

Network Working Group  
Request for Comments: 4911  
Category: Experimental

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July 2007

## Encoding Instructions for the Robust XML Encoding Rules (RXER)

### Status of This Memo

This memo defines an Experimental Protocol for the Internet community. It does not specify an Internet standard of any kind. Discussion and suggestions for improvement are requested. Distribution of this memo is unlimited.

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### Abstract

This document defines encoding instructions that may be used in an Abstract Syntax Notation One (ASN.1) specification to alter how ASN.1 values are encoded by the Robust XML Encoding Rules (RXER) and Canonical Robust XML Encoding Rules (CRXER), for example, to encode a component of an ASN.1 value as an Extensible Markup Language (XML) attribute rather than as a child element. Some of these encoding instructions also affect how an ASN.1 specification is translated into an Abstract Syntax Notation X (ASN.X) specification. Encoding instructions that allow an ASN.1 specification to reference definitions in other XML schema languages are also defined.

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## 1. Introduction

This document defines encoding instructions [X.680-1] that may be used in an Abstract Syntax Notation One (ASN.1) [X.680] specification to alter how ASN.1 values are encoded by the Robust XML Encoding Rules (RXER) [RXER] and Canonical Robust XML Encoding Rules (CRXER) [RXER], for example, to encode a component of an ASN.1 value as an Extensible Markup Language (XML) [XML10] attribute rather than as a child element. Some of these encoding instructions also affect how an ASN.1 specification is translated into an Abstract Syntax Notation X (ASN.X) specification [ASN.X].

This document also defines encoding instructions that allow an ASN.1 specification to incorporate the definitions of types, elements, and attributes in specifications written in other XML schema languages. References to XML Schema [XSD1] types, elements, and attributes, RELAX NG [RNG] named patterns and elements, and XML document type definition (DTD) [XML10] element types are supported.

In most cases, the effect of an encoding instruction is only briefly mentioned in this document. The precise effects of these encoding instructions are described fully in the specifications for RXER [RXER] and ASN.X [ASN.X], at the points where they apply.

## 2. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED" and "MAY" in this document are to be interpreted as described in BCP 14, RFC 2119 [BCP14]. The key word "OPTIONAL" is exclusively used with its ASN.1 meaning.

Throughout this document "type" shall be taken to mean an ASN.1 type, and "value" shall be taken to mean an ASN.1 abstract value, unless qualified otherwise.

A reference to an ASN.1 production [X.680] (e.g., Type, NamedType) is a reference to text in an ASN.1 specification corresponding to that production. Throughout this document, "component" is synonymous with NamedType.

This document uses the namespace prefix "xsi:" to stand for the namespace name [XMLNS10] "http://www.w3.org/2001/XMLSchema-instance".

Example ASN.1 definitions in this document are assumed to be defined in an ASN.1 module with a TagDefault of "AUTOMATIC TAGS" and an EncodingReferenceDefault [X.680-1] of "RXER INSTRUCTIONS".

### 3. Definitions

The following definition of base type is used in specifying a number of encoding instructions.

Definition (base type): If a type, T, is a constrained type, then the base type of T is the base type of the type that is constrained; else if T is a prefixed type, then the base type of T is the base type of the type that is prefixed; else if T is a type notation that references or denotes another type (i.e., DefinedType, ObjectClassFieldType, SelectionType, TypeFromObject, or ValueSetFromObjects), then the base type of T is the base type of the type that is referenced or denoted; otherwise, the base type of T is T itself.

Aside: A tagged type is a special case of a prefixed type.

### 4. Notation for RXER Encoding Instructions

The grammar of ASN.1 permits the application of encoding instructions [X.680-1], through type prefixes and encoding control sections, that modify how abstract values are encoded by nominated encoding rules.

The generic notation for type prefixes and encoding control sections is defined by the ASN.1 basic notation [X.680] [X.680-1], and includes an encoding reference to identify the specific encoding rules that are affected by the encoding instruction.

The encoding reference that identifies the Robust XML Encoding rules is literally RXER. An RXER encoding instruction applies equally to both RXER and CRXER encodings.

The specific notation for an encoding instruction for a specific set of encoding rules is left to the specification of those encoding rules. Consequently, this companion document to the RXER specification [RXER] defines the notation for RXER encoding instructions. Specifically, it elaborates the EncodingInstruction and EncodingInstructionAssignmentList placeholder productions of the ASN.1 basic notation.

In the context of the RXER encoding reference, the EncodingInstruction production is defined as follows, using the conventions of the ASN.1 basic notation:

```

EncodingInstruction ::=
    AttributeInstruction |
    AttributeRefInstruction |
    ComponentRefInstruction |
    ElementRefInstruction |
    GroupInstruction |
    InsertionsInstruction |
    ListInstruction |
    NameInstruction |
    RefAsElementInstruction |
    RefAsTypeInstruction |
    SimpleContentInstruction |
    TypeAsVersionInstruction |
    TypeRefInstruction |
    UnionInstruction |
    ValuesInstruction |
    VersionIndicatorInstruction

```

In the context of the RXER encoding reference, the `EncodingInstructionAssignmentList` production (which only appears in an encoding control section) is defined as follows:

```

EncodingInstructionAssignmentList ::=
    SchemaIdentityInstruction ?
    TargetNamespaceInstruction ?
    TopLevelComponents ?

```

```

TopLevelComponents ::= TopLevelComponent TopLevelComponents ?

```

```

TopLevelComponent ::= "COMPONENT" NamedType

```

Definition (top-level `NamedType`): A `NamedType` is a top-level `NamedType` (equivalently, a top-level component) if and only if it is the `NamedType` in a `TopLevelComponent`. A `NamedType` nested within the `Type` of the `NamedType` of a `TopLevelComponent` is not itself a top-level `NamedType`.

Aside: Specification writers should note that non-trivial types defined within a top-level `NamedType` will not be visible to ASN.1 tools that do not understand RXER.

Although a top-level `NamedType` only appears in an RXER encoding control section, the default encoding reference for the module [X.680-1] still applies when parsing a top-level `NamedType`.

Each top-level `NamedType` within a module SHALL have a distinct identifier.

The NamedType production is defined by the ASN.1 basic notation. The other productions are described in subsequent sections and make use of the following productions:

NCNameValue ::= Value

AnyURIValue ::= Value

QNameValue ::= Value

NameValue ::= Value

The Value production is defined by the ASN.1 basic notation.

The governing type for the Value in an NCNameValue is the NCName type from the AdditionalBasicDefinitions module [RXER].

The governing type for the Value in an AnyURIValue is the AnyURI type from the AdditionalBasicDefinitions module.

The governing type for the Value in a QNameValue is the QName type from the AdditionalBasicDefinitions module.

The governing type for the Value in a NameValue is the Name type from the AdditionalBasicDefinitions module.

The Value in an NCNameValue, AnyURIValue, QNameValue, or NameValue SHALL NOT be a DummyReference [X.683] and SHALL NOT textually contain a nested DummyReference.

Aside: Thus, encoding instructions are not permitted to be parameterized in any way. This restriction will become important if a future specification for ASN.X explicitly represents parameterized definitions and parameterized references instead of expanding out parameterized references as in the current specification. A parameterized definition could not be directly translated into ASN.X if it contained encoding instructions that were not fully specified.

## 5. Component Encoding Instructions

Certain of the RXER encoding instructions are categorized as component encoding instructions. The component encoding instructions are the ATTRIBUTE, ATTRIBUTE-REF, COMPONENT-REF, GROUP, ELEMENT-REF, NAME, REF-AS-ELEMENT, SIMPLE-CONTENT, TYPE-AS-VERSION, and VERSION-INDICATOR encoding instructions (whose notations are described respectively by AttributeInstruction, AttributeRefInstruction, ComponentRefInstruction, GroupInstruction,

ElementRefInstruction, NameInstruction, RefAsElementInstruction, SimpleContentInstruction, TypeAsVersionInstruction, and VersionIndicatorInstruction).

The Type in the EncodingPrefixedType for a component encoding instruction SHALL be either:

- (1) the Type in a NamedType, or
- (2) the Type in an EncodingPrefixedType in a PrefixedType in a BuiltinType in a Type that is one of (1) to (4), or
- (3) the Type in an TaggedType in a PrefixedType in a BuiltinType in a Type that is one of (1) to (4), or
- (4) the Type in a ConstrainedType (excluding a TypeWithConstraint) in a Type that is one of (1) to (4).

Aside: The effect of this condition is to force the component encoding instructions to be textually within the NamedType to which they apply. Only case (2) can be true on the first iteration as the Type belongs to an EncodingPrefixedType; however, any of (1) to (4) can be true on subsequent iterations.

Case (4) is not permitted when the encoding instruction is the ATTRIBUTE-REF, COMPONENT-REF, ELEMENT-REF, or REF-AS-ELEMENT encoding instruction.

The NamedType in case (1) is said to be "subject to" the component encoding instruction.

A top-level NamedType SHALL NOT be subject to an ATTRIBUTE-REF, COMPONENT-REF, GROUP, ELEMENT-REF, REF-AS-ELEMENT, or SIMPLE-CONTENT encoding instruction.

Aside: This condition does not preclude these encoding instructions being used on a nested NamedType.

A NamedType SHALL NOT be subject to two or more component encoding instructions of the same kind, e.g., a NamedType is not permitted to be subject to two NAME encoding instructions.

The ATTRIBUTE, ATTRIBUTE-REF, COMPONENT-REF, GROUP, ELEMENT-REF, REF-AS-ELEMENT, SIMPLE-CONTENT, and TYPE-AS-VERSION encoding instructions are mutually exclusive. The NAME, ATTRIBUTE-REF, COMPONENT-REF, ELEMENT-REF, and REF-AS-ELEMENT encoding instructions are mutually exclusive. A NamedType SHALL NOT be subject to two or more encoding instructions that are mutually exclusive.

A SelectionType [X.680] SHALL NOT be used to select the Type from a NamedType that is subject to an ATTRIBUTE-REF, COMPONENT-REF, ELEMENT-REF or REF-AS-ELEMENT encoding instruction. The other component encoding instructions are not inherited by the type denoted by a SelectionType.

Definition (attribute component): An attribute component is a NamedType that is subject to an ATTRIBUTE or ATTRIBUTE-REF encoding instruction, or subject to a COMPONENT-REF encoding instruction that references a top-level NamedType that is subject to an ATTRIBUTE encoding instruction.

Definition (element component): An element component is a NamedType that is not subject to an ATTRIBUTE, ATTRIBUTE-REF, GROUP, or SIMPLE-CONTENT encoding instruction, and not subject to a COMPONENT-REF encoding instruction that references a top-level NamedType that is subject to an ATTRIBUTE encoding instruction.

Aside: A NamedType subject to a GROUP or SIMPLE-CONTENT encoding instruction is neither an attribute component nor an element component.

## 6. Reference Encoding Instructions

Certain of the RXER encoding instructions are categorized as reference encoding instructions. The reference encoding instructions are the ATTRIBUTE-REF, COMPONENT-REF, ELEMENT-REF, REF-AS-ELEMENT, REF-AS-TYPE, and TYPE-REF encoding instructions (whose notations are described respectively by AttributeRefInstruction, ComponentRefInstruction, ElementRefInstruction, RefAsElementInstruction, RefAsTypeInstruction, and TypeRefInstruction). These encoding instructions (except COMPONENT-REF) allow an ASN.1 specification to incorporate the definitions of types, elements, and attributes in specifications written in other XML schema languages, through implied constraints on the markup that may appear in values of the Markup ASN.1 type from the AdditionalBasicDefinitions module [RXER] (for ELEMENT-REF, REF-AS-ELEMENT, REF-AS-TYPE, and TYPE-REF) or the UTF8String type (for ATTRIBUTE-REF). References to XML Schema [XSD1] types, elements, and attributes, RELAX NG [RNG] named patterns and elements, and XML document type definition (DTD) [XML10] element types are supported. References to ASN.1 types and top-level components are also permitted. The COMPONENT-REF encoding instruction provides a more direct method of referencing a top-level component.

The Type in the EncodingPrefixedType for an ELEMENT-REF, REF-AS-ELEMENT, REF-AS-TYPE, or TYPE-REF encoding instruction SHALL be either:

- (1) a `ReferencedType` that is a `DefinedType` that is a `typereference` (not a `DummyReference`) or `ExternalTypeReference` that references the Markup ASN.1 type from the `AdditionalBasicDefinitions` module [RXER], or
- (2) a `BuiltinType` that is a `PrefixedType` that is a `TaggedType` where the `Type` in the `TaggedType` is one of (1) to (3), or
- (3) a `BuiltinType` that is a `PrefixedType` that is an `EncodingPrefixedType` where the `Type` in the `EncodingPrefixedType` is one of (1) to (3) and the `EncodingPrefix` in the `EncodingPrefixedType` does not contain a reference encoding instruction.

Aside: Case (3) and similar cases for the `ATTRIBUTE-REF` and `COMPONENT-REF` encoding instructions have the effect of making the reference encoding instructions mutually exclusive as well as singly occurring.

With respect to the `REF-AS-TYPE` and `TYPE-REF` encoding instructions, the `DefinedType` in case (1) is said to be "subject to" the encoding instruction.

The restrictions on the `Type` in the `EncodingPrefixedType` for an `ATTRIBUTE-REF` encoding instruction are specified in Section 9. The restrictions on the `Type` in the `EncodingPrefixedType` for a `COMPONENT-REF` encoding instruction are specified in Section 10.

The reference encoding instructions make use of a common production defined as follows:

```
RefParameters ::= ContextParameter ?
```

```
ContextParameter ::= "CONTEXT" AnyURIValue
```

A `RefParameters` instance provides extra information about a reference to a definition. A `ContextParameter` is used when a reference is ambiguous, i.e., refers to definitions in more than one schema document or external DTD subset. This situation would occur, for example, when importing types with the same name from independently developed XML Schemas defined without a target namespace [XSD1]. When used in conjunction with a reference to an element type in an external DTD subset, the `AnyURIValue` in the `ContextParameter` is the system identifier (a Uniform Resource Identifier or URI [URI]) of the external DTD subset; otherwise, the `AnyURIValue` is a URI that indicates the intended schema document, either an XML Schema specification, a RELAX NG specification, or an ASN.1 or ASN.X specification.

## 7. Expanded Names of Components

Each `NamedType` has an associated expanded name [XMLNS10], determined as follows:

- (1) if the `NamedType` is subject to a `NAME` encoding instruction, then the local name of the expanded name is the character string specified by the `NCNameValue` of the `NAME` encoding instruction,
- (2) else if the `NamedType` is subject to a `COMPONENT-REF` encoding instruction, then the expanded name is the same as the expanded name of the referenced top-level `NamedType`,
- (3) else if the `NamedType` is subject to an `ATTRIBUTE-REF` or `ELEMENT-REF` encoding instruction, then the namespace name of the expanded name is equal to the namespace-name component of the `QNameValue` of the encoding instruction, and the local name is equal to the local-name component of the `QNameValue`,
- (4) else if the `NamedType` is subject to a `REF-AS-ELEMENT` encoding instruction, then the local name of the expanded name is the `LocalPart` [XMLNS10] of the qualified name specified by the `NameValue` of the encoding instruction,
- (5) otherwise, the local name of the expanded name is the identifier of the `NamedType`.

In cases (1) and (5), if the `NamedType` is a top-level `NamedType` and the module containing the `NamedType` has a `TARGET-NAMESPACE` encoding instruction, then the namespace name of the expanded name is the character string specified by the `AnyURIValue` of the `TARGET-NAMESPACE` encoding instruction; otherwise, the namespace name has no value.

Aside: Thus, the `TARGET-NAMESPACE` encoding instruction applies to a top-level `NamedType` but not to any other `NamedType`.

In case (4), if the encoding instruction contains a `Namespace`, then the namespace name of the expanded name is the character string specified by the `AnyURIValue` of the `Namespace`; otherwise, the namespace name has no value.

The expanded names for the attribute components of a `CHOICE`, `SEQUENCE`, or `SET` type MUST be distinct. The expanded names for the components of a `CHOICE`, `SEQUENCE`, or `SET` type that are not attribute components MUST be distinct. These tests are applied after the `COMPONENTS OF` transformation specified in X.680, Clause 24.4 [X.680].

