# PKOC Specification

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|---|---|
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| **Control:** | Uncontrolled when printed |
| **Date** | 10/25/2023 |

## Document History

| Version | Date | Author | Description |
|---|---|---|---|
| 0.0-.99 | Oct 8, 2021 | Mohammad Soleimani | Initial Document |
| 1.0RC1 | Oct 22, 2021 | Mohammad Soleimani, Alex Lammers | Changed to PSIA Stationary |
| 1.0RC2 | Oct 27, 2021 | Mohammad Soleimani | Added ECDHE Perfect Forward Secrecy Flow<br>Updated drawings for ECDHE to remove Normal Flow section |
| 1.0 | Nov 5, 2021 | | Released Specification |
| 2.0RC1.0 | OCT 25,2023 | Mohammad Soleimani | Comprehensive updates |
| 2.1 | FEB 28, 2024 | Jason Ouellette | Changed encryption from AES-GCM to AES-CCM for today providing a path for AES-GCM; Added privacy protection for PKOC bit length to be unique in an PACS |

## Disclaimer

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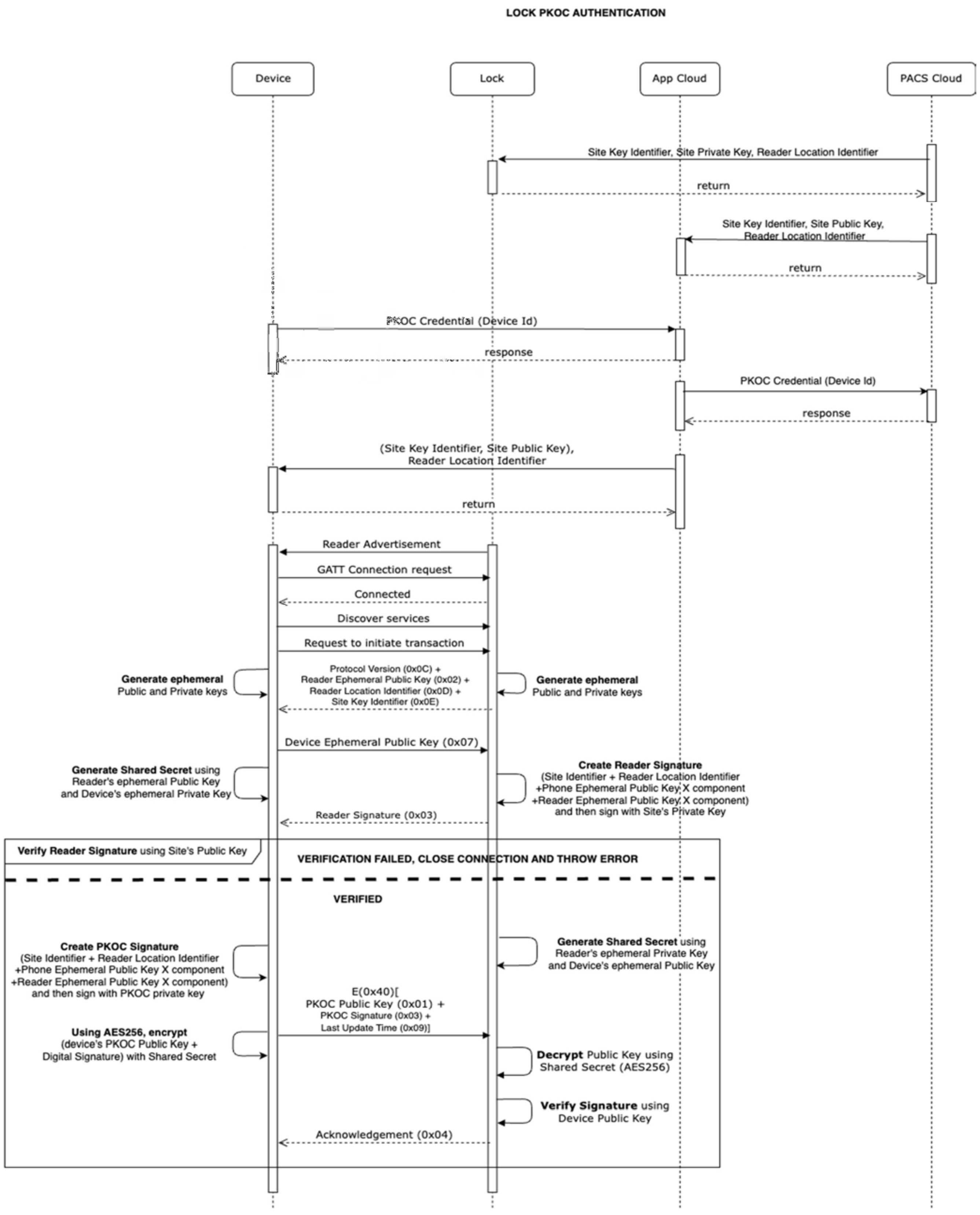
LOCK PKOC AUTHENTICATION
Device
Lock
App Cloud
PACS Cloud
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Generate Shared Secret using Reader's ephemeral Private Key and Device's ephemeral Public Key
E(0x40)[ PKOC Public Key (0x01) + PKOC Signature (0x03) + Last Update Time (0x09)]
Using AES256, encrypt (device's PKOC Public Key + Digital Signature) with Shared Secret
Decrypt Public Key using Shared Secret (AES256)
Verify Signature using Device Public Key
Acknowledgement (0x04)

## Introduction:

This document describes an open air-interface protocol for Bluetooth Low Energy (BLE) interactions for a secure credential exchange with a lock or a Reader for access control. This specification is based on Public Key Open Credential (PKOC) concept, which is a system solution for secure, interoperable credentials by utilizing distributed asymmetric encryption key creation. A phone/smart device will generate an asymmetric key pair using EC (Elliptic Curve) algorithm and store it in a secure element (secure enclave in iOS and key store in android). The Reader/lock will receive the public key from the phone and authenticate it via challenge-response before granting access.

## Glossary:

Android – An operating system for mobile devices developed and maintained by Google, Inc.

Application (App) – A software application developed to run on a mobile operating system.

Asymmetric Key Cryptography – A method of communicating where two keys are used, one public which can be transmitted securely in the open, and the other private which should be kept secret. A message can then be either encrypted and/or signed using one key to be decrypted and/or verified by the corresponding key.

Bluetooth Low Energy (BLE) – A subset of the Bluetooth specification designed for low power wireless data exchange without the need to pair devices or maintain a persistent connection.

