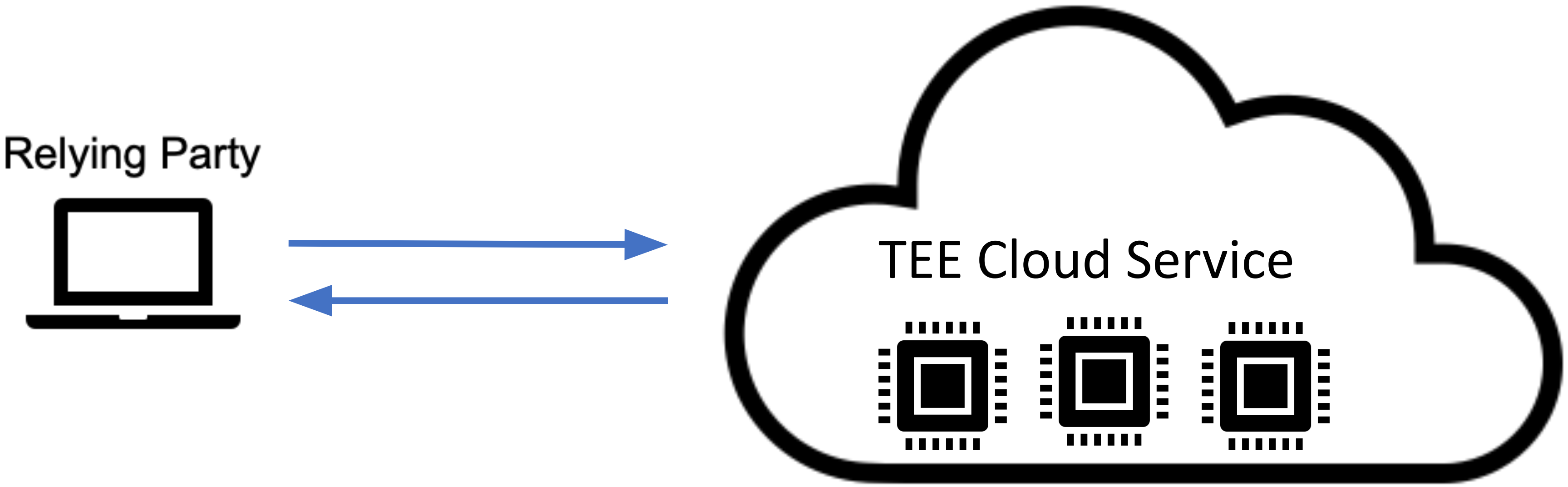
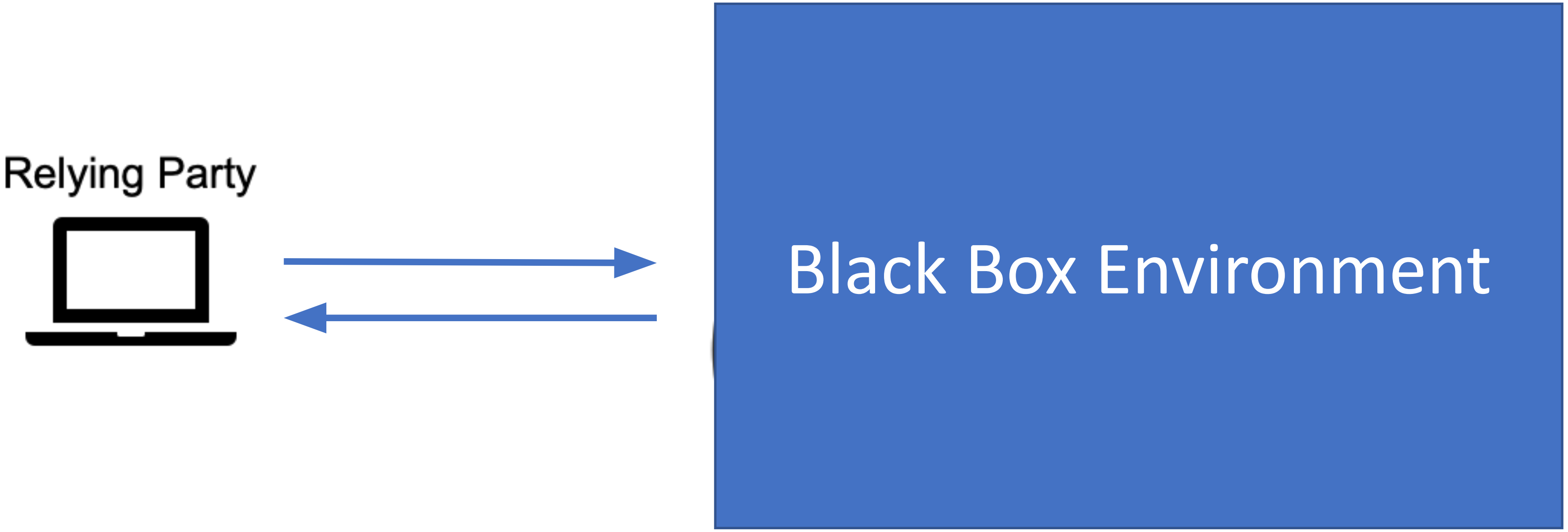
Trustless Attestation Verification in Distributed Confidential Computing

Donghang Lu
Research Scientist @TikTok

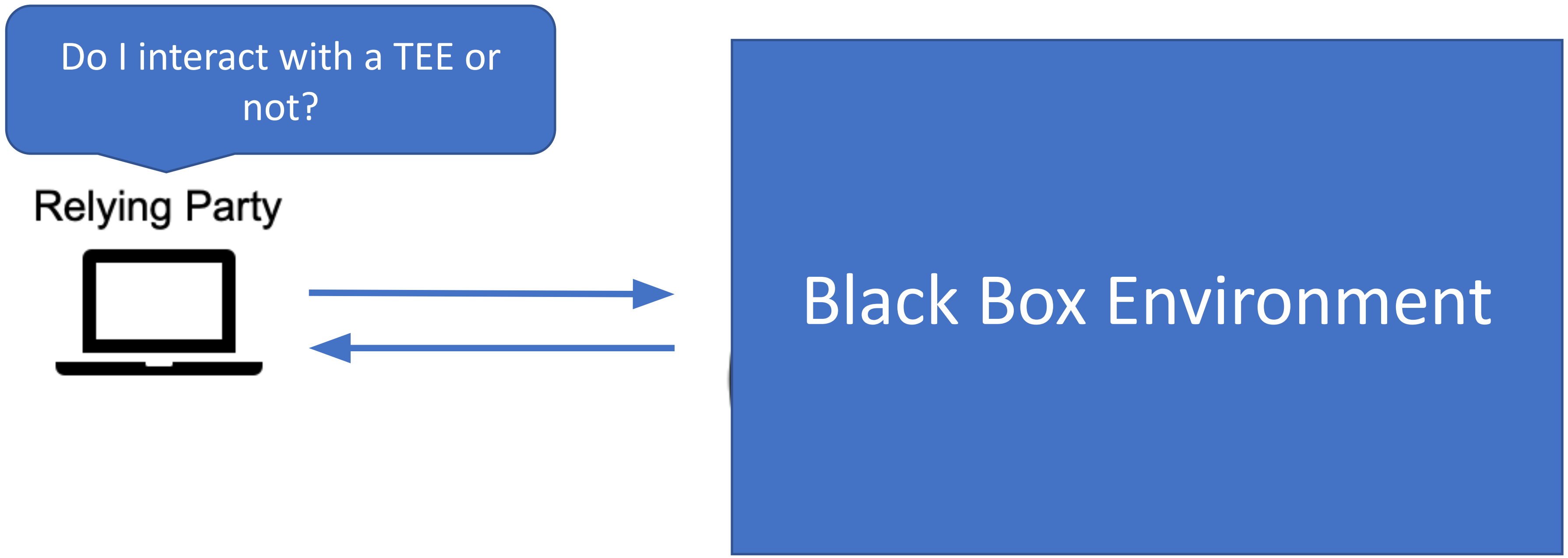
Our Scenario: TEE in a cloud service



Relying Party has no visibility inside the cloud



TEE Cluster needs to prove that the relying party is interacting with a legit and secure TEE