Aside: Two components of the same CHOICE, SEQUENCE, or SET type may have the same expanded name if one of them is an attribute component and the other is not. Note that the "not" case includes components that are subject to a GROUP or SIMPLE-CONTENT encoding instruction.

The expanded name of a top-level NamedType subject to an ATTRIBUTE encoding instruction MUST be distinct from the expanded name of every other top-level NamedType subject to an ATTRIBUTE encoding instruction in the same module.

The expanded name of a top-level NamedType not subject to an ATTRIBUTE encoding instruction MUST be distinct from the expanded name of every other top-level NamedType not subject to an ATTRIBUTE encoding instruction in the same module.

Aside: Two top-level components may have the same expanded name if one of them is an attribute component and the other is not.

## 8. The ATTRIBUTE Encoding Instruction

The ATTRIBUTE encoding instruction causes an RXER encoder to encode a value of the component to which it is applied as an XML attribute instead of as a child element.

The notation for an ATTRIBUTE encoding instruction is defined as follows:

AttributeInstruction ::= "ATTRIBUTE"

The base type of the type of a NamedType that is subject to an ATTRIBUTE encoding instruction SHALL NOT be:

- (1) a CHOICE, SET, or SET OF type, or
- (2) a SEQUENCE type other than the one defining the QName type from the AdditionalBasicDefinitions module [RXER] (i.e., QName is allowed), or
- (3) a SEQUENCE OF type where the SequenceOfType is not subject to a LIST encoding instruction, or
- (4) an open type.

## Example

```
PersonalDetails ::= SEQUENCE {  
    firstName [ATTRIBUTE] UTF8String,  
    middleName [ATTRIBUTE] UTF8String,  
    surname [ATTRIBUTE] UTF8String  
}
```

## 9. The ATTRIBUTE-REF Encoding Instruction

The ATTRIBUTE-REF encoding instruction causes an RXER encoder to encode a value of the component to which it is applied as an XML attribute instead of as a child element, where the attribute's name is a qualified name of the attribute declaration referenced by the encoding instruction. In addition, the ATTRIBUTE-REF encoding instruction causes values of the UTF8String type to be restricted to conform to the type of the attribute declaration.

The notation for an ATTRIBUTE-REF encoding instruction is defined as follows:

```
AttributeRefInstruction ::=  
    "ATTRIBUTE-REF" QNameValue RefParameters
```

Taken together, the QNameValue and the ContextParameter in the RefParameters (if present) MUST reference an XML Schema attribute declaration or a top-level NamedType that is subject to an ATTRIBUTE encoding instruction.

The type of a referenced XML Schema attribute declaration SHALL NOT be, either directly or by derivation, the XML Schema type QName, NOTATION, ENTITY, ENTITIES, or anySimpleType.

Aside: Values of these types require information from the context of the attribute for interpretation. Because an ATTRIBUTE-REF encoding instruction is restricted to prefixing the ASN.1 UTF8String type, there is no mechanism to capture such context.

The type of a referenced top-level NamedType SHALL NOT be, either directly or by subtyping, the QName type from the AdditionalBasicDefinitions module [RXER].

The Type in the EncodingPrefixedType for an ATTRIBUTE-REF encoding instruction SHALL be either:

- (1) the UTF8String type, or

- (2) a BuiltinType that is a PrefixedType that is a TaggedType where the Type in the TaggedType is one of (1) to (3), or
- (3) a BuiltinType that is a PrefixedType that is an EncodingPrefixedType where the Type in the EncodingPrefixedType is one of (1) to (3) and the EncodingPrefix in the EncodingPrefixedType does not contain a reference encoding instruction.

The identifier of a NamedType subject to an ATTRIBUTE-REF encoding instruction does not contribute to the name of attributes in an RXER encoding. For the sake of consistency, the identifier SHOULD, where possible, be the same as the local name of the referenced attribute declaration.

#### 10. The COMPONENT-REF Encoding Instruction

The ASN.1 basic notation does not have a concept of a top-level NamedType and therefore does not have a mechanism to reference a top-level NamedType. The COMPONENT-REF encoding instruction provides a way to specify that a NamedType within a combining type definition is equivalent to a referenced top-level NamedType.

The notation for a COMPONENT-REF encoding instruction is defined as follows:

```
ComponentRefInstruction ::= "COMPONENT-REF" ComponentReference
```

```
ComponentReference ::=
    InternalComponentReference |
    ExternalComponentReference
```

```
InternalComponentReference ::= identifier FromModule ?
```

```
FromModule ::= "FROM" GlobalModuleReference
```

```
ExternalComponentReference ::= modulereference "." identifier
```

The GlobalModuleReference production is defined by the ASN.1 basic notation [X.680]. If the GlobalModuleReference is absent from an InternalComponentReference, then the identifier MUST be the identifier of a top-level NamedType in the same module. If the GlobalModuleReference is present in an InternalComponentReference, then the identifier MUST be the identifier of a top-level NamedType in the referenced module.

The `modulereference` in an `ExternalComponentReference` is used in the same way as a `modulereference` in an `ExternalTypeReference`. The identifier in an `ExternalComponentReference` MUST be the identifier of a top-level `NamedType` in the referenced module.

The `Type` in the `EncodingPrefixedType` for a `COMPONENT-REF` encoding instruction SHALL be either:

- (1) a `ReferencedType` that is a `DefinedType` that is a `typereference` (not a `DummyReference`) or an `ExternalTypeReference`, or
- (2) a `BuiltinType` or `ReferencedType` that is one of the productions in Table 1 in Section 5 of the specification for RXER [RXER], or
- (3) a `BuiltinType` that is a `PrefixedType` that is a `TaggedType` where the `Type` in the `TaggedType` is one of (1) to (4), or
- (4) a `BuiltinType` that is a `PrefixedType` that is an `EncodingPrefixedType` where the `Type` in the `EncodingPrefixedType` is one of (1) to (4) and the `EncodingPrefix` in the `EncodingPrefixedType` does not contain a reference encoding instruction.

The restrictions on the use of RXER encoding instructions are such that no other RXER encoding instruction is permitted within a `NamedType` if the `NamedType` is subject to a `COMPONENT-REF` encoding instruction.

The `Type` in the top-level `NamedType` referenced by the `COMPONENT-REF` encoding instruction MUST be either:

- (a) if the preceding case (1) is used, a `ReferencedType` that is a `DefinedType` that is a `typereference` or `ExternalTypeReference` that references the same type as the `DefinedType` in case (1), or
- (b) if the preceding case (2) is used, a `BuiltinType` or `ReferencedType` that is the same as the `BuiltinType` or `ReferencedType` in case (2), or
- (c) a `BuiltinType` that is a `PrefixedType` that is an `EncodingPrefixedType` where the `Type` in the `EncodingPrefixedType` is one of (a) to (c), and the `EncodingPrefix` in the `EncodingPrefixedType` contains an RXER encoding instruction.

In principle, the `COMPONENT-REF` encoding instruction creates a notional `NamedType` where the expanded name is that of the referenced top-level `NamedType` and the `Type` in case (1) or (2) is substituted by the `Type` of the referenced top-level `NamedType`.

In practice, it is sufficient for non-RXER encoders and decoders to use the original NamedType rather than the notional NamedType because the Type in case (1) or (2) can only differ from the Type of the referenced top-level NamedType by having fewer RXER encoding instructions, and RXER encoding instructions are ignored by non-RXER encoders and decoders.

Although any prefixes for the Type in case (1) or (2) would be bypassed, it is sufficient for RXER encoders and decoders to use the referenced top-level NamedType instead of the notional NamedType because these prefixes cannot be RXER encoding instructions (except, of course, for the COMPONENT-REF encoding instruction) and can have no effect on an RXER encoding.

Example

```
Modules ::= SEQUENCE OF
  module [COMPONENT-REF module
    FROM AbstractSyntaxNotation-X
    { 1 3 6 1 4 1 21472 1 0 1 }]
  ModuleDefinition
```

Note that the "module" top-level NamedType in the AbstractSyntaxNotation-X module is defined like so:

```
COMPONENT module ModuleDefinition
```

The ASN.X translation of the SEQUENCE OF type definition provides a more natural representation:

```
<namedType xmlns:asn="urn:ietf:params:xml:ns:asn"
  name="Modules">
  <sequenceOf>
    <element ref="asn:module"/>
  </sequenceOf>
</namedType>
```

Aside: The <namedType> element in ASN.X corresponds to a TypeAssignment, not a NamedType.

The identifier of a NamedType subject to a COMPONENT-REF encoding instruction does not contribute to an RXER encoding. For the sake of consistency with other encoding rules, the identifier SHOULD be the same as the identifier in the ComponentRefInstruction.

## 11. The ELEMENT-REF Encoding Instruction

The ELEMENT-REF encoding instruction causes an RXER encoder to encode a value of the component to which it is applied as an element where the element's name is a qualified name of the element declaration referenced by the encoding instruction. In addition, the ELEMENT-REF encoding instruction causes values of the Markup ASN.1 type to be restricted to conform to the type of the element declaration.

The notation for an ELEMENT-REF encoding instruction is defined as follows:

```
ElementRefInstruction ::= "ELEMENT-REF" QNameValue RefParameters
```

Taken together, the QNameValue and the ContextParameter in the RefParameters (if present) MUST reference an XML Schema element declaration, a RELAX NG element definition, or a top-level NamedType that is not subject to an ATTRIBUTE encoding instruction.

A referenced XML Schema element declaration MUST NOT have a type that requires the presence of values for the XML Schema ENTITY or ENTITIES types.

Aside: Entity declarations are not supported by CRXER.

Example

```
AnySchema ::= CHOICE {
  module    [ELEMENT-REF {
    namespace-name
      "urn:ietf:params:xml:ns:asnx",
    local-name "module" }]
  Markup,
  schema    [ELEMENT-REF {
    namespace-name
      "http://www.w3.org/2001/XMLSchema",
    local-name "schema" }]
  Markup,
  grammar   [ELEMENT-REF {
    namespace-name
      "http://relaxng.org/ns/structure/1.0",
    local-name "grammar" }]
  Markup
}
```

The ASN.X translation of the choice type definition provides a more natural representation:

```
<namedType xmlns:asn="urn:ietf:params:xml:ns:asn"
            xmlns:xs="http://www.w3.org/2001/XMLSchema"
            xmlns:rng="http://relaxng.org/ns/structure/1.0"
            name="AnySchema">
  <choice>
    <element ref="asn:module" embedded="true"/>
    <element ref="xs:schema" embedded="true"/>
    <element ref="rng:grammar" embedded="true"/>
  </choice>
</namedType>
```

The identifier of a NamedType subject to an ELEMENT-REF encoding instruction does not contribute to the name of an element in an RXER encoding. For the sake of consistency, the identifier SHOULD, where possible, be the same as the local name of the referenced element declaration.

## 12. The LIST Encoding Instruction

The LIST encoding instruction causes an RXER encoder to encode a value of a SEQUENCE OF type as a white-space-separated list of the component values.

The notation for a LIST encoding instruction is defined as follows:

ListInstruction ::= "LIST"

The Type in an EncodingPrefixedType for a LIST encoding instruction SHALL be either:

- (1) a BuiltinType that is a SequenceOfType of the "SEQUENCE OF NamedType" form, or
- (2) a ConstrainedType that is a TypeWithConstraint of the "SEQUENCE Constraint OF NamedType" form or "SEQUENCE SizeConstraint OF NamedType" form, or
- (3) a ConstrainedType that is not a TypeWithConstraint where the Type in the ConstrainedType is one of (1) to (5), or
- (4) a BuiltinType that is a PrefixedType that is a TaggedType where the Type in the TaggedType is one of (1) to (5), or
- (5) a BuiltinType that is a PrefixedType that is an EncodingPrefixedType where the Type in the EncodingPrefixedType is one of (1) to (5).

The effect of this condition is to force the LIST encoding instruction to be textually co-located with the SequenceOfType or TypeWithConstraint to which it applies.

Aside: This makes it clear to a reader that the encoding instruction applies to every use of the type no matter how it might be referenced.

The SequenceOfType in case (1) and the TypeWithConstraint in case (2) are said to be "subject to" the LIST encoding instruction.

A SequenceOfType or TypeWithConstraint SHALL NOT be subject to more than one LIST encoding instruction.

The base type of the component type of a SequenceOfType or TypeWithConstraint that is subject to a LIST encoding instruction MUST be one of the following:

- (1) the BOOLEAN, INTEGER, ENUMERATED, REAL, OBJECT IDENTIFIER, RELATIVE-OID, GeneralizedTime, or UTCTime type, or
- (2) the NCName, AnyURI, Name, or QName type from the AdditionalBasicDefinitions module [RXER].

Aside: While it would be feasible to allow the component type to also be any character string type that is constrained such that all its abstract values have a length greater than zero and none of its abstract values contain any white space characters, testing whether this condition is satisfied can be quite involved. For the sake of simplicity, only certain immediately useful constrained UTF8String types, which are known to be suitable, are permitted (i.e., NCName, AnyURI, and Name).

The NamedType in a SequenceOfType or TypeWithConstraint that is subject to a LIST encoding instruction MUST NOT be subject to an ATTRIBUTE, ATTRIBUTE-REF, COMPONENT-REF, GROUP, ELEMENT-REF, REF-AS-ELEMENT, SIMPLE-CONTENT, or TYPE-AS-VERSION encoding instruction.

Example

UpdateTimes ::= [LIST] SEQUENCE OF updateTime GeneralizedTime

### 13. The NAME Encoding Instruction

The NAME encoding instruction causes an RXER encoder to use a nominated character string instead of a component's identifier wherever that identifier would otherwise appear in the encoding (e.g., as an element or attribute name).

The notation for a NAME encoding instruction is defined as follows:

```
NameInstruction ::= "NAME" "AS"? NCNameValue
```

Example

```
CHOICE {  
    foo-att  [ATTRIBUTE] [NAME AS "Foo"] INTEGER,  
    foo-elem [NAME "Foo"] INTEGER  
}
```

### 14. The REF-AS-ELEMENT Encoding Instruction

The REF-AS-ELEMENT encoding instruction causes an RXER encoder to encode a value of the component to which it is applied as an element where the element's name is the name of the external DTD subset element type declaration referenced by the encoding instruction. In addition, the REF-AS-ELEMENT encoding instruction causes values of the Markup ASN.1 type to be restricted to conform to the content and attributes permitted by that element type declaration and its associated attribute-list declarations.

The notation for a REF-AS-ELEMENT encoding instruction is defined as follows:

```
RefAsElementInstruction ::=  
    "REF-AS-ELEMENT" NameValue Namespace ? RefParameters
```

```
Namespace ::= "NAMESPACE" AnyURIValue
```

Taken together, the NameValue and the ContextParameter in the RefParameters (if present) MUST reference an element type declaration in an external DTD subset that is conformant with Namespaces in XML 1.0 [XMLNS10].

The Namespace is present if and only if the Name of the referenced element type declaration conforms to a PrefixedName (a QName) [XMLNS10], in which case the Namespace specifies the namespace name to be associated with the Prefix of the PrefixedName.

The referenced element type declaration MUST NOT require the presence of attributes of type ENTITY or ENTITIES.

Aside: Entity declarations are not supported by CRXER.

#### Example

Suppose that the following external DTD subset has been defined with a system identifier of "http://www.example.com/inventory":

```
<?xml version='1.0'?>
<!ELEMENT product EMPTY>
<!ATTLIST product
  name          CDATA #IMPLIED
  partNumber    CDATA #REQUIRED
  quantity      CDATA #REQUIRED >
```

The product element type declaration can be referenced as an element in an ASN.1 type definition:

```
CHOICE {
  product [REF-AS-ELEMENT "product"
           CONTEXT "http://www.example.com/inventory"]
  Markup
}
```

Here is the ASN.X translation of this ASN.1 type definition:

```
<type>
<choice>
  <element elementType="product"
           context="http://www.example.com/inventory"/>
</choice>
</type>
```

The identifier of a NamedType subject to a REF-AS-ELEMENT encoding instruction does not contribute to the name of an element in an RXER encoding. For the sake of consistency, the identifier SHOULD, where possible, be the same as the Name of the referenced element type declaration (or the LocalPart if the Name conforms to a PrefixedName).

