Email Transport Security in Practice

Email Client Selftest Service

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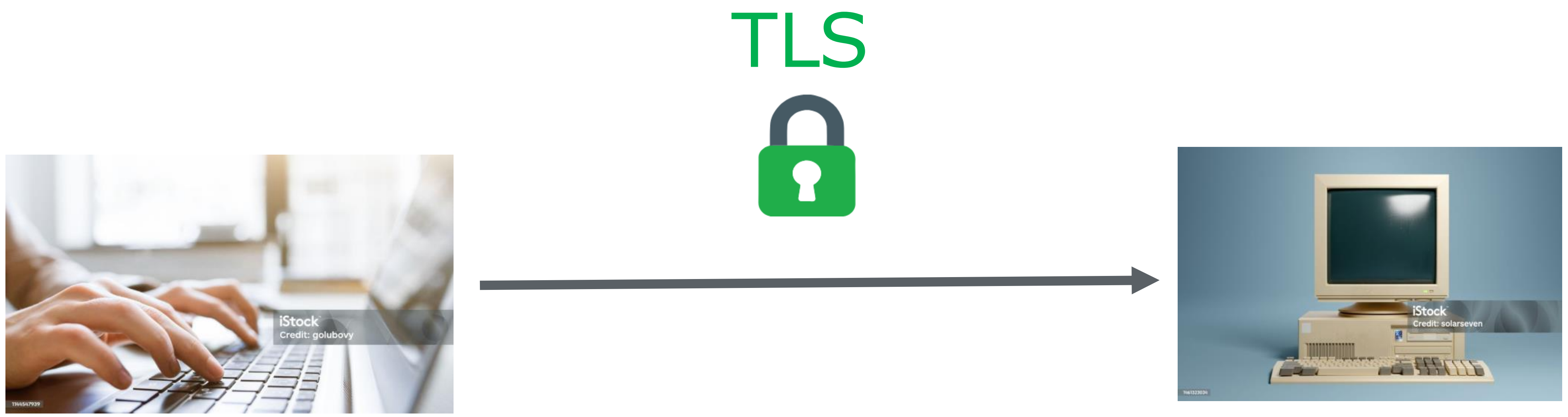
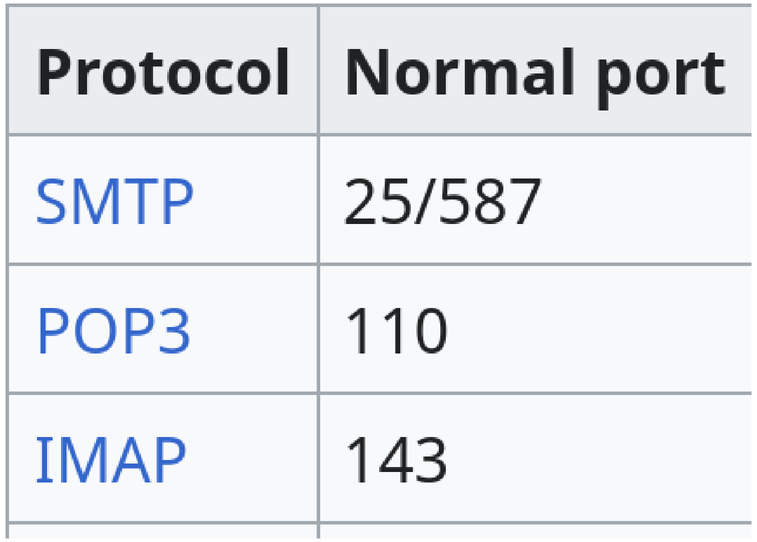
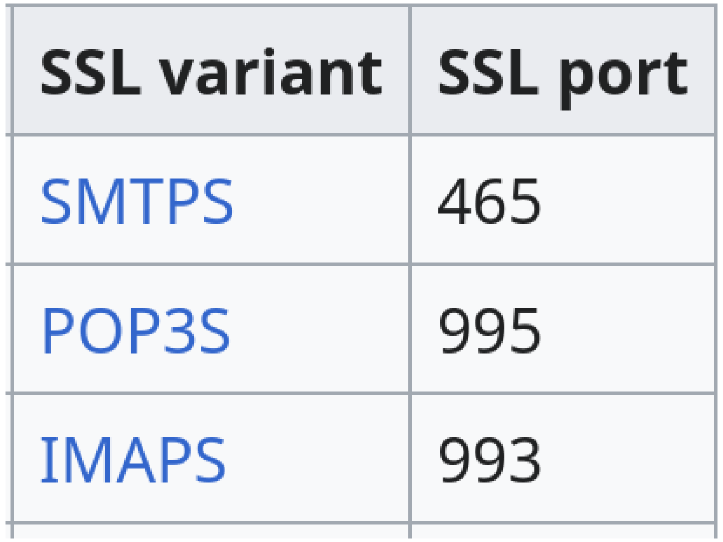
TLS and Email protocols



- TLS secures communication on the Internet: Encryption, Integrity, Authentication
- HTTP VS HTTP**S**
- Email uses its own dedicated protocols
  - To send emails: SMTP
  - To receive emails: IMAP or POP3
- Email protocols with TLS: SMTP**S,** IMAP**S,** POP3**S**



Protocol	Normal port
SMTP	25/587
POP3	110
IMAP	143



SSL variant	SSL port
SMTPS	465
POP3S	995
IMAPS	993

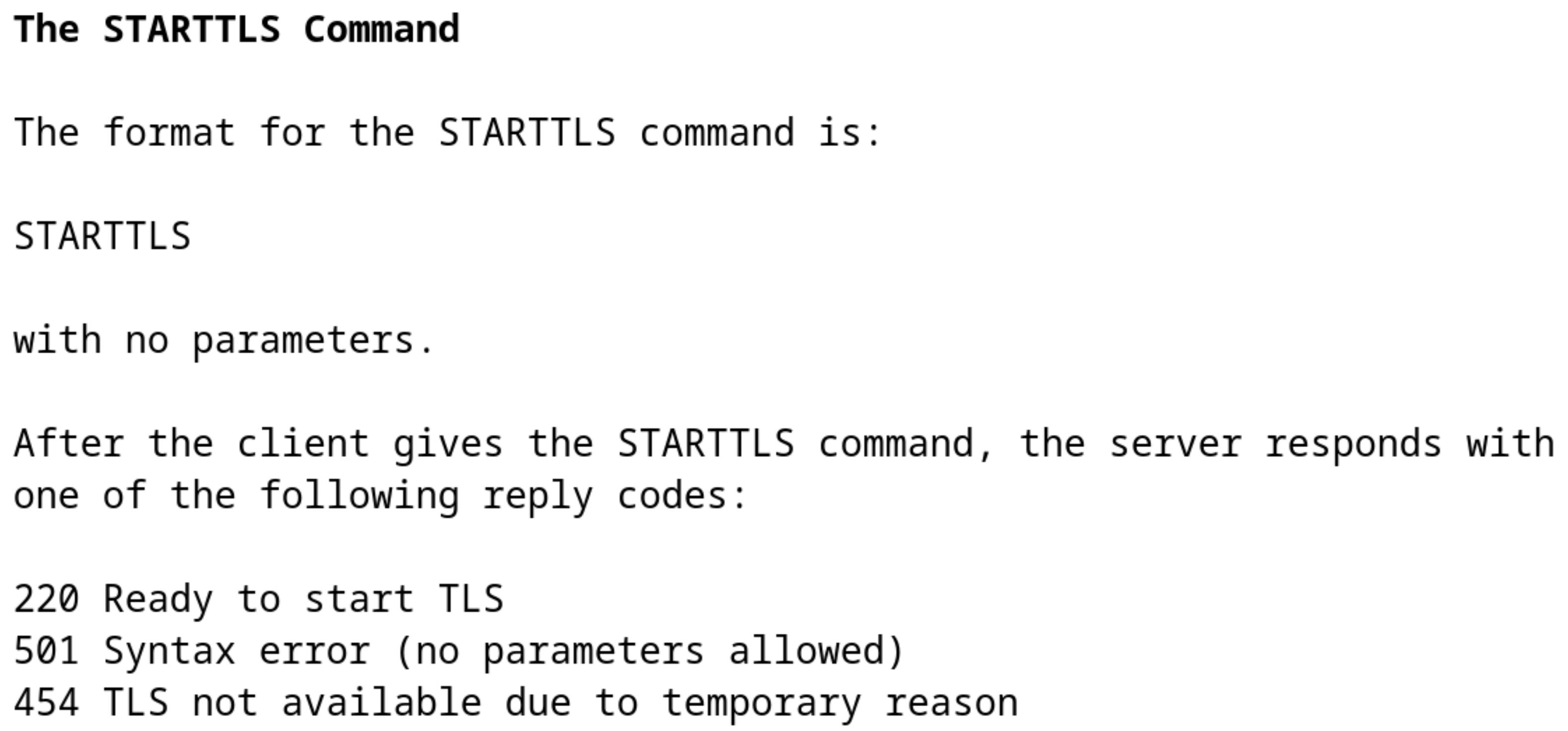
Original protocols communicate in plaintext

But: Upgrade to TLS-protected connection is possible via STARTTLS

Later secure protocol versions: implicit TLS support on dedicated ports

What is STARTTLS?

- STARTTLS extension to SMTP/POP3/IMAP
- An additional command that an email client can send during email protocol execution
- Upgrades a plaintext SMTP/POP3/IMAP connection to a secure TLS connection



```
The STARTTLS Command

The format for the STARTTLS command is:

STARTTLS

with no parameters.

After the client gives the STARTTLS command, the server responds with
one of the following reply codes:

220 Ready to start TLS
501 Syntax error (no parameters allowed)
454 TLS not available due to temporary reason
```

https://www.rfc-editor.org/rfc/rfc3207

Historical context

TLS support: two approaches

Implicit TLS	“Opportunistic” TLS
SMTPS:465	SMTP:587/25
POP3S:995	POP3:110
IMAPS:993	IMAP:143

+ StartTLS

Insecure!

