
# Android Cryptography and Network Security

## Lecture 6

Security of Mobile Devices

2018

# Outline

# JCA Provider Architecture

- Java Cryptography Architecture (JCA)
  - Extensible cryptographic provider framework
  - Set of APIs - major cryptographic primitives
  - Applications specify an algorithm, do not depend on particular provider implementation
- Cryptographic Service Provider (CSP)
  - Package with implementation of cryptographic services
  - Advertises the implemented services and algorithms
  - JCA maintains a registry of providers and their algorithms
  - Providers in a order of preference
- Service Provider Interface (SPI)
  - Common interface for implementations of a specific algorithm
  - Abstract class implemented by provider

# JCA Engine Classes

- JCA engines provide:
  - Cryptographic operations (encrypt/decrypt, sign/verify, hash)
  - Generation or conversion of cryptographic material (keys, parameters)
  - Management and storage of cryptographic objects (keys, certificates)
- Decouple client code from algorithm implementation
- Static factory method `getInstance()`
- Request implementation indirectly

```
static EngineClassName getInstance(String algorithm)
        throws NoSuchAlgorithmException
static EngineClassName getInstance(String algorithm, String provider)
        throws NoSuchAlgorithmException, NoSuchProviderException
static EngineClassName getInstance(String algorithm, Provider provider)
        throws NoSuchAlgorithmException
```

# Message Digest

- Hash function

```
MessageDigest md = MessageDigest.getInstance("SHA-256");
byte[] data = getMessage();
byte[] hash = md.digest(data);
```

- Data provided in chuncks using `update()` then call `digest()`
- If data is short and fixed - hashed in one step using `digest()`

# Signature

- Digital signature algorithms based on asymmetric encryption
- Algorithm name: `<digest>with<encryption>`
- Sign:

```
byte[] data = "message to be signed".getBytes("ASCII");

Signature s = Signature.getInstance("SHA256withRSA");
s.initSign(privKey);
s.update(data);
byte[] signature = s.sign();
```

- Verify:

```
Signature s = Signature.getInstance("SHA256withRSA");
s.initVerify(pubKey);
s.update(data);
boolean valid = s.verify(signature);
```

# Cipher

- Encryption and decryption operations
- Encryption:

```
Secret key = getSecretKey();

Cipher c = Cipher.getInstance("AES/CBC/PKCS5Padding");

byte[] iv = new byte[c.getBlockSize()];
SecureRandom sr = new SecureRandom();
sr.nextBytes(iv);
IvParameterSpec ivp = new IvParameterSpec(iv);
c.init(Cipher.ENCRYPT_MODE, key, ivp);

byte[] data = "Message to encrypt".getBytes("UTF-8");
byte[] ciphertext = c.doFinal(data);
```

# Cipher

- Decryption:

```
Cipher c = Cipher.getInstance("AES/CBC/PKCS5Padding");
c.init(Cipher.DECRYPT_MODE, key, ivp);

byte[] data = c.doFinal(ciphertext);
```

# MAC

- Message Authentication Code algorithms

```
SecretKey key = getSecretKey();
Mac m = Mac.getInstance("HmacSha256");
m.init(key);
byte[] data = "Message".getBytes("UTF-8");
byte[] hmac = m.doFinal(data);
```

# KeyGenerator

- Generates symmetric keys
- Additional checks for weak keys
- Set key parity when necessary
- Takes advantage of the cryptographic hardware

```
KeyGenerator kg = KeyGenerator.getInstance("HmacSha256");
SecretKey key = kg.generateKey();
```

```
KeyGenerator kg = KeyGenerator.getInstance("AES");
kg.init(256);
SecretKey key = kg.generateKey();
```

# KeyPairGenerator

- Generates public and private keys

```
KeyPairGenerator kpg = KeyPairGenerator.getInstance("RSA");
kpg.initialize(1024);
KeyPair pair = kpg.generateKeyPair();
PrivateKey priv = pair.getPrivate();
PublicKey pub = pair.getPublic();
```

# Android JCA Providers

- Harmony's Crypto Provider
  - Limited JCA provider part of the Java runtime library
  - SecureRandom (SHA1PRNG), KeyFactory (DSA)
  - MessageDigest (SHA-1), Signature (SHA1withDSA)
- Android's Bouncy Castle Provider
  - Full-featured JCA provider
  - Part of the Bouncy Castle Crypto API
  - Cipher, KeyGenerator, Mac, MessageDigest, SecretKeyFactory, Signature, CertificateFactory
  - Large number of algorithms
- AndroidOpenSSL Provider
  - Native code, performance reasons
  - Covers most functionality of Bouncy Castle
  - Preferred provider
  - Implementation uses JNI to access OpenSSL's native code