#### 15. The REF-AS-TYPE Encoding Instruction

The REF-AS-TYPE encoding instruction causes values of the Markup ASN.1 type to be restricted to conform to the content and attributes permitted by a nominated element type declaration and its associated attribute-list declarations in an external DTD subset.

The notation for a REF-AS-TYPE encoding instruction is defined as follows:

```
RefAsTypeInstruction ::= "REF-AS-TYPE" NameValue RefParameters
```

Taken together, the NameValue and the ContextParameter of the RefParameters (if present) MUST reference an element type declaration in an external DTD subset that is conformant with Namespaces in XML 1.0 [XMLNS10].

The referenced element type declaration MUST NOT require the presence of attributes of type ENTITY or ENTITIES.

Aside: Entity declarations are not supported by CRXER.

#### Example

The product element type declaration can be referenced as a type in an ASN.1 definition:

```
SEQUENCE OF
    inventoryItem
        [REF-AS-TYPE "product"
          CONTEXT "http://www.example.com/inventory"]
Markup
```

Here is the ASN.X translation of this definition:

```
<sequenceOf>
  <element name="inventoryItem">
    <type elementType="product"
      context="http://www.example.com/inventory"/>
  </element>
</sequenceOf>
```

Note that when an element type declaration is referenced as a type, the Name of the element type declaration does not contribute to RXER encodings. For example, child elements in the RXER encoding of values of the above SEQUENCE OF type would resemble the following:

```
<inventoryItem name="hammer" partNumber="1543" quantity="29"/>
```

## 16. The SCHEMA-IDENTITY Encoding Instruction

The SCHEMA-IDENTITY encoding instruction associates a unique identifier, a URI [URI], with the ASN.1 module containing the encoding instruction. This encoding instruction has no effect on an RXER encoder but does have an effect on the translation of an ASN.1 specification into an ASN.X representation.

The notation for a SCHEMA-IDENTITY encoding instruction is defined as follows:

```
SchemaIdentityInstruction ::= "SCHEMA-IDENTITY" AnyURIValue
```

The character string specified by the AnyURIValue of each SCHEMA-IDENTITY encoding instruction MUST be distinct. In particular, successive versions of an ASN.1 module must each have a different schema identity URI value.

## 17. The SIMPLE-CONTENT Encoding Instruction

The SIMPLE-CONTENT encoding instruction causes an RXER encoder to encode a value of a component of a SEQUENCE or SET type without encapsulation in a child element.

The notation for a SIMPLE-CONTENT encoding instruction is defined as follows:

```
SimpleContentInstruction ::= "SIMPLE-CONTENT"
```

A NamedType subject to a SIMPLE-CONTENT encoding instruction SHALL be in a ComponentType in a ComponentTypeList in a RootComponentTypeList. At most one such NamedType of a SEQUENCE or SET type is permitted to be subject to a SIMPLE-CONTENT encoding instruction. If any component is subject to a SIMPLE-CONTENT encoding instruction, then all other components in the same SEQUENCE or SET type definition MUST be attribute components. These tests are applied after the COMPONENTS OF transformation specified in X.680, Clause 24.4 [X.680].

Aside: Child elements and simple content are mutually exclusive. Specification writers should note that use of the SIMPLE-CONTENT encoding instruction on a component of an extensible SEQUENCE or SET type means that all future extensions to the SEQUENCE or SET type are restricted to being attribute components with the limited set of types that are permitted for attribute components. Using an ATTRIBUTE encoding instruction instead of a SIMPLE-CONTENT encoding instruction avoids this limitation.

The base type of the type of a `NamedType` that is subject to a `SIMPLE-CONTENT` encoding instruction SHALL NOT be:

- (1) a `SET` or `SET OF` type, or
- (2) a `CHOICE` type where the `ChoiceType` is not subject to a `UNION` encoding instruction, or
- (3) a `SEQUENCE` type other than the one defining the `QName` type from the `AdditionalBasicDefinitions` module [RXER] (i.e., `QName` is allowed), or
- (4) a `SEQUENCE OF` type where the `SequenceOfType` is not subject to a `LIST` encoding instruction, or
- (5) an open type.

If the type of a `NamedType` subject to a `SIMPLE-CONTENT` encoding instruction has abstract values with an empty character data translation [RXER] (i.e., an empty encoding), then the `NamedType` SHALL NOT be marked `OPTIONAL` or `DEFAULT`.

Example

```
SEQUENCE {  
    units    [ATTRIBUTE] UTF8String,  
    amount  [SIMPLE-CONTENT] INTEGER  
}
```

## 18. The `TARGET-NAMESPACE` Encoding Instruction

The `TARGET-NAMESPACE` encoding instruction associates an XML namespace name [XMLNS10], a URI [URI], with the type, object class, value, object, and object set references defined in the ASN.1 module containing the encoding instruction. In addition, it associates the namespace name with each top-level `NamedType` in the RXER encoding control section.

The notation for a `TARGET-NAMESPACE` encoding instruction is defined as follows:

```
TargetNamespaceInstruction ::=  
    "TARGET-NAMESPACE" AnyURIValue Prefix ?
```

```
Prefix ::= "PREFIX" NCNameValue
```

The `AnyURIValue` SHALL NOT specify an empty string.

Definition (target namespace): If an ASN.1 module contains a TARGET-NAMESPACE encoding instruction, then the target namespace of the module is the character string specified by the AnyURIValue of the TARGET-NAMESPACE encoding instruction; otherwise, the target namespace of the module is said to be absent.

Two or more ASN.1 modules MAY have the same non-absent target namespace if and only if the expanded names of the top-level attribute components are distinct across all those modules, the expanded names of the top-level element components are distinct across all those modules, and the defined type, object class, value, object, and object set references are distinct in their category across all those modules.

The Prefix, if present, suggests an NCName to use as the namespace prefix in namespace declarations involving the target namespace. An RXER encoder is not obligated to use the nominated namespace prefix.

If there are no top-level components, then the RXER encodings produced using a module with a TARGET-NAMESPACE encoding instruction are backward compatible with the RXER encodings produced by the same module without the TARGET-NAMESPACE encoding instruction.

#### 19. The TYPE-AS-VERSION Encoding Instruction

The TYPE-AS-VERSION encoding instruction causes an RXER encoder to include an xsi:type attribute in the encoding of a value of the component to which the encoding instruction is applied. This attribute allows an XML Schema [XSD1] validator to select, if available, the appropriate XML Schema translation for the version of the ASN.1 specification used to create the encoding.

Aside: Translations of an ASN.1 specification into a compatible XML Schema are expected to be slightly different across versions because of progressive extensions to the ASN.1 specification. Any incompatibilities between these translations can be accommodated if each version uses a different target namespace. The target namespace will be evident in the value of the xsi:type attribute and will cause an XML Schema validator to use the appropriate version. This mechanism also accommodates an ASN.1 type that is renamed in a later version of the ASN.1 specification.

The notation for a TYPE-AS-VERSION encoding instruction is defined as follows:

TypeAsVersionInstruction ::= "TYPE-AS-VERSION"

The Type in a NamedType that is subject to a TYPE-AS-VERSION encoding instruction MUST be a namespace-qualified reference [RXER].

The addition of a TYPE-AS-VERSION encoding instruction does not affect the backward compatibility of RXER encodings.

Aside: In a translation of an ASN.1 specification into XML Schema, any Type in a NamedType that is subject to a TYPE-AS-VERSION encoding instruction is expected to be translated into the XML Schema anyType so that the xsi:type attribute acts as a switch to select the appropriate version.

## 20. The TYPE-REF Encoding Instruction

The TYPE-REF encoding instruction causes values of the Markup ASN.1 type to be restricted to conform to a specific XML Schema named type, RELAX NG named pattern or an ASN.1 defined type.

Aside: Referencing an ASN.1 type in a TYPE-REF encoding instruction does not have the effect of imposing a requirement to preserve the Infoset [INFOSET] representation of the RXER encoding of an abstract value of the type. It is still sufficient to preserve just the abstract value.

The notation for a TYPE-REF encoding instruction is defined as follows:

```
TypeRefInstruction ::= "TYPE-REF" QNameValue RefParameters
```

Taken together, the QNameValue and the ContextParameter of the RefParameters (if present) MUST reference an XML Schema named type, a RELAX NG named pattern, or an ASN.1 defined type.

A referenced XML Schema type MUST NOT require the presence of values for the XML Schema ENTITY or ENTITIES types.

Aside: Entity declarations are not supported by CRXER.

The QNameValue SHALL NOT be a direct reference to the XML Schema NOTATION type [XSD2] (i.e., the namespace name "http://www.w3.org/2001/XMLSchema" and local name "NOTATION"); however, a reference to an XML Schema type derived from the NOTATION type is permitted.

Aside: This restriction is to ensure that the lexical space [XSD2] of the referenced type is actually populated with the names of notations [XSD1].

## Example

```
MyDecimal ::=
  [TYPE-REF {
    namespace-name "http://www.w3.org/2001/XMLSchema",
    local-name     "decimal" }]
Markup
```

Note that the ASN.X translation of this ASN.1 type definition provides a more natural way to reference the XML Schema decimal type:

```
<namedType xmlns:xs="http://www.w3.org/2001/XMLSchema"
            name="MyDecimal">
  <type ref="xs:decimal" embedded="true"/>
</namedType>
```

## 21. The UNION Encoding Instruction

The UNION encoding instruction causes an RXER encoder to encode the value of an alternative of a CHOICE type without encapsulation in a child element. The chosen alternative is optionally indicated with a member attribute. The optional PrecedenceList also allows a specification writer to alter the order in which an RXER decoder will consider the alternatives of the CHOICE as it determines which alternative has been used (if the actual alternative has not been specified through the member attribute).

The notation for a UNION encoding instruction is defined as follows:

```
UnionInstruction ::= "UNION" AlternativesPrecedence ?
AlternativesPrecedence ::= "PRECEDENCE" PrecedenceList
PrecedenceList ::= identifier PrecedenceList ?
```

The Type in the EncodingPrefixedType for a UNION encoding instruction SHALL be either:

- (1) a BuiltinType that is a ChoiceType, or
- (2) a ConstrainedType that is not a TypeWithConstraint where the Type in the ConstrainedType is one of (1) to (4), or
- (3) a BuiltinType that is a PrefixedType that is a TaggedType where the Type in the TaggedType is one of (1) to (4), or

- (4) a `BuiltinType` that is a `PrefixedType` that is an `EncodingPrefixedType` where the `Type` in the `EncodingPrefixedType` is one of (1) to (4).

The `ChoiceType` in case (1) is said to be "subject to" the UNION encoding instruction.

The base type of the type of each alternative of a `ChoiceType` that is subject to a UNION encoding instruction SHALL NOT be:

- (1) a CHOICE, SET, or SET OF type, or
- (2) a SEQUENCE type other than the one defining the `QName` type from the `AdditionalBasicDefinitions` module [RXER] (i.e., `QName` is allowed), or
- (3) a SEQUENCE OF type where the `SequenceOfType` is not subject to a LIST encoding instruction, or
- (4) an open type.

Each identifier in the `PrecedenceList` MUST be the identifier of a `NamedType` in the `ChoiceType`.

A particular identifier SHALL NOT appear more than once in the same `PrecedenceList`.

Every `NamedType` in a `ChoiceType` that is subject to a UNION encoding instruction MUST NOT be subject to an `ATTRIBUTE`, `ATTRIBUTE-REF`, `COMPONENT-REF`, `GROUP`, `ELEMENT-REF`, `REF-AS-ELEMENT`, `SIMPLE-CONTENT`, or `TYPE-AS-VERSION` encoding instruction.

Example

```
[UNION PRECEDENCE basicName] CHOICE {
    extendedName  UTF8String,
    basicName     PrintableString
}
```

## 22. The VALUES Encoding Instruction

The `VALUES` encoding instruction causes an RXER encoder to use nominated names instead of the identifiers that would otherwise appear in the encoding of a value of a `BIT STRING`, `ENUMERATED`, or `INTEGER` type.

The notation for a VALUES encoding instruction is defined as follows:

```

ValuesInstruction ::=
    "VALUES" AllValuesMapped ? ValueMappingList ?

AllValuesMapped ::= AllCapitalized | AllUppercased

AllCapitalized ::= "ALL" "CAPITALIZED"

AllUppercased ::= "ALL" "UPPERCASED"

ValueMappingList ::= ValueMapping ValueMappingList ?

ValueMapping ::= "," identifier "AS" NCNameValue

```

The Type in the EncodingPrefixedType for a VALUES encoding instruction SHALL be either:

- (1) a BuiltinType that is a BitStringType with a NamedBitList, or
- (2) a BuiltinType that is an EnumeratedType, or
- (3) a BuiltinType that is an IntegerType with a NamedNumberList, or
- (4) a ConstrainedType that is not a TypeWithConstraint where the Type in the ConstrainedType is one of (1) to (6), or
- (5) a BuiltinType that is a PrefixedType that is a TaggedType where the Type in the TaggedType is one of (1) to (6), or
- (6) a BuiltinType that is a PrefixedType that is an EncodingPrefixedType where the Type in the EncodingPrefixedType is one of (1) to (6).

The effect of this condition is to force the VALUES encoding instruction to be textually co-located with the type definition to which it applies.

The BitStringType, EnumeratedType, or IntegerType in case (1), (2), or (3), respectively, is said to be "subject to" the VALUES encoding instruction.

A BitStringType, EnumeratedType, or IntegerType SHALL NOT be subject to more than one VALUES encoding instruction.

Each identifier in a ValueMapping MUST be an identifier appearing in the NamedBitList, Enumerations, or NamedNumberList, as the case may be.

The identifier in a ValueMapping SHALL NOT be the same as the identifier in any other ValueMapping for the same ValueMappingList.

Definition (replacement name): Each identifier in a BitStringType, EnumeratedType, or IntegerType subject to a VALUES encoding instruction has a replacement name. If there is a ValueMapping for the identifier, then the replacement name is the character string specified by the NCNameValue in the ValueMapping; else if AllCapitalized is used, then the replacement name is the identifier with the first character uppercased; else if AllUppercased is used, then the replacement name is the identifier with all its characters uppercased; otherwise, the replacement name is the identifier.

The replacement names for the identifiers in a BitStringType subject to a VALUES encoding instruction MUST be distinct.

The replacement names for the identifiers in an EnumeratedType subject to a VALUES encoding instruction MUST be distinct.

The replacement names for the identifiers in an IntegerType subject to a VALUES encoding instruction MUST be distinct.

Example

```
Traffic-Light ::= [VALUES ALL CAPITALIZED, red AS "RED"]
  ENUMERATED {
    red,      -- Replacement name is RED.
    amber,    -- Replacement name is Amber.
    green     -- Replacement name is Green.
  }
```

## 23. Insertion Encoding Instructions

Certain of the RXER encoding instructions are categorized as insertion encoding instructions. The insertion encoding instructions are the NO-INSERTIONS, HOLLOW-INSERTIONS, SINGULAR-INSERTIONS, UNIFORM-INSERTIONS, and MULTIFORM-INSERTIONS encoding instructions (whose notations are described respectively by NoInsertionsInstruction, HollowInsertionsInstruction, SingularInsertionsInstruction, UniformInsertionsInstruction, and MultiformInsertionsInstruction).

The notation for the insertion encoding instructions is defined as follows:

```
InsertionsInstruction ::=
    NoInsertionsInstruction |
    HollowInsertionsInstruction |
    SingularInsertionsInstruction |
    UniformInsertionsInstruction |
    MultiformInsertionsInstruction

NoInsertionsInstruction ::= "NO-INSERTIONS"

HollowInsertionsInstruction ::= "HOLLOW-INSERTIONS"

SingularInsertionsInstruction ::= "SINGULAR-INSERTIONS"

UniformInsertionsInstruction ::= "UNIFORM-INSERTIONS"

MultiformInsertionsInstruction ::= "MULTIFORM-INSERTIONS"
```

Using the GROUP encoding instruction on components with extensible types can lead to situations where an unknown extension could be associated with more than one extension insertion point. The insertion encoding instructions remove this ambiguity by limiting the form that extensions can take. That is, the insertion encoding instructions indicate what extensions can be made to an ASN.1 specification without breaking forward compatibility for RXER encodings.

