Resilience and System Level Security

July 14, 2016
Lee Badger
Computer Security Division
National Institute of Standards and Technology

Disclaimer: Any mention of a vendor or product is NOT an endorsement or recommendation by NIST.
Resilience, Slightly Structured

Focusing mostly on the *when*:

- **Proactive** resilience
  - Triggered via non-attack event
  - Administratively-imposed or automated

- **Reactive** resilience
  - Triggered by an attack event --- maybe
Proactive Resilience

A few examples

- Required updates of authentication credentials
  - Yet another complex password... or RSA token...
  - Or, coming soon, use of the Common Access Card.
- Automated software diversity transforms.
- Error masking.
- Micro-reboot [Candea, Fox].
- Key refresh.
- Software rejuvenation [Trivedi]
- Self-cleaning Intrusion Tolerance [Sood].
- Log file rotation.
- Virtual Machine migration.
- more...
Reactive Resilience

- Behavior deviated from a specification
  - How to get the specification
    - Logic induction [Ko], language-assisted [Ko], static analysis [Wagner, Dean]
- Behavior matched a bad pattern (misuse)
  - State Transition Analysis [Ilgun, Kemmerer]
  - Rule-based misuse detection [Lindqvist, Porras]
- Behavior is unusual (and presumed bad)
  - Statistical anomaly on users [IDES system]
  - Frequency distribution changes [Emerald system]
  - Sequence-based anomaly detection [Forrest et al]
The Complexity of Configurations

**Selected Platforms** (http://usgcb.nist.gov)

- Windows 7 \( \geq 406 \) settings
- IE8 \( \geq 114 \) settings
- IE 7 \( \geq 106 \) settings
- Windows XP \( \geq 260 \) settings
- Redhat Linux 5 Desktop \( \geq 258 \) settings

... e.g.

- `xccdf:gov.mnist_rule_credential_validation` selected="true"/
- `xccdf:gov.mnist_rule_security_group_management` selected="true"/
- `xccdf:gov.mnist_rule_user_account_management` selected="true"/
- `xccdf:gov.mnist_rule_process_creation` selected="true"/
- `xccdf:gov.mnist_rule_logoff` selected="true"/
- `xccdf:gov.mnist_rule_logon` selected="true"/
- `xccdf:gov.mnist_rule_special_logon` selected="true"/
- `xccdf:gov.mnist_rule_file_system` selected="true"/
- `xccdf:gov.mnist_rule_registry` selected="true"/
- `xccdf:gov.mnist_rule_audit_policy_change` selected="true"/
- `xccdf:gov.mnist_rule_authentication_policy_change` selected="true"/
- `xccdf:gov.mnist_rule_sensitive_privilege_use` selected="true"/
- `xccdf:gov.mnist_rule_ipsec_driver` selected="true"/

Credit: NIST SP 800-70-rev2
National Checklist Program (http://web.nvd.nist.gov/view/ncp/repository)
A Specific Configuration: OS X 10.10 Yosemite

Set individually or in groups.

Interaction between locally-applied and "managed" settings values hard to pin down!

The actual meaning of a setting depends on how reading software interprets it.

Several DARPA Projects Touching on Resilience

AWDRAT (MIT, Teknowledge)
CORTEX (Honeywell)
DAWSON (GITI)
PMOP (MIT, Teknowledge)
GENESIS (UVA, CMU)
LRTSHS (MIT)
Steward (JHU, Purdue)
VICI (Komoku)
RAMSES (GITI, Stony Brook U.)
CSISM (BBN, Adventium, PACE)
LMRAC (MIT, Determina)
DPASA (BBN)

And more......
A few Observations and Idea Sketches

• **Mission/workflow specifications (rules, constraints) facilitated adaptation.**
  - Detection via spec violation is very helpful!
  - Tradeoffs: need to write the specifications.
  - **Idea:** further research in expressing mission/workflows
    • And runtime checking.
    • Big semantic gap.

• **Redundancy with discardable components facilitated service maintenance, provided a chance to adapt.**
  - Enabled fallback, diagnosis of attacks.
  - Components sometimes automatically repairable.
  - **Idea:** apply discardable components approach to modern execution environments
    • Virtual machines, containers, microservices.

• **Secure configurations hard to define and author.**
  - The NIST Secure Content Automation Protocol (SCAP) provides a basis for representing configurations.
    • E.g., see the National Checklist Program ([http://www.nist.gov/itl/csd/scm/ncp.cfm](http://www.nist.gov/itl/csd/scm/ncp.cfm))
    • But content authoring is often labor-intensive, skills-intensive, and error-prone.
  - **Idea:** additional research into generative approaches to content creation (e.g. templating, wizards, macros).
System Level Security

Take advantage of emerging systems architecture patterns to strategically improve assurance.

- Modern software/service packaging strategies are flexible, dynamic, and efficient, but:
  - **Isolation is configuration-based.**
  - Can assurance be maintained or improved?
  - Reasons for both Optimism and Concern.
  - Building blocks include: physical machines, physical networks, virtual machines, virtual networks, web browsers, containers, microservices, and more.

- **Operating System Containers**
  - “A container is an object isolating some resources of the host, for the application or system running in it.” From the Ubuntu lxc(7) man page.

