CISPA
HELMHOLTZ CENTER FOR INFORMATION SECURITY

Why Eve and Mallory Still Love Android: Revisiting TLS (In)Security in Android Applications

Marten Oltrogge, Nicolas Huaman, Sabrina Amft
Yasemin Acar, Michael Backes, Sascha Fahl

Android and TLS - Prior Research

CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

Long History of research on the urgent state of custom TLS in Android apps rendering them vulnerable for MITMAs

FAHL et al. Why Eve and Mallory love Android: An analysis of Android SSL (in)security [54]

FAHL et al. Rethinking SSL Development in an Appified World [56]

GEORGIEV et al. The most dangerous code in the world: validating SSL certificates in non-browser software [58]

CHOTHIA et al. Why banker bob (still) can't get tls right: A security analysis of tls in leading uk banking apps [47]

CONTI et al. Mind the hand you shake-protecting mobile devices from SSL usage vulnerabilities [48]

OLTROGGE et al. To Pin or Not to Pin - Helping App Developers Bullet Proof Their TLS Connections [74]

ONWUZURIKE et al. Danger is my middle name: experimenting with SSL vulnerabilities in Android apps [77]

SOUNTHIRARAJ et al. SMV-Hunter: Large scale, automated detection of SSL/TLS man-in-the-middle vulnerabilities in android apps [84]

TENDULKAR et al. An Application Package Configuration Approach to Mitigating Android SSL Vulnerabilities [85]

OLTROGGE et al. The rise of the citizen developer: Assessing the security impact of online app generators [75]

Some proposed countermeasures

[56] and [85] propose a declarative configuration-driven approach letting developers implement custom TLS without code

```
@Override
public boolean verify(
    String host,
    SSLSession session) {
    return true;
}
```

```
@Override
public void checkServerTrusted(
    X509Certificate[] chain, String authType)
throws CertificateException {
}
```

```
@Override
public void onReceivedSslError (
      WebView view,
      SslErrorHandler handler,
      SslError error) {
         handler.proceed();
}
```

Android and TLS - New Countermeasures

To address this urgent state, new countermeasures and novel mechanisms have been introduced:

- **Network Security Configuration (NSC)** added in Android 7 to keep developers from implementing possibly insecure custom certificate validation code
- **Safe defaults** to make mounting of MITMAs harder
  - Not trust for user CAs by default in Android 7
  - Enforcing HTTPS by default in Android 9
- **Safeguards** to block apps containing vulnerable certificate validation code

		Date	Android Version	Description
🤖	1	2015-10-05	Android 6 (API 23)	Android introduces the "android:usesCleartextTraffic" flag for Manifest files, and removes the Apache HTTP Client library [33,59,64].
▶	2	2016-05-17		Google Play blocks apps containing unsafe implementations of the X509TrustManager interface [67].
🤖	3	2016-08-22	Android 7 (API 24)	Android introduces NSC, distrusts user-installed certificates, and ignores the "android:usesCleartextTraffic" flag in case a NSC file is available [44,60].
▶	4	2016-11-25		Google Play blocks apps containing unsafe implementations of the onReceivedSslError method in WebViews [66].
▶	5	2017-03-01		Google Play blocks apps containing unsafe implementations of the HostnameVerifier interface [68].
🤖	6	2017-08-21	Android 8 (API 26)	Android adds support for the "cleartextTrafficPermitted" flag for the WebView class [61].
▶	7	2018-08-01		New apps need to target at least Android 8; makes new safe defaults introduced with Android 7 (2016-08-22) and Android 8 (2017-08-21) [49,65] available to those apps.
🤖	8	2018-08-08	Android 9 (API 28)	Sets "cleartextTrafficPermitted" to false; enforces HTTPS connections by default. Developers can revert this for specific domains or globally in NSC) settings [63].
▶	9	2018-11-01		App updates need to target at least Android 8; makes new safe defaults introduced with Android 7 (2016-08-22) and Android 8 (2017-08-21) [49,65] available to existing apps.
▶	10	2019-08-01		New apps need to target at least Android 9; makes new safe defaults introduced with Android 9 (2018-08-08) [49,65] available to those apps.
▶	11	2019-11-01		Updates need to target at least Android 9; existing apps benefit from new safe defaults introduced with Android 9 (2018-08-08) [49,65].

