Generalized Single Packet Authorization for Cloud Computing Environments

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Agenda

- Brief Port Knocking / Single Packet Authorization Primer
- Lengthy demo – SPA integrated into Amazon's Cloud
- General integration points for Cloud providers
- fwknop-2.5 release – HMAC-SHA256 support
- Where is SPA headed?

PK/SPA Assertion

There is a security benefit in service concealment behind a default-drop packet filter + plus a lightweight passive authentication layer

(Not a defense for client-side vulnerabilities)

No Shortage of Server Vulns

- Cisco rsh vuln (HD Moore: “Hacking Like It's 1985”):

  http://goo.gl/gL6ZJ (https://community.rapid7.com/community/metasploit/blog...)

- UPnP vulnerabilities (affecting millions of devices):

  https://community.rapid7.com/docs/DOC-2150

- SHODAN enumeration of Internet connected SCADA devices:

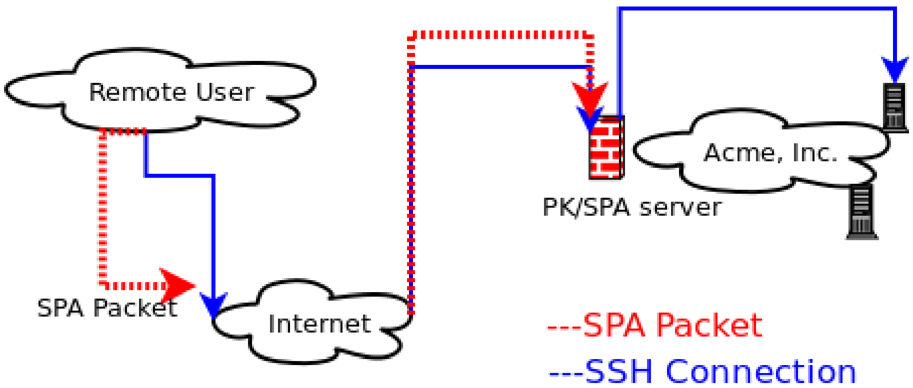
  http://goo.gl/9OZly (https://threatpost.com/en_us/blogs/shodan-search-engine...)

- Barracuda Networks SSH backdoors (Stefan Viehböck):

  http://krebsonsecurity.com/2013/01/backdoors-found-in-barracuda-networks-gear/

Typical PK/SPA Work Flow

- User wants SSH access behind PK/SPA firewall
- User executes PK/SPA client
- Firewall is reconfigured to allow SSH connections from the specified IP
- PK/SPA packet(s) passively monitored
- PK/SPA packet(s) never acknowledged in any way
- SSHD cannot be scanned for
- *Think beyond SSHD*



General Goal of fwknop

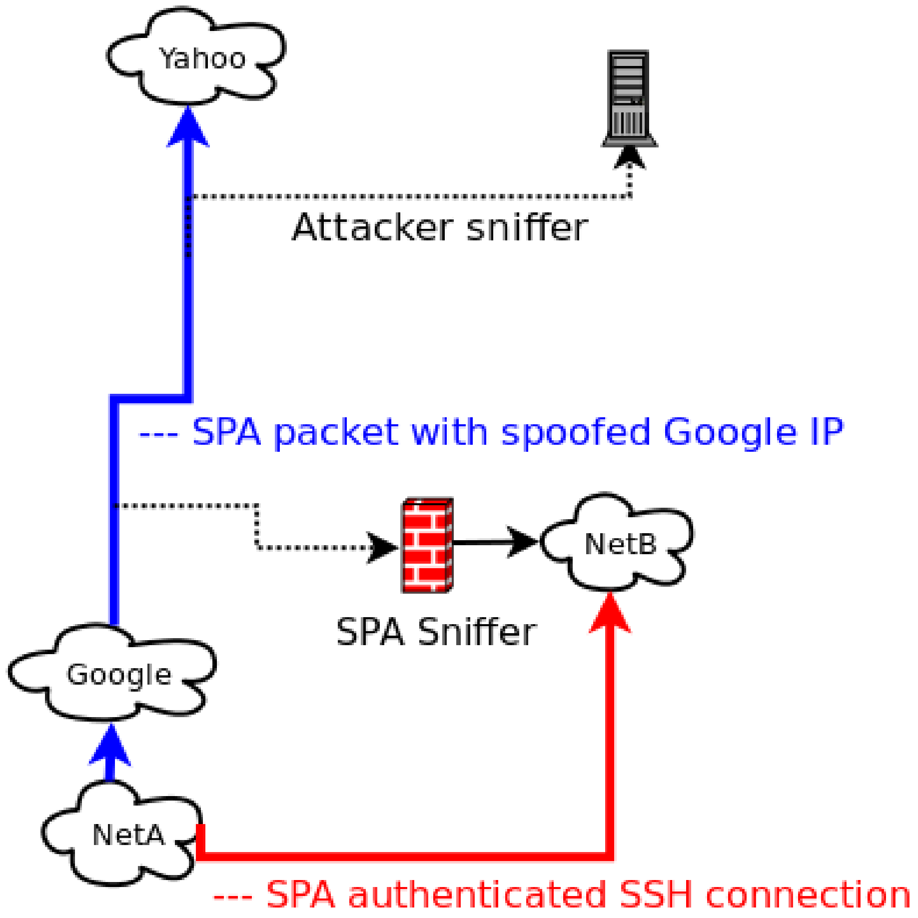
Solve PK limitations while simultaneously retaining its benefits

