Mercury

Bandwidth-effective Prevention of Rollback Attacks Against Community Repositories

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Software repositories

Software updates

- Experts agree: software updates the most important thing (USENIX SOUPS 2015)
- Updates fix security vulnerabilities
- However, important problem in software updates often neglected...

"...no one can hack my mind": Comparing Expert and Non-Expert Security Practices

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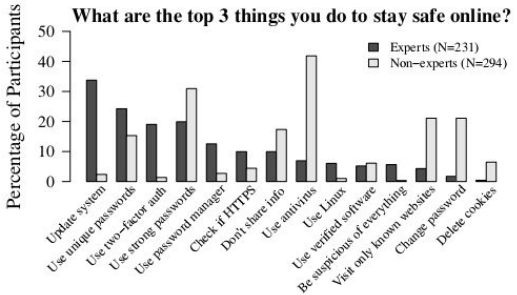


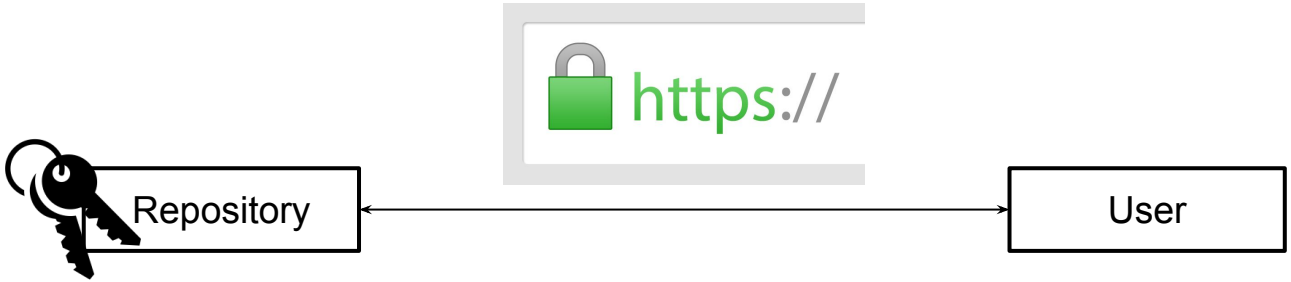
Figure 1: Security measures mentioned by at least 5% of each group. While most experts said they keep their system updated and use two-factor authentication to stay safe online, non-experts emphasized using antivirus software and using strong passwords.

Repository compromise: impact

- Nation state actors:
  - Microsoft Windows Update (2012): Flame malware targeted Iran nuclear efforts
  - South Korea cyberattack (2013): >$750M USD in economic damage
  - NotPetya (2017): infected multinational corporations
- Compromise millions of devices
- Worst case: human lives

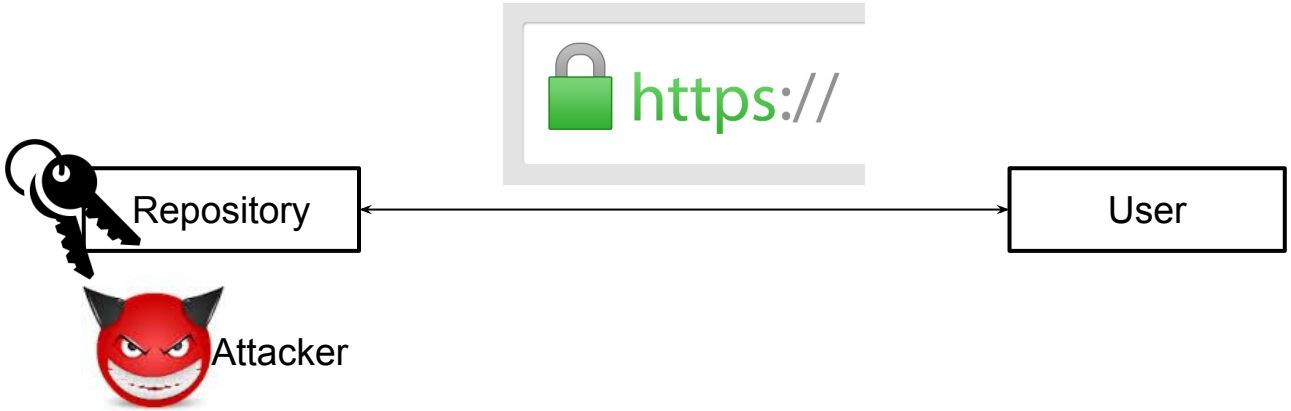
SSL / TLS

- Use online key to sign all updates (e.g., SSL / TLS, CUP)
- Protects users from man-in-the-middle attacks



The problem with SSL / TLS

- Doesn’t say anything about the security of the server: just the connection
- Single point of failure: easy to compromise
- If repository is compromised, attacker can install malware and control devices



GPG / RSA

- Why not sign updates using GPG / RSA keys kept off repository?

GPG / RSA

- Why not sign updates using GPG / RSA keys kept off repository?
- Assumes key distribution problem solved, but OK...
- Mission accomplished, right?

In Proceedings of the 8th USENIX Security Symposium, August 1999, pp. 169-183

Why Johnny Can't Encrypt:
A Usability Evaluation of PGP 5.0

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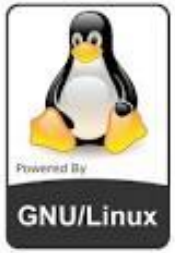
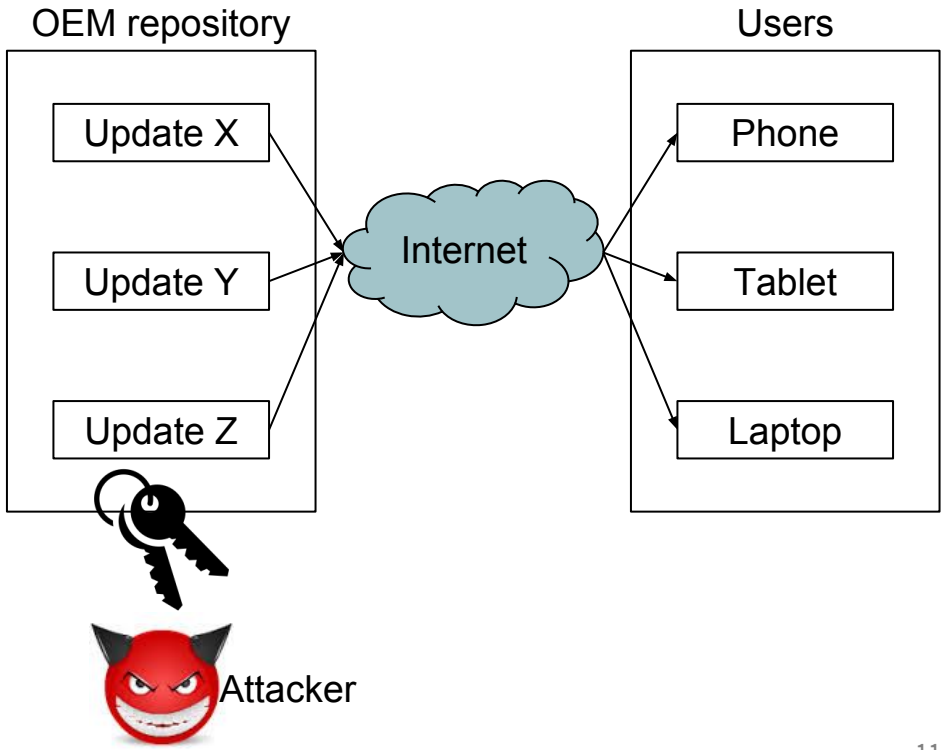
What do these organizations have in common?



Vulnerabilities in software updates

Goal: compromise-resilience

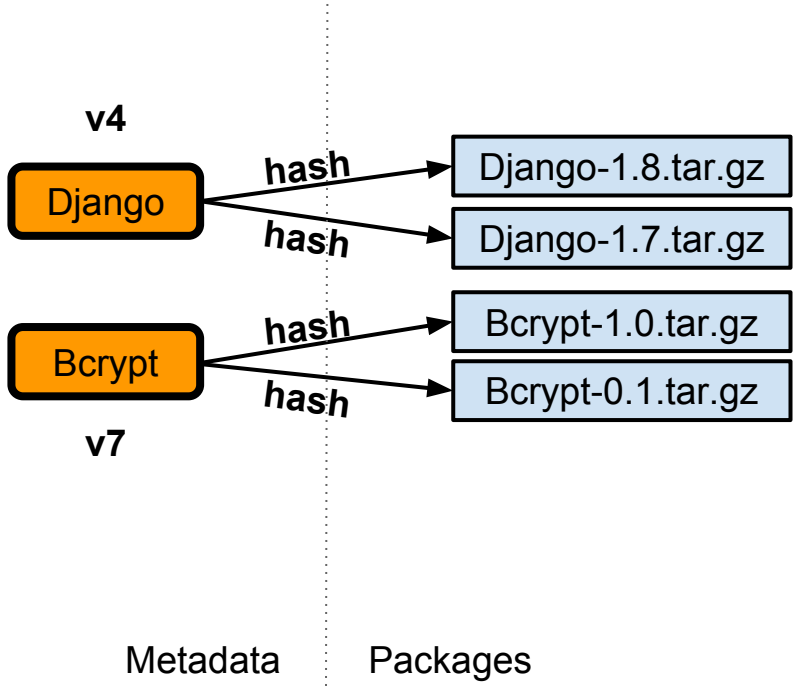
- Only a question of when, not if
- Cannot prevent a compromise
- But must severely limit its impact



