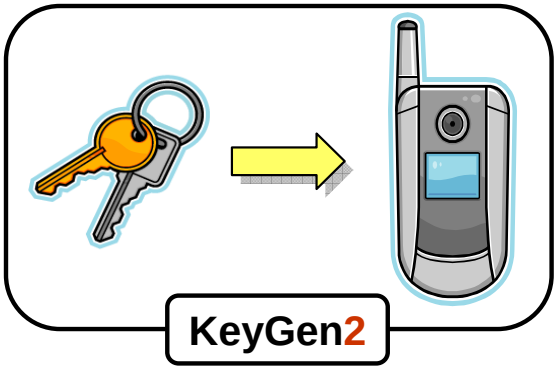


KeyGen2* – “Universal Provisioning”

KeyGen2 is an effort creating a standard for browser-based on-line provisioning of PKI user-certificates and keys.

In addition, KeyGen2 supports an option for “piggybacking” symmetric keys like OTP (One Time Password) seeds on PKI, which is a way of leveraging KeyGen2 as well as providing higher security, more sophisticated key-management facilities, and improved flexibility compared to most current symmetric-key-only provisioning systems.

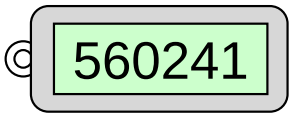
Using a generic credential extension mechanism, KeyGen2 can support things like Microsoft InfoCards and downloadable code associated with a specific key.

One of the core targets for KeyGen2 are mobile phones equipped with TPMs (Trusted Platform Modules), which properly applied, *can securely emulate any number of smart-cards*. Although TPMs definitely is not a standard utility *today*, it is anticipated that TPMs will be the norm within five years or so.

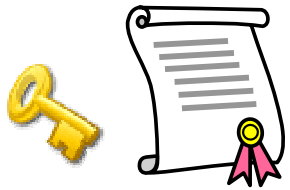
* KeyGen2 is a tribute to KeyGen which was the first browser-based PKI provisioning protocol, introduced by Netscape 1996.

KeyGen2 – Core Features

- Supports all the authentication and signature keys a *consumer*, *citizen*, or *employee* may need (*any organization* + *any technology*)
- Supports user-key lifecycle management operations ranging from semi-automatic renewals to credential policy updates
- Supports issuer-specific PIN-codes, policies, and PUKs
- Supports a Browser as well as a “Web Service” interface
- Builds on established Internet standards such as HTTPS, MIME, XML Schema, XML Signature, and XML Encryption
- Works equally well in a non-managed device as well as in a managed device
- Supports cryptographic containers vouching for generated keys through endorsement-key signatures, which enable issuers verifying that keys actually reside in a "safe harbor" rather than in unknown territory



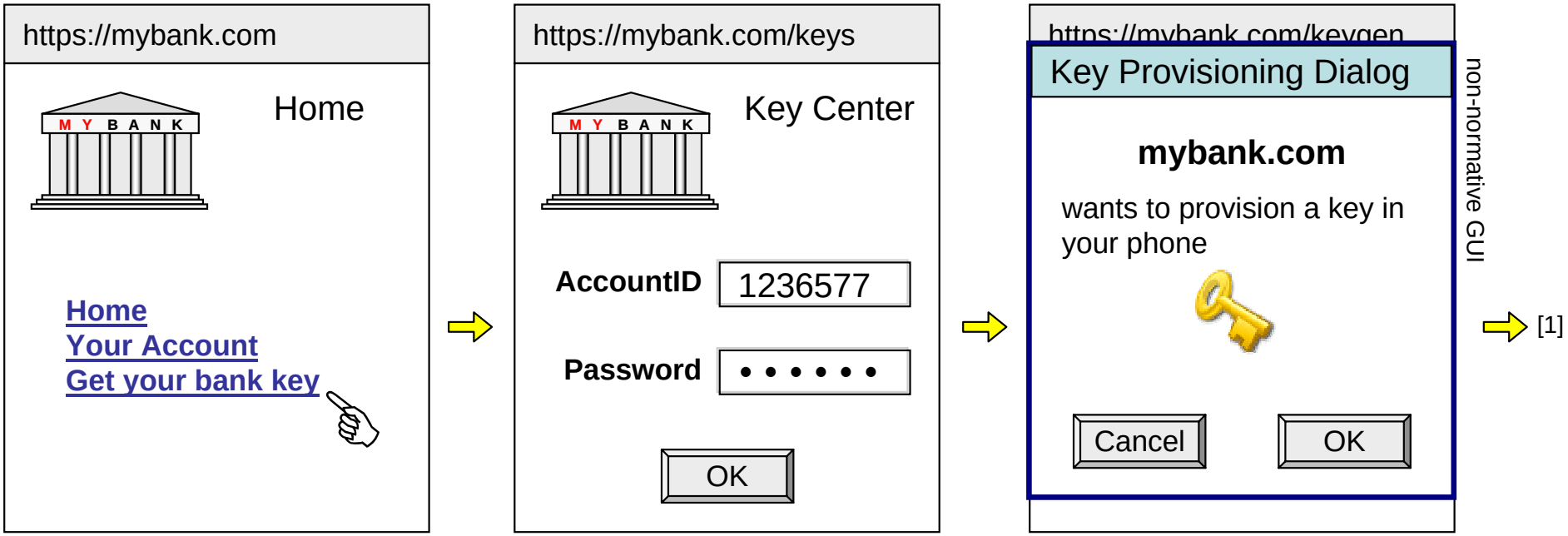
OTP (One Time Password)