Attestation enables TEEs to self-prove

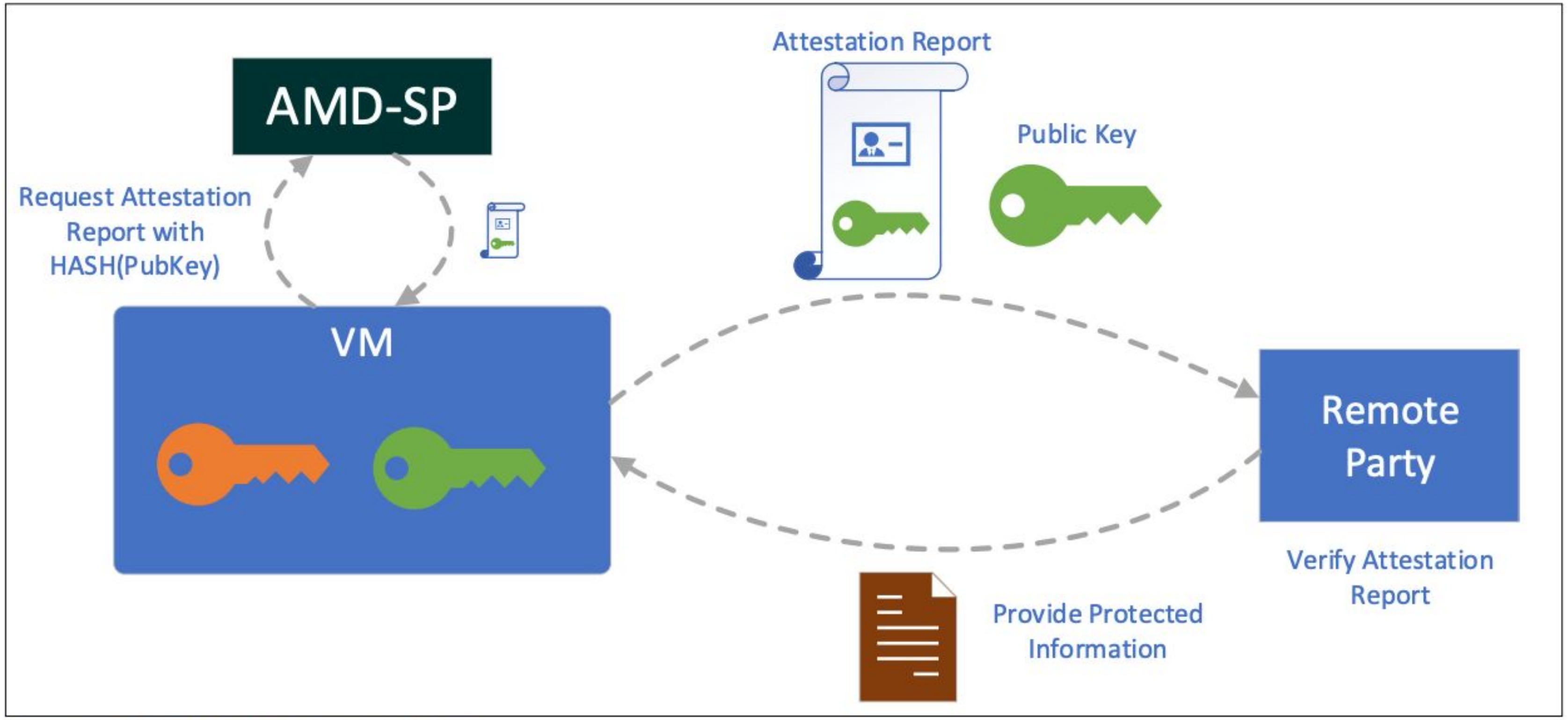
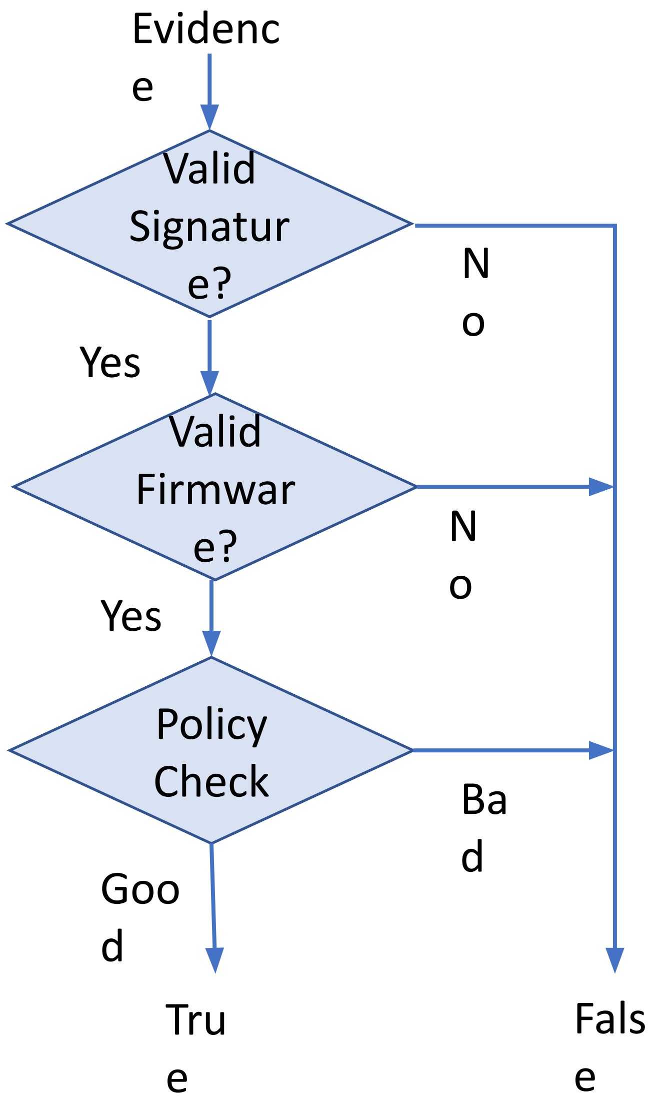


FIGURE 10: SEV-SNP ATTESTATION

Figure Source: AMD SEV-SNP: Strengthening VM Isolation with Integrity Protection and Mo

Attestation enables TEEs to prove their identity

- Attestation Procedure
  - Whether the certificate of TEE is signed by legit hardware vendor?
  - Whether the report is properly signed?
  - The firmware version / Microcode version
  - Guest image/ Software stack
  - …