The fwknop Design

- **Firewall default drop stance for protected services**
- **Passive collection of authentication information (libpcap*)**
- **Support for Symmetric and Asymmetric ciphers**
- **Encrypted and non-replayable SPA packets**
  - Do not want anything that trusts an IP in the network layer header
- **Server portable to embedded systems**
  - Do not want a heavyweight interpreted language (this is a trade off)
- **Server portable to different firewall architectures and router ACL languages**
  - Make sophisticated use of NAT
- **Client portable to everything from Cygwin to the iPhone**
  - Do not want to require raw socket manipulation of packet headers or admin privileges
- **Minimize library dependencies**

Things Aren't Always as They Seem

- User gains access to NetB from NetA with SPA
- Attacker: Which system to attack?
- SPA server can be anywhere on the routing path of an SPA packet – not just the SPA destination IP
- SPA packet source IP can be spoofed too
- ***Neither the SPA source nor destination IP matters***



Tutorial

Single Packet Authorization: A Comprehensive Guide to Strong Service Hardening with fwknop

http://www.cipherdyne.org/fwknop/docs/fwknop-tutorial.html

SPA in the Amazon Cloud

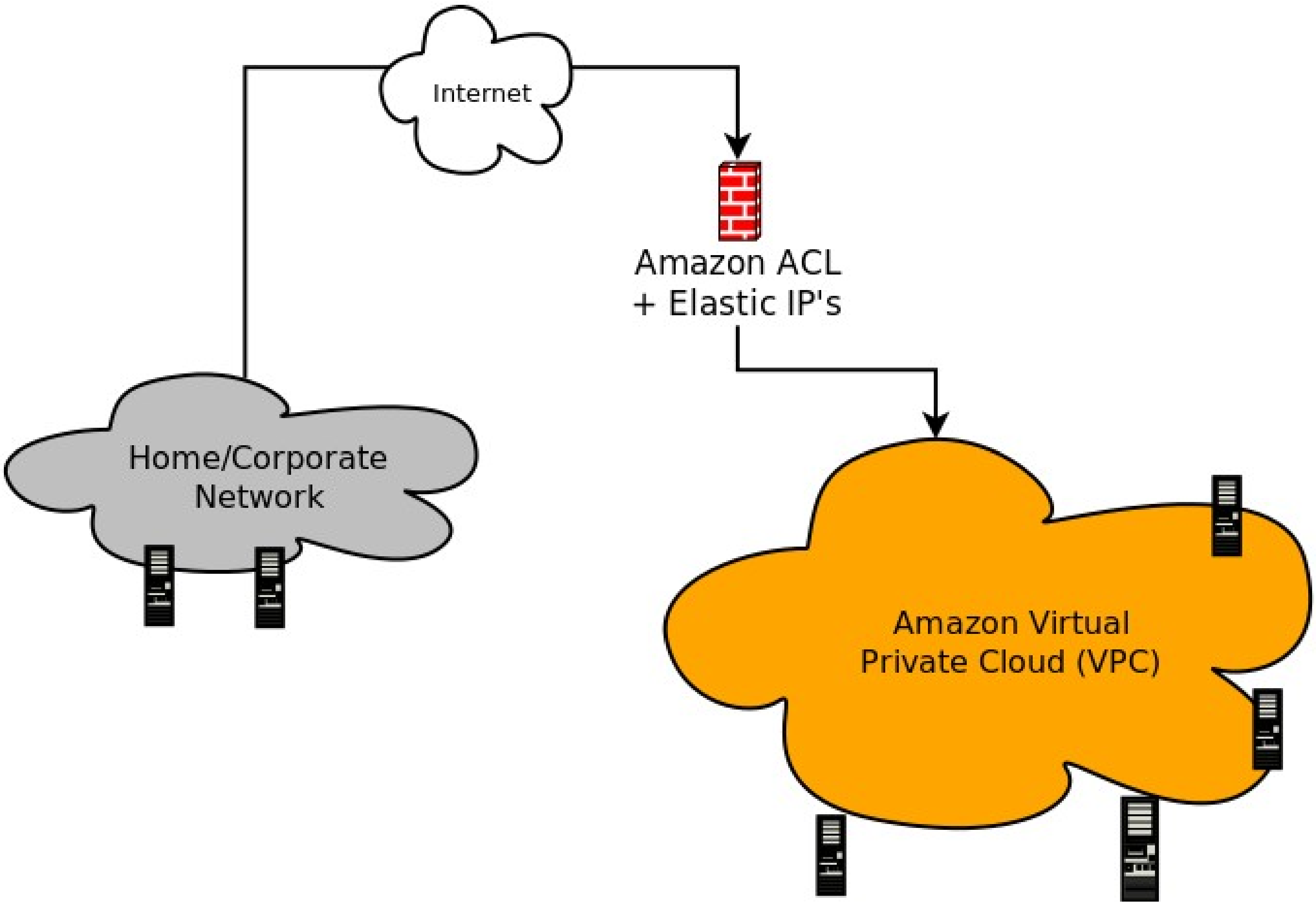
http://aws.amazon.com/

Amazon AWS User Agreement

“...**4.2 Other Security and Backup**. You are responsible for properly configuring and using the Service Offerings and taking your own steps to maintain appropriate security, protection and backup of Your Content, ***which may include the use of encryption technology to protect Your Content from unauthorized access*** and routine archiving Your Content...”

