Auditing IoT Communications with TLS-RaR

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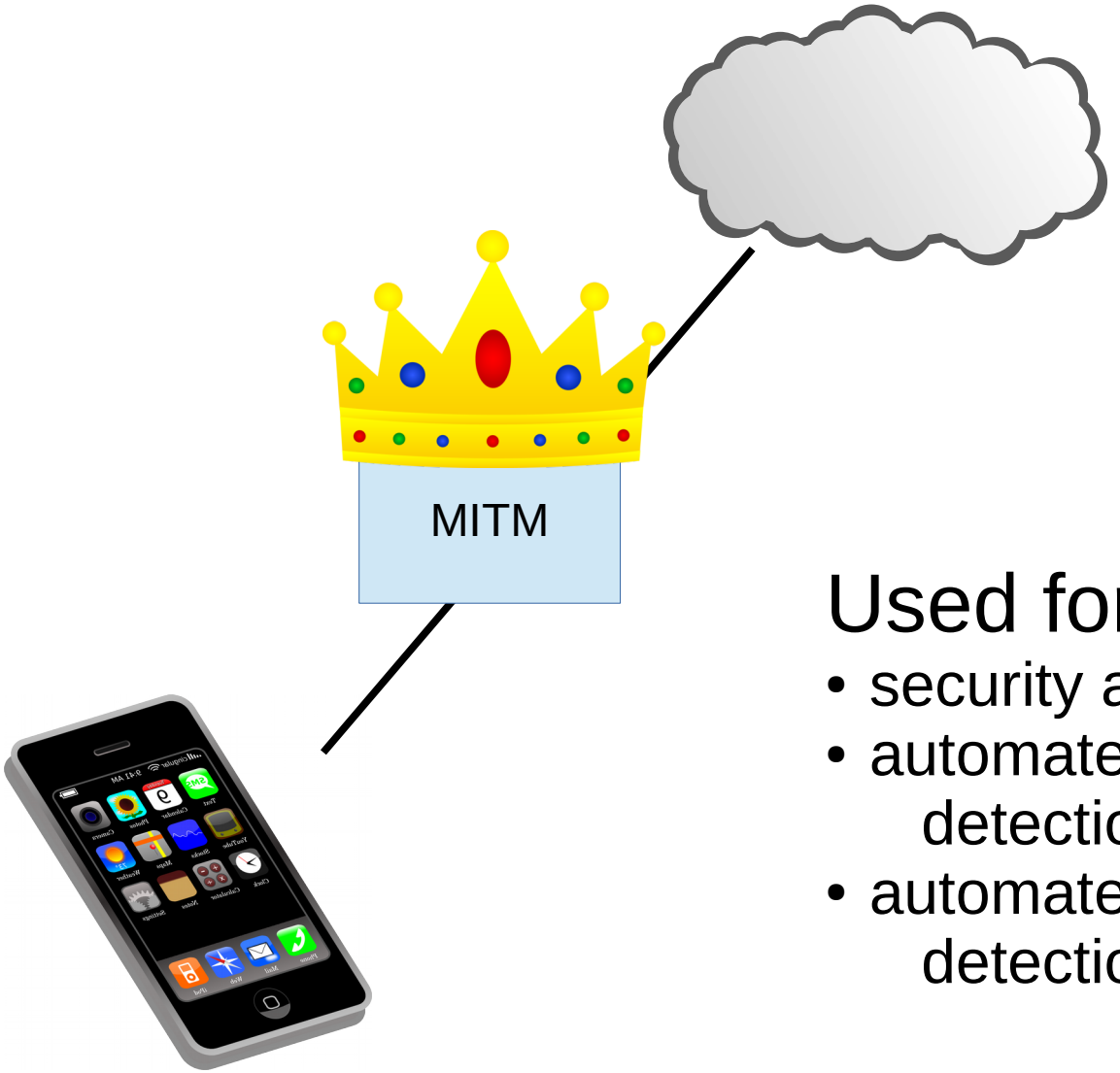
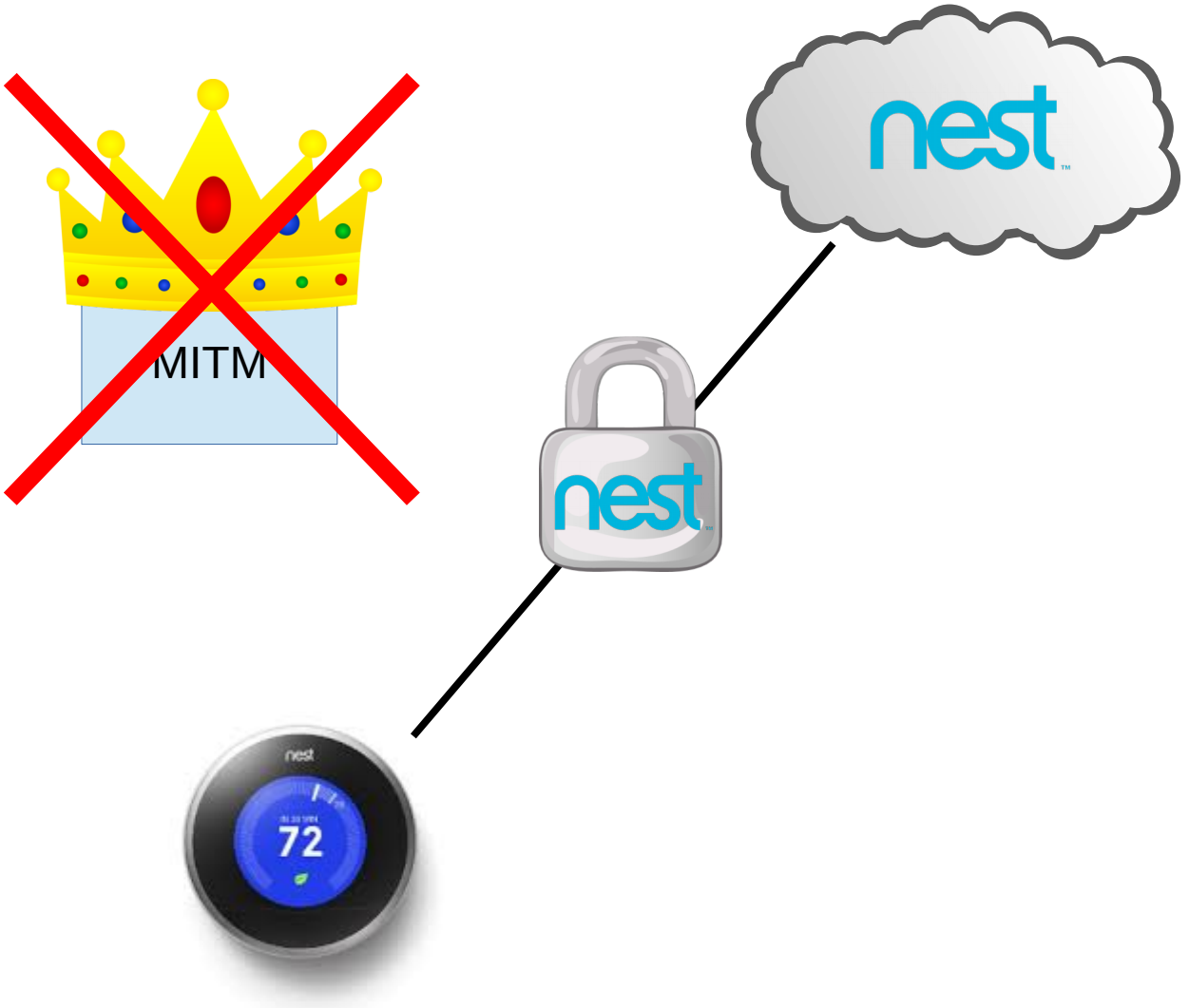
Auditing Standard Devices



Used for:

- security audit
- automated exfiltration detection
- automated intrusion detection

IoT is Different



Troubling Facts

1) We have no way to audit IoT communications, so we must trust companies to do what they claim.

