Cryptographic Protocol Design for LocalMart

KV6009 Advanced Security

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Confidentiality: Protecting Customer Data

Key Exchange

ECDHE on NIST P-256

Asymmetric · forward secrecy

NIST SP 800-56A

Bulk Encryption

AES-256-GCM

Symmetric AEAD · per-record nonce

FIPS 197

TLS Cipher Suite

TLS_AES_256_GCM_SHA384

Negotiated in TLS 1.3 handshake

RFC 8446

Forward secrecy: per-session ECDHE produces shared secret S = d_A · Q_B and is discarded after the handshake. Past traffic stays safe even if long-term keys leak.

Key Custody

Who	Long-term keys	Per-session keys	Sees
Certificate Authority	Root signing key	—	Issues server certs
LocalMart server	X.509 private key	Ephemeral ECDHE pair	Cart, address, never PAN
Customer browser	—	Ephemeral ECDHE pair	LocalMart public key + AES key
Stripe gateway	TLS + tokenisation keys	—	PAN (tokenised)

When? Keys generated at handshake → derived via HKDF → AES-256-GCM per record → discarded at session end.

TLS 1.3 Handshake

How the secure channel is established

1

Client Hello

Client offers AEAD ciphers, signature schemes, and an ephemeral ECDHE public key.

2

Server Hello

Server picks TLS_AES_256_GCM_SHA384, sends its ECDHE share, X.509 certificate, and CertificateVerify signature.

3

Shared Secret

Both sides compute S = d_A · Q_B and derive handshake + traffic keys via HKDF.

4

Encrypted Records

Client Finished + first request encrypted under AES-256-GCM. Ephemeral keys destroyed at session end.

RFC 8446 · Rescorla, 2018 · RFC 5869 · Krawczyk & Eronen, 2010 (HKDF) · Sullivan, 2018

Integrity: Detecting Tampering

In Transit

AES-256-GCM Authentication Tag

128-bit GHASH tag over GF(2^{128}), computed across ciphertext + AAD per record. Random forgery probability: $1 / 2^{128}$.

NIST SP 800-38D · Dworkin, 2007

At Rest

HMAC-SHA-256 Audit Tag

Per-order tag, server-held key. 256-bit output → birthday bound 2^{128}. Avalanche: ~half the bits flip per single-bit change in input.

FIPS 198-1 · NIST, 2008

Avalanche example: Flipping quantity 3 → 30 produces a completely different audit tag

```
"Order #1234: 2x cat food, 3x pickles, 2x trash bags - £20.00"
openssl dgst -sha256 -hmac "localmart-audit-key"
SHA2-256(stdin)= 7e2aad94679ef4c1b963870a28...

"Order #1224: 2x cat food, 30x pickles, 2x trash bags - £20.00"
openssl dgst -sha256 -hmac "localmart-audit-key"
SHA2-256(stdin)= a4f2e8d9c1bfgu7tfdt7dv87...  (completely different)
```

Cafe Wi-Fi MITM: flips 3 → 30: GCM tag check fails, record dropped, connection torn down.

Authentication: Verifying Identities

Server → Customer

X.509 Certificates

CA signs the certificate → server presents it on TLS handshake → browser verifies via the trust chain (root pre-installed).

Attack

Phishing site impersonates localmart.com to harvest credentials.

Why it fails

Forging a valid cert = breaking RSA-2048 (2^{112} operations) or finding a SHA-256 collision (2^{128}). Both infeasible. Browser detects the mismatch → TLS aborts before the password leaves the device.

RFC 5280 · Cooper et al., 2008

Customer → Server

bcrypt + JWT

1. Customer submits email + password over TLS.
2. Server verifies against bcrypt hash (cost 12).
3. Server issues HMAC-SHA-256 signed JWT (15–30 min).
4. Browser sends JWT per request; signature validated.

Attack

Stolen credential database → brute-force on password hashes.

Why it fails

bcrypt cost 12 = 4 hashes/sec/core. An 8-char alphanumeric password ($62^8 = 2.2\times10^{14}$ candidates) takes 1.7 million CPU years to exhaust. JWT forgery requires a 256-bit HMAC key = 2^{256} opperations.

RFC 7519 · Jones, Bradley & Sakimura, 2015

Security Analysis: Threat Defences

Eavesdropping

TLS 1.3 encrypts all data with AES-256-GCM; handshake itself is encrypted after Server Hello.

RFC 8446 · Rescorla, 2018

Man-in-the-Middle

X.509 certs verified via CA trust chain; CertificateVerify proves the server holds the private key.

RFC 5280; RFC 8446 §4.4.3

Replay Attack

TLS sequence numbers in IV; ephemeral session keys.

RFC 8446 §5.3 · Rescorla, 2018

Tampering

GCM auth tag detects in-transit modification; HMAC-SHA-256 audit tag protects stored orders.

NIST SP 800-38D; FIPS 198-1

Session Hijacking

Short-lived JWTs (15–30 min) over TLS only; HMAC-SHA-256 signed; refresh-token rotation.

RFC 7519; RFC 9700

Brute Force

bcrypt cost 12 (3–4 attempts/sec); rate limiting on login; optional MFA.

Provos & Mazières, 1999; OWASP, n.d.

Defence-in-depth

Transport	Credential	Session	Record	At-rest	PCI scope
TLS 1.3	bcrypt	JWT	GCM tag	HMAC-SHA-256	tokenisation

Limitations & Compliance

Limitations

No Client Certificates

Security rests on password strength; mitigated by MFA.

CA Trust Dependency

Compromised CA → MITM (DigiNotar). Fix: CT logs + CAA.

Hoogstraaten, 2012; RFC 6962; RFC 8659

Payment Gateway Trust

Stripe breach risk; PCI-DSS Level 1 + SLAs.