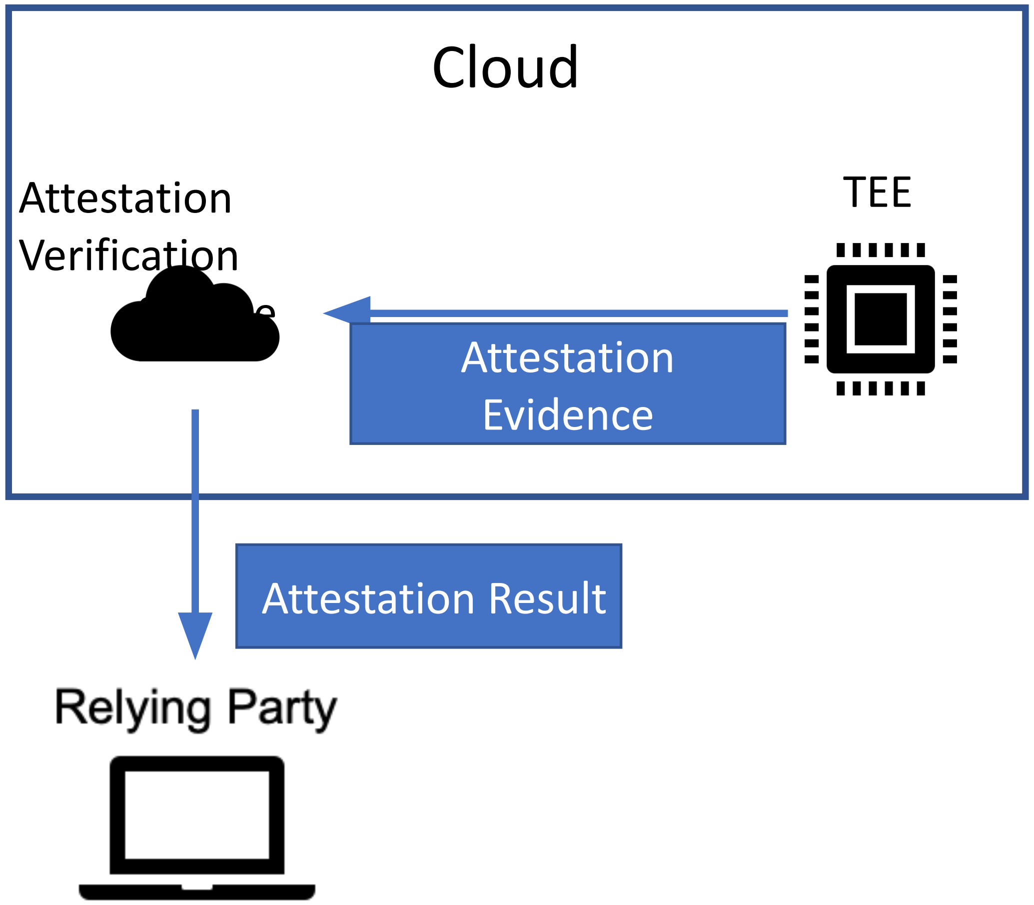


Attestation in Cloud Setting

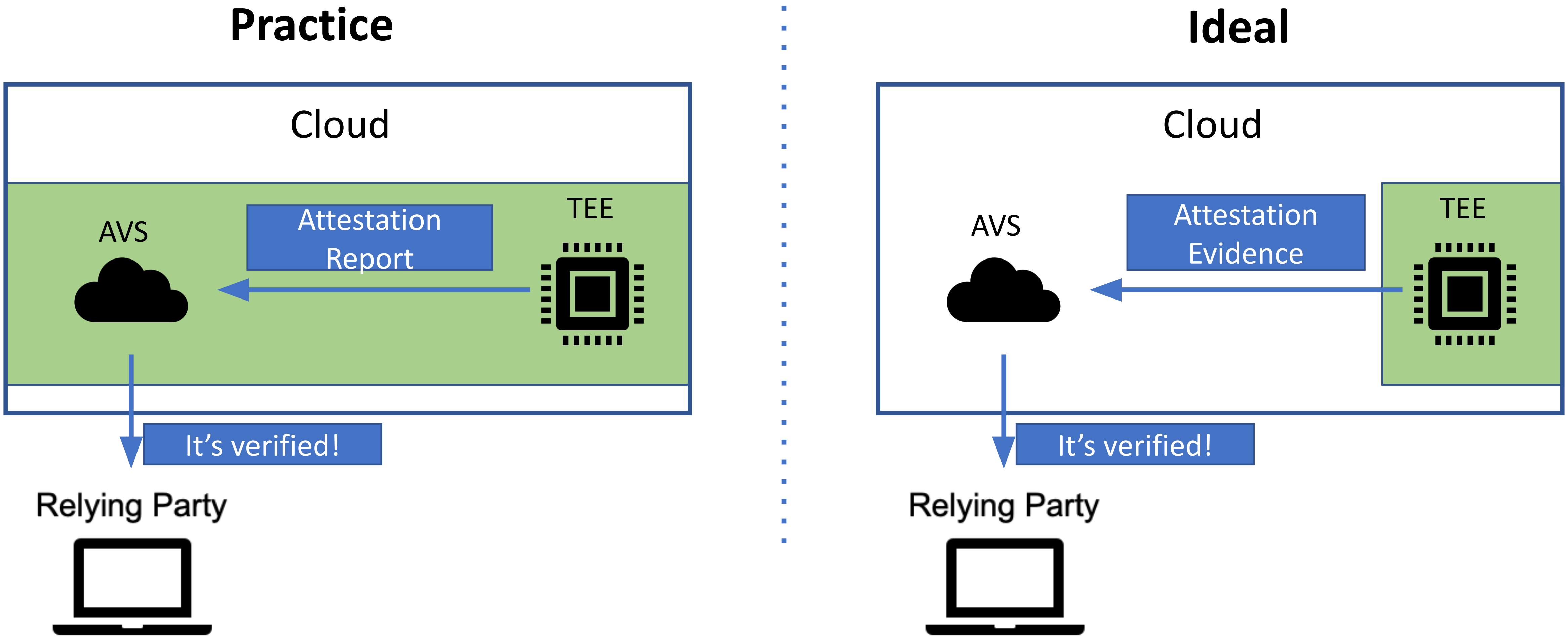
- Option 1: Relying parties can verify the attestation reports by themselves
  - Relying parties may have to track latest reference values.
  - Relying parties may have to do additional computation.
  - The trust boundary remains the same.

Attestation in Cloud: Attestation Verification Service (AVS)

- The cloud Service **provides remote attestation verification service (AVS)**
  - Easier for the cloud provider to manage reference values.
  - The remote attestation service can be easier to integrate with other cloud functionalities (authentication, issuing tokens, etc.)
  - However, the attestation verification service has to be trusted!

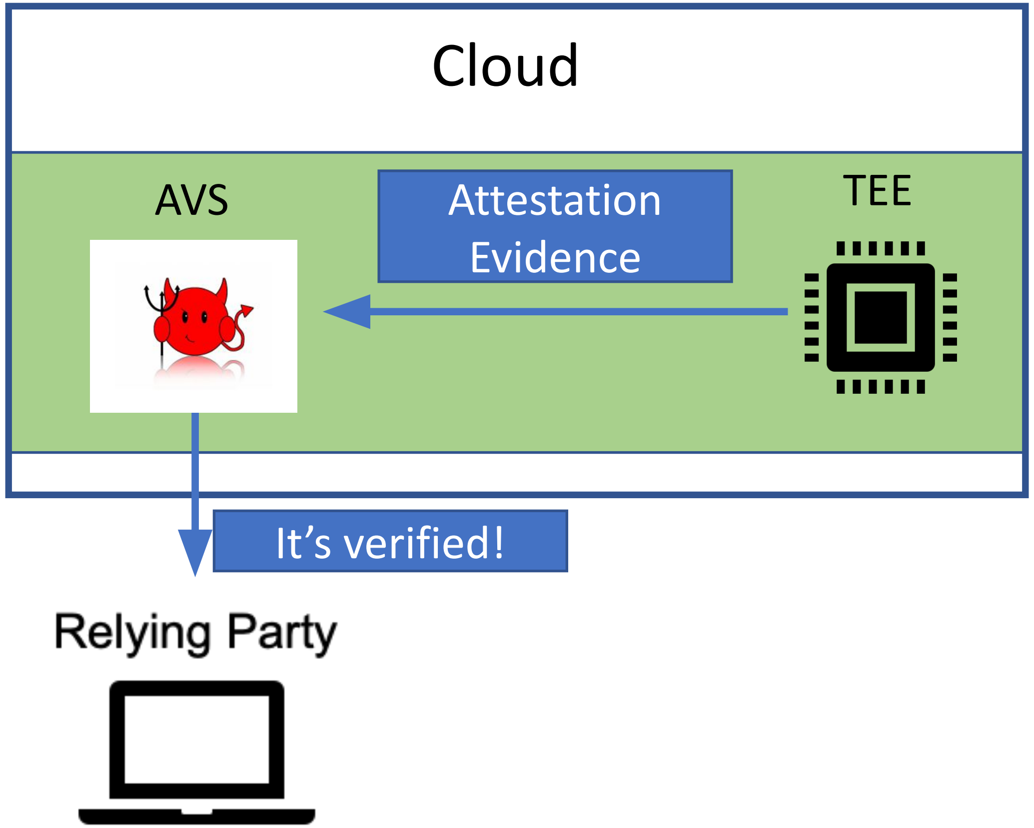


Why current attestation verification services are not perfect: Trust boundary is expanded.



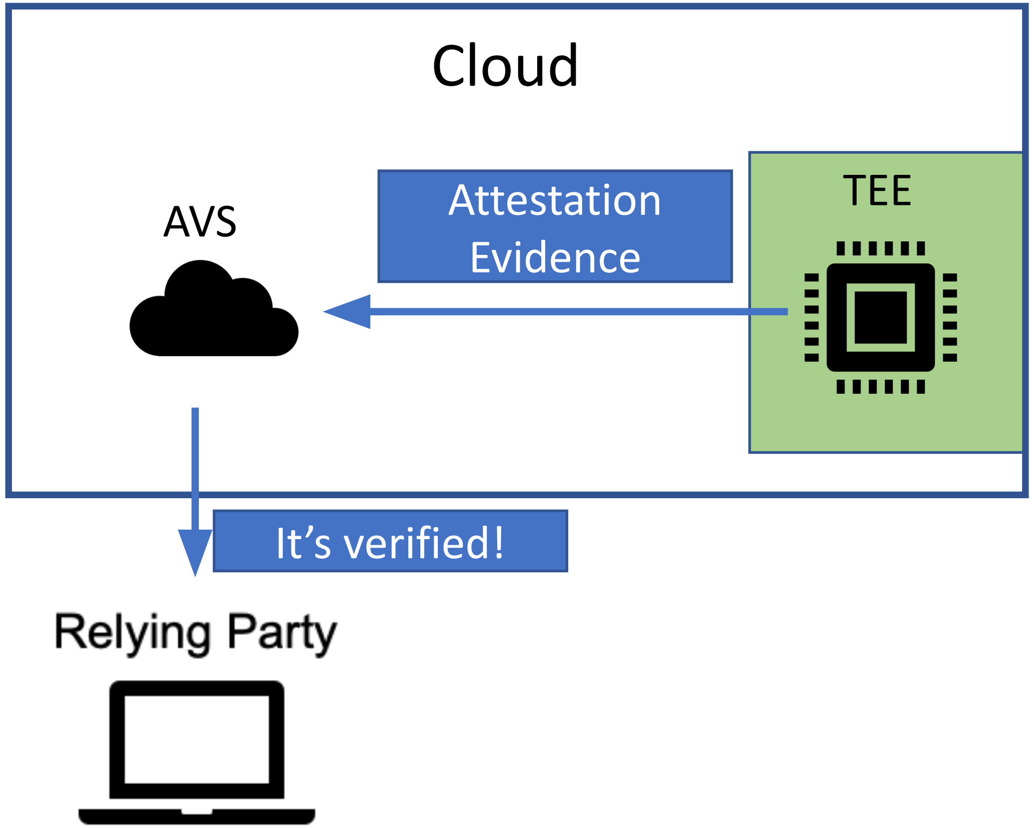
Although the cloud service provider are trustworthy most of the time…

- What if the attestation verification service is malfunctioning or buggy?
- What if the attacker launches attack on the remote attestation itself instead of TEE?
- Larger trust boundary means larger risks.