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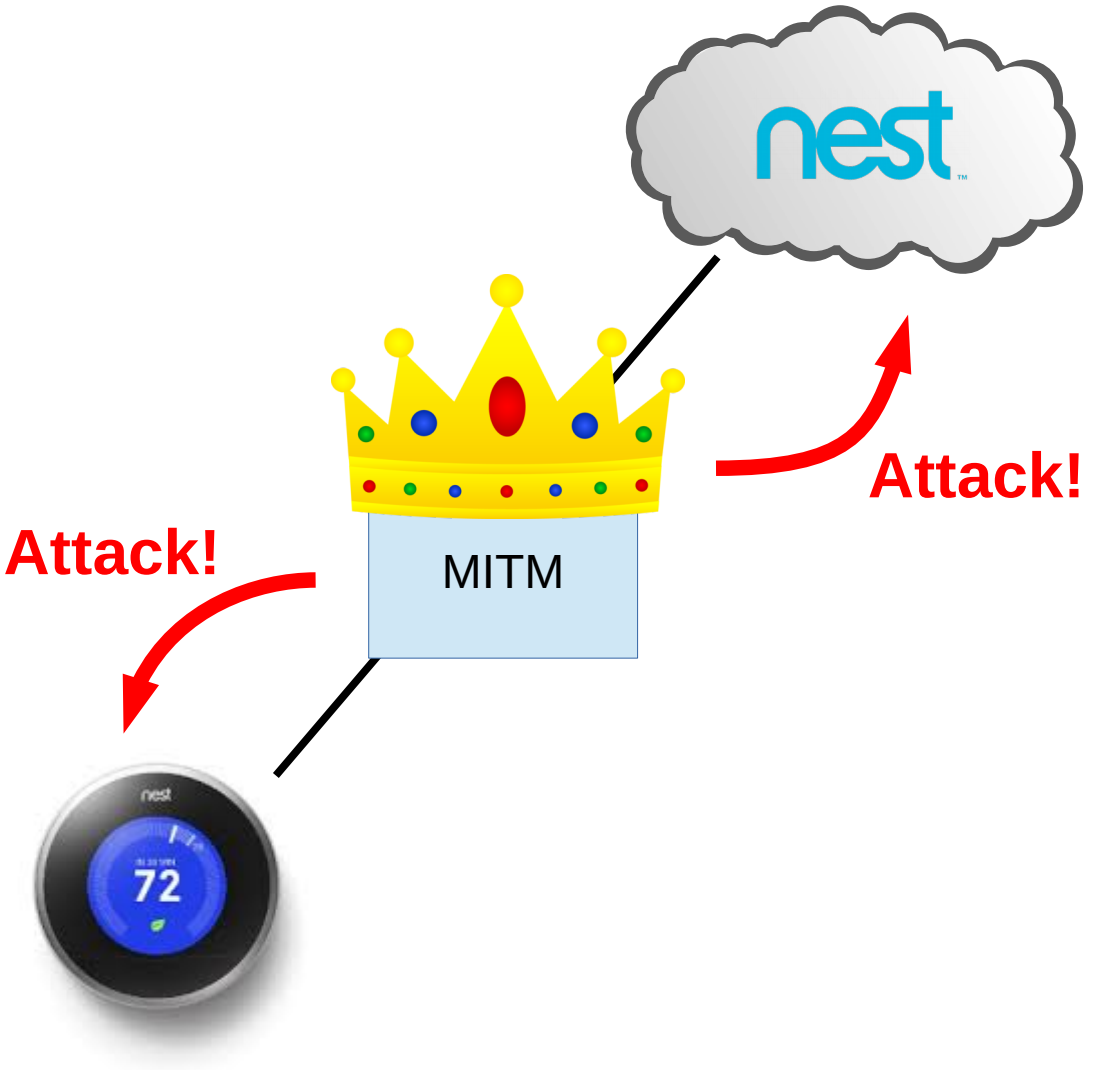
2) Respected Companies Have Misrepresented Their Actions

- Google
  - *“Google's iPhone Tracking, Web Giant, Others Bypassed Apple Browser Settings for Guarding Privacy.” WSJ, Feb. 17, 2012.*
- Volkswagen
  - *“Volkswagen Admits to Cheating on U.S. Emissions Tests,” Bloomberg, Sept. 18, 2015*
- ...

MITM does have problems.



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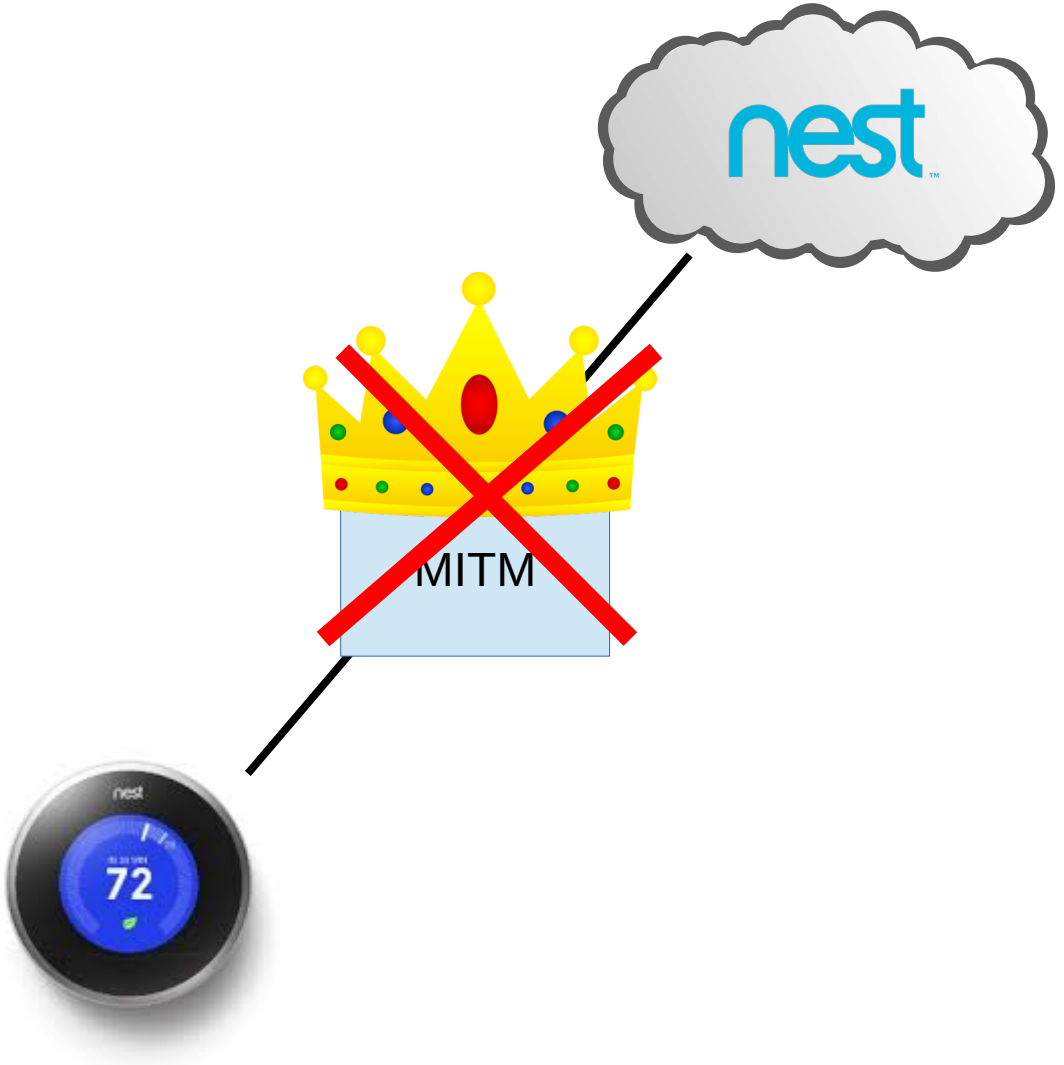


Overview

- Setting
- **Technical Problem**
- Our Scheme: TLS RaR
  - Main Idea
  - Corner Cases
    - Secure Key Release
    - Clean Shutdown
- Evaluation
- Related Work
- Conclusions

