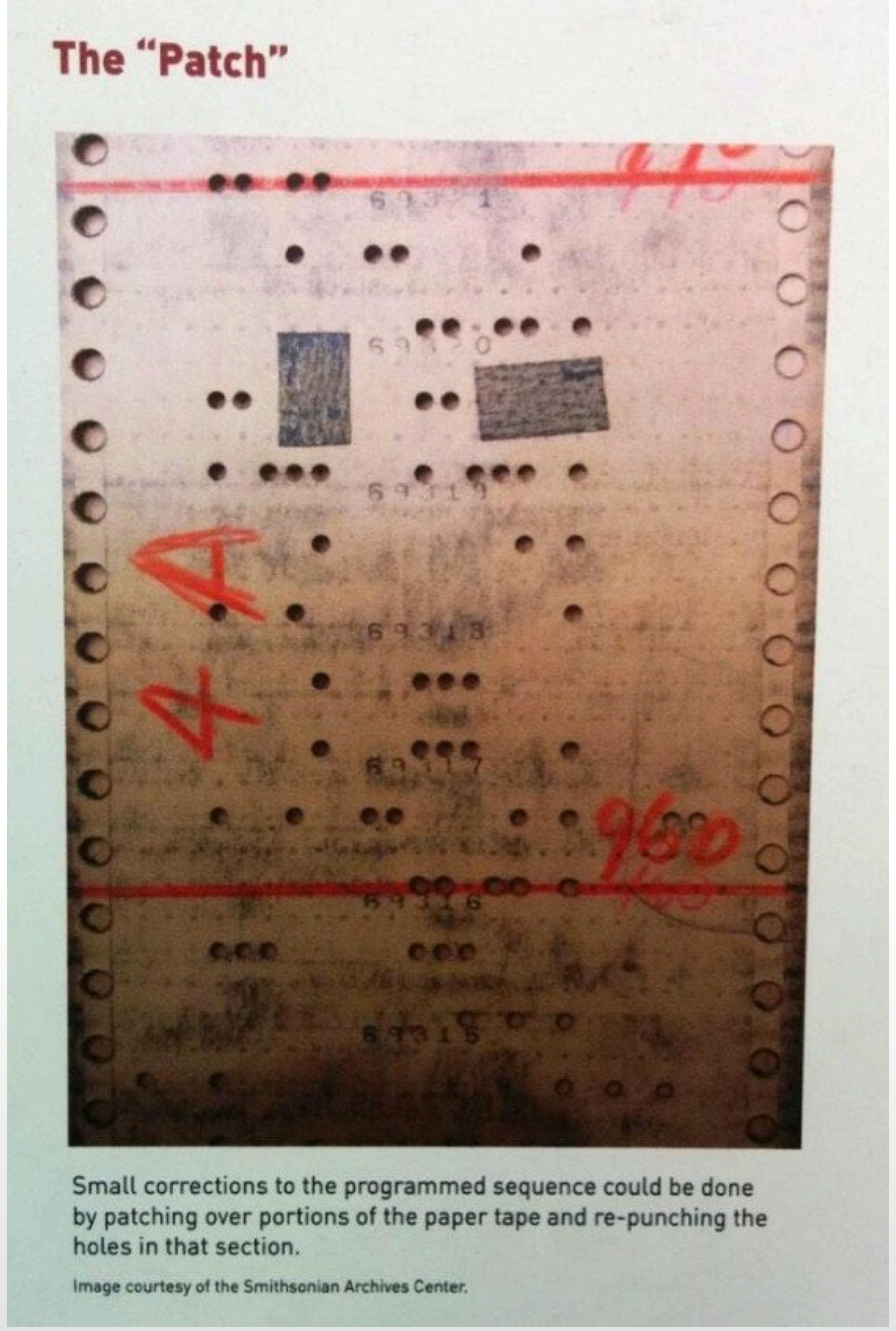
CHAINIAC: Proactive Software-Update Transparency via Collectively Signed Skipchains and Verified Builds

[1]**Kirill Nikitin**, [1]Eleftherios Kokoris-Kogias, [1]Philipp Jovanovic, [1]Linus Gasser,
[1]Nicolas Gailly, [2]Ismail Khoffi, [3]Justin Cappos, [1]Bryan Ford

[1]École polytechnique fédérale de Lausanne (EPFL)
[2]University of Bonn
[3]New York University

Software Updates

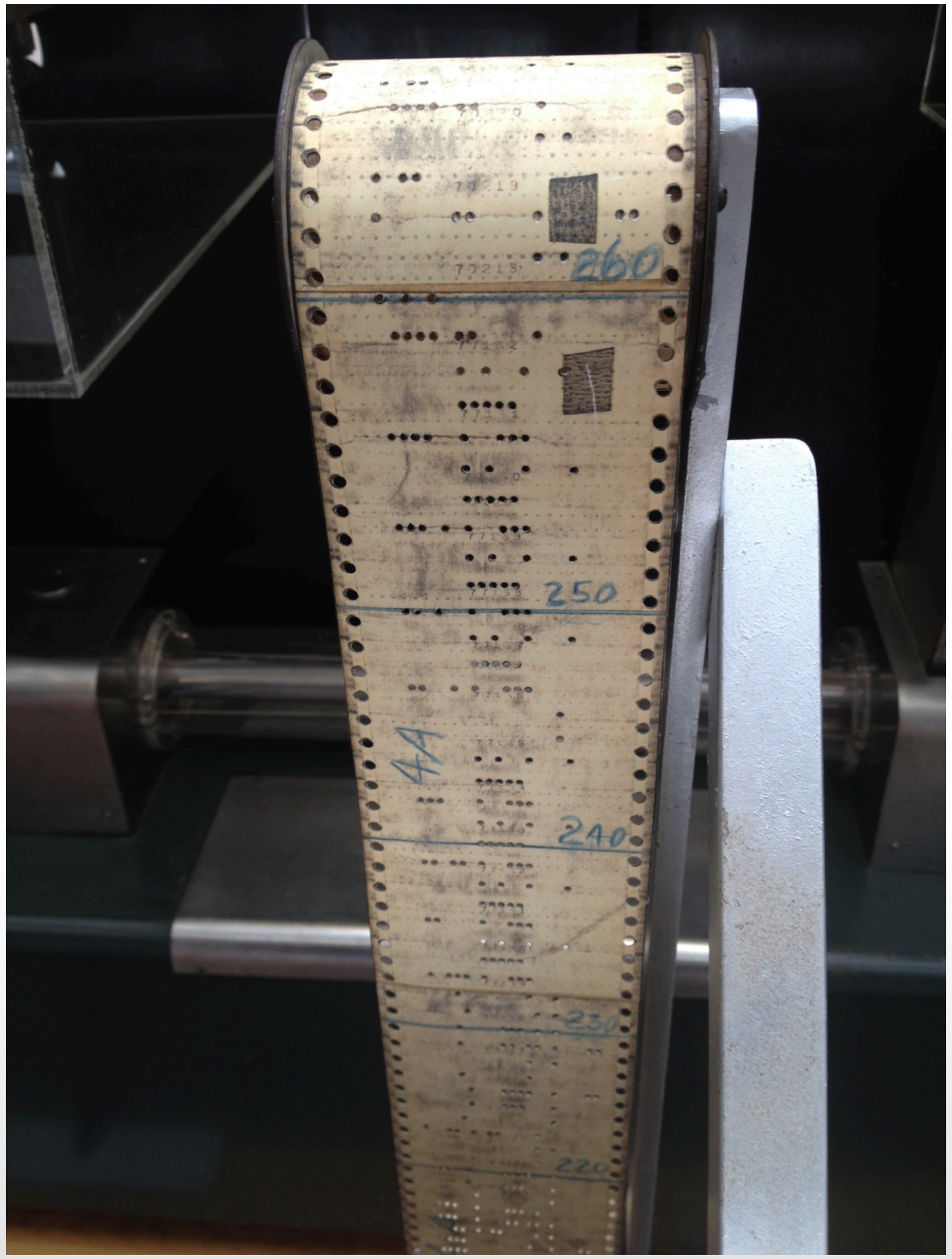


The "Patch"

Small corrections to the programmed sequence could be done by patching over portions of the paper tape and re-punching the holes in that section.

Image courtesy of the Smithsonian Archives Center.

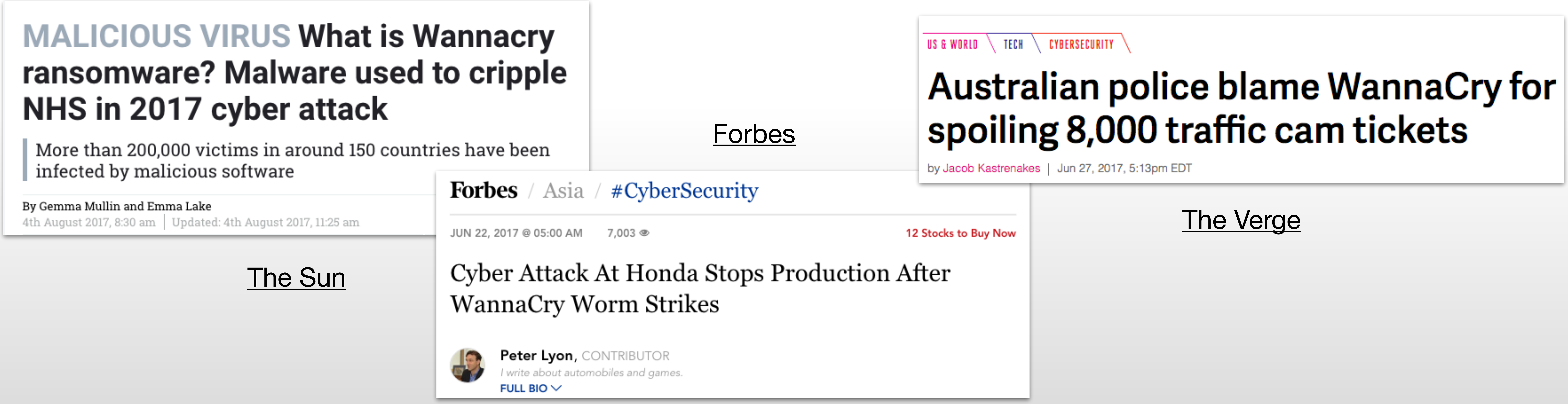
Hilary Mason's Twitter



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

Software Updates

- Softwares 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…



MALICIOUS VIRUS What is Wannacry ransomware? Malware used to cripple NHS in 2017 cyber attack

More than 200,000 victims in around 150 countries have been infected by malicious software

By Gemma Mullin and Emma Lake
4th August 2017, 8:30 am | Updated: 4th August 2017, 11:25 am

The Sun

Forbes / Asia / #CyberSecurity

JUN 22, 2017 @ 05:00 AM 7,003 👁 12 Stocks to Buy Now

Cyber Attack At Honda Stops Production After WannaCry Worm Strikes

Peter Lyon, CONTRIBUTOR
I write about automobiles and games.
FULL BIO

Forbes

US & WORLD \ TECH \ CYBERSECURITY

Australian police blame WannaCry for spoiling 8,000 traffic cam tickets

by Jacob Kastrenakes | Jun 27, 2017, 5:13pm EDT

The Verge

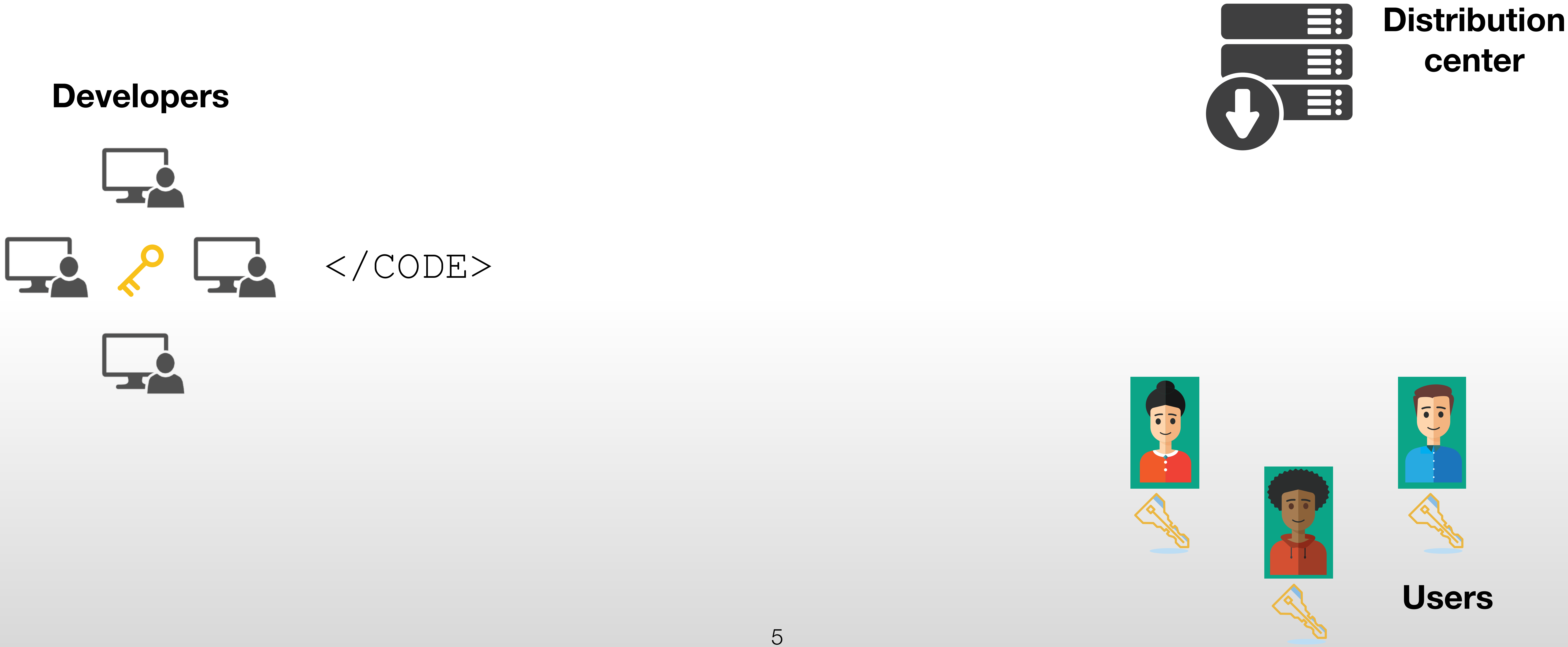
Software Updates

- 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



Distribution center

Developers

</CODE>

Users

Software Release Pipeline

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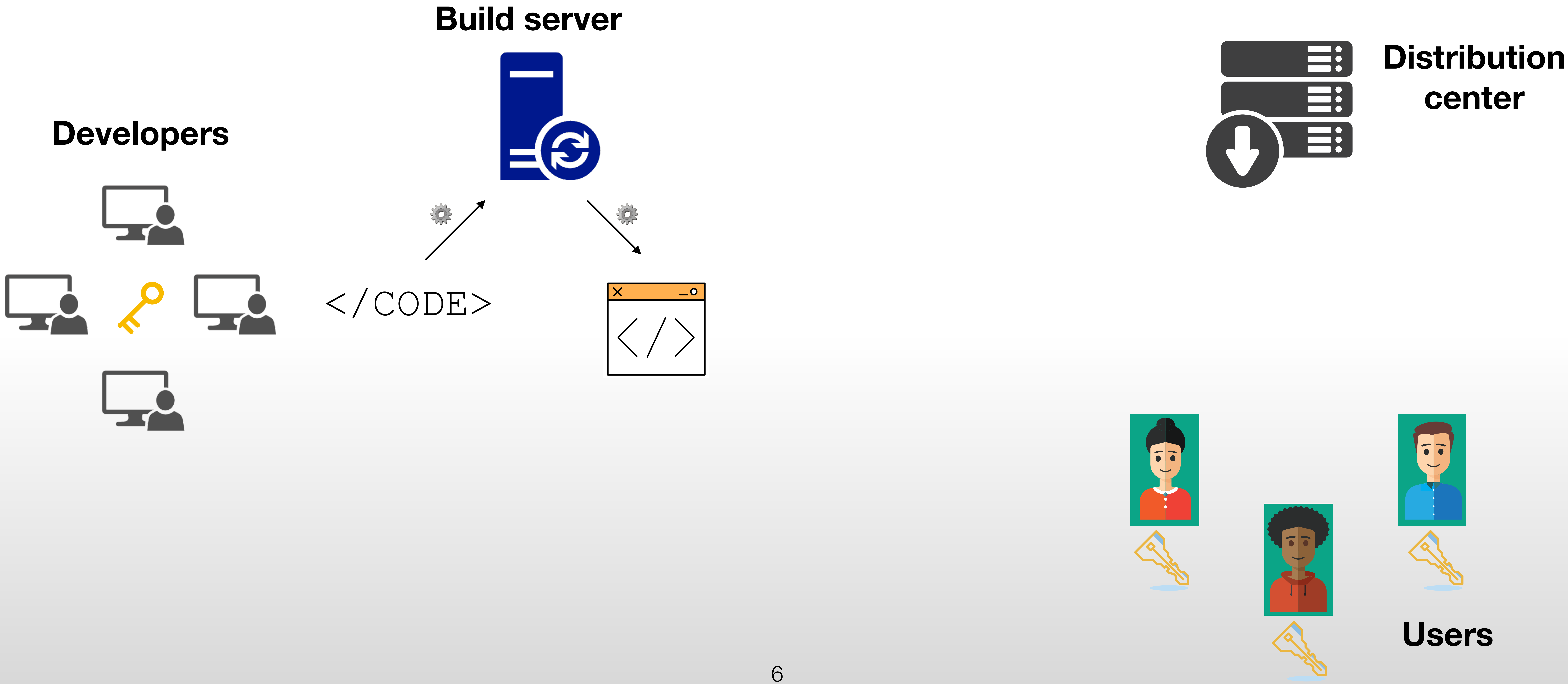

Build server

Developers

</CODE>

Distribution center

Users

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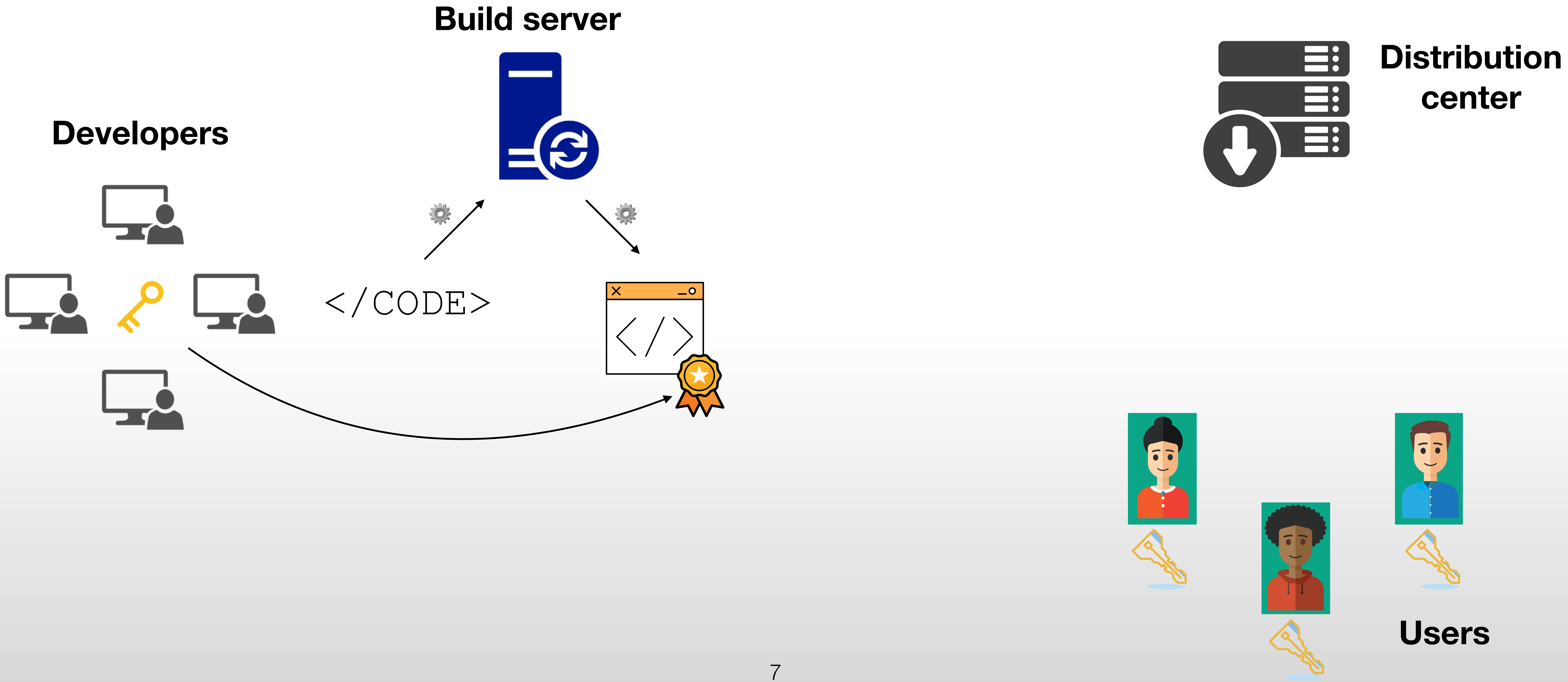

