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XML Wrapping Attack Mitigation using Positional Token

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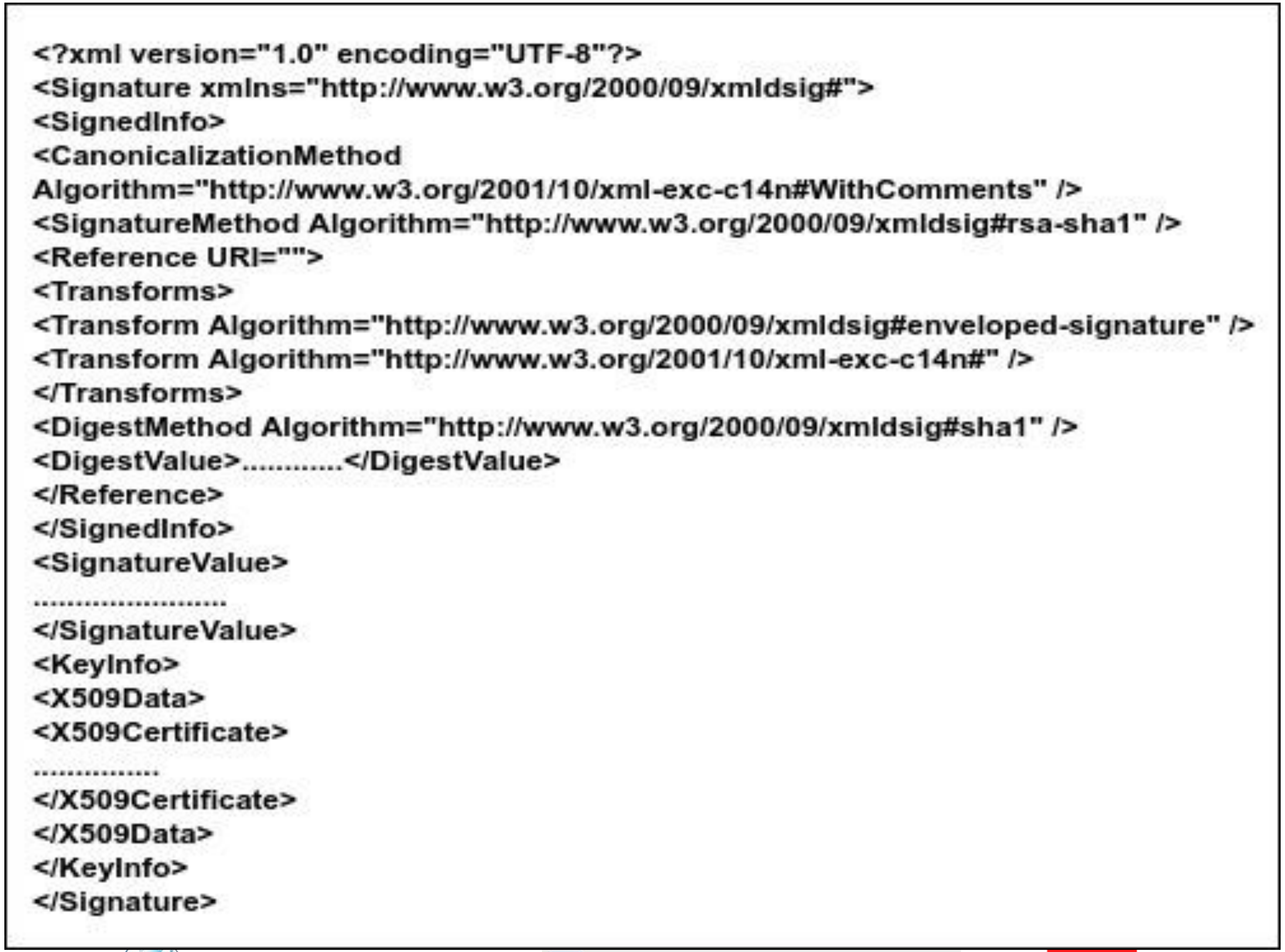
XML Digital Signature

- XML Signatures are a kind of digital signatures designed for catering the need of XML message exchange or XML transactions.
- XML Signature has been designed in such a way that it can sign a specific portion of a XML document rather than signing the whole document
- XML Signature standard defined by W3C and IETF
  - www.w3.org, 'XML Signature Syntax and Processing Version 2.0', 2015. [Online]. Available: http://www.w3.org/TR/xmldsig-core/.

Schematic of XML Signature



```
<?xml version="1.0" encoding="UTF-8"?>
<Signature xmlns="http://www.w3.org/2000/09/xmldsig#">
<SignedInfo>
<CanonicalizationMethod
Algorithm="http://www.w3.org/2001/10/xml-exc-c14n#WithComments" />
<SignatureMethod Algorithm="http://www.w3.org/2000/09/xmldsig#rsa-sha1" />
<Reference URI="">
<Transforms>
<Transform Algorithm="http://www.w3.org/2000/09/xmldsig#enveloped-signature" />
<Transform Algorithm="http://www.w3.org/2001/10/xml-exc-c14n#" />
</Transforms>
<DigestMethod Algorithm="http://www.w3.org/2000/09/xmldsig#sha1" />
<DigestValue>............</DigestValue>
</Reference>
</SignedInfo>
<SignatureValue>
.........................
</SignatureValue>
<KeyInfo>
<X509Data>
<X509Certificate>
................
</X509Certificate>
</X509Data>
</KeyInfo>
</Signature>
```

Basic structure of an XMLDSIG

- Signed Info
  - Metadata describing the content being signed.
- Signature Value
  - Signature of the digest of the Signed Info metadata
- Key Info
  - Metadata about or the actual key used.