Different Parties, Different Concerns

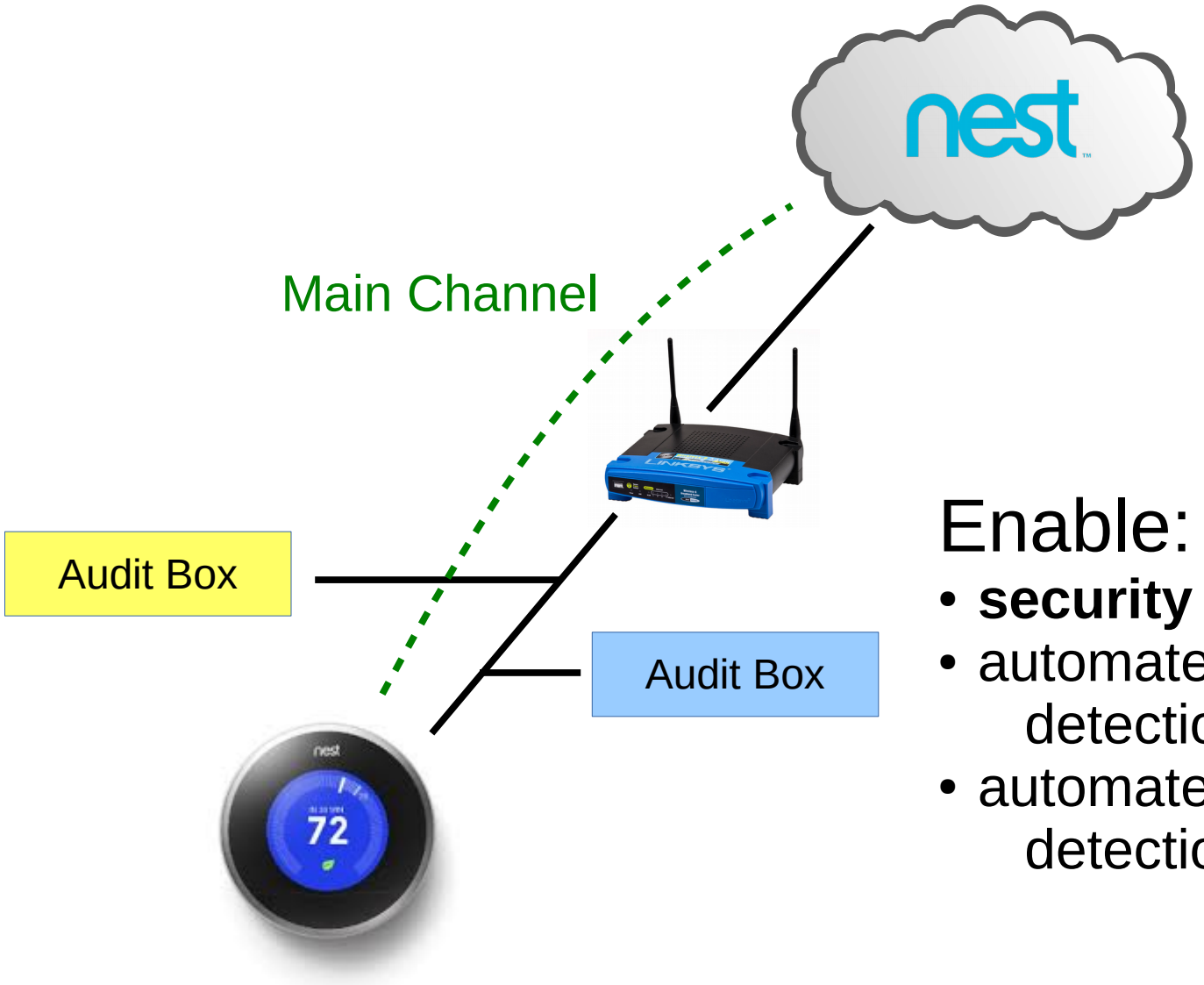
<u>Potential</u> concerns of IoT device company:

- Prevent tampering, back doors
- Prevent usage of device on other services
- Solution that is easy to incorporate.
- Protecting customer data

Customer's concerns:

- Desire an accurate audit, as good as MITM
- Preserve privacy

Compromise: Replace MITM with passive, read only auditors.



Enable:

- **security audit**
- automated exfiltration detection
- automated intrusion detection

The Technical Problem:

Create a method for passive, read only auditing of TLS-protected communication, to replace the man in the middle method.

In other words: Remove the TLS barrier from a communications audit.

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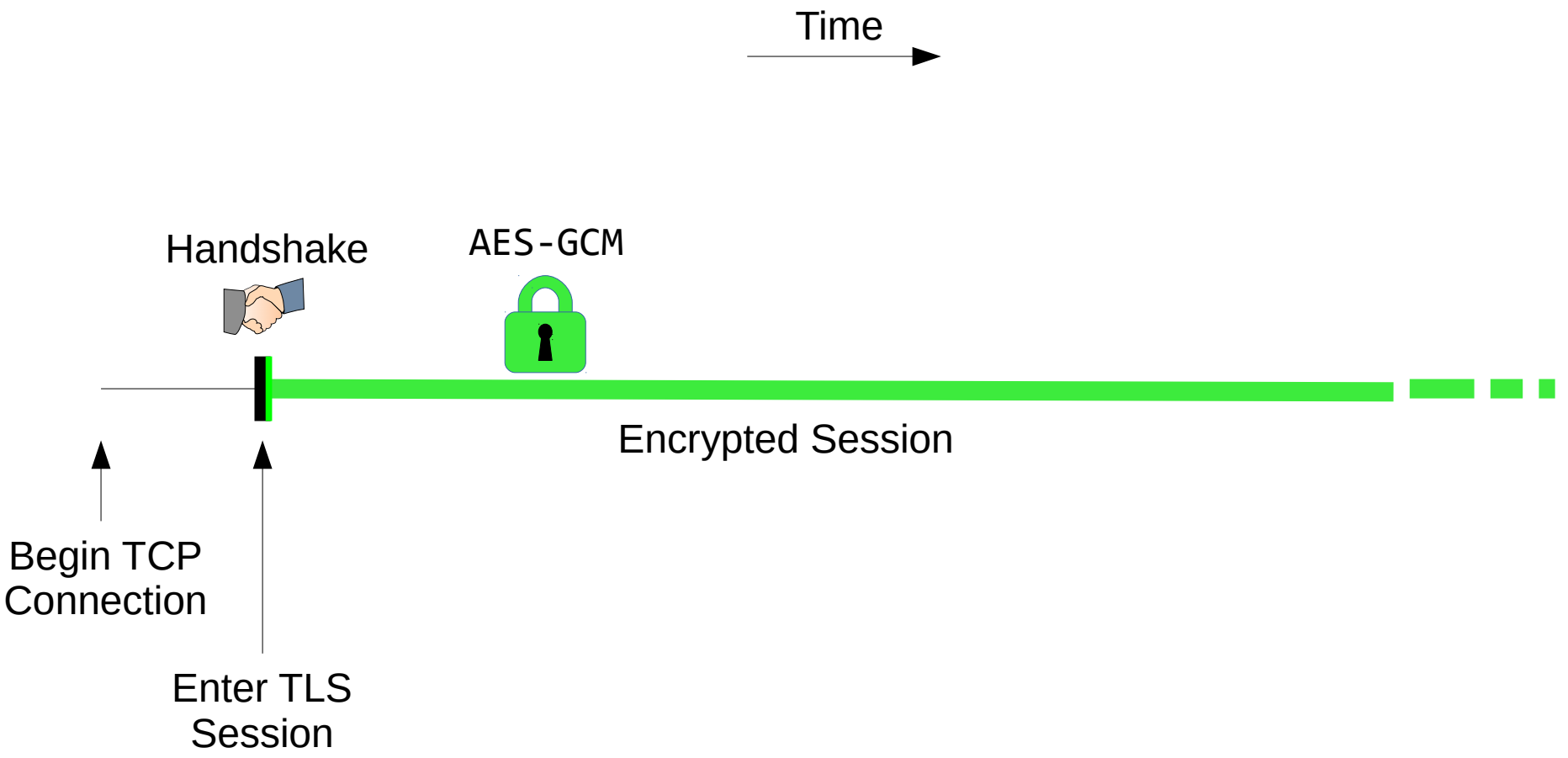
TLS-RaR: Rotate and Release