http://aws.amazon.com/agreement/

Amazon VPC Networks

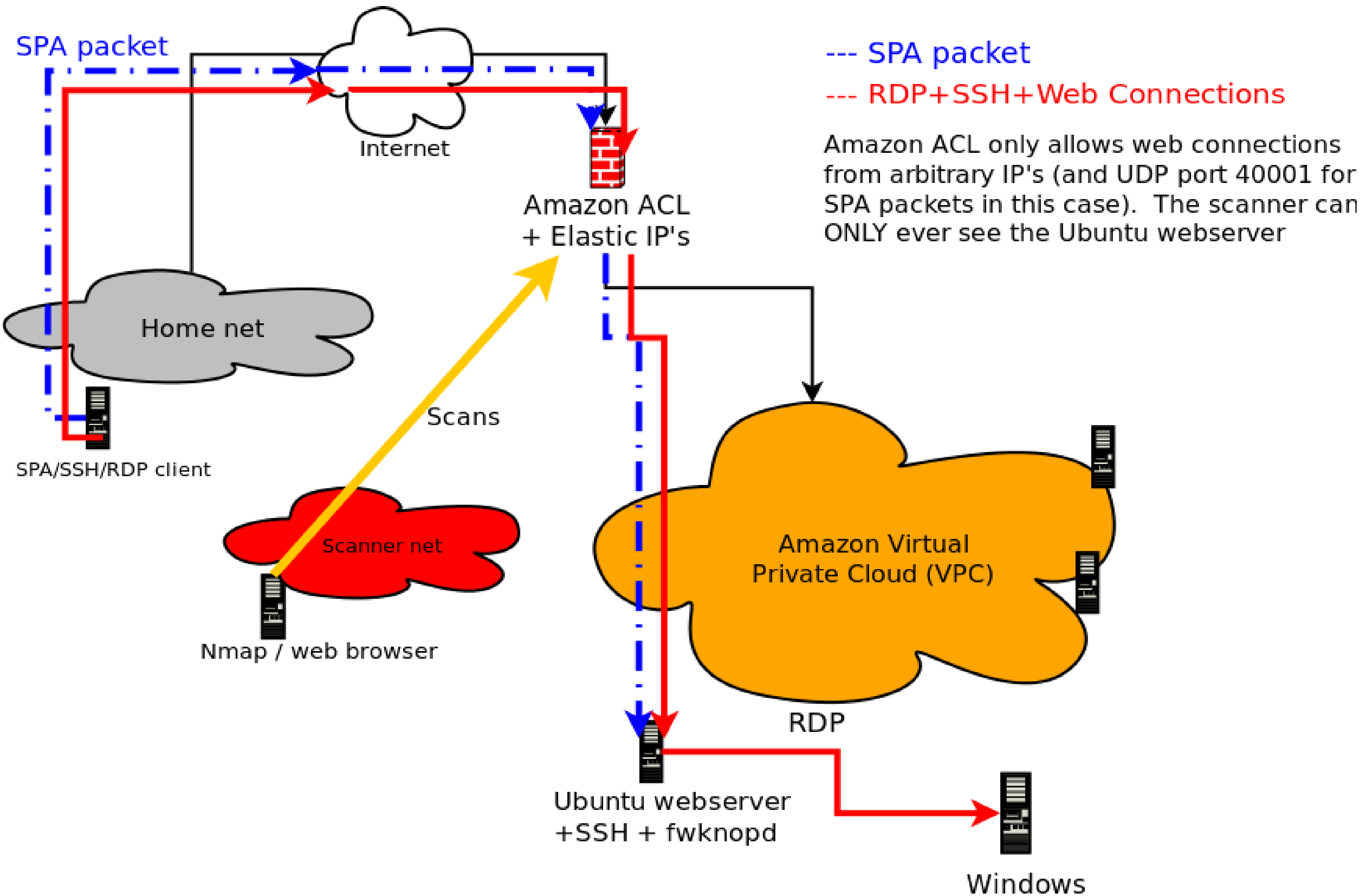


The Perfect SPA Use Case

- Microsoft RDP vulnerability last year (CVE-2012-0002)
- Full remote code execution potential, although Metasploit only has a DoS module
- For a time, Cloud provider Windows images were vulnerable

- Problem: fwknop does not support a Windows firewall

Amazon VPC + SPA Setup



fwknopd Configuration

- We're going to create an SPA “jump” host gateway

 # cat /etc/fwknop/fwknopd.conf

```
PCAP_FILTER                 udp port 40001;
ENABLE_IPT_FORWARDING       Y;
ENABLE_IPT_LOCAL_NAT        Y;
ENABLE_IPT_SNAT             Y;
SNAT_TRANSLATE_IP           10.0.0.12;
```

 # cat /etc/fwknop/access.conf

```
SOURCE: ANY;
KEY: test1234;
FORCE_NAT: 10.0.0.12 22;
REQUIRE_SOURCE: Y;

SOURCE: ANY;
KEY: 1234test;
REQUIRE_SOURCE: Y;
```

Demo (video)

Demo: Key Points

- **Do not have any direct integration with AWS border controls**
- **All SPA principles apply**
  - Default-drop firewall policy – cannot scan for a target
  - Passive packet acquisition – SPA packets are never acknowledged
  - Replay detection
  - Temporary firewall reconfiguration for service access
- **Access to *any* service on *any* VPC system all through a single routable Elastic IP**
  - SPA hardened “jump” host
  - Sophisticated usage of NAT
  - Accessed hosts don't even need a route to the Internet (DNAT + SNAT usage)
- **“Ghost” services**
  - Scanners only see Apache (or whatever), but SPA allows access to SSHD or any other service
  - iptables SPA NAT rules intercept connections out from under local userspace services
  - fwknop has supported ghost services since the old perl days

Can We Generalize This to Other Cloud Computing Environments?