XML Signature generation algorithm

- Find the nodes within XML documents designated for signing.
- Digest of each node to be signed is calculated.
- For each node getting signed, a <Reference> element is added inside <SignedInfo> node.
- Before being subjected to signature generation, XML node is canonicalized using an algorithm mentioned by <Transform> node inside <Reference> node.
- Calculate digest of specified node and resultant digest value is placed inside <DigestValue> node.
- After, having calculated digest for each designated node, <SignedInfo> node, now contains a set of <Reference> elements corresponding to each node whose digest was created in previous step.
- Sign <SignedInfo> node by calculating the digest of the <SignedInfo> element and encrypting the digest and enclosing this encrypted content inside <SignatureValue> node.

XML Signature verification algorithm

- Recalculate the digest of the <SignedInfo> element (the algorithm to calculate digest is specified in <SignatureMethod> element).
- Decrypt the value inside <SignatureValue> using public key and match this decrypted content with the calculated digest of <SignedInfo>.
- If the previous step is successful, then, recalculate the digests of all references inside <SingedInfo> node and match the calculated digest of referenced elements with the respective digests contained inside the <DigestValue> inside <SignedInfo> node, if a perfect match happens for every references, then it results into a successful signature verification

Web Service

- Web Service is a remote service accessible over open protocols
  - Most prominent protocol is SOAP and standards used such as WSDL and UDDI.
  - SOAP is a XML based protocol.
- As most web services performs important task involving valuable data transaction.
  - Security related issues arise.
  - Securing SOAP messages using digital signature for solving issues related to authentication, data integrity and non repudiation.

XML Wrapping Attacks

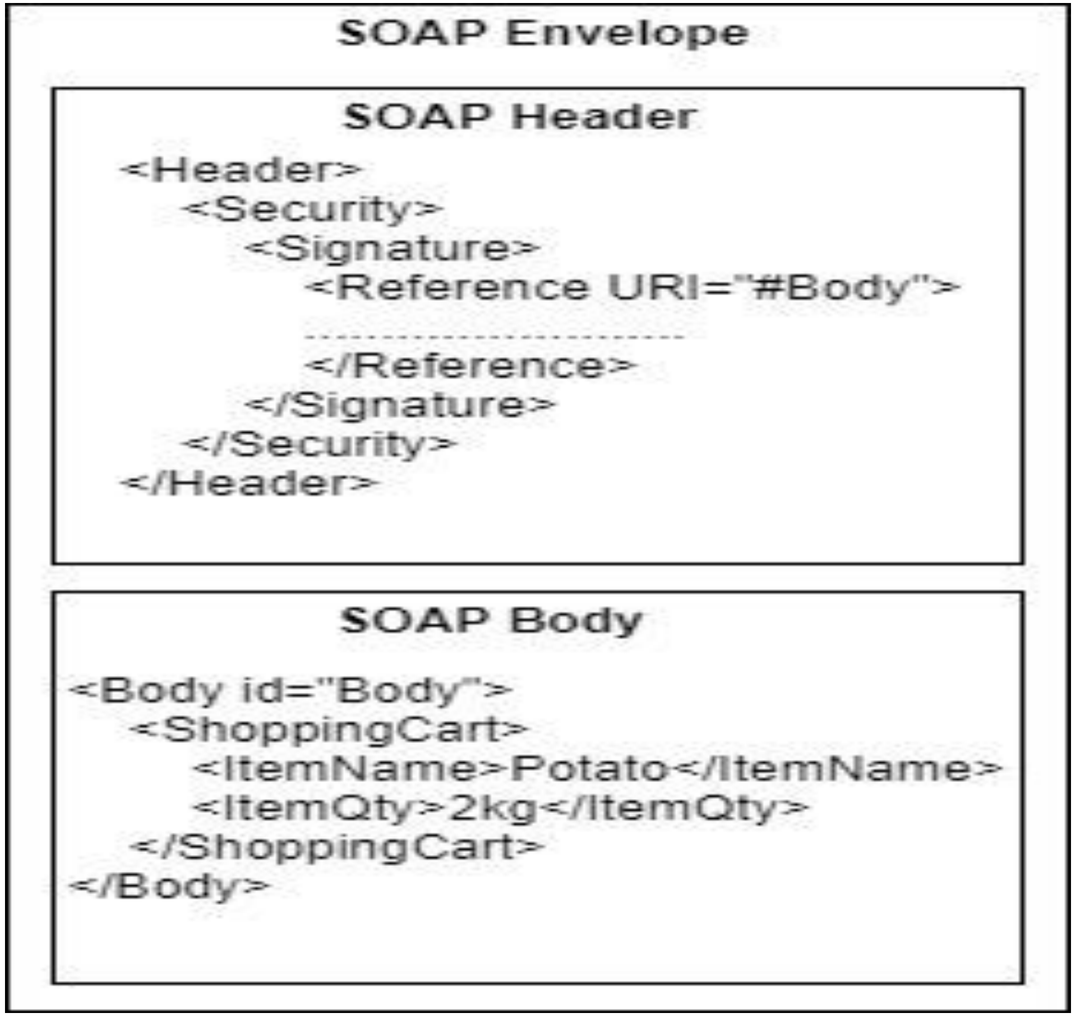
- XML signature standard defined by IETF/W3C references or identifies signed elements by their unique identities specified by “id“ attribute values in the given XML document.
- Hence, signed XML elements can be shifted from one location to another location in a XML document, and still, it does not have any effect on its ability to verify its signature.
- This flexibility paves the way for an attacker to tweak original XML message without getting noticed by the receiver.