Device to Cloud TLS



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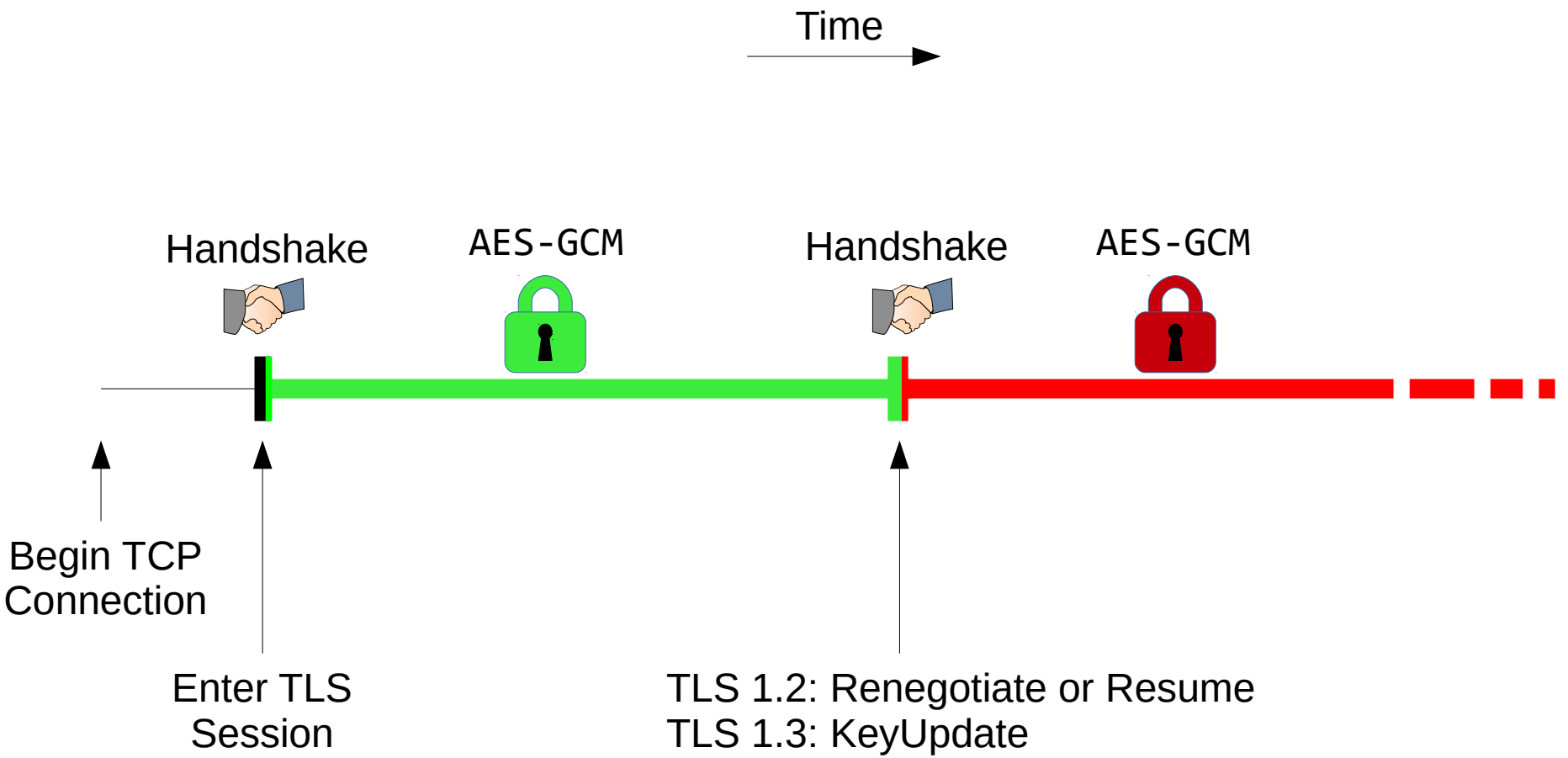
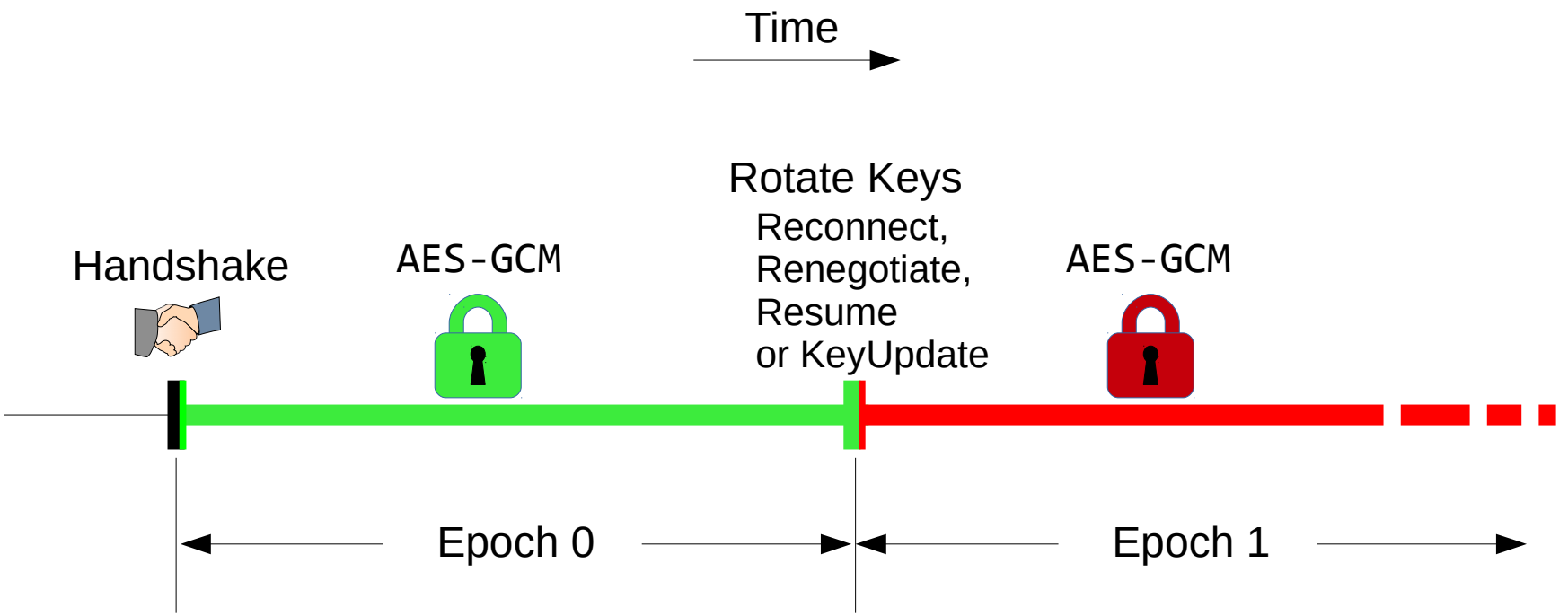


Device to Cloud TLS
With a Twist



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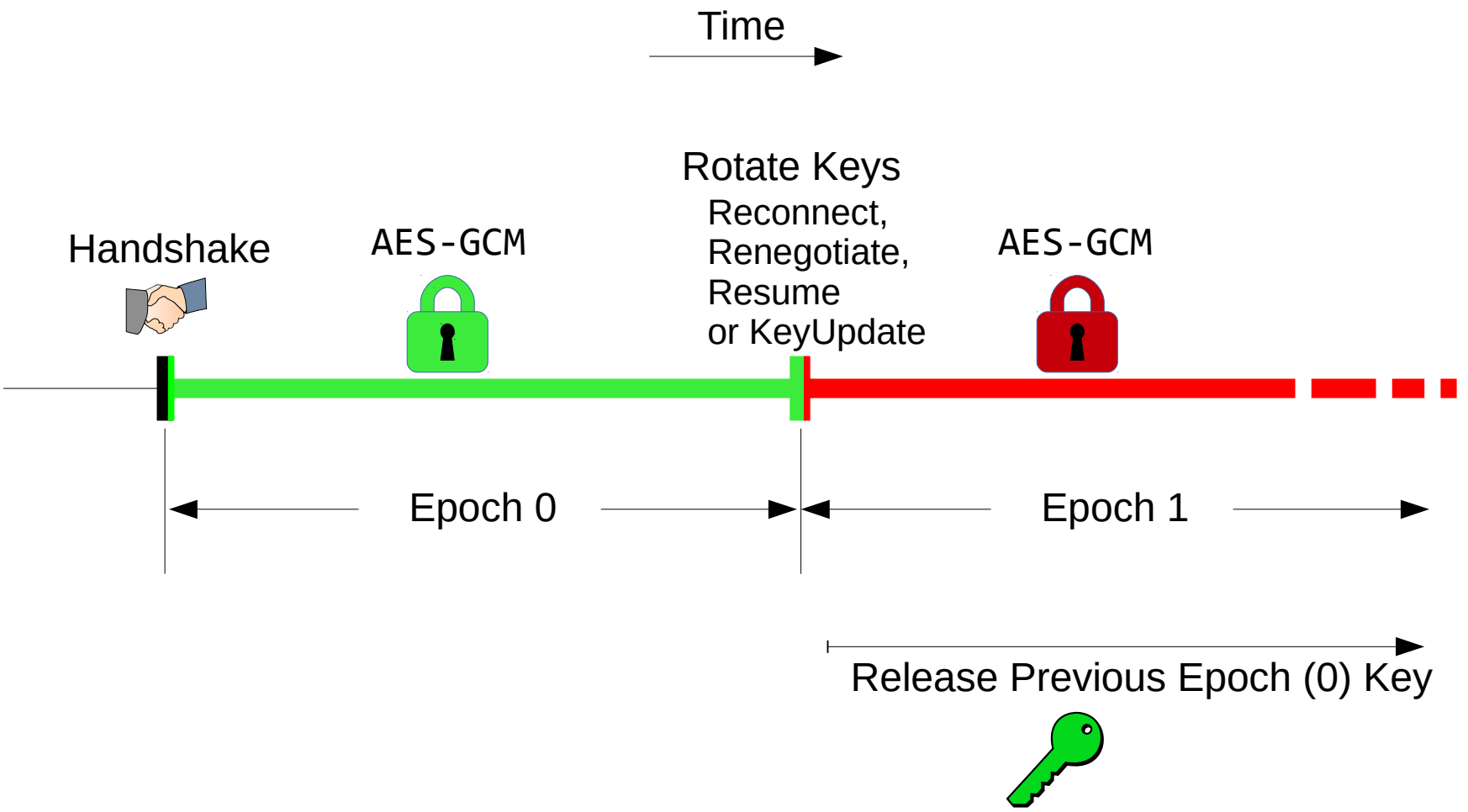