# Outline

# Secure Communication

- Cryptographic providers for securing communication
- Recommendation: standardized security protocols
- Secure Sockets Layer (SSL) and Transport Layer Security (TLS)
- SSL is the predecesor of TLS

# SSL/TLS

- Secure point-to-point communication protocols
- Authentication, message confidentiality and integrity for communication over TCP/IP
- Combination of symmetric and asymmetric encryption for confidentiality and integrity
- Public key certificates for authentication

# Cipher Suite

- Cipher suite = set of algorithms for key agreement, authentication, integrity protection and encryption
- Client sends SSL version and list of cipher suites
- Client and server negotiate common cipher suite

# Authentication and Encryption

- Authenticate through certificates
  - Usually only server authentication
  - Client authentication is also supported
- Compute shared symmetric key
- Secure communication using symmetric encryption & key

# Public Key Certificates

- Binding an identity to a public key
- X.509 certificates
- Signature algorithm
- Validity
- Subject DN
- Issuer DN

| | |
|---|---|
| **Subject Name** | |
| Country | US |
| State/Province | California |
| Locality | Mountain View |
| Organization | Google Inc |
| Common Name | *.google.com |
| **Issuer Name** | |
| Country | US |
| Organization | Google Inc |
| Common Name | Google Internet Authority G2 |
| Serial Number | 9085461370495713600 |
| Version | 3 |
| Signature Algorithm | SHA-256 with RSA Encryption |

# Direct Trust

- SSL client communicates with a small number of servers
- Set of trusted server certificates = trust anchors
- Can be self-signed
- A server is trusted if it's certificate is part of the set
- Good control over trusted server
- Hard to update server key and certificate

# Private CAs

- Private Certificate Authority (CA) -> trust anchor
- Signs server certificate
- Client trusts any certificate issued by the CA
- Easy to update server key and certificate
- Single point of failure

# Public CAs

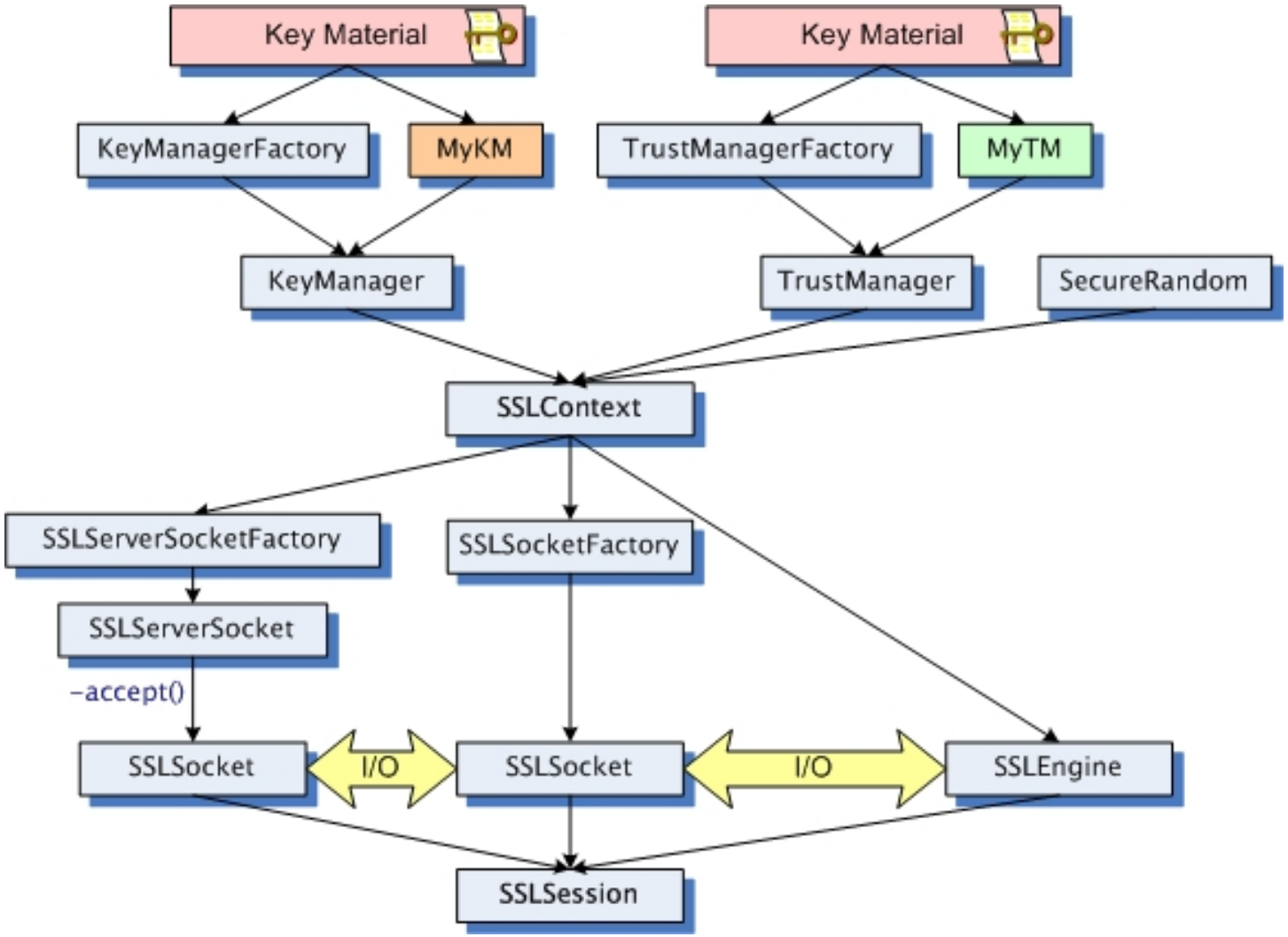
- Public Certificate Authorities (CAs) -> trust anchors
- Client configured with a set of trust anchors
- Web browsers - more than 100 CAs