🤖 Affects Android OS & NSC – ▶ Affects Google Play security policy & safeguards.

```
@Override
public boolean verify(
    String host,
    SSLSession session) {
    return true;
}

@Over
public voi                verTrusted(
    X509Ce                chain, String authType)
throws C                  ption {
}

@Override
public void onReceivedSslError (
      WebView view,
      SslErrorHandler handler,
      SslError error) {
         handler.proceed();
}
```

Network security configuration - Features

- Allows to implement custom network security behaviour without writing code
  - Allow or disallow cleartext traffic

```
<?xml version="1.0" ?>
<network-security-config>
    <base-config cleartextTrafficPermitted="[true|false]"/>
    <domain-config cleartextTrafficPermitted="[true|false]">
        <domain includeSubdomains="true">example.com</domain>
    </domain-config>
</network-security-config>
```

Network security configuration - Features

- Allows to implement custom network security behaviour without writing code
  - Allow or disallow cleartext traffic
  - Configure trust anchors

```
<?xml version="1.0" ?>
<network-security-config>
   <domain-config>
        <domain includeSubdomains="true">example.com</domain>
        <trust-anchors>
              <certificates src="system"/>
              <certificates src="user"/>
              <certificates src="@raw/ca"/>
        </trust-anchors>
   </domain-config>
</network-security-config>
```

Network security configuration - Features

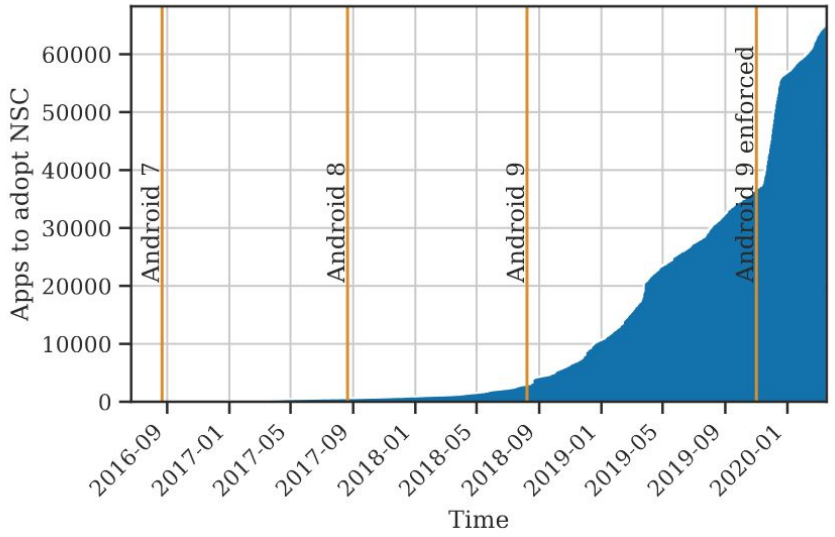
- Allows to implement custom network security behaviour without writing code
  - Allow or disallow cleartext traffic
  - Configure trust anchors
  - Implement Pinning without any code

```
<?xml version="1.0" ?>
<network-security-config>
   <domain-config>
       <domain includeSubdomains="true">example.com</domain>
       <pin-set expiration="...">
              <pin digest="SHA-256">7HIpactkIAq2Y49orFOOQKurWxmmSFZhBCoQYcRhJ3Y=</pin>
              <pin digest="SHA-256">fwza0LRMXouZHRC8Ei+4PyuldPDcf3UKgO/04cDM1oE=</pin>
        </pin-set>
   </domain-config>
</network-security-config>
```

Network security configuration - Security Analysis

- Collected 1,335,322 Apps (between 2016/08/22 and 2020/03/18)
- Detected NSC in 99,212 Apps
- Could analyze 96,400 custom NSC files