Some Observations About Amazon

- Could fully control and configure internal OS images (install software, manipulate firewall rules, etc.)
- No (apparent) specialized filtering in AWS border ACL
- Not restricted to accessing VPC hosts with specialized applications controlled by Amazon – any application that is compatible with ACL configuration will work
- The above translates to greater ease of use and deployment for Amazon customers independent of SPA or anything else – e.g. it is a good architecture that other Cloud providers will emulate

SPA Integration with Arbitrary Cloud IaaS Providers

- “Useful” Cloud infrastructures provide remote access via SSH/RDP/VPN protocol to customizable OS images
  - Universal HTTP/HTTPS for Cloud usage is not generally compatible with SPA
- Cloud providers usually implement a network ACL capability
  - May or may not be customizable by the user
  - SPA client must communicate in a compatible fashion
- We don't necessarily need NAT capabilities in the SPA implementation (support less complex cloud environments)

- **IaaS (Infrastructure as a Service) providers are generally SPA-compatible**

Cloud Providers

- Wikipedia currently lists 129 different Cloud providers:

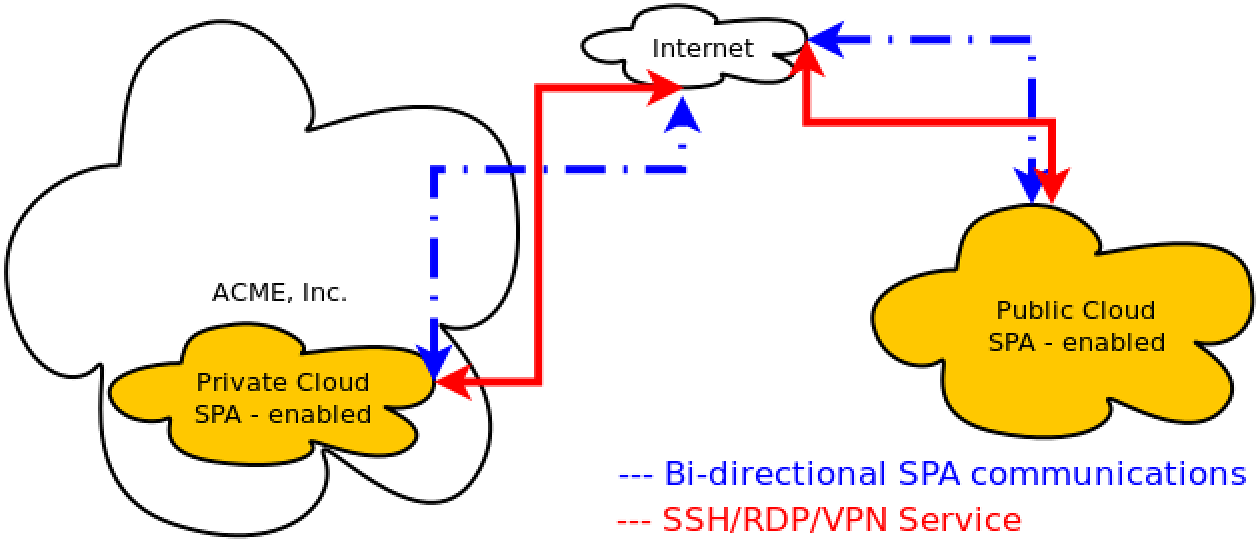
http://en.wikipedia.org/wiki/Category:Cloud_computing_providers