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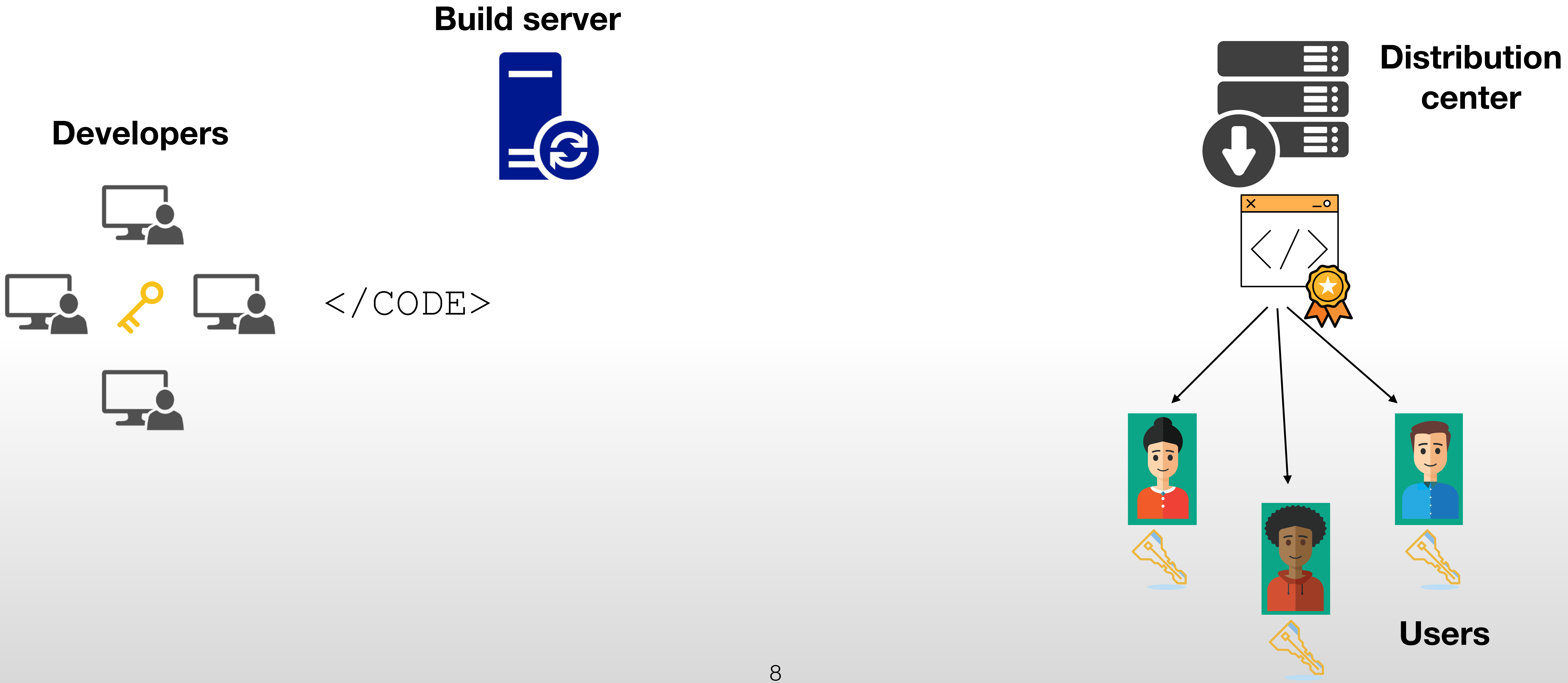

Build server

Developers

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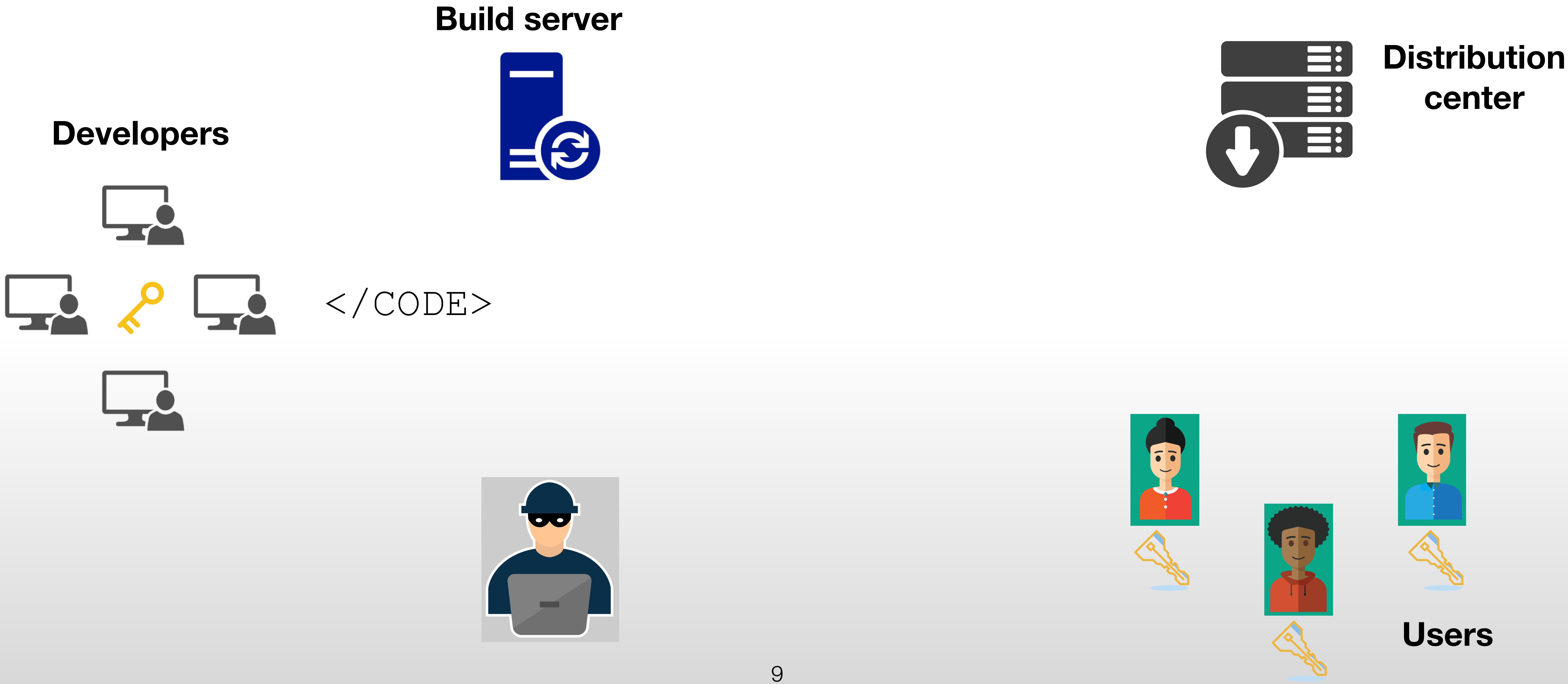
Distribution center

Users

Challenges

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



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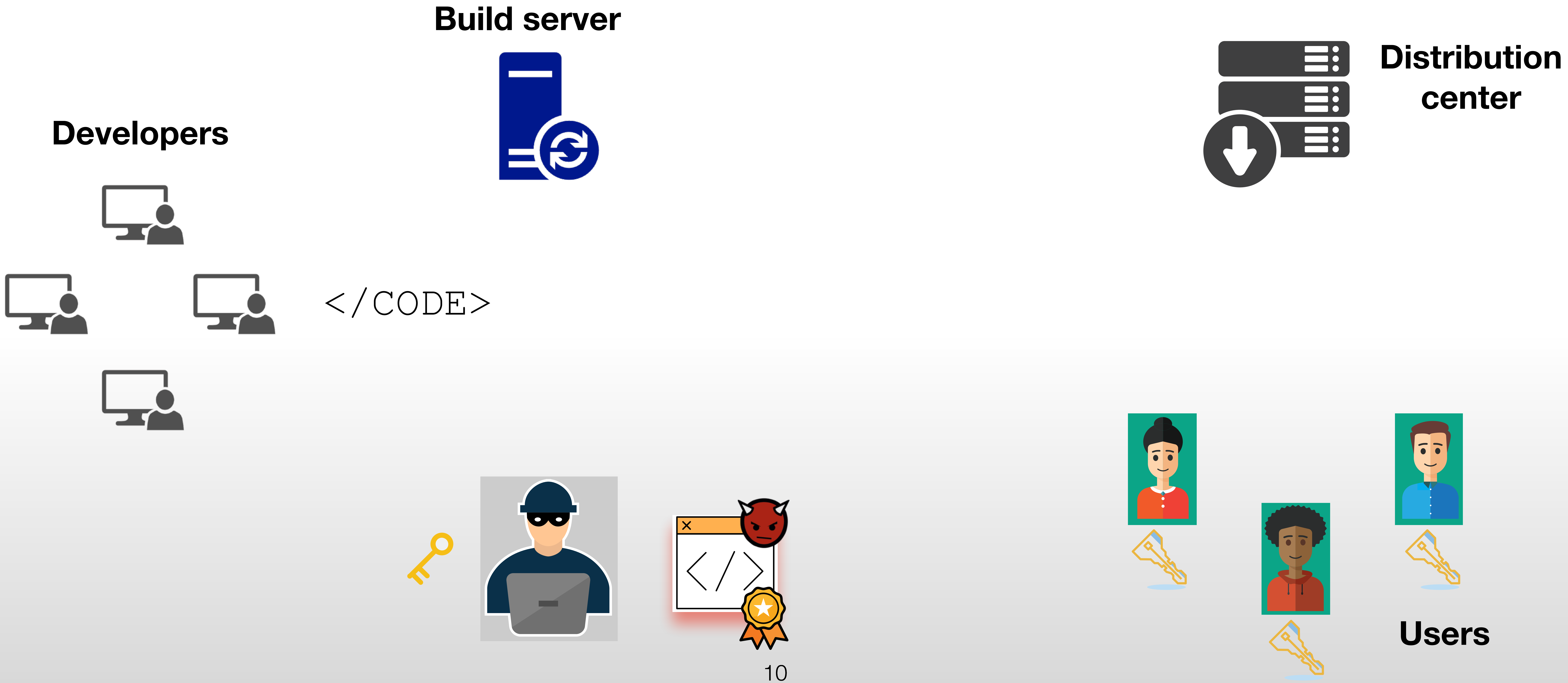

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Distribution center

Developers

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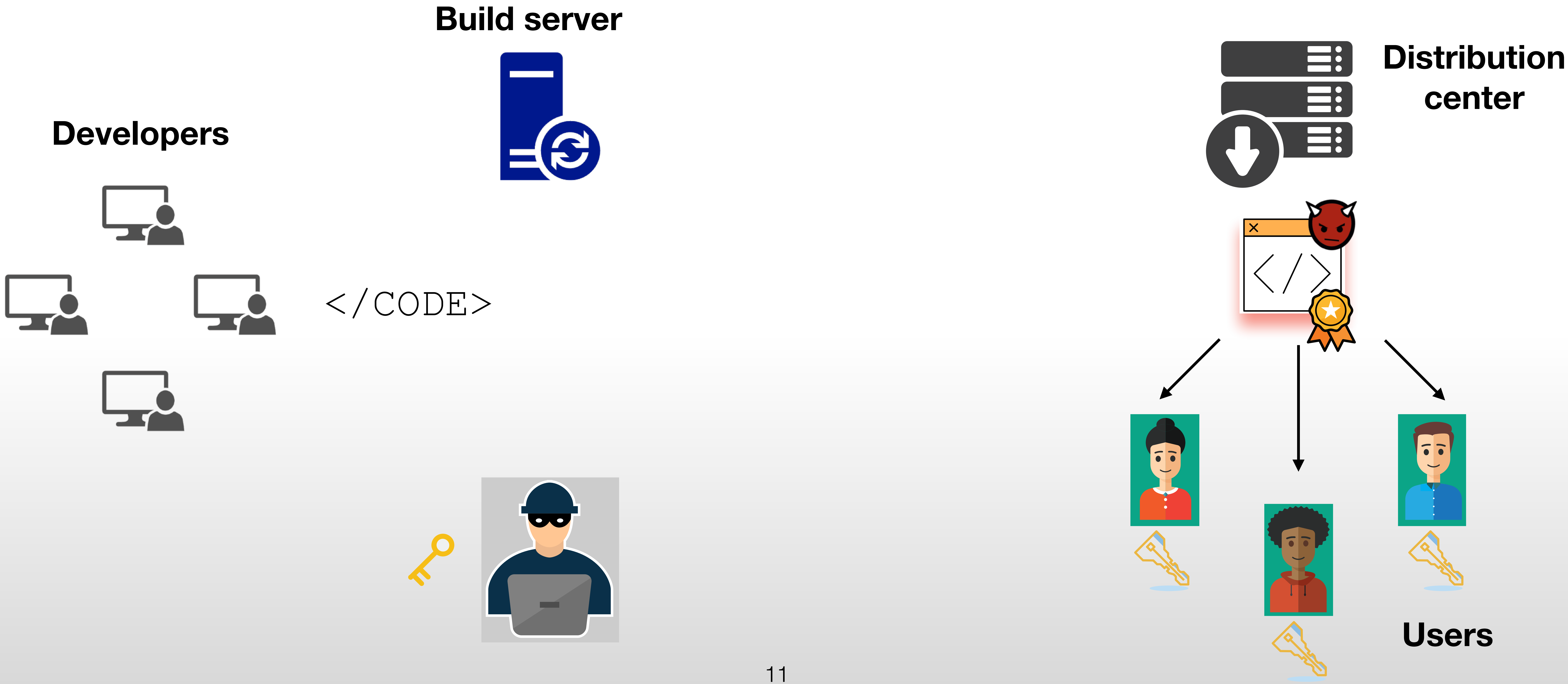

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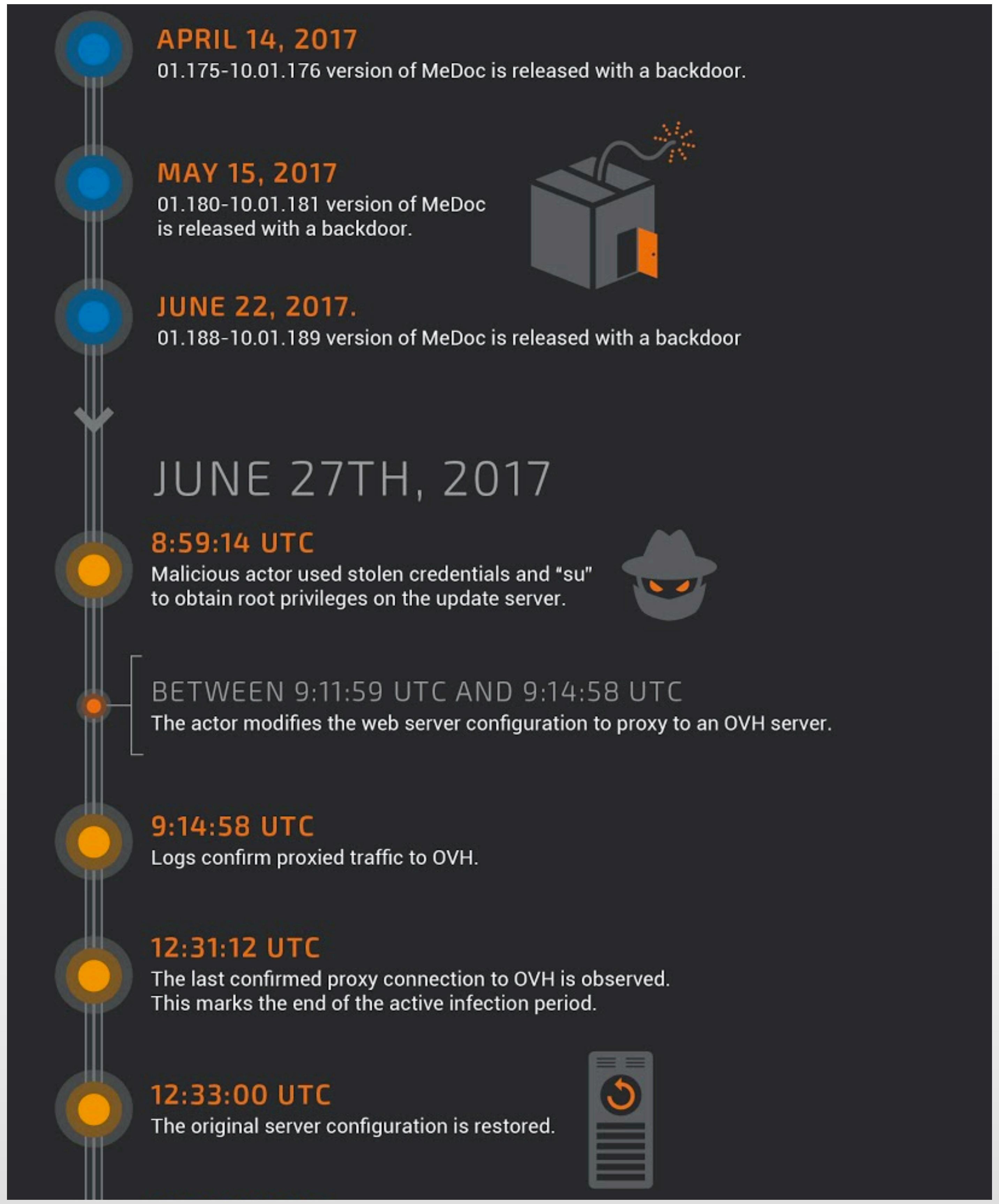


APRIL 14, 2017
01.175-10.01.176 version of MeDoc is released with a backdoor.

MAY 15, 2017
01.180-10.01.181 version of MeDoc is released with a backdoor.

JUNE 22, 2017.
01.188-10.01.189 version of MeDoc is released with a backdoor

JUNE 27TH, 2017

8:59:14 UTC
Malicious actor used stolen credentials and "su" to obtain root privileges on the update server.

BETWEEN 9:11:59 UTC AND 9:14:58 UTC
The actor modifies the web server configuration to proxy to an OVH server.

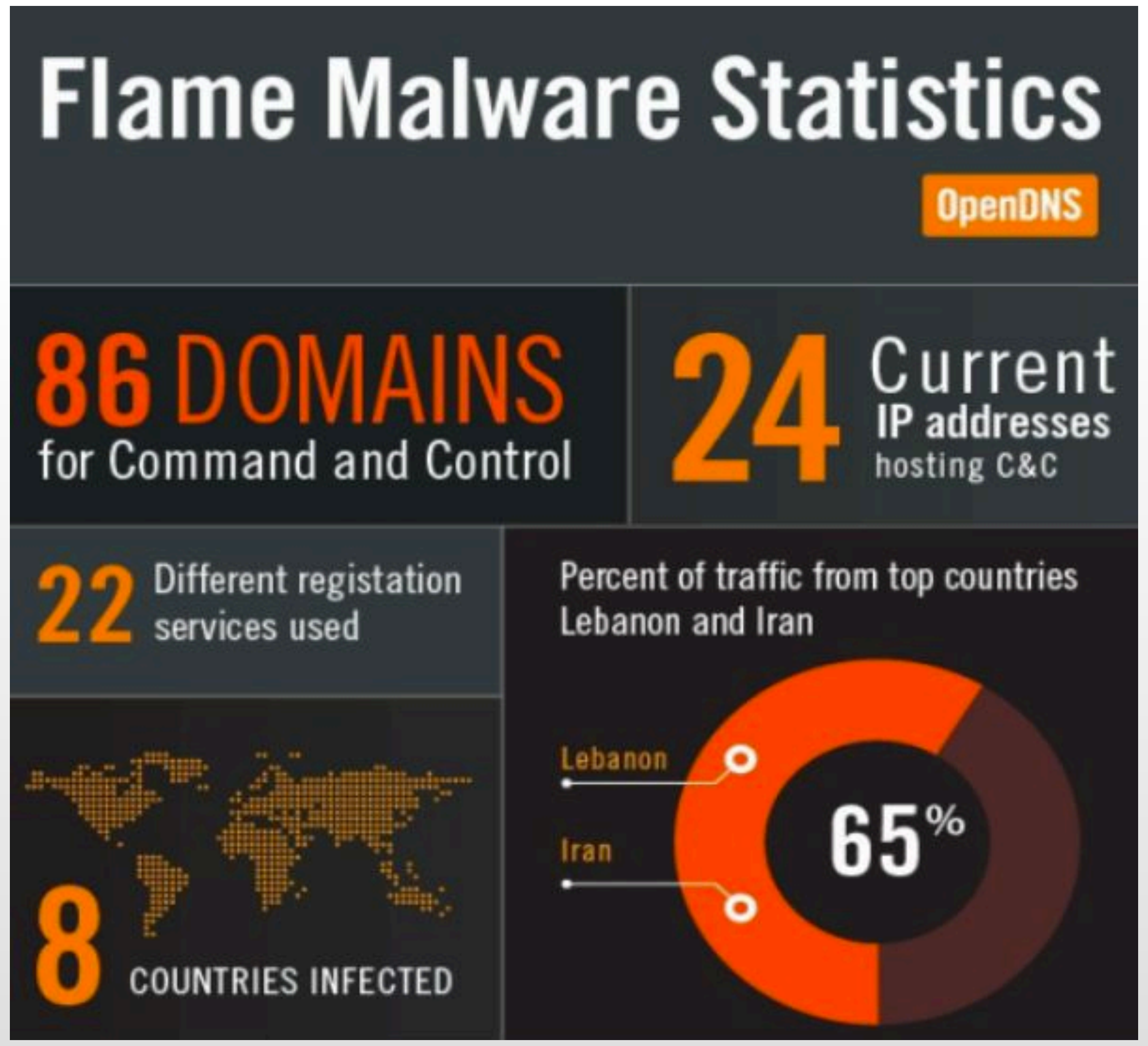
9:14:58 UTC
Logs confirm proxied traffic to OVH.