TLS and Email in Practice: How to Configure an Email Server

SMTP Configuration with Postfix

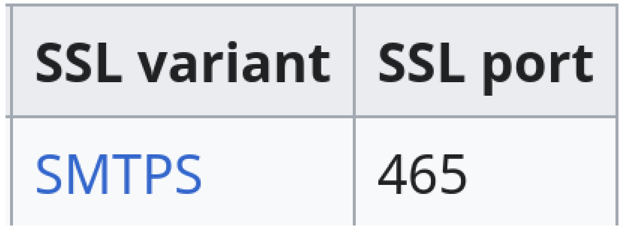
Advice for email server admins:

1. Enable TLS-only port

   for client mail submission

File: */etc/postfix/master.cf*

```
# Port 465 (Implicit TLS)
smtps inet n - y - - smtpd
-o syslog_name=postfix/smtps
-o smtpd_tls_wrappermode=yes
-o smtpd_sasl_auth_enable=yes
```

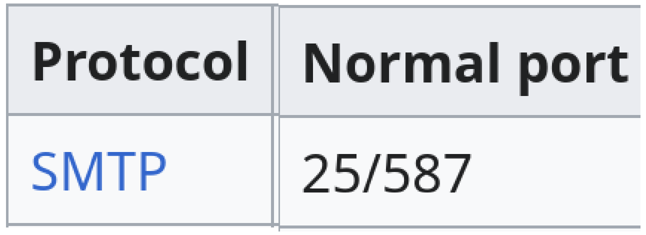


SSL variant	SSL port
SMTPS	465

2. Often support for legacy ports is needed, ensure TLS is enforced

File: */etc/postfix/master.cf*

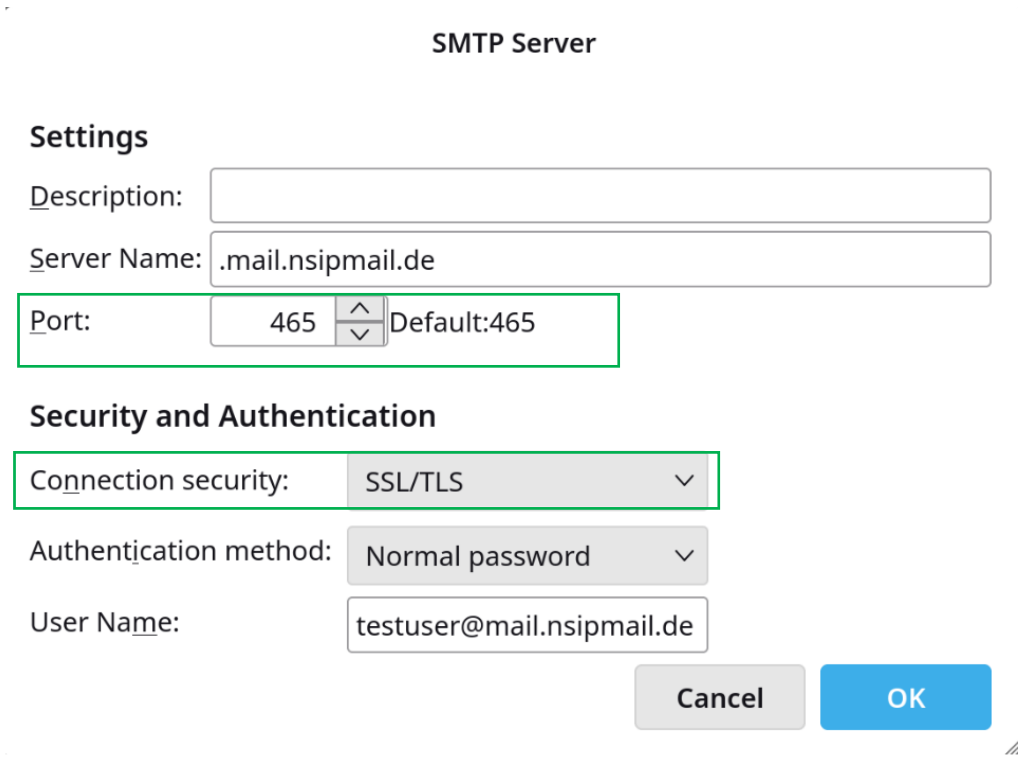
```
# Port 587 (STARTTLS)
submission inet n - y - - smtpd
  # -o smtpd_tls_security_level=may
  # -o smtpd_tls_auth_only=no
  -o smtpd_tls_security_level=encrypt
  -o smtpd_tls_auth_only=yes
```



Protocol	Normal port
SMTP	25/587

TLS and Email in Practice: Client-Side perspective

In Thunderbird:


SMTP Server

Settings

Description:	
Server Name:	.mail.nsipmail.de
Port:	465 Default:465

Security and Authentication

Connection security:	SSL/TLS
Authentication method:	Normal password
User Name:	testuser@mail.nsipmail.de

Usually Email Clients automatically suggest TLS configuration

Advice to users:

- Use secure email clients
  - Example: Microsoft Outlook mail client only supports SMTPS
- Do not change TLS settings with no good reason

Problem: Users do not control how email clients enforce TLS internally

A client may: fall back to insecure connection on disruption, automatically apply insecure options with autodetection mechanism

TLS and Email in Practice: Server and Client Side

Summary

Email Server Admins should:

- Allow Email clients to submit mail on TLS-only port
- *For legacy ports enforce TLS-only connections*

-> Email Server Configuration Scanner for admins

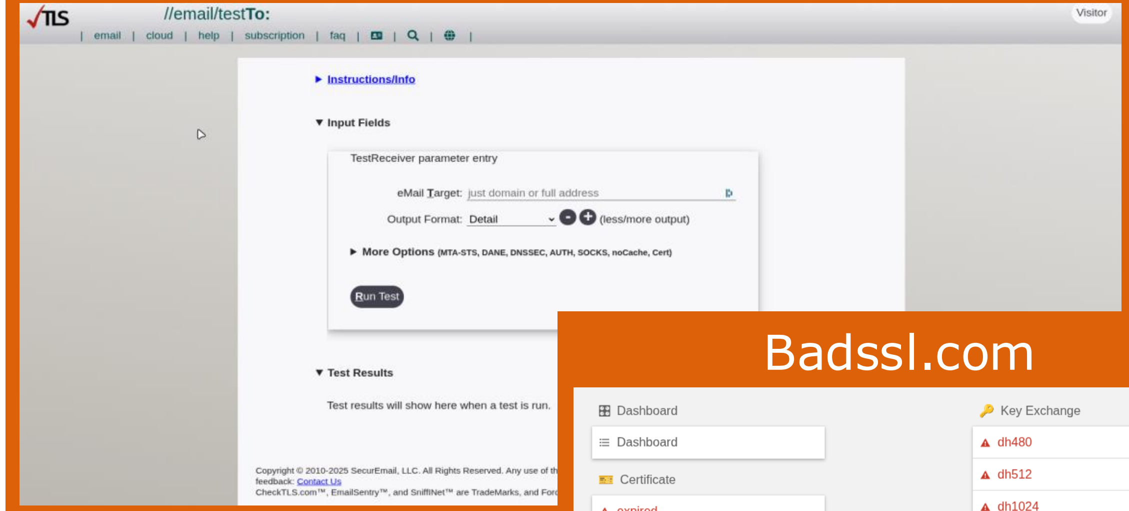
Email Users should:

- *Select trusted Email Clients*

-> Email Client Selftest Service for users

Current State of Email Security Testing

checktls.com



▶ Instructions/Info

▼ Input Fields

TestReceiver parameter entry

eMail Target: just domain or full address

Output Format: Detail (less/more output)

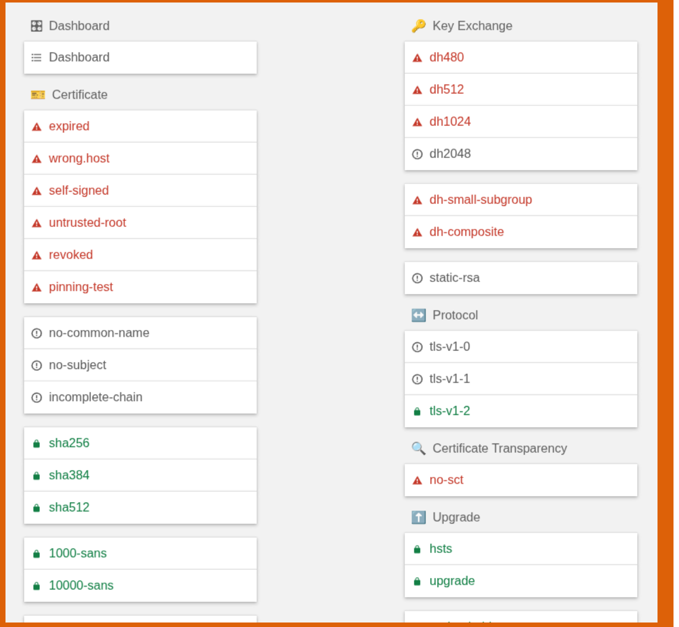
▶ More Options (MTA-STS, DANE, DNSSEC, AUTH, SOCKS, noCache, Cert)

Run Test

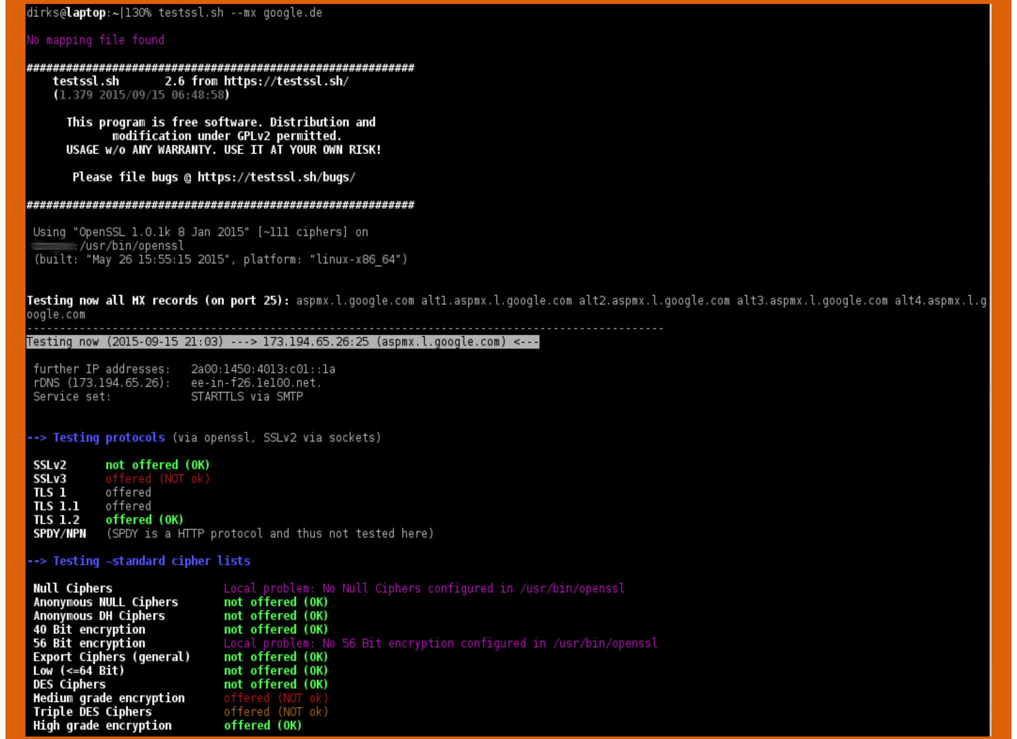
▼ Test Results

Test results will show here when a test is run.