Can we make AVS trustless?

- Attestation verification service can prove to relying parties that it is following the correct attestation logic.
- Cryptographic Proof.
- Instead of trusting attestation service, you can trust math.



Zero Knowledge Proofs (ZKP) provides proof of computation without trusting third parties

- ZKP allows one party (the prover) to prove to another party (the verifier) that a statement is true without revealing any additional information.
- Examples:
  - prove that you're a citizen of a country, without giving your name or passport number.
  - Prove that your age is over 18, without disclosing your age or your ID card.

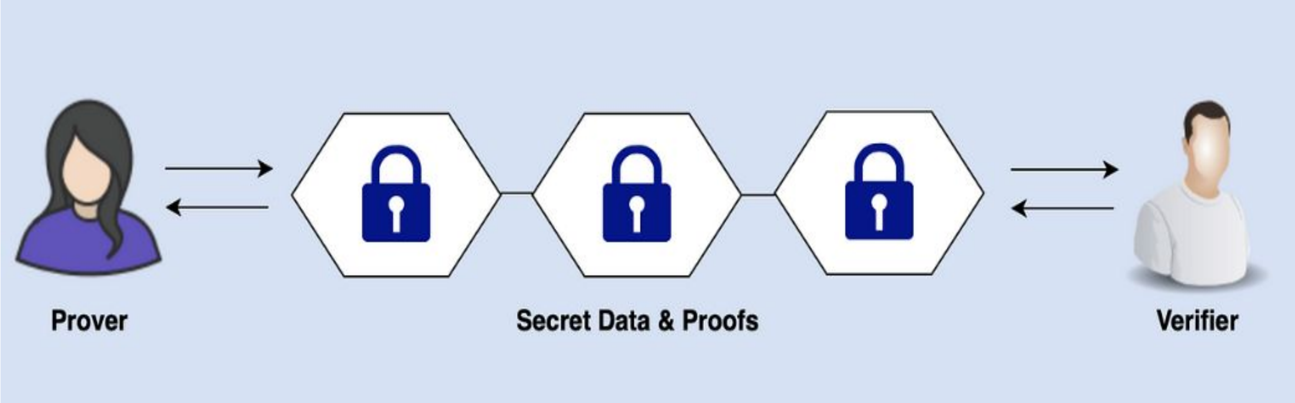


Image Source: Wikipidia

ZKP is efficient for large scale computation

- ZKP becomes efficient enough now to prove large circuits.
- In Blockchain, ZKP is widely used to prove the correctness of computation.
    - E.g., Ethereum uses ZKP to verify off-chain computations.
- ZK-SNARK (Succinct Non-interactive Argument of Knowledge)
    - Fast verification
    - Constant proof size

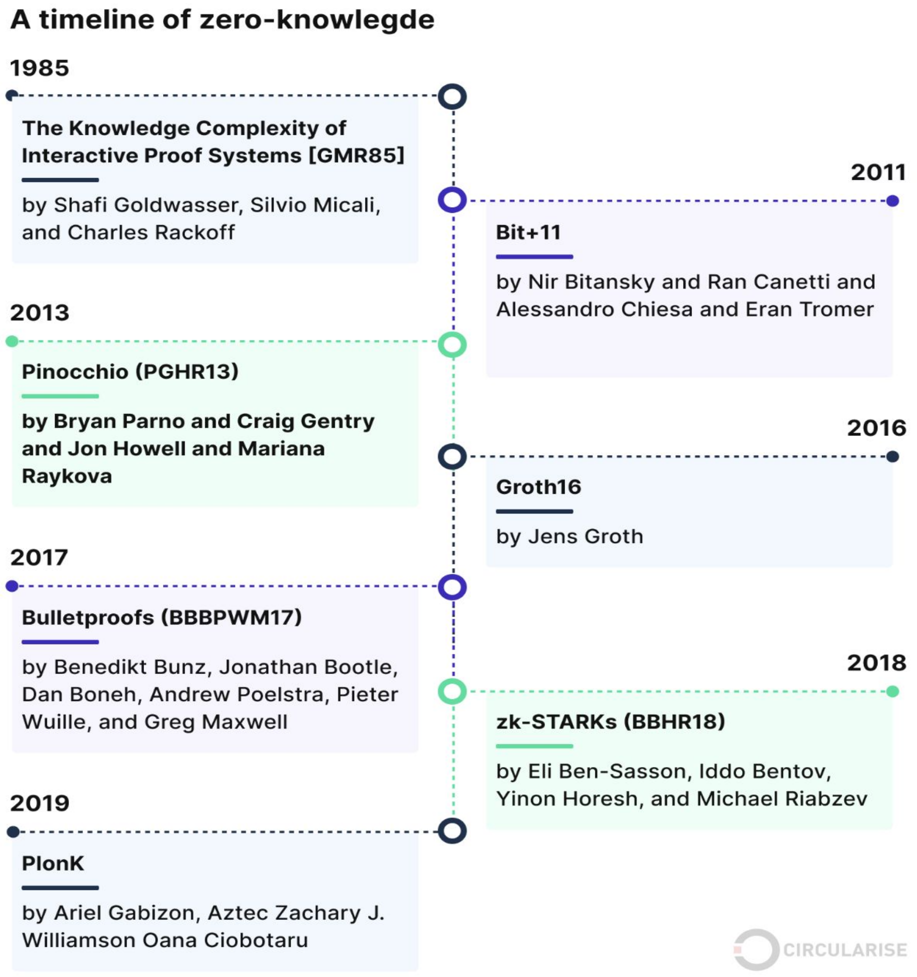
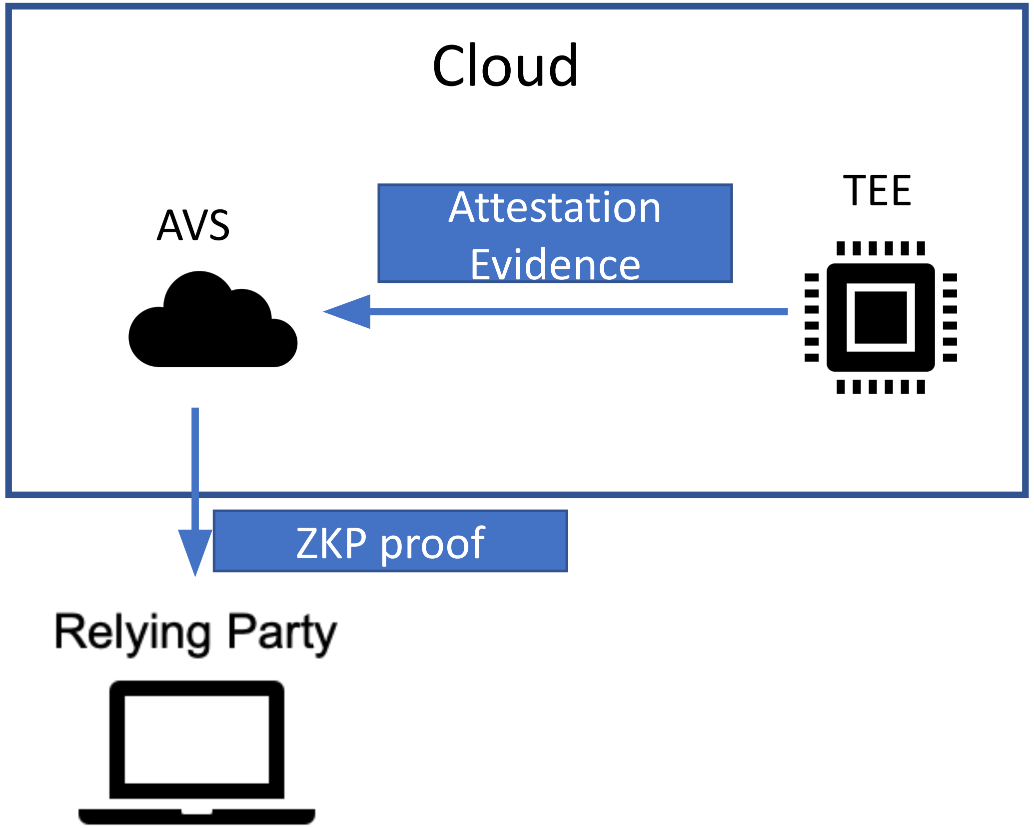