12:31:12 UTC
The last confirmed proxy connection to OVH is observed. This marks the end of the active infection period.

12:33:00 UTC
The original server configuration is restored.

Talos report on
Petya/NotPetya attacks

Kaspersky Securelist



Mashable

DigiNotar Internet Trust Services

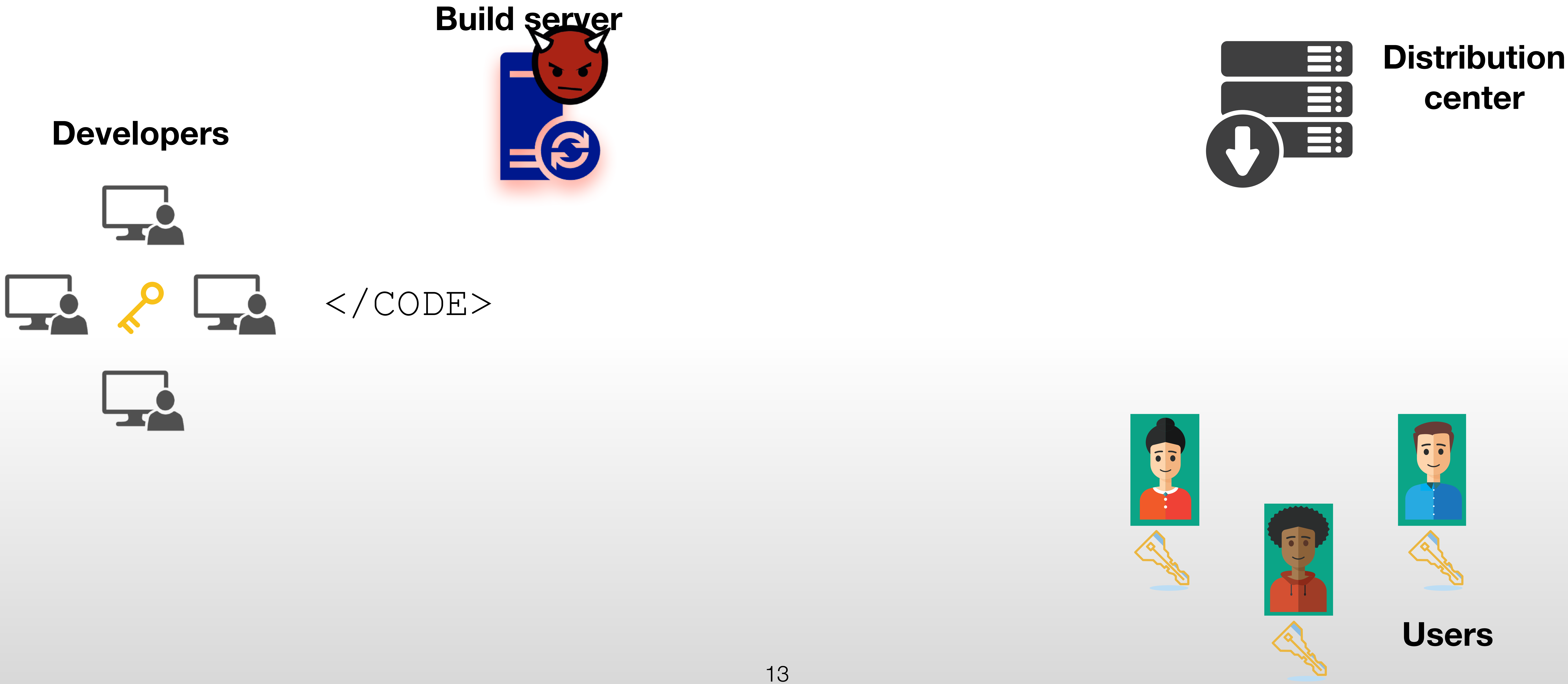
COMODO SSLCERTIFICATE

fedora

redhat

Challenges

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



Build server

Distribution center

Developers

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Users

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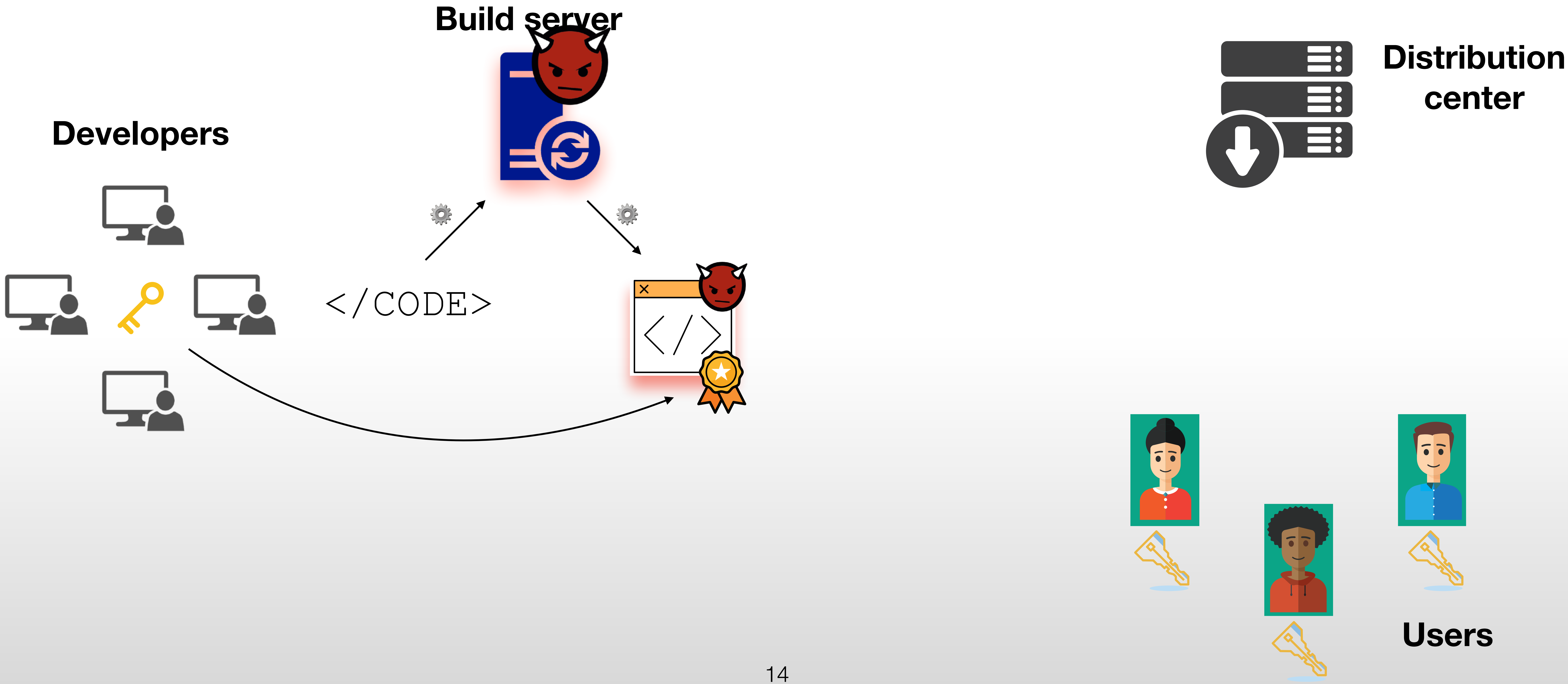

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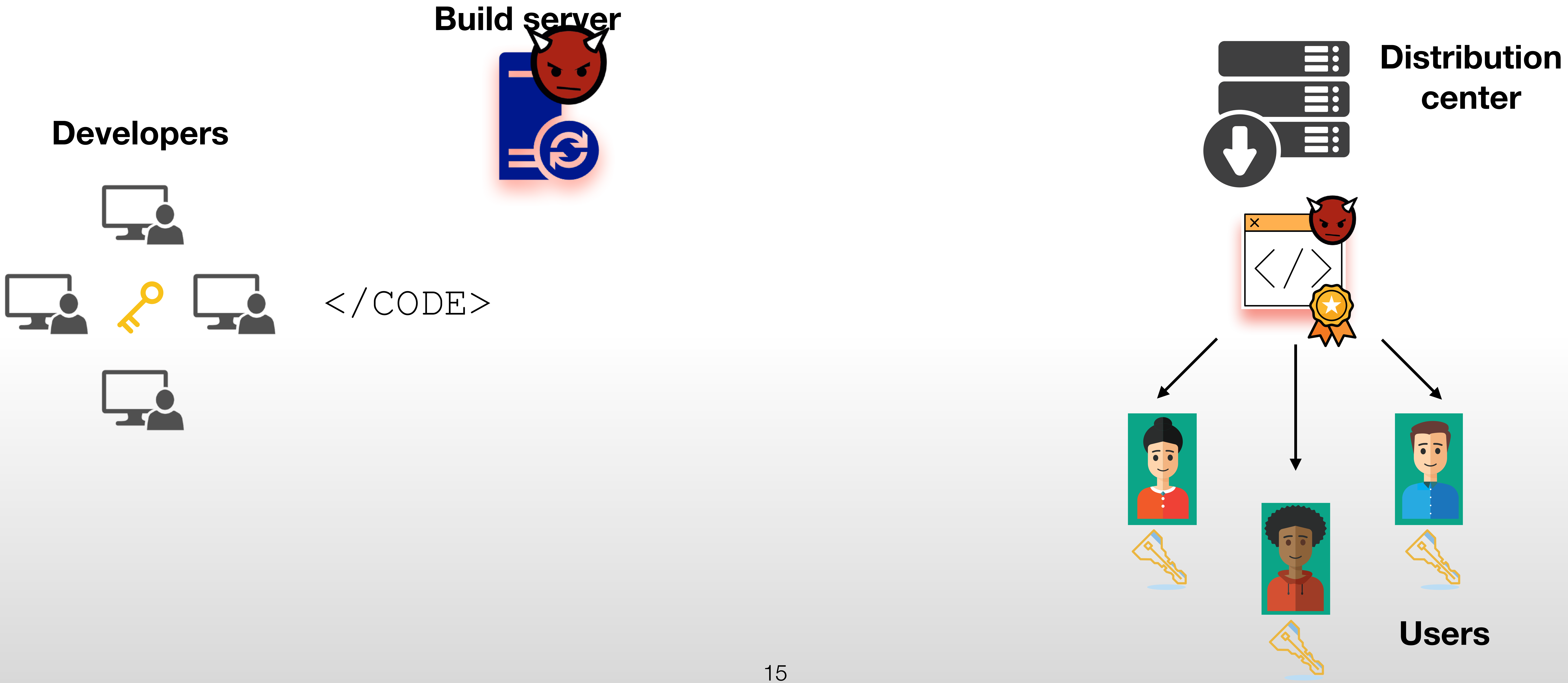


Build server

Developers

</CODE>

Distribution center

Users

Challenges

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

reproducible-builds.org

Provide a verifiable path from source code to binary.

debian

GNU/Linux

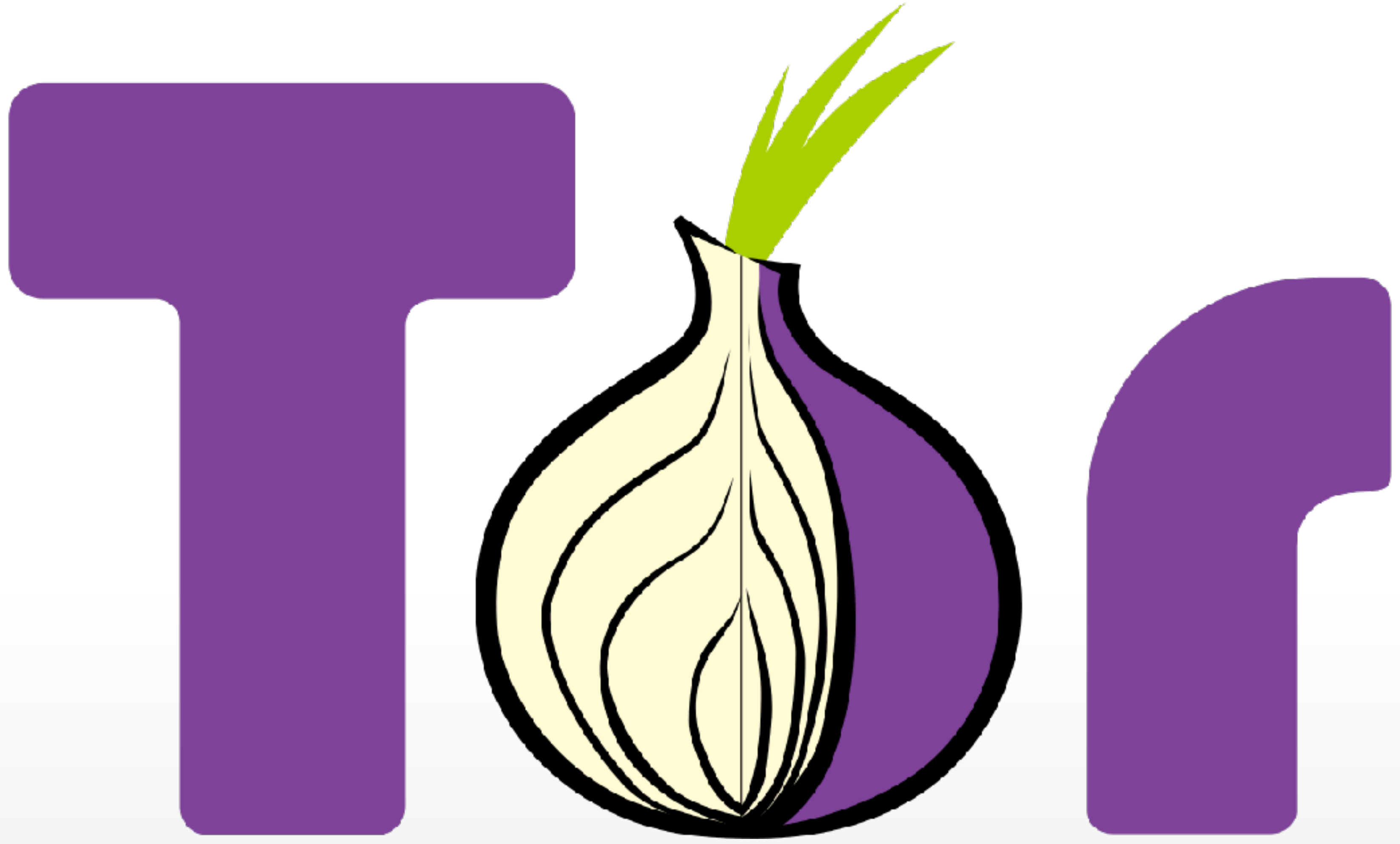
Over 90% of the source packages included in Debian 9 will build bit-for-bit identical binary packages

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

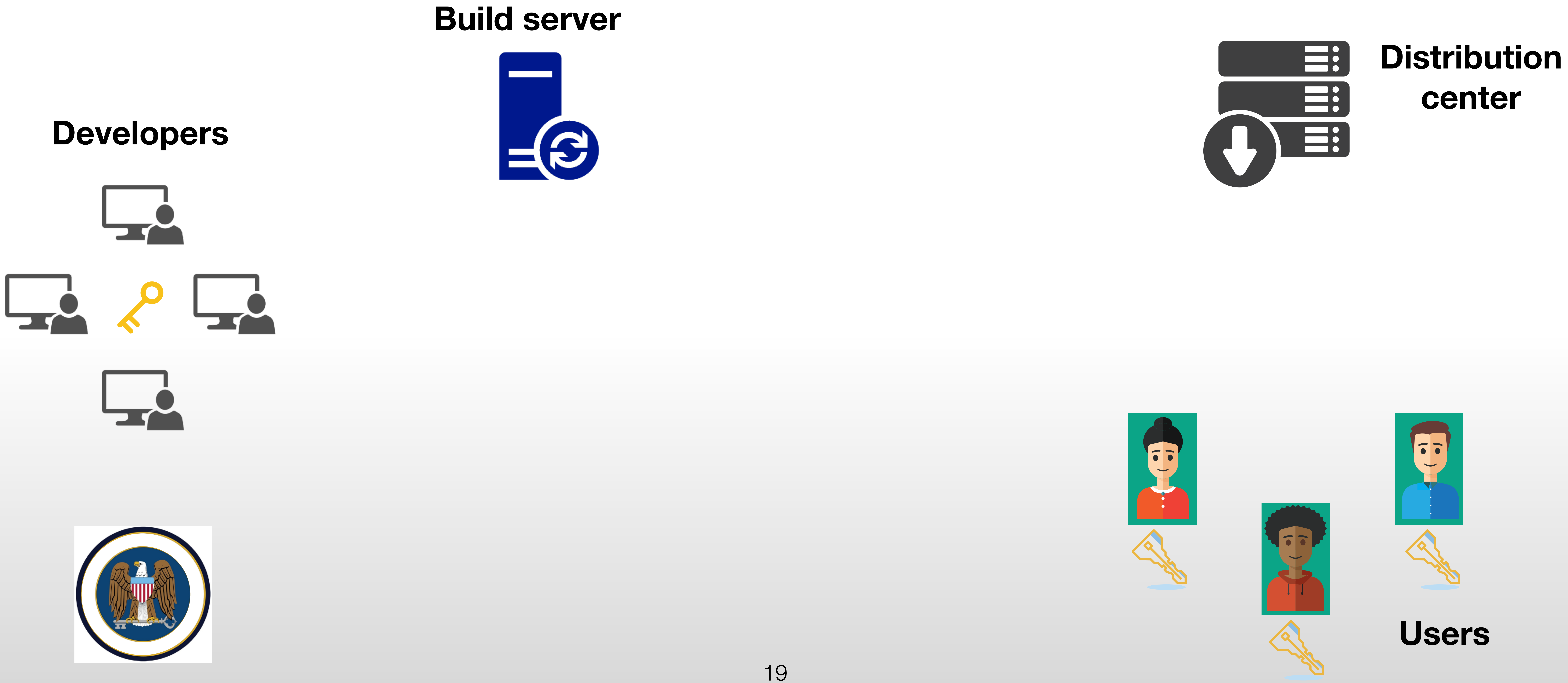


Building the Tor Browser bundle
takes 32 hours on a modern laptop

Closed-source software?