Badssl.com

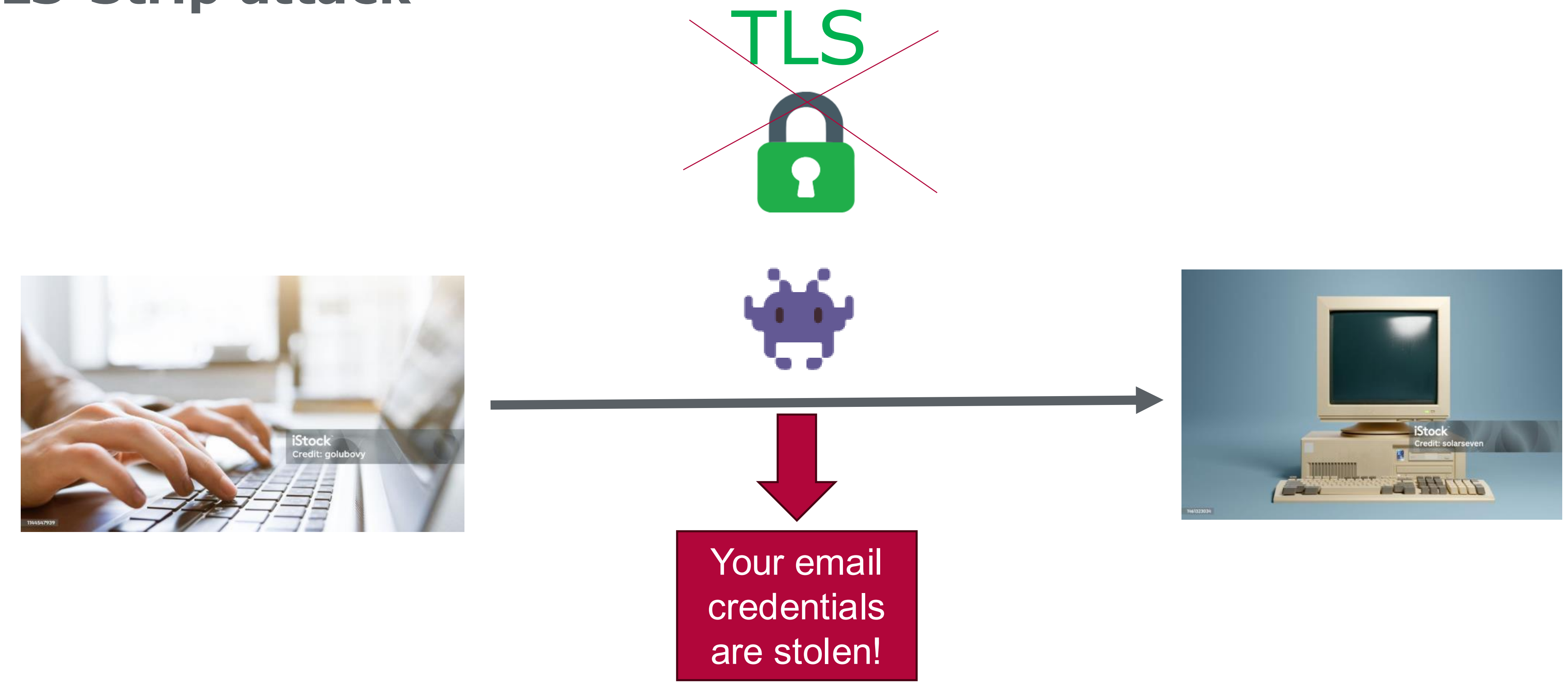


Testssl.sh



```
dirks@laptop:~|130% testssl.sh --mx google.de

No mapping file found

###########################################################
    testssl.sh       2.6 from https://testssl.sh/
    (1.379 2015/09/15 06:48:58)

      This program is free software. Distribution and
             modification under GPLv2 permitted.
      USAGE w/o ANY WARRANTY. USE IT AT YOUR OWN RISK!

       Please file bugs @ https://testssl.sh/bugs/

###########################################################

 Using "OpenSSL 1.0.1k 8 Jan 2015" [~111 ciphers] on
 [redacted]:/usr/bin/openssl
 (built: "May 26 15:55:15 2015", platform: "linux-x86_64")


Testing now all MX records (on port 25): aspmx.l.google.com alt1.aspmx.l.google.com alt2.aspmx.l.google.com alt3.aspmx.l.google.com alt4.aspmx.l.g
oogle.com
-----------------------------------------------------------------------------------------------------
Testing now (2015-09-15 21:03) ---> 173.194.65.26:25 (aspmx.l.google.com) <---

 further IP addresses:   2a00:1450:4013:c01::1a
 rDNS (173.194.65.26):   ee-in-f26.1e100.net.
 Service set:            STARTTLS via SMTP


--> Testing protocols (via openssl, SSLv2 via sockets)

 SSLv2      not offered (OK)
 SSLv3      offered (NOT ok)
 TLS 1      offered
 TLS 1.1    offered
 TLS 1.2    offered (OK)
 SPDY/NPN   (SPDY is a HTTP protocol and thus not tested here)

--> Testing ~standard cipher lists

 Null Ciphers                 Local problem: No Null Ciphers configured in /usr/bin/openssl
 Anonymous NULL Ciphers       not offered (OK)
 Anonymous DH Ciphers         not offered (OK)
 40 Bit encryption            not offered (OK)
 56 Bit encryption            Local problem: No 56 Bit encryption configured in /usr/bin/openssl
 Export Ciphers (general)     not offered (OK)
 Low (<=64 Bit)               not offered (OK)
 DES Ciphers                  not offered (OK)
 Medium grade encryption      offered (NOT ok)
 Triple DES Ciphers           offered (NOT ok)
 High grade encryption        offered (OK)
```

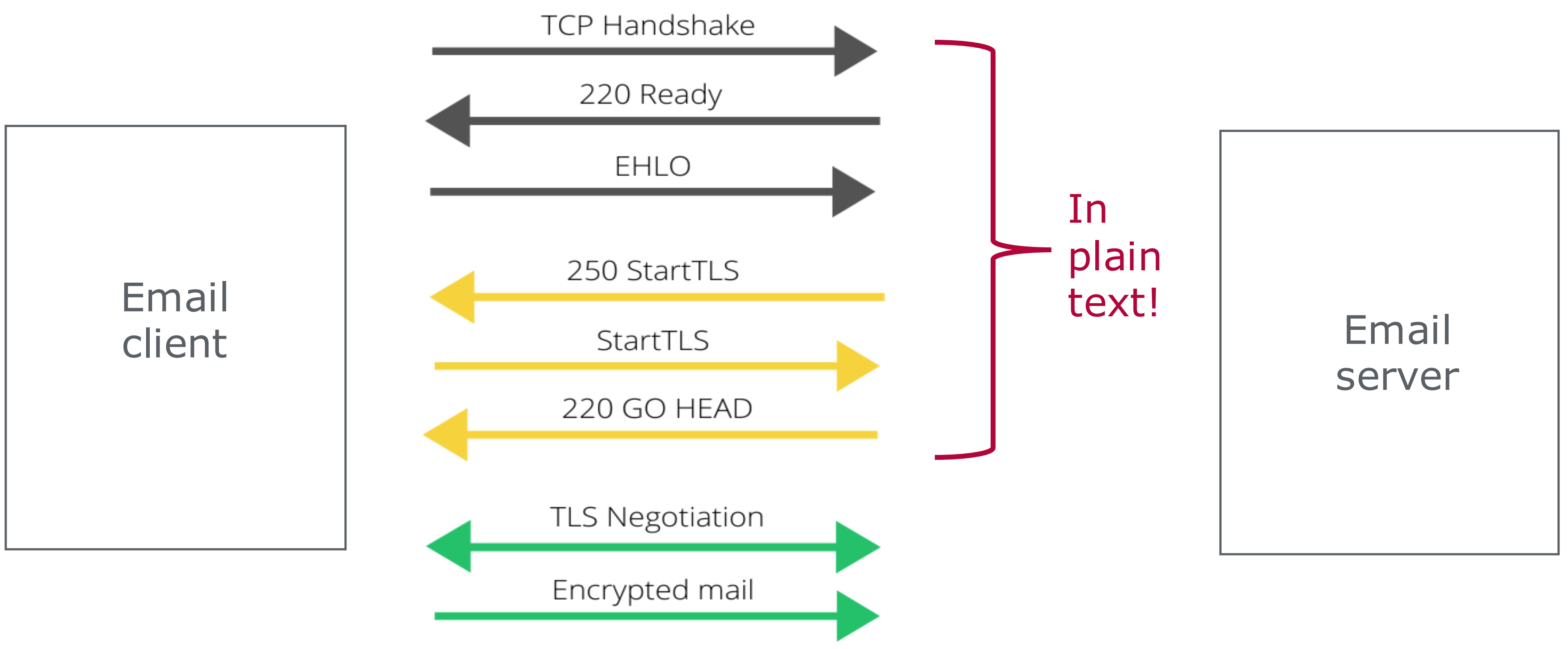
TLS-Strip attack



Your email credentials are stolen!

How Is That Possible?

Vulnerability details: Opportunistic TLS



An active attacker on the network can strip StartTLS and force no-TLS

if email server and client don't explicitly disallow it

SMTP protocol with StartTLS

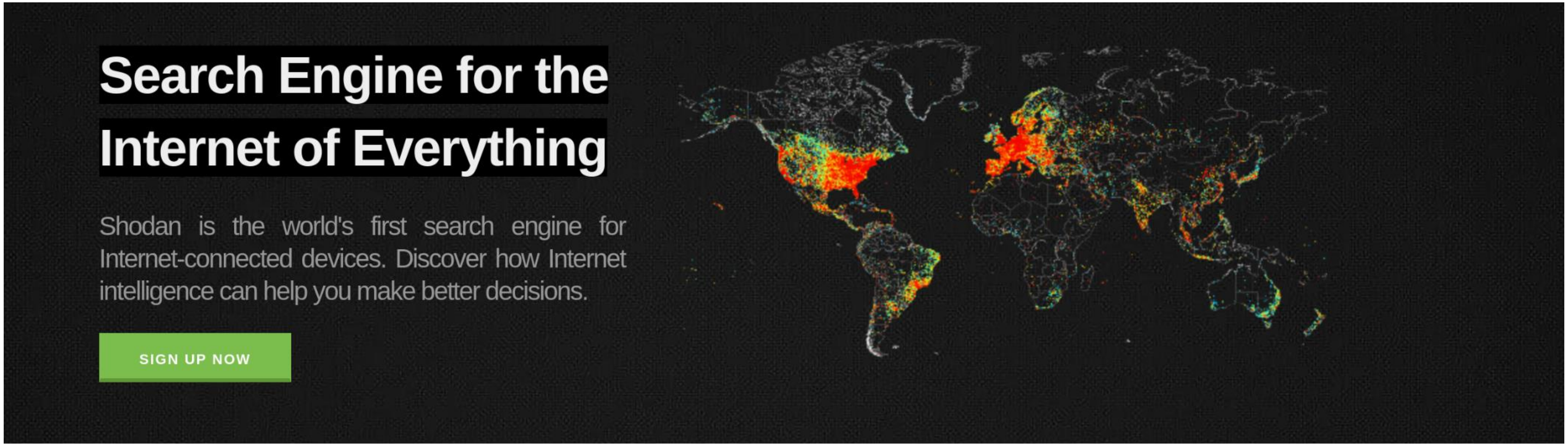
https://www.twilio.com/en-us/blog/insights/what-is-starttls

Security downgrade is possible if **email server** and client don’t explicitly disallow it

Vulnerable Servers

How many email servers would accept plaintext?