Image Source: circularise

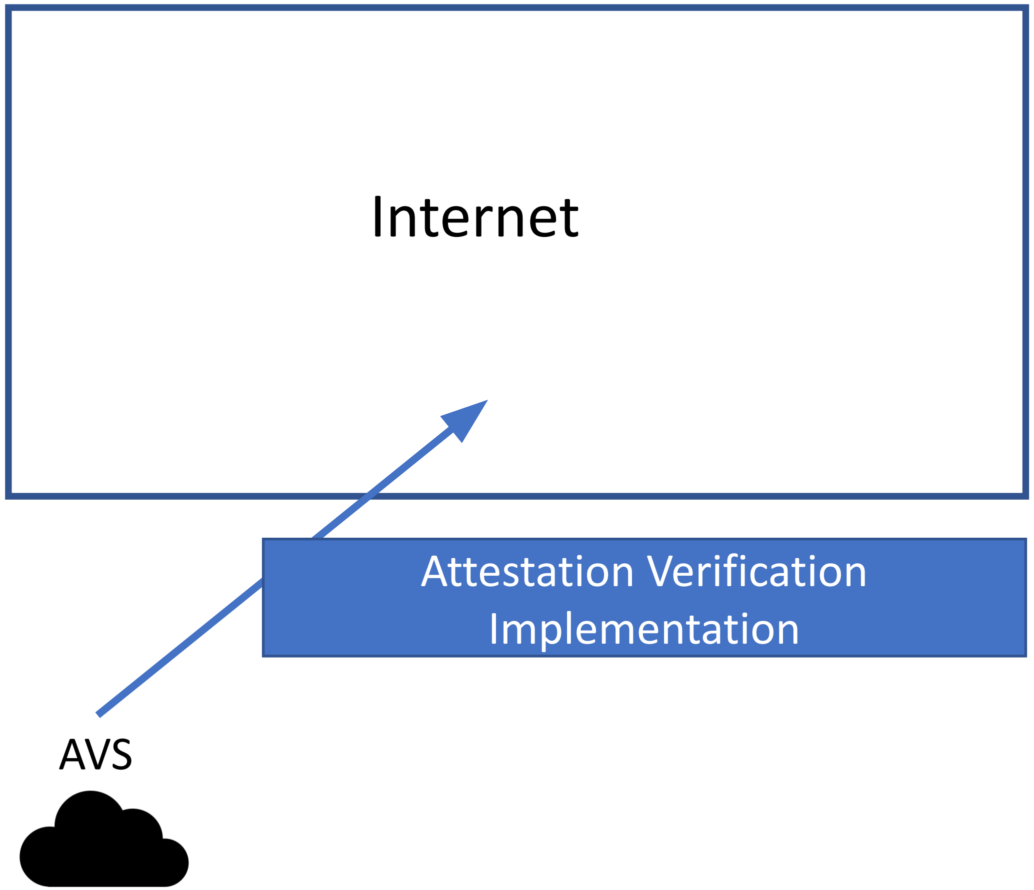
Our solution: embed ZKP into attestation verification

- Ask attestation verification service to generate a ZKP proof, so that anyone can verify that the attestation service honestly executed expected attestation logic.



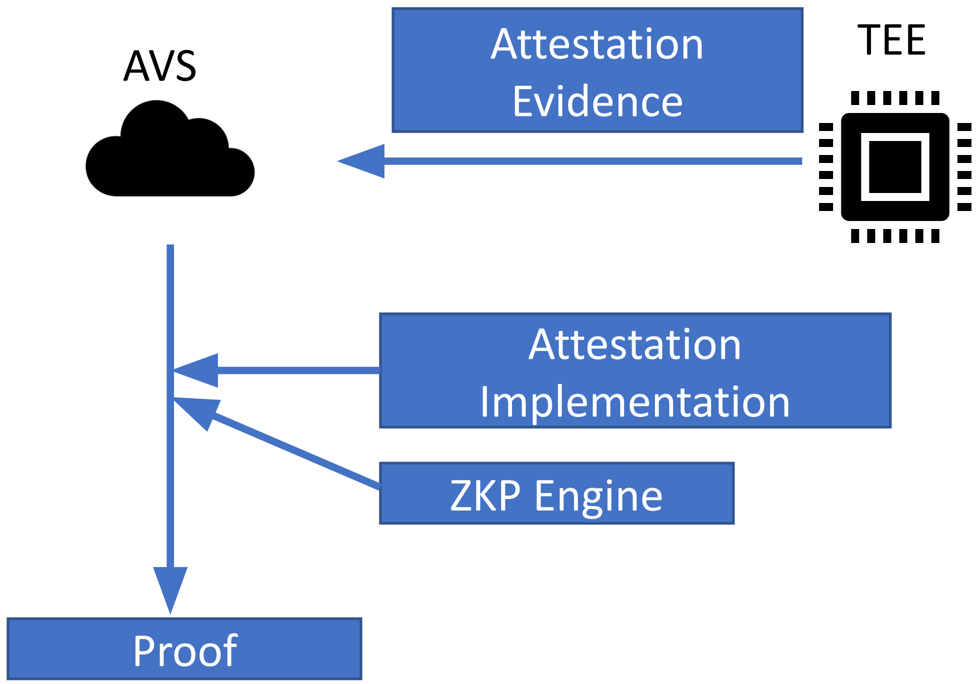
Work Flow: setup

- Attestation verification implementation should be open-sourced and public to everyone.
- Any party can audit, endorse, or challenge it.
- Finally, we have an attestation verification logic that is publicly endorsed.



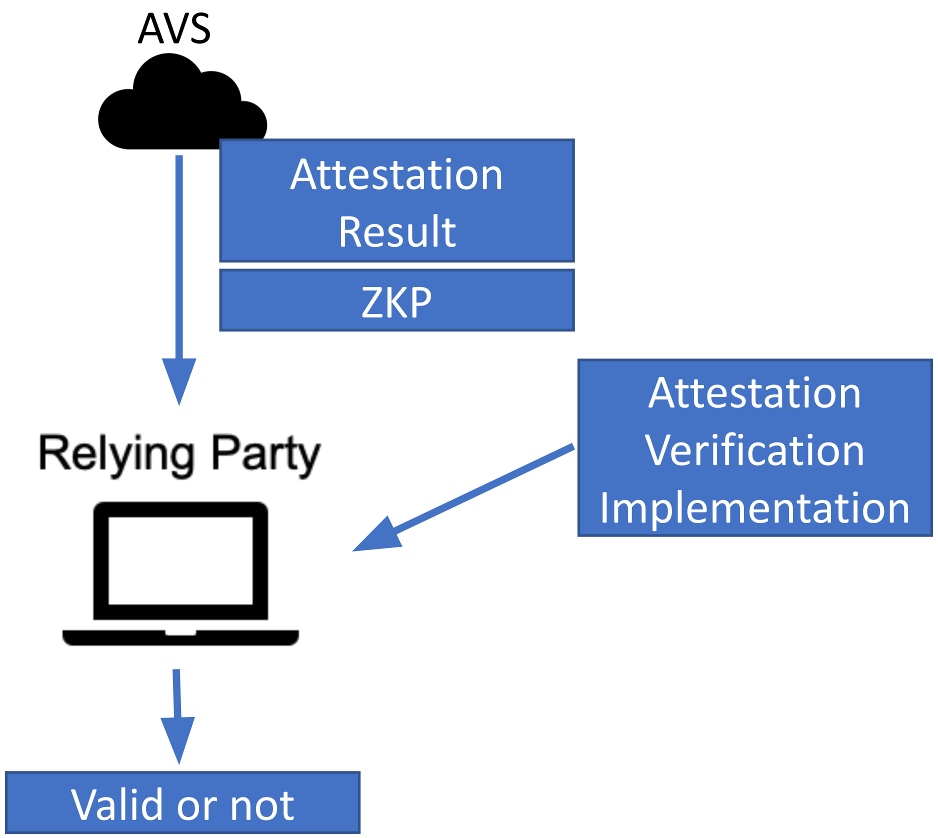
Work Flow: proof of attestation verification

- During attestation verification, AVS proves that the code it runs is consistent with the open-sourced version.



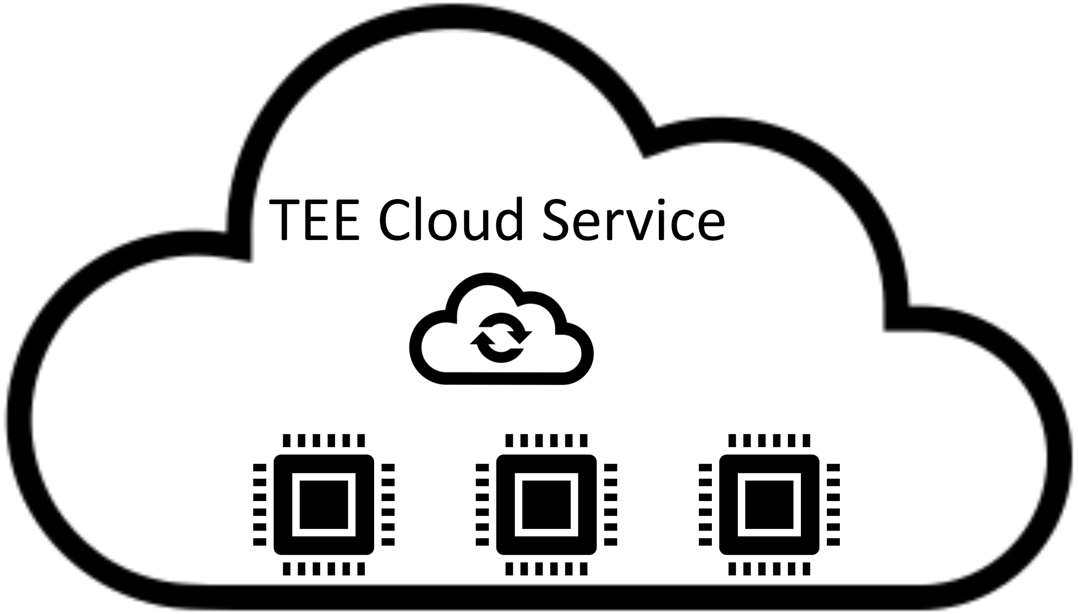
Work Flow: verifying Zero-knowledge Proof

- Relying parties can quickly verify whether the ZKP is valid.