Challenges

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



Build server

Distribution center

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Users

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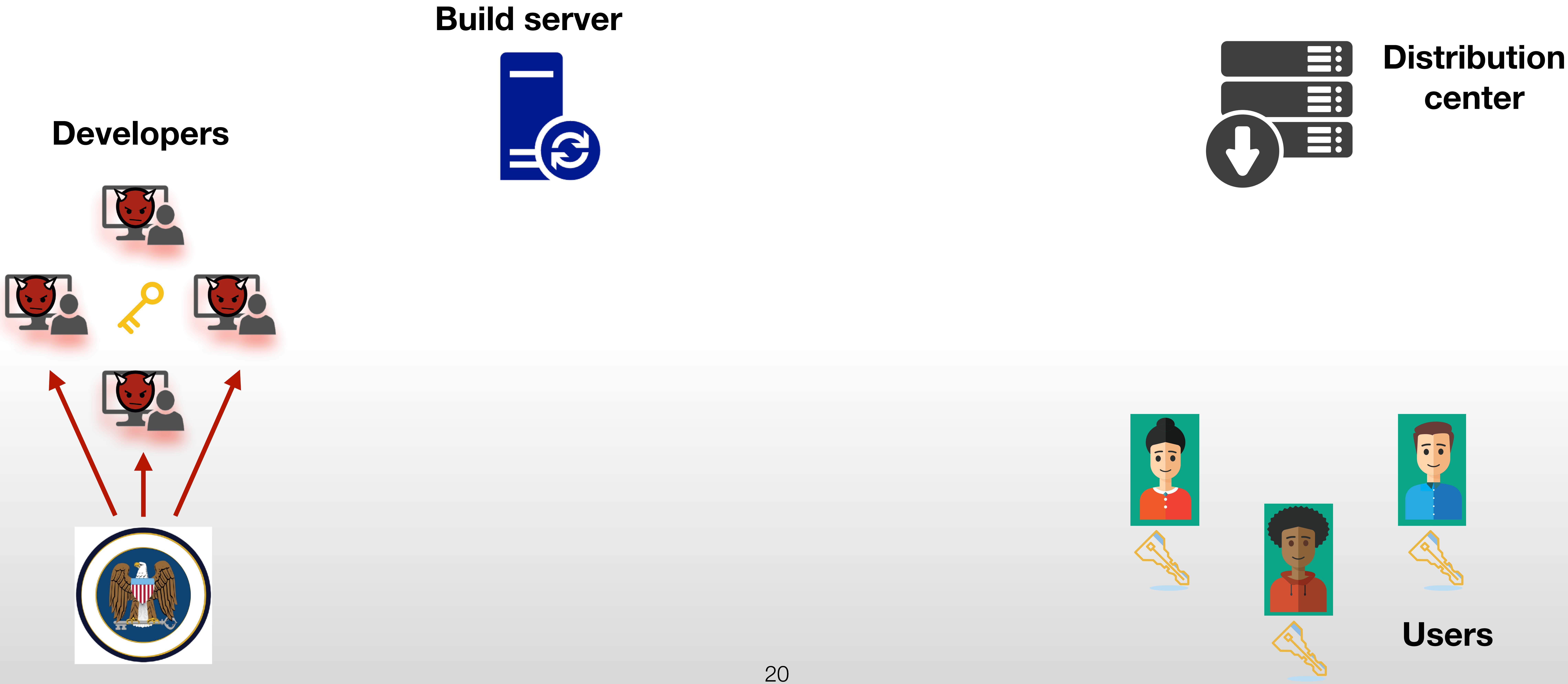

Build server

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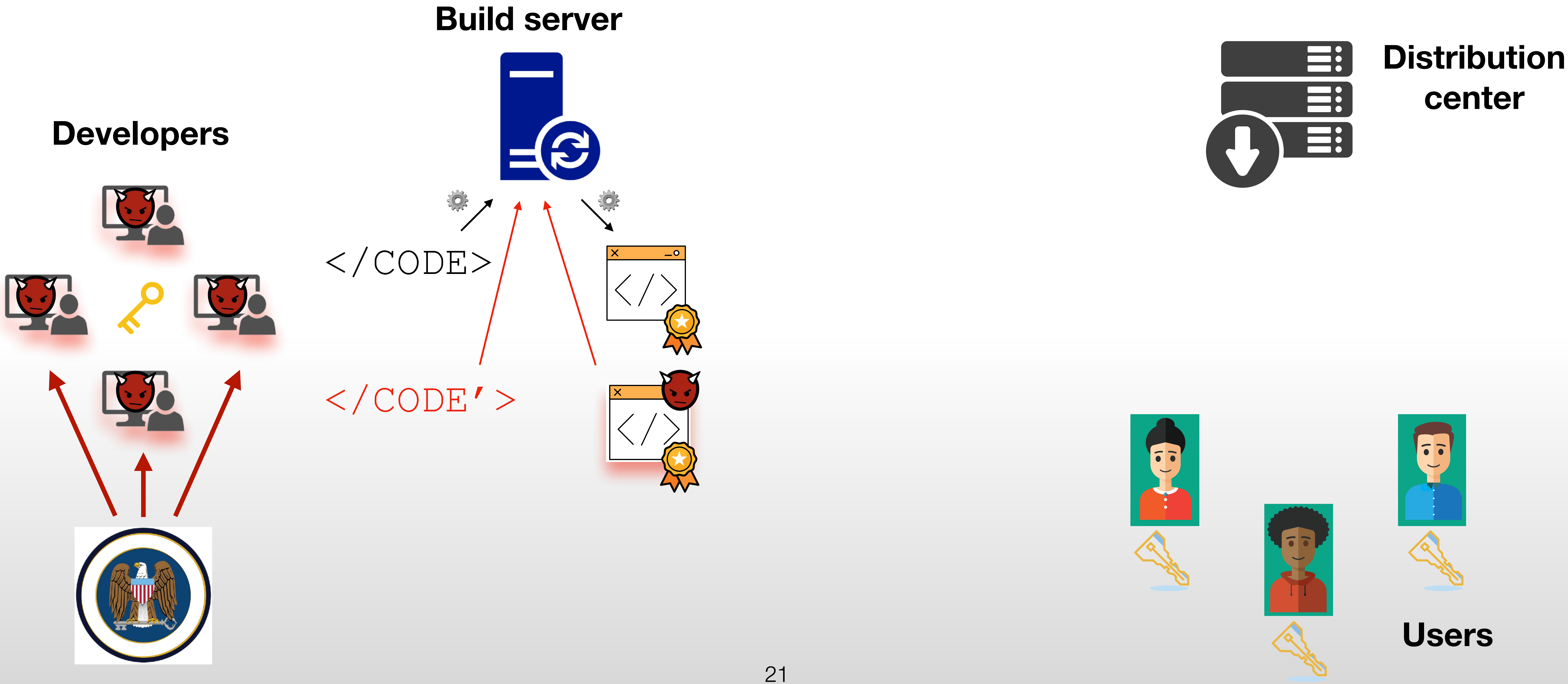

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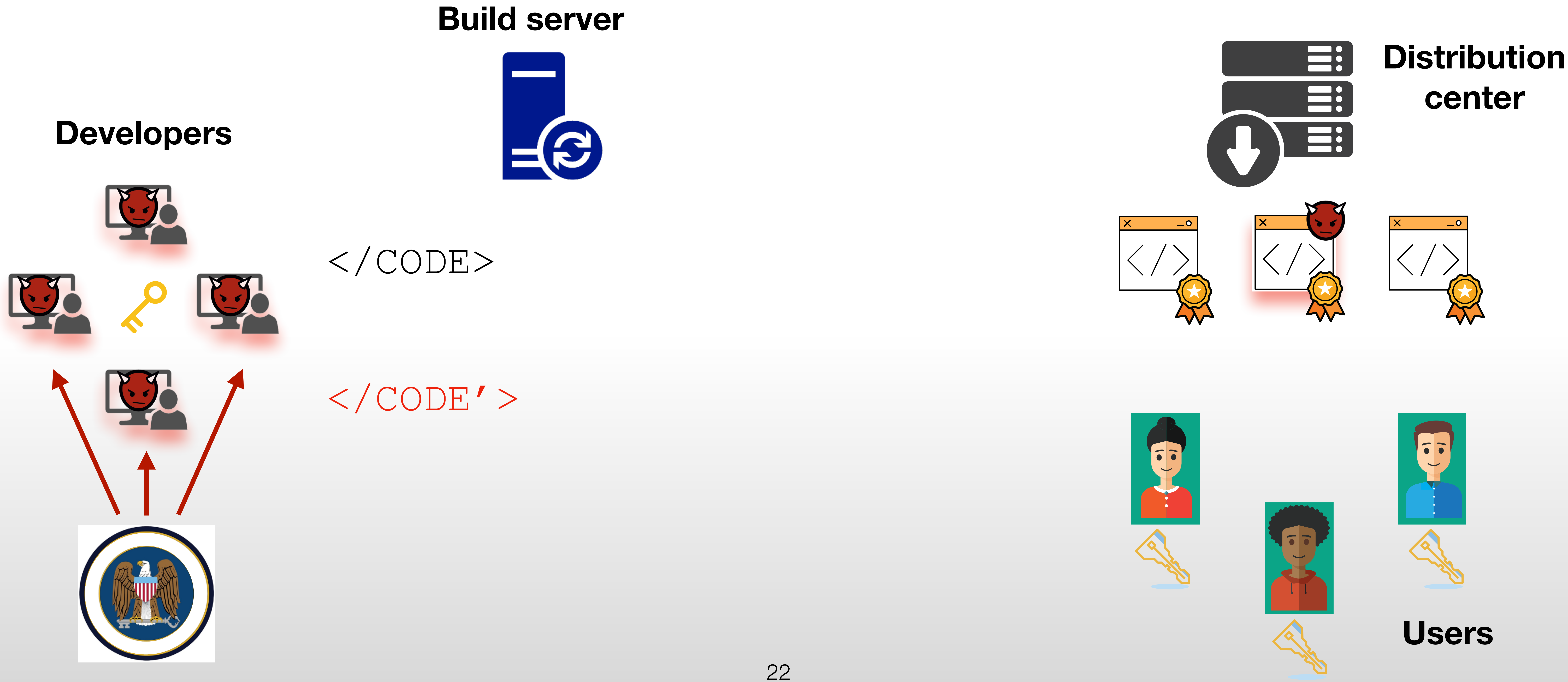

Build server

Developers

Distribution center

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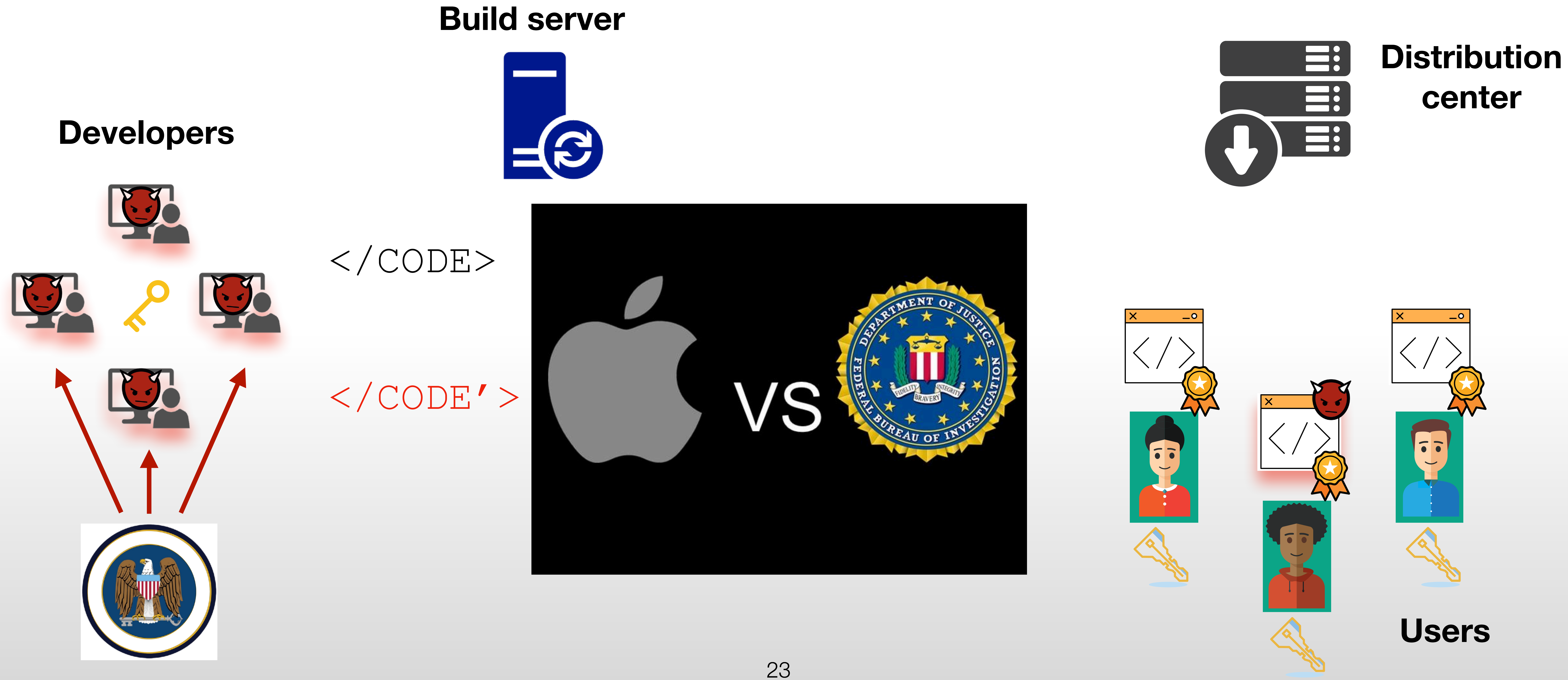

Build server

Developers

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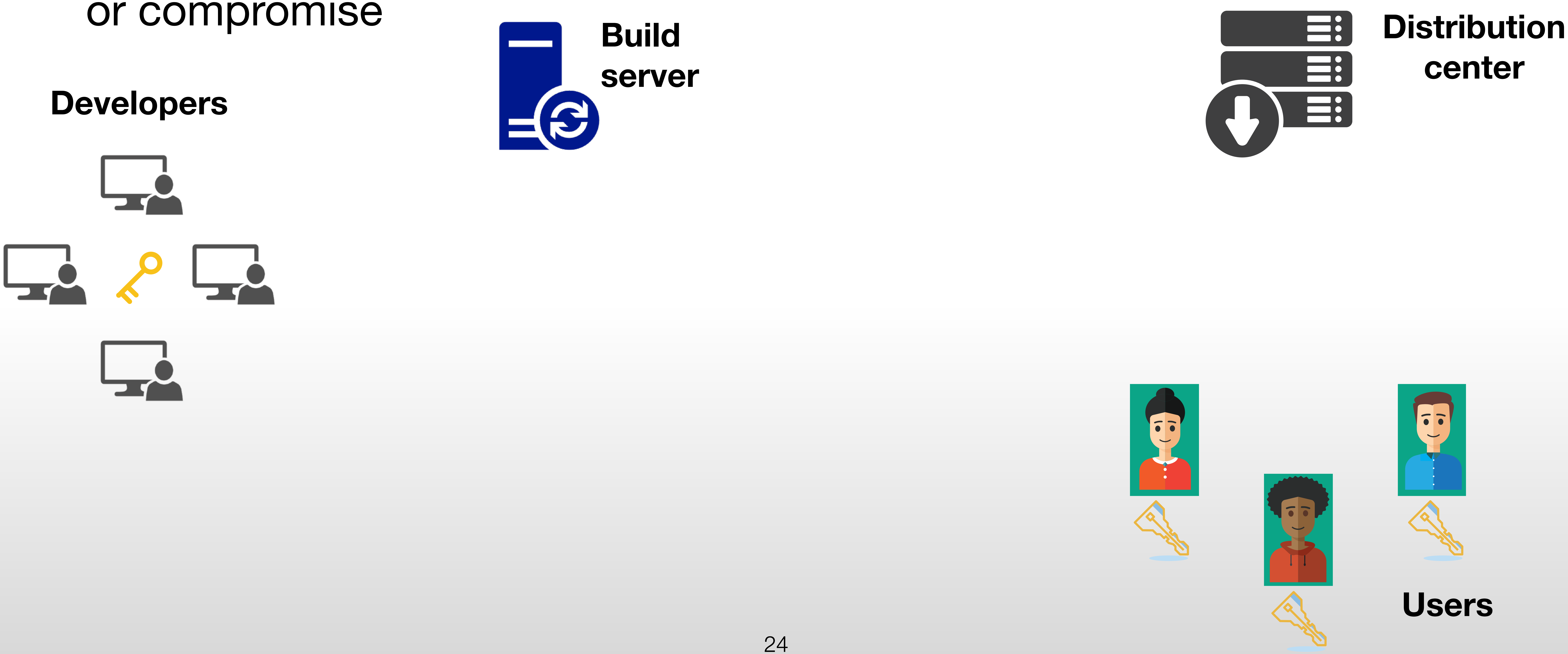
Distribution center

Users

Challenges

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



Challenges

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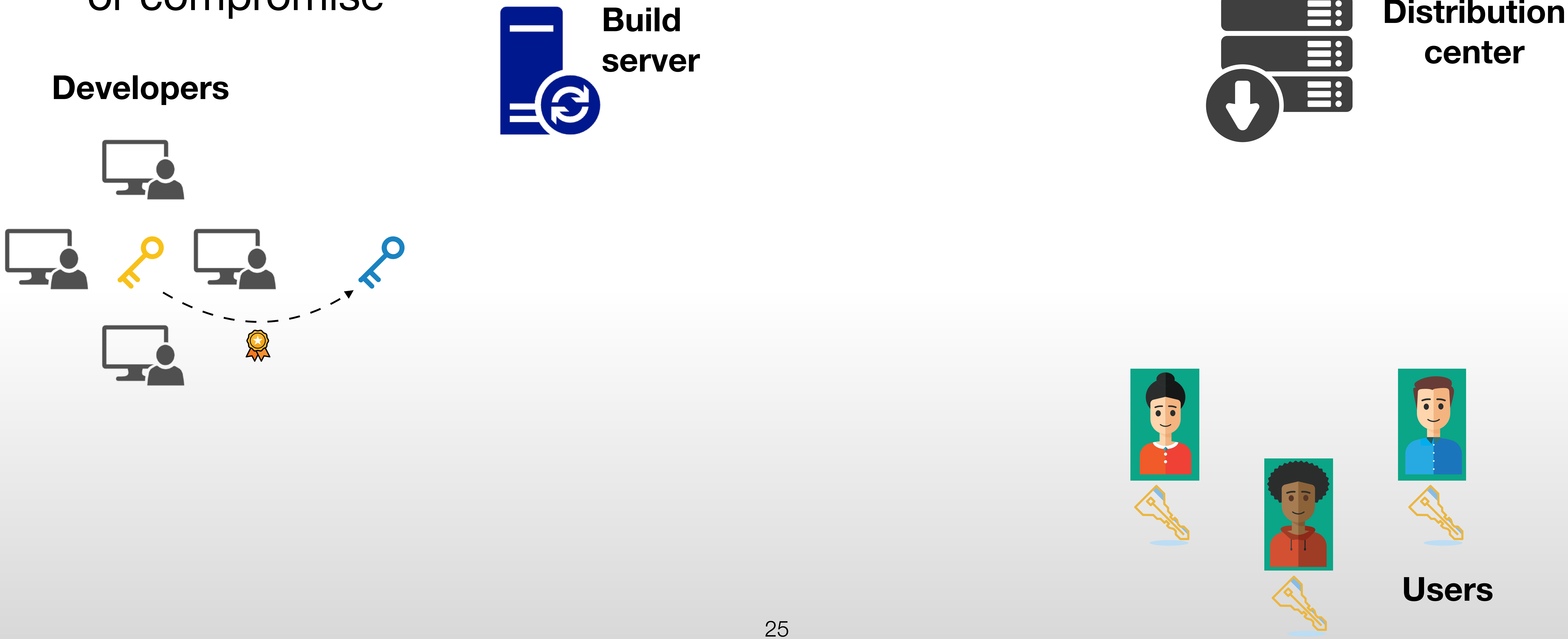