Private Clouds

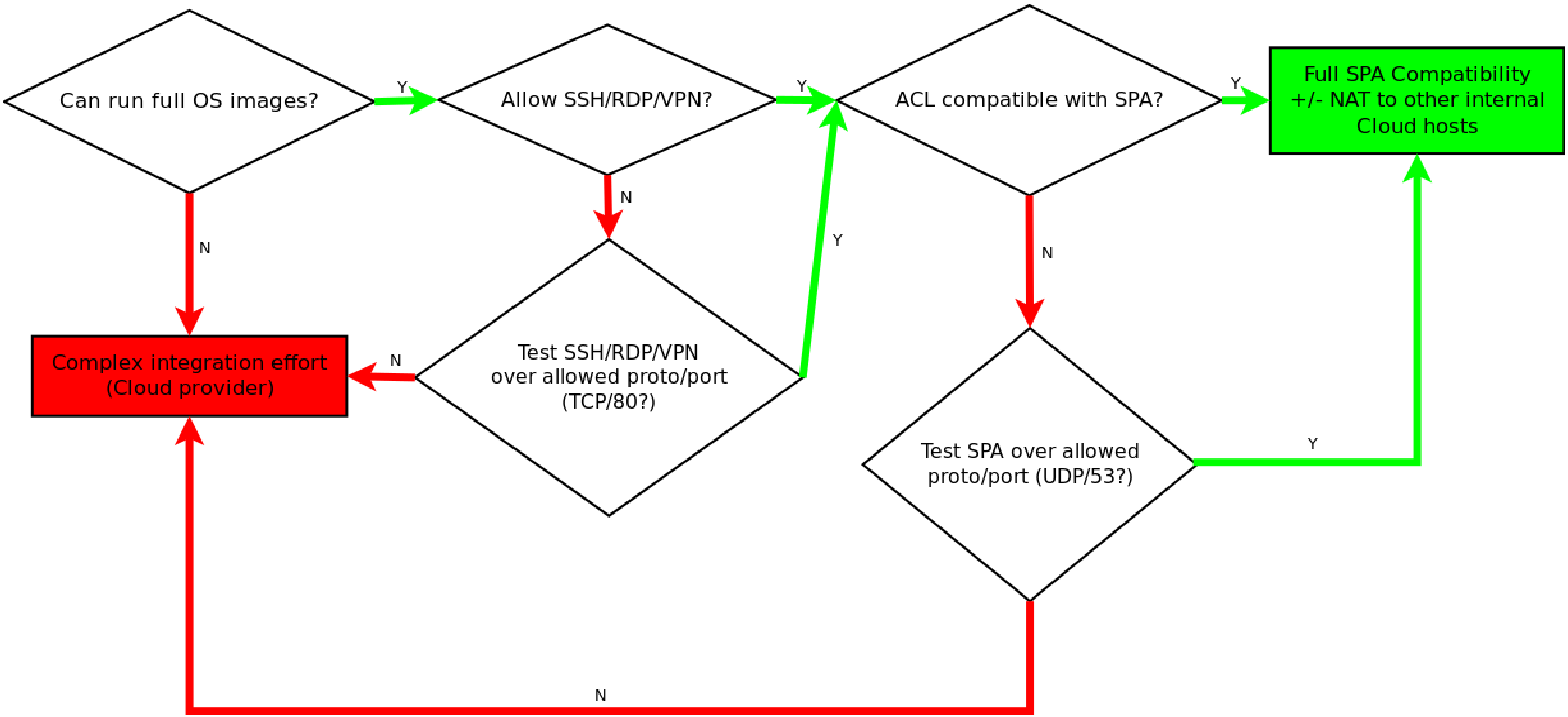
- Bare metal owned by a private entity
- Cloud layer provided by open source or proprietary computing stack
- SPA is likely compatible in two ways:
  - Integration with raw OS underneath the virtualization layer
  - Integration with guest OS instances (e.g. similar to AWS deployment)

Hybrid Clouds

- SPA is likely compatible ***bi-directionally*** if public portion is compatible