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- Minimal change to OpenSSL on the device
  - ➔ Easy to reason about security of the implementation
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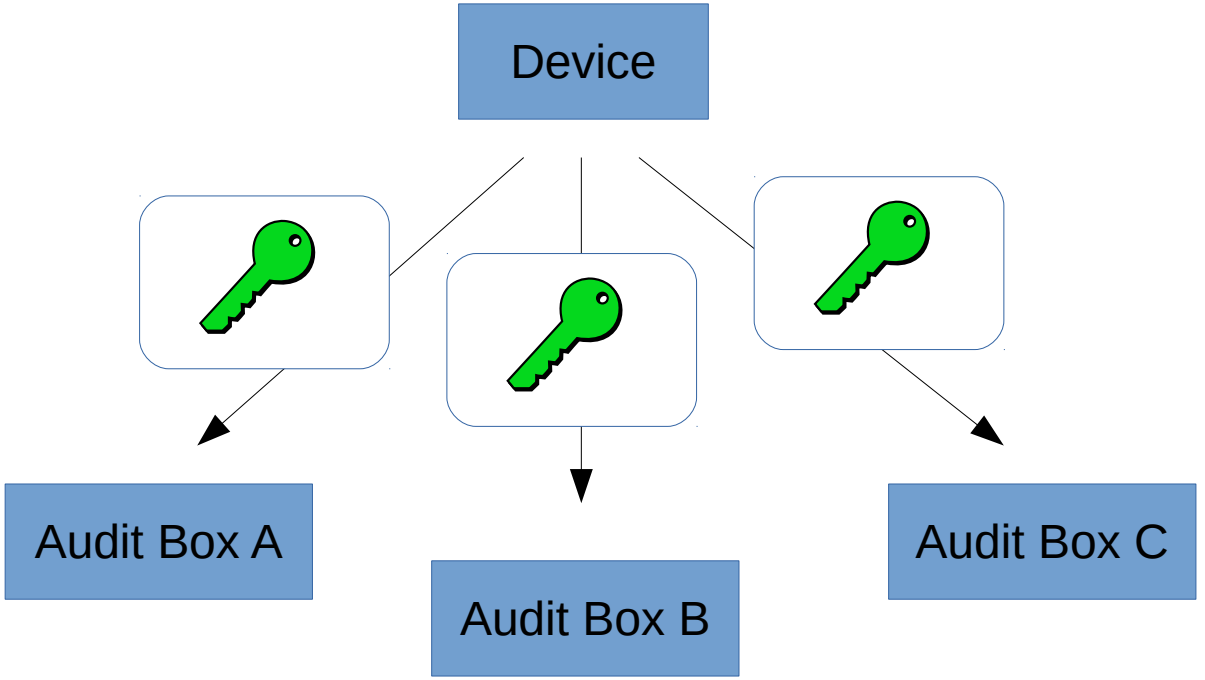
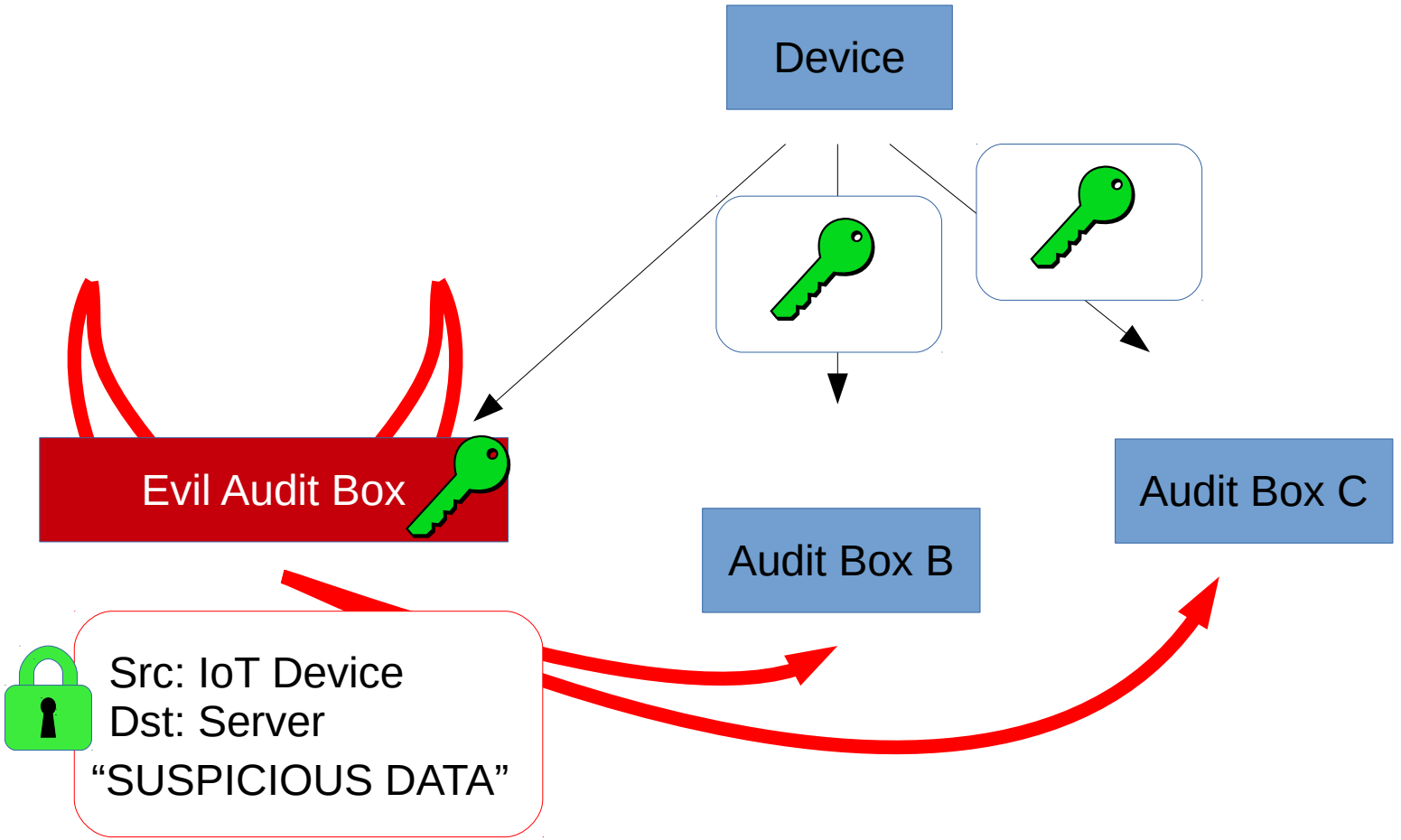
Key Release Procedure: Straw Man

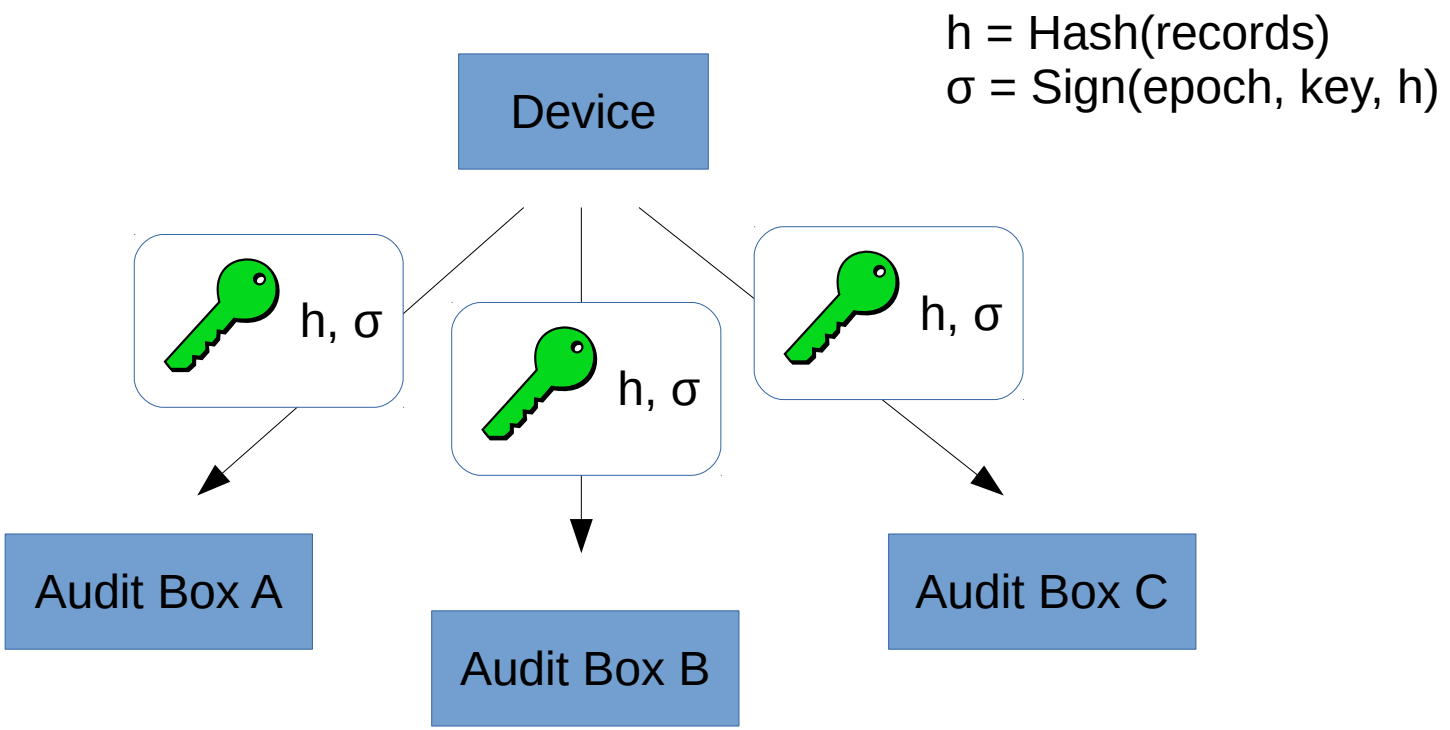


Device simply distributes key to Audit Boxes.