PKI (Public Key Infrastructure)

Microsoft CardSpace

Browser-based Key Provisioning - 1/2



- Using a mobile browser makes the enrolment procedure and authentication method independent of the final key provisioning step
- A browser scheme is most suited for entities that do not manage the device
- A browser-based key provisioning system can be made compatible with traditional e-mail loop back address verification over the Internet as well as with strict procedures in a passport office using an NFC/Bluetooth connection to a local provisioning server

1] Additional key provisioning steps left out for brevity

Browser-based Key Provisioning - 2/2

Arbitrary GET or POST operation through the mobile browser

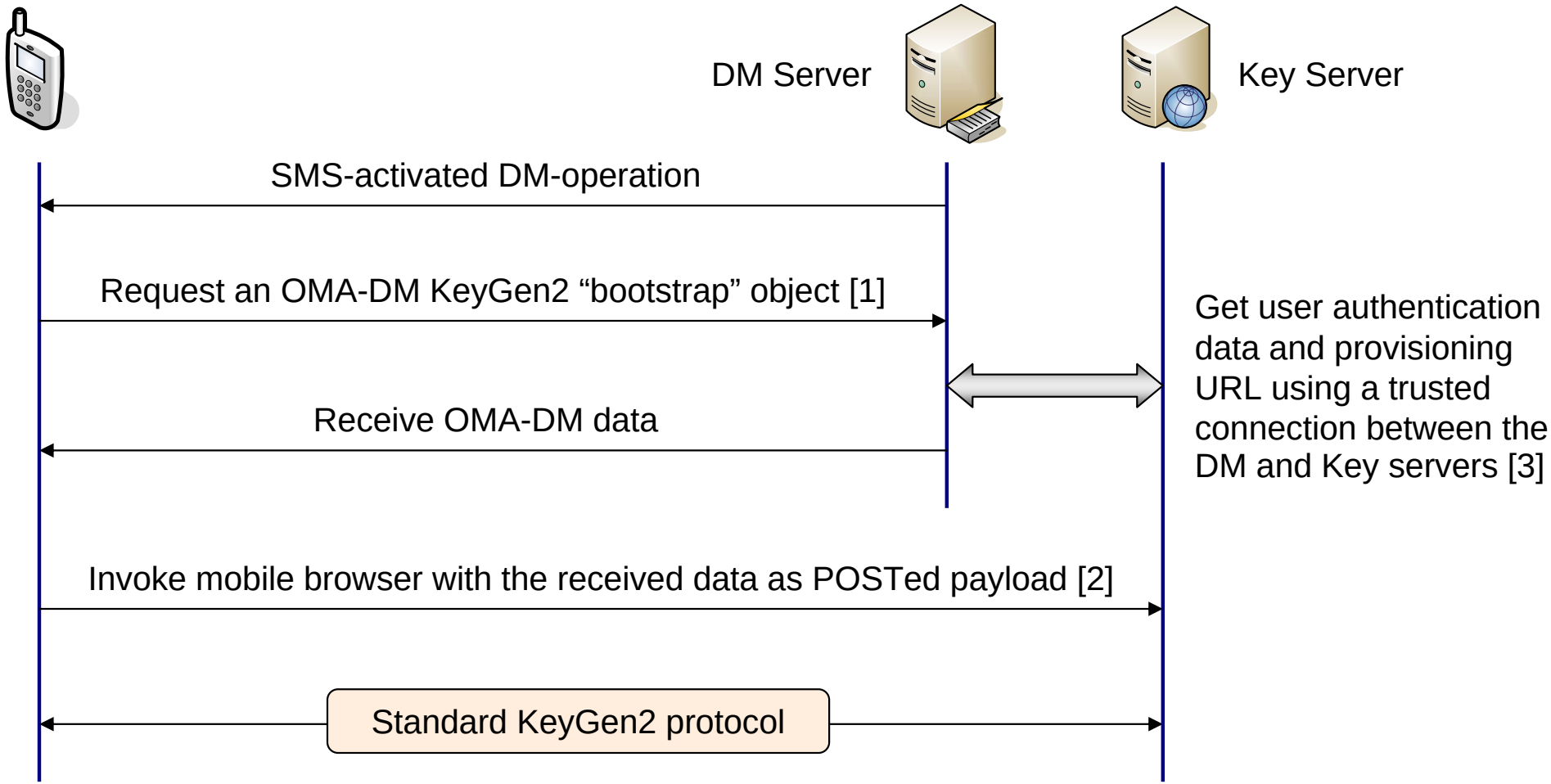
Response using the MIME-type `application/xbpp+xml`