Challenge-Response – An authentication protocol where a trusted device sends a single-use challenge that an untrusted device performs a cryptographic operation with using a secret to generate a response that establishes that the untrusted device possesses and controls the secret.

Credential – A physical or digital token which contains a unique identifier for the individual to whom it was issued. The credential can then be used to assert the identity of the individual to whom it was issued to systems that recognize the issuer.

Digital Signature – Additional data attached to a message that uses encryption and decryption algorithms to verify the message's origin and contents.

Elliptic Curve Diffie-Hellman Ephemeral (ECDHE) - is an anonymous key agreement protocol that allows two parties, each having an elliptic curve public-private key pair, to establish a shared secret over an insecure channel.

iOS – An operating system for mobile devices developed and maintained by Apple, Inc.

CCM - CBC counter mode, is a mode of operation for cryptographic block ciphers. It is an authenticated encryption algorithm designed to provide both authentication and confidentiality. CCM mode is only defined for block ciphers with a block length of 128 bits.

GCM – Galois/Counter Mode, an authenticated encryption mode for block ciphers like AES. It produces both a ciphertext and a tag used to validate the encrypted data.

Lock – A physical device designed to prevent access without the use of a corresponding key.

Mobile Device – A portable telephone or other network-connected smart device designed to be carried or worn by the owner.

Nonce – A single use number used as a challenge with Challenge-Response.

Panel – A computing device that is maintained within the secured perimeter of a building that electronically locks and unlocks doors or devices based on messages received at the point of access from a Reader.

Public Key Open Credential (PKOC) – A method of permitting the secure authentication and transmission of the credential of an individual using public keys which can be securely passed in the open which are not issued or created by a centralized authority.

Reader – A small device that is mounted near or embedded within a Lock that permits the transmission of a credential to a Panel using a magnetic stripe, RFID, NFC, or Bluetooth to exchange data with a credential issued to an individual.

Secure Element - A hardware component that provides all cryptographic operations for authenticating the user and is designed to be secure even if the operating system kernel is hacked (e.g., Secure Enclave in iOS and Key Store in Android.)

Universally Unique Identifier (UUID) – a 128-bit number used to identify a unique object on a computer system.

## Recommended App Registration Process:

In the app, we would have a registration where:

- The app will generate the asymmetric key pair with Elliptic Curve (EC) cryptography and save it to the secure element.
- It will send the public key to the cloud at the time of registration. The public key should be transferred in an encrypted format.

## Registration Sequence Diagram:

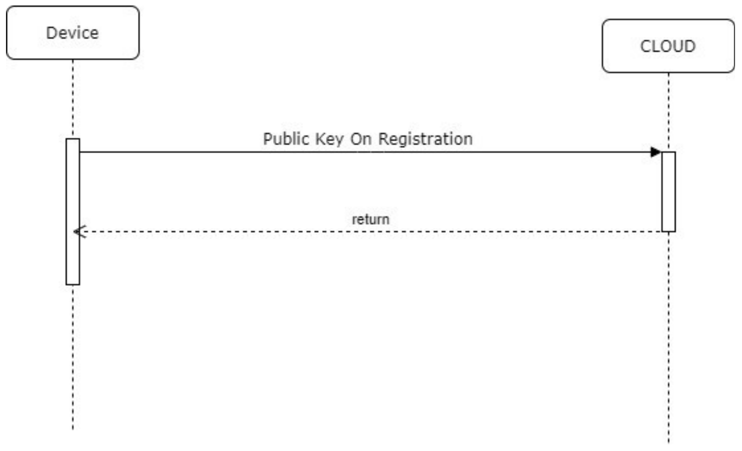


*Figure 1 - Registration Sequence*

## PKOC Requirements:

### PKOC- Credential Creation and Provisioning

The device will generate a public/private key pair using the NIST secp256r1 (P256) curve, stored in an internal secure element. The private key never leaves the device, and the public key is used as a user's Public Key Open Credential (PKOC).
The physical access control system shall define a unique bit length specific for use with PKOC credentials system wide. This prevents an unauthenticated transaction with non-compliant readers. The PACS shall allocate a PKOC credential format of a minimum of 64 bits but should use the largest bit length that can be supported up to the maximum 256 bit "X" portion of the public key.

See below for examples of extracting the credential from the full 65-byte Public Key.

**For 256 bits -**
04**BEA02AA1320054CFF1DFD2F88FA583B5B059833BA87CEC415ABDAE0791F0EC66**A913C71 04A725F6497B8C0 8FF91217B106FEF7B51ACD4ADF6645E765E4E88D84 For

**64 bits -**
04BEA02AA1320054CFF1DFD2F88FA583B5B059833BA87CEC41**5ABDAE0791F0EC66**A913C710 4A725F6497B8C0 8FF91217B106FEF7B51ACD4ADF6645E765E4E88D84

### Reader

To meet the data transmission requirements for PKOC all Readers must support BLE 4.2[1] or later and utilize the Data Packet Length Extension to permit up to 242 bytes of data to be transmitted. Any reference to Reader in this specification can also refer to a passthrough from a Reader to a Panel where the Panel performs the Reader's actions.

[1] https://www.bluetooth.com/specifications/specs/core-specification-4-2/

## Mobile Device

To interface with a PKOC compliant Reader a mobile device must also support BLE 4.2 or later.  Of the most common mobile operating systems in use today this would requires IOS 9.2.1 or later, and Android 6.0.1 or later[2].  Developers are strongly encouraged to support Android 9.0 and later to utilize the operating system level secure enclave.

## Cryptographic Functions

PKOC utilizes asymmetric cryptographic functions to securely transmit public keys and other data to Readers. To generate digital signatures on the most common mobile operating systems EcdsaSignatureMessageX962Sha256 is preferred for IOS and SHA256WithECSDA for Android. The signature must follow DER x9.62 encoding but transmit only the 64-byte "real numbers" from the 72-74 byte DER encoded signature. For the Reader, cryptographic functions must be performed by a hardware secure element.

[2] https://devzone.nordicsemi.com/f/nordic-q-a/11678/ble-4-2-and-smart-phones-os-compatibility

## PKOC BLE Exchange:

### Initial Advertisement and GATT Service Setup

The BLE beacon advertisement and service UUID for PKOC Readers will be 41fb60a1-d4d0-4ae9-8cbbb62b5ae81810

There would be a PKOC GATT Service (UUID: 41fb60a1-d4d0-4ae9-8cbb-b62b5ae81810) which will have two characteristics:

1. **PKOC Write** (UUID: fe278a85-89ae-191f-5dde-841202693835) which will support: write with notification, write without response.
2. **PKOC Read** (UUID: e5b1b3b5-3cca-3f76-cd86-a884cc239692) which will support: read, notify, indicate.