One way GPG / RSA is insecure

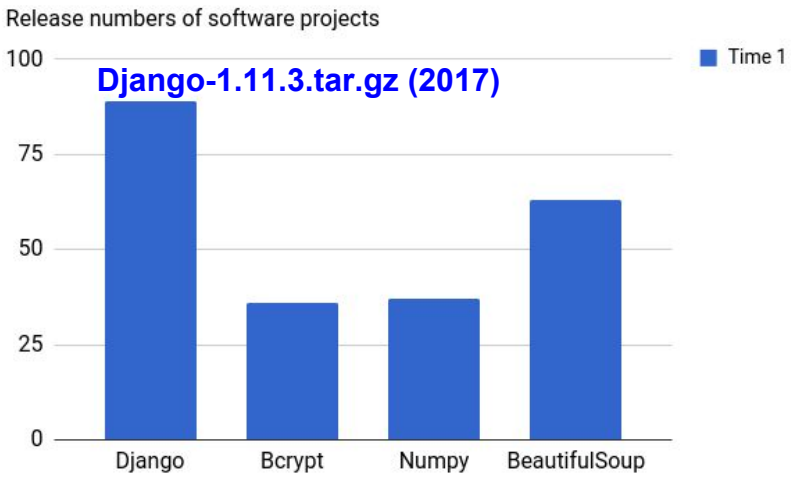
Project metadata & packages

- A repository has many projects
- A project has many packages
- A project signs a metadata file listing packages



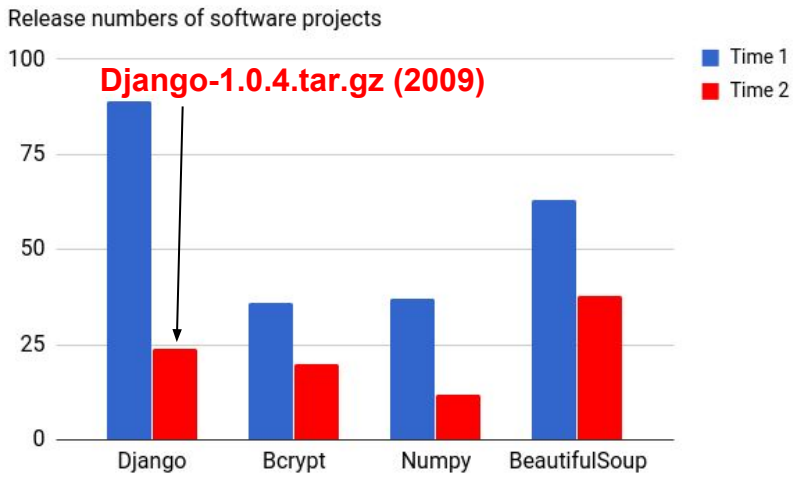
Rollback attacks

- Choose obsolete updates with known security vulnerabilities



Rollback attacks

- No need to tamper with signed updates
- Just replace new signed updates with old signed updates!



Why rollback attacks are bad

- Compromise users w/o tampering with updates! [CCS 2008]
- Obsolete = vulnerable = just as bad as malware

A Look In the Mirror: Attacks on Package Managers

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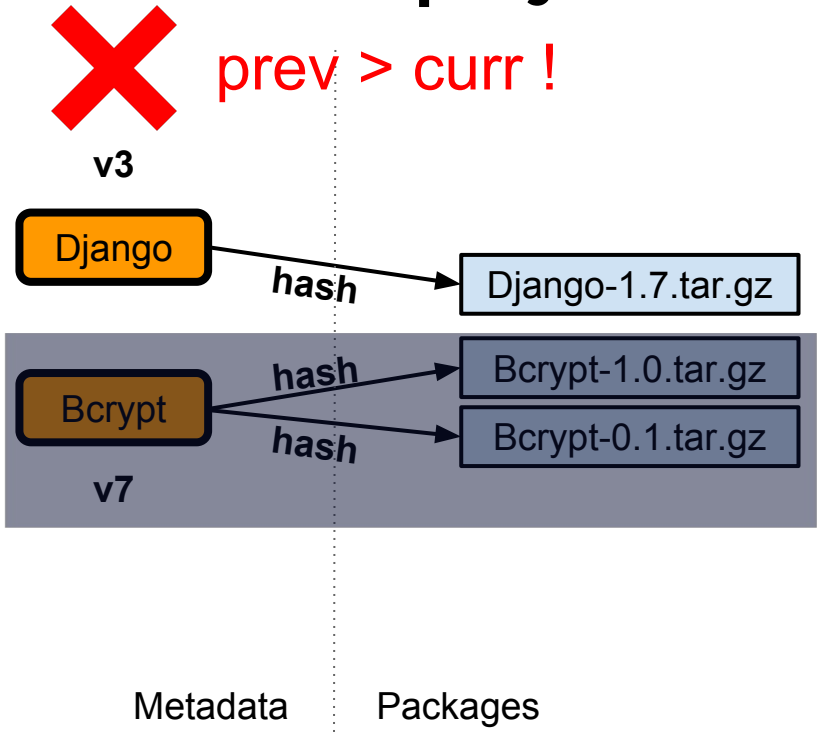
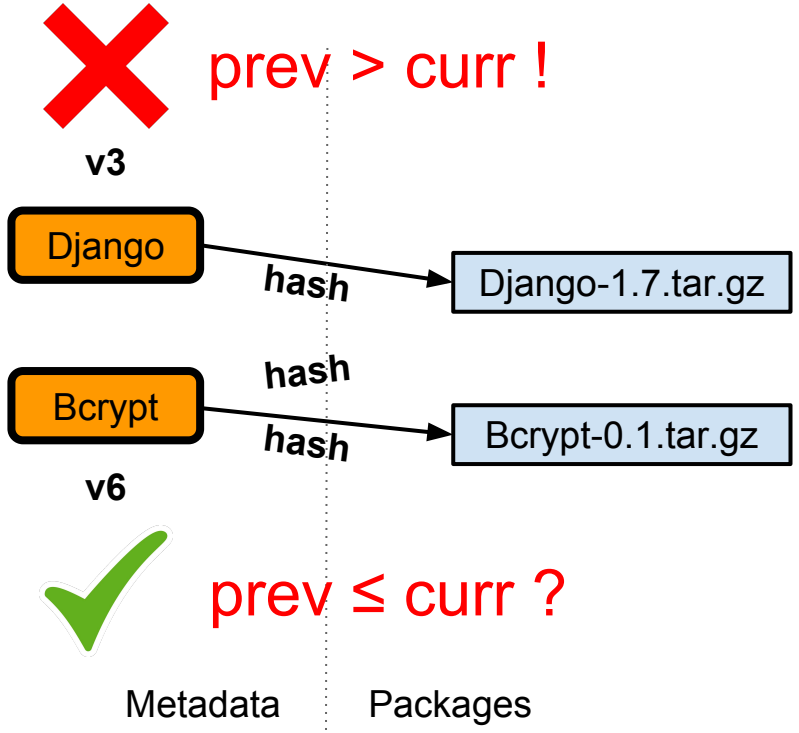
Prevents rollback attacks on installed projects

- Verify project metadata to verify packages
- Download project metadata for only package to be installed
- Compare previous & current version numbers of project metadata



What about projects *yet* to be installed?

- **BAD! Does not prevent rollback attacks on projects *yet to be installed***
- What is the previous version number?



Compromise-resilience with Diplomat

The Update Framework (TUF)

- Design principles
  - Separation of duties
  - Threshold signatures
  - Explicit & implicit revocation of keys
  - Minimizing risk using offline keys
  - Selective delegation of trust
- CCS 2010

Survivable Key Compromise in Software Update Systems

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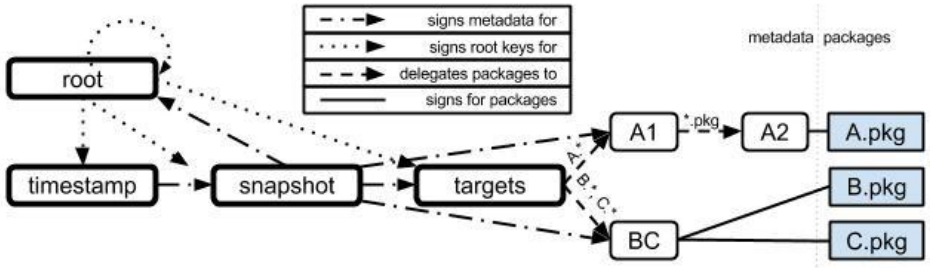

Diplomat

- Provides compromise-resilience & immediate project registration
- USENIX NSDI 2016