Check if the returned data contains an XML object with the KeyGen2 namespace and a `PlatformNegotiationRequest` top element

KeyGen2 protocol invocation!

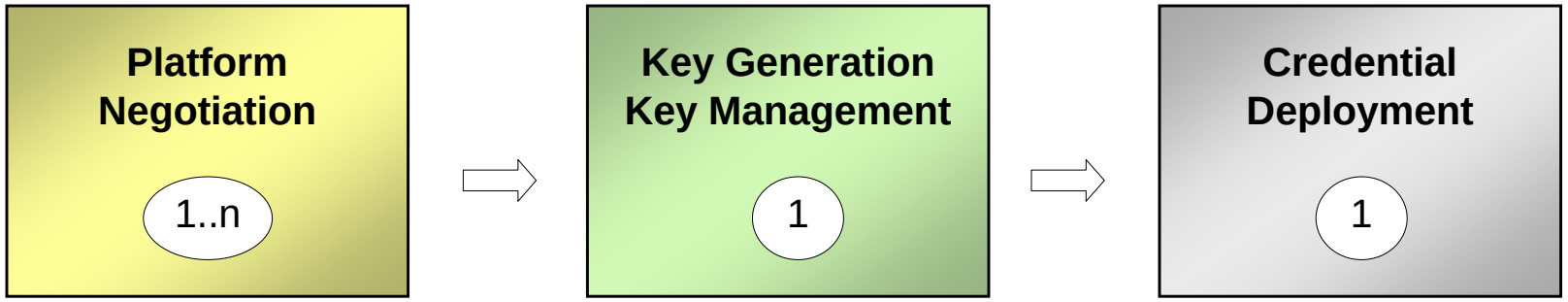
The rest of the KeyGen2 protocol exchanges

Device Managed Key Provisioning



Notes: 1. User authentication may be limited to what OMA-DM offers but may also be augmented (2) with OOB-provided information given to the user. 3. Directory servers typically also needs to be a part of a key provisioning scheme but this does not change the principle.

KeyGen2 Protocol Phases



The number in the circle tells how many times the actual phase may occur. Platform Negotiation essentially deals with figuring out what cryptographic container to use as well as algorithm capabilities of the client-platform (like if it does it supports ECDSA).

The last phase, Credential Deployment may run as a separate task in the case there is a certification-period or similar between the Key Generation and the actual issuance of credentials.