- Adoption correlates with enforcement of Android 9 which deactivates cleartext traffic by default



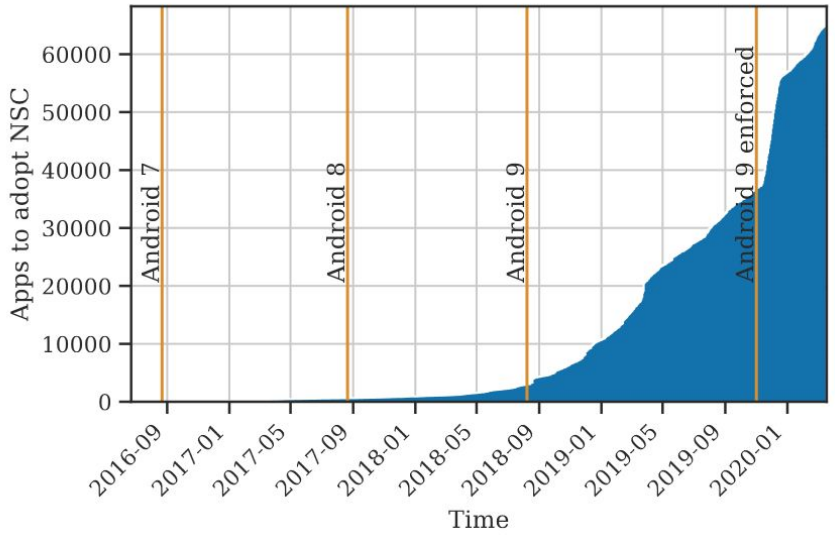
	Total Apps	Apps w. NSC
Target SDK		
< Android 7⋆	236,843	68
>= Android 7	1,098,479	96,332
>= Android 8	963,750	95,826
>= Android 9	565,910	88,854
Total	1,335,322	96,400

⋆ Though NSC is only supported for Android 7 and higher, apps with lower target SDKs can use backport-libraries (e.g., TrustKit. [25]) to implement NSC.

Network security configuration - Security Analysis

- Cleartext traffic configuration
  - **Allowing cleartext traffic again is most prominent use case of NSC (>98%)**
  - **Undermine safe defaults (introduced in Android 9)**

  - In-depth analysis of affected domains
    - Cleartext traffic allowed for 24,653 domains
    - 8,935 of these domains support HTTPS ⟶ cleartext traffic not necessary
  - We find especially third party libraries to instruct developers to allow cleartext traffic
    - Local caching & Ad-Libraries



Target	true	false
>= Android 9	○	◐
Global	57,123	1,252
Domain Specific	34,246	2,712
Total	84,060	3,908
< Android 9	◐	●
Global	4,002	36
Domain Specific	826	151
Total	4,709	185
All Android Versions	88,769	4,093

○ Negative impact on security; ◐ No impact on security; ● Positive impact on security

Network security configuration - Security Analysis

- Custom Trust Anchors configuration
  - **8,606 Apps re-enable trust for user CAs (8.67%)**
  - **Undermine safe defaults (introduced with Android 7)**

  - Gathered data on distribution of Trust Anchor configurations
  - In-depth analysis of Custom Trusted CAs
    - 759 (partially) only trust their own set of CAs (30 globally, 744 for domains)
    - 836 apps added supplementary certificates (784 globally, 58 for domains)
  - Find Mis-Use of debug configuration
    - At least for 41 cases, we find “Proxy” Certificates registered outside <debug-overrides>

```
<trust-anchors>
        <certificates src="system"/>
        <certificates src="user"/>
        <certificates src="@raw/ca"/>
</trust-anchors>
```

Network security configuration - Security Analysis

- Pinning configuration
  - **Only 663 Apps (0.67%) make use pinning**
  - Limited use of NSC for security enhancements