Aside: Forward compatibility means the ability for a decoder to successfully decode an encoding containing extensions introduced into a version of the specification that is more recent than the one used by the decoder.

In the most general case, an extension to a CHOICE, SET, or SEQUENCE type will generate zero or more attributes and zero or more elements, due to the potential use of the GROUP and ATTRIBUTE encoding instructions by the extension.

The MULTIFORM-INSERTIONS encoding instruction indicates that the RXER encodings produced by forward-compatible extensions to a type will always consist of one or more elements and zero or more attributes. No restriction is placed on the names of the elements.

Aside: Of necessity, the names of the attributes will all be different in any given encoding.

The UNIFORM-INSERTIONS encoding instruction indicates that the RXER encodings produced by forward-compatible extensions to a type will always consist of one or more elements having the same expanded name, and zero or more attributes. The expanded name shared by the

elements in one particular encoding is not required to be the same as the expanded name shared by the elements in any other encoding of the extension. For example, in one encoding of the extension the elements might all be called "foo", while in another encoding of the extension they might all be called "bar".

The SINGULAR-INSERTIONS encoding instruction indicates that the RXER encodings produced by forward-compatible extensions to a type will always consist of a single element and zero or more attributes. The name of the single element is not required to be the same in every possible encoding of the extension.

The HOLLOW-INSERTIONS encoding instruction indicates that the RXER encodings produced by forward-compatible extensions to a type will always consist of zero elements and zero or more attributes.

The NO-INSERTIONS encoding instruction indicates that no forward-compatible extensions can be made to a type.

Examples of forward-compatible extensions are provided in Appendix C.

The Type in the EncodingPrefixedType for an insertion encoding instruction SHALL be either:

- (1) a BuiltinType that is a ChoiceType where the ChoiceType is not subject to a UNION encoding instruction, or
- (2) a BuiltinType that is a SequenceType or SetType, or
- (3) a ConstrainedType that is not a TypeWithConstraint where the Type in the ConstrainedType is one of (1) to (5), or
- (4) a BuiltinType that is a PrefixedType that is a TaggedType where the Type in the TaggedType is one of (1) to (5), or
- (5) a BuiltinType that is a PrefixedType that is an EncodingPrefixedType where the Type in the EncodingPrefixedType is one of (1) to (5).

Case (2) is not permitted when the insertion encoding instruction is the SINGULAR-INSERTIONS, UNIFORM-INSERTIONS, or MULTIFORM-INSERTIONS encoding instruction.

Aside: Because extensions to a SET or SEQUENCE type are serial and effectively optional, the SINGULAR-INSERTIONS, UNIFORM-INSERTIONS, and MULTIFORM-INSERTIONS encoding instructions offer no advantage over unrestricted extensions (for a SET or SEQUENCE). For example, an optional series of singular insertions generates zero or more elements and zero or more attributes, just like an unrestricted extension.

The Type in case (1) or case (2) is said to be "subject to" the insertion encoding instruction.

The Type in case (1) or case (2) MUST be extensible, either explicitly or by default.

A Type SHALL NOT be subject to more than one insertion encoding instruction.

The insertion encoding instructions indicate what kinds of extensions can be made to a type without breaking forward compatibility, but they do not prohibit extensions that do break forward compatibility. That is, it is not an error for a type's base type to contain extensions that do not satisfy an insertion encoding instruction affecting the type. However, if any such extensions are made, then a new value SHOULD be introduced into the extensible set of permitted values for a version indicator attribute, or attributes (see Section 24), whose scope encompasses the extensions. An example is provided in Appendix C.

#### 24. The VERSION-INDICATOR Encoding Instruction

The VERSION-INDICATOR encoding instruction provides a mechanism for RXER decoders to be alerted that an encoding contains extensions that break forward compatibility (see the preceding section).

The notation for a VERSION-INDICATOR encoding instruction is defined as follows:

VersionIndicatorInstruction ::= "VERSION-INDICATOR"

A NamedType that is subject to a VERSION-INDICATOR encoding instruction MUST also be subject to an ATTRIBUTE encoding instruction.

The type of the NamedType that is subject to the VERSION-INDICATOR encoding instruction MUST be directly or indirectly a constrained type where the set of permitted values is defined to be extensible. Each value represents a different version of the ASN.1 specification. Ordinarily, an application will set the value of a version indicator

attribute to be the last of these permitted values. An application MAY set the value of the version indicator attribute to the value corresponding to an earlier version of the specification if it has not used any of the extensions added in a subsequent version.

If an RXER decoder encounters a value of the type that is not one of the root values or extension additions (but that is still allowed since the set of permitted values is extensible), then this indicates that the decoder is using a version of the ASN.1 specification that is not compatible with the version used to produce the encoding. In such cases, the decoder SHOULD treat the element containing the attribute as having an unknown ASN.1 type.

Aside: A version indicator attribute only indicates an incompatibility with respect to RXER encodings. Other encodings are not affected because the GROUP encoding instruction does not apply to them.

#### Examples

In this first example, the decoder is using an incompatible older version if the value of the version attribute in a received RXER encoding is not 1, 2, or 3.

```
SEQUENCE {
    version  [ATTRIBUTE] [VERSION-INDICATOR]
              INTEGER (1, ..., 2..3),
    message  MessageType
}
```

In this second example, the decoder is using an incompatible older version if the value of the format attribute in a received RXER encoding is not "1.0", "1.1", or "2.0".

```
SEQUENCE {
    format   [ATTRIBUTE] [VERSION-INDICATOR]
              UTF8String ("1.0", ..., "1.1" | "2.0"),
    message  MessageType
}
```

An extensive example is provided in Appendix C.

It is not necessary for every extensible type to have its own version indicator attribute. It would be typical for only the types of top-level element components to include a version indicator attribute, which would serve as the version indicator for all of the nested components.

## 25. The GROUP Encoding Instruction

The GROUP encoding instruction causes an RXER encoder to encode a value of the component to which it is applied without encapsulation as an element. It allows the construction of non-trivial content models for element content.

The notation for a GROUP encoding instruction is defined as follows:

GroupInstruction ::= "GROUP"

The base type of the type of a NamedType that is subject to a GROUP encoding instruction SHALL be either:

- (1) a SEQUENCE, SET, or SET OF type, or
- (2) a CHOICE type where the ChoiceType is not subject to a UNION encoding instruction, or
- (3) a SEQUENCE OF type where the SequenceOfType is not subject to a LIST encoding instruction.

The SEQUENCE type in case (1) SHALL NOT be the associated type for a built-in type, SHALL NOT be a type from the AdditionalBasicDefinitions module [RXER], and SHALL NOT contain a component that is subject to a SIMPLE-CONTENT encoding instruction.

Aside: Thus, the CHARACTER STRING, EMBEDDED PDV, EXTERNAL, REAL, and QName types are excluded.

The CHOICE type in case (2) SHALL NOT be a type from the AdditionalBasicDefinitions module.

Aside: Thus, the Markup type is excluded.

Definition (visible component): Ignoring all type constraints, the visible components for a type that is directly or indirectly a combining ASN.1 type (i.e., SEQUENCE, SET, CHOICE, SEQUENCE OF, or SET OF) is the set of components of the combining type definition plus, for each NamedType (of the combining type definition) that is subject to a GROUP encoding instruction, the visible components for the type of the NamedType. The visible components are determined after the COMPONENTS OF transformation specified in X.680, Clause 24.4 [X.680].

Aside: The set of visible attribute and element components for a type is the set of all the components of the type, and any nested types, that describe attributes and child elements appearing in the RXER encodings of values of the outer type.

A GROUP encoding instruction MUST NOT be used where it would cause a NamedType to be a visible component of the type of that same NamedType (which is only possible if the type definition is recursive).

Aside: Components subject to a GROUP encoding instruction might be translated into a compatible XML Schema [XSD1] as group definitions. A NamedType that is visible to its own type is analogous to a circular group, which XML Schema disallows.

Section 25.1 imposes additional conditions on the use of the GROUP encoding instruction.

In any use of the GROUP encoding instruction, there is a type, the including type, that contains the component subject to the GROUP encoding instruction, and a type, the included type, that is the base type of that component. Either type can have an extensible content model, either by directly using ASN.1 extensibility or by including through another GROUP encoding instruction some other type that is extensible.

The including and included types may be defined in different ASN.1 modules, in which case the owner of the including type, i.e., the person or organization having the authority to add extensions to the including type's definition, may be different from the owner of the included type.

If the owner of the including type is not using the most recent version of the included type's definition, then the owner of the including type might add an extension to the including type that is valid with respect to the older version of the included type, but is later found to be invalid when the latest versions of the including and included type definitions are brought together (perhaps by a third party). Although the owner of the including type must necessarily be aware of the existence of the included type, the reverse is not necessarily true. The owner of the included type could add an extension to the included type without realizing that it invalidates someone else's including type.

To avoid these problems, a GROUP encoding instruction MUST NOT be used if:

- (1) the included type is defined in a different module from the including type, and
- (2) the included type has an extensible content model, and
- (3) changes to the included type are not coordinated with the owner of the including type.

Changes in the included type are coordinated with the owner of the including type if:

- (1) the owner of the included type is also the owner of the including type, or
- (2) the owner of the including type is collaborating with the owner of the included type, or
- (3) all changes will be vetted by a common third party before being approved and published.

#### 25.1. Unambiguous Encodings

Unregulated use of the GROUP encoding instruction can easily lead to specifications in which distinct abstract values have indistinguishable RXER encodings, i.e., ambiguous encodings. This section imposes restrictions on the use of the GROUP encoding instruction to ensure that distinct abstract values have distinct RXER encodings. In addition, these restrictions ensure that an abstract value can be easily decoded in a single pass without back-tracking.

An RXER decoder for an ASN.1 type can be abstracted as a recognizer for a notional language, consisting of element and attribute expanded names, where the type definition describes the grammar for that language (in fact it is a context-free grammar). The restrictions on a type definition to ensure easy, unambiguous decoding are more conveniently, completely, and simply expressed as conditions on this associated grammar. Implementations are not expected to verify type definitions exactly in the manner to be described; however, the procedure used MUST produce the same result.

Section 25.1.1 describes the procedure for recasting as a grammar a type definition containing components subject to the GROUP encoding instruction. Sections 25.1.2 and 25.1.3 specify conditions that the

grammar must satisfy for the type definition to be valid. Section 25.1.4 describes how unrecognized attributes are accepted by the grammar for an extensible type.

Appendices A and B have extensive examples.

#### 25.1.1. Grammar Construction

A grammar consists of a collection of productions. A production has a left-hand side and a right-hand side (in this document, separated by the "::=" symbol). The left-hand side (in a context-free grammar) is a single non-terminal symbol. The right-hand side is a sequence of non-terminal and terminal symbols. The terminal symbols are the lexical items of the language that the grammar describes. One of the non-terminals is nominated to be the start symbol. A valid sequence of terminals for the language can be generated from the grammar by beginning with the start symbol and repeatedly replacing any non-terminal with the right-hand side of one of the productions where that non-terminal is on the production's left-hand side. The final sequence of terminals is achieved when there are no remaining non-terminals to replace.

Aside: X.680 describes the ASN.1 basic notation using a context-free grammar.

Each NamedType has an associated primary and secondary non-terminal.

Aside: The secondary non-terminal for a NamedType is used when the base type of the type in the NamedType is a SEQUENCE OF type or SET OF type.

Each ExtensionAddition and ExtensionAdditionAlternative has an associated non-terminal. There is a non-terminal associated with the extension insertion point of each extensible type. There is also a primary start non-terminal (this is the start symbol) and a secondary start non-terminal. The exact nature of the non-terminals is not important, however all the non-terminals MUST be mutually distinct.

It is adequate for most of the examples in this document (though not in the most general case) for the primary non-terminal for a NamedType to be the identifier of the NamedType, for the primary start non-terminal to be S, for the non-terminals for the instances of ExtensionAddition and ExtensionAdditionAlternative to be E1, E2, E3, and so on, and for the non-terminals for the extension insertion points to be I1, I2, I3, and so on. The secondary non-terminals are labelled by appending a "'" character to the primary non-terminal label, e.g., the primary and secondary start non-terminals are S and S', respectively.

Each NamedType and extension insertion point has an associated terminal. There exists a terminal called the general extension terminal that is not associated with any specific notation. The general extension terminal and the terminals for the extension insertion points are used to represent elements in unknown extensions. The exact nature of the terminals is not important; however, the aforementioned terminals MUST be mutually distinct. The terminals are further categorized as either element terminals or attribute terminals. A terminal for a NamedType is an attribute terminal if its associated NamedType is an attribute component; otherwise, it is an element terminal. The general extension terminal and the terminals for the extension insertion points are categorized as element terminals.

Terminals for attributes in unknown extensions are not explicitly provided in the grammar. Certain productions in the grammar are categorized as insertion point productions, and their role in accepting unknown attributes is described in Section 25.1.4.

In the examples in this document, the terminal for a component other than an attribute component will be represented as the local name of the expanded name of the component enclosed in double quotes, and the terminal for an attribute component will be represented as the local name of the expanded name of the component prefixed by the '@' character and enclosed in double quotes. The general extension terminal will be represented as "\*" and the terminals for the extension insertion points will be represented as "\*1", "\*2", "\*3", and so on.

The productions generated from a NamedType depend on the base type of the type of the NamedType. The productions for the start non-terminals depend on the combining type definition being tested. In either case, the procedure for generating productions takes a primary non-terminal, a secondary non-terminal (sometimes), and a type definition.

The grammar is constructed beginning with the start non-terminals and the combining type definition being tested.

A grammar is constructed after the COMPONENTS OF transformation specified in X.680, Clause 24.4 [X.680].

Given a primary non-terminal, N, and a type where the base type is a SEQUENCE or SET type, a production is added to the grammar with N as the left-hand side. The right-hand side is constructed from an initial empty state according to the following cases considered in order:

- (1) If an initial `RootComponentTypeList` is present in the base type, then the sequence of primary non-terminals for the components nested in that `RootComponentTypeList` are appended to the right-hand side in the order of their definition.
- (2) If an `ExtensionAdditions` instance is present in the base type and not empty, then the non-terminal for the first `ExtensionAddition` nested in the `ExtensionAdditions` instance is appended to the right-hand side.
- (3) If an `ExtensionAdditions` instance is empty or not present in the base type, and the base type is extensible (explicitly or by default), and the base type is not subject to a `NO-INSERTIONS` or `HOLLOW-INSERTIONS` encoding instruction, then the non-terminal for the extension insertion point of the base type is appended to the right-hand side.
- (4) If a final `RootComponentTypeList` is present in the base type, then the primary non-terminals for the components nested in that `RootComponentTypeList` are appended to the right-hand side in the order of their definition.

The production is an insertion point production if an `ExtensionAdditions` instance is empty or not present in the base type, and the base type is extensible (explicitly or by default), and the base type is not subject to a `NO-INSERTIONS` encoding instruction.

If a component in a `ComponentTypeList` (in either a `RootComponentTypeList` or an `ExtensionAdditionGroup`) is marked `OPTIONAL` or `DEFAULT`, then a production with the primary non-terminal of the component as the left-hand side and an empty right-hand side is added to the grammar.

If a component (regardless of the ASN.1 combining type containing it) is subject to a `GROUP` encoding instruction, then one or more productions constructed according to the component's type are added to the grammar. Each of these productions has the primary non-terminal of the component as the left-hand side.

If a component (regardless of the ASN.1 combining type containing it) is not subject to a `GROUP` encoding instruction, then a production is added to the grammar with the primary non-terminal of the component as the left-hand side and the terminal of the component as the right-hand side.