KeyGen2 - Protocol Basics

Note: Platform Negotiation is currently TBD

In the beginning there was an empty key-store…

A key-issuer requests the owner (client) to “mint” a fresh RSA key-pair

```
<KeyOperationRequest RequestID="I.535100037738" ... >

   <CreateObject>

      <KeyPair ID="Key.1" KeyUsage="authentication">
         <RSA KeySize="2048"/>
      </KeyPair>

   </CreateObject>

</KeyOperationRequest>
```

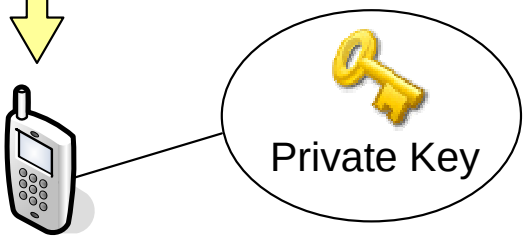
The client's response

```
<KeyOperationResponse ... >
  <GeneratedPublicKey ID="Key.1" RequestID="I.535100037738">
    <ds:Signature>
      <ds:SignedInfo>
        <ds:CanonicalizationMethod Algorithm="http://www.w3.org/2001/10/xml-exc-c14n#"/>
        <ds:SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1"/>
        <ds:Reference URI="#Key.1">
          <ds:Transforms>
            <ds:Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature"/>
            <ds:Transform Algorithm="http://www.w3.org/2001/10/xml-exc-c14n#"/>
          </ds:Transforms>
          <ds:DigestMethod Algorithm="http://www.w3.org/2000/09/xmldsig#sha1"/>
          <ds:DigestValue>kqvBiyGe27B1twVFykLLuVq5kPs=</ds:DigestValue>
        </ds:Reference>
      </ds:SignedInfo>
      <ds:SignatureValue>TObiq9I….Mvj+oU=</ds:SignatureValue>
      <ds:KeyInfo>
        <ds:KeyValue>
          <ds:RSAKeyValue>
            <ds:Modulus>AKPRc….kESkV</ds:Modulus>
            <ds:Exponent>AQAB</ds:Exponent>
          </ds:RSAKeyValue>
        </ds:KeyValue>
      </ds:KeyInfo>
    </ds:Signature>
  </GeneratedPublicKey>

</KeyOperationResponse>
```

This is the generated RSA public key. The XML- signature functions as a "proof-of-possession" of the matching private key which only the client has access to. A conforming KeyGen2 implementation SHOULD also include a `Reference` to the `KeyInfo` object (i.e. signing the public key itself).

Install the certified key returned by the issuer in the key-store

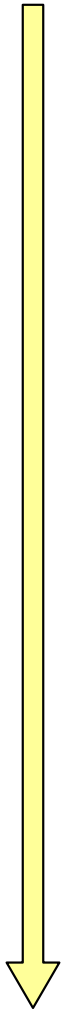
```
<CredentialDeploymentRequest ... >

   <CertifiedPublicKey ID="Key.1">
      <ds:X509Data>
         <ds:X509Certificate>MIIDnTCC…AoWgA=</ds:X509Certificate>
      </ds:X509Data>
   </CertifiedPublicKey>

</CredentialDeploymentRequest>
```



The private key and associated public key certificate are now ready to use!

KeyGen2 - Advanced Protocol Examples

Adding PIN-code protection and associated policies to a key

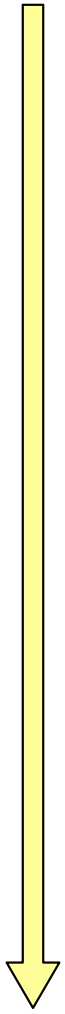


```
<KeyOperationRequest ... >

    <CreateObject>

      <PINPolicy Format="numeric" MaxLength="8" MinLength="5"
                 PatternRestrictions="three-in-a-row sequence" RetryLimit="3">

        <KeyPair ID="Key.1" KeyUsage="authentication">
          <RSA KeySize="2048"/>
        </KeyPair>

      </PINPolicy>

    </CreateObject>

</KeyOperationRequest>
```

The sample above only shows a part of the possible options regarding PIN-codes. You may also have the PIN preset as well as *enclosing multiple keys*. The policy specified in the sample would flag the following PINs as invalid:

654321	Sequence
11123	Three in a row
1A567	Not numeric
4097	Too short

Performing object-management operations on a remote key-store in a *secure*, *robust*, and *issuer-independent* way



```
<KeyOperationRequest ... >

  <ManageObject ID="Section.1" SessionID="S.395428043255">

    <DeleteKey CertificateSHA1="cmLMkegXx2ezBiUapI+TMJdUBdo="/>

    <ds:Signature>
        ....
      <ds:Reference URI="#Section.1">
        ....
      <ds:SignatureValue>TObiq9I….Mvj+oU=</ds:SignatureValue>
        ....
        <ds:X509Certificate>MIIDizCC … kJorHs=</ds:X509Certificate>
        ....
    </ds:Signature>

  </ManageObject>
```