NOTE: The PKOC GATT service UUID and Write and Read characteristic UUIDs are static for PKOC Readers.

### Manufacturer Specific Advertising Data

It is recommended to include a Manufacturer Specific Advertising Data element to provide common advertisement-level information about the reader for use in hands-free ranging and reader discovery.

| Data Element | Length | Description |
|---|---|---|
| Company Identifier Code | 2 bytes | Individual Company Identifier, if required |
| Reserved | 1 byte | Reserved |
| Ranging Calibration Data | 4 bits | Expected RSSI value at 1 meter distance, as defined by the Calibration Data table |
| Ranging Activation Range | 4 bits | Expected distance to connect, as defined by the Activation Range table |
| Reader Location Identifier | 4 bytes | Least significant 4 bytes of the Reader Location Identifier |

## Calibration Data Table

Device reference for calibration data is an Apple iPhone 14.

| Value | RSSI (dBm) |
|---|---|
| 0 | Invalid |
| 1 | -52 |
| 2 | -54 |
| 3 | -56 |
| 4 | -58 |
| 5 | -60 |
| 6 | -62 |
| 7 | -64 |
| 8 | -66 |
| 9 | -68 |
| 10 | -70 |
| 11 | -72 |
| 12 | -74 |
| 13 | -76 |
| 14 | -78 |
| 15 | -80 |

## Activation Range Table

| Value | Range (centimeters) |
|---|---|
| 0 | Invalid |
| 1 | 5 |
| 2 | 7 |
| 3 | 10 |
| 4 | 14 |
| 5 | 20 |
| 6 | 28 |
| 7 | 40 |
| 8 | 56 |
| 9 | 80 |
| 10 | 113 |
| 11 | 160 |
| 12 | 226 |
| 13 | 320 |
| 14 | 452 |
| 15 | 640 |

## Message Types

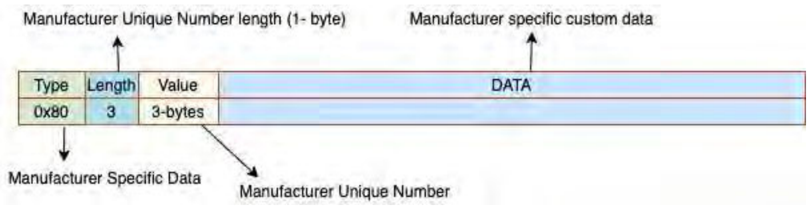
- Messages will utilize a Type/Length/Value (TLV) command structure.
    - Type will be fixed at 1 byte.
    - Length will be fixed at 1 byte permitting a maximum 240 bytes to be usable for the value.
    - Value will contain the data needed to fill but not exceed the length specified.
- Packets can contain more than one message using concatenation.
    - Additional messages will begin at the byte immediately following the last message. o There is no limit on the number of messages that can be concatenated subject to the maximum transmission unit size of 242 bytes.

Types can be sent or received in any order. Support for the following messages is mandatory to be PKOC compliant. The reader and device must ignore types not included in this list.

### *GATT Specific Type*

| Type | Details | Data | |
|---|---|---|---|
| 0x01 | Uncompressed Public Key ECC P-256 (65 Bytes) | 65-byte Non-Ephemeral Public Key | PKOC Write |
| 0x02 | Compressed Ephemeral Public Key | 33 byte Compressed Public Key | PKOC Read |
| 0x03 | Digital Signature | 64-byte ECDSA Signature (R \|\| S) | PKOC Write |
| 0x04 | Response | See Error Codes | PKOC Write |
| 0x05 | Reserved (Deprecated Functionality) | | |
| 0x06 | Reserved (Deprecated Functionality) | | |
| 0x07 | Uncompressed Ephemeral Public Key | 65-byte Ephemeral Public Key | PKOC Write |
| 0x09 | Last Update Time | 4-byte unsigned Unix Epoch time. Update time of the most recent change to a PKOC credential or any associated access information. | PKOC Write |
| 0x0A | Reserved (Deprecated Functionality) | | |
| 0x0C | Protocol Version | List of 2 byte versions (major ver, minor ver)<br><br>0x0200: 2.0, this document | PKOC Read |
| 0x0D | Reader Location Identifier | 16-byte GUID logical identifier for the reader location. It is not hardware specific. | PKOC Read |
| 0x0E | Site Identifier | 16-byte GUID logical identifier for the device's public key. This can be shared between readers in a given area/building. | PKOC Read |
| 0x40 | Encrypted Data | Variable length ciphertext | PKOC Read/Write |
| 0x80 | MFG Specific | 3-byte Manufacturer Identifier | PKOC Read/Write |

- **Manufacturer Specific Data:** Type 0x80h will be reserved to allow Manufacturer Specific Data (GATT) for the transmission of non-standard data within the standard messaging protocol. This will be in TLV format.
    - Type must be 1 byte with a value of 0x80h for Manufacturer Specific Data.
    - Length will be 1 byte with a value of 0x03h for the Manufacturer Unique Number length.
    - Value must be 3 bytes for the Manufacturer Unique Number[3] followed by the rest of the data.


Manufacturer Unique Number length (1- byte)
Manufacturer specific custom data
Type
Length
Value
DATA
0x80
3
3-bytes
Manufacturer Specific Data
Manufacturer Unique Number

- Reader/Panel will perform data verification steps and will send the acknowledge byte to the Device.

[3] Manufacturer's Unique Number is obtained from the IEEE

https://standards.ieee.org/products-programs/regauth/oui36/

## Error Codes

These come from the reader, the Device is not required to send these messages.

| Name | Value | Use |
|---|---|---|
| Unknown Failure | 0x00 | Miscellaneous error |
| Success | 0x01 | Operation completed successfully. This does not mean that Access was Granted. |
| Access Denied | 0x02 | Access was explicitly denied. Readers that cannot determine this information directly do not need to support this feature. |
| Access Granted | 0x03 | Access was explicitly granted. Readers that cannot determine this information do not need to support this feature, and Applications should not require it. |
| Decryption Error | 0x04 | Decrypted data could not be validated (GCM failure) |
| Invalid Security Status | 0x05 | Receipt of an encrypted packet without having derived a secret |
| Signature Invalid | 0x06 | Reader could not validate signature |
| Decryption Error | 0x07 | Decrypted data could not be validated (CCM failure) |

## PKOC Transmission Flows:

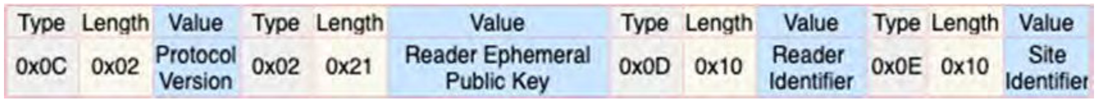
PKOC supports two (2) types of data communication between the PKOC Reader and an App on a mobile device: ECDHE or Un-Obfuscated. The App will scan for a PKOC Service UUID when a Reader is discovered.