# Outline

# Java Secure Socket Extension (JSSE)

- Android provides support for SSL/TLS through JSSE
- `javax.net` and `javax.net.ssl`
- Provides:
  - SSL client and server sockets
  - Socket factories
  - SSLEngine - producing and consuming SSL streams
  - SSLContext - creates socket factories and engines
  - KeyManager, TrustManager and factories
  - HttpsURLConnection

# JSSE Classes




Source: http://docs.oracle.com/javase/7/docs/technotes/guides/security/jsse/JSSERefGuide.html

# SSLSocket

- `SSLSocket` is created:
  - Through `SSLSocketFactory`
  - Accepting a connection on a `SSLServerSocket`
- `SSLServerSocket` created through `SSLServerSocketFactory`
- `SSLEngine`:
  - Created by `SSLContext`
  - I/O operations handled by the application

# SSLContext

- SSL Context obtained in two ways
- 1. `getDefault()` method of `SSLServerSocketFactory` or `SSLSocketFactory`
  - Default context initialized with default KeyManager, default TrustManager and secure random generator
  - Key material from system properties

# SSLContext

- 2. `getInstance()` static method of `SSLContext`
  - Context initialized with array of KeyManager, array of TrustManager, secure random generator
  - KeyManager obtained from KeyManagerFactory
  - TrustManager obtained from TrustManagerFactory
  - Factories initialized with KeyStore (key material)

# SSLSession

- Established SSL connection -> `SSLSession` object
- Includes identities, cipher suites, etc.
- `SSLSession` used in multiple connections between same entities

# TrustManager and KeyManager

- JSSE delegates trust decisions to `TrustManager`
- Delegates authentication key selection to `KeyManager`
- Each `SSLSocket` has access to them through `SSLContext`
- `TrustManager` has a set of trusted CA certificates (trust anchors)
  - A certificate issued by a trusted CA is considered trustworthy

# System Trust Store

- Default JSSE `TrustManager` initialized using the system trust store
  - Major commercial and government CA certificates
  - `/system/etc/security/cacerts.bks`

```
TrustManagerFactory tmf = TrustManagerFactory
        .getInstance(TrustManagerFactory.getDefaultAlgorithm());
tmf.init((KeyStore) null);

X509TrustManager xtm = (X509TrustManager) tmf
        .getTrustManagers()[0];

for (X509Certificate cert : xtm.getAcceptedIssuers()) {
    String certStr = "S:" + cert.getSubjectDN().getName()
                + "\nI:" + cert.getIssuerDN().getName();
    Log.d(TAG, certStr);
}
```

# System Trust Store

- Until Android 4.0,
  - A single file: `/system/etc/security/cacerts.bks`
  - Read-only partition
- From Android 4.0
  - In addition, two directories
  - `/data/misc/keychain/cacerts-added`
  - `/data/misc/keychain/cacerts-removed`
  - Modified only by the system user
  - Add trust anchors through `TrustedCertificateStore` class