Target key

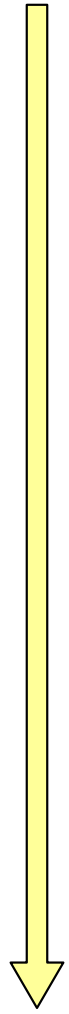
"Certifies"

KeyGen2 builds on the [fairly reasonable] idea that an issuer should only be able to manage keys that is has actually issued. To maintain this integrity requirement, management operations like `DeleteKey` must be augmented with a fresh "proof-of-issuance" enveloped signature where the signing certificate holds the actual CA certificate of the key to be managed. Due to this arrangement there is no need for end-users explicitly trusting CAs (installing root certificates), since it is technically infeasible for an issuer to manipulate keys from other issuers. Because PINs and PUKs are bound to provisioned keys, secure remote management is facilitated for these objects as well.

In addition to `DeleteKey`, KeyGen2 management operations include: `CloneKey`, `ReplaceKey`, `DeleteKeysByContent`, `UpdatePINPolicy`, `UpdatePUKPolicy` and `UpdatePresetPIN`.

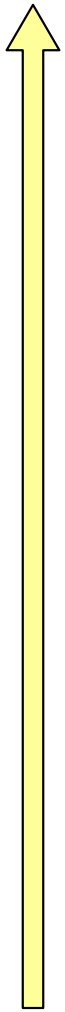
Adding a PUK (Personal Unlock Key) and associated policies to a key

```
<KeyOperationRequest ... >

   </CreateObject>

     <PUKPolicy Format="numeric" Hidden="true" RetryLimit="3"
                ValueReference="Item.1">

       <PINPolicy Format="numeric" MaxLength="8" MinLength="5"
                  PatternRestrictions="three-in-a-row sequence" RetryLimit="3">

         <KeyPair ID="Key.1" KeyUsage="authentication">
           <RSA KeySize="2048"/>
         </KeyPair>

       </PINPolicy>

     </PUKPolicy>

   </CreateObject>

</KeyOperationRequest>
```



KeyGen2 enables PUKs to be created and managed on an issuer-basis which is important for creating a scheme that "emulates" a set of independently issued smart cards. Note that `Hidden="true"` makes the provisioned PUK code unknown for the user which is a possible issuer policy. `ValueReference` points to a table with encrypted values.

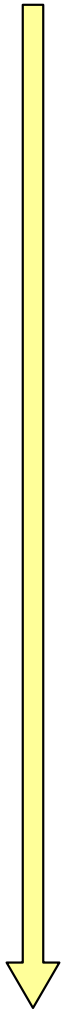
Adding a TPM endorsement signature to a generated key



```
<KeyOperationResponse ID="S.395428043255" ... >

  <GeneratedPublicKey ID="Key.1" RequestID="I.535100037738">
    <ds:Signature>
          …
           <ds:RSAKeyValue>
              <ds:Modulus>AKPRcU … kESkV</ds:Modulus>
              <ds:Exponent>AQAB</ds:Exponent>
           </ds:RSAKeyValue>
          …
    </ds:Signature>
  </GeneratedPublicKey>

  <Attestation>
    <EndorsementKey>
      <ds:Signature>
          …
           <ds:Reference URI="#S.395428043255">
              …
              <!-- CN=TPM Endorsement Key, SerialNumber=SSS/0567753333/A.2 -->
              <ds:X509Certificate>MIIC2D … NdcJfLt</ds:X509Certificate>
              …
      </ds:Signature>
    </EndorsementKey>
  </Attestation>

</KeyOperationResponse>
```

The purpose of an embedding TPM endorsement signature using a TPM (or similar) platform certificate is to vouch for that the matching private keys actually are stored and “executed” in a secure environment rather than in software. An attestation signature may also vouch for that the device operating system has been “measured” as secure.