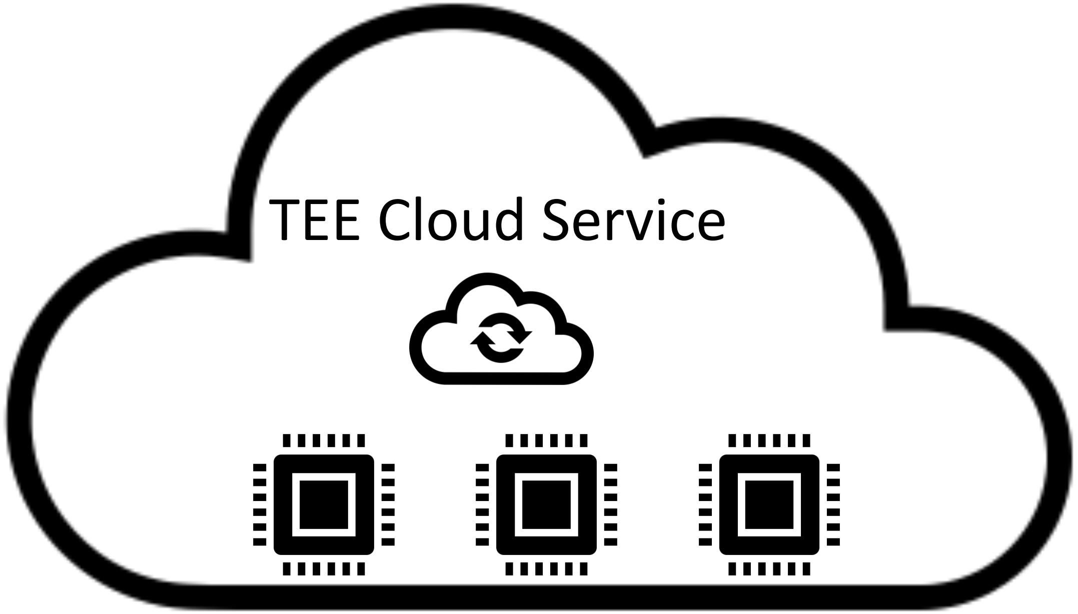
Challenges introduced by distributed confidential computing

- Multiple TEE nodes collaboratively provide services.
- Relying party needs to ensure all of them are legit.
- TEEs require mutual attestation.



Minimizing the efforts of relying party

Relying party still only verifies one proof and ensures that the entire cloud is attested properly.



Proof Aggregation for ZKP: verify everything in one shot

The final proof is valid only if all single proofs and aggregated proofs are valid.

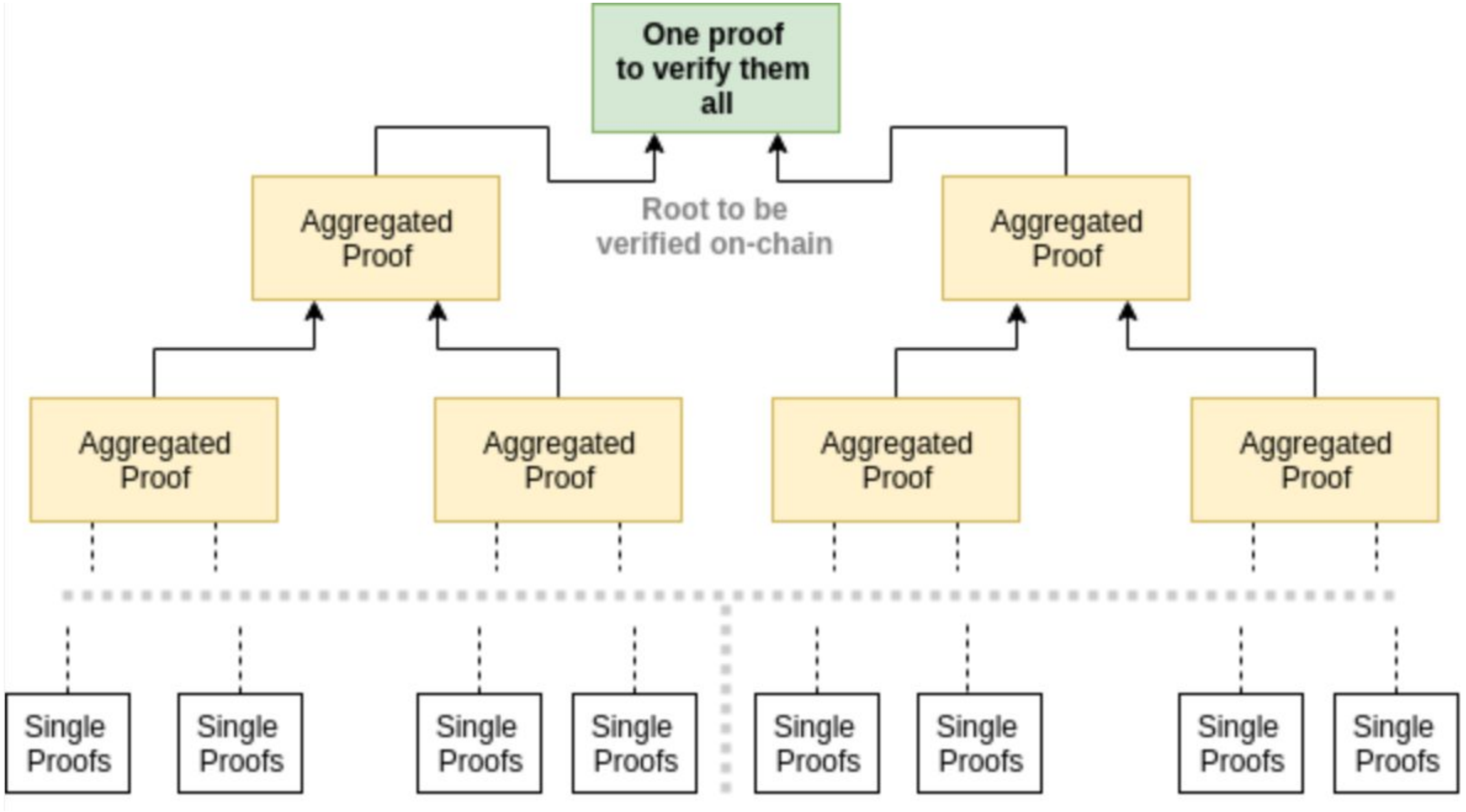
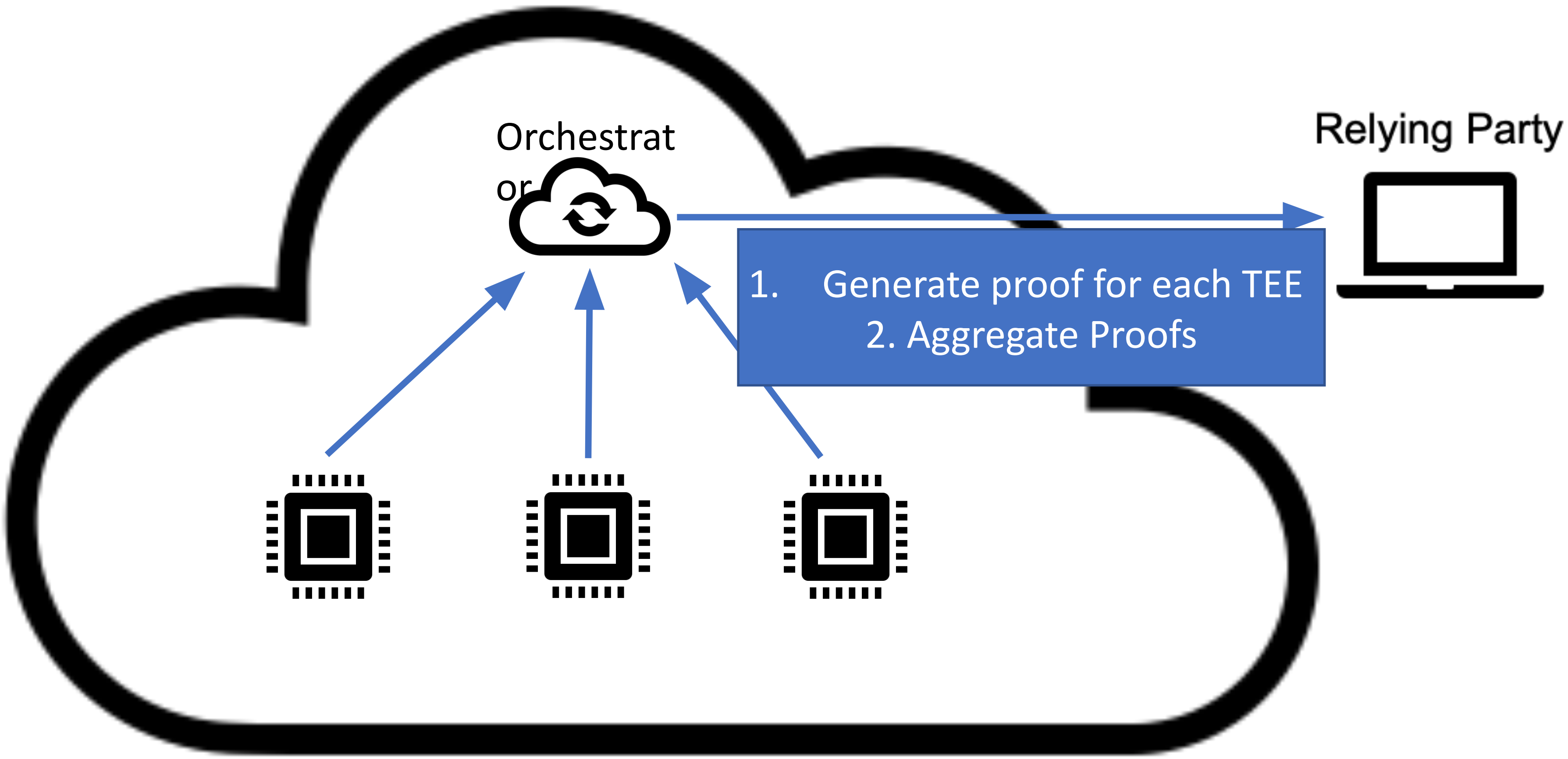
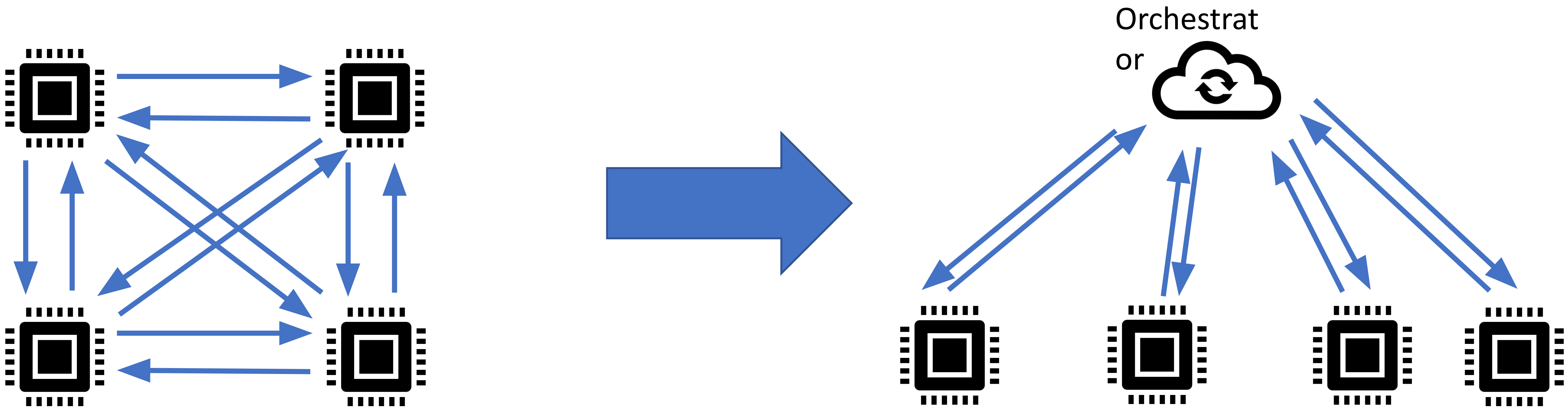