Diplomat: Using Delegations to Protect Community Repositories

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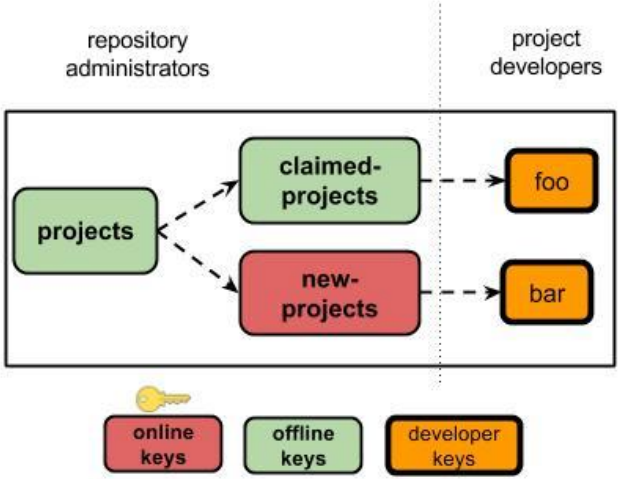
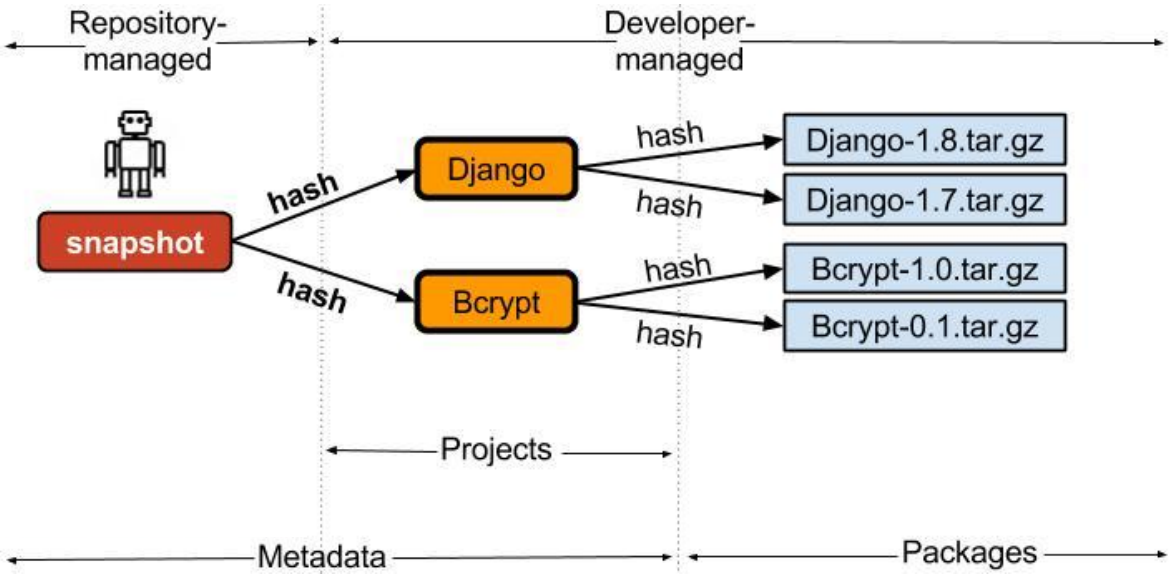


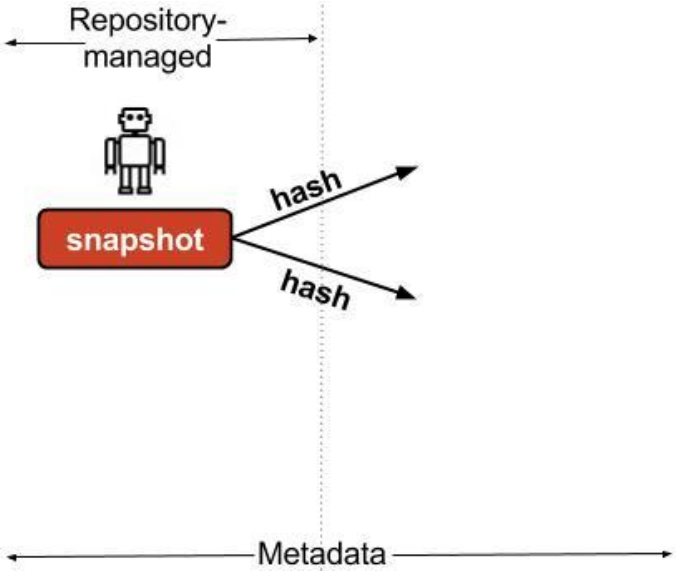
Snapshot metadata

- Repositories distribute snapshot metadata, or manifest of all projects



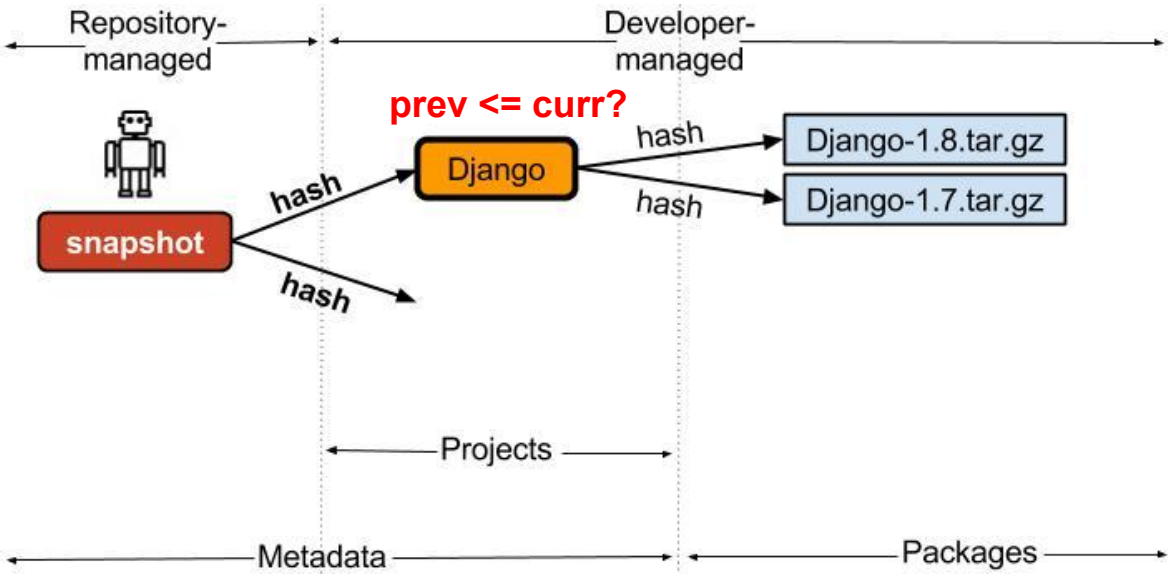
Download snapshot metadata

- To prevent rollback attacks, first download snapshot metadata



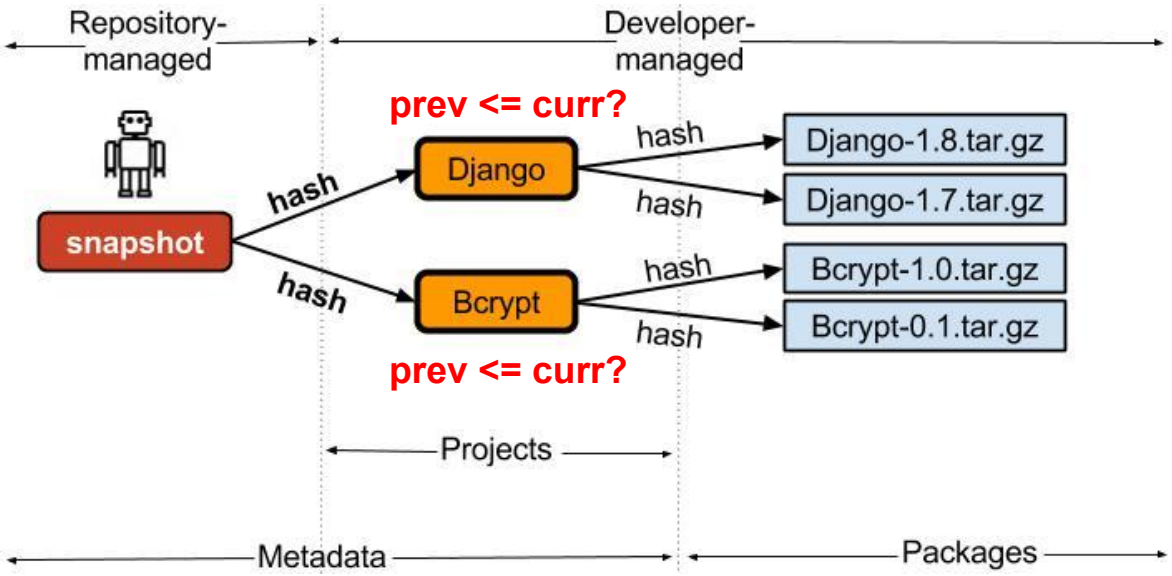
Download project metadata

- Then, compare previous & current version number of project metadata



Download *all* project metadata

- Do this for every single project metadata file listed in snapshot metadata



Integrations & deployments

Flynn

Problem

- Diplomat too expensive on some repositories like PyPI
- A large number of frequently updated projects

Bandwidth cost for new users

- Requires *new* users to download *all* project metadata
- 20MB (31x!)

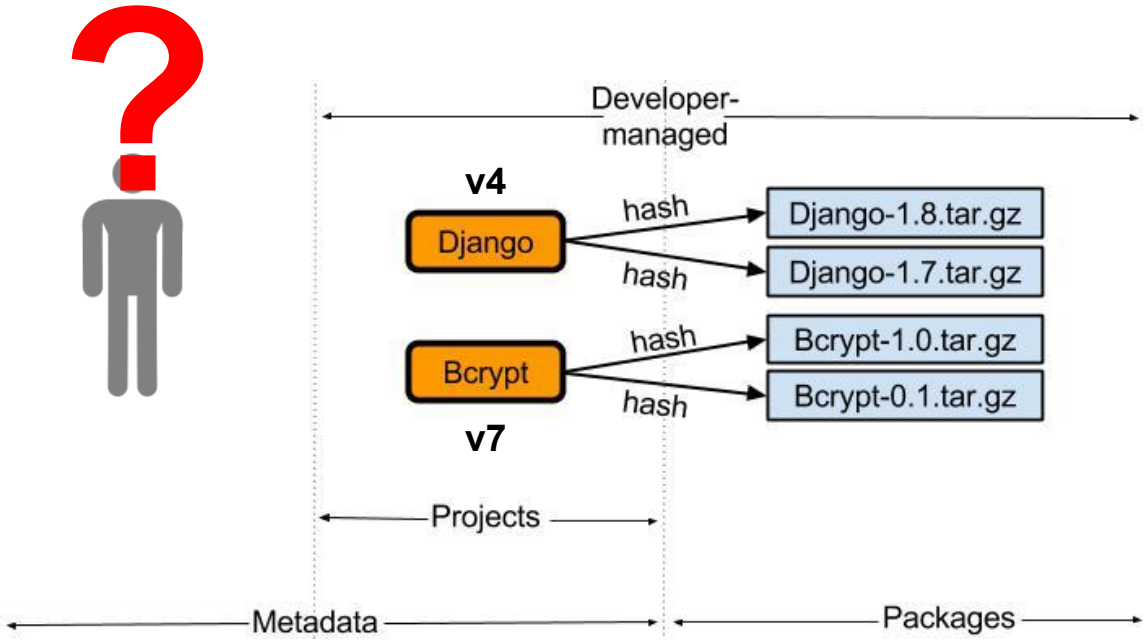
Bandwidth cost for returning users

- Requires *returning* users to download all *new* or *updated* project metadata
- 2.1MB (3.2x!)