Shodan



Search Engine for the Internet of Everything

Shodan is the world's first search engine for Internet-connected devices. Discover how Internet intelligence can help you make better decisions.

- A web-based search platform for Internet connected devices
- We query Shodan API - https://api.shodan.io/shodan/host/count
- Example query: port:587 ("ESMTP" OR "EHLO" OR "250-")
- Shodan searches its database, we do not connect to actual servers on the Internet

Passive Measurement with Shodan

Idea: scan Internet for email servers that advertise plain auth

SMTP example:

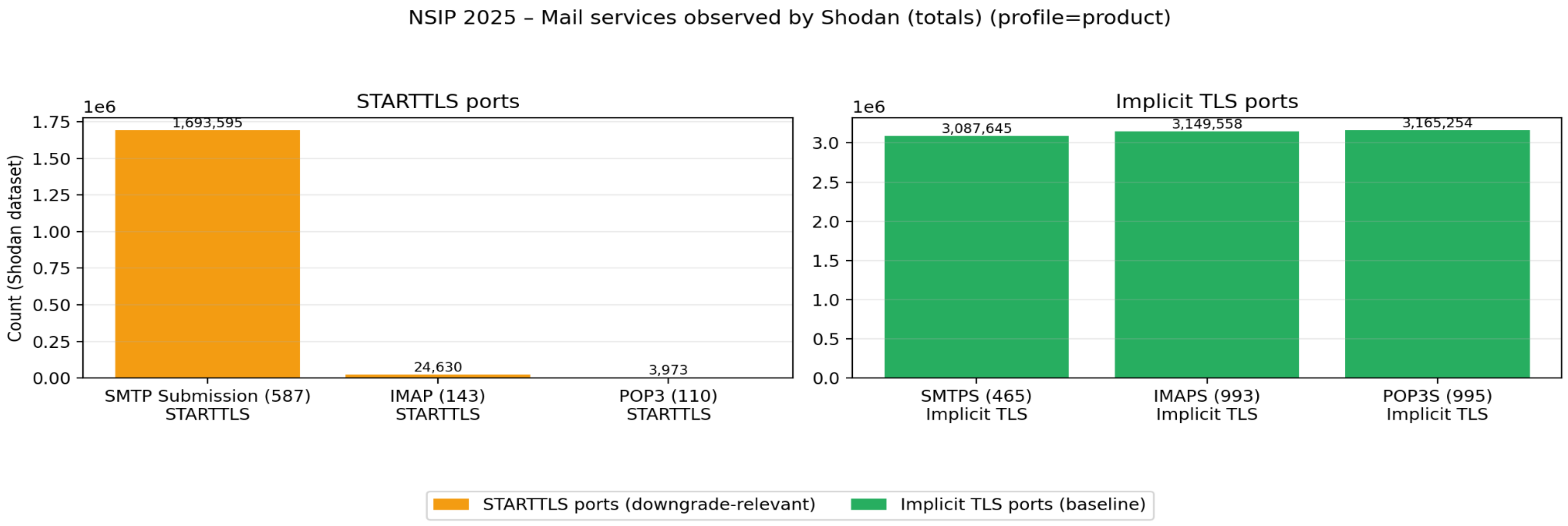
1. Client requests capabilities from server	EHLO test.com
2. Server lists capabilities	250-mail.nsipmail.de 250-PIPELINING 250-SIZE 10240000 250-VRFY 250-ETRN 250-STARTTLS **250-AUTH PLAIN LOGIN** ...

potentially effective before TLS $\longrightarrow$ **250-AUTH PLAIN LOGIN**

This does not guarantee server's vulnerability:

Client tries to login	C: AUTH PLAIN AGFsaWNlAHNlY3JldA==
Server rejects	S: 530 5.7.0 Must issue a STARTTLS command first

Passive Measurement with Shodan: results



Totals are counts of Shodan-observed services (not unique organizations).

Email Server Configuration Scanner

- Bash script
- Postfix (SMTP) & Dovecot (IMAP, POP3)

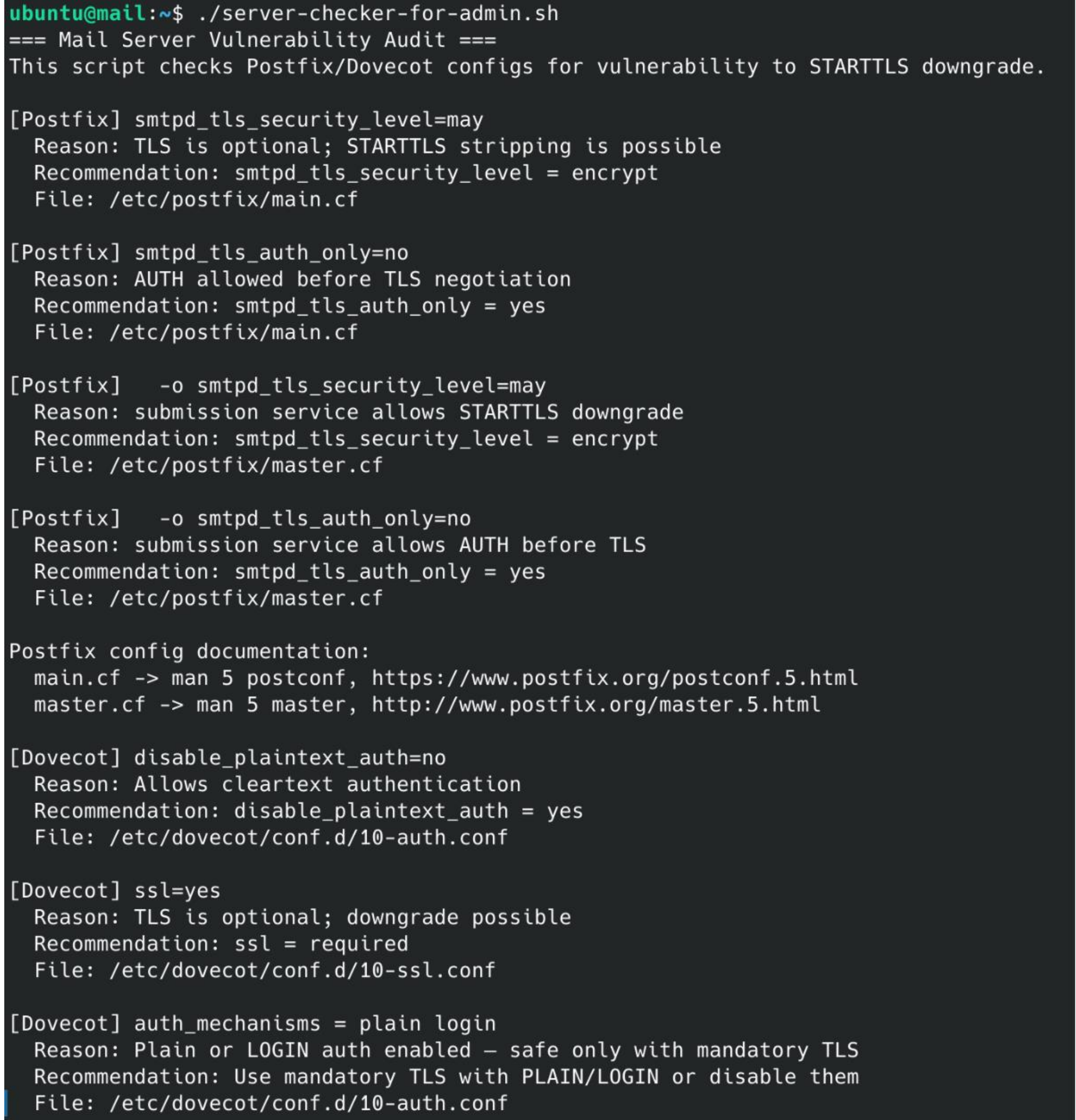
Detects and issues warnings if:

- TLS is optional instead of mandatory
- insecure authentication options (plain, login)

Multiple config file support:

• Dovecot: Handles split(*conf.d/*) and monolithic(*dovecot.conf*) configurations

• Postfix: Supports *main.cf* and *master.cf*



```
ubuntu@mail:~$ ./server-checker-for-admin.sh
=== Mail Server Vulnerability Audit ===
This script checks Postfix/Dovecot configs for vulnerability to STARTTLS downgrade.

[Postfix] smtpd_tls_security_level=may
  Reason: TLS is optional; STARTTLS stripping is possible
  Recommendation: smtpd_tls_security_level = encrypt
  File: /etc/postfix/main.cf

[Postfix] smtpd_tls_auth_only=no
  Reason: AUTH allowed before TLS negotiation
  Recommendation: smtpd_tls_auth_only = yes
  File: /etc/postfix/main.cf

[Postfix]   -o smtpd_tls_security_level=may
  Reason: submission service allows STARTTLS downgrade
  Recommendation: smtpd_tls_security_level = encrypt
  File: /etc/postfix/master.cf

[Postfix]   -o smtpd_tls_auth_only=no
  Reason: submission service allows AUTH before TLS
  Recommendation: smtpd_tls_auth_only = yes
  File: /etc/postfix/master.cf

Postfix config documentation:
  main.cf -> man 5 postconf, https://www.postfix.org/postconf.5.html
  master.cf -> man 5 master, http://www.postfix.org/master.5.html

[Dovecot] disable_plaintext_auth=no
  Reason: Allows cleartext authentication
  Recommendation: disable_plaintext_auth = yes
  File: /etc/dovecot/conf.d/10-auth.conf

[Dovecot] ssl=yes
  Reason: TLS is optional; downgrade possible
  Recommendation: ssl = required
  File: /etc/dovecot/conf.d/10-ssl.conf

[Dovecot] auth_mechanisms = plain login
  Reason: Plain or LOGIN auth enabled – safe only with mandatory TLS
  Recommendation: Use mandatory TLS with PLAIN/LOGIN or disable them
  File: /etc/dovecot/conf.d/10-auth.conf
```