- **Microservices**
Virtualization vs Containers

- Ubuntu/vbox5.0.24 base VM: **5,101 M**
- Ubuntu base container: **332 M**
  - Control groups: namespace, cpu, memory,
  - Name spaces: UTS, IPC, User, PID, Network
  - Device Drivers
  - Configure to “isolate” an application or a system

Control group info from the Ubuntu lxc man page (note: “l” in “lxc” is lowercase L).
Kick the Tires: Installing

From Scratch Installation

Make a new Container: fast

```
$ sudo lxc-create -n ubu-c -t ubuntu
[sudo] password for lbadger:
Sorry, try again.
[sudo] password for lbadger:
Checking cache download in /var/cache/lxc/xenial/rootfs-amd64 ...
Installing packages in template: apt-transport-https,ssh,vim,language-pack-en
Installing package: xenserver-bridge-0.9.0-36.1
[...]
I: Retrieving InRelease
I: Checking Release signature
I: Valid Release signature (key ID 790BC7277767219C42C86F933B4FE6A3C0B21F32)
I: Retrieving Packages
I: Validating Packages

##
# The default user is 'ubuntu' with password 'ubuntu'!
# Use the 'sudo' command to run tasks as root in the container.
##

```

```
$ time sudo lxc-create -n ubu3-c -t ubuntu

##
# The default user is 'ubuntu' with password 'ubuntu'!
# Use the 'sudo' command to run tasks as root in the container.
##

real    0m3.046s
user    0m1.008s
sys     0m1.280s
```
Kick the Tires: Running

We’ve made some containers

Run one of them

Run a single command in a container (and exit)
Complex Configuration

- Architecture
- Hostname
- Halt signal
- Reboot signal
- Stop signal
- Init command
- Init id
- Psedo ttys
- Console
- /dev dir
- Mount points

- Root fs
- Avail syscalls
- Control group
- Network
  - Type
  - Link
  - Mtu
  - Name
  - Hwadr
  - Ipv4
  - Ipv4 gateway
  - Ipv6
  - Ipv6 gateway

- Lifecycle hooksx
- Logging

Info from ‘man lxc.container.conf’
A few Observations and Idea Sketches

• **Container configurations are highly expressive, but easy to get wrong**
  – Configuration templates and change tracking already being addressed: e.g., Docker, LXC templates
  – **Idea:** further research in semantically checking container configurations; e.g., a container “lint” utility.

• **Lightweight containers can promote the principle of least privilege.**
    • Economy-of-mechanism, fail-safe-defaults, complete-mediation, open-design, separation-of-privilege, **least-privilege**, least-common-mechanism, psychological-acceptability
  – **Idea:** develop analysis techniques/tools to generate custom containers that approximate least-privilege for important classes of programs.
Microservices

• **Microservices**

• Not really a new idea:
  – Remember web services?
  – Remember the Mach microkernel or GNU HURD?

• But some goals do appear to be different:
  – Services should be easy to replace.
    • So connective protocols need to be simple.
  – Services should implement business capabilities.
  – Services should have their own refresh cycles.
  – Services should be programming-language agnostic.

Credit: info from martinfowler.com/articles/microservices.html
A “Hello World” Microservice”

```python
# hello.py
from nameko.rpc import rpc
class GreetingService(object):
    name = "greeting_service"
    @rpc
def hello(self, name):
        return "Hello, {}!".format(name)
```

- Import the necessary framework.
- Define the service.
- Decorator exposes the function that implements the service.
- Return a string to the client.

• This example is from: nameko.readthedocs.io/en/stable/index.html.
• Nameko is one of numerous frameworks that can be used.
• Used here for convenience because it’s simple Python, and open source.
A “Hello World” Microservice”

# hello.py

```python
from nameko.rpc import rpc

class GreetingService(object):
    name = "greeting_service"

    @rpc
def hello(self, name):
        return "Hello, {}!".format(name)
```

- This example is from: nameko.readthedocs.io/en/stable/index.html.
- Nameko is one of numerous frameworks that can be used.
- Used here for convenience because it’s simple Python, and open source.

But this would be too simple...
• Nameko depends on rabbitmq, an open source queuing framework.
Kick the Tires: Microservices

Note: the rabbitmq queuing system must already be running: start it with the “rabbitmq-server” command.
Some Achievable Properties

- Decoupling of logic from computing resources.
- Explicit inter-service interface specifications.
  - Support Saltzer/Shroeder principles
- Independent update cycles.

```python
from nameko.rpc import rpc, RpcProxy
class Service(object):
    name = "service"

    other_rpc = RpcProxy("another service")

@rpc
def hello(self):
    pass
```

- A dependency on another microservice.
- Dynamically linked when a "worker" object is created.
- A worker object exists only for the duration of a single method’s execution.
  - (in the nameko framework)
- This is a form of "software rejuvenation".
  - (the concept that restarting software components clears out some bugs)

A few Observations and Idea Sketches

• **Trusted Microservices**
  – Properly formulated, could some services (and their messaging fabrics) be viewed as Reference Monitors?
    • Concept from the Anderson Report in the 1970s: always invoked, tamperproof, verified.
  – **Idea**: research aspects of microservices interfaces and interactions and how assurance arguments could (or could not) be constructed for systems implemented with microservices.

• **Interposition-based Enhancements**
  – Interposition on the right interfaces can augment, transform, deny, or monitor uses of the interfaces.
    • However, interposition can also destabilize systems, and impose slowdowns.
  – **Idea**: research interposition strategies that are compatible with microservices-based systems.
Thanks