Mercury: a new security system

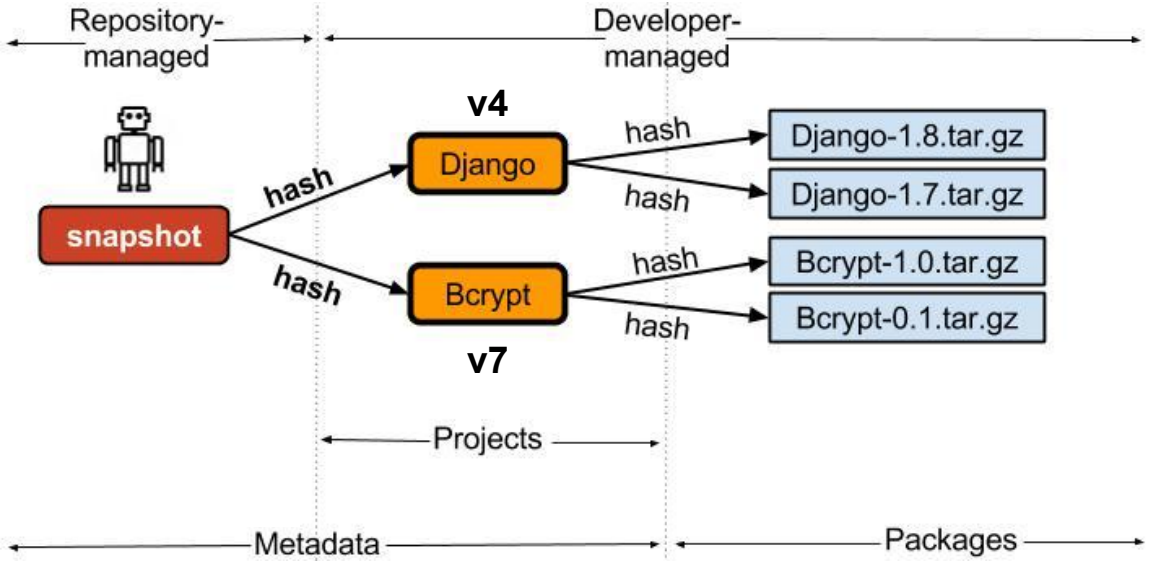
Diplomat: repository cannot be trusted

- No trusted party (e.g., humans) to always correctly indicate new project metadata
- Projects are updated too rapidly



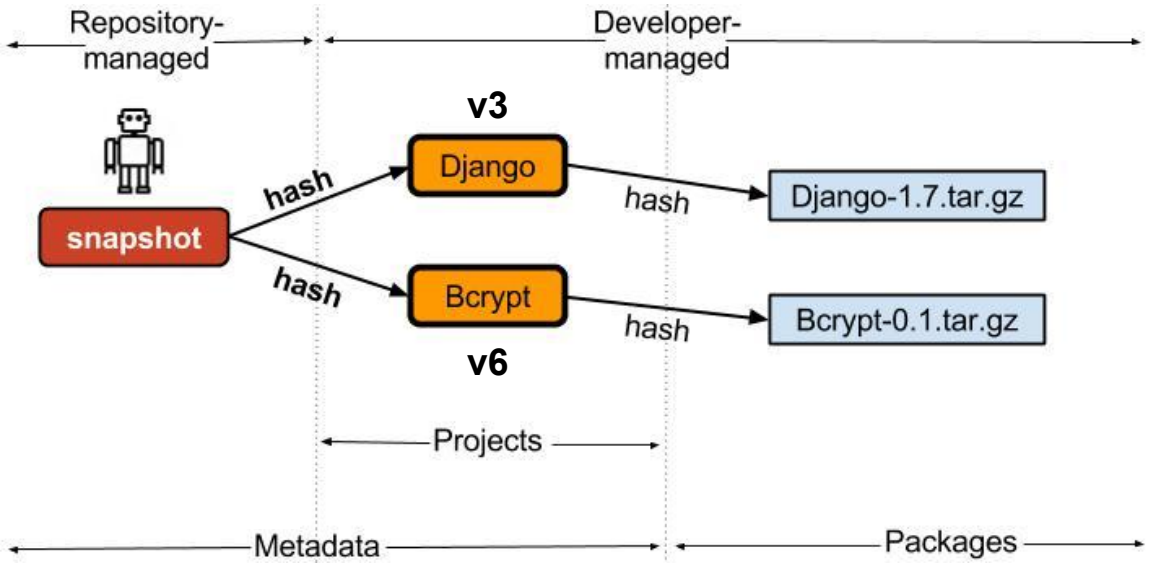
Diplomat: repository cannot be trusted

- Repositories use automation to indicate only *which* projects have been updated



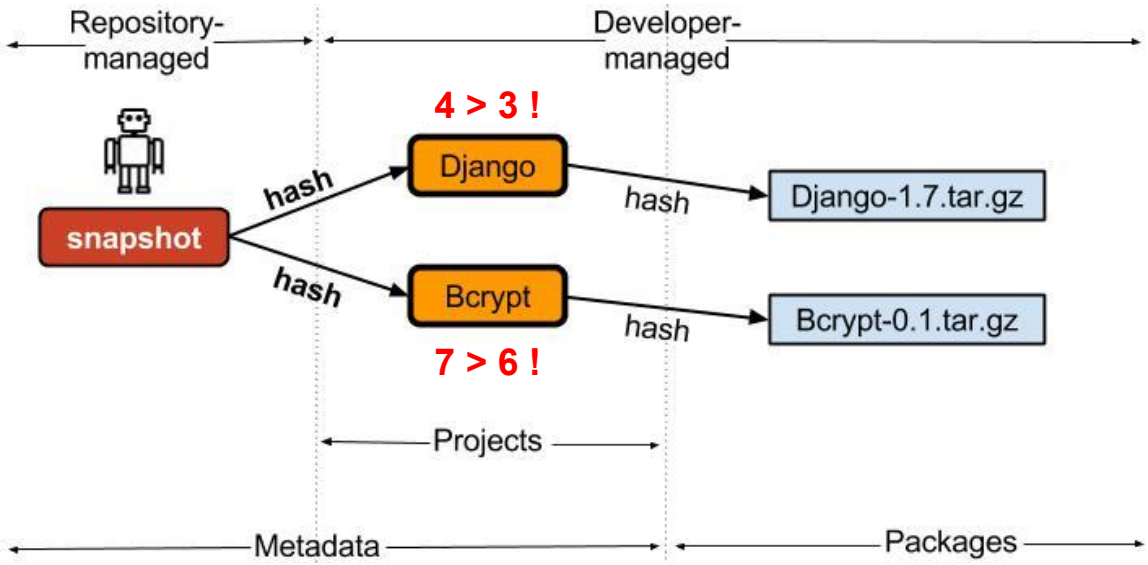
Diplomat: repository cannot be trusted

- But attackers who compromise repository can launch rollback attacks
- Just point to obsolete project metadata!



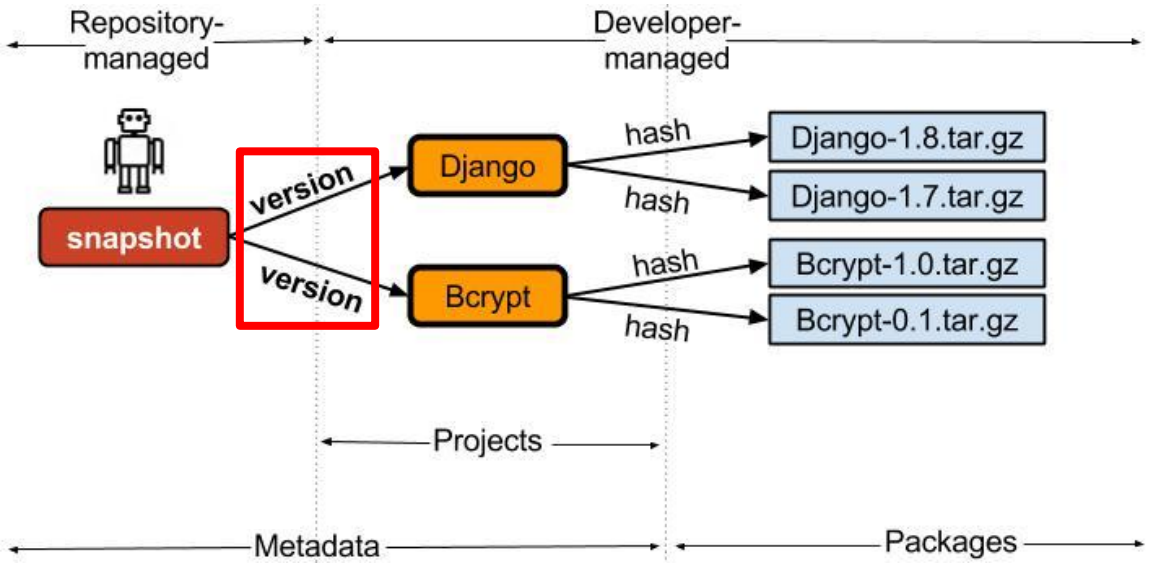
Diplomat: only developers can be trusted