Security downgrade is possible if email server and **client** don’t explicitly disallow it

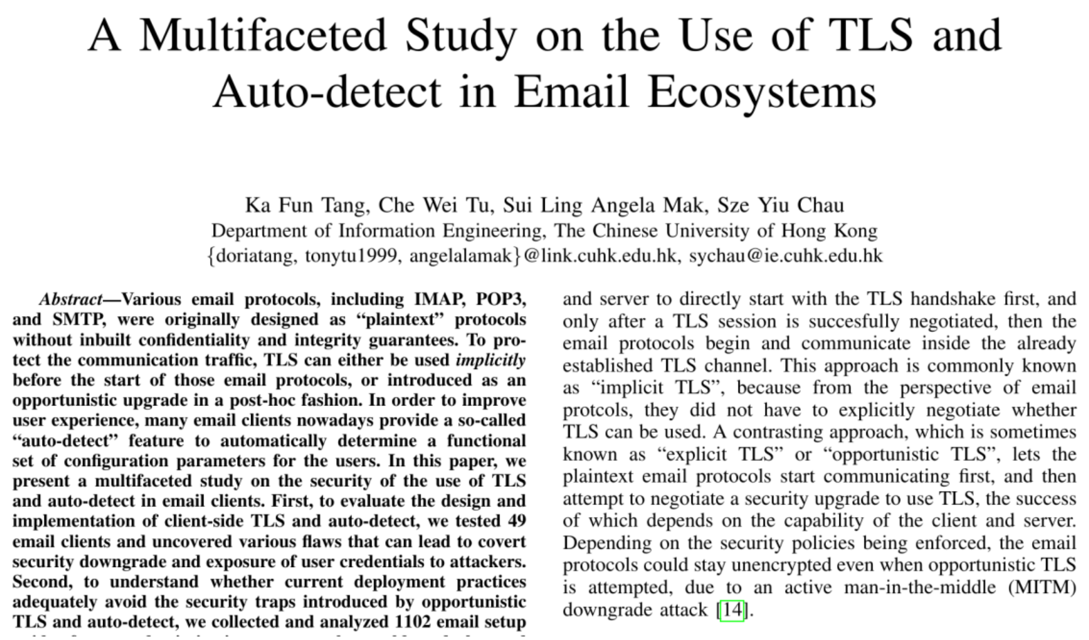
Vulnerable Clients

How many email clients would authenticate in plaintext?

A Multifaceted Study on the Use of TLS and Auto-detect in Email Ecosystems (2025)

- A study evaluating 49 real-world email clients' behavior in case of TLS disruptions
- Methodology: lab setup with MiTM-proxy between email client and server
- 19/49 clients were found to be insecure

- This motivates the need for users to be able to check their email client's security



A Multifaceted Study on the Use of TLS and Auto-detect in Email Ecosystems

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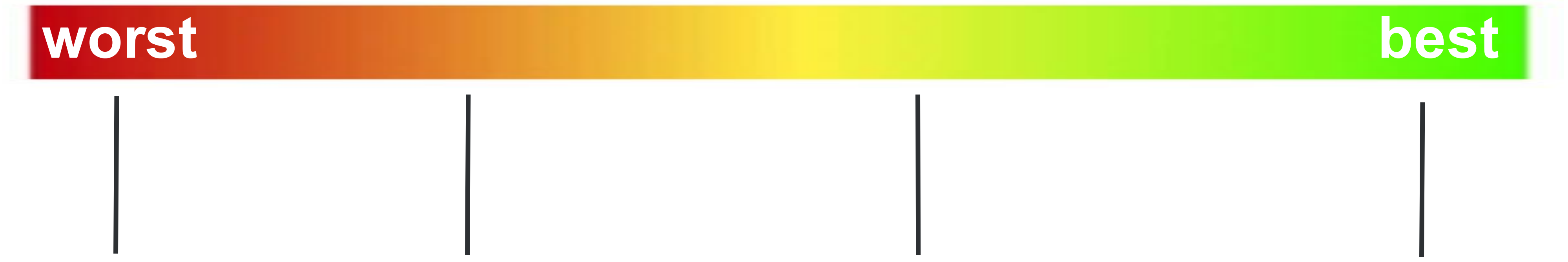
***Abstract*—Various email protocols, including IMAP, POP3, and SMTP, were originally designed as “plaintext” protocols without inbuilt confidentiality and integrity guarantees. To protect the communication traffic, TLS can either be used *implicitly* before the start of those email protocols, or introduced as an opportunistic upgrade in a post-hoc fashion. In order to improve user experience, many email clients nowadays provide a so-called “auto-detect” feature to automatically determine a functional set of configuration parameters for the users. In this paper, we present a multifaceted study on the security of the use of TLS and auto-detect in email clients. First, to evaluate the design and implementation of client-side TLS and auto-detect, we tested 49 email clients and uncovered various flaws that can lead to covert security downgrade and exposure of user credentials to attackers. Second, to understand whether current deployment practices adequately avoid the security traps introduced by opportunistic TLS and auto-detect, we collected and analyzed 1102 email setup**

and server to directly start with the TLS handshake first, and only after a TLS session is succesfully negotiated, then the email protocols begin and communicate inside the already established TLS channel. This approach is commonly known as “implicit TLS”, because from the perspective of email protcols, they did not have to explicitly negotiate whether TLS can be used. A contrasting approach, which is sometimes known as “explicit TLS” or “opportunistic TLS”, lets the plaintext email protocols start communicating first, and then attempt to negotiate a security upgrade to use TLS, the success of which depends on the capability of the client and server. Depending on the security policies being enforced, the email protocols could stay unencrypted even when opportunistic TLS is attempted, due to an active man-in-the-middle (MITM) downgrade attack [14].

A Multifaceted Study on the Use of TLS and Auto-detect in Email Ecosystems (2025)

Email client behavior*:

*can differ depending on email protocol and TLS downgrade test case



Downgrade to no-TLS without notifying the user

Ask user permission to authenticate without TLS

Continuously attempt to reconnect

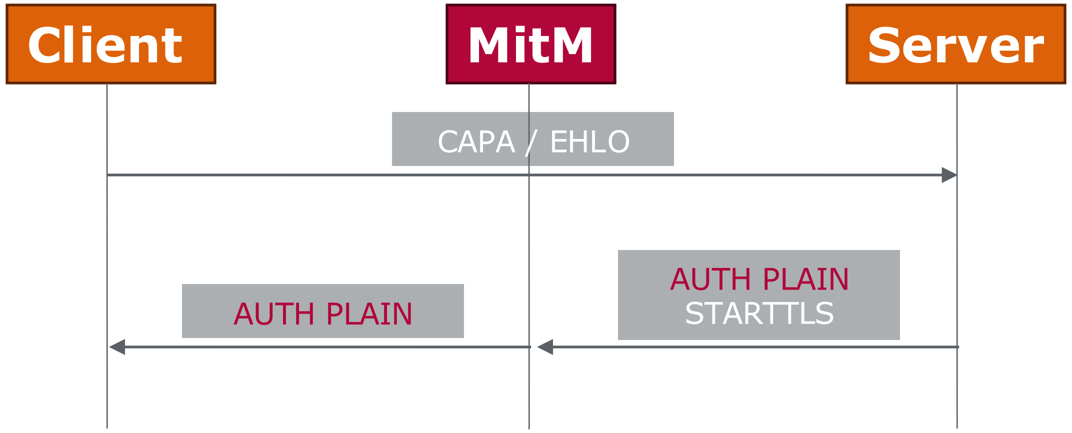
Do not authenticate without TLS

19 out of 49 tested clients may silently downgrade to no-TLS

A Multifaceted Study on the Use of TLS and Auto-detect in Email Ecosystems (2025)

Testing email client behavior: 4 variations of disruptions

T1:
"classic" strip
StartTLS test



T2: disrupt during TLS handshake
T3: disrupt after client selects STARTTLS
T4: disrupt ongoing TLS session

Is your email client vulnerable?

Selftest Service

A way to test your email client in use.

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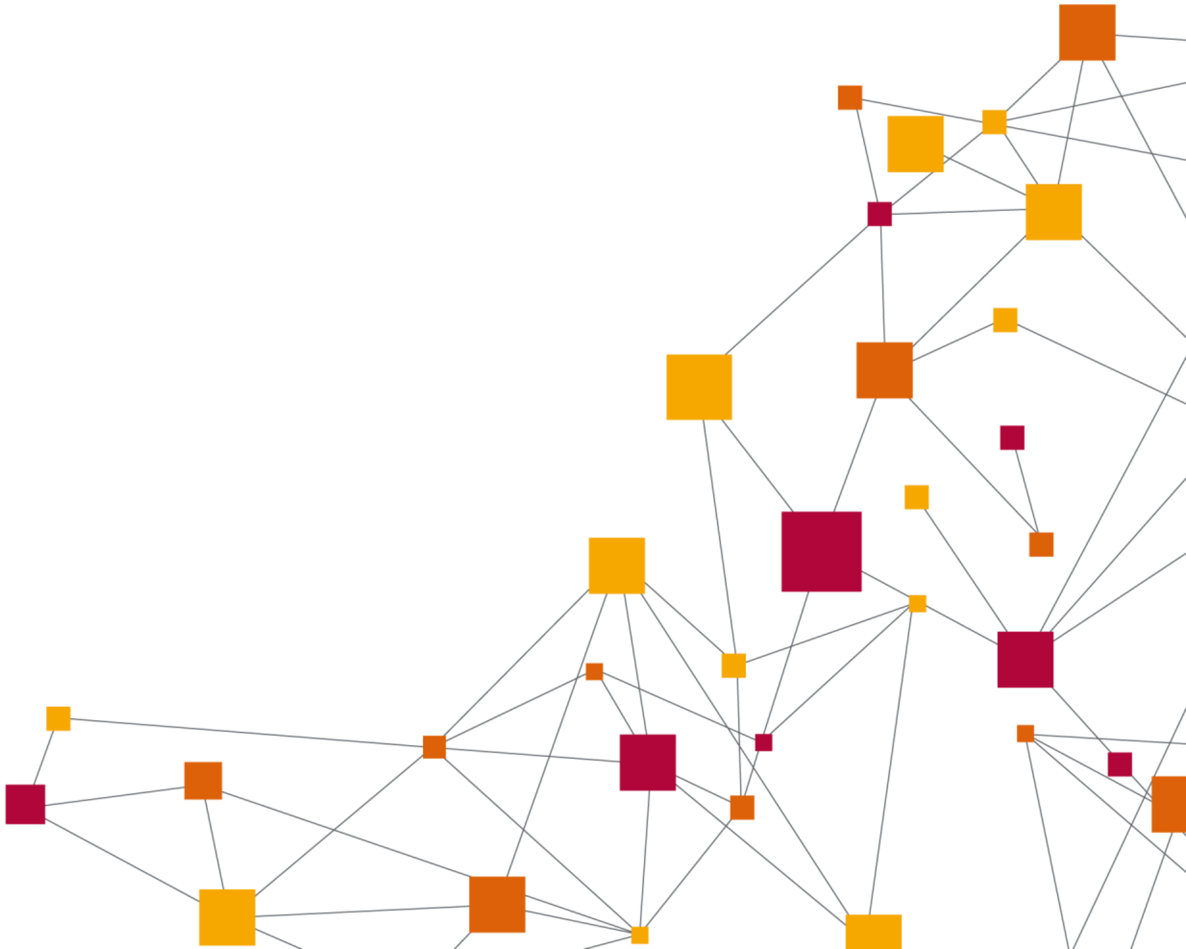

What did we build?