Image Source: https://scryptplatform.medium.com/recursive-zero-knowledge-proofs-27f2d934f953

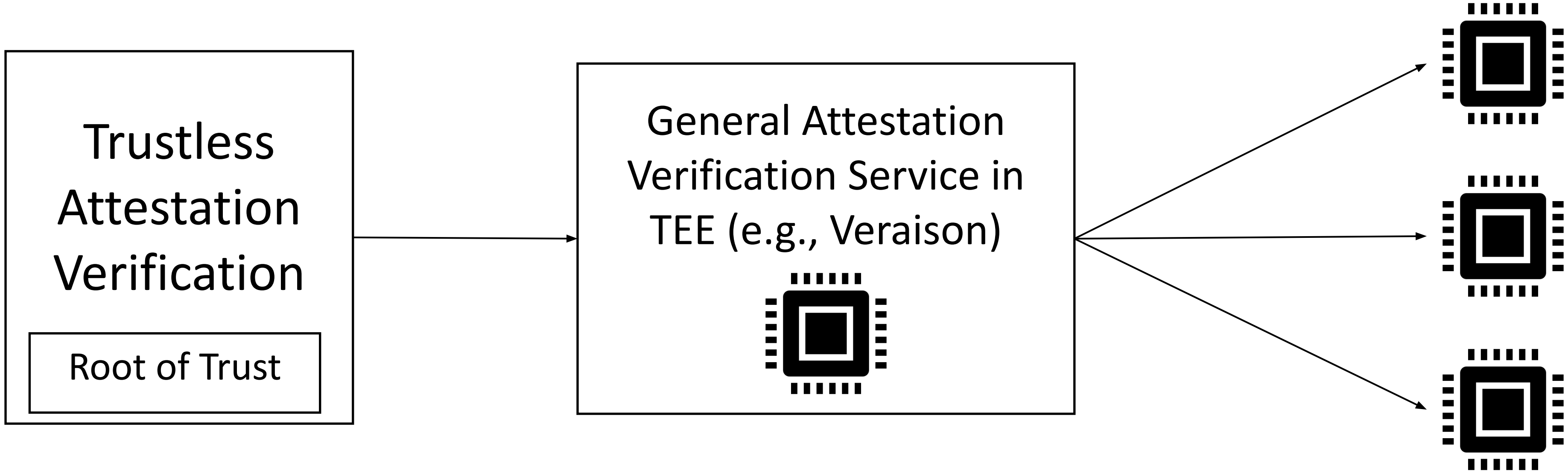
Proof aggregation in distributed TEE system



Mutual attestation becomes easier



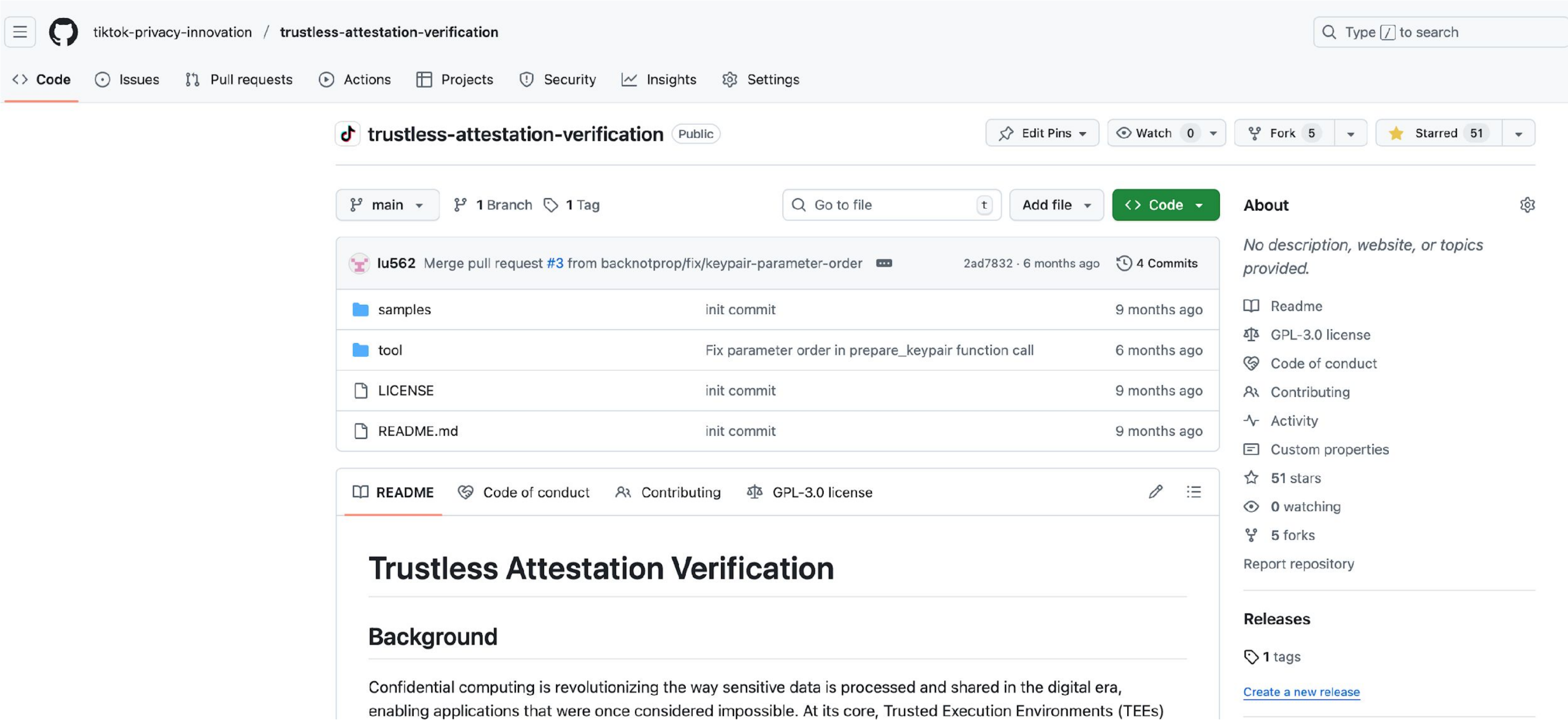
Alternative Setup: Using trustless attestation to bootstrap a TEE-based attestation verification service