Reference

- "XML Signature Element Wrapping Attacks and Countermeasures"
  - Michael McIntosh & Paula Austel
  - IBM Research, Hawthorne, NY
  - Workshop On Secure Web Services
  - Proceedings of the 2005 Workshop on Secure Web Services
  - ACM Press

  https://dl.acm.org/citation.cfm?id=1103026&jmp=cit&coll=ACM&dl=ACM#CIT

Actual SOAP request



SOAP Envelope

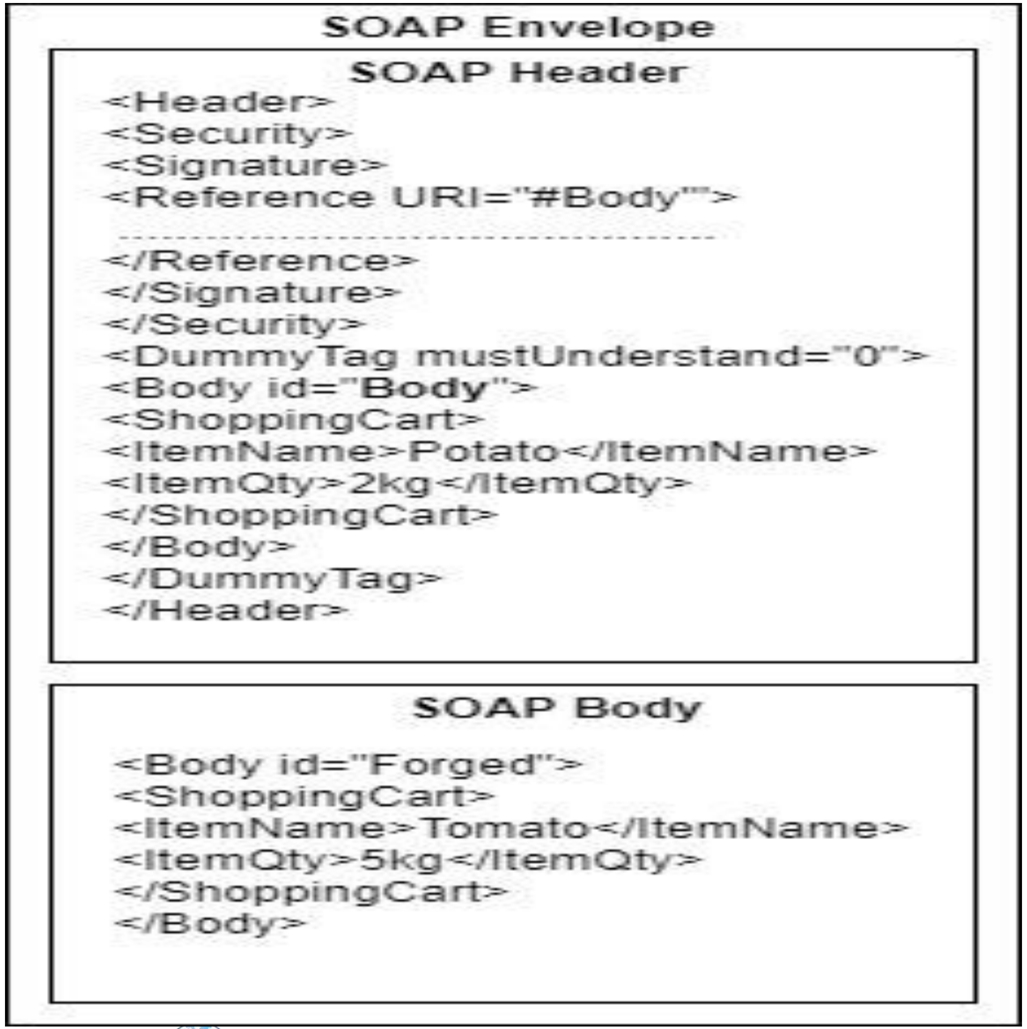
SOAP Header

```
<Header>
   <Security>
      <Signature>
         <Reference URI="#Body">
         ------------------------------
         </Reference>
      </Signature>
   </Security>
</Header>
```