PCI SSC, 2024

TLS 1.3 0-RTT Risk

0-RTT is replay-vulnerable; disabled for state changes.

RFC 8446 §8 · Rescorla, 2018

bcrypt over Argon2id

Argon2id = OWASP first pick; bcrypt cost 12 above min.

RFC 9106; OWASP, n.d.

Compliance

PCI-DSS Req 4.2.1

Strong cryptography for PAN in transit (TLS 1.3 + AES-256-GCM).

PCI SSC, 2024

PCI-DSS Req 8

Strong authentication (bcrypt cost 12 + signed JWT).

PCI SSC, 2024

GDPR Art. 32

Appropriate technical measures (AES-256-GCM, audit trail).

EU Parliament & Council, 2016

GDPR Art. 25

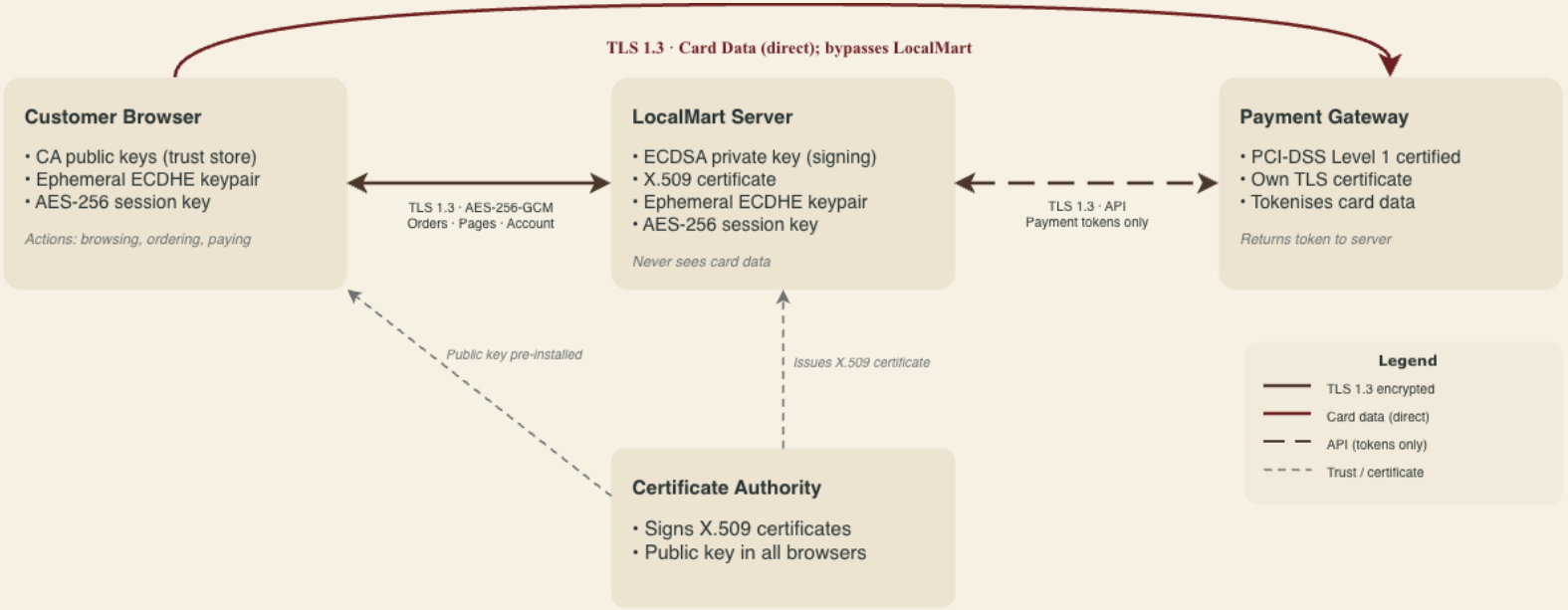
Privacy by design; data minimisation; tokenised PANs.

EU Parliament & Council, 2016

Security Posture

Criteria	Before	After
Data in Transit	Plaintext HTTP. Orders, passwords, card fields readable in transit.	TLS 1.3: ECDHE (P-256) + AES-256-GCM record encryption. RFC 8446; FIPS 197
Server Identity	Not verified. Customers cannot tell LocalMart from an imposter.	X.509 cert signed by trusted CA; trust chain validated by browser. RFC 5280
Customer Login	Passwords transmitted in plaintext; replayable; no brute-force protection.	bcrypt (cost 12) + HMAC-SHA-256 JWT (15–30 min). Provos & Mazières, 1999; RFC 7519
Order Integrity	Modifiable in transit and at rest; no detection; no audit trail.	AES-256-GCM auth tag in transit; HMAC-SHA-256 audit tag at rest. NIST SP 800-38D; FIPS 198-1
Card Data	PANs stored on the local server (in PCI scope; breach risk).	Tokenised via PCI-DSS Level 1 gateway; PANs never touch server. PCI SSC, 2024
Compliance	Fails PCI-DSS and GDPR baseline obligations.	PCI-DSS Req 4.2.1 & Req 8 met; GDPR Art. 25 & Art. 32 met. PCI SSC, 2024; EU, 2016

System Architecture Overview



Transaction Flow

1. Browse	2. Order	3. Pay	4. Confirm
TLS 1.3 · public catalogue · no auth	bcrypt login · HMAC-SHA256 JWT · encrypted cart	Browser → Stripe direct · token to server	signed confirmation · HMAC-SHA-256 audit log

Cipher Suite: **TLS_AES_256_GCM_SHA384** · Key Exchange: **ECDHE** · Signatures: **ECDSA** · All transport via TLS 1.3

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