## Example

Consider the following ASN.1 type definition:

```
SEQUENCE {  
    -- Start of initial RootComponentTypeList.  
    one    [ATTRIBUTE] UTF8String,  
    two    BOOLEAN OPTIONAL,  
    three  INTEGER  
    -- End of initial RootComponentTypeList.  
}
```

Here is the grammar derived from this type:

```
S ::= one two three  
one ::= "@one"  
two  ::= "two"  
two  ::=  
three ::= "three"
```

For each ExtensionAddition (of a SEQUENCE or SET base type), a production is added to the grammar where the left-hand side is the non-terminal for the ExtensionAddition and the right-hand side is initially empty. If the ExtensionAddition is a ComponentType, then the primary non-terminal for the NamedType in the ComponentType is appended to the right-hand side; otherwise (an ExtensionAdditionGroup), the sequence of primary non-terminals for the components nested in the ComponentTypeList in the ExtensionAdditionGroup are appended to the right-hand side in the order of their definition. If the ExtensionAddition is followed by another ExtensionAddition, then the non-terminal for the next ExtensionAddition is appended to the right-hand side; otherwise, if the base type is not subject to a NO-INSERTIONS or HOLLOW-INSERTIONS encoding instruction, then the non-terminal for the extension insertion point of the base type is appended to the right-hand side. If the ExtensionAddition is not followed by another ExtensionAddition and the base type is not subject to a NO-INSERTIONS encoding instruction, then the production is an insertion point production. If the empty sequence of terminals cannot be generated from the production (it may be necessary to wait until the grammar is otherwise complete before making this determination), then another production is added to the grammar where the left-hand side is the non-terminal for the ExtensionAddition and the right-hand side is empty.

Aside: An extension is always effectively optional since a sender may be using an earlier version of the ASN.1 specification where none, or only some, of the extensions have been defined.

Aside: The grammar generated for ExtensionAdditions is structured to take account of the condition that an extension can only be used if all the earlier extensions are also used [X.680].

If a SEQUENCE or SET base type is extensible (explicitly or by default) and is not subject to a NO-INSERTIONS or HOLLOW-INSERTIONS encoding instruction, then:

- (1) a production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is the general extension terminal followed by the non-terminal for the extension insertion point, and
- (2) a production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point and the right-hand side is empty.

#### Example

Consider the following ASN.1 type definition:

```
SEQUENCE {
    -- Start of initial RootComponentTypeList.
    one    BOOLEAN,
    two    INTEGER OPTIONAL,
    -- End of initial RootComponentTypeList.
    ...,
    -- Start of ExtensionAdditions.
    four   INTEGER, -- First ExtensionAddition (E1).
    five   BOOLEAN OPTIONAL, -- Second ExtensionAddition (E2).
    [[ -- An ExtensionAdditionGroup.
        six    UTF8String,
        seven  INTEGER OPTIONAL
    ]], -- Third ExtensionAddition (E3).
    -- End of ExtensionAdditions.
    -- The extension insertion point is here (I1).
    ...,
    -- Start of final RootComponentTypeList.
    three  INTEGER
}
```

Here is the grammar derived from this type:

```
S ::= one two E1 three

E1 ::= four E2
E1 ::=
```

```
E2 ::= five E3
E3 ::= six seven I1
E3 ::=
```

```
I1 ::= "*" I1
I1 ::=
```

```
one ::= "one"
two ::= "two"
two ::=
three ::= "three"
four ::= "four"
five ::= "five"
five ::=
six ::= "six"
seven ::= "seven"
seven ::=
```

If the SEQUENCE type were subject to a NO-INSERTIONS or HOLLOW-INSERTIONS encoding instruction, then the productions for I1 would not appear, and the first production for E3 would be:

```
E3 ::= six seven
```

Given a primary non-terminal, N, and a type where the base type is a CHOICE type:

- (1) A production is added to the grammar for each NamedType nested in the RootAlternativeTypeList of the base type, where the left-hand side is N and the right-hand side is the primary non-terminal for the NamedType.
- (2) A production is added to the grammar for each ExtensionAdditionAlternative of the base type, where the left-hand side is N and the right-hand side is the non-terminal for the ExtensionAdditionAlternative.
- (3) If the base type is extensible (explicitly or by default) and the base type is not subject to an insertion encoding instruction, then:
  - (a) A production is added to the grammar where the left-hand side is N and the right-hand side is the non-terminal for the extension insertion point of the base type. This production is an insertion point production.

- (b) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is the general extension terminal followed by the non-terminal for the extension insertion point.
  - (c) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is empty.
- (4) If the base type is subject to a HOLLOW-INSERTIONS encoding instruction, then a production is added to the grammar where the left-hand side is N and the right-hand side is empty. This production is an insertion point production.
- (5) If the base type is subject to a SINGULAR-INSERTIONS encoding instruction, then a production is added to the grammar where the left-hand side is N and the right-hand side is the general extension terminal. This production is an insertion point production.
- (6) If the base type is subject to a UNIFORM-INSERTIONS encoding instruction, then:
- (a) A production is added to the grammar where the left-hand side is N and the right-hand side is the general extension terminal.

Aside: This production is used to verify the correctness of an ASN.1 type definition, but would not be used in the implementation of an RXER decoder. The next production takes precedence over it for accepting an unknown element.

- (b) A production is added to the grammar where the left-hand side is N and the right-hand side is the terminal for the extension insertion point of the base type followed by the non-terminal for the extension insertion point. This production is an insertion point production.
- (c) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is the terminal for the extension insertion point followed by the non-terminal for the extension insertion point.
- (d) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is empty.

- (7) If the base type is subject to a MULTIFORM-INSERTIONS encoding instruction, then:
- (a) A production is added to the grammar where the left-hand side is N and the right-hand side is the general extension terminal followed by the non-terminal for the extension insertion point of the base type. This production is an insertion point production.
  - (b) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is the general extension terminal followed by the non-terminal for the extension insertion point.
  - (c) A production is added to the grammar where the left-hand side is the non-terminal for the extension insertion point of the base type and the right-hand side is empty.

If an ExtensionAdditionAlternative is a NamedType, then a production is added to the grammar where the left-hand side is the non-terminal for the ExtensionAdditionAlternative and the right-hand side is the primary non-terminal for the NamedType.

If an ExtensionAdditionAlternative is an ExtensionAdditionAlternativesGroup, then a production is added to the grammar for each NamedType nested in the ExtensionAdditionAlternativesGroup, where the left-hand side is the non-terminal for the ExtensionAdditionAlternative and the right-hand side is the primary non-terminal for the NamedType.

## Example

Consider the following ASN.1 type definition:

```
CHOICE {
  -- Start of RootAlternativeTypeList.
  one    BOOLEAN,
  two    INTEGER,
  -- End of RootAlternativeTypeList.
  ...,
  -- Start of ExtensionAdditionAlternatives.
  three  INTEGER, -- First ExtensionAdditionAlternative (E1).
  [[ -- An ExtensionAdditionAlternativesGroup.
    four  UTF8String,
    five  INTEGER
  ]] -- Second ExtensionAdditionAlternative (E2).
  -- The extension insertion point is here (I1).
}
```

Here is the grammar derived from this type:

```
S ::= one
S ::= two
S ::= E1
S ::= E2
S ::= I1

I1 ::= "*" I1
I1 ::=

E1 ::= three
E2 ::= four
E2 ::= five

one ::= "one"
two ::= "two"
three ::= "three"
four ::= "four"
five ::= "five"
```

If the CHOICE type were subject to a NO-INSERTIONS encoding instruction, then the fifth, sixth, and seventh productions would be removed.

If the CHOICE type were subject to a HOLLOW-INSERTIONS encoding instruction, then the fifth, sixth, and seventh productions would be replaced by:

S ::=

If the CHOICE type were subject to a SINGULAR-INSERTIONS encoding instruction, then the fifth, sixth, and seventh productions would be replaced by:

S ::= "\*"

If the CHOICE type were subject to a UNIFORM-INSERTIONS encoding instruction, then the fifth and sixth productions would be replaced by:

S ::= "\*"

S ::= "\*1" I1

I1 ::= "\*1" I1

If the CHOICE type were subject to a MULTIFORM-INSERTIONS encoding instruction, then the fifth production would be replaced by:

S ::= "\*" I1

Constraints on a SEQUENCE, SET, or CHOICE type are ignored. They do not affect the grammar being generated.

Aside: This avoids an awkward situation where values of a subtype have to be decoded differently from values of the parent type. It also simplifies the verification procedure.

Given a primary non-terminal, N, and a type that has a SEQUENCE OF or SET OF base type and that permits a value of size zero (i.e., an empty sequence or set):

- (1) a production is added to the grammar where the left-hand side of the production is N and the right-hand side is the primary non-terminal for the NamedType of the component of the SEQUENCE OF or SET OF base type, followed by N, and
- (2) a production is added to the grammar where the left-hand side of the production is N and the right-hand side is empty.

Given a primary non-terminal, N, a secondary non-terminal, N', and a type that has a SEQUENCE OF or SET OF base type and that does not permit a value of size zero:

- (1) a production is added to the grammar where the left-hand side of the production is N and the right-hand side is the primary non-terminal for the NamedType of the component of the SEQUENCE OF or SET OF base type, followed by N', and
- (2) a production is added to the grammar where the left-hand side of the production is N' and the right-hand side is the primary non-terminal for the NamedType of the component of the SEQUENCE OF or SET OF base type, followed by N', and
- (3) a production is added to the grammar where the left-hand side of the production is N' and the right-hand side is empty.

#### Example

Consider the following ASN.1 type definition:

```
SEQUENCE SIZE(1..MAX) OF number INTEGER
```

Here is the grammar derived from this type:

```
S ::= number S'
S' ::= number S'
S' ::=
    number ::= "number"
```

All inner subtyping (InnerTypeConstraints) is ignored for the purposes of deciding whether a value of size zero is permitted by a SEQUENCE OF or SET OF type.

This completes the description of the transformation of ASN.1 combining type definitions into a grammar.

#### 25.1.2. Unique Component Attribution

This section describes conditions that the grammar must satisfy so that each element and attribute in a received RXER encoding can be uniquely associated with an ASN.1 component definition.

Definition (used by the grammar): A non-terminal, N, is used by the grammar if:

- (1) N is the start symbol or
- (2) N appears on the right-hand side of a production where the non-terminal on the left-hand side is used by the grammar.

Definition (multiple derivation paths): A non-terminal, N, has multiple derivation paths if:

- (1) N appears on the right-hand side of a production where the non-terminal on the left-hand side has multiple derivation paths, or
- (2) N appears on the right-hand side of more than one production where the non-terminal on the left-hand side is used by the grammar, or
- (3) N is the start symbol and it appears on the right-hand side of a production where the non-terminal on the left-hand side is used by the grammar.

For every ASN.1 type with a base type containing components that are subject to a GROUP encoding instruction, the grammar derived by the method described in this document MUST NOT have:

- (1) two or more primary non-terminals that are used by the grammar and are associated with element components having the same expanded name, or
- (2) two or more primary non-terminals that are used by the grammar and are associated with attribute components having the same expanded name, or
- (3) a primary non-terminal that has multiple derivation paths and is associated with an attribute component.

Aside: Case (1) is in response to component referencing notations that are evaluated with respect to the XML encoding of an abstract value. Case (1) guarantees, without having to do extensive testing (which would necessarily have to take account of encoding instructions for all other encoding rules), that all sibling elements with the same expanded name will be associated with equivalent type definitions. Such equivalence allows a component referenced by element name to be re-encoded using a different set of ASN.1 encoding rules without ambiguity as to which type definition and encoding instructions apply.

Cases (2) and (3) ensure that an attribute name is always uniquely associated with one component that can occur at most once and is always nested in the same part of an abstract value.

## Example

The following example types illustrate various uses and misuses of the GROUP encoding instruction with respect to unique component attribution:

```

TA ::= SEQUENCE {
  a [GROUP] TB,
  b [GROUP] CHOICE {
    a [GROUP] TB,
    b [NAME AS "c"] [ATTRIBUTE] INTEGER,
    c INTEGER,
    d TB,
    e [GROUP] TD,
    f [ATTRIBUTE] UTF8String
  },
  c [ATTRIBUTE] INTEGER,
  d [GROUP] SEQUENCE OF
    a [GROUP] SEQUENCE {
      a [ATTRIBUTE] OBJECT IDENTIFIER,
      b INTEGER
    },
  e [NAME AS "c"] INTEGER,
  COMPONENTS OF TD
}

TB ::= SEQUENCE {
  a INTEGER,
  b [ATTRIBUTE] BOOLEAN,
  COMPONENTS OF TC
}

TC ::= SEQUENCE {
  f OBJECT IDENTIFIER
}

TD ::= SEQUENCE {
  g OBJECT IDENTIFIER
}

```

The grammar for TA is constructed after performing the COMPONENTS OF transformation. The result of this transformation is shown next. This example will depart from the usual convention of using just the identifier of a NamedType to represent the primary non-terminal for that NamedType. A label relative to the outermost type will be used instead to better illustrate unique component attribution. The labels used for the non-terminals are shown down the right-hand side.

```

TA ::= SEQUENCE {
    a [GROUP] TB, -- TA.a
    b [GROUP] CHOICE { -- TA.b
        a [GROUP] TB, -- TA.b.a
        b [NAME AS "c"] [ATTRIBUTE] INTEGER, -- TA.b.b
        c INTEGER, -- TA.b.c
        d TB, -- TA.b.d
        e [GROUP] TD, -- TA.b.e
        f [ATTRIBUTE] UTF8String -- TA.b.f
    },
    c [ATTRIBUTE] INTEGER, -- TA.c
    d [GROUP] SEQUENCE OF -- TA.d
        a [GROUP] SEQUENCE { -- TA.d.a
            a [ATTRIBUTE] OBJECT IDENTIFIER, -- TA.d.a.a
            b INTEGER -- TA.d.a.b
        },
    e [NAME AS "c"] INTEGER, -- TA.e
    g OBJECT IDENTIFIER -- TA.g
}

TB ::= SEQUENCE {
    a INTEGER, -- TB.a
    b [ATTRIBUTE] BOOLEAN, -- TB.b
    f OBJECT IDENTIFIER -- TB.f
}

-- Type TC is no longer of interest. --

TD ::= SEQUENCE {
    g OBJECT IDENTIFIER -- TD.g
}

```

The associated grammar is:

```

S ::= TA.a TA.b TA.c TA.d TA.e TA.g

TA.a ::= TB.a TB.b TB.f

TB.a ::= "a"
TB.b ::= "@b"
TB.f ::= "f"

TA.b ::= TA.b.a
TA.b ::= TA.b.b
TA.b ::= TA.b.c
TA.b ::= TA.b.d
TA.b ::= TA.b.e
TA.b ::= TA.b.f

```

```
TA.b.a ::= TB.a TB.b TB.f
TA.b.b ::= "@c"
TA.b.c ::= "c"
TA.b.d ::= "d"
TA.b.e ::= TD.g
TA.b.f ::= "@f"

TD.g ::= "g"

TA.c ::= "@c"

TA.d ::= TA.d.a TA.d
TA.d ::=

TA.d.a ::= TA.d.a.a TA.d.a.b

TA.d.a.a := "@a"
TA.d.a.b ::= "b"

TA.e ::= "c"

TA.g ::= "g"
```

All the non-terminals are used by the grammar.

The type definition for TA is invalid because there are two instances where two or more primary non-terminals are associated with element components having the same expanded name:

- (1) TA.b.c and TA.e (both generate the terminal "c"), and
- (2) TD.g and TA.g (both generate the terminal "g").

In case (2), TD.g and TA.g are derived from the same instance of NamedType notation, but become distinct components following the COMPONENTS OF transformation. AUTOMATIC tagging is applied after the COMPONENTS OF transformation, which means that the types of the components corresponding to TD.g and TA.g will end up with different tags, and therefore the types will not be equivalent.

The type definition for TA is also invalid because there is one instance where two or more primary non-terminals are associated with attribute components having the same expanded name: TA.b.b and TA.c (both generate the terminal "@c").

The non-terminals with multiple derivation paths are: TA.d, TA.d.a, TA.d.a.a, TA.d.a.b, TB.a, TB.b, and TB.f. The type definition for TA is also invalid because TA.d.a.a and TB.b are primary non-terminals that are associated with an attribute component.