SOAP Body

```
<Body id="Body">
   <ShoppingCart>
      <ItemName>Potato</ItemName>
      <ItemQty>2kg</ItemQty>
   </ShoppingCart>
</Body>
```

Forged SOAP request



SOAP Envelope

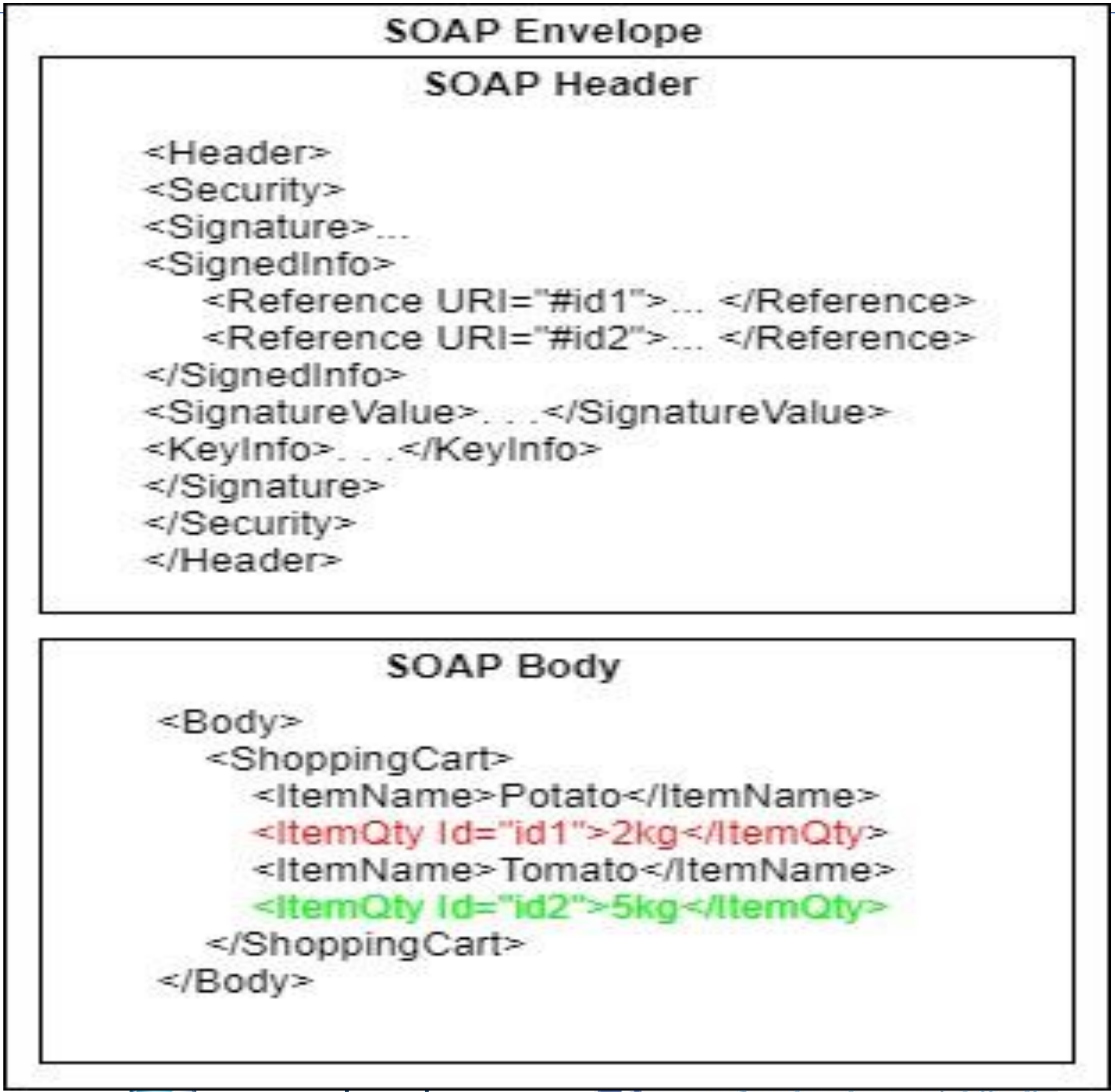
SOAP Header

```
<Header>
<Security>
<Signature>
<Reference URI="#Body"">
  ----------------------------------------
</Reference>
</Signature>
</Security>
<DummyTag mustUnderstand="0">
<Body id="Body">
<ShoppingCart>
<ItemName>Potato</ItemName>
<ItemQty>2kg</ItemQty>
</ShoppingCart>
</Body>
</DummyTag>
</Header>
```

SOAP Body

```
<Body id="Forged">
<ShoppingCart>
<ItemName>Tomato</ItemName>
<ItemQty>5kg</ItemQty>
</ShoppingCart>
</Body>
```