- Public, server-side **mail client self-test** for **SMTP + IMAP**
- Tests whether a client can be coerced into **plaintext authentication** when TLS protection is disrupted
- Implements **baseline + T1–T4** behaviors (paper-inspired)

Why did we build it?

- Paper setup assumes a **MITM/lab environment** (hard to reproduce for normal users)
- We want a **“click** → **configure account** → **observe result”** workflow
- No local proxy, no custom CA, no special network setup required

Demo

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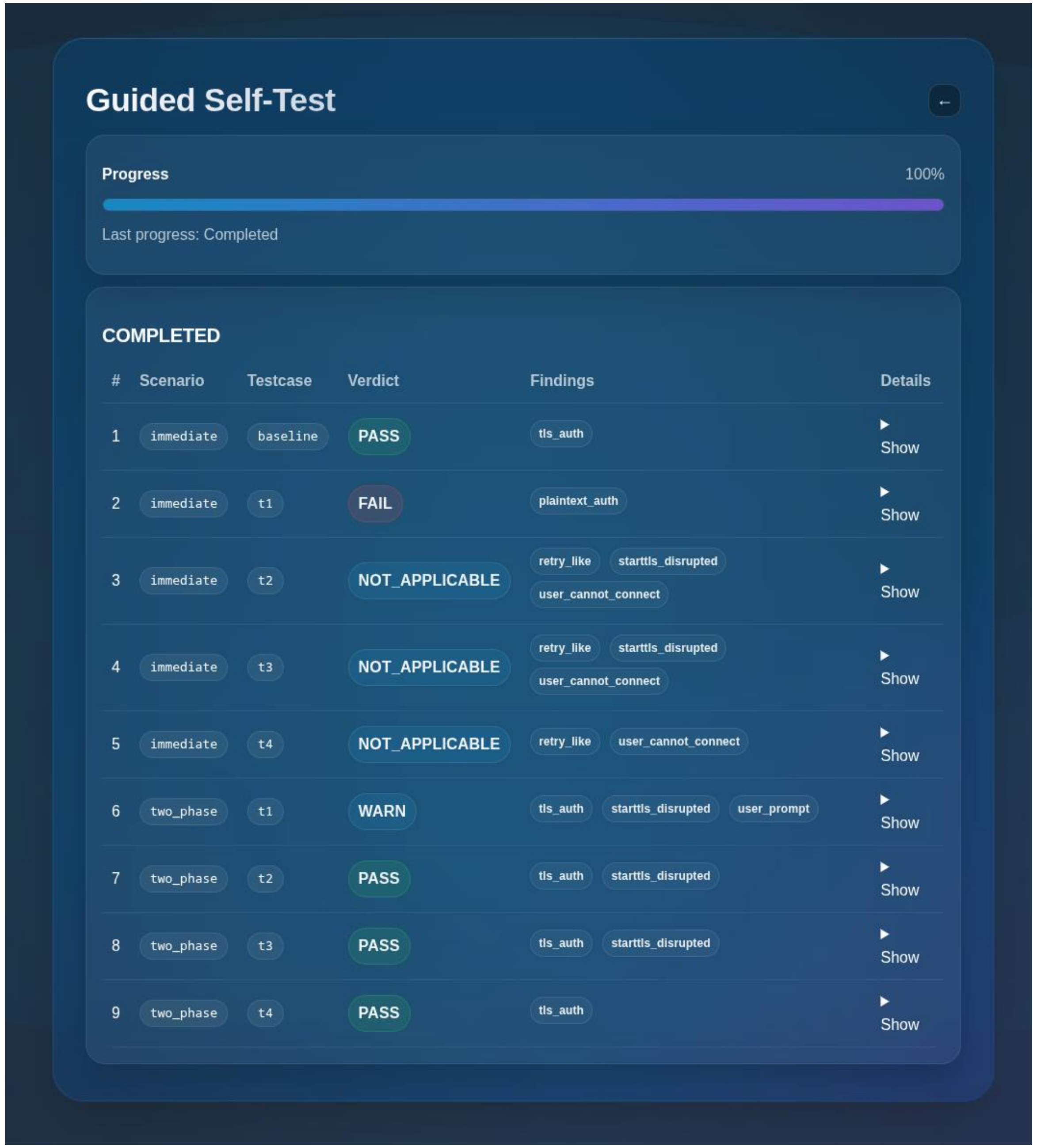
Result example



Guided Self-Test

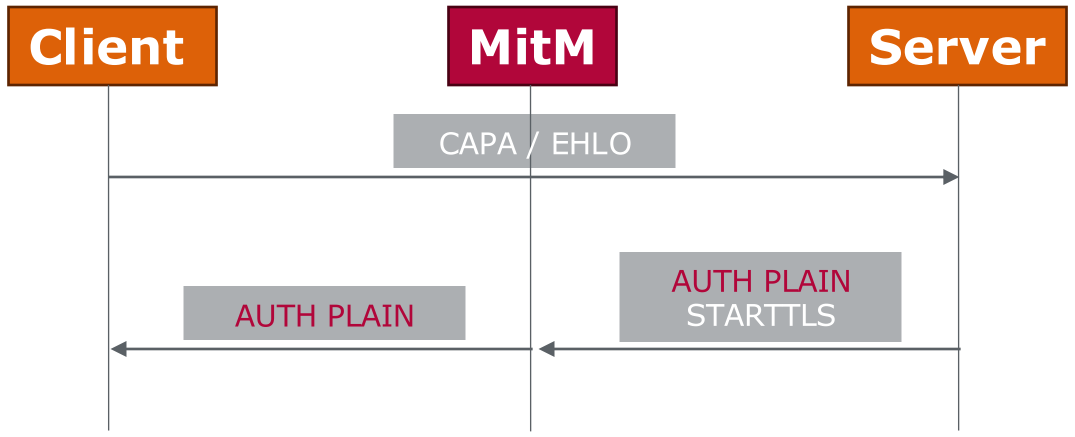
Progress 100%

Last progress: Completed

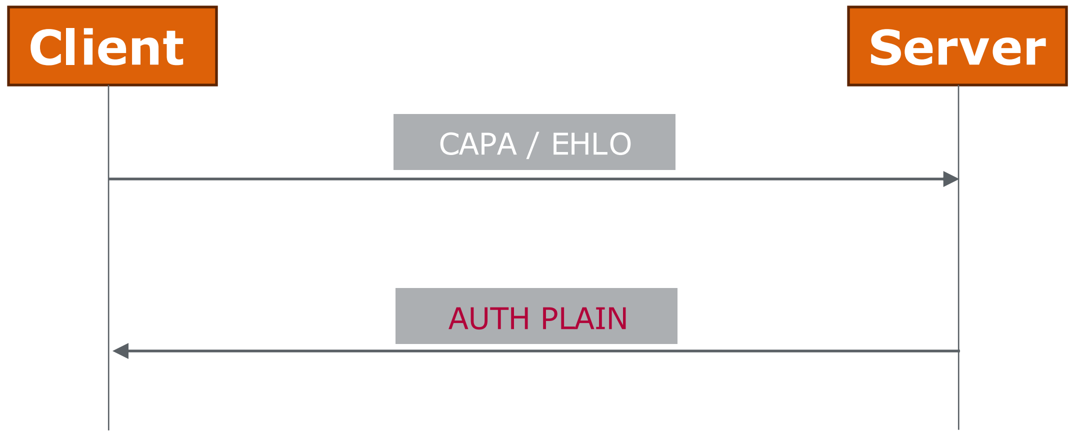
COMPLETED

#	Scenario	Testcase	Verdict	Findings	Details
1	immediate	baseline	PASS	tls_auth	▶ Show
2	immediate	t1	FAIL	plaintext_auth	▶ Show
3	immediate	t2	NOT_APPLICABLE	retry_like, starttls_disrupted, user_cannot_connect	▶ Show
4	immediate	t3	NOT_APPLICABLE	retry_like, starttls_disrupted, user_cannot_connect	▶ Show
5	immediate	t4	NOT_APPLICABLE	retry_like, user_cannot_connect	▶ Show
6	two_phase	t1	WARN	tls_auth, starttls_disrupted, user_prompt	▶ Show
7	two_phase	t2	PASS	tls_auth, starttls_disrupted	▶ Show
8	two_phase	t3	PASS	tls_auth, starttls_disrupted	▶ Show
9	two_phase	t4	PASS	tls_auth	▶ Show