NOTE: While both the flows are required in the Reader to support the PKOC specification, the app will select either of the flows.

### Common Handshake for both the flows

The below steps are the handshake procedures before the app selects which flow it will authenticate with.

1. App will scan for PKOC Service UUID, if the Reader is discovered.
2. App will make connection with the Reader.
3. App will discover the PKOC GATT Service.
4. App will discover the PKOC Characteristic UUIDs.
5. App will Request to initiate the transaction to the Reader.
6. Reader will send Protocol Version (0x0C) + Reader Ephemeral Public Key (0x02) + Reader Location Identifier (0x0D) + Site Key Identifier (0x0E) to the App.



| Type | Length | Value | Type | Length | Value | Type | Length | Value | Type | Length | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0x0C | 0x02 | Protocol Version | 0x02 | 0x21 | Reader Ephemeral Public Key | 0x0D | 0x10 | Reader Identifier | 0x0E | 0x10 | Site Identifier |

Based on the Reader id in advertisement data, the App will decide whether it can follow the ECDHE or Un-Obfuscated Flow.

**NOTE**: Going forward, protocol version can be used to indicate shift of encryption mode from AES-CCM to AES-GCM.

## ECDHE with Perfect Forward Secrecy Flow

This protocol primarily utilizes a Full-ECDHE-based flow to establish a secure channel for use in transporting credentials securely.

The ECDHE Flow transmits the PKOC using Elliptic Curve encryption. This flow provides the maximum amount of privacy with Forward Secrecy but requires prior knowledge of the public key of the Site.

### Cryptography

To prevent man-in-the-middle attacks, data from both the reader and device are used in the signature computation. The input to the signature function is the following, concatenated:

| Data | Length (Bytes) |
|---|---|
| Site Identifier | 16 |
| Reader Location Identifier | 16 |
| Phone Ephemeral Public Key X Component | 32 |
| Reader Ephemeral Public Key X Component | 32 |

### *Secure Session*

Once the reader and device have shared ephemeral keys, they will each compute a shared secret key using the ECKA-DH key agreement protocol (see BSI TR-03111 section 4.3), using SHA-256 as the final key derivation hash. The output of this function, $Z_{AB}$, will be used directly as a 256bit AES-CCM key (see NIST SP 800-38D).

Encrypted packets are marked using the Encrypted Data TLV, which contains the encrypted data and the 16-byte Tag. This tag must be validated prior to decryption.

The IV is 12 bytes, in the format of 0x0000000000000001AABBCCDD, where AABBCCDD is a 4-byte counter that increments after every encrypted message sent. It starts at 1 and is encoded Big Endian. There is a separate counter for the reader and the device. If the counter rolls over the secure session is invalidated and all encrypted communications should fail until a new session is established.

### Flow Description

To establish a secure communications channel, the Device and Reader interact as follows:

1. The Device has recognized the Reader from the Reader's advertisement and already has the Site's public key
2. Device sends a transaction initiation request and creates an Ephemeral Key pair
3. Reader Performs below operation:
    - a Generates Ephemeral EC Keys
    - b Sends below TLVs to the Device:
        - i Protocol Version
        - ii Reader Ephemeral Public Key
        - iii Reader Location Identifier
        - iv Site Key Identifier
4. Device Performs below operations:
    - a Send below TLVs to the Reader:
        - i Ephemeral Public Key
    - b Device generates Shared Secret
5. Reader Performs below operations:
    - a Sends Digital Signature to the Device after performing:
        - i Reader concatenates below data:
            - 1 Site Identifier
            - 2 Reader Location Identifier
            - 3 Device Ephemeral Public Key X component
            - 4 Reader Ephemeral Public Key X component
        - ii And then signs it with site private key
    - b Generates Shared Secret
6. Device verifies the Reader Digital Signature
    - a If verification fails, it closes the connection and throws error
    - b Else:
        - i Creates PKOC Digital Signature using below steps:
            - 1 Device concatenates below data:
                - a Site Identifier
                - b Reader Location Identifier
                - c Device Ephemeral Public Key X component
                - d Reader Ephemeral Public Key X component
            - 2 And then sign with PKOC private key
        - ii Encrypt the below TLVs using Device's shared secret key:
            - 1 Device's PKOC Public Key
            - 2 Digital Signature
            - 3 Last Update Time
        - iii Send the above encrypted data to the Reader, wrapped in an Encrypted Data TLV
7. Reader on receiving the encrypted data:
    - a Decrypts the Encrypted Data TLV using Reader's Shared Secret key
    - b Verifies Digital Signature using Device's Public key

   a. Sends back the response to the Device

Note: Details of different error codes are mentioned in the Error Codes section.

8. Upon receipt of an encryption error (if any), the Device and Reader *must* close the current connection and re-connect (including new ECDHE negotiation, if necessary).

## Un-Obfuscated Flow:

The Un-Obfuscated flow is a plaintext flow for passing the PKOC credential. For security purposes, this must be limited use:

- PKOC credentials sent over the un-obfuscated flow must be time-limited (temporary access, visitor pass, etc.).
- Applications cannot use the un-obfuscated flow for hands-free operation, the user must actively initiate the connection (select the reader from UI).

### Cryptography

To validate the PKOC public key, the device will generate a signature that the reader will validate. The input to that function is the raw bytes of the Reader's Ephemeral Public Key TLV as sent by the reader (33 bytes).