Actual SOAP request



SOAP Envelope

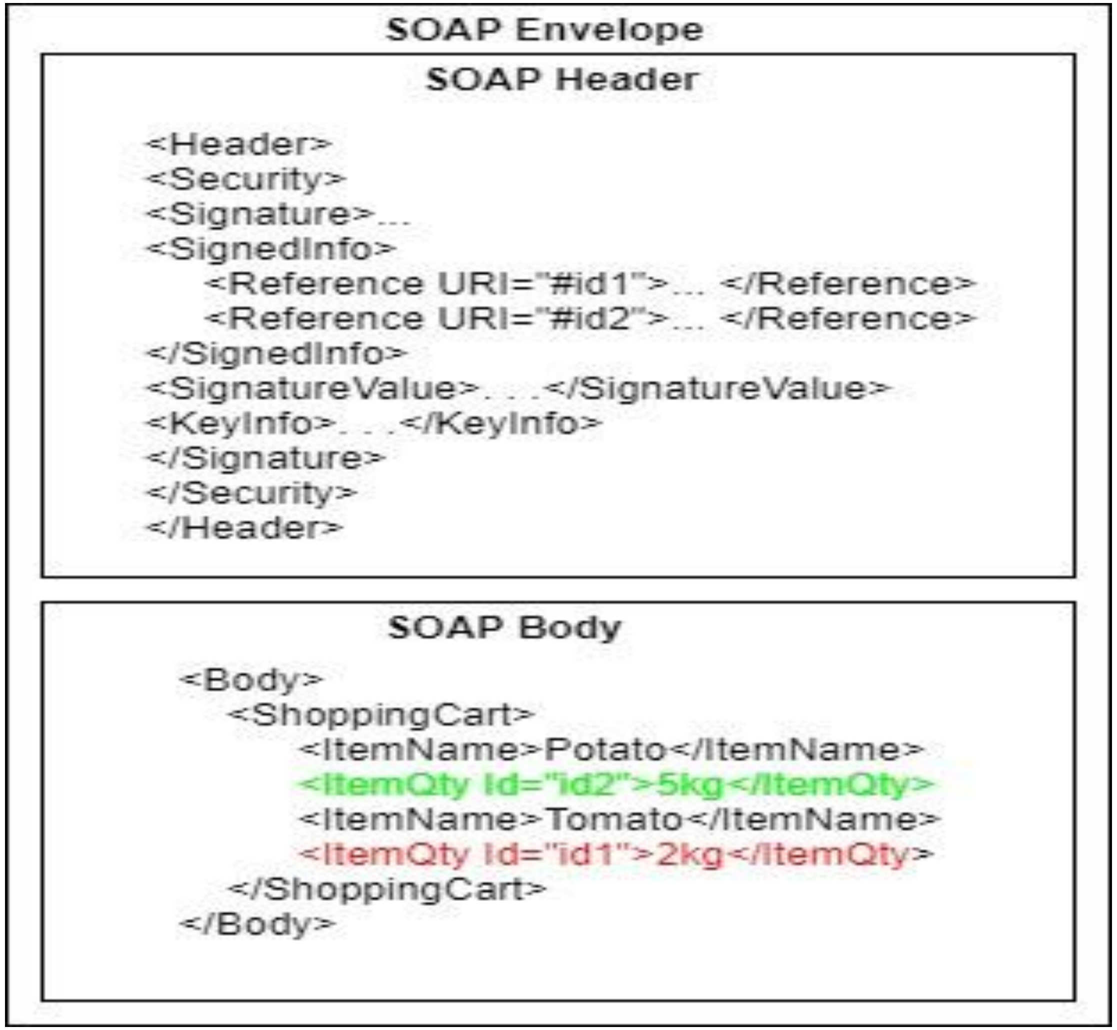
SOAP Header

```
<Header>
<Security>
<Signature>...
<SignedInfo>
    <Reference URI="#id1">... </Reference>
    <Reference URI="#id2">... </Reference>
</SignedInfo>
<SignatureValue>. . .</SignatureValue>
<KeyInfo>. . .</KeyInfo>
</Signature>
</Security>
</Header>
```

SOAP Body

```
<Body>
   <ShoppingCart>
      <ItemName>Potato</ItemName>
      <ItemQty Id="id1">2kg</ItemQty>
      <ItemName>Tomato</ItemName>
      <ItemQty Id="id2">5kg</ItemQty>
   </ShoppingCart>
</Body>
```

Elements jumbled wrapping attack



SOAP Envelope

SOAP Header

```
<Header>
<Security>
<Signature>...
<SignedInfo>
    <Reference URI="#id1">... </Reference>
    <Reference URI="#id2">... </Reference>
</SignedInfo>
<SignatureValue>. . .</SignatureValue>
<KeyInfo>. . .</KeyInfo>
</Signature>
</Security>
</Header>
```

SOAP Body

```
<Body>
  <ShoppingCart>
      <ItemName>Potato</ItemName>
      <ItemQty Id="id2">5kg</ItemQty>
      <ItemName>Tomato</ItemName>
      <ItemQty Id="id1">2kg</ItemQty>
  </ShoppingCart>
</Body>
```

