Replay Attack in TLS 1.3 0-RTT Handshake: Countermeasure Techniques

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Version 2

The Paper

- **Conference:** 2023 IEEE 6th International Conference on Electrical, Electronics and System Engineering (ICEESE)
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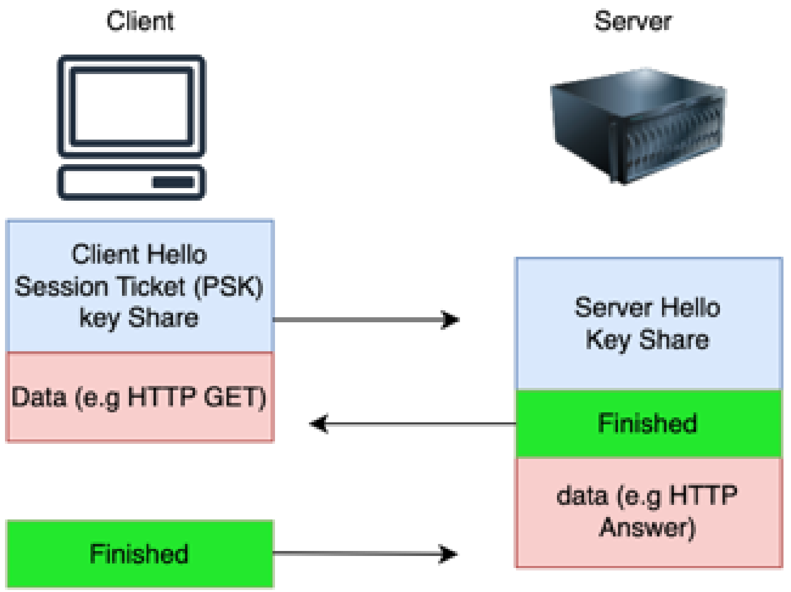
- **Goal:** review anti-replay protection techniques
- **Keywords:** TLS 1.3, replay attack, 0-RTT, handshake