- Only developers trusted to provide version numbers
- Price: prohibitive b/w costs



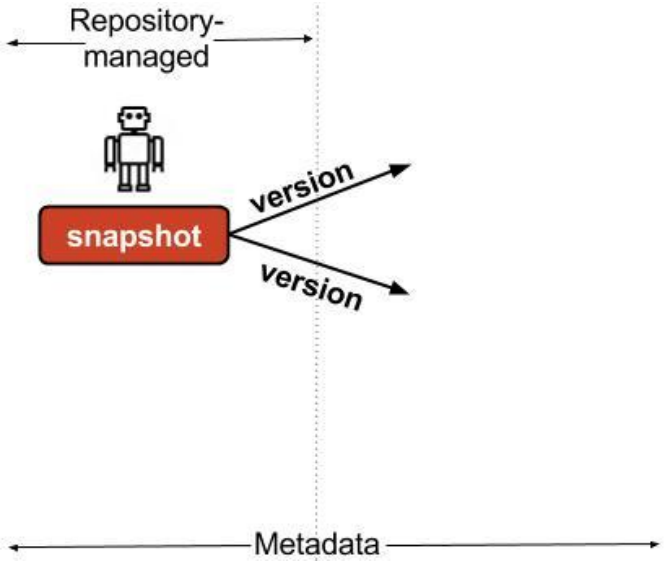
Mercury: shift trust from developers to repository

- Safely shift source of trust from developers to repository
- Snapshot metadata indicates *version numbers* of project metadata



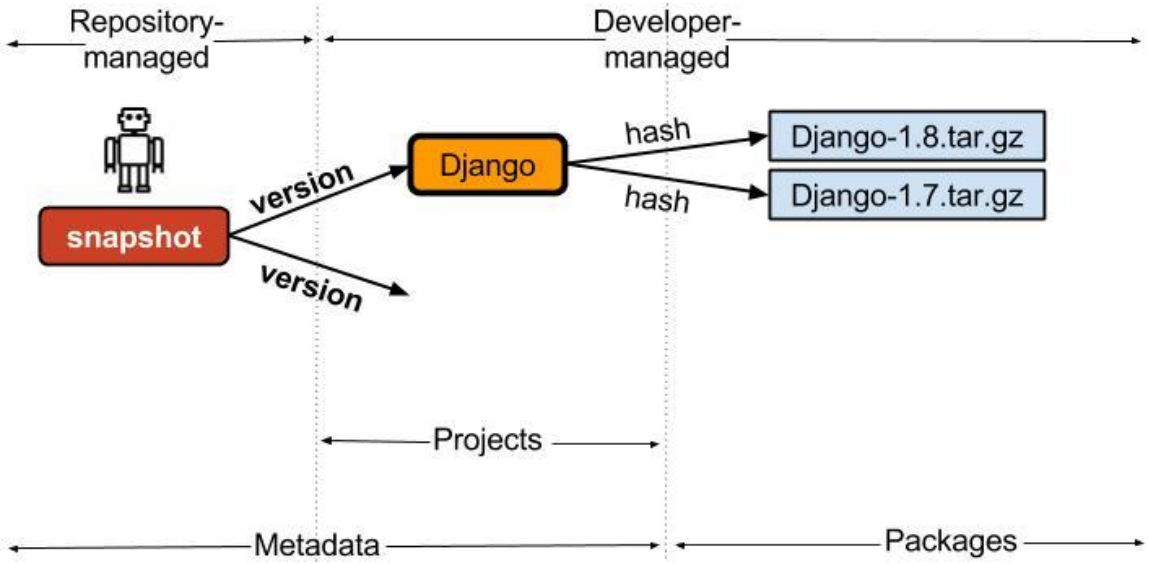
Mercury: low bandwidth cost

- Uses low bandwidth costs
- To prevent rollback attacks, first download snapshot metadata



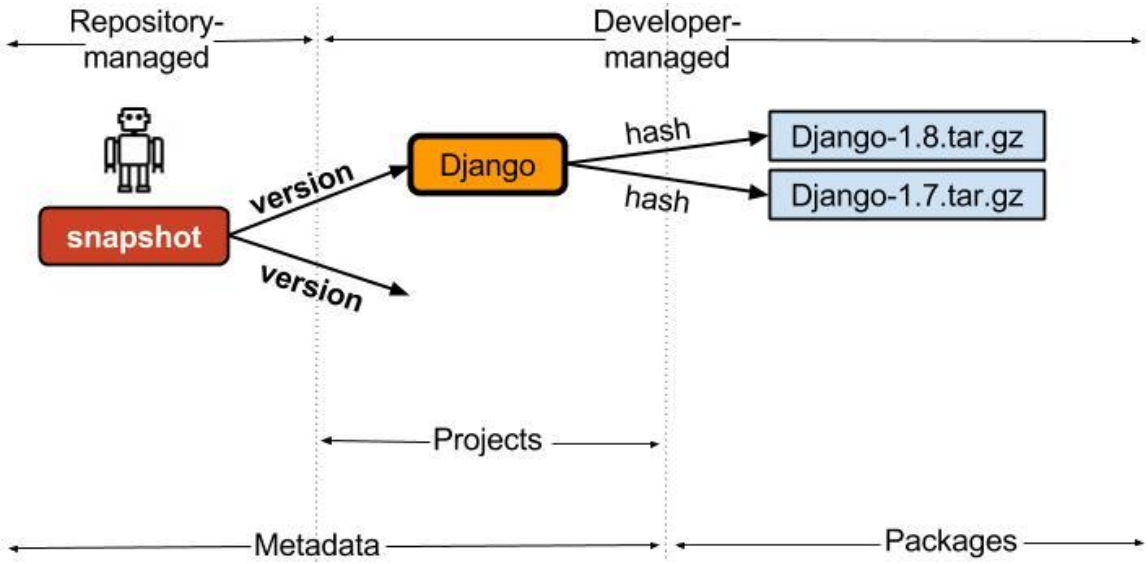
Mercury: low bandwidth cost

- Download project metadata for only package to be installed
- Use delta compression for more savings



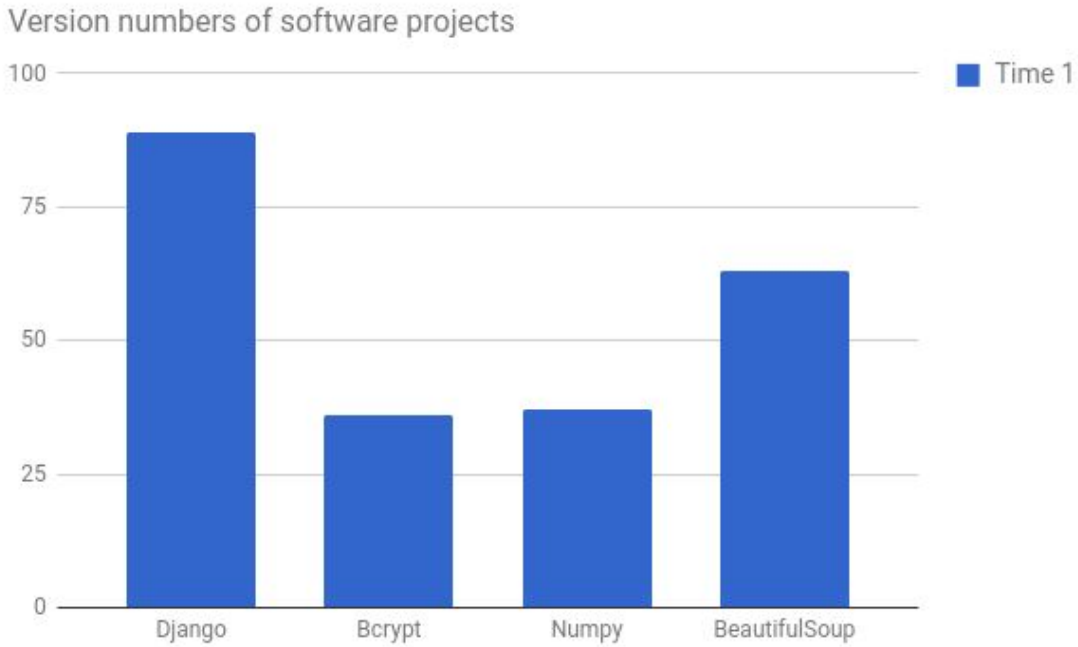
Security analysis

- But is it secure?