Key Release Procedure: Straw Man



Sealed-History Key Release



Cryptographic Hashes and Signatures ensure integrity to the auditors.

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Problem: Auditor can't decrypt the last epoch.

Clean Connection Shutdown

Clean shutdown: IoT application ensures the last key encrypting data is not useful (e.g. authenticated acknowledgment), then securely releases the key.

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Note: Unclean shutdown can be caused by hardware/network failure or actions by IoT device, cloud server, and unauthenticated third parties.

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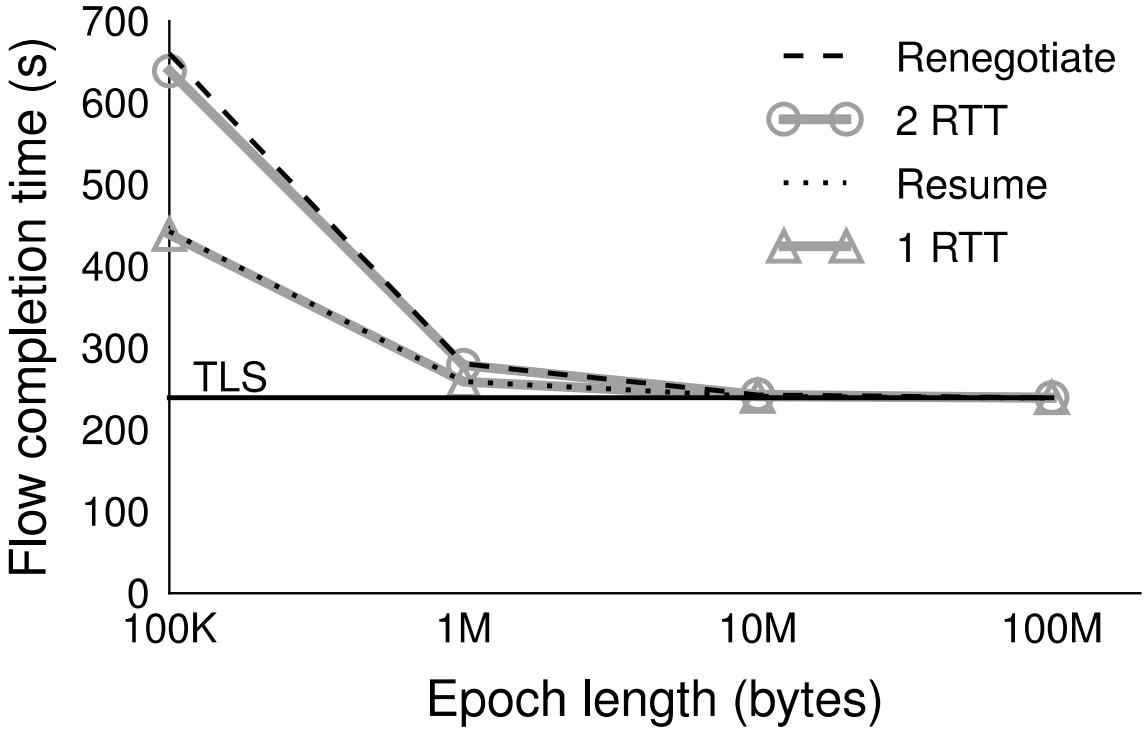
Alexa Top 1,000,000 Compatibility Survey

	Fraction of Servers*
Rotation by Reconnect	54.2%
Rotation by Renegotiation	12.2%
Rotation by Resume (requires heartbeat)	0.5%

*Includes only the ≈400,000 servers that support HTTPS and keep-alive, January, 2016.

Performance Impact

Completion time for 1000 simulated sequential downloads of a 100kB resource, over a 24 Mbps link with 100 ms latency:



Takeaway: In the *worst case* scenario (unlikely in IoT), epoch lengths can be chosen for minimal impact.

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  - `SSL_read()` returns same data for all trusted viewers
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Questions?

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Backup Slides

Security Properties

- Present-Moment Integrity
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- Present-Moment Secrecy
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- Past Auditability
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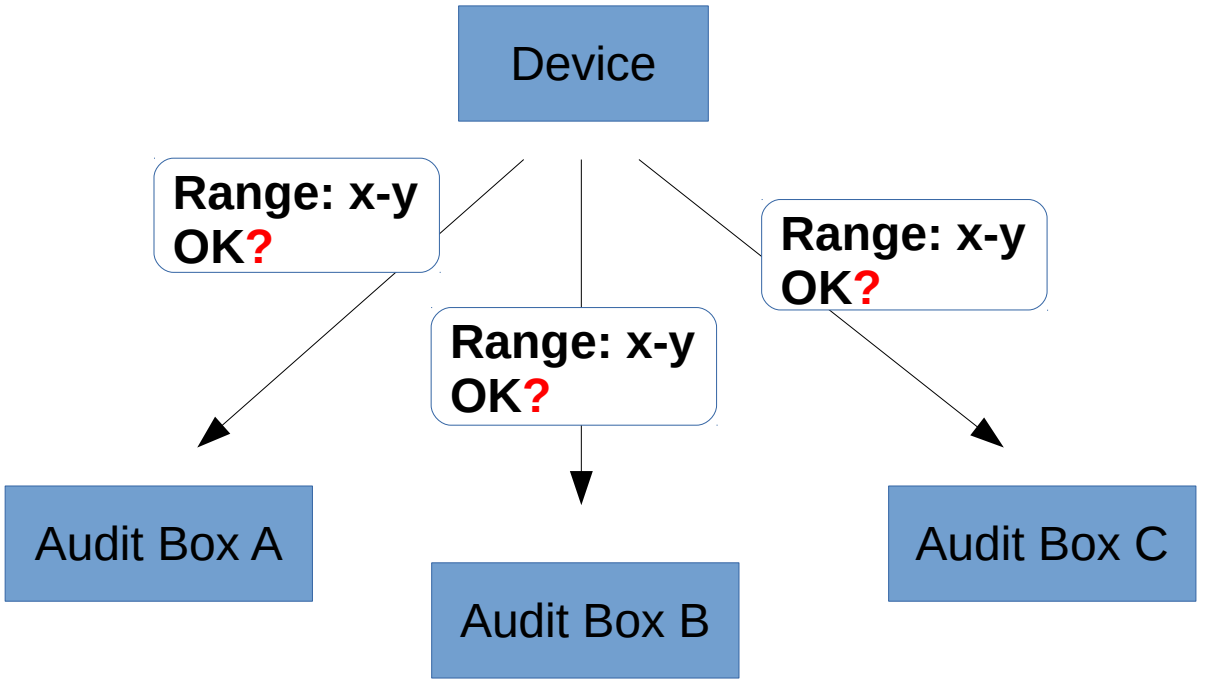
- Audit Robustness
  - ➔ Auditors cannot be convinced that a forgery (possibly from another auditor) came from one of the endpoints.

Unmitigated Threats

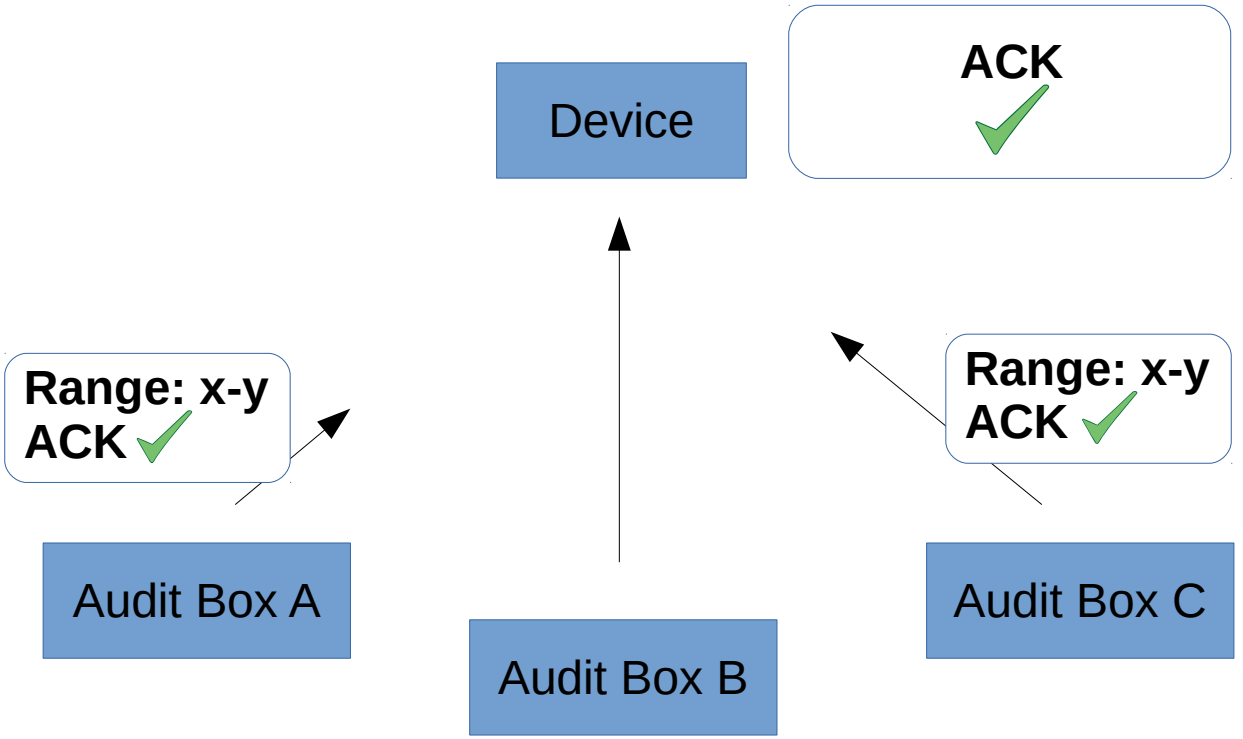
- Covert Channels
  - ➔ TLS-RaR cannot prevent secret communication between endpoints.
- Denial of Service
- Incompatible Application-Layer Authentication
  - ➔ Auditors may see and replay all plaintext, including cookies, passwords, and tickets.
  - ➔ Remedy: Use TLS client certificates