Supporting semi-automated key-renewals

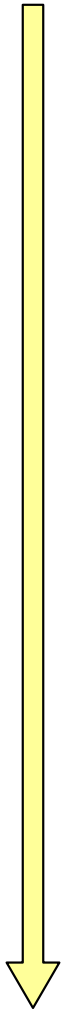


```
<CredentialDeploymentRequest ... >

   <CertifiedPublicKey ID="Key.1">
      <ds:X509Data>
         <ds:X509Certificate>MIIDnT…. n4dPY=</ds:X509Certificate>
      </ds:X509Data>
      <RenewalService NotifyDaysBeforeExpiry="14">
         <URL>http://ca.mybank.com/update</URL>
      </RenewalService>
   </CertifiedPublicKey>

</CredentialDeploymentRequest>
```

The assumption is that there is a local service that checks if a credential is about to expire and optionally asks the user if he/she wants to renew which simply opens the browser to the specified URL. The URL may contain information concerning the specific key, further reducing the number of steps that the user has to perform in order to renew. This scheme is similar to the update schemes used by software vendors like Microsoft, Adobe and SUN.

Provisioning of Symmetric Keys using PKI “Piggybacking”

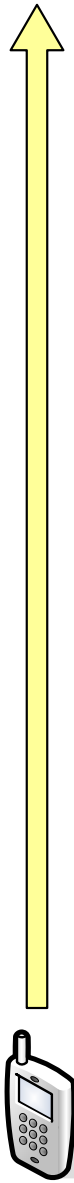
Provisioning an OTP “seed” or similar symmetric shared key



```
<KeyOperationRequest RequestID="I.535100037738" ... >

  <CreateObject>

    <KeyPair ID="Key.1" KeyUsage="piggybacked-symmetric-key">
      <RSA KeySize="1024"/>
    </KeyPair>

  </CreateObject>

</KeyOperationRequest>
```

For the initial request nothing particular has to be performed (*in the client platform NB*), compared to PKI. However, for preserving consistency over the provisioning session, the requester MUST set the key-usage attribute to `"piggybacked-symmetric-key"`.

Provisioning an OTP “seed” or similar symmetric shared key



```
<KeyOperationResponse ID="S.395428043255" ... >

  <GeneratedPublicKey ID="Key.1" RequestID="I.535100037738">
    <ds:Signature>
        ...
         <ds:Reference URI="#Key.1">
          ...
           <ds:RSAKeyValue>
              <ds:Modulus>AKPRcU … kESkV</ds:Modulus>
              <ds:Exponent>AQAB</ds:Exponent>
           </ds:RSAKeyValue>
          ...
    </ds:Signature>
  </GeneratedPublicKey>

</KeyOperationResponse>
```

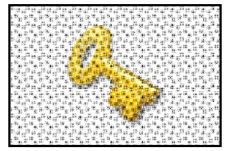
Self-signed public key and core request data

This step is *identical* to that of PKI. On the next page you can see what the provisioning protocol is eventually supposed to return.

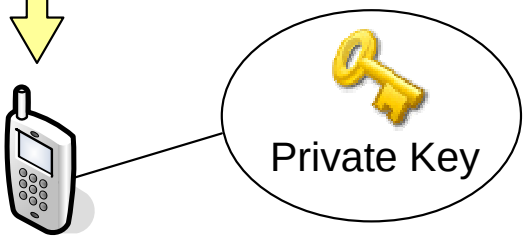
Provisioning an OTP “seed” or similar symmetric shared key

```
<CredentialDeploymentRequest ... >

  <CertifiedPublicKey ID="Key.1">
    <ds:X509Data>
      <ds:X509Certificate>MIIDnT … Yn4dPY=</ds:X509Certificate>
    </ds:X509Data>
    <PiggybackedSymmetricKey MAC="h54fg … 6LA3dj="
      EndorsedAlgorithms="http://www.w3.org/2000/09/xmldsig#hmac-sha1">
      <xenc:EncryptedKey>
        <xenc:EncryptionMethod Algorithm="http://www.w3.org/2001/04/xmlenc#rsa-1_5"/>
        <xenc:CipherData>
          <xenc:CipherValue>IqKkjf2LuLL … 2JF8g+6Q=</xenc:CipherValue>
        </xenc:CipherData>
      </xenc:EncryptedKey>
    </PiggybackedSymmetricKey>
    <PropertyBag Type="urn:otpstd:spec">
      <Property Name="login" Value="janedoe"/>
      <Property Name="digits" Value="8"/>
      <Property Name="counter" Value="456" Writable="true"/>
    </PropertyBag>
  </CertifiedPublicKey>
```

Public Key
(X509v3 Cert)



Wrapped
Symmetric
Key



In order to fully provision a symmetric key, you now need to decrypt the wrapped symmetric key with the matching private key as well as storing possible additional key attribute-data (`Property` objects). To benefit from KeyGen2’s object-management scheme you also need to make a link between the “piggybacked” certificate and the symmetric key. `EndorsedAlgorithms` holds a list of issuer-endorsed algorithms.