Open Source Status

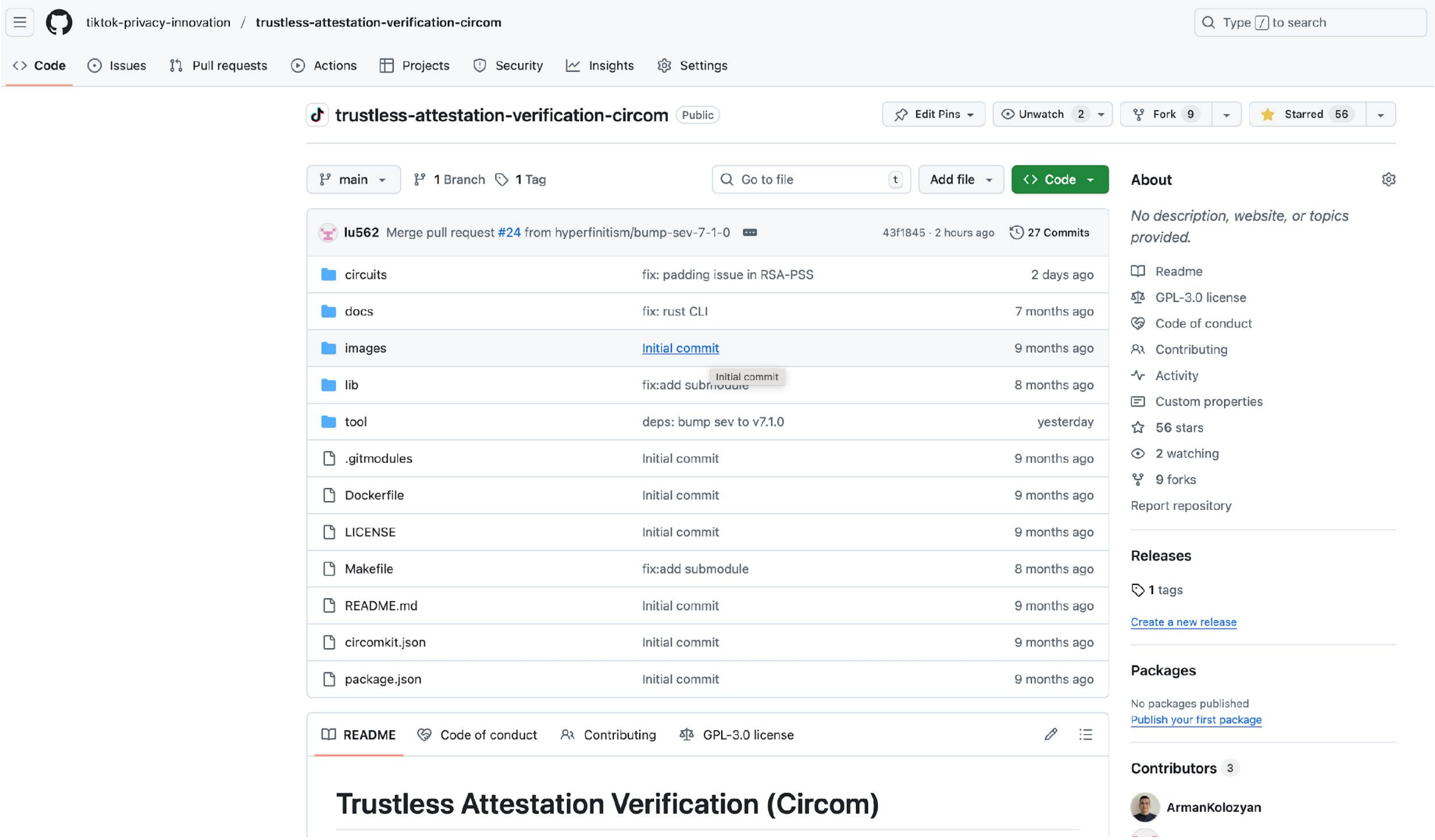
- Implementation with various ZKP backends.
  - Circom
    - Circuit-based ZKP backend supporting Groth16.
    - Pros: Transparent trusted setup, clear security model.
    - Cons: Slow.
  - RiscZero
    - VM-based ZKP backend supporting Rust as high level language.
    - Pros: (1) easy to implement and audit. (2) Fast.
    - Cons: More complicated security model.

We have already open-sourced two repositories.



https://github.com/tiktok-privacy-innovation/trustless-attestation-verification

We have already open-sourced two repositories.



https://github.com/tiktok-privacy-innovation/trustless-attestation-verification-circom

We have already open-sourced two repositories.

Circom Implementation

- Groth16 proof (zk-SNARK) for AMD-SEV-SNP attestation verification.
- User-friendly CLI based on Makefile.

==>circom
CIRCUIT COMPILER

Steps

0. Pull and initiate submodules

This command will pull all the required submodules and set them up.

```
make prepare
```

1. Launch Trusted Setup

Run the following command to initiate the trusted setup:

```
make trusted_setup
```

This generates a .ptau file containing the common reference string required by ZK-SNARK. Please note that this process can be time-consuming (approximately 1.5 hours based on our tests).

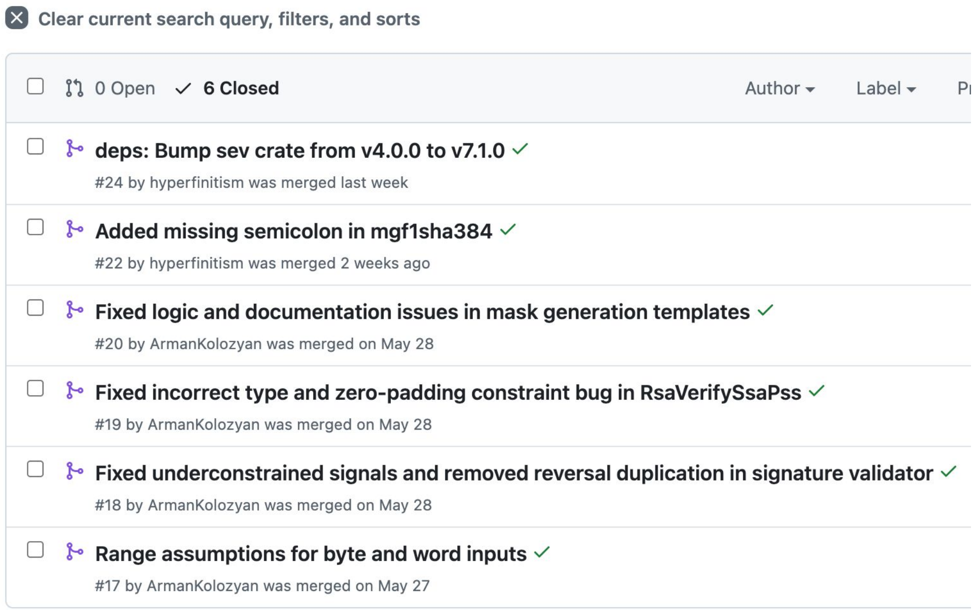
2. Compile Circuits

Next, compile the circuits:

```
make compile_circuits
```

We got support from the community!

- Connected with multiple ZKP companies.
- Independent community contributors have opened 20+ issues and submitted 6 pull requests.
- We are also testing the deployment in the internal use cases.
- It’s still early, but the momentum is solid.



Timeline

2025/10	2026 Q1	2026 Q2	2026 Q3
Open Source RiscZero Version	Provide Integration Demo	Proof Aggretation Demo	Supporting more TEEs

Thank You!