Two-Phase Key Release Procedure



1) Device requests auditors' permission to release key protecting TCP data sequence numbers x through y.

Two-Phase Key Release Procedure



2) Audit Boxes acknowledge after they are ready for **other** Audit Boxes to receive the key.

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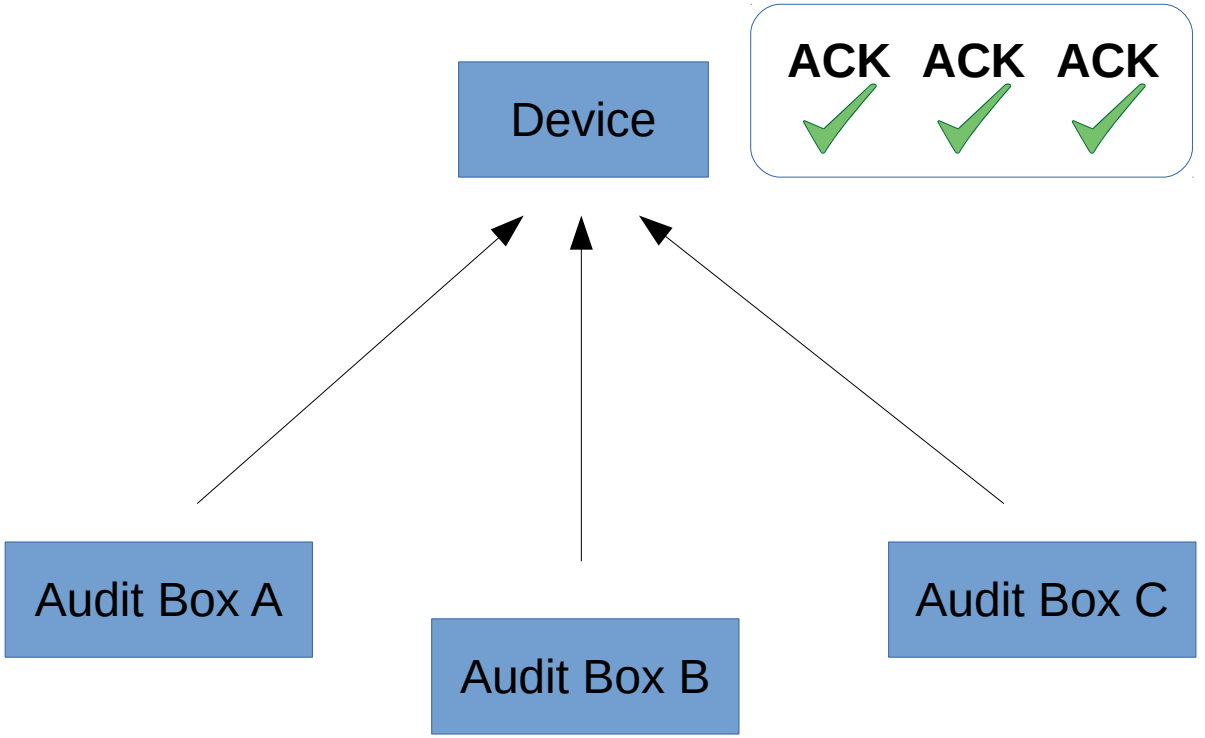

3) Device waits for all Audit Boxes to respond.
   (May time out and notify Audit Boxes.)

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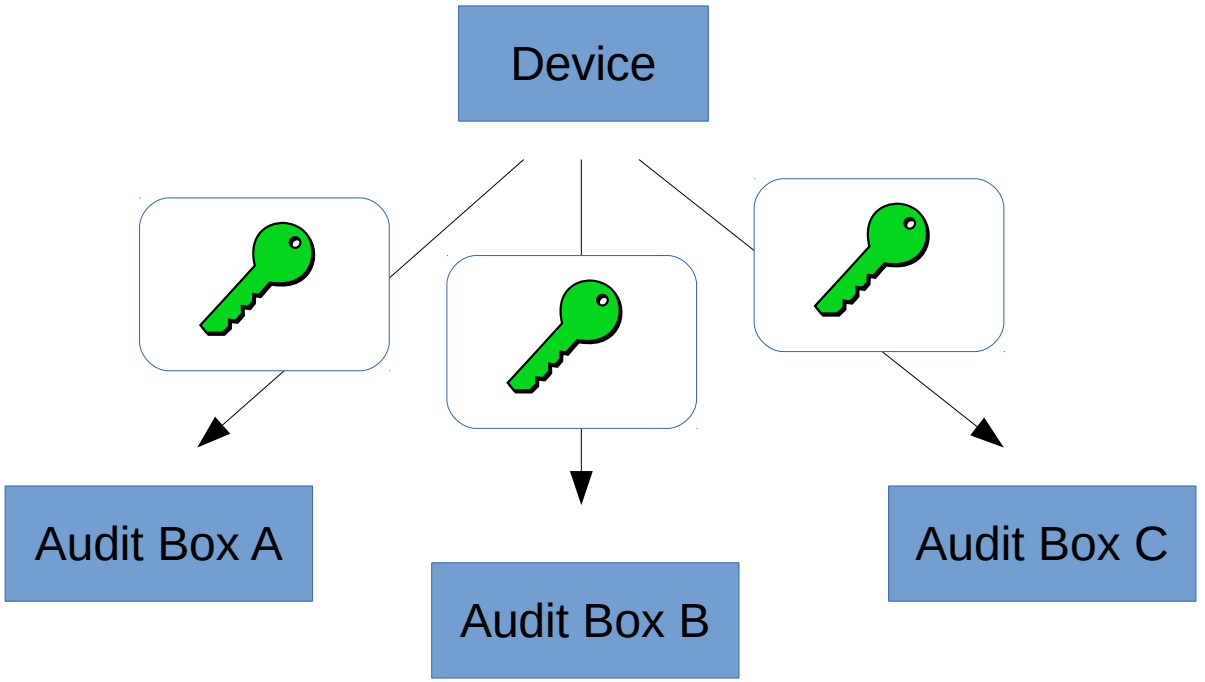

4) Device distributes key to Audit Boxes.

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Related Work

mcTLS [Naylor et. al. 2015]

- targets several problems, including read only middleboxes which could be auditors
- different approach: uses multiple MACs

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BlindBox [Sherry et. al. 2015]

- solves the opposite problem, a “blind” inspection
- different trust model

Rotation Policy

Device attempts to limit Epoch length by:

- **Age** of data under new key: **60 seconds**
- **Amount** of data protected by new key: **10 MB**

Auditor logs when:

- **Age** of data under new key: **5 minutes**
- **Amount** of data protected by new key: **50 MB**

TLS 1.2 Key Generation (RFC 5246)

Inputs:

`client_random, server_random:` random data (nonces) from client/server

`pre_master_secret:` shared secret from client or Diffie-Hellman key exchange.