### 25.1.1.3. Deterministic Grammars

Let the First Set of a production P, denoted First(P), be the set of all element terminals T where T is the first element terminal in a sequence of terminals that can be generated from the right-hand side of P. There can be any number of leading attribute terminals before T.

Let the Follow Set of a non-terminal N, denoted Follow(N), be the set of all element terminals T where T is the first element terminal following N in a sequence of non-terminals and terminals that can be generated from the grammar. There can be any number of attribute terminals between N and T. If a sequence of non-terminals and terminals can be generated from the grammar where N is not followed by any element terminals, then Follow(N) also contains a special end terminal, denoted by "\$".

Aside: If N does not appear on the right-hand side of any production, then Follow(N) will be empty.

For a production P, let the predicate Empty(P) be true if and only if the empty sequence of terminals can be generated from P. Otherwise, Empty(P) is false.

Definition (base grammar): The base grammar is a rewriting of the grammar in which the non-terminals for every ExtensionAddition and ExtensionAdditionAlternative are removed from the right-hand side of all productions.

For a production P, let the predicate Preselected(P) be true if and only if every sequence of terminals that can be generated from the right-hand side of P using only the base grammar contains at least one attribute terminal. Otherwise, Preselected(P) is false.

The Select Set of a production P, denoted Select(P), is empty if Preselected(P) is true; otherwise, it contains First(P). Let N be the non-terminal on the left-hand side of P. If Empty(P) is true, then Select(P) also contains Follow(N).

Aside: It may appear somewhat dubious to include the attribute components in the grammar because, in reality, attributes appear unordered within the start tag of an element, and not interspersed with the child elements as the grammar would suggest. This is why attribute terminals are ignored in composing the First Sets and Follow Sets. However, the attribute terminals are important in composing the Select Sets because they can preselect a production and can prevent a production from being able to generate an empty sequence of terminals. In real terms, this corresponds to an RXER decoder using the attributes to determine the presence or absence of optional components and to select between the alternatives of a CHOICE, even before considering the child elements.

An attribute appearing in an extension isn't used to preselect a production since, in general, a decoder using an earlier version of the specification would not be able to associate the attribute with any particular extension insertion point.

Let the Reach Set of a non-terminal  $N$ , denoted  $\text{Reach}(N)$ , be the set of all element terminals  $T$  where  $T$  appears in a sequence of terminals that can be generated from  $N$ .

Aside: It can be readily shown that all the optional attribute components and all but one of the mandatory attribute components of a SEQUENCE or SET type can be ignored in constructing the grammar because their omission does not alter the First, Follow, Select, or Reach Sets, or the evaluation of the Preselected and Empty predicates.

A grammar is deterministic (for the purposes of an RXER decoder) if and only if:

- (1) there do not exist two productions  $P$  and  $Q$ , with the same non-terminal on the left-hand side, where the intersection of  $\text{Select}(P)$  and  $\text{Select}(Q)$  is not empty, and
- (2) there does not exist a non-terminal  $E$  for an ExtensionAddition or ExtensionAdditionAlternative where the intersection of  $\text{Reach}(E)$  and  $\text{Follow}(E)$  is not empty.

Aside: In case (1), if the intersection is not empty, then a decoder would have two or more possible ways to attempt to decode the input into an abstract value. In case (2), if the intersection is not empty, then a decoder using an earlier version of the ASN.1 specification would confuse an element in an unknown (to that decoder) extension with a known component following the extension.

Aside: In the absence of any attribute components, case (1) is the test for an LL(1) grammar.

For every ASN.1 type with a base type containing components that are subject to a GROUP encoding instruction, the grammar derived by the method described in this document MUST be deterministic.

#### 25.1.4. Attributes in Unknown Extensions

An insertion point production is able to accept unknown attributes if the non-terminal on the left-hand side of the production does not have multiple derivation paths.

Aside: If the non-terminal has multiple derivation paths, then any future extension cannot possibly contain an attribute component because that would violate the requirements of Section 25.1.2.

For a deterministic grammar, there is only one possible way to construct a sequence of element terminals matching the element content of an element in a correctly formed RXER encoding. Any unknown attributes of the element are accepted if at least one insertion point production that is able to accept unknown attributes is used in that construction.

#### Example

Consider this type definition:

```
CHOICE {
  one  UTF8String,
  two  [GROUP] SEQUENCE {
    three  INTEGER,
    ...
  }
}
```

The associated grammar is:

```
S ::= one
S ::= two

two ::= three I1

I1 ::= "*" I1
I1 ::=

one ::= "one"
three ::= "three"
```

The third production is an insertion point production, and it is able to accept unknown attributes.

When decoding a value of this type, if the element content contains a <one> child element, then any unrecognized attribute would be illegal as the insertion point production would not be used to recognize the input (the "one" alternative does not admit an extension insertion point). If the element content contains a <three> element, then an unrecognized attribute would be accepted because the insertion point production would be used to recognize the input (the "two" alternative that generates the <three> element has an extensible type).

If the SEQUENCE type were prefixed by a NO-INSERTIONS encoding instruction, then the third, fourth, and fifth productions would be replaced by:

```
two ::= three
```

With this change, any unrecognized attribute would be illegal for the "two" alternative also, since the replacement production is not an insertion point production.

If more than one insertion point production that is able to accept unknown attributes is used in constructing a matching sequence of element terminals, then a decoder is free to associate an unrecognized attribute with any one of the extension insertion points corresponding to those insertion point productions. The justification for doing so comes from the following two observations:

- (1) If the encoding of an abstract value contains an extension where the type of the extension is unknown to the receiver, then it is generally impossible to re-encode the value using a different set of encoding rules, including the canonical variant of the received encoding. This is true no matter which encoding rules are being used. It is desirable for a decoder to be able to accept and store the raw encoding of an extension without raising an error, and to re-insert the raw encoding of the extension when re-encoding the abstract value using the same non-canonical encoding rules. However, there is little more that an application can do with an unknown extension.

An application using RXER can successfully accept, store, and re-encode an unrecognized attribute regardless of which extension insertion point it might be ascribed to.

- (2) Even if there is a single extension insertion point, an unknown extension could still be the encoding of a value of any one of an infinite number of valid type definitions. For example, an attribute or element component could be nested to any arbitrary depth within CHOICES whose components are subject to GROUP encoding instructions.

Aside: A similar series of nested CHOICES could describe an unknown extension in a Basic Encoding Rules (BER) encoding [X.690].

## 26. Security Considerations

ASN.1 compiler implementors should take special care to be thorough in checking that the GROUP encoding instruction has been correctly used; otherwise, ASN.1 specifications with ambiguous RXER encodings could be deployed.

Ambiguous encodings mean that the abstract value recovered by a decoder may differ from the original abstract value that was encoded. If that is the case, then a digital signature generated with respect to the original abstract value (using a canonical encoding other than CRXER) will not be successfully verified by a receiver using the decoded abstract value. Also, an abstract value may have security-sensitive fields, and in particular, fields used to grant or deny access. If the decoded abstract value differs from the encoded abstract value, then a receiver using the decoded abstract value will be applying different security policy than that embodied in the original abstract value.

## 27. References

### 27.1. Normative References

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## 27.2. Informative References

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## Appendix A. GROUP Encoding Instruction Examples

This appendix is non-normative.

This appendix contains examples of both correct and incorrect use of the GROUP encoding instruction, determined with respect to the grammars derived from the example type definitions. The productions of the grammars are labeled for convenience. Sets and predicates for non-terminals with only one production will be omitted from the examples since they never indicate non-determinism.

The requirements of Section 25.1.2 ("Unique Component Attribution") are satisfied by all the examples in this appendix and the appendices that follow it.

### A.1. Example 1

Consider this type definition:

```
SEQUENCE {
    one    [GROUP] SEQUENCE {
        two    UTF8String OPTIONAL
    } OPTIONAL,
    three  INTEGER
}
```

The associated grammar is:

```
P1: S ::= one three
P2: one ::= two
P3: one ::=
P4: two ::= "two"
P5: two ::=
P6: three ::= "three"
```

Select Sets have to be evaluated to test the validity of the type definition. The grammar leads to the following sets and predicates:

```
First(P2) = { "two" }
First(P3) = { }
Preselected(P2) = Preselected(P3) = false
Empty(P2) = Empty(P3) = true
Follow(one) = { "three" }
Select(P2) = First(P2) + Follow(one) = { "two", "three" }
Select(P3) = First(P3) + Follow(one) = { "three" }
```

```

First(P4) = { "two" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(two) = { "three" }
Select(P4) = First(P4) = { "two" }
Select(P5) = First(P5) + Follow(two) = { "three" }

```

The intersection of Select(P2) and Select(P3) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the RXER encoding of a value of the type does not have a child element <two>, then it is not possible to determine whether the "one" component is present or absent in the value.

Now consider this type definition with attributes in the "one" component:

```

SEQUENCE {
  one [GROUP] SEQUENCE {
    two UTF8String OPTIONAL,
    four [ATTRIBUTE] BOOLEAN,
    five [ATTRIBUTE] BOOLEAN OPTIONAL
  } OPTIONAL,
  three INTEGER
}

```

The associated grammar is:

```

P1: S ::= one three
P2: one ::= two four five
P3: one ::=
P4: two ::= "two"
P5: two ::=
P6: four ::= "@four"
P7: five ::= "@five"
P8: five ::=
P9: three ::= "three"

```

This grammar leads to the following sets and predicates:

```

First(P2) = { "two" }
First(P3) = { }
Preselected(P3) = Empty(P2) = false
Preselected(P2) = Empty(P3) = true
Follow(one) = { "three" }
Select(P2) = { }
Select(P3) = First(P3) + Follow(one) = { "three" }

```

```

First(P4) = { "two" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(two) = { "three" }
Select(P4) = First(P4) = { "two" }
Select(P5) = First(P5) + Follow(two) = { "three" }

First(P7) = { }
First(P8) = { }
Preselected(P8) = Empty(P7) = false
Preselected(P7) = Empty(P8) = true
Follow(five) = { "three" }
Select(P7) = { }
Select(P8) = First(P8) + Follow(five) = { "three" }

```

The intersection of Select(P2) and Select(P3) is empty, as is the intersection of Select(P4) and Select(P5) and the intersection of Select(P7) and Select(P8); hence, the grammar is deterministic, and the type definition is valid. In a correct RXER encoding, the "one" component will be present if and only if the "four" attribute is present.

## A.2. Example 2

Consider this type definition:

```

CHOICE {
  one    [GROUP] SEQUENCE {
    two    [ATTRIBUTE] BOOLEAN OPTIONAL
  },
  three  INTEGER,
  four   [GROUP] SEQUENCE {
    five   BOOLEAN OPTIONAL
  }
}

```

The associated grammar is:

```

P1: S ::= one
P2: S ::= three
P3: S ::= four
P4: one ::= two
P5: two ::= "@two"
P6: two ::=
P7: three ::= "three"
P8: four ::= five
P9: five ::= "five"

```

P10: five ::=

This grammar leads to the following sets and predicates:

```

First(P1) = { }
First(P2) = { "three" }
First(P3) = { "five" }
Preselected(P1) = Preselected(P2) = Preselected(P3) = false
Empty(P2) = false
Empty(P1) = Empty(P3) = true
Follow(S) = { "$" }
Select(P1) = First(P1) + Follow(S) = { "$" }
Select(P2) = First(P2) = { "three" }
Select(P3) = First(P3) + Follow(S) = { "five", "$" }

First(P5) = { }
First(P6) = { }
Preselected(P6) = Empty(P5) = false
Preselected(P5) = Empty(P6) = true
Follow(two) = { "$" }
Select(P5) = { }
Select(P6) = First(P6) + Follow(two) = { "$" }

First(P9) = { "five" }
First(P10) = { }
Preselected(P9) = Preselected(P10) = Empty(P9) = false
Empty(P10) = true
Follow(five) = { "$" }
Select(P9) = First(P9) = { "five" }
Select(P10) = First(P10) + Follow(five) = { "$" }

```

The intersection of Select(P1) and Select(P3) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the RXER encoding of a value of the type is empty, then it is not possible to determine whether the "one" alternative or the "four" alternative has been chosen.

Now consider this slightly different type definition:

```

CHOICE {
  one    [GROUP] SEQUENCE {
    two   [ATTRIBUTE] BOOLEAN
  },
  three  INTEGER,
  four   [GROUP] SEQUENCE {
    five  BOOLEAN OPTIONAL
  }
}

```

The associated grammar is:

```
P1: S ::= one
P2: S ::= three
P3: S ::= four
P4: one ::= two
P5: two ::= "@two"
P6: three ::= "three"
P7: four ::= five
P8: five ::= "five"
P9: five ::=
```

This grammar leads to the following sets and predicates:

```
First(P1) = { }
First(P2) = { "three" }
First(P3) = { "five" }
Preselected(P2) = Preselected(P3) = false
Empty(P1) = Empty(P2) = false
Preselected(P1) = Empty(P3) = true
Follow(S) = { "$" }
Select(P1) = { }
Select(P2) = First(P2) = { "three" }
Select(P3) = First(P3) + Follow(S) = { "five", "$" }

First(P8) = { "five" }
First(P9) = { }
Preselected(P8) = Preselected(P9) = Empty(P8) = false
Empty(P9) = true
Follow(five) = { "$" }
Select(P8) = First(P8) = { "five" }
Select(P9) = First(P9) + Follow(five) = { "$" }
```

The intersection of Select(P1) and Select(P2) is empty, the intersection of Select(P1) and Select(P3) is empty, the intersection of Select(P2) and Select(P3) is empty, and the intersection of Select(P8) and Select(P9) is empty; hence, the grammar is deterministic, and the type definition is valid. The "one" and "four" alternatives can be distinguished because the "one" alternative has a mandatory attribute.

## A.3. Example 3

Consider this type definition:

```
SEQUENCE {
  one [GROUP] CHOICE {
    two [ATTRIBUTE] BOOLEAN,
    three [GROUP] SEQUENCE OF number INTEGER
  } OPTIONAL
}
```

The associated grammar is:

```
P1: S ::= one
P2: one ::= two
P3: one ::= three
P4: one ::=
P5: two ::= "@two"
P6: three ::= number three
P7: three ::=
P8: number ::= "number"
```

This grammar leads to the following sets and predicates:

```
First(P2) = { }
First(P3) = { "number" }
First(P4) = { }
Preselected(P3) = Preselected(P4) = Empty(P2) = false
Preselected(P2) = Empty(P3) = Empty(P4) = true
Follow(one) = { "$" }
Select(P2) = { }
Select(P3) = First(P3) + Follow(one) = { "number", "$" }
Select(P4) = First(P4) + Follow(one) = { "$" }

First(P6) = { "number" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
Follow(three) = { "$" }
Select(P6) = First(P6) = { "number" }
Select(P7) = First(P7) + Follow(three) = { "$" }
```

The intersection of Select(P3) and Select(P4) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the RXER encoding of a value of the type is empty, then it is not possible to determine whether the "one" component is absent or the empty "three" alternative has been chosen.

## A.4. Example 4

Consider this type definition:

```
SEQUENCE {
  one [GROUP] CHOICE {
    two [ATTRIBUTE] BOOLEAN,
    three [ATTRIBUTE] BOOLEAN
  } OPTIONAL
}
```

The associated grammar is:

```
P1: S ::= one
P2: one ::= two
P3: one ::= three
P4: one ::=
P5: two ::= "@two"
P6: three ::= "@three"
```

This grammar leads to the following sets and predicates:

```
First(P2) = { }
First(P3) = { }
First(P4) = { }
Preselected(P4) = Empty(P2) = Empty(P3) = false
Preselected(P2) = Preselected(P3) = Empty(P4) = true
Follow(one) = { "$" }
Select(P2) = { }
Select(P3) = { }
Select(P4) = First(P4) + Follow(one) = { "$" }
```

The intersection of Select(P2) and Select(P3) is empty, the intersection of Select(P2) and Select(P4) is empty, and the intersection of Select(P3) and Select(P4) is empty; hence, the grammar is deterministic, and the type definition is valid.