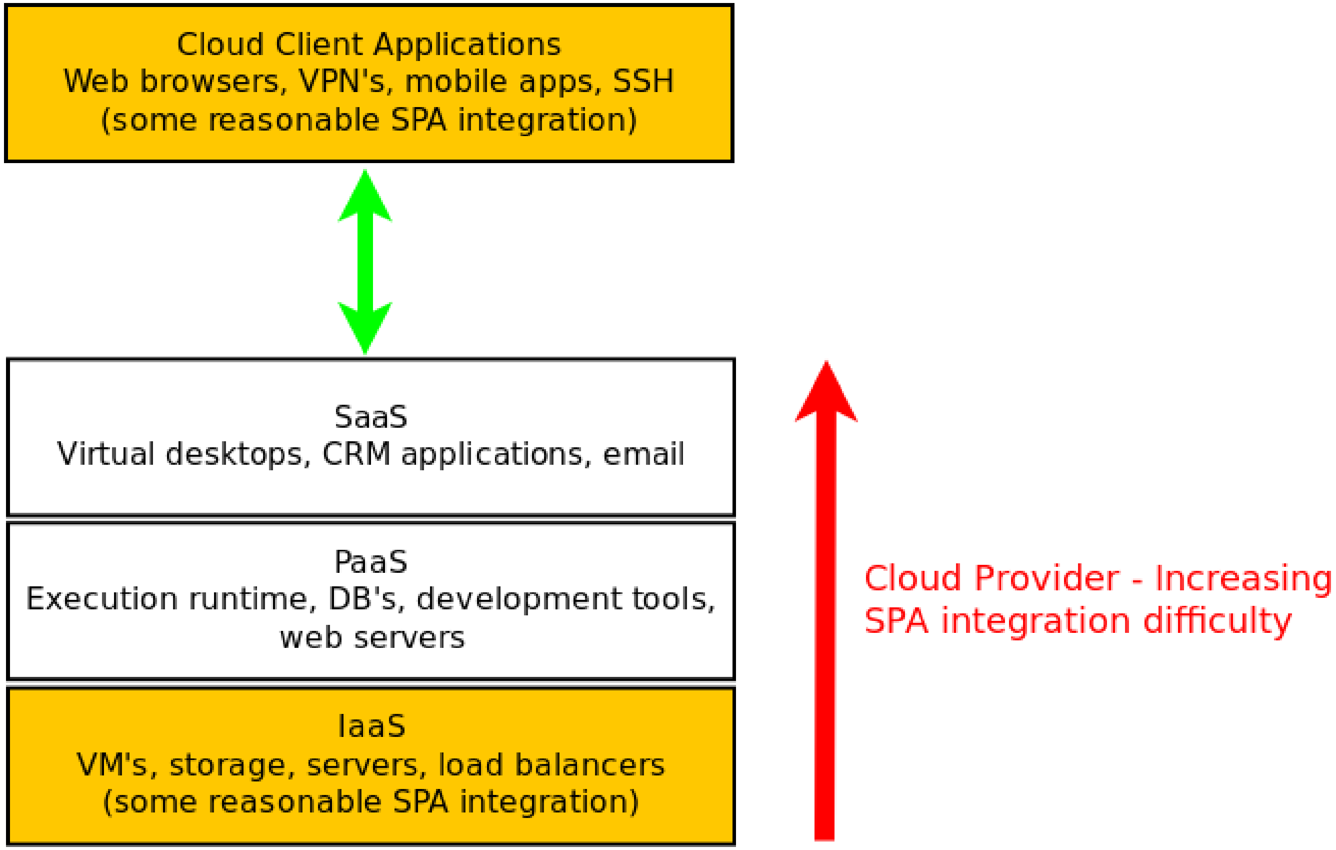


Evaluating Cloud IaaS + SPA Compatibility



Moving Up the Cloud Stack

- We've shown SPA integrates well with IaaS, but what about PaaS (Platform as a Service) and SaaS (Software as a Service) models?

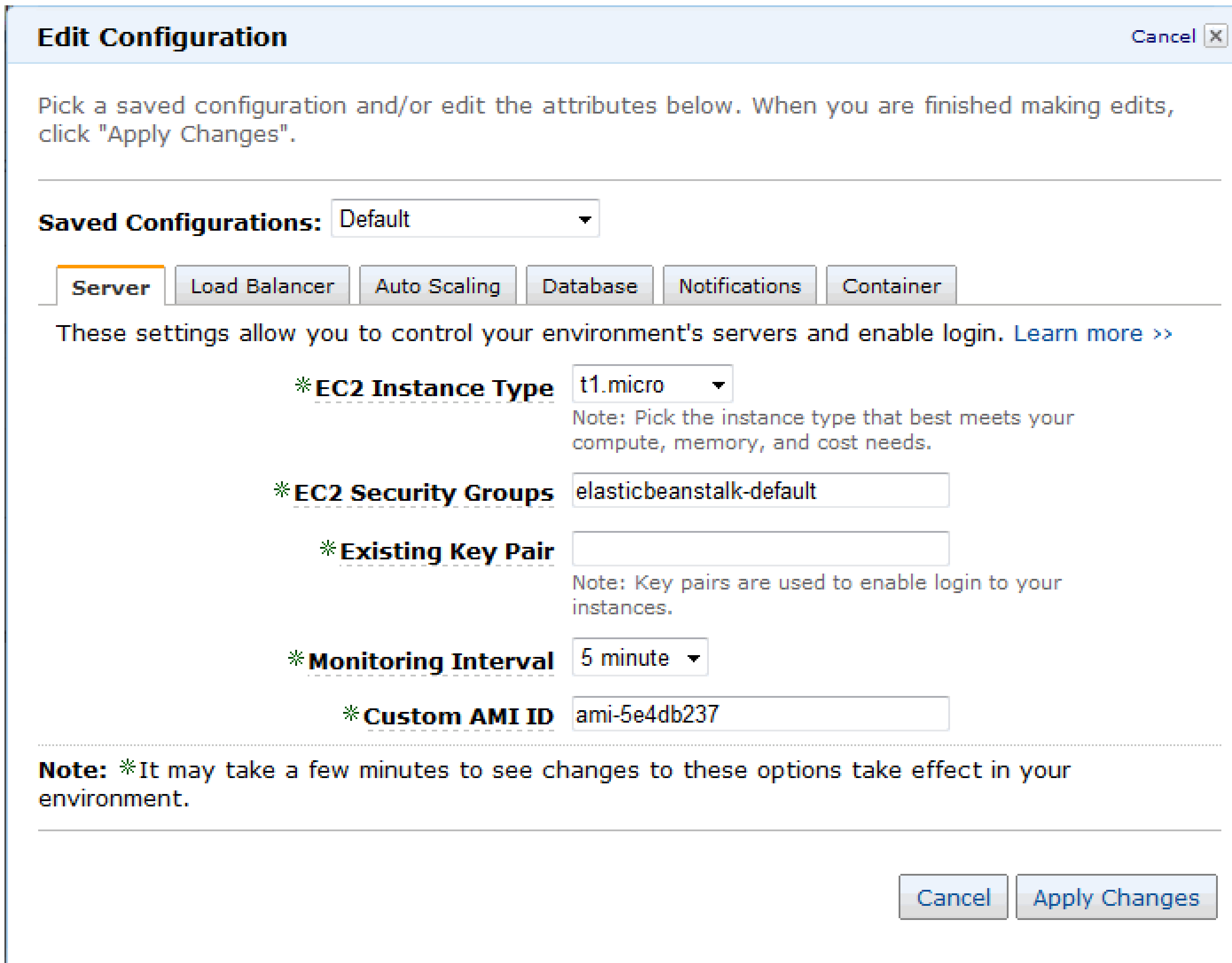


Moving Up the Cloud Stack (cont'd)

- SPA PaaS integration to the extent that the base infrastructure is under user control
  - Amazon Elastic Beanstalk
- SaaS not generally SPA compatible
  - Users do not have infrastructure control
  - Would require massive integration effort, and drastically changes usage model

Amazon Elastic Beanstalk

- http://docs.aws.amazon.com/elasticbeanstalk/latest/dg/GettingStarted.Walkthrough.html



Specialized Cloud Providers

- Cloud storage providers (DropBox, Mozy, etc.)
  - Not generally SPA-compatible (SaaS model)
  - Such providers construct purpose-built cloud infrastructure that is accessed through a dedicated client-side application (web browser or custom app)
- Clouds optimized for computing performance (e.g. Penguin Computing)
  - SPA compatibility likely for IaaS portion
  - SPA not generally a good fit for HPC jobs

Further Research...