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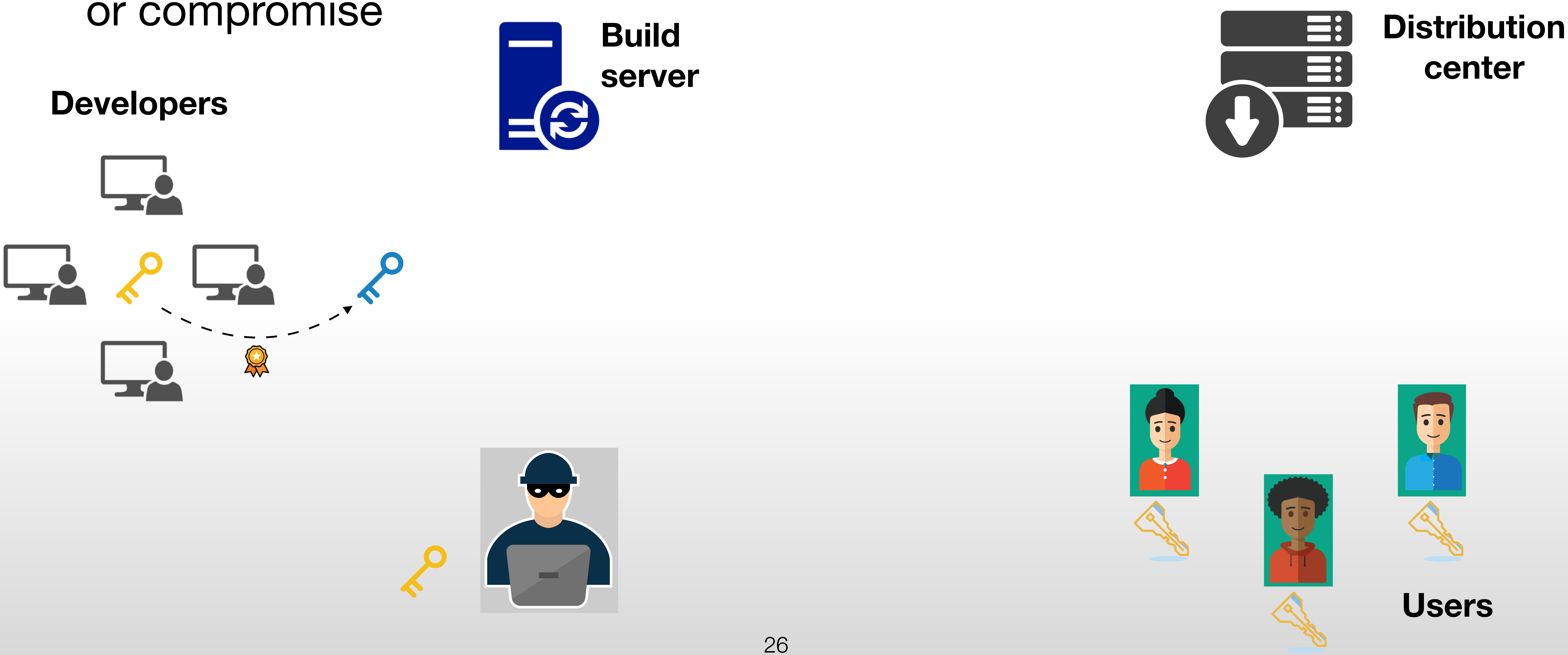

Build server

Distribution center

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Users

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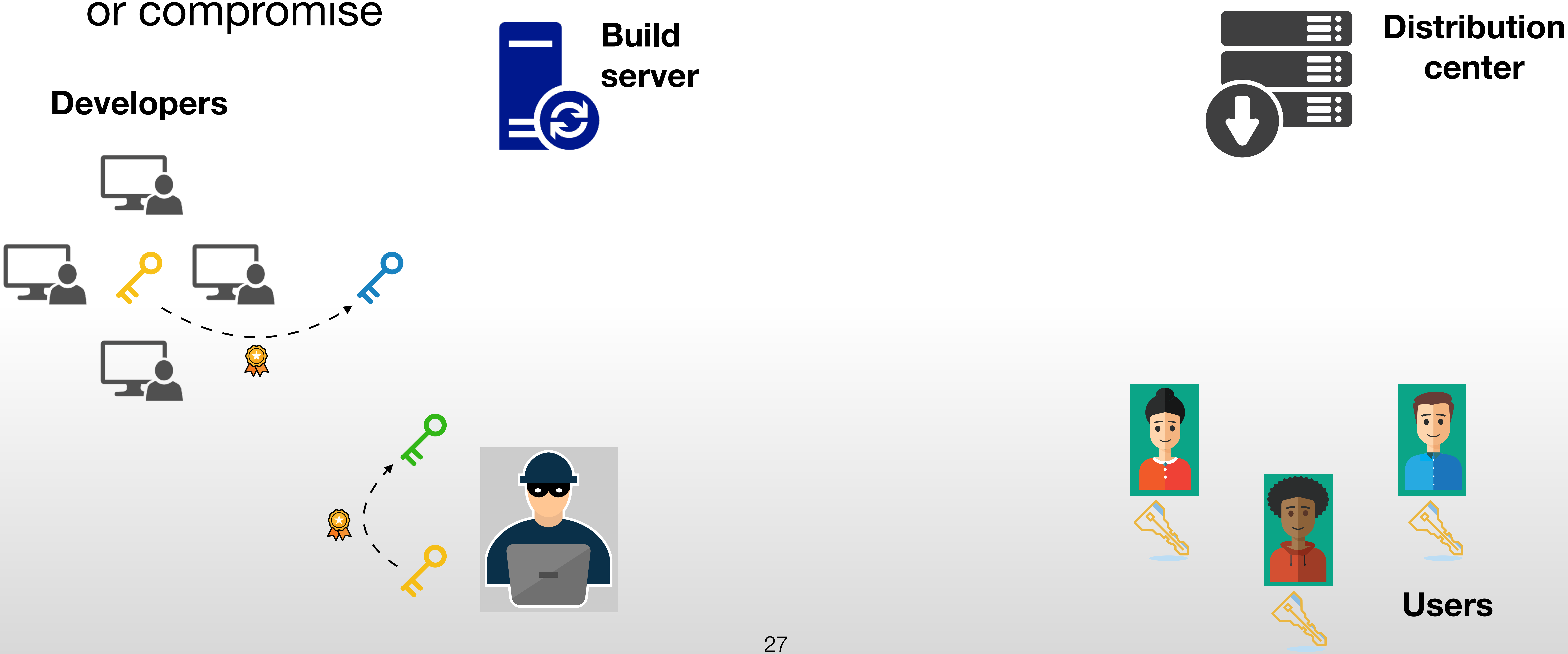
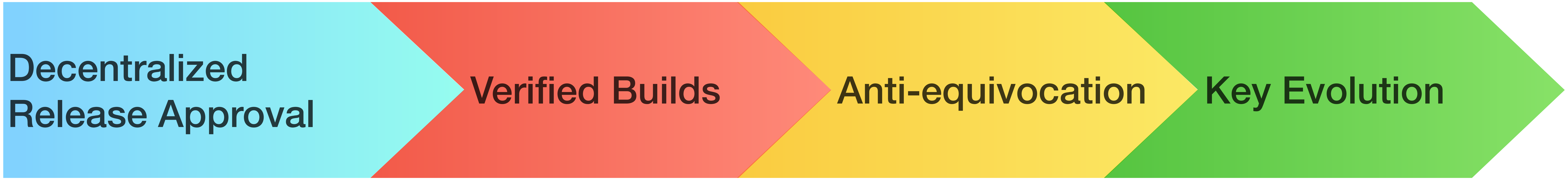


Design of CHAINIAC

Roadmap to CHAINIAC



Decentralized Release Approval

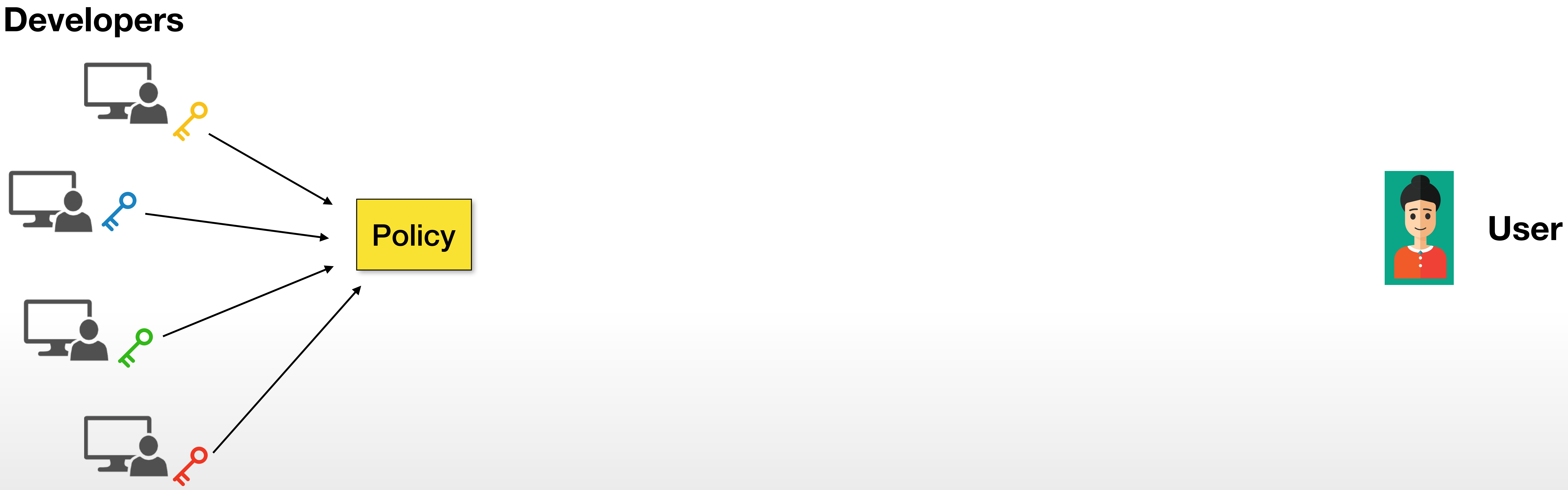
Verified Builds

Anti-equivocation

Key Evolution

Decentralized Release-Approval

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



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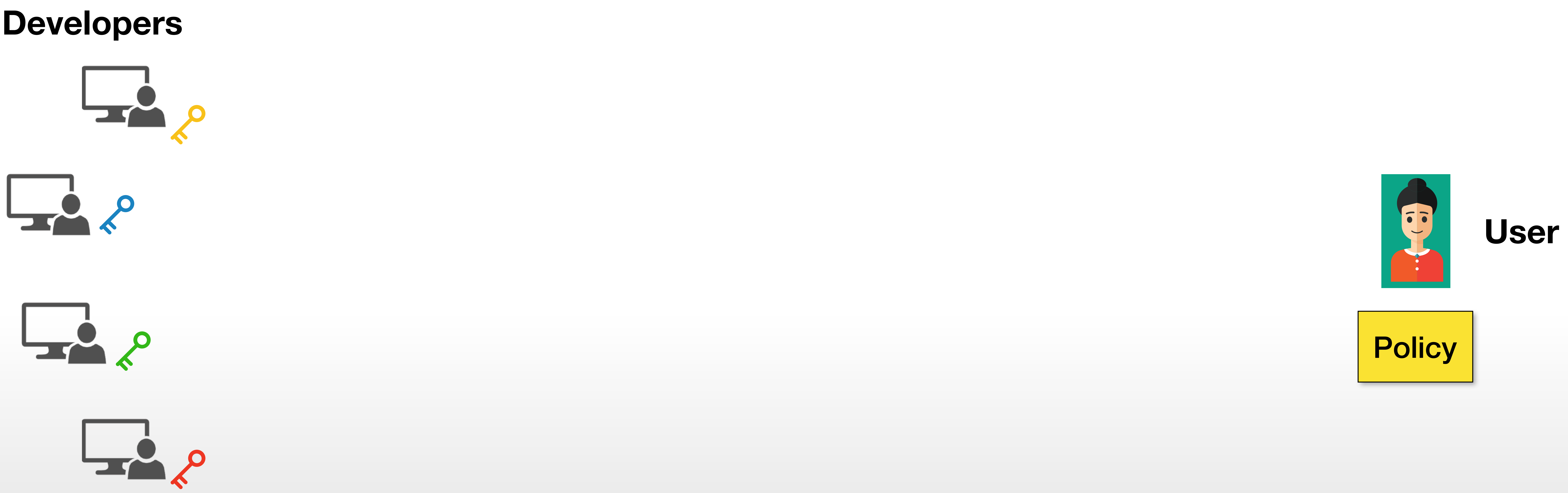

Developers

User

Policy

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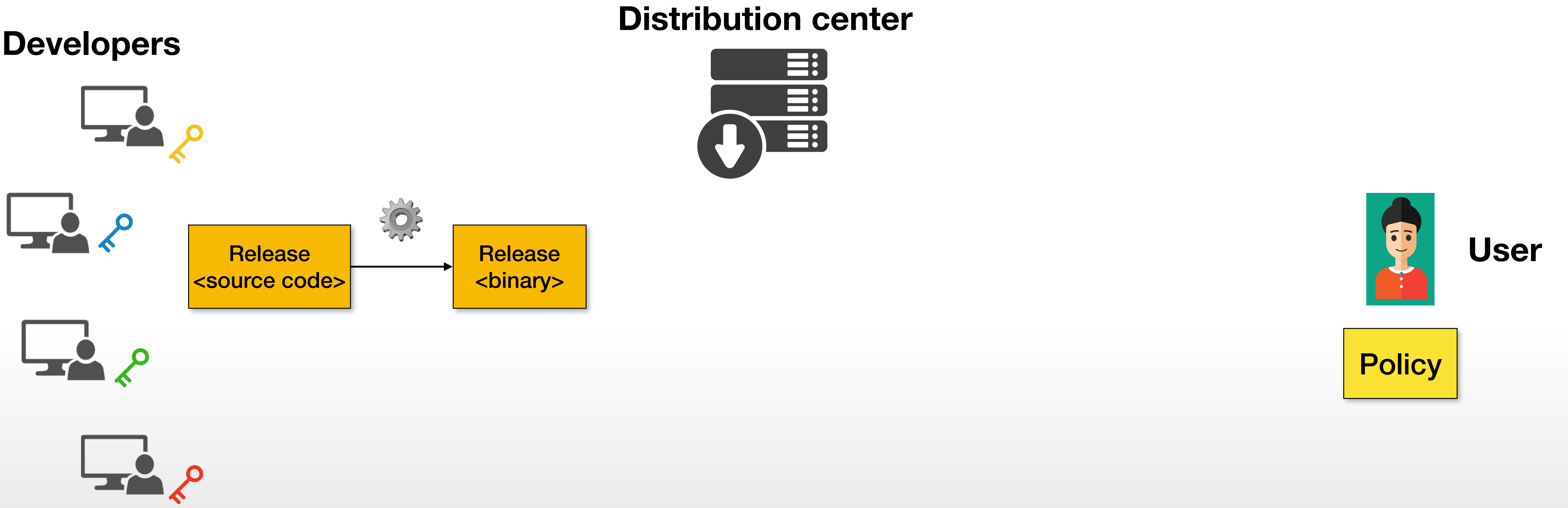

Distribution center

Developers

Release <source code>

Release <binary>

User

Policy

Decentralized Release-Approval

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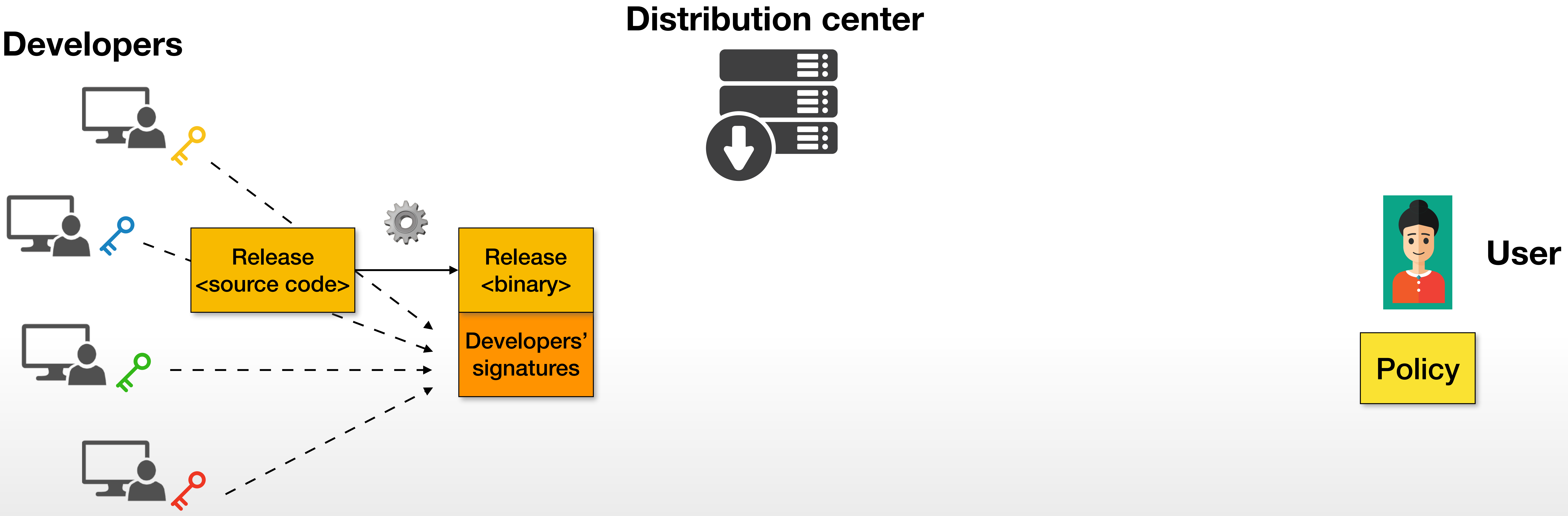

Distribution center

Developers

Release <source code>

Release <binary>

Developers' signatures

User

Policy

Decentralized Release-Approval

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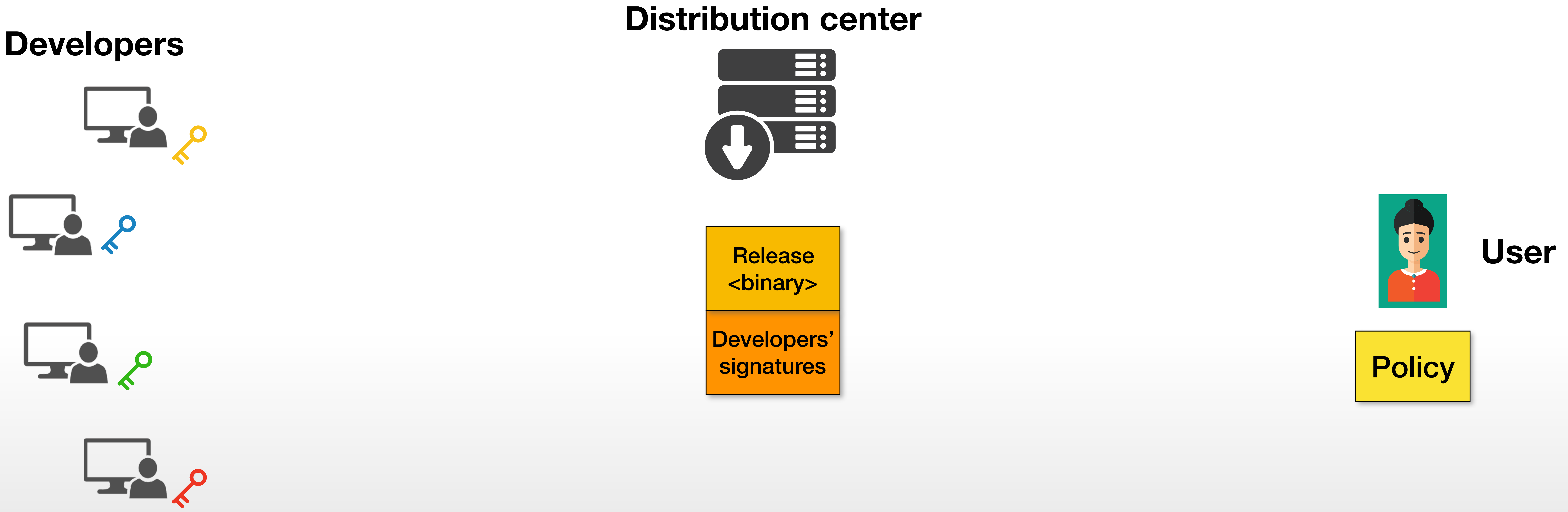