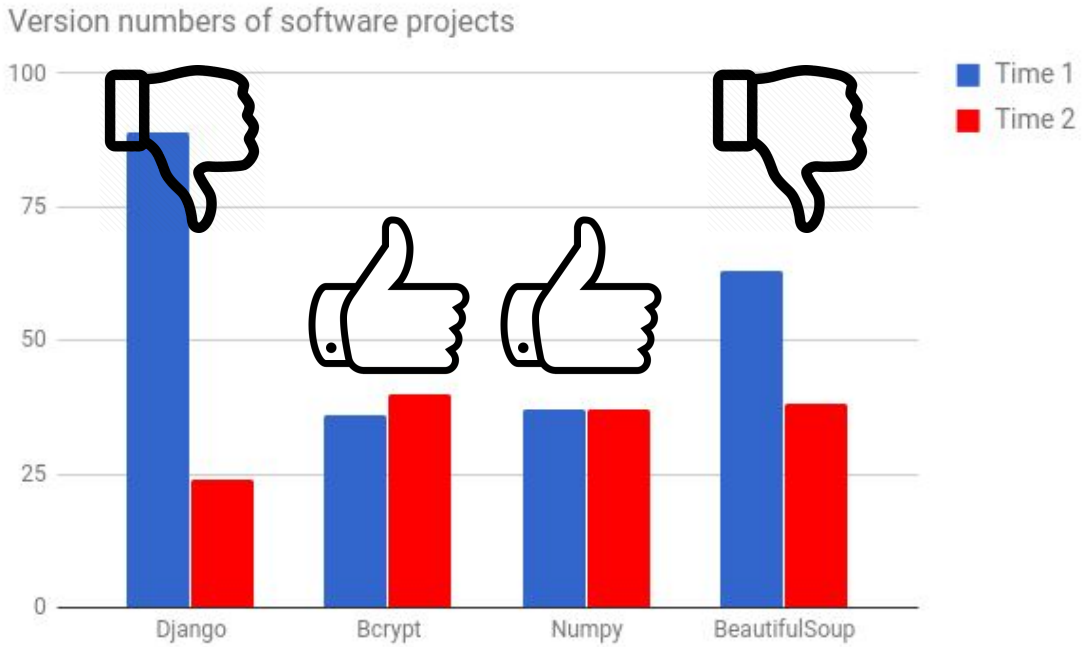
Security analysis: rollback attacks

- Mercury always prevents rollback attacks



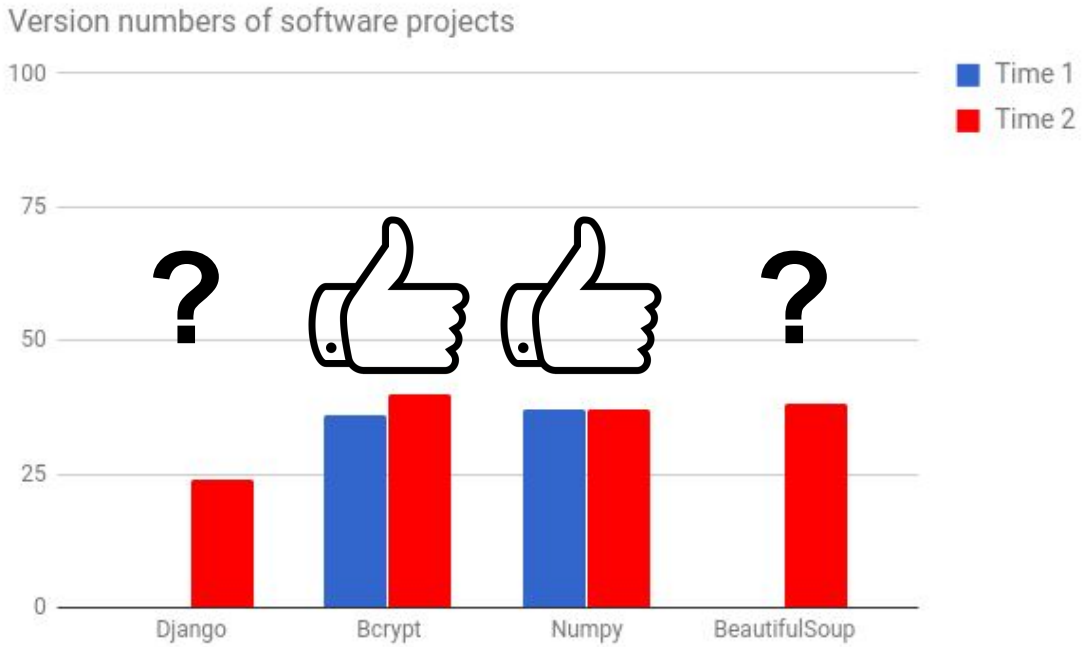
Security analysis: rollback attacks

- Always compare previous & current version numbers in snapshot metadata



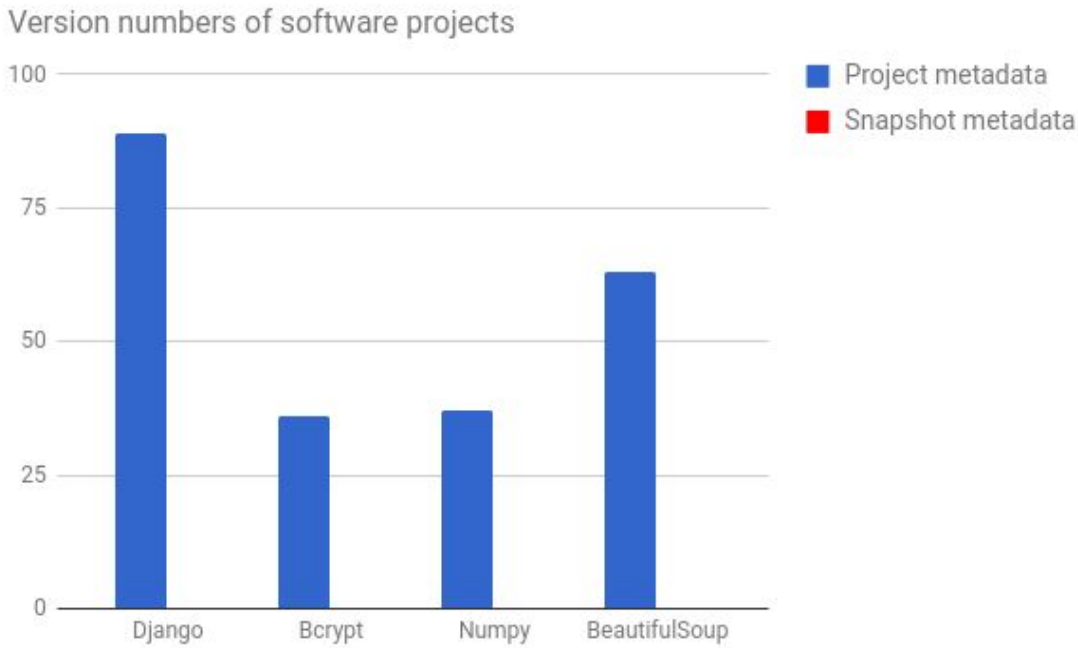
Security analysis: rollback attacks

- Do *not* delete projects from snapshot metadata
- Otherwise, attackers can rollback these projects