### Flow Description

To establish a communications channel, the Device and Reader interact as follows:

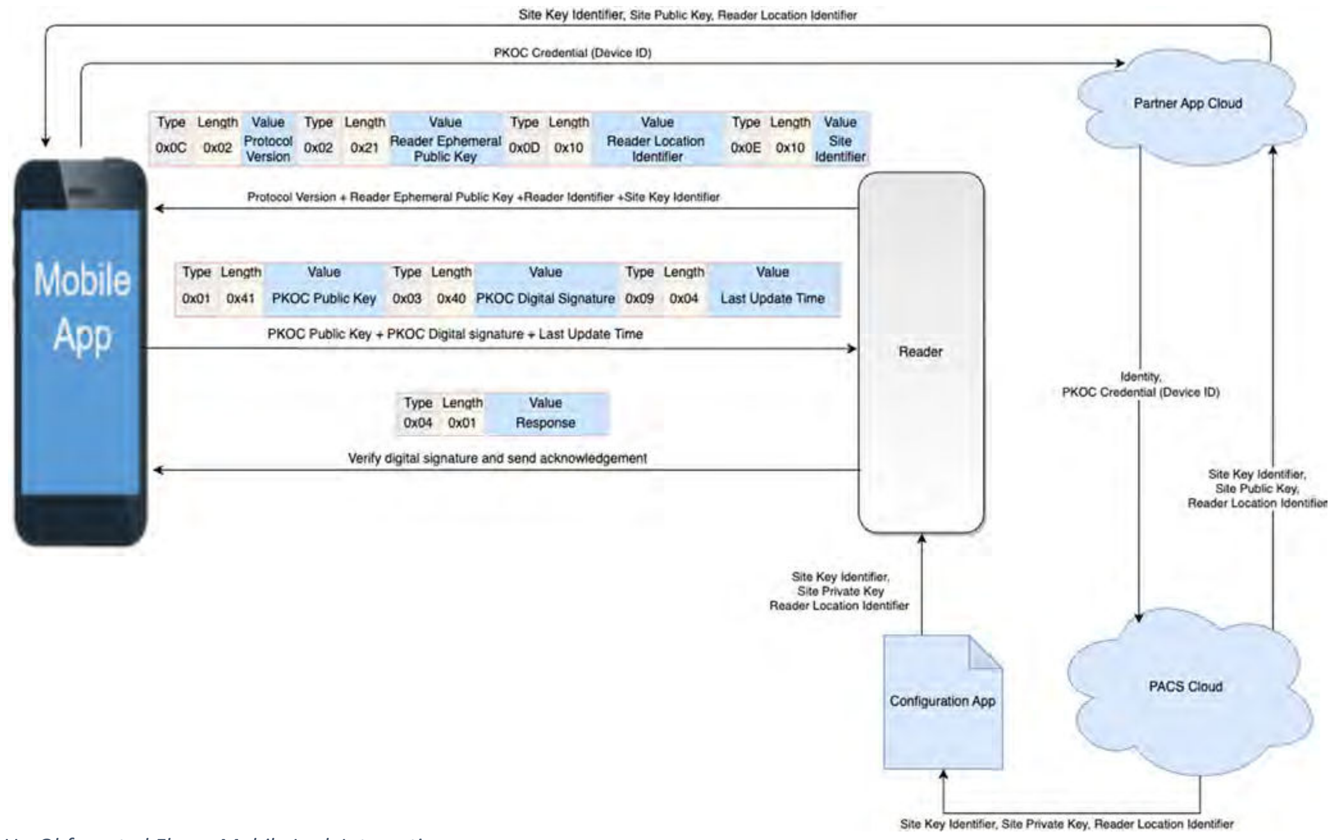
1. The Device has recognized the Reader from the advertisement
2. Device sends a transaction initiation request
3. Reader Performs below operations:
    - a Generates Ephemeral EC Keys
    - b Sends below TLVs to the Device
        - i Protocol Version
        - ii Reader Ephemeral Public Key
        - iii Reader Location Identifier
        - iv Site Key Identifier
4. Device creates PKOC Digital Signature using below steps:
    - a Generates the digital signature by signing the Reader's Ephemeral Public Key with the PKOC Private Key
    - b Device concatenates below TLVs and sends to the reader
        - i Device's PKOC Public Key
        - ii Digital Signature
        - iii Last Update Time
5. Reader on receiving the Digital Signature
    - a Verifies Digital Signature using PKOC Public key
    - b Sends back the response to the Device.

Note: Details of different error codes are mentioned in the Error Codes section.

6. Upon receipt of an encryption error (if any) or success, the Device and Reader must close the current connection and re-connect (including new ECDH negotiation, if necessary).

## High Level Interaction Diagrams

### Un-Obfuscated Flow



| Type | Length | Value | Type | Length | Value | Type | Length | Value | Type | Length | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0x0C | 0x02 | Protocol Version | 0x02 | 0x21 | Reader Ephemeral Public Key | 0x0D | 0x10 | Reader Location Identifier | 0x0E | 0x10 | Site Identifier |