Developers

Distribution center

Release <binary>

Developers' signatures

User

Policy

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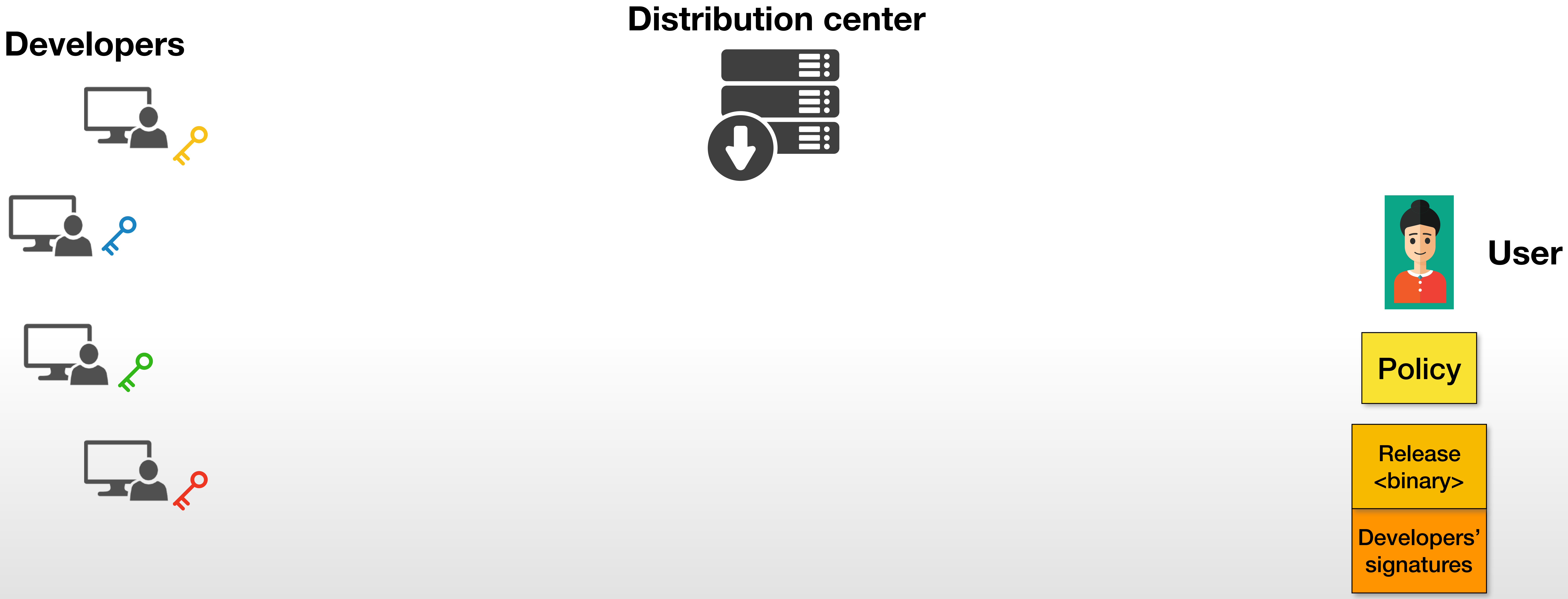


Distribution center

Developers

User

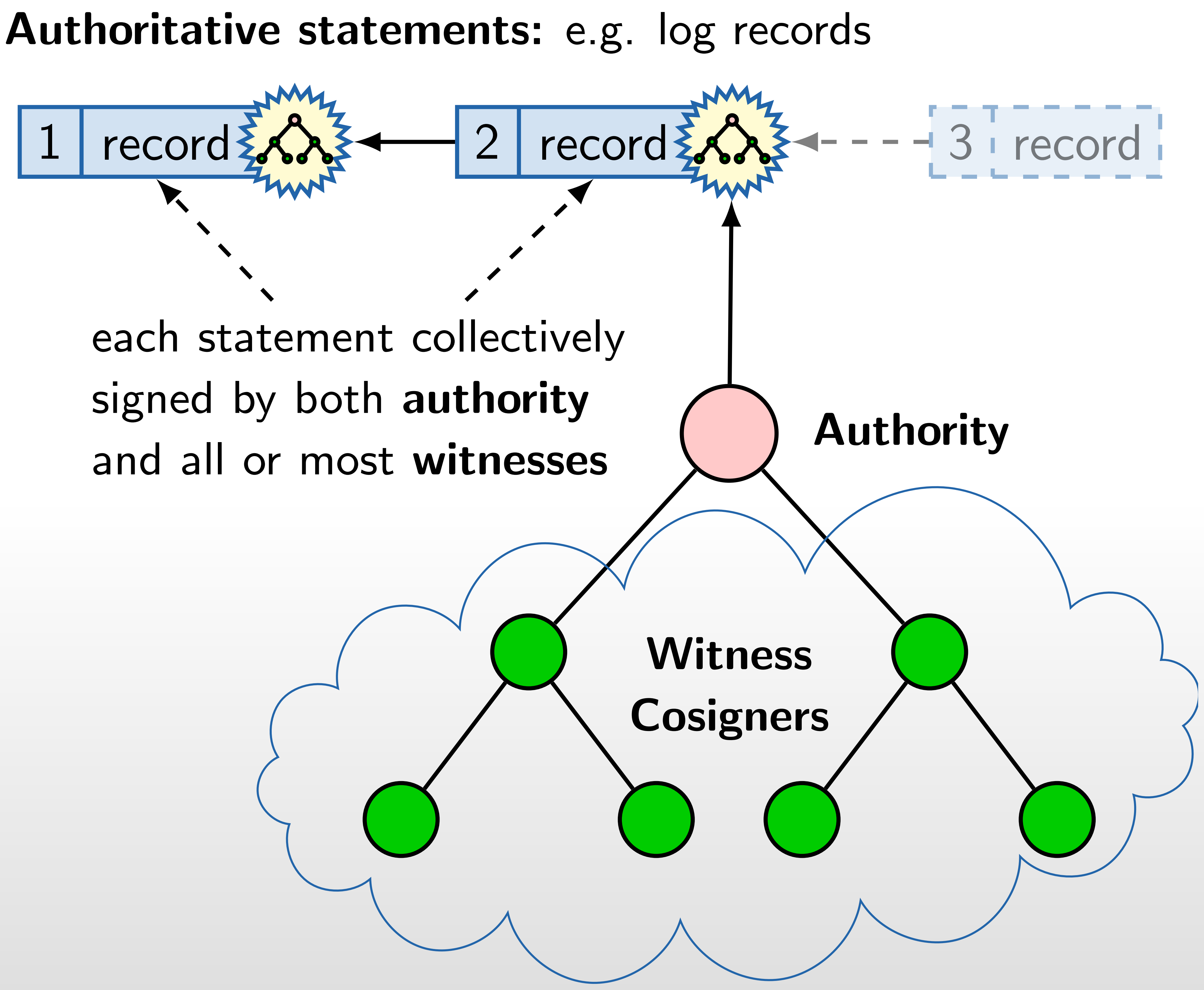
Policy

Release <binary>

Developers' signatures

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**
Authority
Witness Cosigners

References

- Ewa Syta, Iulia Tamas, Dylan Visher, David Isaac Wolinsky, Philipp Jovanovic, Linus Gasser, Nicolas Gailly, Ismail Khoffi, and Bryan Ford. Keeping Authorities "Honest or Bust" with Decentralized Witness Cosigning. In *37th IEEE Symposium on Security and Privacy*, May 2016.
- Eleftherios Kokoris-Kogias, Philipp Jovanovic, Nicolas Gailly, Ismail Khoffi, Linus Gasser, and Bryan Ford. Enhancing Bitcoin Security and Performance with Strong Consistency via Collective Signing. In *Proceedings of the 25th USENIX Conference on Security Symposium*, 2016.

Verified Builds

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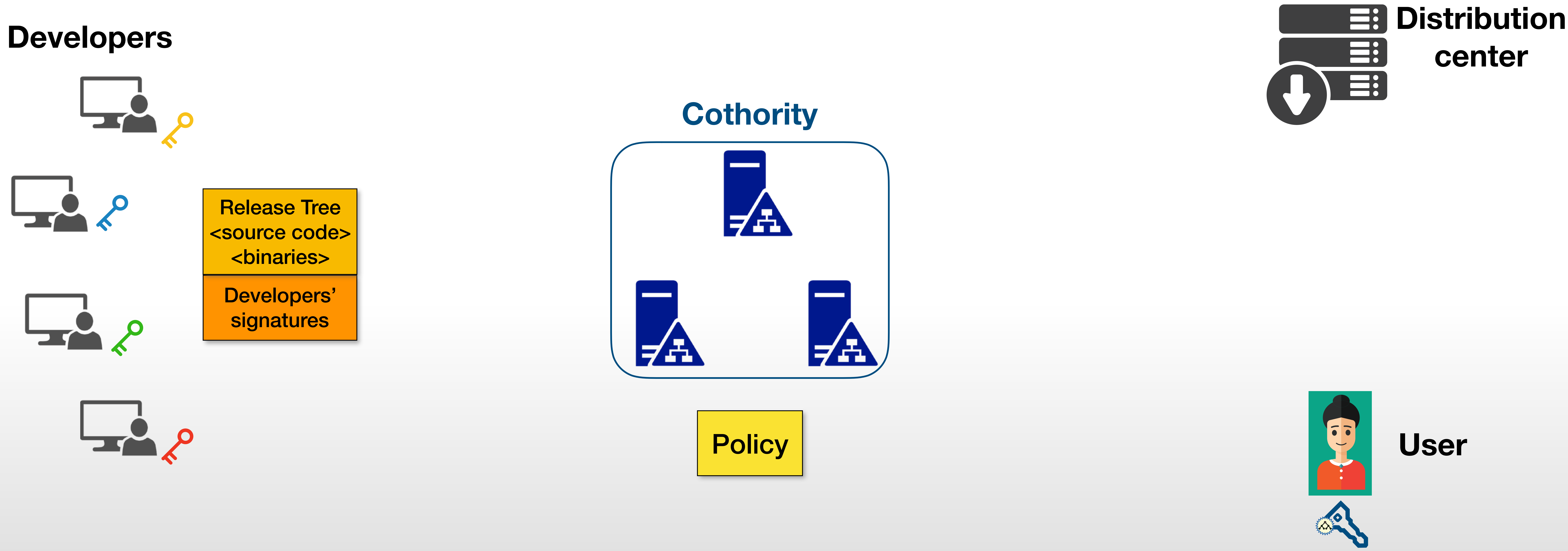

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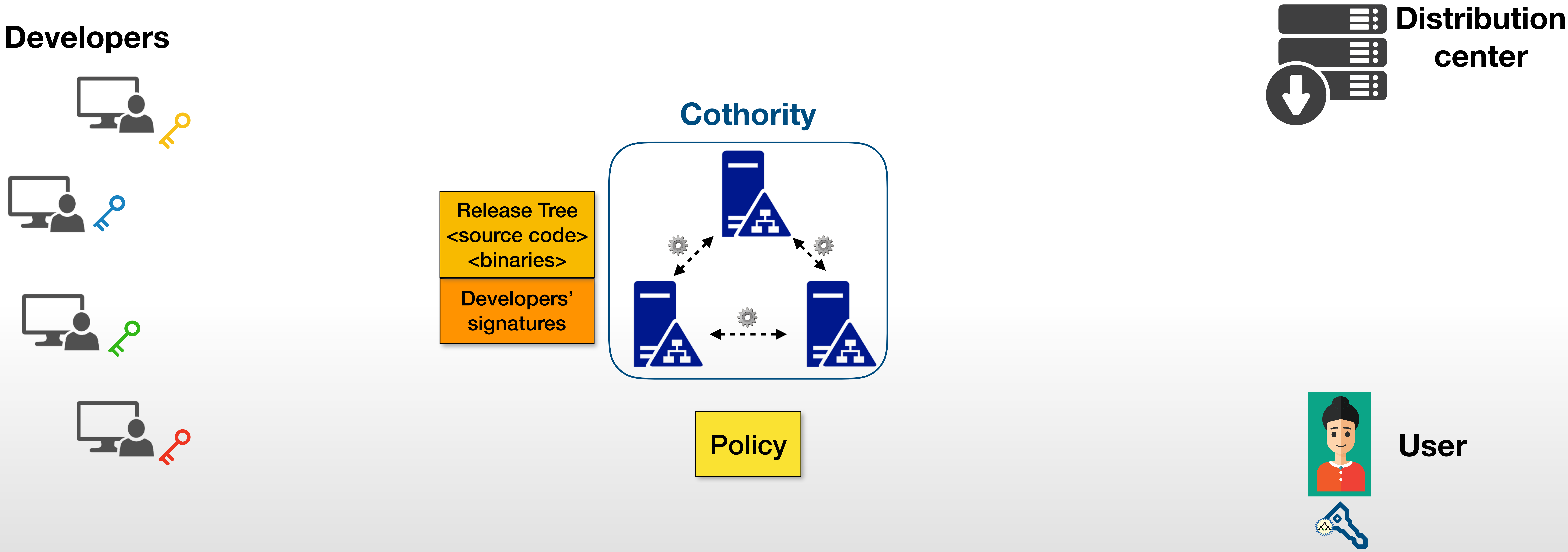

Developers

Cothority

Release Tree
<source code>
<binaries>

Developers’ signatures

Policy

Distribution center

User

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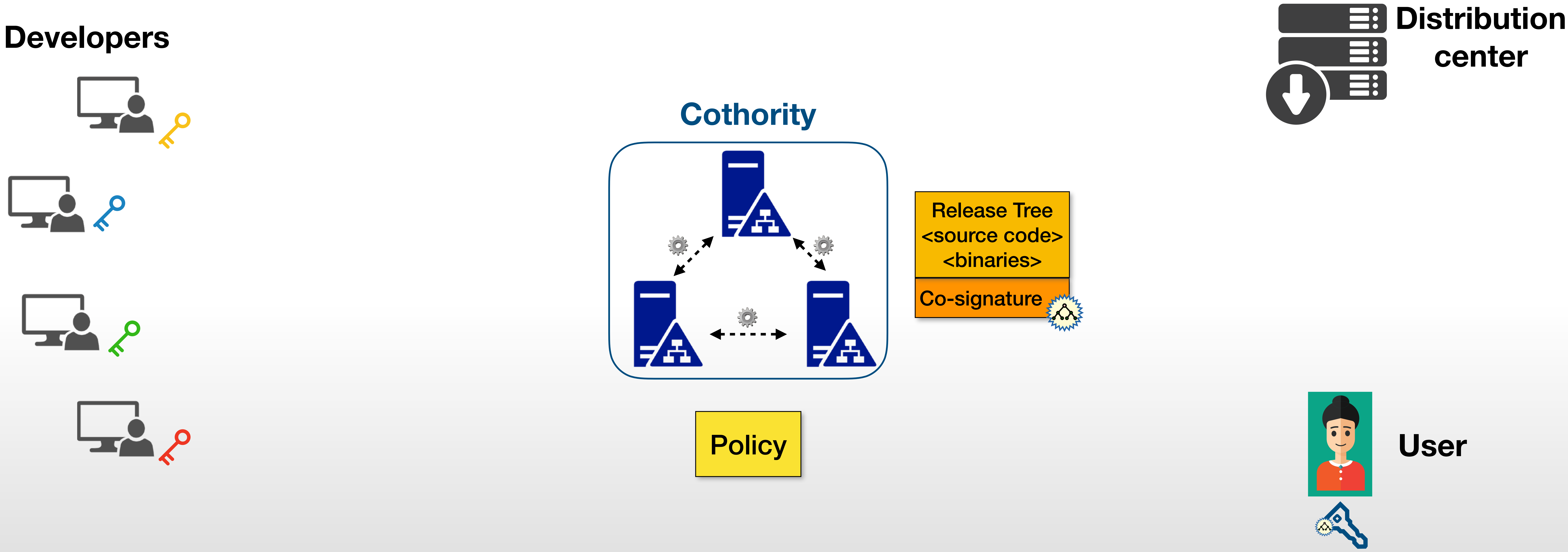

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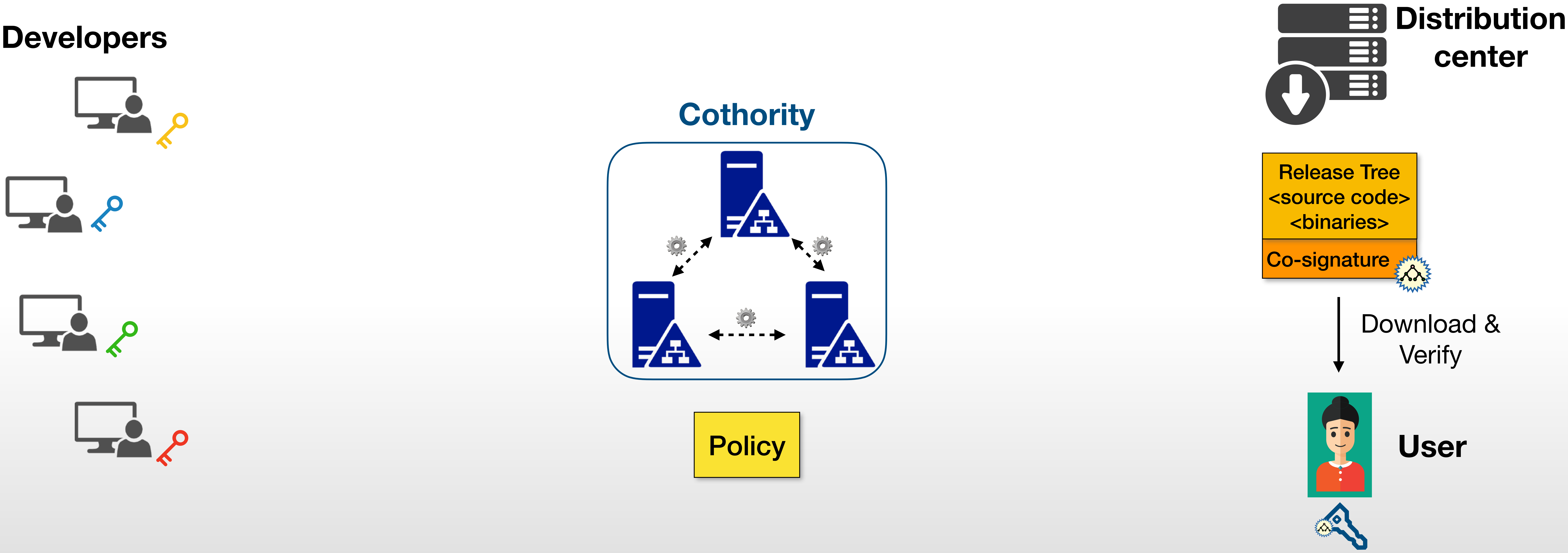


Developers

Cothority

Policy

Distribution center

Release Tree <source code> <binaries>

Co-signature

Download & Verify

User

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

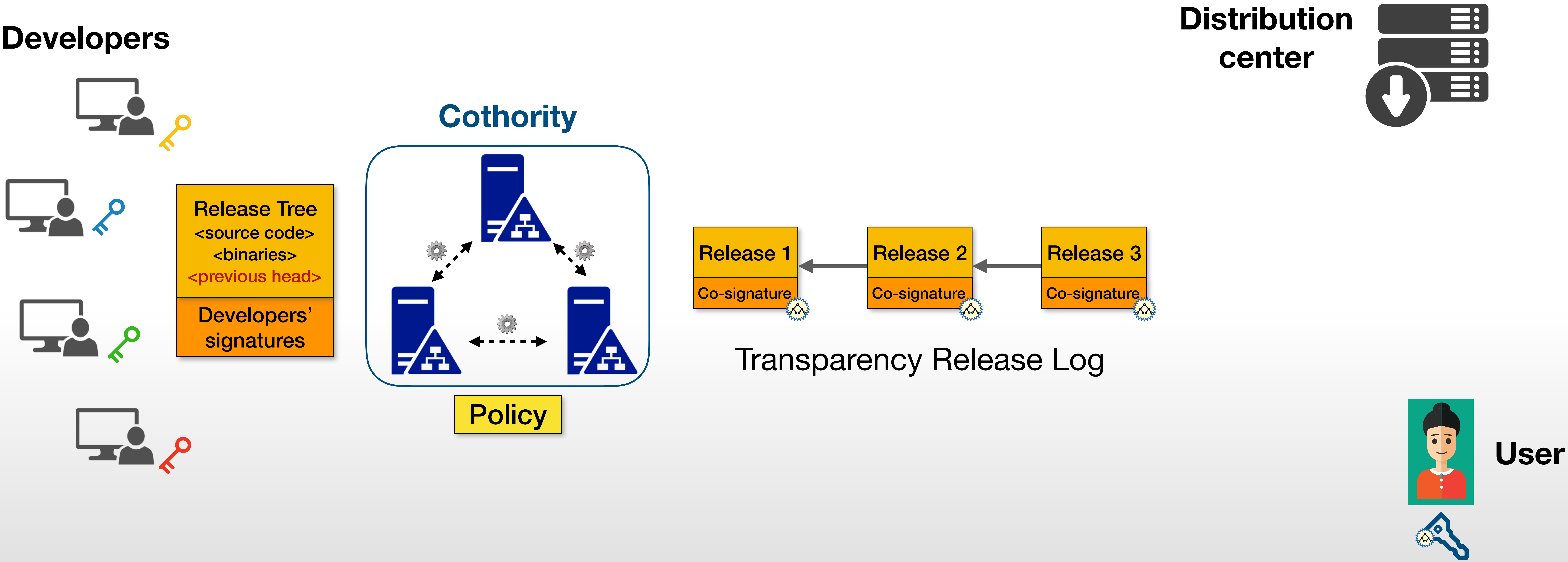
Verified Builds

Release Policy File

- List of individual developer public keys
- Signing threshold
- Cothority public key
- Supported platforms for verified builds
- …