  - Conducted an in-depth Pin Analysis for domains in pinning configurations
    - Fetched certificates for domains to match against pins
  - Analysis of backup pins
  - Analysis of pins' expiration

```
<domain-config>
    <domain includeSubdomains="true">example.com</domain>
    <pin-set expiration="...">
        <pin digest="SHA-256">7HIpactkIAq2Y49orFOOQKurWxmmSFZhBCoQYcRhJ3Y=</pin>
        <pin digest="SHA-256">fwza0LRMXouZHRC8Ei+4PyuldPDcf3UKgO/04cDM1oE=</pin>
    </pin-set>
</domain-config>
```

Network security configuration - Security Analysis

- Malformed NSC configurations
  - Flawed parameter values for <domain> → <domain-config> has no effect
    - e.g. using URLs (e.g. https://...) instead of domains
  - Ambiguous Pinning configurations → Pinning has no effect
    - 6 Apps with trust anchors with *oververridePins=”true”*
    - Apps that allow cleartext traffic for pinned domains
    - Obviously non-functional pins
- Root causes: C/P, limited documentation and tool support

```
<domain-config>
    <domain cleartextTrafficPermitted="true">https://example.com</domain>
    <pin-set expiration="...">
        <pin digest="SHA-256">BBBBBBBBBBBBBBBBBBB...BBBBBBBBBBBBBBBBBB</pin>
    </pin-set>
    <trust-anchors>
        <certificates src="system" overridePins=”true”/>
    </trust-anchors>
</domain-config>
```

Efficacy of Google Play Safeguards

- Evaluating the efficacy of Google Play Safeguards:
  - Built various insecure custom TLS samples
  - Published on Play

```
@Override
public boolean verify(
    String host,
    SSLSession session) {
    return true;
}
```

```
@Override
public void checkServerTrusted(
    X509Certificate[] chain, String authType)
throws CertificateException {
}
```

```
@Override
public void onReceivedSslError (
      WebView view,
      SslErrorHandler handler,
      SslError error) {
         handler.proceed();
}
```

Efficacy of Google Play Safeguards

- Evaluating the efficacy of Google Play Safeguards:
  - Built various insecure custom TLS samples
  - Published on Play
  - Violating policies

```
@Override
public boolean verify(
    String host,
    SSLSession session) {
    return true;
}

@Override
public void onReceivedSslError (
      WebView view,
      SslErrorHandler handler,
      SslError error) {
         handler.proceed();
}
```

Efficacy of Google Play Safeguards

- Evaluating the efficacy of Google Play Safeguards:
  - Built various insecure custom TLS samples
  - Published on Play
  - Violating policies

- Result
  - Only in two cases app was rejected
    - WebViewClient only calling proceed() on TLS error
    - Insecure version of Acra library → likely fingerprinted as parts are not blocked
  - Limited capabilities for detecting dangerous implementations
  - Only trivial cases catched