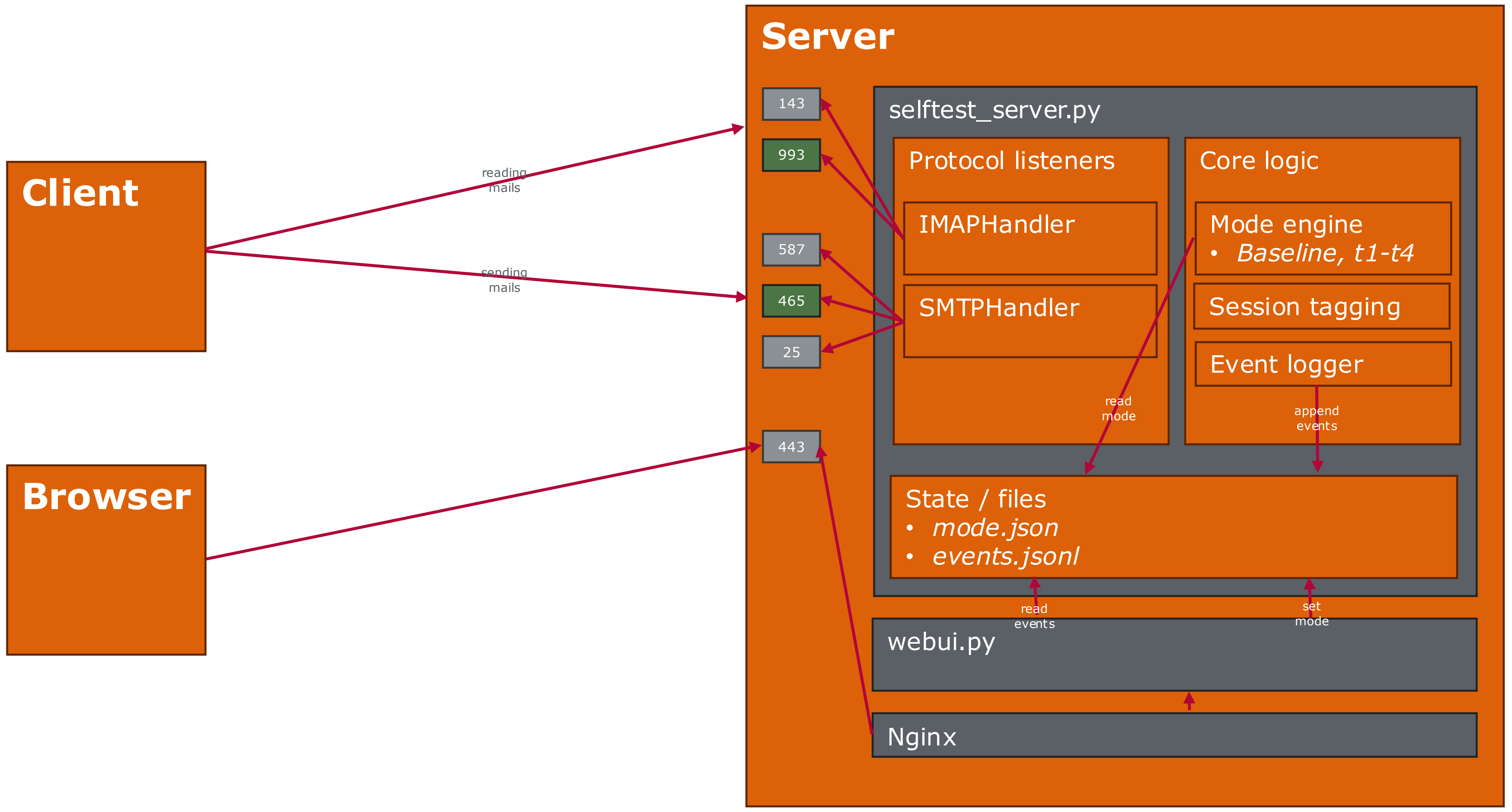
"Simulation" Diagram of T1



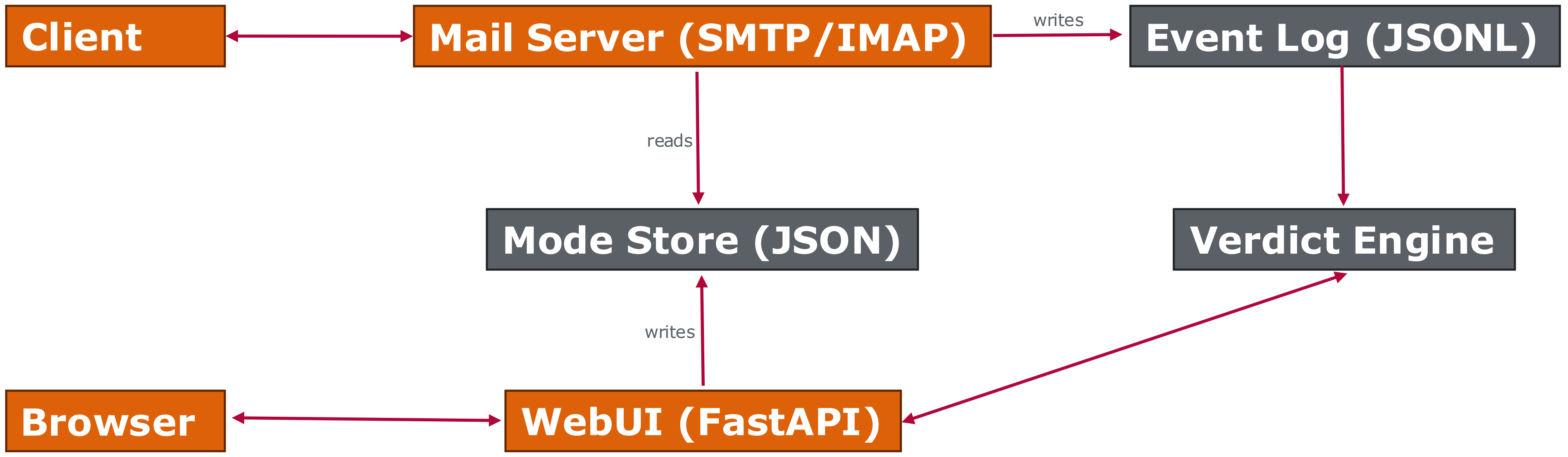
"Simulation" Diagram of T1



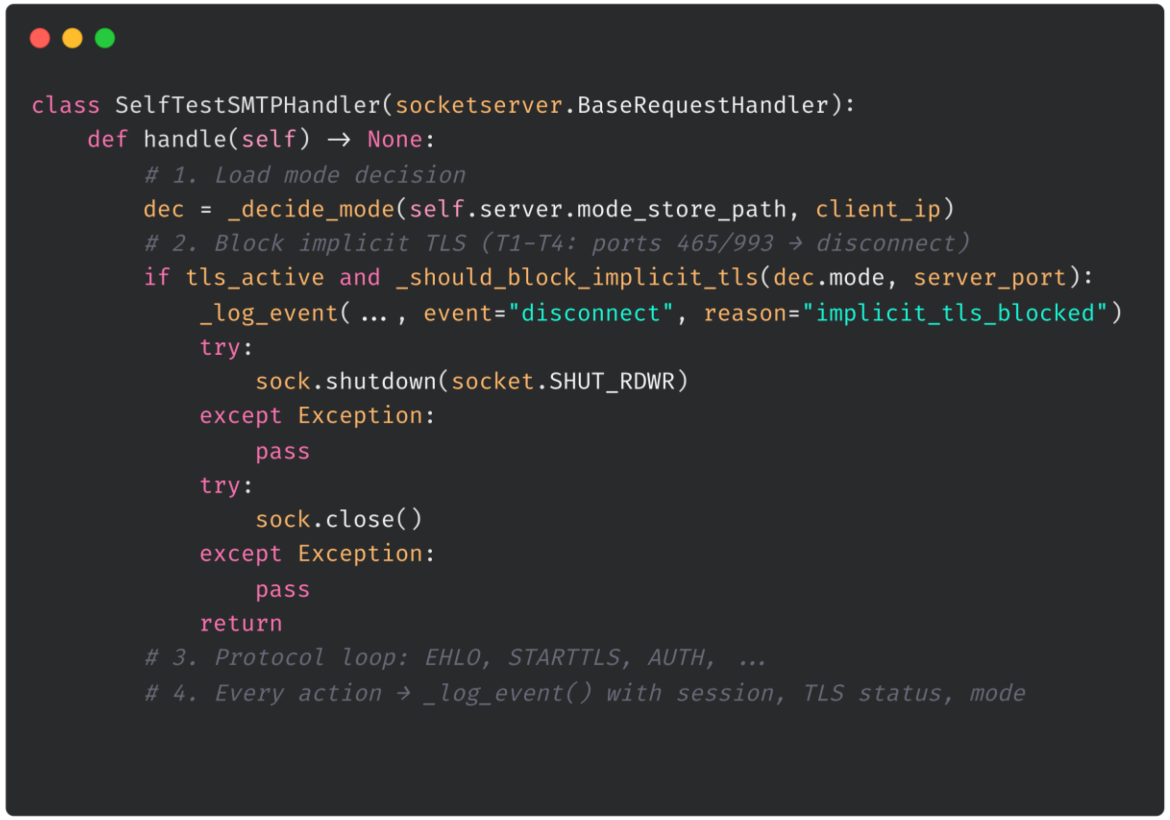
Selftest-Service architecture



Selftest-Service architecture



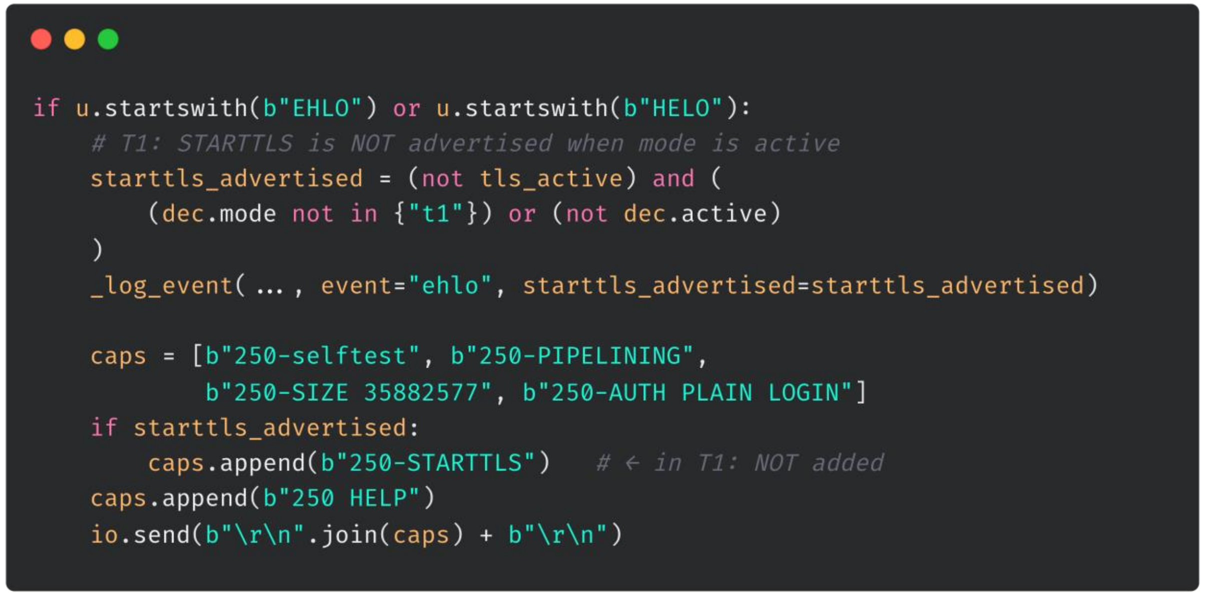
Handler Architecture – Code Overview



```python
class SelfTestSMTPHandler(socketserver.BaseRequestHandler):
    def handle(self) → None:
        # 1. Load mode decision
        dec = _decide_mode(self.server.mode_store_path, client_ip)
        # 2. Block implicit TLS (T1-T4: ports 465/993 → disconnect)
        if tls_active and _should_block_implicit_tls(dec.mode, server_port):
            _log_event( ... , event="disconnect", reason="implicit_tls_blocked")
            try:
                sock.shutdown(socket.SHUT_RDWR)
            except Exception:
                pass
            try:
                sock.close()
            except Exception:
                pass
            return
        # 3. Protocol loop: EHLO, STARTTLS, AUTH, ...
        # 4. Every action → _log_event() with session, TLS status, mode
```