- To what extent are packet filters used within Cloud computing stacks? (Independent of OS packet filters.)
  - This may hint at direct SPA integration with Cloud software
- Are there natural SPA integration points for distributed computing jobs?
  - If so, is there a security benefit? (Cloud-specific threat modeling.)
  - Are there integration points for admin layers below distributed content distribution services (e.g. Amazon Cloud Front)?
- Do any major IaaS Cloud providers leverage packet filters in ways that are incompatible with SPA? (Probably not.)

fwknop Development

fwknop-2.5 (coming soon)

- HMAC-SHA256
  - $HMAC(K,m) = H((K \oplus opad) \parallel H((K \oplus ipad) \parallel m))$
  - SPA encrypted message = m ‖ HMAC
  - K != encryption key

- fwknop uses the encrypt-then-authenticate paradigm
  - SSH uses encrypt-and-MAC
  - SSL uses MAC-then-encrypt ← Has made the *Vaudenay and more recent "Lucky 13" padding oracle attacks possible*
  - IPSEC uses encrypt-then-MAC ← *INT-CTXT and IND-CCA2 secure*

fwknop Vulnerabilities

- CVE-2012-4435 – Improper IP validation (requires a valid encryption key to exploit)
- CVE-2012-4436 – Client side `--last` processing overflow (local exploit)

- Fixed since 2.0.3. (Latest release is 2.0.4)
- *CREDIT: Fernando Arnaboldi, IOActive. Additional thanks to Erik Gomez for helping to make this auditing effort possible.*

What are we doing about this?

- Test suite driven valgrind validation
  - Every new commit is tested against a valgrind baseline
  - Lightweight C code helps a lot here
- SPA packet fuzzer
- Compile time security options
- Usage of static analyzers (e.g. splint, Clang static analyzer, etc.)
- SPA protocol review

SPA Packet Fuzzer

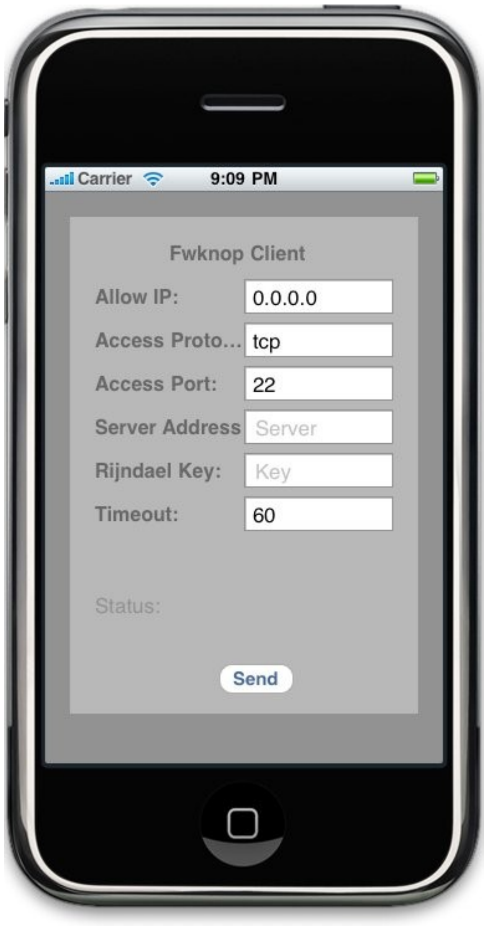
- Builds encrypted SPA packets with malicious payloads
- Series of patches against libfko to remove various constraints and validation steps
- Automatically tested via the `test/test-fwknop.pl` test suite
- Over 2,000 fuzzing packets currently used in different modes