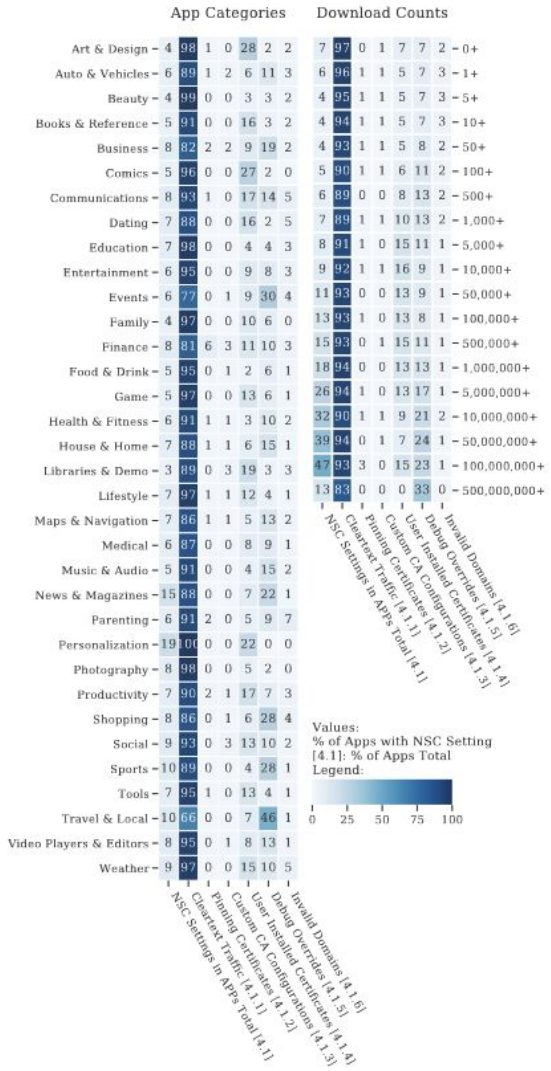
Experiment	Reachability	Passed	Validation Logic
TrustManager			
TM-U	○	✓	No Validation at All
TM-R	●	✓	No Validation at All
TM-D	◐	✓	No Validation at All
TM-R-renamed	●	✓	No Validation at All, Renamed
TM-R-expired	●	✓	Cert Is Not Expired
TM-R-selfsigned	●	✓	Cert Is selfsigned and Not Expired
TM-R-chain	●	✓	Cert Has a Chain
TM-R-chainexpired	●	✓	Cert Has a Chain or Is Not Expired
HostnameVerifier			
HV-R	●	✓	No Validation at All
HV-D	◐	✓	No Validation at All, Debug switch
HV-R-global	●	✓	No Validation at All, Used by Default
HV-R-contains	●	✓	Verify Hostname Using "string.contains"
WebViewClient			
WV-R	●	X	always proceed
WV-D	◐	✓	always proceed, Debug switch
WV-wrapped	●	✓	always proceed, Depend on invariant condition
Library			
LB-U-acra	○	X	Acra with Insecure TM
LB-U-jsoup	○	✓	JSoup with Insecure TM and HV
LB-U-asynchttp	○	✓	async-http with insecure TM

● Always (R)eachable; ◐ Hidden Using a Debug Flag; ○ (U)nreachable
✓ App was accepted by Google Play; X App was blocked by Google Play

Security impact of our findings

- Assessing impact of NSC settings
  - NSC impacts security on all levels of popularity
  - Manual analysis of apps allowing HTTP
    - threats for eavesdropping
    - sensitive data transmitted via HTTP
    - including Login Data

- Assessing prevalence of insecure TLS code in Apps:
  - Replicated Fahl et al. [54]
  - Used CryptoGuard for 15,000 recent Apps
  - Checked for insecure HostnameVerifier and TrustManager implementations
  - Result
    - Still find insecure TLS code in 5,511 Apps
    - Results in line with prior work



Discussion and Takeaways

Customization is still Harmful:

- New safe defaults enhanced security
  - HTTPS and no trust for user CAs by default
  - Reduce attack surface for MITMAs
- NSC mostly used to undermine safe defaults (>88%)
- Sparse use to actually enhancing security as only 663 use pinning

Customization is Error-Prone:

- New forms of misconfiguration & misconception
- Even if intended to enhance security
  - Can cause the opposite
  - If tools are not used correctly
- Undiscerning use of C/P code samples
- Limited (tool) support (e.g. LINT)

Safeguards are insufficient:

- New policies to avoid common pitfalls of insecure certificate validation implementations
- Enforcement still insufficient
- Insecure implementation still present in the wild

Recommendation:

- Need for better (tool) support and documentation
- Enhanced capabilities of Safeguards

Thank you

Questions?

Why Eve and Mallory Still Love Android:
Revisiting TLS (In)Security in Android Applications

Marten Oltrogge* *marten.oltrogge@cispa.saarland*

Nicolas Huaman† *huaman@sec.uni-hannover.de*

Sabrina Amft† *amft@sec.uni-hannover.de*

Yasemin Acar† *acar@sec.uni-hannover.de*

Michael Backes* *backes@cispa.saarland*

Sascha Fahl† *fahl@sec.uni-hannover.de*

**CISPA Helmholtz Center for Information Security*

†*Leibniz University Hannover*