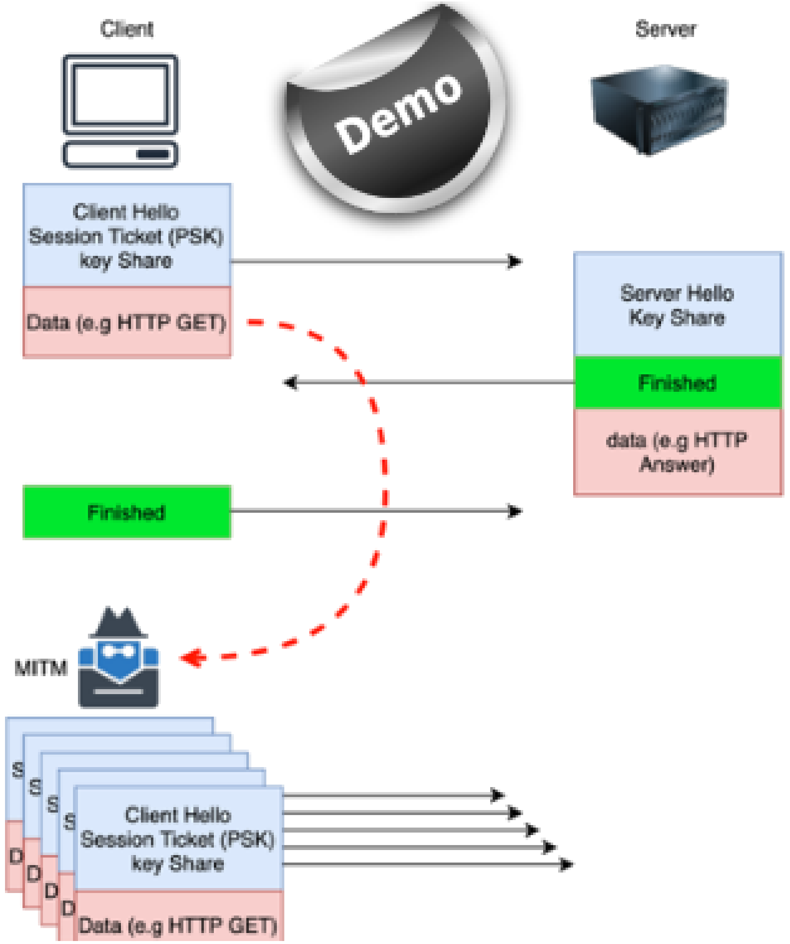
Context

- TLS resumable connections
- TLS 1.3 introduced **0-RTT** resume mode, based on a **Session Ticket** created during the initial full handshake encrypted with a Session Ticket Encryption Key (**STEK**)
- 0-RTT obtained by sending a **single message** that contains both the **ClientHello** (with a Session Ticket encrypted with a known STEK) and **Application Data** (also known as **Early Data**)



Attack Scenarios

- **Replay** attack
- Attacker intercepts and replays **ClientHello** messages with **Early Data**
- The replayed message is syntactically valid because the **ClientHello** contains a **Session Ticket** recognized by the server
- **ALTERNATIVE SCENARIO:** the attacker performs a **MITM blocking server 0-RTT responses** and triggering a **resending**



Freshness check

Reject **ClientHello** messages whose **gmt_unix_time** too much in the past

> ✅ Simple implementation
> ❌ Can be inconvenient and there is an exploitable time window for attackers

ClientHello Recording

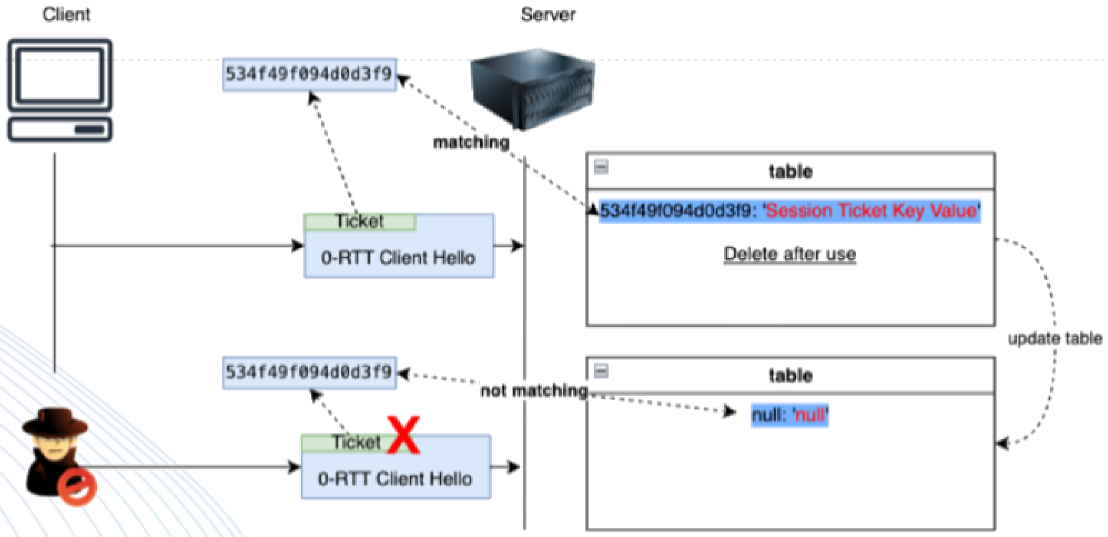
The server keeps a list of received **ClientHello** messages and uses it to detect and discard replays

> ✅ Can block all replay attacks
> ❌ Complex setup in distributed environments, complex synchronization

Single-Use Tickets

The server **deletes** the **STEK** used to decrypt the early data after the first 0-RTT resume, making it impossible to decrypt the Session Tickets of replayed messages.

> ✅ Can block all replay attacks, no space overhead
> ❌ Complex setup in distributed environments, complex synchronization



Application Profile

Each application should implement a specific **profile** that specifies under which conditions it will use 0-RTT (e.g. HTTP GET).