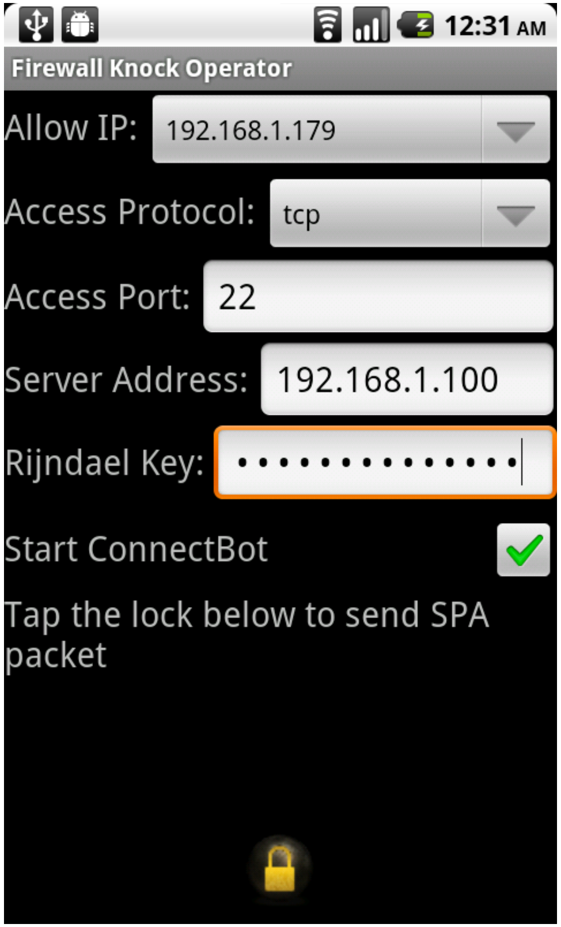
Test Suite:

```
# ./test-fwknop.pl
[build security] [client] Position Independent Executable (PIE).....pass (3)
[build security] [client] stack protected binary....................pass (4)
[build security] [client] fortify source functions..................pass (5)
[build security] [client] read-only relocations.....................pass (6)
[build security] [client] immediate binding.........................pass (7)
[build security] [server] Position Independent Executable (PIE).....pass (8)
[build security] [server] stack protected binary....................pass (9)
[build security] [server] fortify source functions..................pass (10)
[build security] [server] read-only relocations.....................pass (11)
[build security] [server] immediate binding.........................pass (12)
```

- This is enabled via:
  - gcc … -fstack-protector-all -fstack-protector -fPIE -pie -D_FORTIFY_SOURCE=2 -Wl,-z,relro -Wl,-z,now

iPhone + Android fwknop Clients



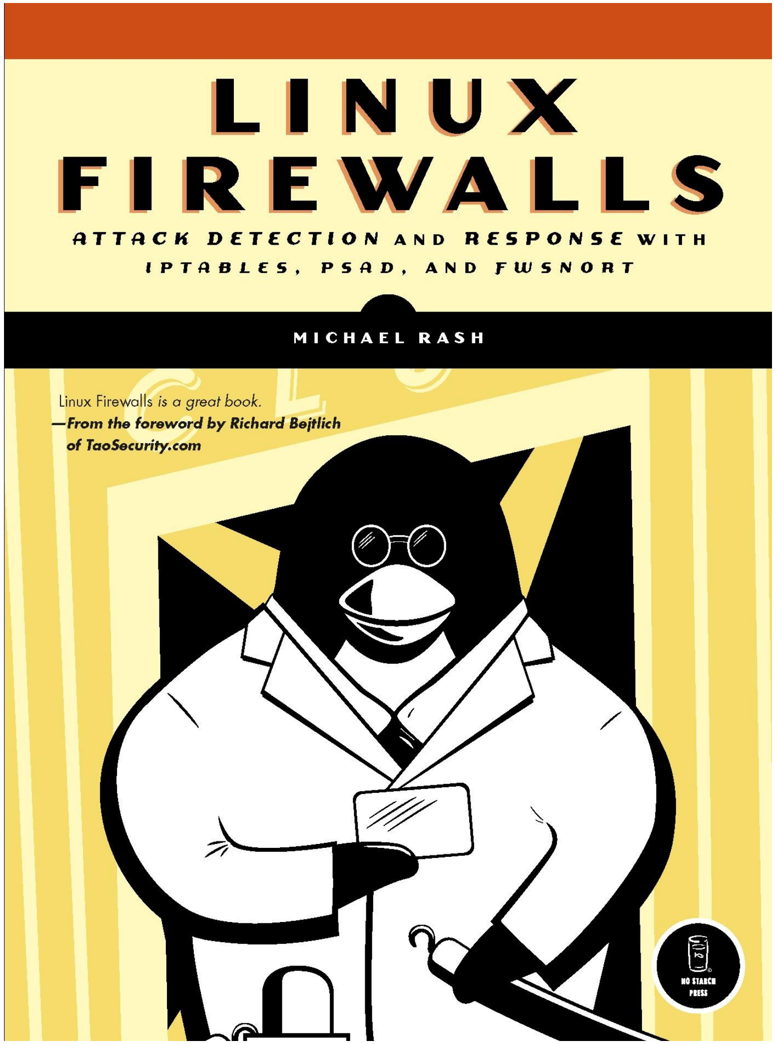


The Future of fwknop

- Mandatory Access Control support via SELinux and/or AppArmor
- Further cloud computing extensions and integration points
- Privilege separation
- Support for libcap-ng
- UDP listener mode
- Tunneling mode extensions (DNS, HTTP, SMTP, Tor)

Linux Firewalls 2nd Edition

To be released in 2014...



Thank You...

- The Amazon Security team
- Damien Stuart – developed the original C port
- Fernando Arnaboldi and Erik Gomez (IOActive)
- Franck Joncourt (Debian)
- Sebastien Jeanquier – authoritative PK/SPA thesis
- Sean Greven (FreeBSD port)
- Vlad Glagolev (OpenBSD port)

Questions?

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http://www.cipherdyne.org/fwknop/

Slides:

http://www.cipherdyne.org/talks/ShmooCon_2013_mrash_Cloud_SPA.pdf

http://www.cipherdyne.org/talks/ShmooCon_2013_mrash_Cloud_SPA_demo.mpg4