Note: The X509 certificate functions as a universal key ID for all credential types.

Supporting Microsoft's Managed InfoCards

```
<CertifiedPublicKey ID="Key.1">
   <ds:X509Data>
      <ds:X509Certificate>MIIDnTCCA … WMYn4dPY=</ds:X509Certificate>
   </ds:X509Data>
   <Extension Type="http://schemas.microsoft.com/ws/2005/05/identity">PGRza ... 0dXJlPg0K</Extension>
</CertifiedPublicKey>
```

Base64-encoded InfoCard

```
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#">
   <Object Id="_Object_InfoCard">
      <InformationCard xml:lang="en-us"
                       xmlns="http://schemas.microsoft.com/ws/2005/05/identity">
         <UserCredential>
            <X509V3Credential>
               <X509Data xmlns="http://www.w3.org/2000/09/xmldsig#">
                  <KeyIdentifier
ValueType="http://docs.oasis-open.org/wss/2004/xx/oasis-2004xx-wss-soap-message-security-1.1#ThumbprintSHA1"
xmlns="http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-wssecurity-secext-1.0.xsd">V43s...Q=</KeyIdentifier>
               </X509Data>
            </X509V3Credential>
         </UserCredential>
         <SupportedTokenTypeList>
            <TokenType xmlns="http://schemas.xmlsoap.org/ws/2005/02/trust">urn:oasis:names:tc:SAML:1.0:assertion</TokenType>
         </SupportedTokenTypeList>
         <SupportedClaimTypeList>
            <SupportedClaimType Uri="http://schemas.microsoft.com/ws/2005/05/identity/claims/givenname">
               <DisplayTag>Given Name</DisplayTag>
            </SupportedClaimType>
         </SupportedClaimTypeList>
      </InformationCard>
   </Object>
</Signature>
```

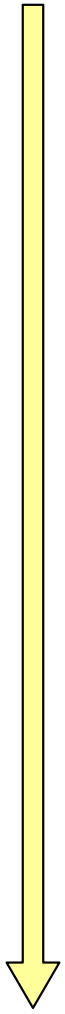
A managed InfoCard using an X.509 credential for authentication to the STS (IdP) needs to be "synchronized" with the certificate since the `KeyIdentifier` holds the certificate hash. Using the KeyGen2 credential extension mechanism the certificate and associated managed InfoCard(s) can be conveniently issued and managed "in parallel". This of course requires that the particular extension is recognized by the client software (which is found out during the platform negotiation phase).

Note: *The InfoCard sample was cut-down substantially in order to fit the page*.

Dealing with downloadable code that is trusted for usage with a specific key

```
<CredentialDeploymentRequest ... >

  <CertifiedPublicKey ID="Key.1">
    <ds:X509Data>
      <ds:X509Certificate>MIIDnT … Yn4dPY=</ds:X509Certificate>
    </ds:X509Data>
    <Extension Type="http://java.com/bytecode"
               Qualifier="EMV-Payment-1.3">PGRza ... 0dXJlPg0K</Extension>
    <ds:Signature>
        …
      <ds:Reference URI="#Key.1">
          …
        <!-- CN=Sub CA, O=example.com -->
        <ds:X509Certificate>MIIC2D … NdcJfLt</ds:X509Certificate>
            …
    </ds:Signature>
  </CertifiedPublicKey>
```

“Certifies”



The similarity between the standard case is that the key (which can be a `PiggybackedSymmetricKey` as well) itself is always provisioned the same way. The difference is that the `Extension` object contains downloadable code (which has been identified as being executable on the target platform during the initial platform negotiation phase), that is trusted by the issuer of the key but not necessarily by the platform. That the code is trusted for use with the key is indicated by the added enveloped signature. The signature certificate MUST be verifiable as the issuer of the lowest member of `CertifiedPublicKey` but does not have to be trusted (known) by the client platform. Key-management operations should include downloaded code as well since such code is just another kind of key attribute.