T1 Deep Dive – STARTTLS Capability Stripping (SMTP)

- **Baseline:** Server responds with `250-STARTTLS` → client upgrades to TLS → secure
- **T1 active:** `250-STARTTLS` is missing from the response → client "sees" no TLS option



```
if u.startswith(b"EHLO") or u.startswith(b"HELO"):
    # T1: STARTTLS is NOT advertised when mode is active
    starttls_advertised = (not tls_active) and (
        (dec.mode not in {"t1"}) or (not dec.active)
    )
    _log_event( ... , event="ehlo", starttls_advertised=starttls_advertised)

    caps = [b"250-selftest", b"250-PIPELINING",
            b"250-SIZE 35882577", b"250-AUTH PLAIN LOGIN"]
    if starttls_advertised:
        caps.append(b"250-STARTTLS")   # ← in T1: NOT added
    caps.append(b"250 HELP")
    io.send(b"\r\n".join(caps) + b"\r\n")
```

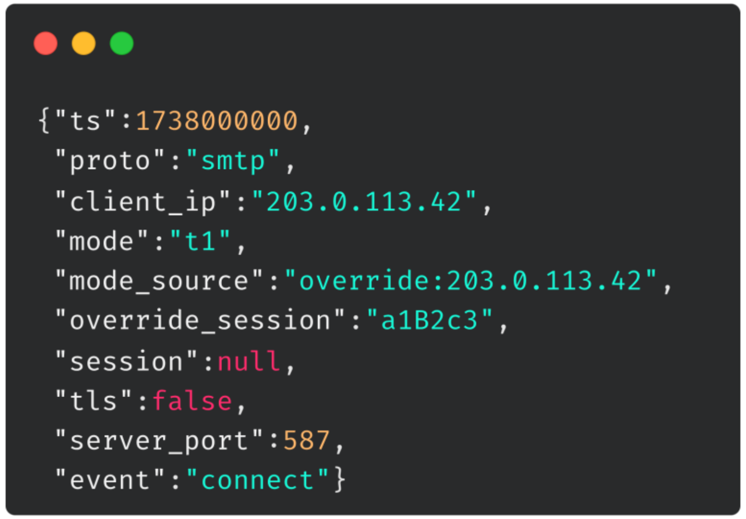
Event Logging – Structure & Examples

Example T1 event sequence (vulnerable client = FAIL):

#	Event	TLS	Meaning
1	connect	false	Client connects on port 587
2	ehlo	false	starttls_advertised: false (T1!)
3	auth_command	false	⚠️ Client sends AUTH without TLS
4	disconnect	false	Connection closed

Example T1 event sequence (secure client = INCONCLUSIVE):

#	Event	TLS	Meaning
1	connect	false	Client connects on port 587
2	ehlo	false	starttls_advertised: false (T1!)
3	disconnect	false	Client aborts (no STARTTLS → no login)



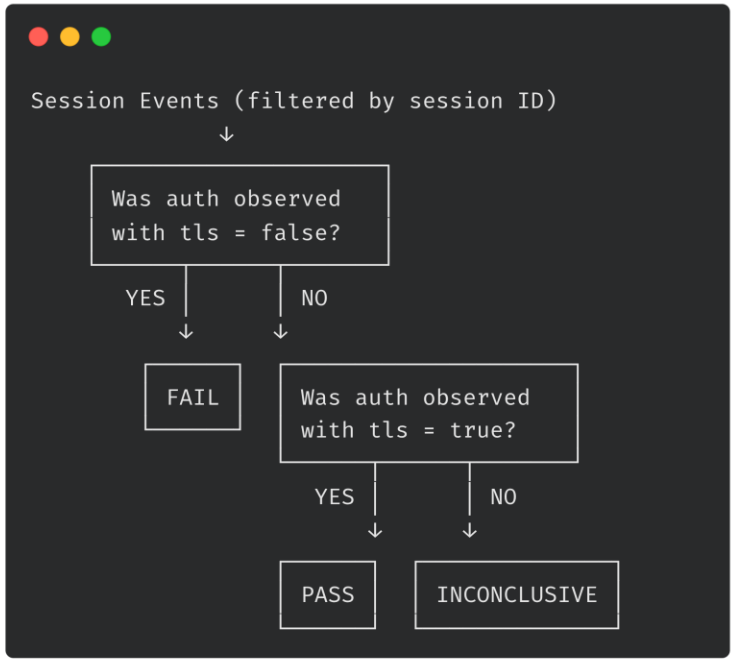
```
{"ts":1738000000,
 "proto":"smtp",
 "client_ip":"203.0.113.42",
 "mode":"t1",
 "mode_source":"override:203.0.113.42",
 "override_session":"a1B2c3",
 "session":null,
 "tls":false,
 "server_port":587,
 "event":"connect"}
```

Possible Verdicts

- **PASS**: Auth/login happened only with TLS (no plaintext credentials seen).
- **FAIL**: Auth/login happened without TLS (plaintext credentials exposure).
- **INCONCLUSIVE**: No auth/login observed (client aborted / got stuck / never reached auth).
- **WARN**: Client showed a security prompt/downgrade warning (user-reported; no plaintext proven).
- **NOT_APPLICABLE**: Test step couldn’t be executed (cannot connect; user-reported).
- **SKIPPED**: Step was skipped in Guided mode

Event Evaluation – Verdict Computation

Signal	Source	Meaning
auth_plain count	Event log (SMTP + IMAP)	Auth attempts observed without TLS
auth_tls count	Event log (SMTP + IMAP)	Auth attempts observed with TLS active
retry_like	≥6 connects, no auth	Client stuck in retry loop (keeps reconnecting)
starttls_refused_like	STARTTLS refused / dropped / wrap failed	Server disrupted TLS upgrade (testcase behavior)
User report: prompt	Manual user input	Client showed a security/downgrade prompt → WARN
User report: cannot_connect	Manual user input	Client could not connect at all → NOT_APPLICABLE



```
Session Events (filtered by session ID)
              ↓
   ┌──────────────────────┐
   │ Was auth observed    │
   │ with tls = false?    │
   └──────────────────────┘
     YES │       │ NO
         ↓       ↓
      ┌──────┐  ┌──────────────────────┐
      │ FAIL │  │ Was auth observed    │
      └──────┘  │ with tls = true?     │
                └──────────────────────┘
                  YES │       │ NO
                      ↓       ↓
                ┌──────┐  ┌──────────────┐
                │ PASS │  │ INCONCLUSIVE │
                └──────┘  └──────────────┘
```

Technical Challenges & Design Decisions

- **Session encoding in username:** `test-SESSION@domain` → server extracts session from username, since no other channel is available (no cookies/headers in SMTP/IMAP)
- **No real MITM required:** The server itself simulates attack behavior → no mitmproxy on client side, no custom CA installation needed
- **Implicit TLS blocking:** In T1–T4, ports 993/465 are immediately disconnected → forces clients onto STARTTLS ports where downgrade behavior is observable
- **Privacy-safe logging:** Passwords are never logged, only username/session + TLS status
- **TTL-based overrides:** Mode store with expiry per IP → no persistent state changes, automatic cleanup
- **Dual storage architecture:** Event log (JSONL) is append-only and crash-safe
- **Persistent historical results:** Guided run data and user-submitted session reports are never pruned

Pre-Authentication Session Binding Problem

```
Client connects (port 587)      ← only IP known
          ↓
Server sends: 220 ESMTP         ← still only IP is known
          ↓
Client: EHLO                    ← server responds with capabilities (T1 decision HERE)
          ↓
Client: AUTH PLAIN <base64>     ← session ID only available NOW (too late)
```

Problems:

- NAT / shared IPs
- CGNAT (mobile carriers)
- VPN / proxy
- Dynamic IP changes
- Race condition

Why no POP3?

- “legacy” protocol
- configuration effort for the user
- Result: adding POP3 would likely reduce completion rate for a public self-test
- For the initial service, IMAP + SMTP submission covers the most common real-world configurations

Existing Tools?

	EAST	CheckTLS	BadSSL	Our Selftest Service
Target	Email client (MUA)	Email server (MTA)	Web browser	Email client (MUA)
Interface	CLI / local VM	Web form	Website	Web app + credentials
Audience	Researchers	Admins	End users	End users / Admins
STARTTLS stripping test	Yes (simulated)	No (passive only)	N/A	Yes (simulated, T1–T4)
Setup required	Local lab environment	None	None	None
Protocols tested	SMTP, IMAP, POP3	SMTP (MTA-to-MTA)	HTTPS	SMTP, IMAP
Key limitation	Requires local proxy + CA	Tests server, not client	Web only, no email	IP-based session binding

	Lynis	testssl.sh	postfix check	Our Server Checker
Focus	Full system audit	TLS handshake analysis	Config syntax	Config logic (auth + TLS)
Depth	Broad (OS, apps, network)	Broad (OS, apps, network)	Superficial	Deep (interdependencies)
Test logic	"Is the service running?"	"Is RC4 enabled?"	"Typo in config?"	"Is auth without TLS possible?"
Mail-specific	Minimal	STARTTLS check only	Postfix only	Postfix + Dovecot
Config source	Static files	Network probes	Static files	Runtime config (postconf -n, doveconf -n)
Cross-check	No	No	No	Yes (e.g., master.cf overrides main.cf)
Output	Compliance report	TLS details	Errors/warnings	Findings + fix recommendations

Summary and Evaluation

Capabilities

- Realistic Attack Simulation
- Accessible to All Users
- Granular Diagnostics
- Server-Checker: Static Configuration Audit

Limitations

- IP-Based Mode Selection
- Destination Server, Not Proxy
- Protocol Scope
- Server Checker: No Runtime Verification