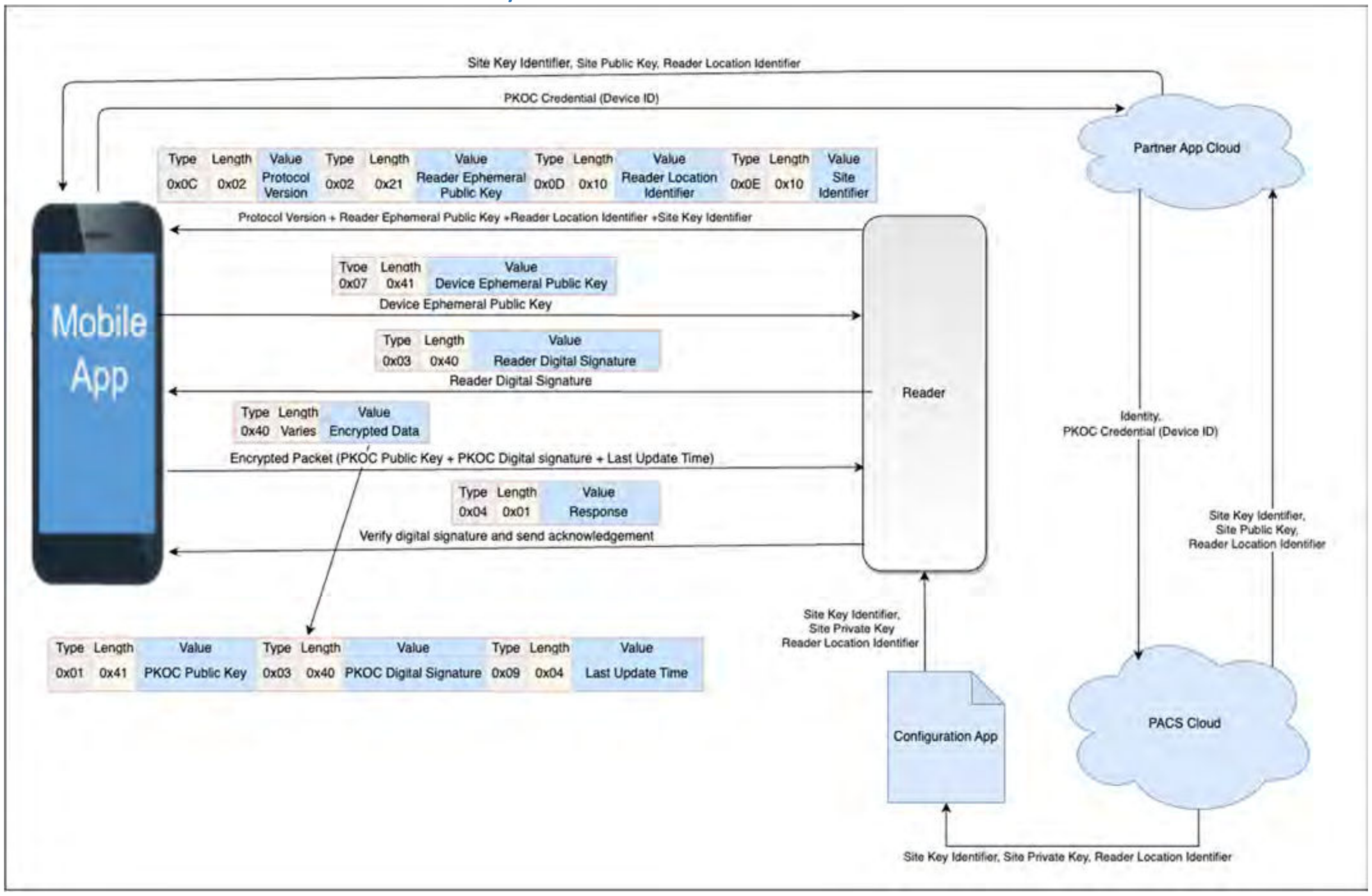
| Type | Length | Value | Type | Length | Value | Type | Length | Value |
|---|---|---|---|---|---|---|---|---|
| 0x01 | 0x41 | PKOC Public Key | 0x03 | 0x40 | PKOC Digital Signature | 0x09 | 0x04 | Last Update Time |

| Type | Length | Value |
|---|---|---|
| 0x04 | 0x01 | Response |

Site Key Identifier, Site Public Key, Reader Location Identifier
PKOC Credential (Device ID)
Partner App Cloud
Mobile App
Protocol Version + Reader Ephemeral Public Key +Reader Identifier +Site Key Identifier
PKOC Public Key + PKOC Digital signature + Last Update Time
Verify digital signature and send acknowledgement
Reader
Identity, PKOC Credential (Device ID)
Site Key Identifier, Site Public Key, Reader Location Identifier
Site Key Identifier, Site Private Key Reader Location Identifier
Configuration App
PACS Cloud
Site Key Identifier, Site Private Key, Reader Location Identifier

*Un-Obfuscated Flow - Mobile Lock Interaction*

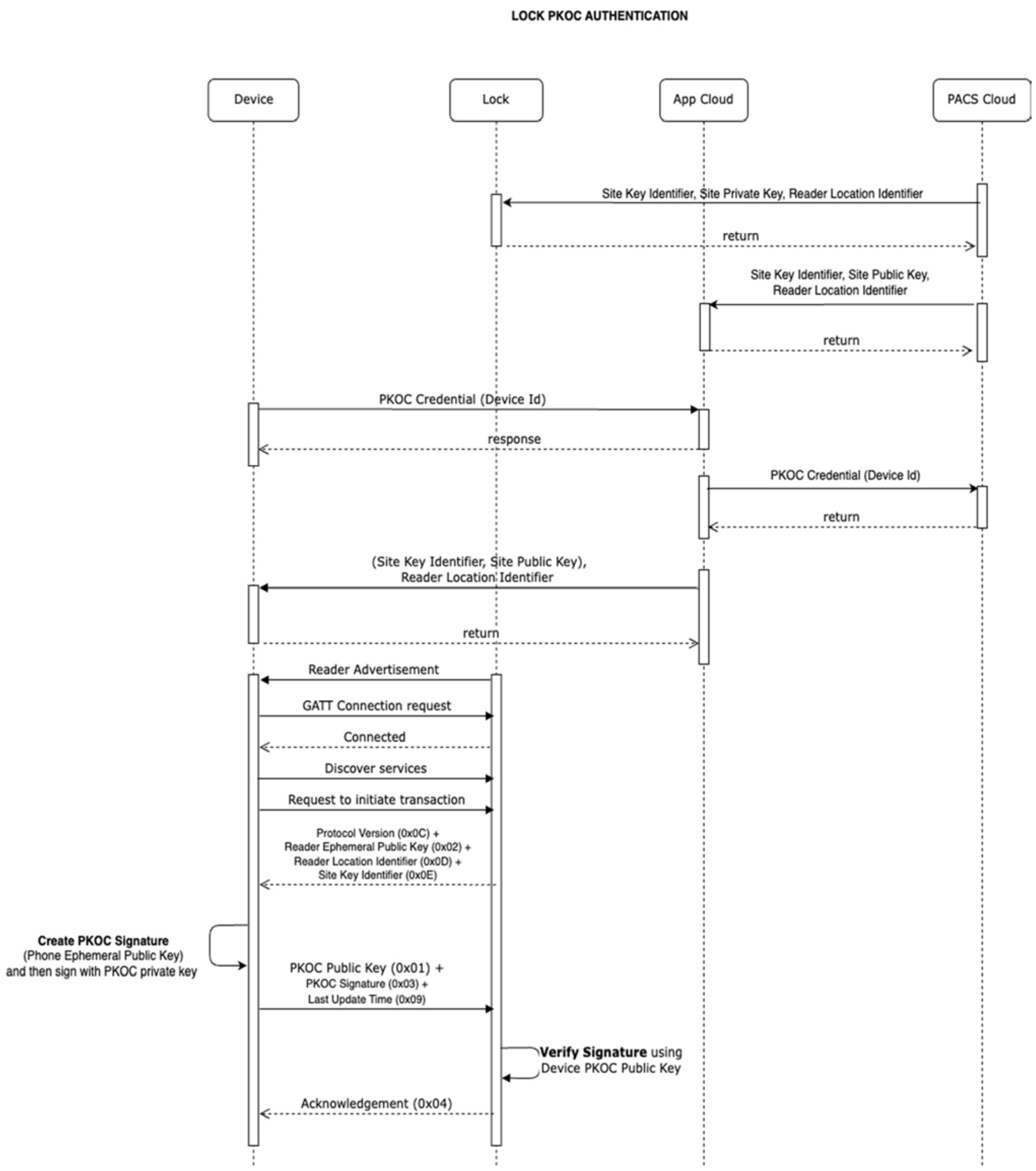
## ECDHE with Perfect Forward Secrecy Flow