Anti-equivocation Measures

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



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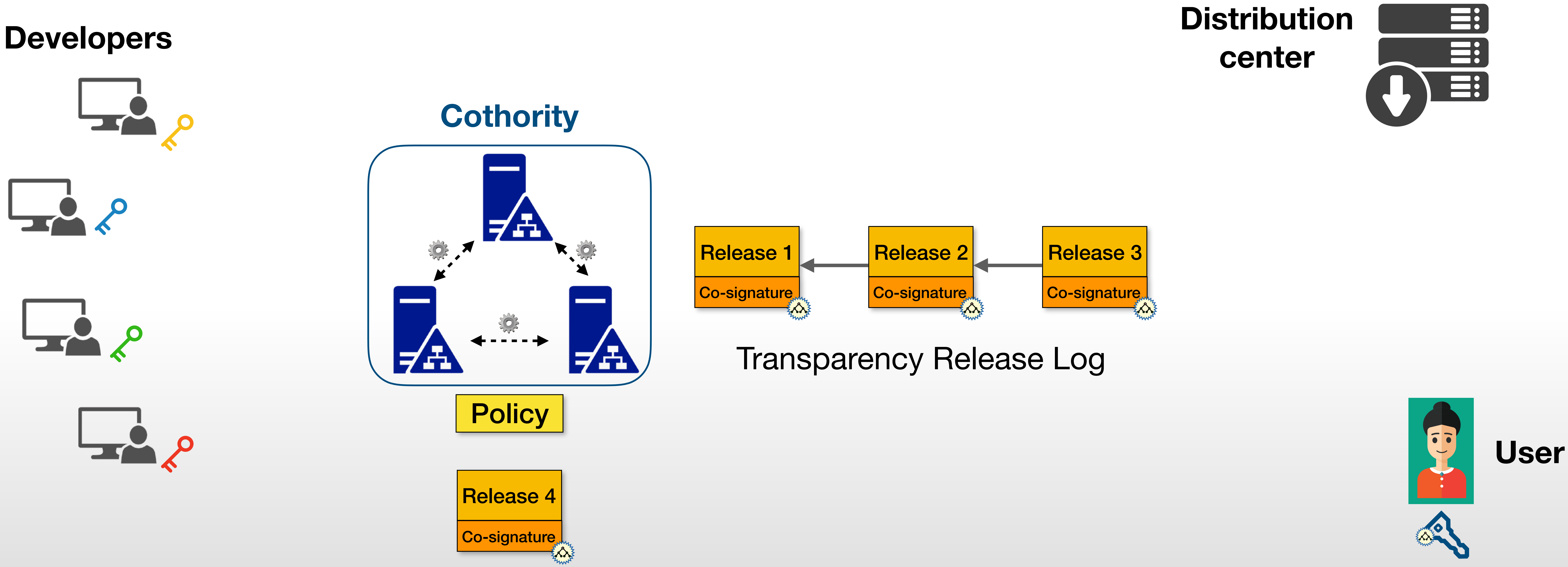

Developers

Cothority

Policy

Release 4

Co-signature

Release 1

Co-signature

Release 2

Co-signature

Release 3

Co-signature

Transparency Release Log

Distribution center

User

Anti-equivocation Measures

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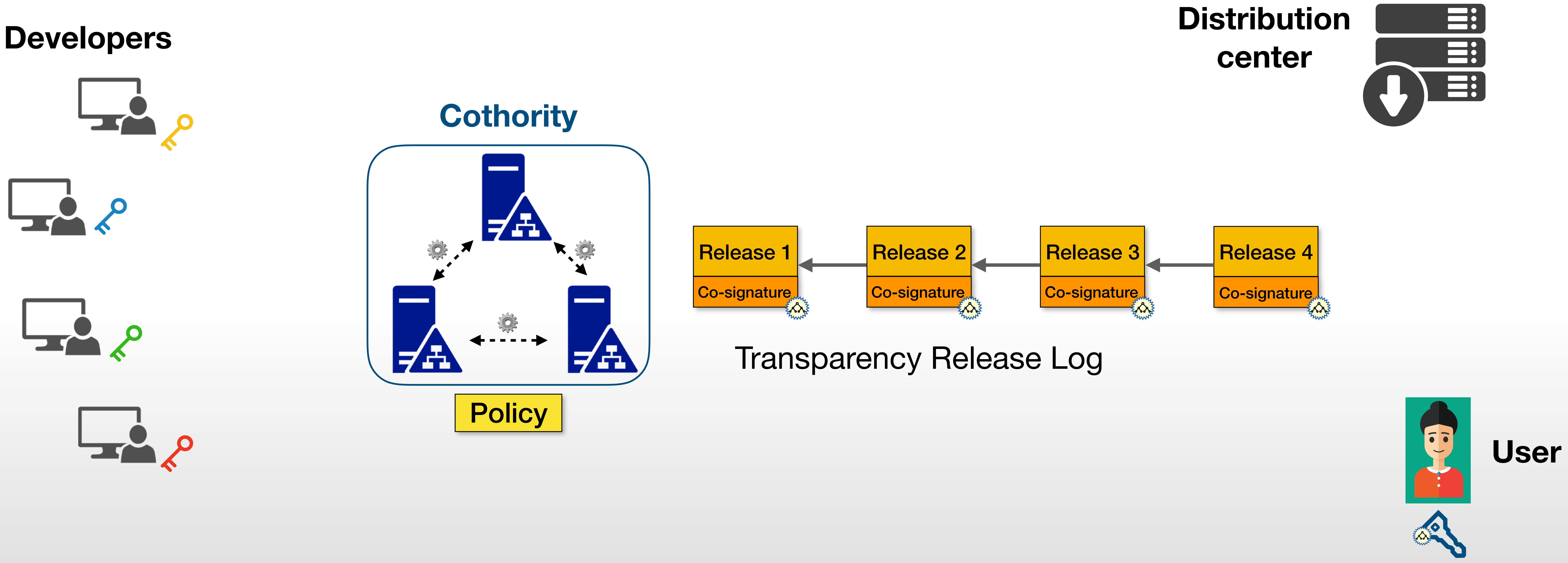


Developers

Cothority

Policy

Release 1

Co-signature

Release 2

Co-signature

Release 3

Co-signature

Release 4

Co-signature

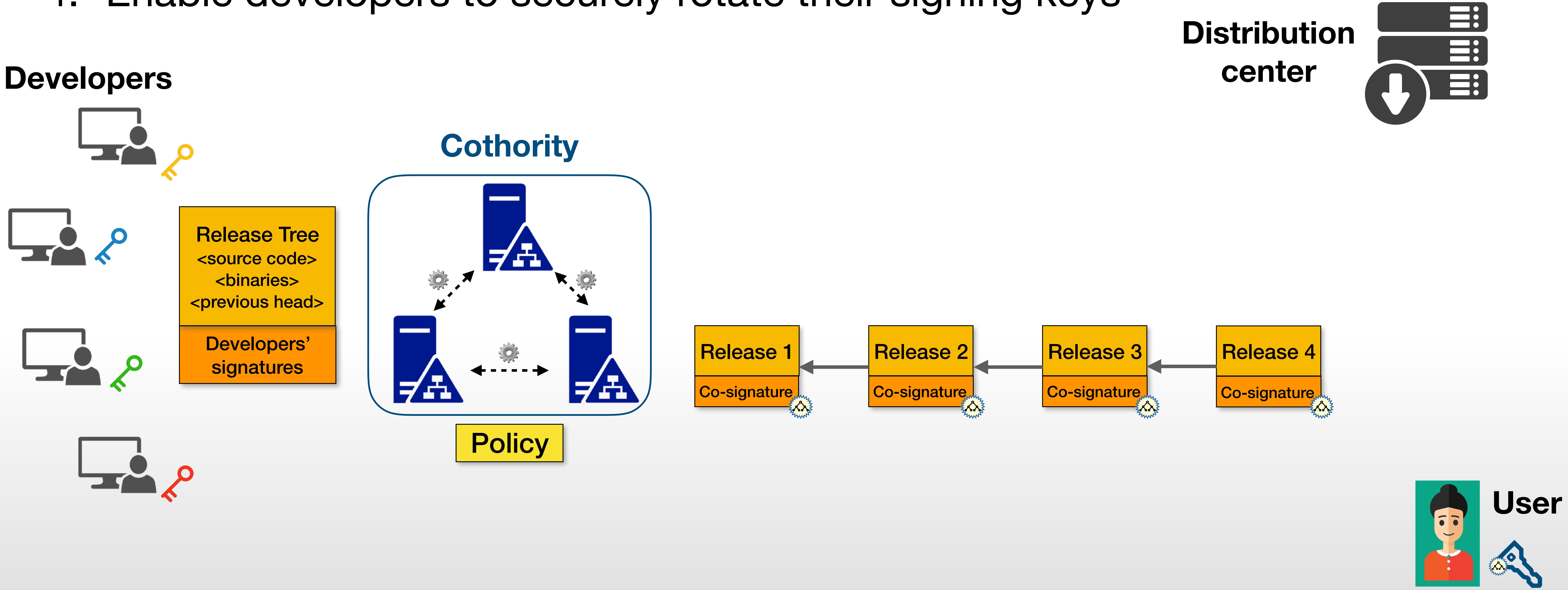
Transparency Release Log

Distribution center

User

Evolution of Developer Keys

4. Enable developers to securely rotate their signing keys



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

Evolution of Developer Keys

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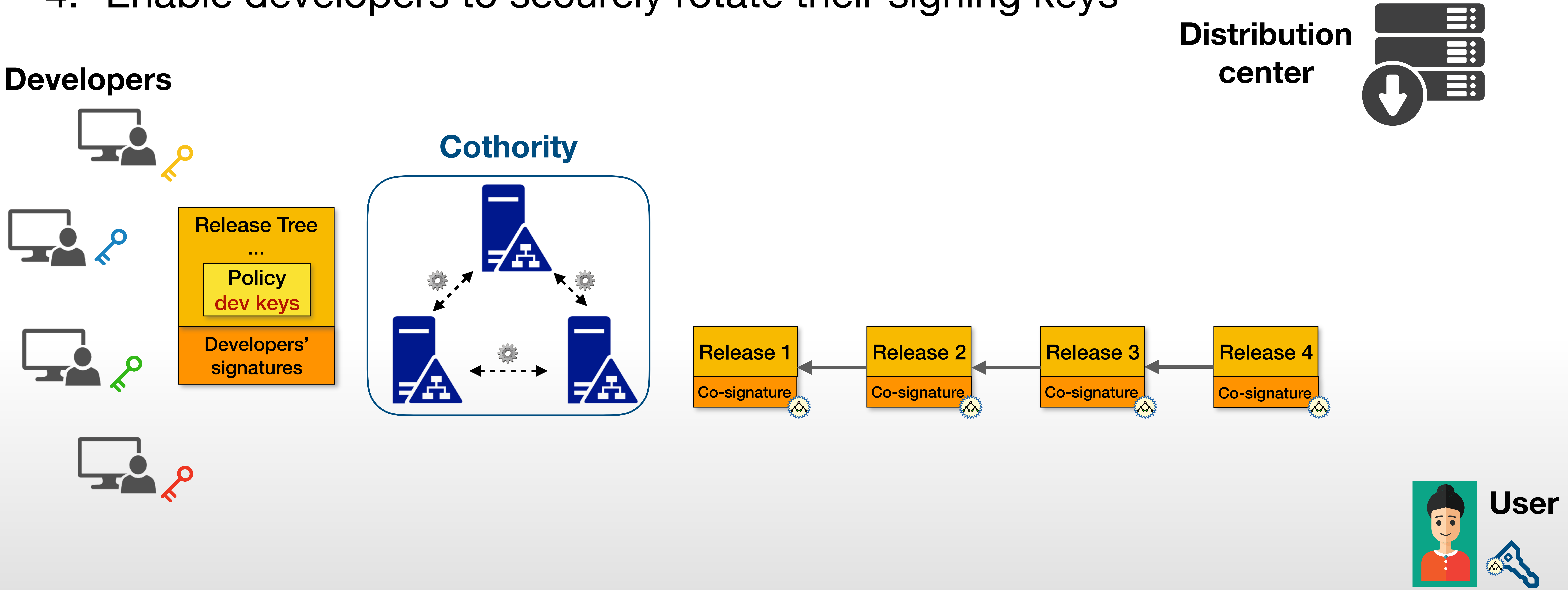

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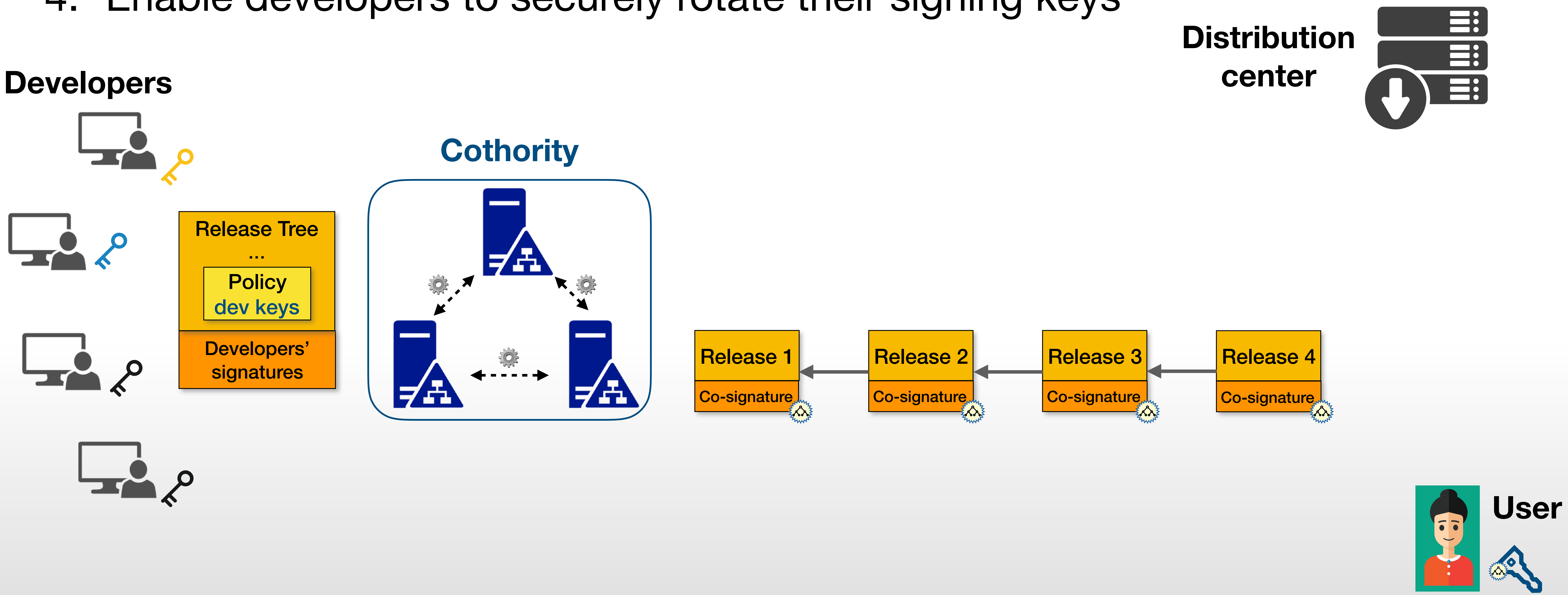

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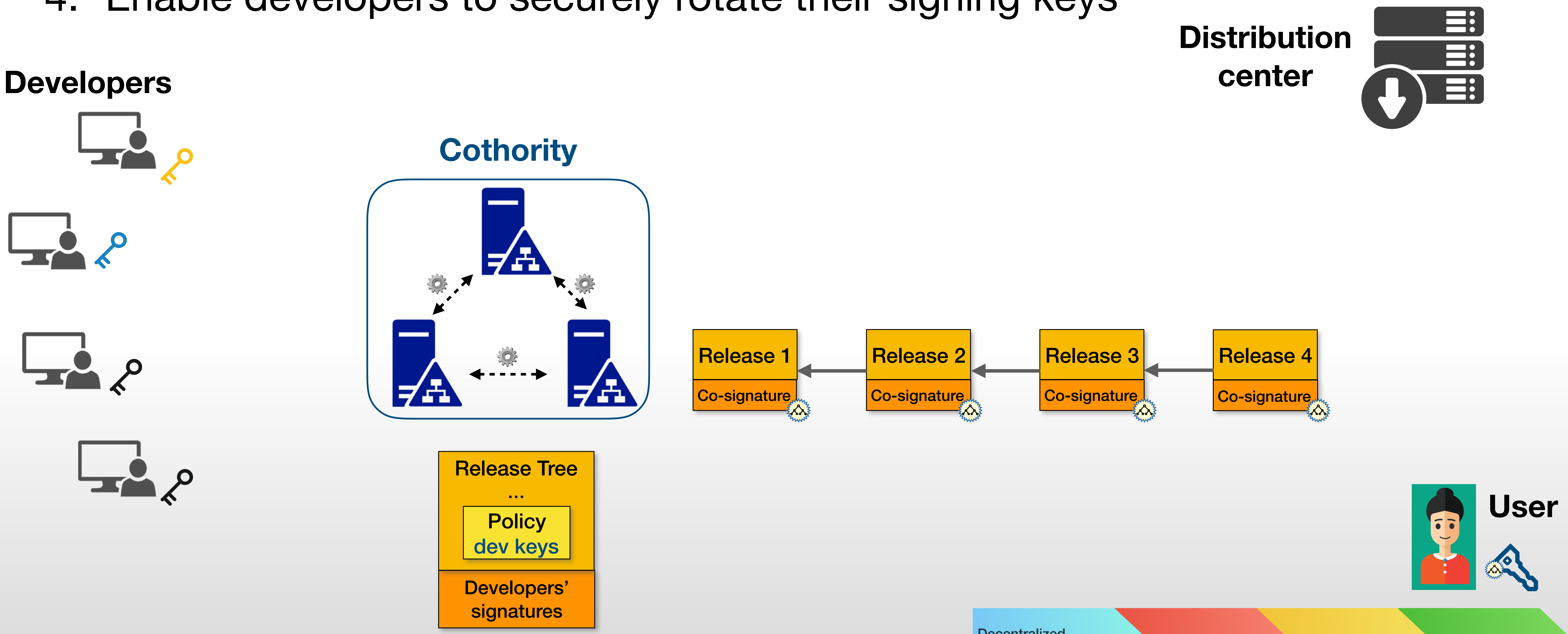
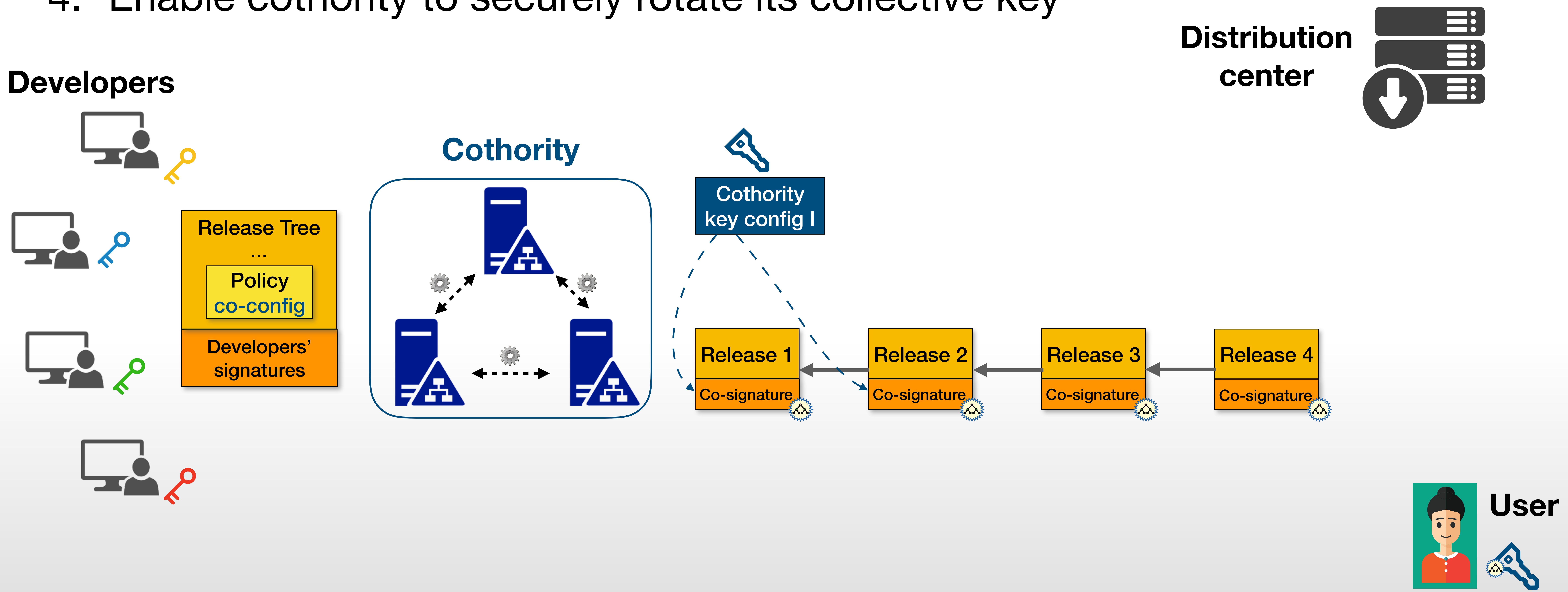


