CHAINIAC: Proactive Software-Update Transparency via Collectively Signed Skipchains and Verified Builds

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Software Updates

Hilary Mason’s Twitter

A program tape for the 1944 Harvard Mark I, one of the first digital computers. Wikipedia.
Software Updates

- Software updates are used to patch disclosed vulnerabilities, add new features, and improve security posture
- If you *do not* update your system, things can go bad…
Software Updates

• But even if you *do* update your system regularly, things can go wrong too…

• Software-update systems are a lucrative attack target due to their *centralized design* and potential impact on users

How can we make software-update systems more secure and transparent?
Software Release Pipeline

**Development/Review** – Building release binaries – Sign-off – Release distribution

Developers

Distribution center

Users
Software Release Pipeline

Development/Review – **Building release binaries** – Sign-off – Release distribution

- Developers
- Build server
- Distribution center
- Users
Software Release Pipeline

Development/Review – Building release binaries – **Sign-off** – Release distribution
Software Release Pipeline

Development/Review – Building release binaries – Sign-off – **Release distribution**

Developers

Build server

Distribution center

Users
Challenges

1. Make software-update process resilient to partial key compromise
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Challenges

2. Prevent malicious substitution of a release binary during building process
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Over 90% of the source packages included in Debian 9 will build bit-for-bit identical binary packages.
Challenges

How many of you have reproducibly built software binaries for personal use?
Challenges

2. Prevent malicious substitution of a release binary during a build process

Building the Tor Browser bundle **takes 32 hours** on a modern laptop
Challenges

3. Protect users from targeted attacks by coerced or bribed developers
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Challenges

4. Enable developers to securely rotate their signing keys in case of renewal or compromise
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Design of CHAINIAC
Roadmap to CHAINIAC

- Decentralized Release Approval
- Verified Builds
- Anti-equivocation
- Key Evolution
Decentralized Release-Approval

1. Make software-update process resilient to partial key compromise
Decentralized Release-Approval

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Developers

Distribution center

Release <source code> Release <binary>

User

Policy
Decentralized Release-Approval

1. Make software-update process resilient to partial key compromise

Developers

Distribution center

User

Policy

Decentralized Release Approval
Verified Builds
Anti-equivocation
Key Evolution
Decentralized Release-Approval

1. Make software-update process resilient to partial key compromise
Decentralized Release-Approval

1. Make software-update process resilient to partial key compromise
Background

- Collective Authority (Cothority), Collective Signing (CoSi), and BFT-CoSi

Authoritative statements: e.g. log records

1 record → 2 record → 3 record

each statement collectively signed by both authority and all or most witnesses

References

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Verified Builds

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Verified Builds
Verified Builds

Release Policy File

- List of individual developer public keys
- Signing threshold
- Couthority public key
- Supported platforms for verified builds
- ...

Verified Builds

Decentralized Release Approval

Anti-equivocation

Key Evolution
Anti-equivocation Measures

3. Protect users from targeted attacks by coerced or bribed developers
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Anti-equivocation Measures

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Developers

Couthority

Policy

Release 1
Co-signature

Release 2
Co-signature

Release 3
Co-signature

Release 4
Co-signature

Transparency Release Log

Distribution center

User

Decentralized Release Approval
Verified Builds
Anti-equivocation
Key Evolution
Evolution of Developer Keys

4. Enable developers to securely rotate their signing keys
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Evolution of Cotherity Configuration

4. Enable cotherity to securely rotate its collective key
Evolution of Cothority Configuration

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Skipchains
Skipchains

• Novel data structure: blockchain + skip lists

• Blocks have multi-hop two-way links:
  ▶ *Backward links* - hashes of past blocks
  ▶ *Forward links* - (collective) signatures

• Secure and efficient traversal of arbitrary long timelines
Skipchains

Cothority configuration

Skipblock

Backward link (hash)

Forward link (co-signature)
Implementation and Evaluation
Implementation

• CHAINIAC is implemented in Go
  ▶ Using the DEDIS Kyber crypto library and Onet networking framework
  ▶ Available open-source at https://github.com/dedis/paper_chainiac
Evaluation Methodology

What is the cost effect of CHAINIAC on cothority nodes and on clients?

• Cothority-node CPU cost of validating releases and maintaining transparency release log
  ▶ The average values for six Debian packages over two years
Evaluation

1. Cothority-node CPU cost of validating releases and maintaining release log
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10$\text{/month server is sufficient to validate and maintain the log of Debian-security repository}
Evaluation Methodology

What is the cost effect of CHAINIAC on cothority nodes and on clients?

• Cothority-node CPU cost of validating releases and maintaining transparency release log
  ‣ The average values of six required Debian packages

• CPU cost of reproducing packages on cothority nodes
  ‣ From 1.5 to 30 minutes to reproduce a package

• Skipchain effect on communication cost
  ‣ Reducing the cost by the factor of 30 on 1.5 million update-requests from the PyPI repository

• CPU and bandwidth cost of securing a multi-package distribution
  ‣ ~20 sec to create a snapshot of >50k-packages Debian repository
Conclusion

• CHAINIAC decentralizes each step of the software-update process to increase trustworthiness and to eliminate single points of failure

• Skipchain structure for efficient logging and secure key evolution; See [https://bford.github.io/2017/08/01/skipchain/](https://bford.github.io/2017/08/01/skipchain/) for more applications

• Verified builds as an improvement over reproducible builds

• Role-based architecture, multi-package Chainiac and more are in the paper

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