Site Key Identifier, Site Public Key, Reader Location Identifier
PKOC Credential (Device ID)
Partner App Cloud
Type Length Value Type Length Value Type Length Value Type Length Value
0x0C 0x02 Protocol Version 0x02 0x21 Reader Ephemeral Public Key 0x0D 0x10 Reader Location Identifier 0x0E 0x10 Site Identifier
Protocol Version + Reader Ephemeral Public Key +Reader Location Identifier +Site Key Identifier
Mobile App
Type Length Value
0x07 0x41 Device Ephemeral Public Key
Device Ephemeral Public Key
Type Length Value
0x03 0x40 Reader Digital Signature
Reader Digital Signature
Reader
Type Length Value
0x40 Varies Encrypted Data
Encrypted Packet (PKOC Public Key + PKOC Digital signature + Last Update Time)
Type Length Value
0x04 0x01 Response
Verify digital signature and send acknowledgement
Identity,
PKOC Credential (Device ID)
Site Key Identifier,
Site Public Key,
Reader Location Identifier
Type Length Value Type Length Value Type Length Value
0x01 0x41 PKOC Public Key 0x03 0x40 PKOC Digital Signature 0x09 0x04 Last Update Time
Site Key Identifier,
Site Private Key
Reader Location Identifier
Configuration App
PACS Cloud
Site Key Identifier, Site Private Key, Reader Location Identifier

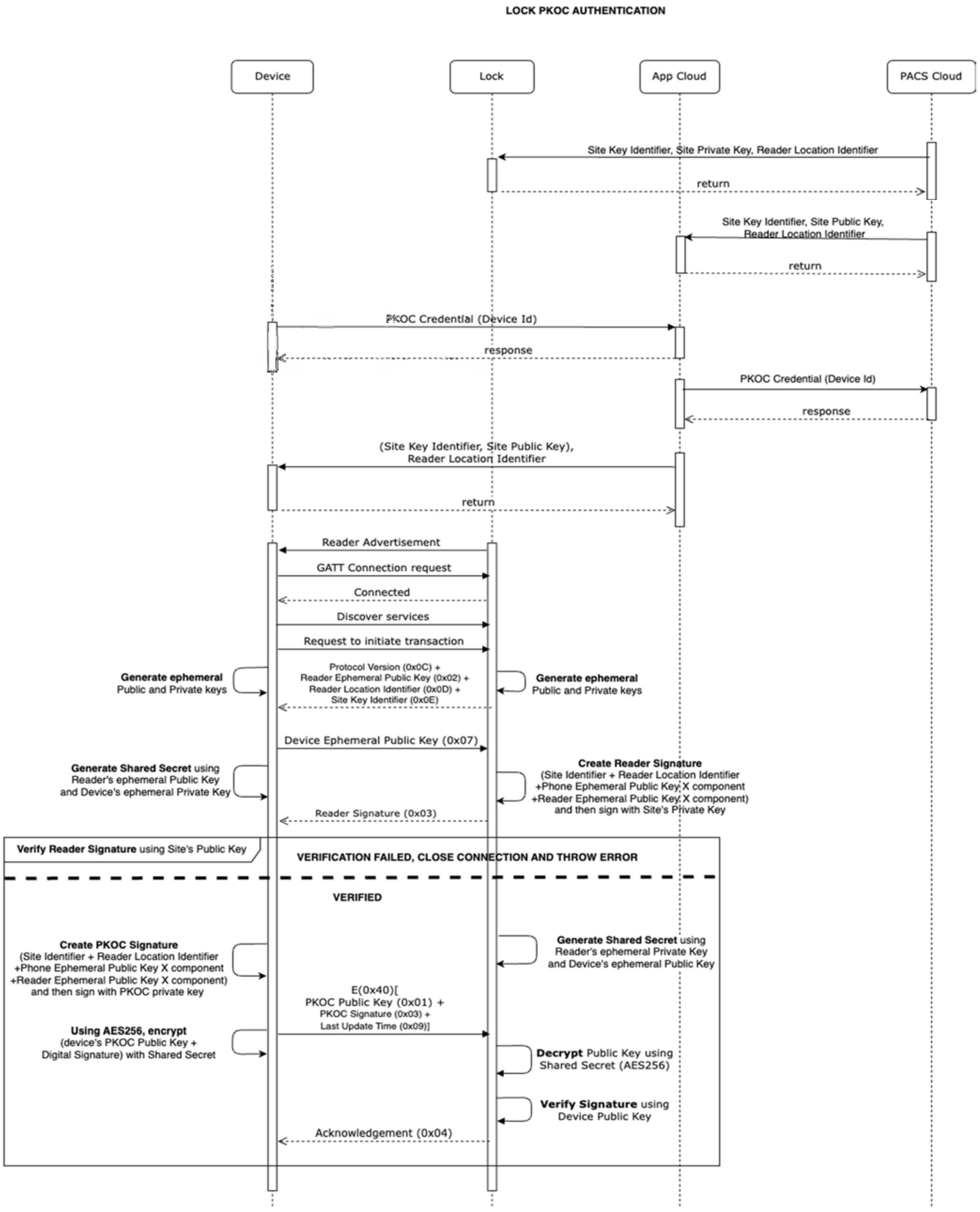
*ECDHE with Perfect Forward Secrecy Flow – Mobile Lock Interaction*

## Sequence Diagram:

### Un-Obfuscated Flow


LOCK PKOC AUTHENTICATION
Device
Lock
App Cloud
PACS Cloud
Site Key Identifier, Site Private Key, Reader Location Identifier
return
Site Key Identifier, Site Public Key, Reader Location Identifier
return
PKOC Credential (Device Id)
response
PKOC Credential (Device Id)
return
(Site Key Identifier, Site Public Key), Reader Location Identifier
return
Reader Advertisement
GATT Connection request
Connected
Discover services
Request to initiate transaction
Protocol Version (0x0C) + Reader Ephemeral Public Key (0x02) + Reader Location Identifier (0x0D) + Site Key Identifier (0x0E)
Create PKOC Signature (Phone Ephemeral Public Key) and then sign with PKOC private key
PKOC Public Key (0x01) + PKOC Signature (0x03) + Last Update Time (0x09)
Verify Signature using Device PKOC Public Key
Acknowledgement (0x04)