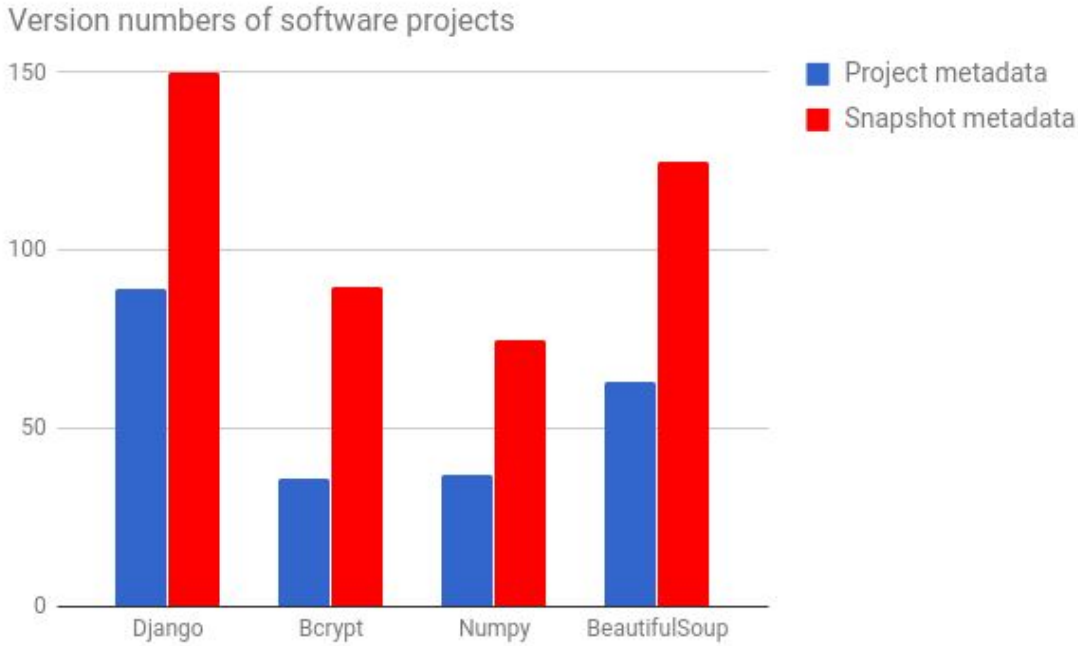
Security analysis: fast-forward attacks

- Unlike Diplomat, susceptible to fast-forward attacks



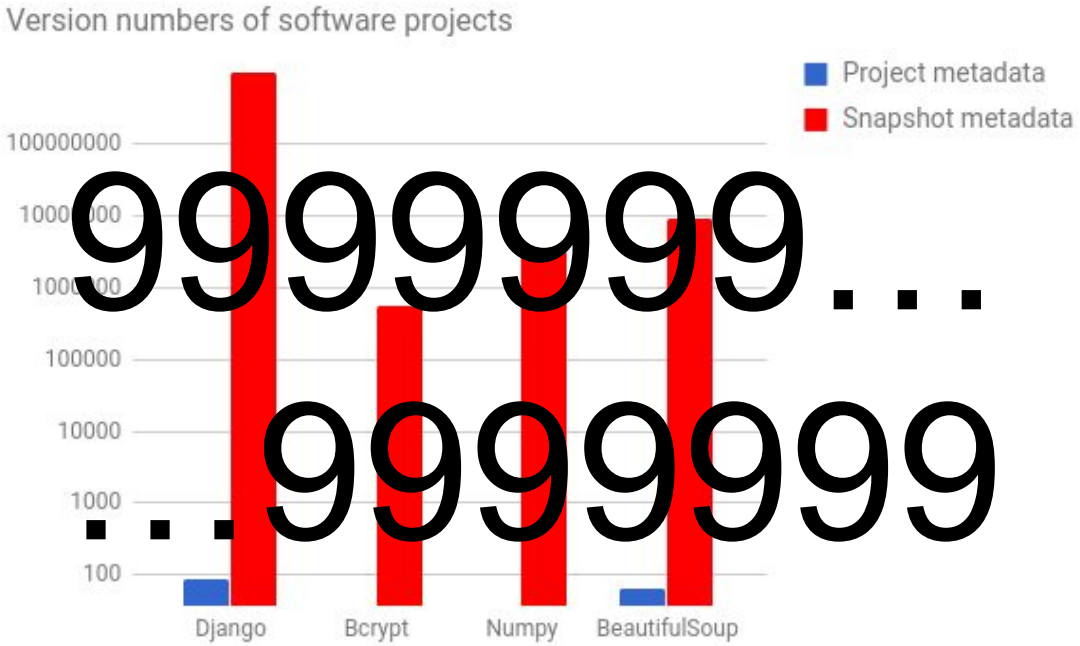
Security analysis: fast-forward attacks

- Arbitrarily increase version numbers in snapshot metadata
- Can deny packages to users



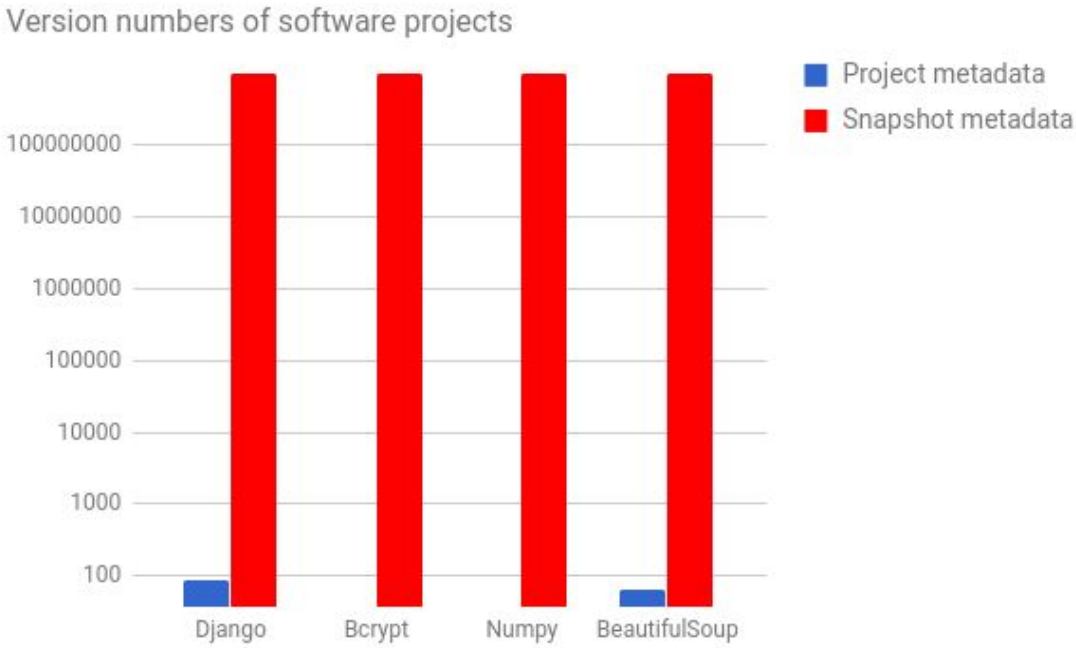
Security analysis: fast-forward attacks

- Waste b/w by setting arbitrarily large version numbers



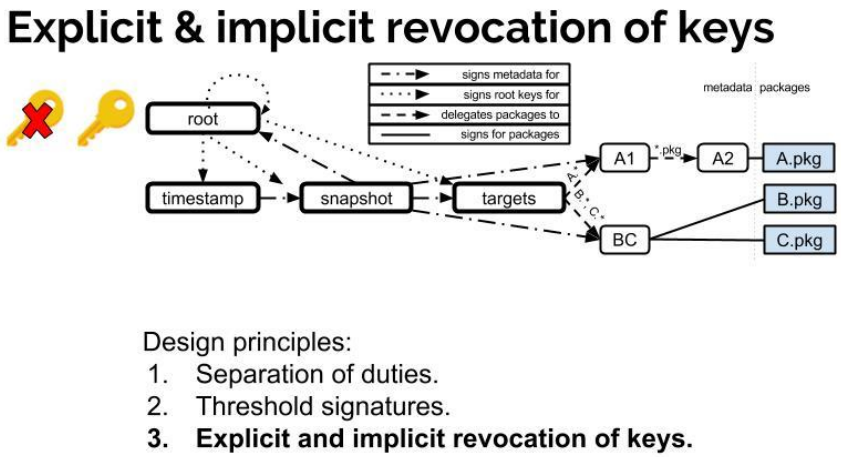
Security analysis: fast-forward attacks

- Increase version numbers to MAXINT
- Makes recovery impossible



Recovering from fast-forward attacks

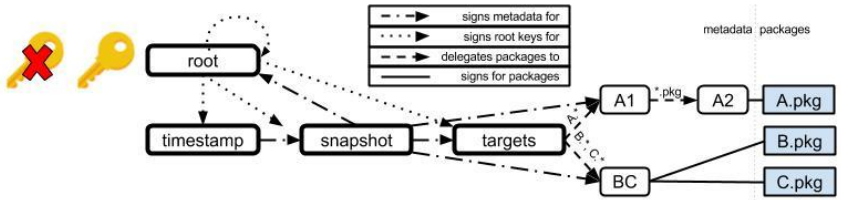
- Revoke and replace keys used to sign snapshot metadata
- Discard and replace snapshot metadata



Recovering from fast-forward attacks

System / Cost	Common case	Rare case
Diplomat	More expensive	Less complicated
Mercury	Less expensive	More complicated

Explicit & implicit revocation of keys



Design principles:

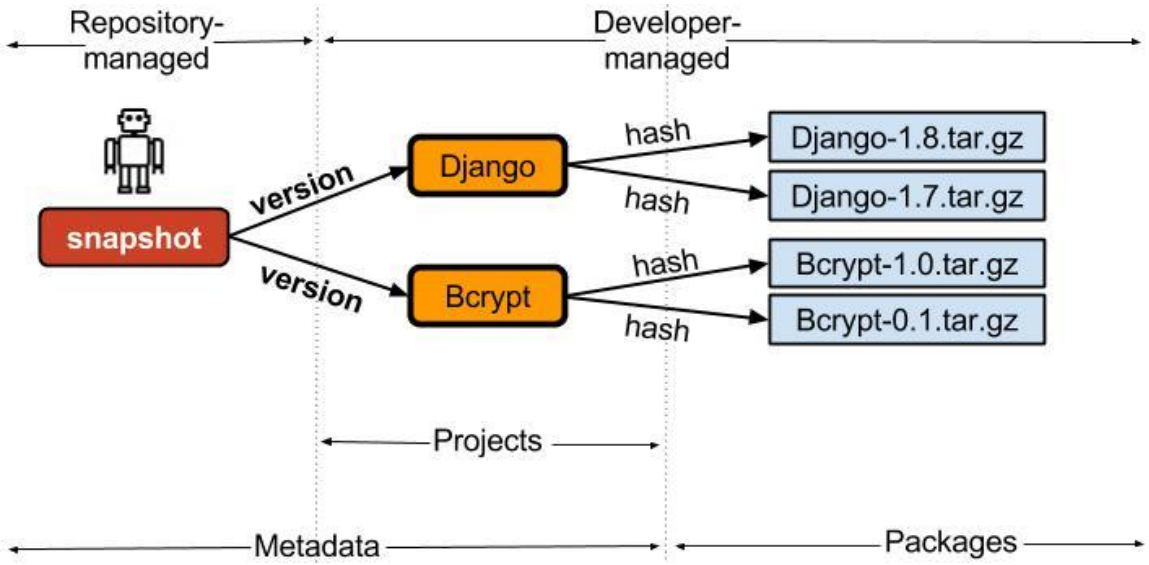
1. Separation of duties.
2. Threshold signatures.
3. **Explicit and implicit revocation of keys.**