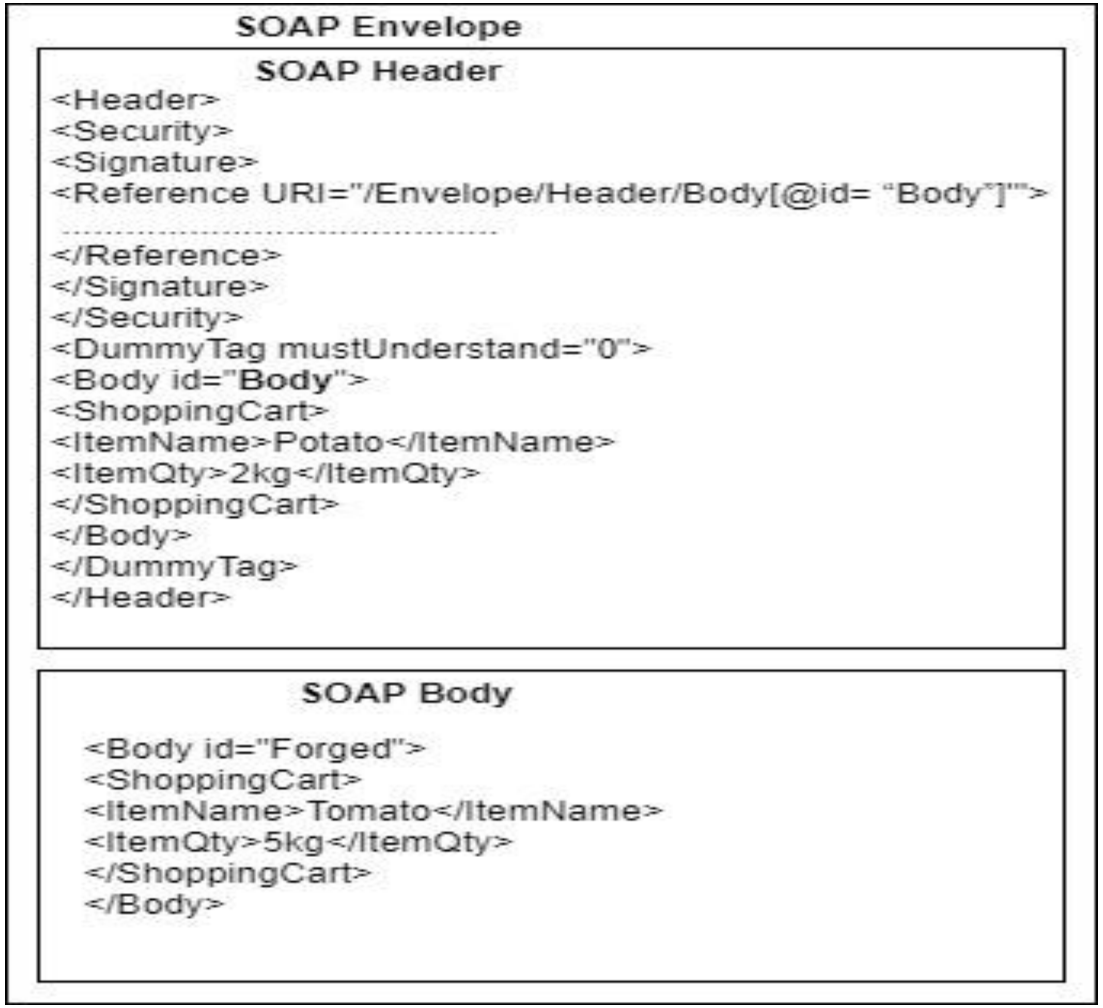
Proposed XML signature generation algorithm.

```
For each element subjected to be signed represented by its “Id” attribute values{
    ABSXpath= “Absolute XPath” of element to be signed as identified with its “id” attribute values
    ProtectTree=SOAP request node identified by ABSXpath
    MixedElement=AppendSyntacticToken(ProtectTree,  ABSXpath)
    /*append a Positional Token as an attribute, “PosToken= ABSXpath” to the ProtectTree */
    H=Hash(MixedElement)
    Add ABSXpath  to <Reference> node  as “URI” attribute value
    Enclose H to <DigestValue> node inside the <Reference> node, as defined in XML Signature standard [9].
}
SignedInfoHash=calculate hash of <SignedInfo> element
/*   calculate the digest of the <SignedInfo> element */
SignedSOAP=Encrypt(SignedInfoHash , PrivateKey)
```

Proposed XML Signature Verification algorithm

```
SignInfoDigest=Calculate digest of the <SignedInfo> element
SignatureValueContent= content inside <SignatureValue> node
Flag=VerifySignature(Public Key, SignatureValueContent, SignInInfoDigest)
If(Flag){
    Ids=All  URI’s in <Reference> nodes inside the <SignedInfo> node
    For each  Id from Ids){
        ABSXpath=Get the content of Id
        Subtree=Get the sub tree identified by ABSXpath
        MixedElement =AppendSyntacticTokenSubTree(Subtree, ABSXpath)
        /*append a Positional Token as an attribute, “PosToken= ABSXpath” to the Subtree  */
        H=Hash (MixedElement)/* generate hash value of signed elements. */
        Digest=Get digest value under the  <Reference> node and inside <DigestValue> node, whose “URI” is equal to Id
        If(H!=Digest){
            return false
} }
```