## Lock PKOC authentication (Forward Secrecy ECDHE)


LOCK PKOC AUTHENTICATION
Device
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Generate ephemeral Public and Private keys
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Generate ephemeral Public and Private keys
Device Ephemeral Public Key (0x07)
Generate Shared Secret using Reader's ephemeral Public Key and Device's ephemeral Private Key
Create Reader Signature (Site Identifier + Reader Location Identifier +Phone Ephemeral Public Key X component +Reader Ephemeral Public Key X component) and then sign with Site's Private Key
Reader Signature (0x03)
Verify Reader Signature using Site's Public Key
VERIFICATION FAILED, CLOSE CONNECTION AND THROW ERROR
VERIFIED
Create PKOC Signature (Site Identifier + Reader Location Identifier +Phone Ephemeral Public Key X component +Reader Ephemeral Public Key X component) and then sign with PKOC private key
Generate Shared Secret using Reader's ephemeral Private Key and Device's ephemeral Public Key
E(0x40)[ PKOC Public Key (0x01) + PKOC Signature (0x03) + Last Update Time (0x09)]
Using AES256, encrypt (device's PKOC Public Key + Digital Signature) with Shared Secret
Decrypt Public Key using Shared Secret (AES256)
Verify Signature using Device Public Key
Acknowledgement (0x04)

## Android PKOC Sample Code:

1. Create a P-256 ECC public/private key pair

```
public void CreateKeyPair1()
{
            KeyPairGenerator keyGenerator =
KeyPairGenerator.GetInstance(KeyProperties.KeyAlgorithmEc, "AndroidKeyStore");

            ECGenParameterSpec ecParam = new ECGenParameterSpec("secp256r1");
            var builder = new KeyGenParameterSpec.Builder(_keyName, KeyStorePurpose.Sign |
KeyStorePurpose.Verify)
                   .SetUserAuthenticationRequired(false)
                   .SetDigests(KeyProperties.DigestSha256)
.SetRandomizedEncryptionRequired(false)
                   .SetKeySize(256)
.SetAlgorithmParameterSpec(ecParam);
            keyGenerator.Initialize(builder.Build())
keyGenerator.GenerateKeyPair(); }
```

2. Get the public key

```
public IKey GetPublicKey()
  {
      if (!_androidKeyStore.ContainsAlias(_keyName))
return null;
       return _androidKeyStore.GetCertificate(_keyName)?.PublicKey;
  }
```

3. Get the signature from PK and the Hash value

```
// Create Signature instance
Signature s = Signature.GetInstance("SHA256withECDSA");
// Get Private Key
var key = ((PrivateKeyEntry)entry).PrivateKey;
// initialization signature with private key.
s.InitSign(privateKey);
// Update the data to be verified.
s.Update(data); // create
signature var signature =
s.Sign();
```

4. Extract 64 Byte of signature

```
public static byte[] RemoveASNHeaderFromSignature(byte[] signature)
{
             if (signature.Length == 64)
             {
                return signature;
             }
             var calculatedSignature = new byte[64];
int xLength = signature[3];                var arrX =
new byte[32];              // copy 32 bytes in arrayX
             Array.Copy(signature, xLength == 32 ? 4 : 5, arrX, 0, 32);
             // copy 32 bytes in aaryaY
             int yLength = signature[3 + xLength + 2];
```

```
             var arrY = new byte[32];
             Array.Copy(signature, yLength == 32 ? (3 + xLength + 2 + 1) :
(3 + xLength + 2 + 1 + 1), arrY, 0, 32);
             // copy arrayX and arrayY in signature bytes.
             Array.Copy(arrX, 0, calculatedSignature, 0, arrX.Length);
             Array.Copy(arrY, 0, calculatedSignature, arrX.Length, arrY.Length);

             return calculatedSignature; }
```

## iOS PKOC Sample Code:

1. Create a P-256 ECC public/private key pair

```
private bool GenerateKECKeyPair() {
using (var access = new SecAccessControl(SecAccessible.AfterFirstUnlockThisDeviceOnly,
SecAccessControlCreateFlags.PrivateKeyUsage) {
                       var secKeyAttributes = new SecPublicPrivateKeyAttrs {
                    ApplicationTag = KeyStoreName,
                    CanDecrypt = true,
                    CanEncrypt = true,
                    CanSign = true,
                    CanVerify = true,
                    IsPermanent = true,


                };
 var secStatusCode = SecKey.GenerateKeyPair(SecKeyType.EC, 256, secKeyAttributes, out SecKey
publicKey, out SecKey privateKey);
 if (secStatusCode == SecStatusCode.Success)
{ return true; }
               else{ return false; }
               }
}
```

2. Get the public key:

```
private  SecKey GetPublicKey()  var Key =
SecKeyChain.QueryAsConcreteType(
new                  SecRecord(SecKind.Key){
KeyType = SecKeyType.EC,
                    ApplicationTag = KeyStoreName,
                },
                out var code);
 code == SecStatusCode.Success ? Key as SecKey : null;
return key.GetPublicKey();
```

3. Get the signature from PK and the Hash value

```
NSData generateDigitalSignature (NSData hashData)
{                 NSData signedData = null;
try {
        SecKey privateKey = getPrivateKey ();
        Console.WriteLine (privateKey);
NSError err;
        if (privateKey == null) {
GetSecureEnclavePublicKey ();
privateKey = getPrivateKey ();         }


 signedData = privateKey?.CreateSignature (SecKeyAlgorithm.EcdsaSignatureMessageX962Sha256, hashData,
out err);
       Console.WriteLine (signedData);
      } catch (Exception ex) {
      }
      return signedData;
  }
```

4. Extract 64 Byte of signature

```
private byte[] RemoveASNHeaderFromSignature(byte[] signature)
        {
            if (signature.Length == 64)
return signature;
            var calculatedSignature = new byte[64];
int xLength = signature[3];             var arrX =
new byte[32];
            Array.Copy(signature, xLength == 32 ? 4 : 5, arrX, 0, 32);
int yLength = signature[3 + xLength + 2];
            var arrY = new byte[32];
           Array.Copy(signature, yLength == 32 ? (3 + xLength + 2 + 1) : (3 + xLength + 2 + 1
+ 1), arrY, 0, 32);
            Array.Copy(arrX, 0, calculatedSignature, 0, arrX.Length);
            Array.Copy(arrY, 0, calculatedSignature, arrX.Length, arrY.Length);
return calculatedSignature;         }
```

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