32

Persistent Mirror + Developer Compromise

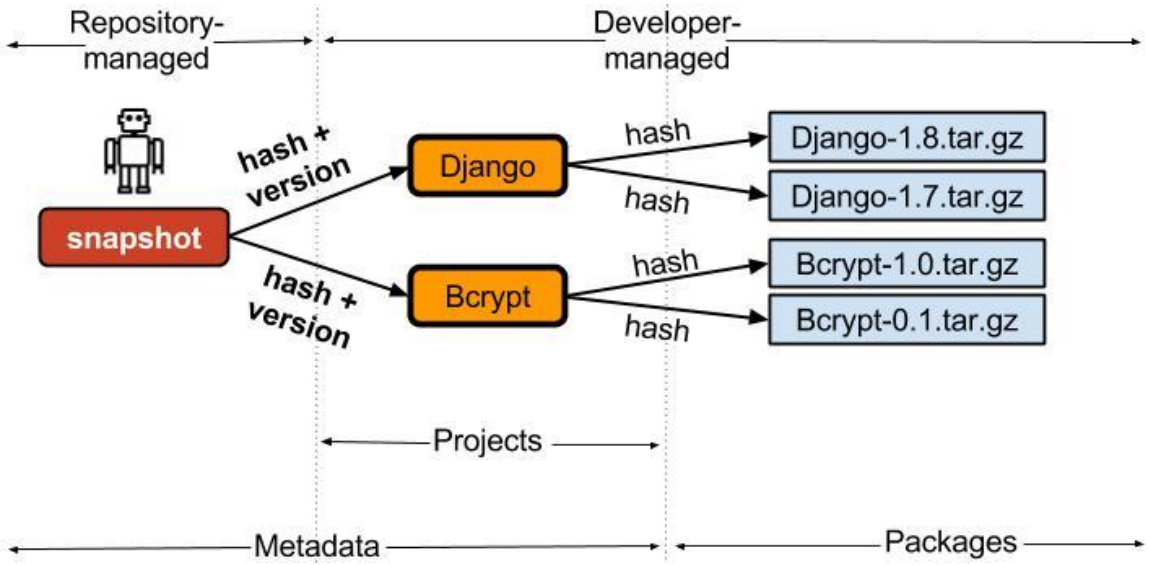
Protection against malicious mirrors

- Malicious mirrors in powerful nation-states
- Cannot sign new snapshot metadata, but can sign some new project metadata
- Can switch project metadata w/o getting caught



Protection against malicious mirrors

- Mercury-hash: hash + version number in snapshot metadata
- Malicious mirrors cannot switch project metadata w/o getting caught
- Higher b/w cost



Evaluation of bandwidth costs

Experimental setup

- Security systems
  - **GPG / RSA** — insecure!
  - **Mercury**
  - **Mercury-hash**
  - **Diplomat-version**: projects sign detached version numbers
  - **Diplomat**
- An anonymized log of a month of package downloads from PyPI

Bandwidth overhead by security system

	Initial cost	Recurring cost	Recovery cost
GPG/RSA	0.6KB (0.1%)	0.02KB (0.003%)	N/A
Mercury	319KB (48%)	23KB (3.5%)	320KB (48%)
Mercury-hash	2.4MB (360%)	156KB (24%)	2.4MB (361%)
Diplomat-version	7.6MB (1,152%)	1.1MB (171%)	2.3MB (350%)
Diplomat	20MB (3,092%)	2.1MB (320%)	2.3MB (350%)

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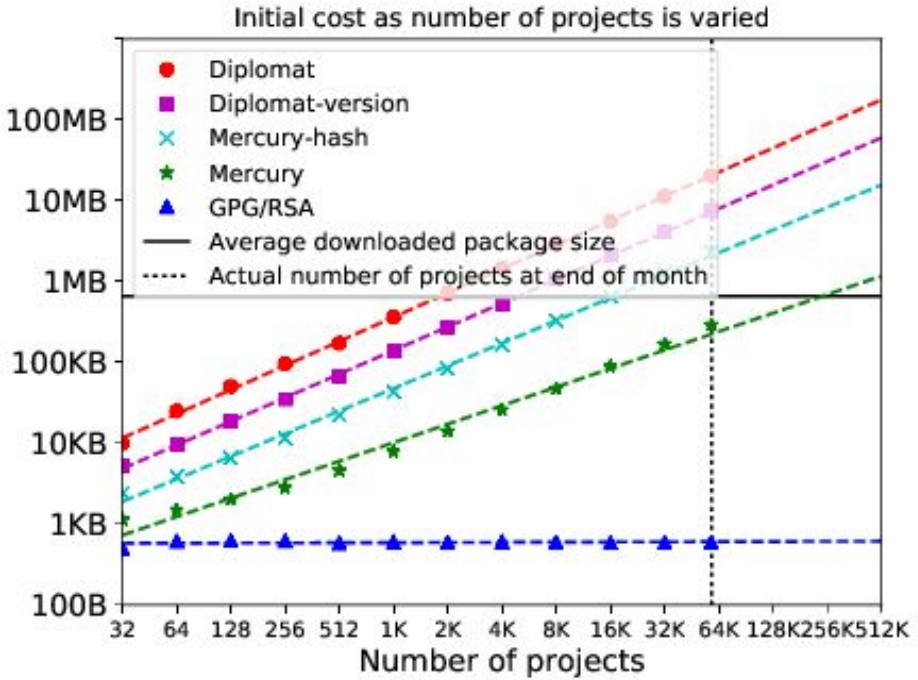
Diplomat	20MB (3,092%)	2.1MB (320%)	2.3MB (350%)

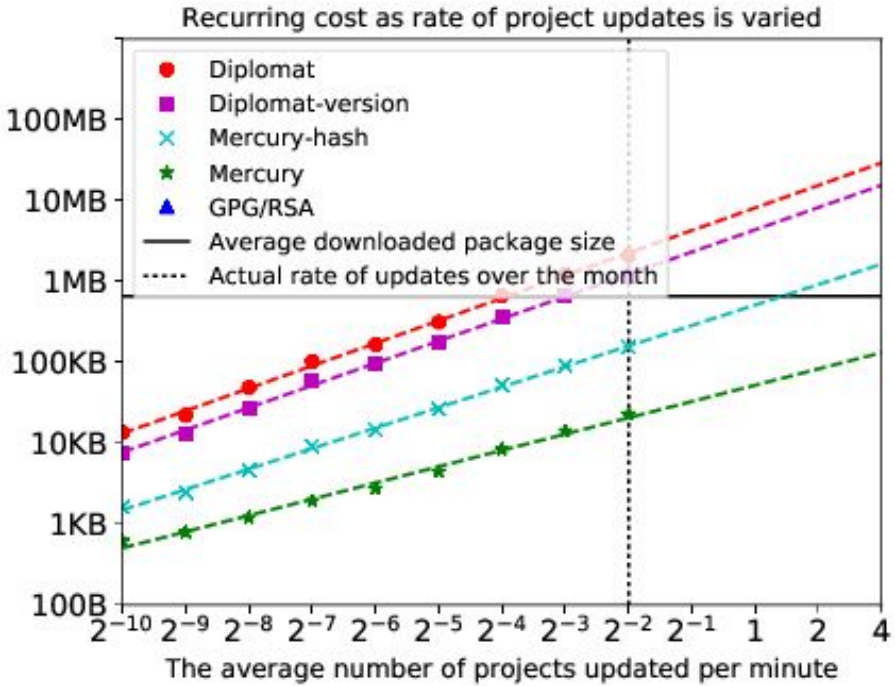
Bandwidth overhead by security system

	Total initial costs of new users
Packages	2.2TB
GPG/RSA	0.005TB (0.2%)
Mercury	0.4TB (17%)
Mercury-hash	2.8TB (125%)
Diplomat-version	8.9TB (396%)
Diplomat	23.9TB (1,067%)

Bandwidth vs. number of projects



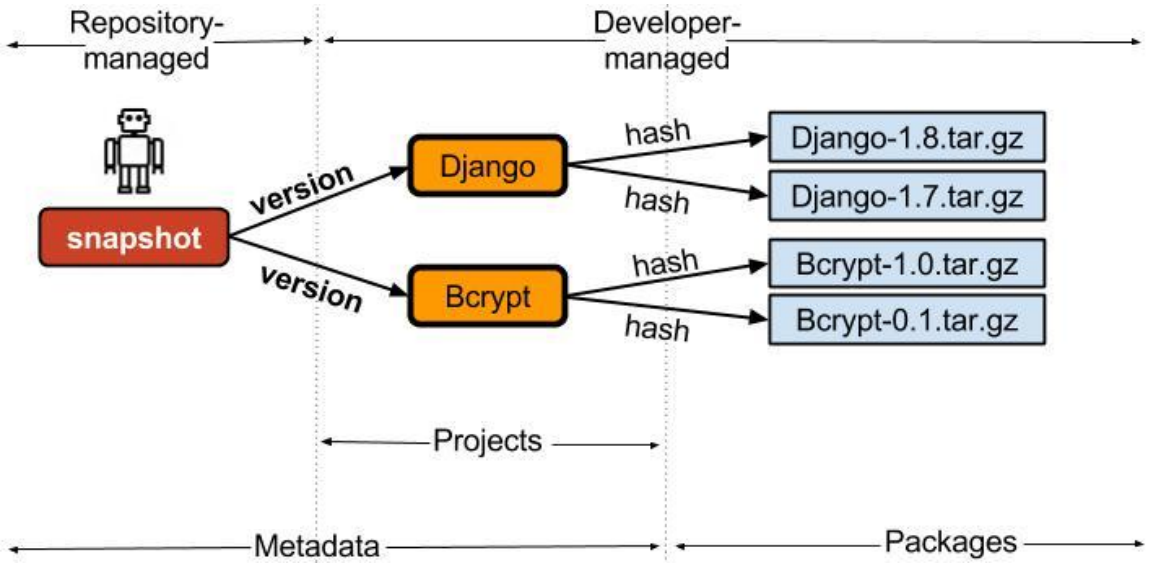
Bandwidth vs. rate of project updates



Conclusions

Takeaways

- Safely shift trust from developers to repository
- Common case less expensive, but rare case slightly more complicated
- Practical use uncovers problems



Integrations & deployments

Flynn

Q & A

Thanks! Questions?

https://theupdateframework.github.io/

https://uptane.github.io/

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