Wrapping attack mitigation, scenario-1



SOAP Envelope

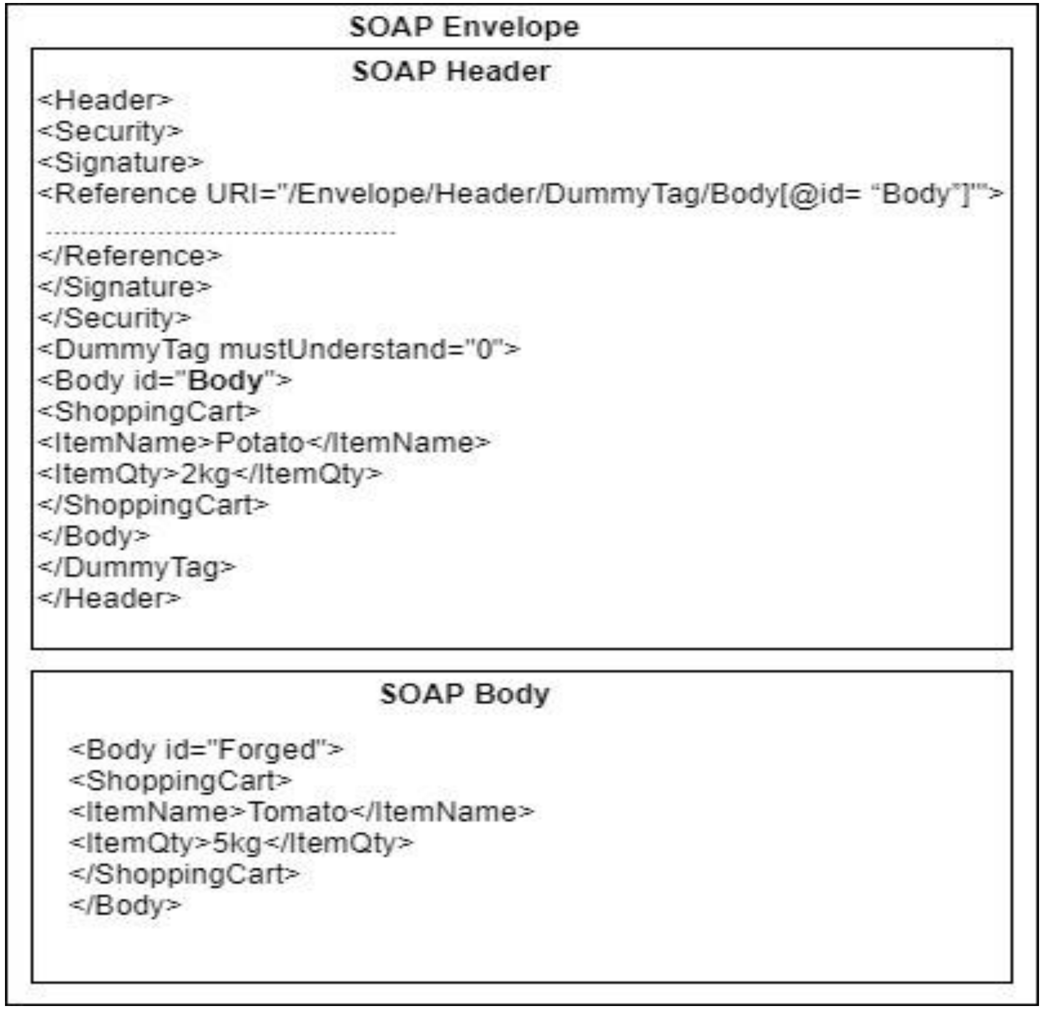
SOAP Header

```
<Header>
<Security>
<Signature>
<Reference URI="/Envelope/Header/Body[@id= “Body”]"">
 ..............................................................
</Reference>
</Signature>
</Security>
<DummyTag mustUnderstand="0">
<Body id="Body">
<ShoppingCart>
<ItemName>Potato</ItemName>
<ItemQty>2kg</ItemQty>
</ShoppingCart>
</Body>
</DummyTag>
</Header>
```

SOAP Body

```
  <Body id="Forged">
  <ShoppingCart>
  <ItemName>Tomato</ItemName>
  <ItemQty>5kg</ItemQty>
  </ShoppingCart>
  </Body>
```