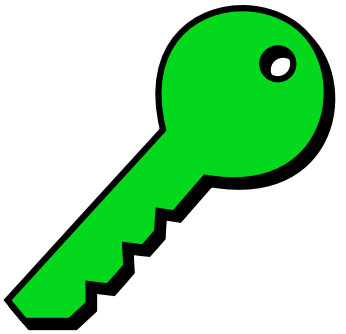
Computations:

```
master_secret = PRF(pre_master_secret, "master secret",
                                       client_random + server_random)

key_block = PRF(master_secret,
                "key expansion",
                server_random +
                client_random);
```

Outptuts:

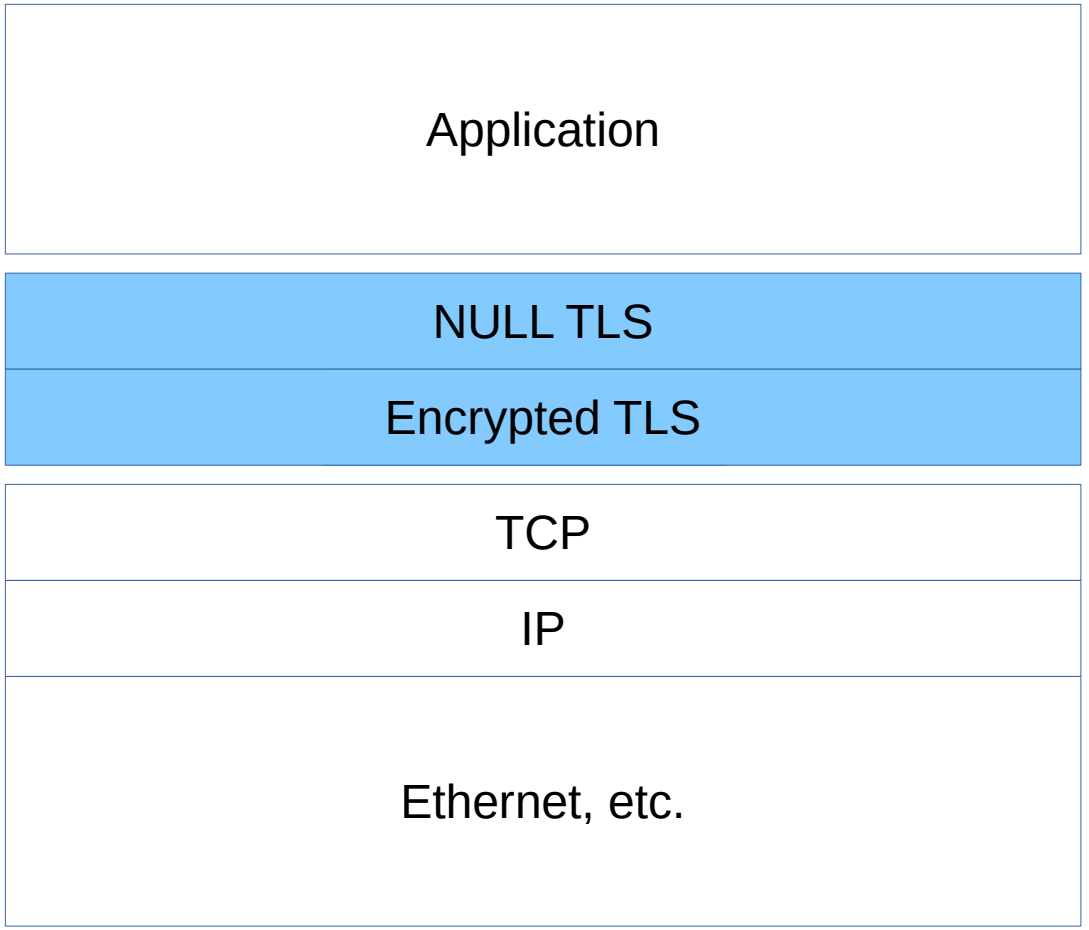
```
key_block {
        client_write_MAC_secret[hash_size]
        server_write_MAC_secret[hash_size]
        client_write_key[key_material_length]
        server_write_key[key_material_length]
        client_write_IV[IV_size]
        server_write_IV[IV_size]
}
```



A Different Idea:

TLS-in-TLS Tunneling

TLS-in-TLS



NULL TLS
- Unencrypted
- End to end integrity and Authenticity.

Encrypted TLS
- Auditor has full access, either by proxy or client releasing the keys.

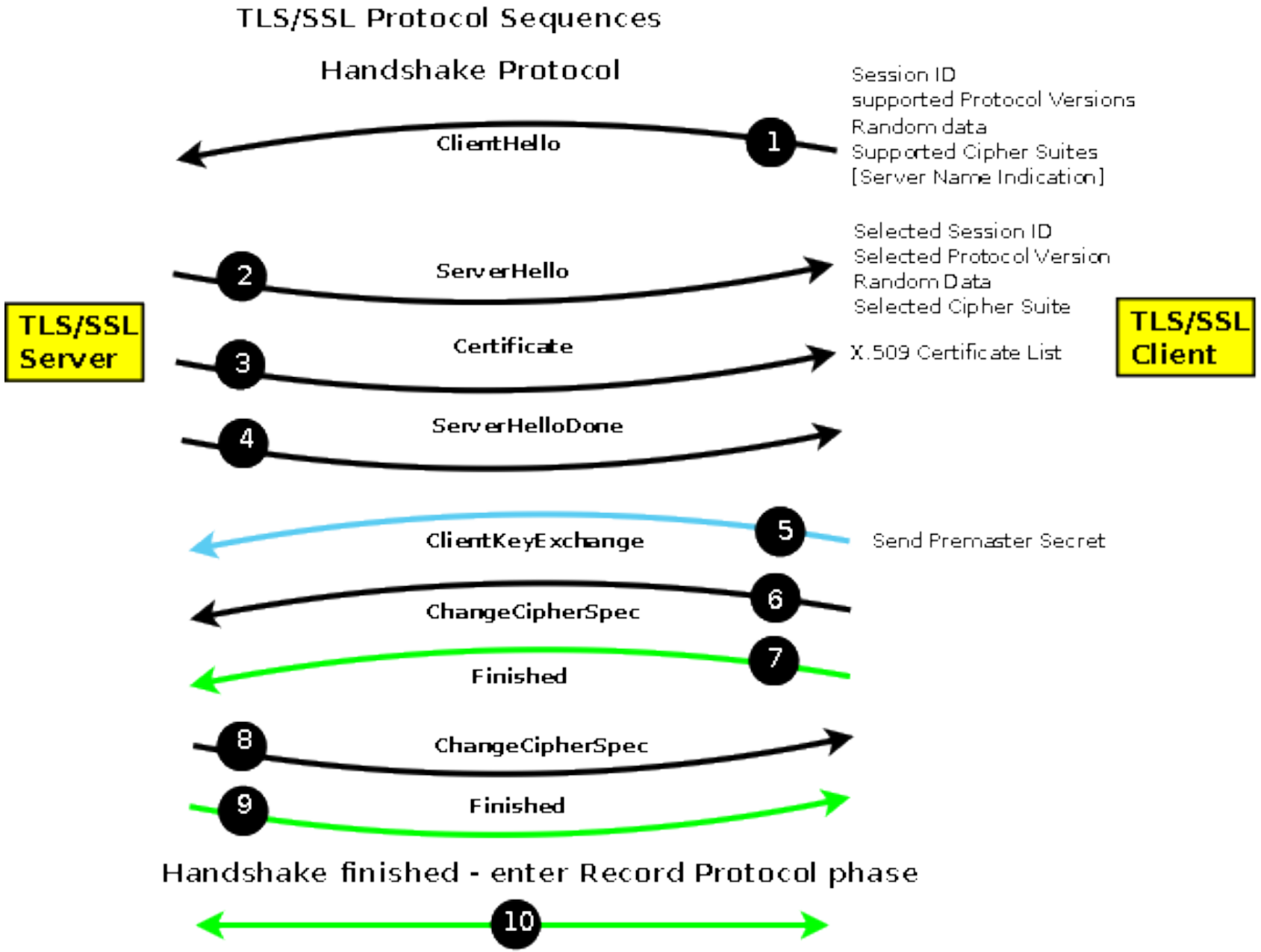
TLS-in-TLS

Benefits:

- TLS is still intact.
- No renegotiation.
- Auditor has instantaneous access to data.

Problems:

- Incompatible with existing web servers, load balancers, SSL terminators.
- Creates a new layer of cryptography where auditor is not trusted.
- NULL ciphers are unsupported, meant as a debug tool.
- Potential attacks between auditors.



Survival guides - TLS/SSL and SSL (X.509) Certificates
http://www.zytrax.com/tech/survival/ssl.html

Same Nice Properties?

BlindBox	mcTLS	
N/A	No	– `SSL_read()` returns same data for all parties.
?	No	– Format of TLS on the wire is not changed.
No	No	– No changes for some servers.
?	?	– Minimal change to OpenSSL.

Threat Model Exclusions

We **exclude** the following threats from our model:

- Malicious parties, including the **IoT device and cloud server**, may communicate by **covert channels**.
- A **malicious auditor** may **leak private data or keys**.
- **Malicious auditors may collude** to produce the same incorrect audit record.

Threat Model

An attacker may attempt anything from the TLS threat model, such as passive eavesdropping, replay and masquerading.

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A malicious audit box may try to:

- **tamper with the communications** that are being audited
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- masquerade as the device or cloud server to **modify the decrypted cleartext in other auditors' records**

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A malicious IoT device and/or cloud server may try to make an audit record different from the data sent (ignoring covert channels).