## A.5. Example 5

Consider this type definition:

```
SEQUENCE {
  one [GROUP] SEQUENCE OF number INTEGER OPTIONAL
}
```

The associated grammar is:

```
P1: S ::= one
P2: one ::= number one
P3: one ::=
P4: one ::=
P5: number ::= "number"
```

P3 is generated during the processing of the SEQUENCE OF type. P4 is generated because the "one" component is optional.

This grammar leads to the following sets and predicates:

```
First(P2) = { "number" }
First(P3) = { }
First(P4) = { }
Preselected(P2) = Preselected(P3) = Preselected(P4) = false
Empty(P2) = false
Empty(P3) = Empty(P4) = true
Follow(one) = { "$" }
Select(P2) = First(P2) = { "number" }
Select(P3) = First(P3) + Follow(one) = { "$" }
Select(P4) = First(P4) + Follow(one) = { "$" }
```

The intersection of Select(P3) and Select(P4) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the RXER encoding of a value of the type does not have any <number> child elements, then it is not possible to determine whether the "one" component is present or absent in the value.

Consider this similar type definition with a SIZE constraint:

```
SEQUENCE {
    one [GROUP] SEQUENCE SIZE(1..MAX) OF number INTEGER OPTIONAL
}
```

The associated grammar is:

```
P1: S ::= one
P2: one ::= number one'
P3: one' ::= number one'
P4: one' ::=
P5: one ::=
P6: number ::= "number"
```

This grammar leads to the following sets and predicates:

```

First(P2) = { "number" }
First(P5) = { }
Preselected(P2) = Preselected(P5) = Empty(P2) = false
Empty(P5) = true
Follow(one) = { "$" }
Select(P2) = First(P2) = { "number" }
Select(P5) = First(P5) + Follow(one) = { "$" }

First(P3) = { "number" }
First(P4) = { }
Preselected(P3) = Preselected(P4) = Empty(P3) = false
Empty(P4) = true
Follow(one') = { "$" }
Select(P3) = First(P3) = { "number" }
Select(P4) = First(P4) + Follow(one') = { "$" }

```

The intersection of Select(P2) and Select(P5) is empty, as is the intersection of Select(P3) and Select(P4); hence, the grammar is deterministic, and the type definition is valid. If there are no <number> child elements, then the "one" component is necessarily absent and there is no ambiguity.

#### A.6. Example 6

Consider this type definition:

```

SEQUENCE {
    beginning [GROUP] List,
    middle    UTF8String OPTIONAL,
    end       [GROUP] List
}

List ::= SEQUENCE OF string UTF8String

```

The associated grammar is:

```

P1: S ::= beginning middle end
P2: beginning ::= string beginning
P3: beginning ::=
P4: middle ::= "middle"
P5: middle ::=
P6: end ::= string end
P7: end ::=
P8: string ::= "string"

```

This grammar leads to the following sets and predicates:

```

First(P2) = { "string" }
First(P3) = { }
Preselected(P2) = Preselected(P3) = Empty(P2) = false
Empty(P3) = true
Follow(beginning) = { "middle", "string", "$" }
Select(P2) = First(P2) = { "string" }
Select(P3) = First(P3) + Follow(beginning)
              = { "middle", "string", "$" }

First(P4) = { "middle" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(middle) = { "string", "$" }
Select(P4) = First(P4) = { "middle" }
Select(P5) = First(P5) + Follow(middle) = { "string", "$" }

First(P6) = { "string" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
Follow(end) = { "$" }
Select(P6) = First(P6) = { "string" }
Select(P7) = First(P7) + Follow(end) = { "$" }

```

The intersection of Select(P2) and Select(P3) is not empty; hence, the grammar is not deterministic, and the type definition is not valid.

Now consider the following type definition:

```

SEQUENCE {
    beginning      [GROUP] List,
    middleAndEnd   [GROUP] SEQUENCE {
        middle      UTF8String,
        end          [GROUP] List
    } OPTIONAL
}

```

The associated grammar is:

```

P1: S ::= beginning middleAndEnd
P2: beginning ::= string beginning
P3: beginning ::=
P4: middleAndEnd ::= middle end
P5: middleAndEnd ::=

```

```

P6: middle ::= "middle"
P7: end ::= string end
P8: end ::=
P9: string ::= "string"

```

This grammar leads to the following sets and predicates:

```

First(P2) = { "string" }
First(P3) = { }
Preselected(P2) = Preselected(P3) = Empty(P2) = false
Empty(P3) = true
Follow(beginning) = { "middle", "$" }
Select(P2) = First(P2) = { "string" }
Select(P3) = First(P3) + Follow(beginning) = { "middle", "$" }

First(P4) = { "middle" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(middleAndEnd) = { "$" }
Select(P4) = First(P4) = { "middle" }
Select(P5) = First(P5) + Follow(middleAndEnd) = { "$" }

First(P7) = { "string" }
First(P8) = { }
Preselected(P7) = Preselected(P8) = Empty(P7) = false
Empty(P8) = true
Follow(end) = { "$" }
Select(P7) = First(P7) = { "string" }
Select(P8) = First(P8) + Follow(end) = { "$" }

```

The intersection of Select(P2) and Select(P3) is empty, as is the intersection of Select(P4) and Select(P5) and the intersection of Select(P7) and Select(P8); hence, the grammar is deterministic, and the type definition is valid.

#### A.7. Example 7

Consider the following type definition:

```

SEQUENCE SIZE(1..MAX) OF
  one  [GROUP] SEQUENCE {
    two    INTEGER OPTIONAL
  }

```

The associated grammar is:

```
P1: S ::= one S'
P2: S' ::= one S'
P3: S' ::=
P4: one ::= two
P5: two ::= "two"
P6: two ::=
```

This grammar leads to the following sets and predicates:

```
First(P2) = { "two" }
First(P3) = { }
Preselected(P2) = Preselected(P3) = false
Empty(P2) = Empty(P3) = true
Follow(S') = { "$" }
Select(P2) = First(P2) + Follow(S') = { "two", "$" }
Select(P3) = First(P3) + Follow(S') = { "$" }

First(P5) = { "two" }
First(P6) = { }
Preselected(P5) = Preselected(P6) = Empty(P5) = false
Empty(P6) = true
Follow(two) = { "two", "$" }
Select(P5) = First(P5) = { "two" }
Select(P6) = First(P6) + Follow(two) = { "two", "$" }
```

The intersection of Select(P2) and Select(P3) is not empty and the intersection of Select(P5) and Select(P6) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. The encoding of a value of the type contains an indeterminate number of empty instances of the component type.

#### A.8. Example 8

Consider the following type definition:

```
SEQUENCE OF
  list [GROUP] SEQUENCE SIZE(1..MAX) OF number INTEGER
```

The associated grammar is:

```
P1: S ::= list S
P2: S ::=
P3: list ::= number list'
P4: list' ::= number list'
P5: list' ::=
P6: number ::= "number"
```

This grammar leads to the following sets and predicates:

```

First(P1) = { "number" }
First(P2) = { }
Preselected(P1) = Preselected(P2) = Empty(P1) = false
Empty(P2) = true
Follow(S) = { "$" }
Select(P1) = First(P1) = { "number" }
Select(P2) = First(P2) + Follow(S) = { "$" }

First(P4) = { "number" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(list') = { "number", "$" }
Select(P4) = First(P4) = { "number" }
Select(P5) = First(P5) + Follow(list') = { "number", "$" }

```

The intersection of Select(P4) and Select(P5) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. The type describes a list of lists, but it is not possible for a decoder to determine where the outer lists begin and end.

#### A.9. Example 9

Consider the following type definition:

```

SEQUENCE OF item [GROUP] SEQUENCE {
    before [GROUP] OneAndTwo,
    core   UTF8String,
    after  [GROUP] OneAndTwo OPTIONAL
}

OneAndTwo ::= SEQUENCE {
    non-core UTF8String
}

```

The associated grammar is:

```

P1: S ::= item S
P2: S ::=
P3: item ::= before core after
P4: before ::= non-core
P5: non-core ::= "non-core"
P6: core ::= "core"
P7: after ::= non-core
P8: after ::=

```

This grammar leads to the following sets and predicates:

```

First(P1) = { "non-core" }
First(P2) = { }
Preselected(P1) = Preselected(P2) = Empty(P1) = false
Empty(P2) = true
Follow(S) = { "$" }
Select(P1) = First(P1) = { "non-core" }
Select(P2) = First(P2) + Follow(S) = { "$" }

First(P7) = { "non-core" }
First(P8) = { }
Preselected(P7) = Preselected(P8) = Empty(P7) = false
Empty(P8) = true
Follow(after) = { "non-core", "$" }
Select(P7) = First(P7) = { "non-core" }
Select(P8) = First(P8) + Follow(after) = { "non-core", "$" }

```

The intersection of Select(P7) and Select(P8) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. There is ambiguity between the end of one item and the start of the next. Without looking ahead in an encoding, it is not possible to determine whether a <non-core> element belongs with the preceding or following <core> element.

#### A.10. Example 10

Consider the following type definition:

```

CHOICE {
  one    [GROUP] List,
  two    [GROUP] SEQUENCE {
    three [ATTRIBUTE] UTF8String,
    four  [GROUP] List
  }
}

```

```
List ::= SEQUENCE OF string UTF8String
```

The associated grammar is:

```

P1: S ::= one
P2: S ::= two
P3: one ::= string one
P4: one ::=
P5: two ::= three four
P6: three ::= "@three"
P7: four ::= string four

```

```
P8:  four ::=
P9:  string ::= "string"
```

This grammar leads to the following sets and predicates:

```
First(P1) = { "string" }
First(P2) = { "string" }
Preselected(P1) = Empty(P2) = false
Preselected(P2) = Empty(P1) = true
Follow(S) = { "$" }
Select(P1) = First(P1) + Follow(S) = { "string", "$" }
Select(P2) = { }

First(P3) = { "string" }
First(P4) = { }
Preselected(P3) = Preselected(P4) = Empty(P3) = false
Empty(P4) = true
Follow(one) = { "$" }
Select(P3) = First(P3) = { "string" }
Select(P4) = First(P4) + Follow(one) = { "$" }

First(P7) = { "string" }
First(P8) = { }
Preselected(P7) = Preselected(P8) = Empty(P7) = false
Empty(P8) = true
Follow(four) = { "$" }
Select(P7) = First(P7) = { "string" }
Select(P8) = First(P8) + Follow(four) = { "$" }
```

The intersection of Select(P1) and Select(P2) is empty, as is the intersection of Select(P3) and Select(P4) and the intersection of Select(P7) and Select(P8); hence, the grammar is deterministic, and the type definition is valid. Although both alternatives of the CHOICE can begin with a <string> element, an RXER decoder would use the presence of a "three" attribute to decide whether to select or disregard the "two" alternative.

However, an attribute in an extension cannot be used to select between alternatives. Consider the following type definition:

```

[SINGULAR-INSERTIONS] CHOICE {
    one    [GROUP] List,
    ...,
    two    [GROUP] SEQUENCE {
        three [ATTRIBUTE] UTF8String,
        four  [GROUP] List
    } -- ExtensionAdditionAlternative (E1).
    -- The extension insertion point is here (I1).
}

```

List ::= SEQUENCE OF string UTF8String

The associated grammar is:

```

P1:  S ::= one
P10: S ::= E1
P11: S ::= "*"
P12: E1 ::= two
P3:  one ::= string one
P4:  one ::=
P5:  two ::= three four
P6:  three ::= "@three"
P7:  four ::= string four
P8:  four ::=
P9:  string ::= "string"

```

This grammar leads to the following sets and predicates for P1, P10 and P11:

```

First(P1) = { "string" }
First(P10) = { "string" }
First(P11) = { "*" }
Preselected(P1) = Preselected(P10) = Preselected(P11) = false
Empty(P10) = Empty(P11) = false
Empty(P1) = true
Follow(S) = { "$" }
Select(P1) = First(P1) + Follow(S) = { "string", "$" }
Select(P10) = First(P10) = { "string" }
Select(P11) = First(P11) = { "*" }

```

Preselected(P10) evaluates to false because Preselected(P10) is evaluated on the base grammar, wherein P10 is rewritten as:

```

P10: S ::=

```

The intersection of `Select(P1)` and `Select(P10)` is not empty; hence, the grammar is not deterministic, and the type definition is not valid. An RXER decoder using the original, unextended version of the definition would not know that the "three" attribute selects between the "one" alternative and the extension.

## Appendix B. Insertion Encoding Instruction Examples

This appendix is non-normative.

This appendix contains examples showing the use of insertion encoding instructions to remove extension ambiguity arising from use of the GROUP encoding instruction.

### B.1. Example 1

Consider the following type definition:

```
SEQUENCE {
  one    [GROUP] SEQUENCE {
    two    UTF8String,
    ... -- Extension insertion point (I1).
  },
  three  INTEGER OPTIONAL,
  ... -- Extension insertion point (I2).
}
```

The associated grammar is:

```
P1: S ::= one three I2
P2: one ::= two I1
P3: two ::= "two"
P4: I1 ::= "*" I1
P5: I1 ::=
P6: three ::= "three"
P7: three ::=
P8: I2 ::= "*" I2
P9: I2 ::=
```

This grammar leads to the following sets and predicates:

```
First(P4) = { "*" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(I1) = { "three", "*", "$" }
Select(P4) = First(P4) = { "*" }
Select(P5) = First(P5) + Follow(I1) = { "three", "*", "$" }
```

```

First(P6) = { "three" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
Follow(three) = { "*", "$" }
Select(P6) = First(P6) = { "three" }
Select(P7) = First(P7) + Follow(three) = { "*", "$" }

First(P8) = { "*" }
First(P9) = { }
Preselected(P8) = Preselected(P9) = Empty(P8) = false
Empty(P9) = true
Follow(I2) = { "$" }
Select(P8) = First(P8) = { "*" }
Select(P9) = First(P9) + Follow(I2) = { "$" }

```

The intersection of Select(P4) and Select(P5) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If an RXER decoder encounters an unrecognized element immediately after a <two> element, then it will not know whether to associate it with extension insertion point I1 or I2.

The non-determinism can be resolved with either a NO-INSERTIONS or HOLLOW-INSERTIONS encoding instruction. Consider this revised type definition:

```

SEQUENCE {
  one    [GROUP] [HOLLOW-INSERTIONS] SEQUENCE {
    two    UTF8String,
    ... -- Extension insertion point (I1).
  },
  three  INTEGER OPTIONAL,
  ... -- Extension insertion point (I2).
}

```

The associated grammar is:

```

P1:  S ::= one three I2
P10: one ::= two
P3:  two ::= "two"
P6:  three ::= "three"
P7:  three ::=
P8:  I2 ::= "*" I2
P9:  I2 ::=

```

With the addition of the HOLLOW-INSERTIONS encoding instruction, the P4 and P5 productions are no longer generated, and the conflict between Select(P4) and Select(P5) no longer exists. The Select Sets

for P6, P7, P8, and P9 are unchanged. A decoder will now assume that an unrecognized element is to be associated with extension insertion point I2. It is still free to associate an unrecognized attribute with either extension insertion point. If a NO-INSERTIONS encoding instruction had been used, then an unrecognized attribute could only be associated with extension insertion point I2.

The non-determinism could also be resolved by adding a NO-INSERTIONS or HOLLOW-INSERTIONS encoding instruction to the outer SEQUENCE:

```
[HOLLOW-INSERTIONS] SEQUENCE {
  one    [GROUP] SEQUENCE {
    two   UTF8String,
    ... -- Extension insertion point (I1).
  },
  three  INTEGER OPTIONAL,
  ... -- Extension insertion point (I2).
}
```

The associated grammar is:

```
P11: S ::= one three
P2:  one ::= two I1
P3:  two ::= "two"
P4:  I1 ::= "*" I1
P5:  I1 ::=
P6:  three ::= "three"
P7:  three ::=
```

This grammar leads to the following sets and predicates:

```
First(P4) = { "*" }
First(P5) = { }
Preselected(P4) = Preselected(P5) = Empty(P4) = false
Empty(P5) = true
Follow(I1) = { "three", "$" }
Select(P4) = First(P4) = { "*" }
Select(P5) = First(P5) + Follow(I1) = { "three", "$" }

First(P6) = { "three" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
Follow(three) = { "$" }
Select(P6) = First(P6) = { "three" }
Select(P7) = First(P7) + Follow(three) = { "$" }
```

The intersection of `Select(P4)` and `Select(P5)` is empty, as is the intersection of `Select(P6)` and `Select(P7)`; hence, the grammar is deterministic, and the type definition is valid. A decoder will now assume that an unrecognized element is to be associated with extension insertion point `I1`. It is still free to associate an unrecognized attribute with either extension insertion point. If a `NO-INSERTIONS` encoding instruction had been used, then an unrecognized attribute could only be associated with extension insertion point `I1`.