> ✅ Flexibility
> ❌ Not 100% safe, requires intervention at application level

Separate API

Both client and servers use libraries that make 0-RTT usage **explicit**, rather than implicit and automatic.

> ✅ Explicit behaviour
> ❌ Requires TLS libs restructuring and programmers attention

Puncture Pseudorandom Function (PPRF)

By using **PPRF** the server can decrypt 0-RTT early data only once.

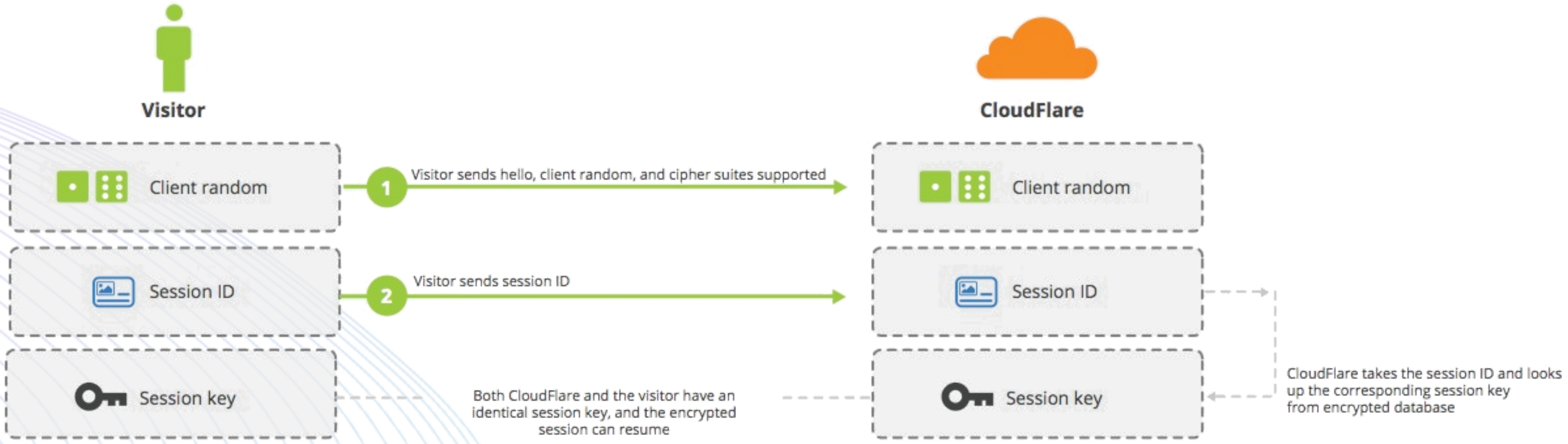
Example approach: a server maintains a Session Ticket Encryption Key (STEK) k that can decrypt any session ticket. Then it uses it to decrypt a ticket t and it generates a STEK k' that can decrypt all session tickets but t and so on...

> ✅ Forward secrecy
> ❌ Long processing time, not practical in distributed environments

Universal SSL

Introduced by **Cloudflare** in 2015 (doesn't support TLS 1.3), Universal SSL stores negotiated sessions into multiple **Memcached** instances. Each session is indexed and encrypted by **Session ID**.

> ✅ Great performance
> ❌ Memcached servers are synchronized only within each Cloudflare PoP



Just-in-Time Shared Keys (JIT-SK)

Based on a **synchronized PRNG**, dynamically changes keys for each session to secure 0-RTT messages (the same key cannot be reused multiple times, so "blind replaying" is impossible).

> ✅ Prevents replay attacks while providing forward secrecy
> ❌ Doesn't support distributed environments

Conclusions

0-RTT is here to stay

The performance improvements are real (the paper states that 0-RTT resume is 44.7% faster than 1-RTT) and the percentage of resumed TLS connections is also quite high (40% in some applications).

0-RTT anti-reply protection requires trade offs:

The evaluated protections introduce overheads and/or inconveniences, especially in distributed environments (e.g. CDNs), therefore 0-RTT replay protection is still an open research topic.

THANK YOU!