Note: *This arrangement still requires that the downloadable code is executed in a sandbox!*

Deferred User Validation/Authentication -

Increasing security, while reducing RA costs

Traditional Signup (Upfront Validation)

- The signup password must be distributed OOB which is expensive as well as making the scheme vulnerable to identity theft
- The signup password is susceptible to “phishing” attacks
- Long (=secure) passwords are inconvenient for users
- Single-use passwords tend to create helpdesk issues

For brevity reasons the PIN-code creation dialog was omitted.

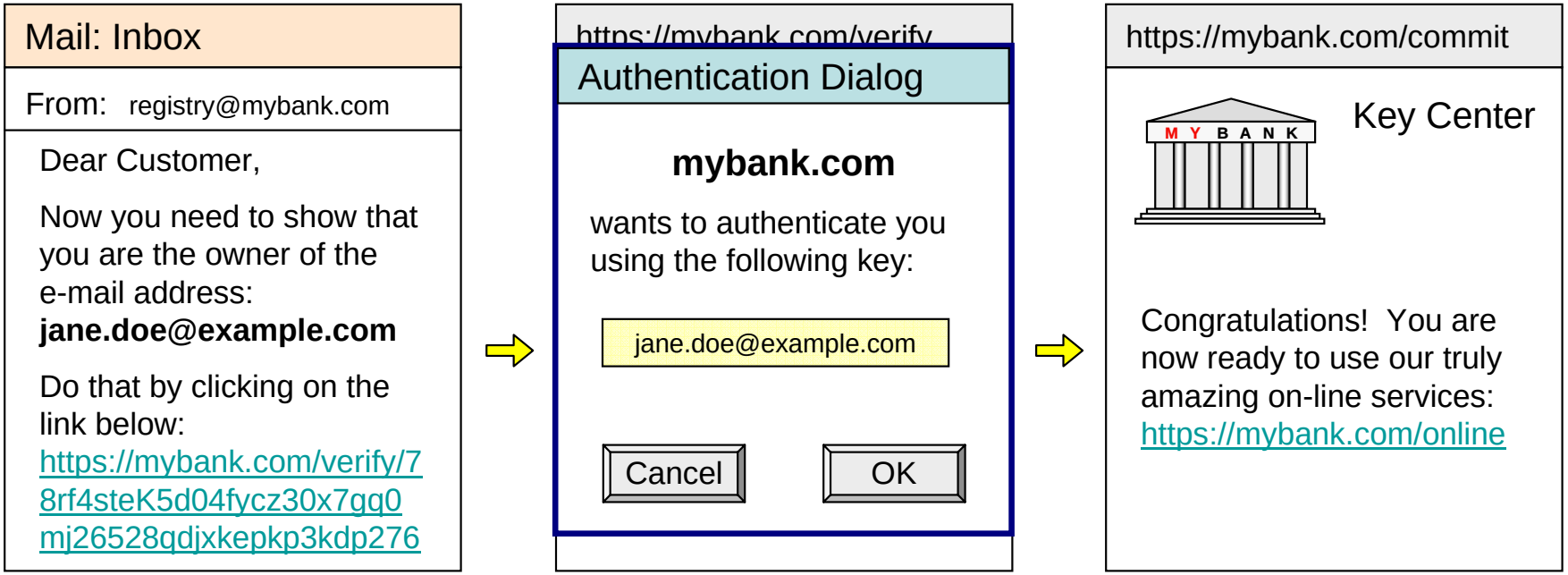
Deferred User Validation

For brevity reasons the PIN-code creation dialog was omitted.

After the step above, the issuer has a “phish-free”, cryptographically secured link to the user (the user’s device to be entirely correct…) *without having distributed any kind of secret*. The address verification URL on the next page may seem like a contradiction to this but the variable part is typically an HMAC of a master secret and the user’s certificate which has no value except for the owner of the matching certificate.

The provider now has a number of options regarding the rest of provisioning. One option is treating the issued credential as a specific sign-up credential which is subsequently replaced with the real credential after the e-mail address has been verified. Another option is putting the issued credential “on hold” until the address has been validated.

Deferred User Validation, continued



- No secrets need to be distributed OOB or on the wire (=nothing to steal except for the device itself)
- Aligned with the most established way of establishing user-identity on the Internet as well as supporting “in person” validation options
- Can also be used with SMS to achieve similar bindings
- “Self-service” oriented

For brevity reasons the PIN-code dialog was omitted.