Stacking” multiple security modules is problematic
- LSM hooks expose kernel internal data structures as parameters

Implementations of LSM

- AppArmor (see lecture on virtualization)
- Linux Intrusion Detection System (LIDS)
- POSIX capabilitites
- Simplified Mandatory Access Control Kernel (Smack)
- TOMOYO
- Security-Enhanced Linux (SELinux)

Ethos OS

- All previous security features of an OS were “add-on”
- System calls, shells interface, utilities etc. implement the POSIX standards for UNIX OSs
- UNIX goes back to the 70s, not designed for security
- Ethos is a new operating-system design
- Project started in 2007 by Jon Solworth at UIC
- Ethos does *not* implement the POSIX standard, it’s radically “clean-slate”
- Ethos is designed for security

Motivation

- "A secure OS by itself is meaningless"
- Main goal and motivation of Ethos: make it easy to write *robust applications*:

  A program is robust if it continues to operate as intended even in the face of an intelligent adversary.
- Typical security-critical application-level failures:
  - Fail to provide adequate security services, e.g., encryption, authentication, authorization
  - Programming flaws like buffer overflows, race conditions, missing or incorrectly used security services
  - Failures at the intersection of mechanisms
- Problem: Too much responsibility for application programmers
- Example: Hundreds of LoC to use OpenSSL in typical server applications
- Solution in Ethos: provide higher-level API (system calls) that takes care of security issues
- Ethos is designed for network (Internet) applications

Design on top of Xen

- Ethos is not running on bare hardware
- Ethos is running inside the Xen Virtual Machine Monitor (VMM)
- Xen Dom0 OS is typically Linux
- Virtualization allows to run Ethos alongside Linux
- Ethos started with Mini-OS (provided by Xen)
- Additions of Ethos to Mini-OS:
  - Processes and system calls
  - Networking and Inter-process communication (IPC)
  - Filesystem
  - Cryptography
  - Authentication
  - Types
  - User-space Debugger
- Also cleaned up lots of code

“Laziness”

Building on top of Xen makes development of a new OS feasible:

- Use a Linux program called `shadowdæmon` that provides services to Ethos running in another Xen domain
- Use RPC over Xen’s virtual network interfaces
- Eventually replace `shadowdæmon` by native Ethos implementations
- **Filesystem:** Use existing filesystem in Dom0 and `shadowdæmon` calls to read/write. `ext4` has >25000 LoC; Ethos file-system component has 1754 + 814 in `shadowdæmon`
- **Networking:** Use ARP implementation in Dom0 with static ARP tables
- **Drivers:** >5 Mio. LoC for drivers in Linux. Ethos’ network driver is 462 LoC, console driver is 296 LoC
- **Debugging:** Use `gdbsx` debugger of Xen
- **Testing:** “Fast” to get a prototype working, can automate testing from Dom0

Pitfalls of using a VMM

- VMM itself can have bugs (Ethos helped one such problem)
- Dom0 in Xen has direct access to
  1. hardware I/O devices
  2. the virtual memory of other virtual machines
- Address problem 1 by encrypting all data sent to communication devices and file systems
- Problem 2 could be addressed in Xen by encrypting memory pages before Dom0 access
- Long-term plans (ideas) for Ethos:
  - Microkernel implementation
  - Develop minimalist VMM
  - Verify VMM

What Ethos ensures

Protection mechanisms are *compulsory*, most important ones:

- **P1:** Processes cannot change owners; instead, processes spawn special children that run as a different owner from inception
- **P2:** Applications do not have access to secret keys; instead, Ethos isolates keys and provides access to cryptographic operations through system calls
- **P3:** All network connections are authenticated
- **P4:** Authentication uses strong techniques
- **P5:** Confidentiality of authentication databases is not essential to security because Ethos uses public-key cryptography
- **P6:** All communication made (client-side/local user) or received (server-side/remote user) are subject to authorization based on the requesting host and user
- **P7:** All data written to disk or network devices is protected using strong cryptography

Etypes

- Typical input to programs in UNIX are byte arrays (from the network, from files, from stdin)
- Parsing to typed inputs is left to applications
- Improper handling of ill-formed (e.g., malicious) inputs is common source of security issues
- Ethos offers *distributed types* in the *Etypes* subsystem:
  - A notation, ETN, for specifying types
  - a machine-readable type description (“type graph”)
  - A single wire format (ETE)
  - Tools (userspace and kernelspace) to transform ETN into code that will encode, decode, and recognize types
  - Extensions to `read` and `write` system calls to check input and output
- Programs specify what input types they allow
- Validity of input (and outputs) enforced by OS

Available types

- Primitive types (`byte`, `int32`)
- Vectors (tuples, strings, arrays)
- Composites (structs, dictionaries, unions)
- Pointers
- RPC interfaces
- Any

Directories and types

- Directories “know” what types they may contain
- Typing is enforced for all non-directory contents of a directory
- Network connections, IPC, are using the filesystem
- Example: All file objects in a directory for IPv4 addresses must have type `int32`
- “Any” type allows traditional directories

System calls

UNIX		Ethos	
`mkdir`	Create directory, given path and mode	`createDirectory`	Create directory, given parent FD, name, label, and type hash
`open`	Open file for successive read/write	`read/writeVar`	Read/Write object in its entirety
`read`	Read a number of bytes	`read`	Read an object
`write`	Write a number of bytes	`write`	Write an object
`seek`	Seek within a file	`n/a`	Seek at object level by using directory as streaming object

Networking in Ethos

Server

```
fdListen = advertise("ping"); // bind
fd , user = import(fdListen); // accept
write (fd, "Hello");
```

Client

```
// connect
fd = ipc("ping", "example.com");
v = read(fd);
```

- Syntax similar to POSIX, but with some cleanups (names instead of numbers, remove excess calls)
- Core difference: semantics! (e.g., `user` for `import` is the *remote* user)

Properties of Ethos networking

- All network communication encrypted and authenticated
- Uses Networking and Cryptography library (NaCl) for crypto
- MinimaLT network protocol (faster than unencrypted TCP/IP)
- Authentication is public-key based
  - user IDs are public keys
  - users can mint as many identities as they like
- Services are named by paths in the file system (readability)
- Directory authorizes both
  - hosts (incoming and outgoing)
  - users (incoming)
- All data passed through Ethos is directory-specified type
  - avoid input vulnerabilities
  - encoder/decoder makes automatically achieves host-independence
- Ethos uses a distributed efficient public-key infrastructure called sayI

Implications

- Attackers cannot read/modify network communication
- Supports anonymous or pseudonymed users
- Unwanted communication eliminated before application code
- Zero LoC in applications for crypto and type conversions
- Applications cannot bypass security services
- Semantics eliminate many security holes
- Simplicity from deep integration of authentication, authorization, and networking

Present and future work in Ethos

Present

- Nearly complete prototype
- Ported Go programming language to Ethos
- Beginning of user-space foundation (EI shell language, graphics)
- Some small applications
- Close to releasing MinimaLT and sayl

Future

- From prototype to production kernel
- Develop EI, tools, graphics
- Build secure Ethos applications

Advertisement

Interested in working on Ethos?

Jon is looking for students who are interested in working on Ethos in their

- Bachelor's thesis
- Master's thesis
- Ph.D. thesis

More details on Ethos are on

http://ethos-os.org