Decentralized Release Approval → Verified Builds → Anti-equivocation → Key Evolution

Evolution of Cothority Configuration

4. Enable cothority to securely rotate its collective key



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

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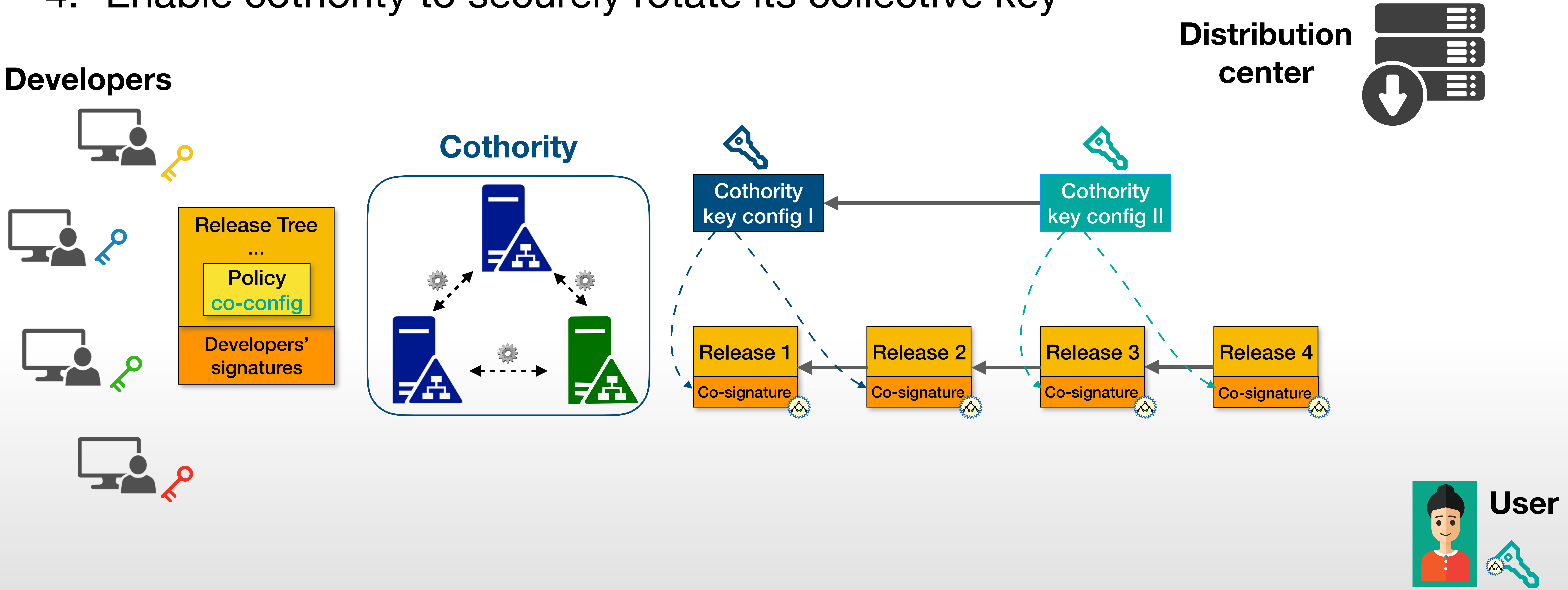


Distribution center

Developers

Cothority

Cothority key config I

Cothority key config II

Release Tree

...

Policy

co-config

Developers’ signatures

Release 1

Co-signature

Release 2

Co-signature

Release 3

Co-signature

Release 4

Co-signature

User

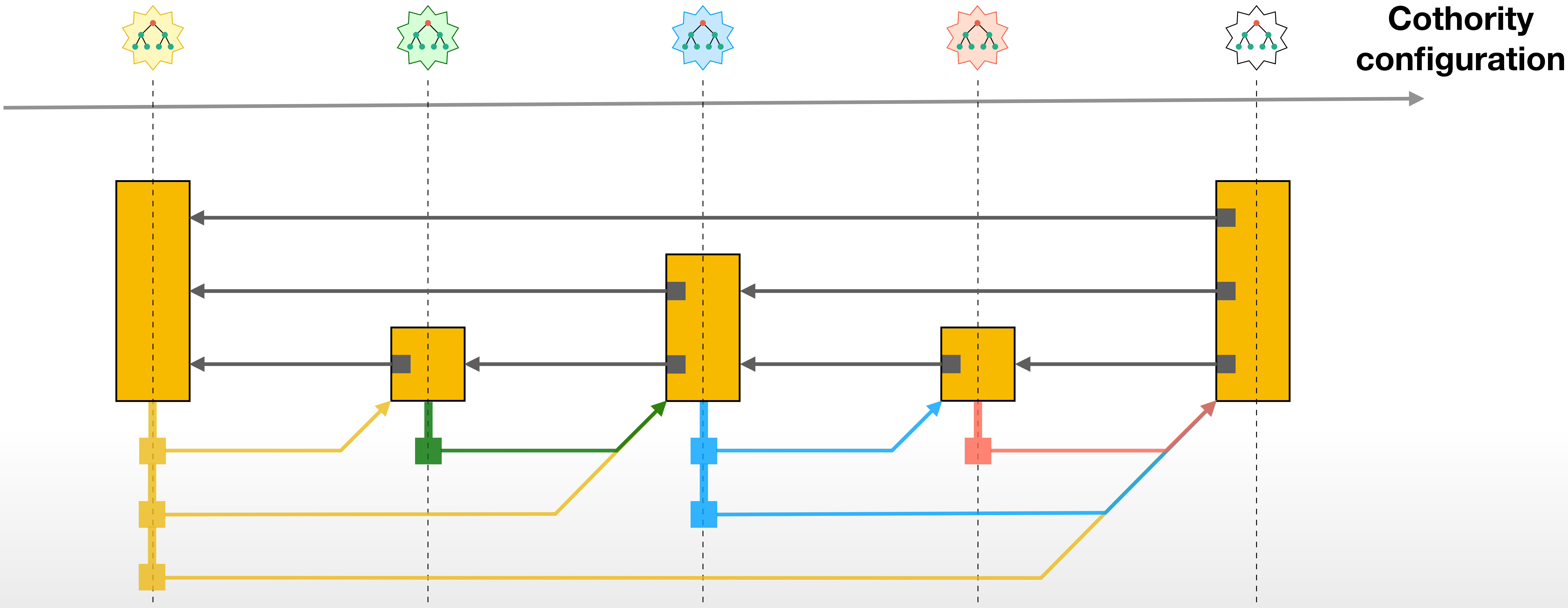
Decentralized Release Approval → Verified Builds → Anti-equivocation → Key Evolution

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



🟧 Skipblock

◀━■ Backward link (hash)

■━▶ Forward link (co-signature)

Implementation and Evaluation

Implementation

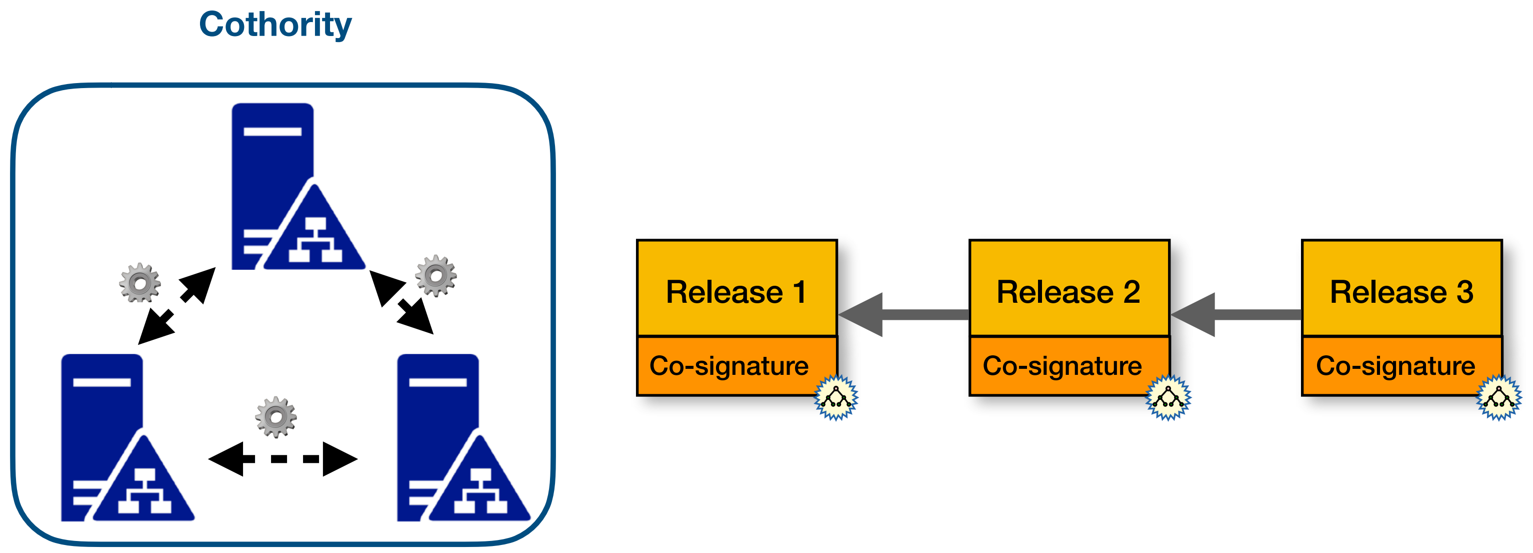
- CHAINIAC is implemented in Go
  - Using the DEDIS Kyber crypto library and Onet networking framework
  - Available open-source at https://github.com/dedis/paper_chainiac

Evaluation Methodology

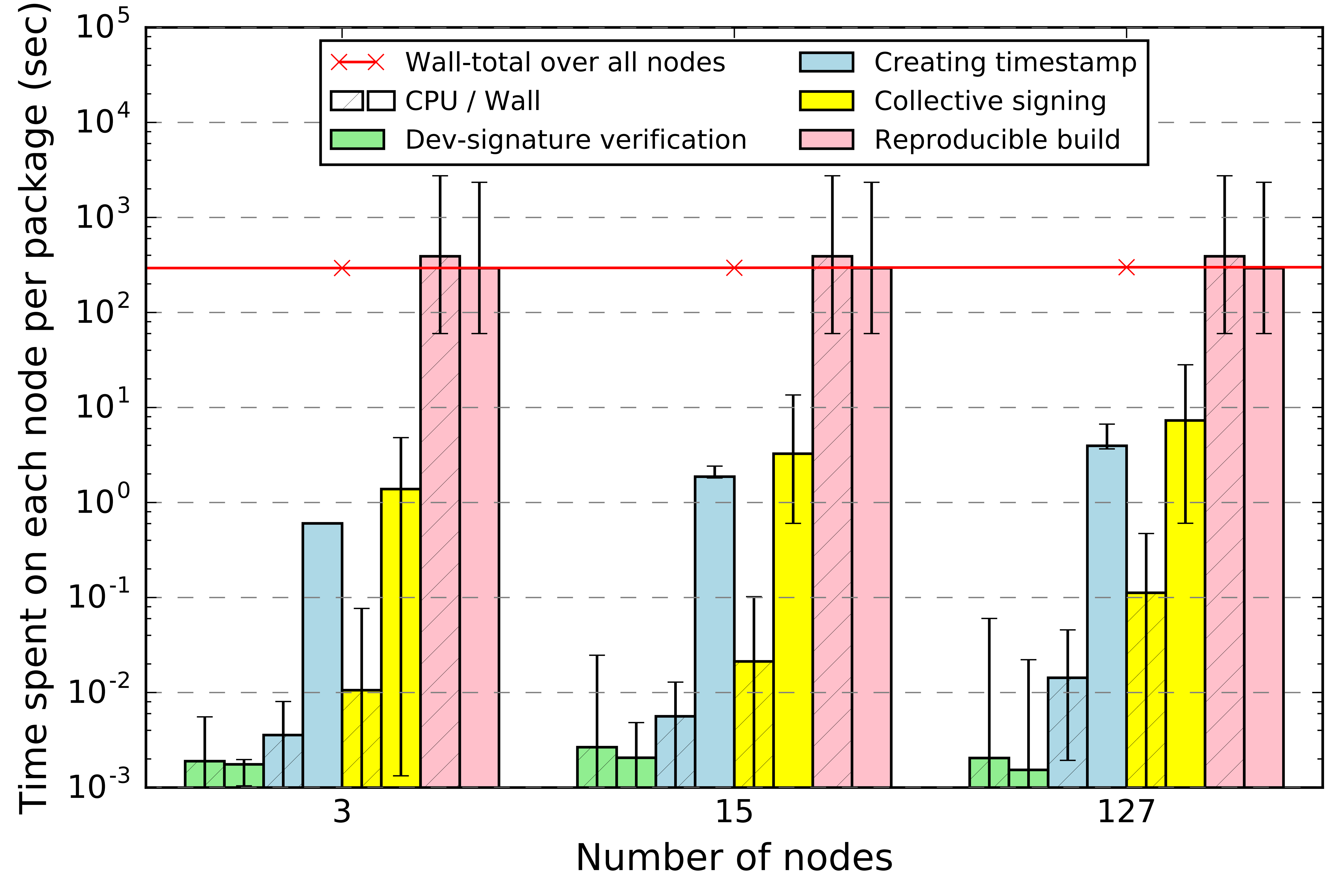
What is the cost effect of CHAINIAC on cothority nodes and on clients?

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

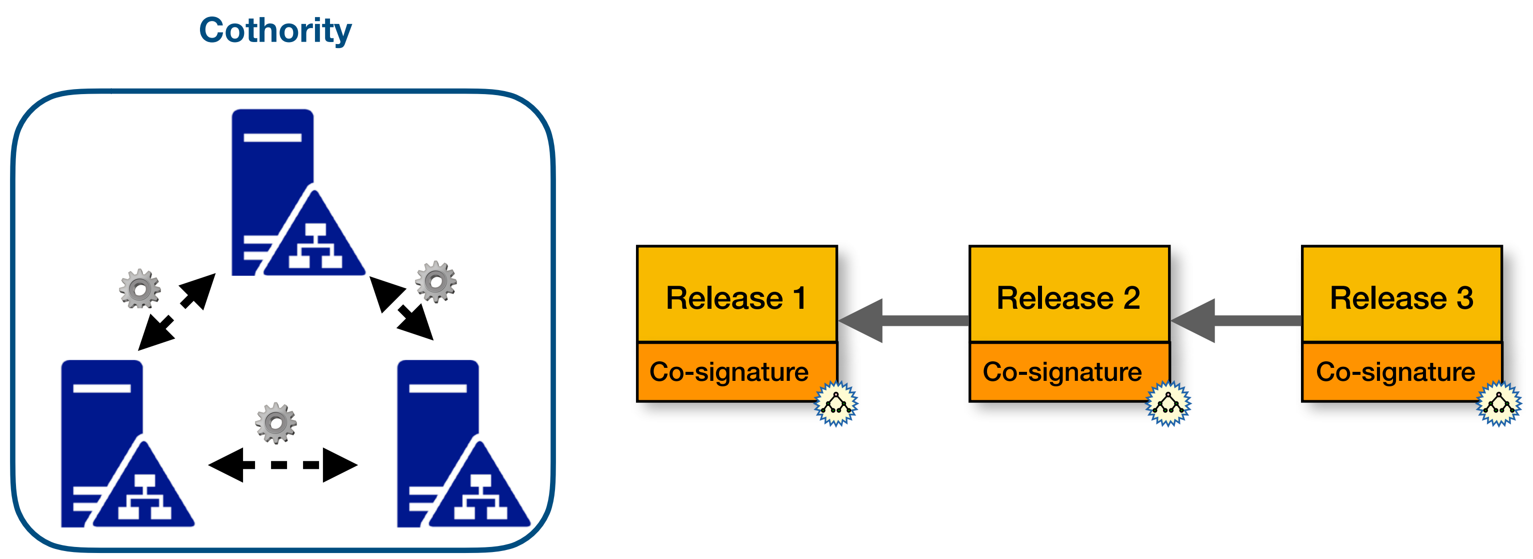
Evaluation



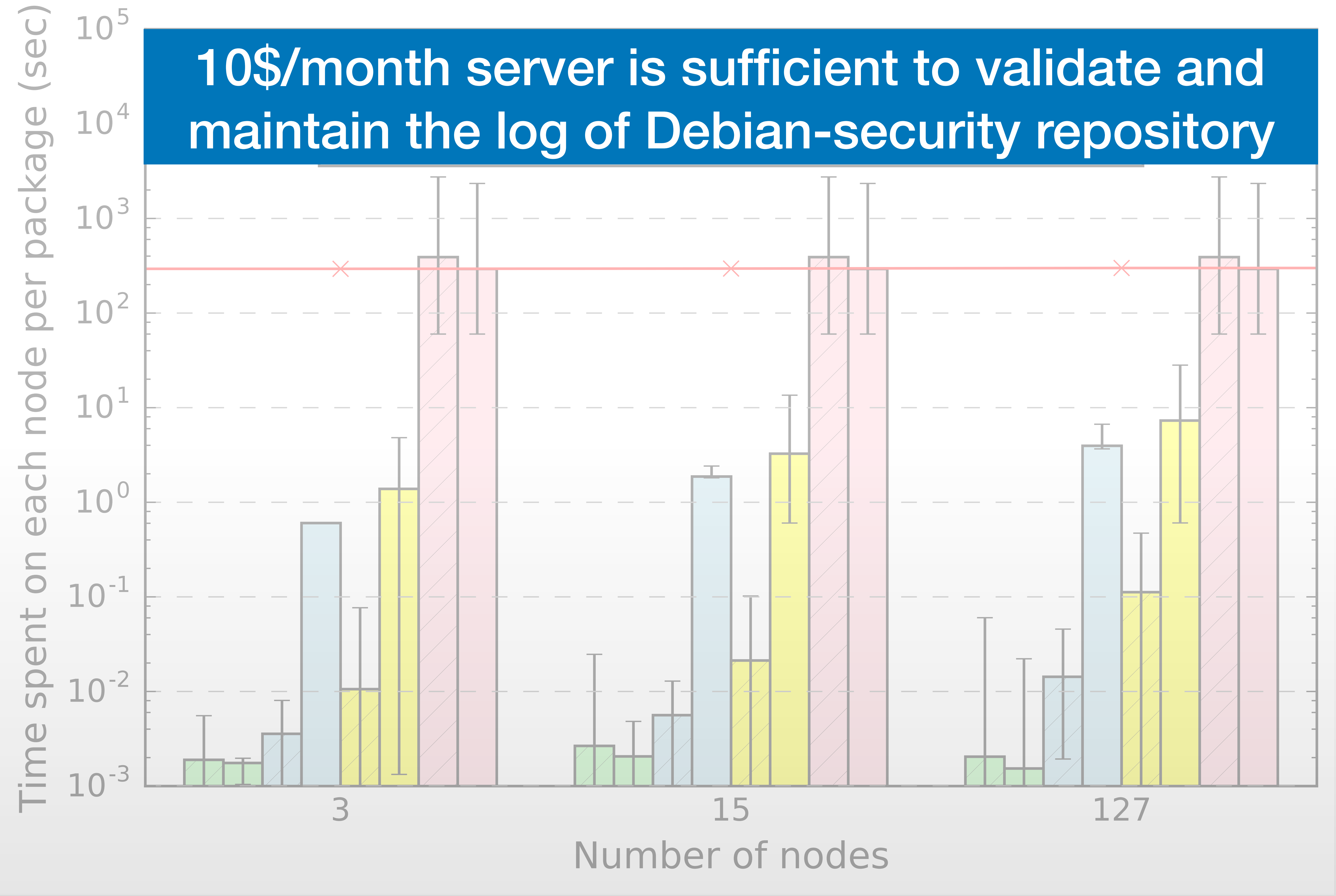
1. Cothority-node CPU cost of validating releases and maintaining release log



Evaluation



1. Cothority-node CPU cost of validating releases and maintaining release log



10$/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/ for more applications
- Verified builds as an improvement over reproducible builds
- Role-based architecture, multi-package Chainiac and more are in the paper

Kirill Nikitin

kirill.nikitin@epfl.ch

@nikir1ll