# Validate Server Certificate

```
TrustManagerFactory tmf = TrustManagerFactory
                                    .getInstance("X509");
tmf.init((KeyStore) null);

TrustManager[] tms = tmf.getTrustManagers();
X509TrustManager xtm = (X509TrustManager) tms[0];

X509Certificate[] certChain = {serverCert};
xtm.checkServerTrusted(certChain, "RSA");
```

- SSLSocket and HttpsURLConnection perform similar validations

# HttpsURLConnection

- Preferred method for connecting to a HTTPS server
- Uses default `SSLSocketFactory` to create secure sockets
- Custom trust store or authentication keys
  - `setDefaultSSLSocketFactory()` or `setSSLSocketFactory()` of `HttpsURLConnection`

# Use your own Trust Store

- Use your own trust store instead of the system trust store
  - Load trust store in a `KeyStore` object
  - Obtain `TrustManagerFactory` and initialize it with trust store
  - Load key material in `KeyStore` object (for client authentication)
  - Obtain `KeyManagerFactory` and initailize it with key store
  - Obtain `SSLContext` and initialize it with TrustManager and KeyManager
  - Create `URL` and `HttpsURLConnection`
  - Associate `SSLSocketFactory` of `SSLContext` to `HttpsURLConnection`

# Use your own Trust Store

```
KeyStore trustStore = loadTrustStore();
KeyStore keyStore = loadKeyStore();

TrustManagerFactory tmf = TrustManagerFactory
      .getInstance(TrustManagerFactory.getDefaultAlgorithm());
tmf.init(trustStore);

KeyManagerFactory kmf = KeyManagerFactory
      .getInstance(KeyManagerFactory.getDefaultAlgorithm());
kmf.init(keyStore, KEYSTORE_PASSWORD.toCharArray());

SSLContext sslCtx = SSLContext.getInstance("TLS");
sslCtx.init(kmf.getKeyManagers(), tmf.getTrustManagers(), null);

URL url = new URL("https://myserver.com");
HttpsURLConnection urlConnection = (HttpsURLConnection) url
urlConnection.setSSLSocketFactory(sslCtx.getSocketFactory());
```

# Use your own Trust Store

- Generate your trust store using Bouncy Castle and openSSL in comand line
- Trust store file in `res/raw/`

```
KeyStore localTrustStore = KeyStore.getInstance("BKS");
InputStream in = getResources().openRawResource(
                    R.raw.mytruststore);
localTrustStore.load(in, TRUSTSTORE_PASSWORD.toCharArray());

TrustManagerFactory tmf = TrustManagerFactory
        .getInstance(TrustManagerFactory.getDefaultAlgorithm());
tmf.init(localTrustStore);

SSLContext sslCtx = SSLContext.getInstance("TLS");
sslCtx.init(null, tmf.getTrustManagers(), null);

URL url = new URL("https://myserver.com");
HttpsURLConnection urlConnection =
                    (HttpsURLConnection) url.openConnection();
urlConnection.setSSLSocketFactory(sslCtx.getSocketFactory());
```

# Outline

# Android JSSE Providers

- JSSE providers implement functionality for engine classes
  - Trust managers, key managers, secure sockets, etc.
  - Developers work with engine classes
- Android includes two JSSE providers:
  - HarmonyJSSE
  - AndroidOpenSSL

# Harmony JSSE

- Implemented in Java
- Java sockets, JCA cryptographic classes
- SSLv3, TLSv1
- Deprecated, not actively maintained

# AndroidOpenSSL

- Calls to OpenSSL native library (JNI)
- TLSv1.1, TLSv1.2
- Server Name Indication (SNI)
  - SSL clients specify target hostname
  - Server with multiple virtual hosts
  - Used by default by `HttpsURLConnection`
- Both providers share `KeyManager` and `TrustManager` code
- Different SSL socket implementation

# Outline

# Bibliography


- Android Security Internals, Nikolay Elenkov
- http://nelenkov.blogspot.ro/2011/12/using-custom-certificate-trust-store-on.html
- https://github.com/nelenkov/custom-cert-https
- http://docs.oracle.com/javase/7/docs/technotes/guides/security/jsse/JSSERefGuide.html

# Keywords

- Java Cryptography Architecture
- Cryptographic Service Provider
- Engine classes
- SSL/TLS
- Trust anchors
- Certificate Authority
- Trust store
- Java Secure Socket Extension
- SSLSocket
- HttpsURLConnection
- AndroidOpenSSL