Wrapping attack mitigation, scenario-2



SOAP Envelope

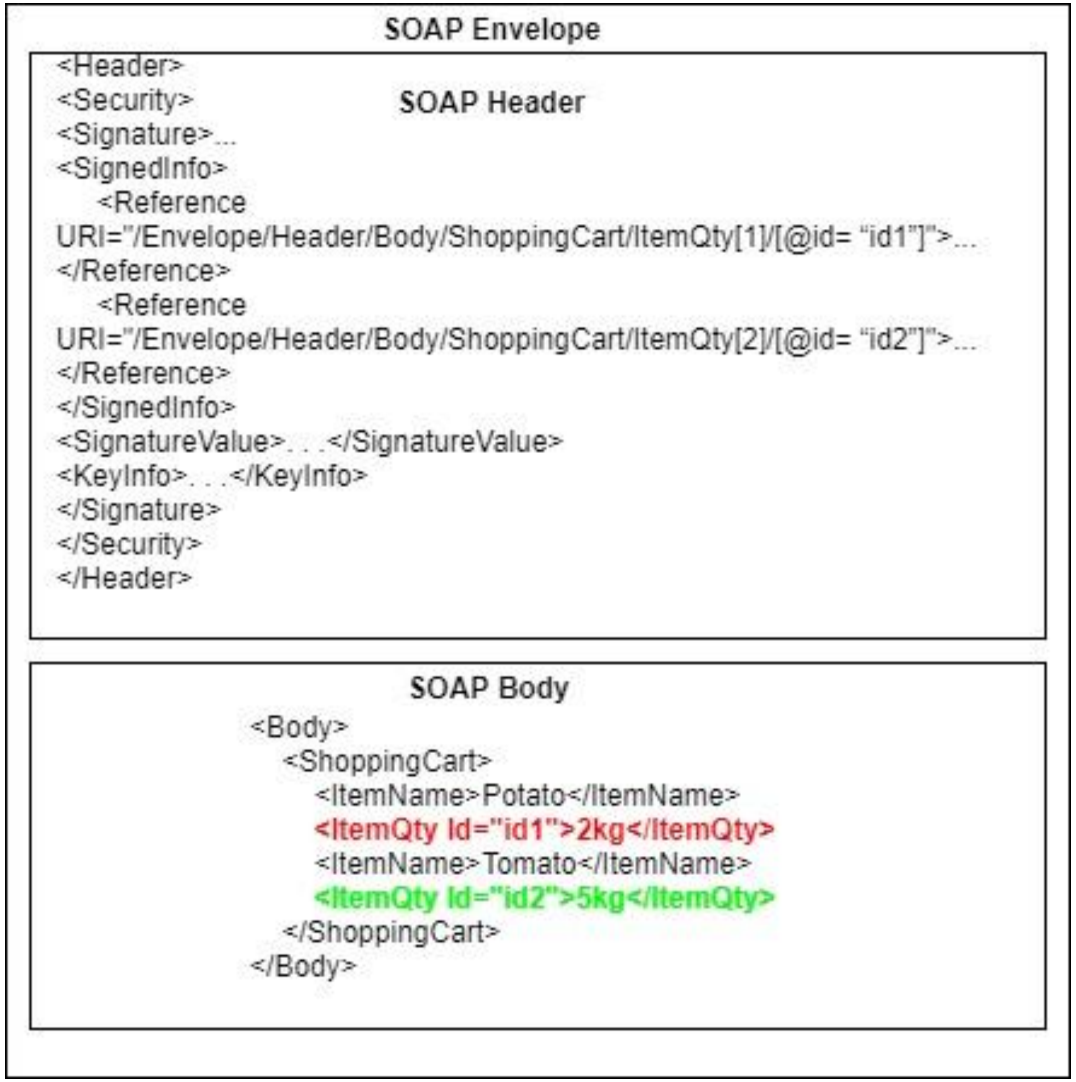
SOAP Header

```
<Header>
<Security>
<Signature>
<Reference URI="/Envelope/Header/DummyTag/Body[@id= "Body"]">
 .............................................
</Reference>
</Signature>
</Security>
<DummyTag mustUnderstand="0">
<Body id="Body">
<ShoppingCart>
<ItemName>Potato</ItemName>
<ItemQty>2kg</ItemQty>
</ShoppingCart>
</Body>
</DummyTag>
</Header>
```

SOAP Body

```
<Body id="Forged">
<ShoppingCart>
<ItemName>Tomato</ItemName>
<ItemQty>5kg</ItemQty>
</ShoppingCart>
</Body>
```

Mitigation of jumbled elements attack



SOAP Envelope

SOAP Header

```
<Header>
<Security>
<Signature>...
<SignedInfo>
    <Reference
URI="/Envelope/Header/Body/ShoppingCart/ItemQty[1]/[@id= “id1”]">...
</Reference>
    <Reference
URI="/Envelope/Header/Body/ShoppingCart/ItemQty[2]/[@id= “id2”]">...
</Reference>
</SignedInfo>
<SignatureValue>. . .</SignatureValue>
<KeyInfo>. . .</KeyInfo>
</Signature>
</Security>
</Header>
```

SOAP Body

```
<Body>
  <ShoppingCart>
    <ItemName>Potato</ItemName>
    <ItemQty Id="id1">2kg</ItemQty>
    <ItemName>Tomato</ItemName>
    <ItemQty Id="id2">5kg</ItemQty>
  </ShoppingCart>
</Body>
```

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Thank You

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