## B.2. Example 2

Consider the following type definition:

```
SEQUENCE {
  one [GROUP] CHOICE {
    two UTF8String,
    ... -- Extension insertion point (I1).
  } OPTIONAL
}
```

The associated grammar is:

```
P1: S ::= one
P2: one ::= two
P3: one ::= I1
P4: one ::=
P5: two ::= "two"
P6: I1 ::= "*" I1
P7: I1 ::=
```

This grammar leads to the following sets and predicates:

```
First(P2) = { "two" }
First(P3) = { "*" }
First(P4) = { }
Preselected(P2) = Preselected(P3) = Preselected(P4) = false
Empty(P2) = false
Empty(P3) = Empty(P4) = true
Follow(one) = { "$" }
Select(P2) = First(P2) = { "two" }
Select(P3) = First(P3) + Follow(one) = { "*", "$" }
Select(P4) = First(P4) + Follow(one) = { "$" }

First(P6) = { "*" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
```

```

Follow(I1) = { "$" }
Select(P6) = First(P6) = { "*" }
Select(P7) = First(P7) + Follow(I1) = { "$" }

```

The intersection of `Select(P3)` and `Select(P4)` is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the `<two>` element is not present, then a decoder cannot determine whether the "one" alternative is absent, or present with an unknown extension that generates no elements.

The non-determinism can be resolved with either a SINGULAR-INSERTIONS, UNIFORM-INSERTIONS, or MULTIFORM-INSERTIONS encoding instruction. The MULTIFORM-INSERTIONS encoding instruction is the least restrictive. Consider this revised type definition:

```

SEQUENCE {
  one [GROUP] [MULTIFORM-INSERTIONS] CHOICE {
    two UTF8String,
    ... -- Extension insertion point (I1).
  } OPTIONAL
}

```

The associated grammar is:

```

P1: S ::= one
P2: one ::= two
P8: one ::= "*" I1
P4: one ::=
P5: two ::= "two"
P6: I1 ::= "*" I1
P7: I1 ::=

```

This grammar leads to the following sets and predicates:

```

First(P2) = { "two" }
First(P8) = { "*" }
First(P4) = { }
Preselected(P2) = Preselected(P8) = Preselected(P4) = false
Empty(P2) = Empty(P8) = false
Empty(P4) = true
Follow(one) = { "$" }
Select(P2) = First(P2) = { "two" }
Select(P8) = First(P8) = { "*" }
Select(P4) = First(P4) + Follow(one) = { "$" }

First(P6) = { "*" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false

```

```

Empty(P7) = true
Follow(I1) = { "$" }
Select(P6) = First(P6) = { "*" }
Select(P7) = First(P7) + Follow(I1) = { "$" }

```

The intersection of Select(P2) and Select(P8) is empty, as is the intersection of Select(P2) and Select(P4), the intersection of Select(P8) and Select(P4), and the intersection of Select(P6) and Select(P7); hence, the grammar is deterministic, and the type definition is valid. A decoder will now assume the "one" alternative is present if it sees at least one unrecognized element, and absent otherwise.

### B.3. Example 3

Consider the following type definition:

```

SEQUENCE {
    one [GROUP] CHOICE {
        two UTF8String,
        ... -- Extension insertion point (I1).
    },
    three [GROUP] CHOICE {
        four UTF8String,
        ... -- Extension insertion point (I2).
    }
}

```

The associated grammar is:

```

P1: S ::= one three
P2: one ::= two
P3: one ::= I1
P4: two ::= "two"
P5: I1 ::= "*" I1
P6: I1 ::=
P7: three ::= four
P8: three ::= I2
P9: four ::= "four"
P10: I2 ::= "*" I2
P11: I2 ::=

```

This grammar leads to the following sets and predicates:

```

First(P2) = { "two" }
First(P3) = { "*" }
Preselected(P2) = Preselected(P3) = Empty(P2) = false
Empty(P3) = true

```

```

Follow(one) = { "four", "*", "$" }
Select(P2) = First(P2) = { "two" }
Select(P3) = First(P3) + Follow(one) = { "*", "four", "$" }

First(P5) = { "*" }
First(P6) = { }
Preselected(P5) = Preselected(P6) = Empty(P5) = false
Empty(P6) = true
Follow(I1) = { "four", "*", "$" }
Select(P5) = First(P5) = { "*" }
Select(P6) = First(P6) + Follow(I1) = { "four", "*", "$" }

First(P7) = { "four" }
First(P8) = { "*" }
Preselected(P7) = Preselected(P8) = Empty(P7) = false
Empty(P8) = true
Follow(three) = { "$" }
Select(P7) = First(P7) = { "four" }
Select(P8) = First(P8) + Follow(three) = { "*", "$" }

First(P10) = { "*" }
First(P11) = { }
Preselected(P10) = Preselected(P11) = Empty(P10) = false
Empty(P11) = true
Follow(I2) = { "$" }
Select(P10) = First(P10) = { "*" }
Select(P11) = First(P11) + Follow(I2) = { "$" }

```

The intersection of Select(P5) and Select(P6) is not empty; hence, the grammar is not deterministic, and the type definition is not valid. If the first child element is an unrecognized element, then a decoder cannot determine whether to associate it with extension insertion point I1, or to associate it with extension insertion point I2 by assuming that the "one" component has an unknown extension that generates no elements.

The non-determinism can be resolved with either a SINGULAR-INSERTIONS or UNIFORM-INSERTIONS encoding instruction. Consider this revised type definition using the SINGULAR-INSERTIONS encoding instruction:

```

SEQUENCE {
  one  [GROUP] [SINGULAR-INSERTIONS] CHOICE {
    two  UTF8String,
    ... -- Extension insertion point (I1).
  },
  three [GROUP] CHOICE {
    four  UTF8String,
    ... -- Extension insertion point (I2).
  }
}

```

The associated grammar is:

```

P1: S ::= one three
P2: one ::= two
P12: one ::= "*"
P4: two ::= "two"
P7: three ::= four
P8: three ::= I2
P9: four ::= "four"
P10: I2 ::= "*" I2
P11: I2 ::=

```

With the addition of the SINGULAR-INSERTIONS encoding instruction, the P5 and P6 productions are no longer generated. The grammar leads to the following sets and predicates for the P2 and P12 productions:

```

First(P2) = { "two" }
First(P12) = { "*" }
Preselected(P2) = Preselected(P12) = false
Empty(P2) = Empty(P12) = false
Follow(one) = { "four", "*", "$" }
Select(P2) = First(P2) = { "two" }
Select(P12) = First(P12) = { "*" }

```

The sets for P5 and P6 are no longer generated, and the remaining sets are unchanged.

The intersection of Select(P2) and Select(P12) is empty, as is the intersection of Select(P7) and Select(P8) and the intersection of Select(P10) and Select(P11); hence, the grammar is deterministic, and the type definition is valid. If the first child element is an unrecognized element, then a decoder will now assume that it is associated with extension insertion point I1. Whatever follows, possibly including another unrecognized element, will belong to the "three" component.

Now consider the type definition using the UNIFORM-INSERTIONS encoding instruction instead:

```
SEQUENCE {
  one    [GROUP] [UNIFORM-INSERTIONS] CHOICE {
    two    UTF8String,
    ... -- Extension insertion point (I1).
  },
  three  [GROUP] CHOICE {
    four    UTF8String,
    ... -- Extension insertion point (I2).
  }
}
```

The associated grammar is:

```
P1:  S ::= one three
P2:  one ::= two
P13: one ::= "*"
P14: one ::= "*1" I1
P4:  two ::= "two"
P15: I1 ::= "*1" I1
P6:  I1 ::=
P7:  three ::= four
P8:  three ::= I2
P9:  four ::= "four"
P10: I2 ::= "*" I2
P11: I2 ::=
```

This grammar leads to the following sets and predicates for the P2, P13, P14, P15, and P6 productions:

```
First(P2) = { "two" }
First(P13) = { "*" }
First(P14) = { "*1" }
Preselected(P2) = Preselected(P13) = Preselected(P14) = false
Empty(P2) = Empty(P13) = Empty(P14) = false
Follow(one) = { "four", "*", "$" }
Select(P2) = First(P2) = { "two" }
Select(P13) = First(P13) = { "*" }
Select(P14) = First(P14) = { "*1" }
```

```

First(P15) = { "*" }
First(P6) = { }
Preselected(P15) = Preselected(P6) = Empty(P15) = false
Empty(P6) = true
Follow(I1) = { "four", "*", "$" }
Select(P15) = First(P15) = { "*" }
Select(P6) = First(P6) + Follow(I1) = { "four", "*", "$" }

```

The remaining sets are unchanged.

The intersection of Select(P2) and Select(P13) is empty, as is the intersection of Select(P2) and Select(P14), the intersection of Select(P13) and Select(P14) and the intersection of Select(P15) and Select(P6); hence, the grammar is deterministic, and the type definition is valid. If the first child element is an unrecognized element, then a decoder will now assume that it and every subsequent unrecognized element with the same name are associated with I1. Whatever follows, possibly including another unrecognized element with a different name, will belong to the "three" component.

A consequence of using the UNIFORM-INSERTIONS encoding instruction is that any future extension to the "three" component will be required to generate elements with names that are different from the names of the elements generated by the "one" component. With the SINGULAR-INSERTIONS encoding instruction, extensions to the "three" component are permitted to generate elements with names that are the same as the names of the elements generated by the "one" component.

#### B.4. Example 4

Consider the following type definition:

```

SEQUENCE OF one [GROUP] CHOICE {
    two    UTF8String,
    ... -- Extension insertion point (I1).
}

```

The associated grammar is:

```

P1: S ::= one S
P2: S ::=
P3: one ::= two
P4: one ::= I1
P5: two ::= "two"
P6: I1 ::= "*" I1
P7: I1 ::=

```

This grammar leads to the following sets and predicates:

```

First(P1) = { "two", "*" }
First(P2) = { }
Preselected(P1) = Preselected(P2) = false
Empty(P1) = Empty(P2) = true
Follow(S) = { "$" }
Select(P1) = First(P1) + Follow(S) = { "two", "*", "$" }
Select(P2) = First(P2) + Follow(S) = { "$" }

First(P3) = { "two" }
First(P4) = { "*" }
Preselected(P3) = Preselected(P4) = Empty(P3) = false
Empty(P4) = true
Follow(one) = { "two", "*", "$" }
Select(P3) = First(P3) = { "two" }
Select(P4) = First(P4) + Follow(one) = { "*", "two", "$" }

First(P6) = { "*" }
First(P7) = { }
Preselected(P6) = Preselected(P7) = Empty(P6) = false
Empty(P7) = true
Follow(I1) = { "two", "*", "$" }
Select(P6) = First(P6) = { "*" }
Select(P7) = First(P7) + Follow(I1) = { "two", "*", "$" }

```

The intersection of Select(P1) and Select(P2) is not empty, as is the intersection of Select(P3) and Select(P4) and the intersection of Select(P6) and Select(P7); hence, the grammar is not deterministic, and the type definition is not valid. If a decoder encounters two or more unrecognized elements in a row, then it cannot determine whether this represents one instance or more than one instance of the "one" component. Even without unrecognized elements, there is still a problem that an encoding could contain an indeterminate number of "one" components using an extension that generates no elements.

The non-determinism cannot be resolved with a UNIFORM-INSERTIONS encoding instruction. Consider this revised type definition using the UNIFORM-INSERTIONS encoding instruction:

```

SEQUENCE OF one [GROUP] [UNIFORM-INSERTIONS] CHOICE {
    two      UTF8String,
    ... -- Extension insertion point (I1).
}

```

The associated grammar is:

```

P1:  S ::= one S
P2:  S ::=
P3:  one ::= two
P8:  one ::= "*"
P9:  one ::= "*1" I1
P5:  two ::= "two"
P10: I1 ::= "*1" I1
P7:  I1 ::=

```

This grammar leads to the following sets and predicates:

```

First(P1) = { "two", "*", "*1" }
First(P2) = { }
Preselected(P1) = Preselected(P2) = Empty(P1) = false
Empty(P2) = true
Follow(S) = { "$" }
Select(P1) = First(P1) = { "two", "*", "*1" }
Select(P2) = First(P2) + Follow(S) = { "$" }

First(P3) = { "two" }
First(P8) = { "*" }
First(P9) = { "*1" }
Preselected(P3) = Preselected(P8) = Preselected(P9) = false
Empty(P3) = Empty(P8) = Empty(P9) = false
Follow(one) = { "two", "*", "*1", "$" }
Select(P3) = First(P3) = { "two" }
Select(P8) = First(P8) = { "*" }
Select(P9) = First(P9) = { "*1" }

First(P10) = { "*1" }
First(P7) = { }
Preselected(P10) = Preselected(P7) = Empty(P10) = false
Empty(P7) = true
Follow(I1) = { "two", "*", "*1", "$" }
Select(P10) = First(P10) = { "*1" }
Select(P7) = First(P7) + Follow(I1) = { "two", "*", "*1", "$" }

```

The intersection of Select(P1) and Select(P2) is now empty, but the intersection of Select(P10) and Select(P7) is not; hence, the grammar is not deterministic, and the type definition is not valid. The problem of an indeterminate number of "one" components from an extension that generates no elements has been solved. However, if a decoder encounters a series of elements with the same name, it cannot determine whether this represents one instance or more than one instance of the "one" component.

The non-determinism can be fully resolved with a SINGULAR-INSERTIONS encoding instruction. Consider this revised type definition:

```
SEQUENCE OF one [GROUP] [SINGULAR-INSERTIONS] CHOICE {
    two    UTF8String,
    ... -- Extension insertion point (I1).
}
```

The associated grammar is:

```
P1: S ::= one S
P2: S ::=
P3: one ::= two
P8: one ::= "*"
P5: two ::= "two"
```

This grammar leads to the following sets and predicates:

```
First(P1) = { "two", "*" }
First(P2) = { }
Preselected(P1) = Preselected(P2) = Empty(P1) = false
Empty(P2) = true
Follow(S) = { "$" }
Select(P1) = First(P1) = { "two", "*" }
Select(P2) = First(P2) + Follow(S) = { "$" }

First(P3) = { "two" }
First(P8) = { "*" }
Preselected(P3) = Preselected(P8) = false
Empty(P3) = Empty(P8) = false
Follow(one) = { "two", "*", "$" }
Select(P3) = First(P3) = { "two" }
Select(P8) = First(P8) = { "*" }
```

The intersection of Select(P1) and Select(P2) is empty, as is the intersection of Select(P3) and Select(P8); hence, the grammar is deterministic, and the type definition is valid. A decoder now knows that every extension to the "one" component will generate a single element, so the correct number of "one" components will be decoded.

## Appendix C. Extension and Versioning Examples

This appendix is non-normative.

### C.1. Valid Extensions for Insertion Encoding Instructions

The first example shows extensions that satisfy the HOLLOW-INSERTIONS encoding instruction.

```
[HOLLOW-INSERTIONS] CHOICE {
    one    BOOLEAN,
    ...,
    two    [ATTRIBUTE] INTEGER,
    three  [GROUP] SEQUENCE {
        four [ATTRIBUTE] UTF8String,
        five [ATTRIBUTE] INTEGER OPTIONAL,
        ...
    },
    six    [GROUP] CHOICE {
        seven [ATTRIBUTE] BOOLEAN,
        eight [ATTRIBUTE] INTEGER
    }
}
```

The "two" and "six" components generate only attributes.

The "three" component in its current form does not generate elements. Any extension to the "three" component will need to do likewise to avoid breaking forward compatibility.

The second example shows extensions that satisfy the SINGULAR-INSERTIONS encoding instruction.

```
[SINGULAR-INSERTIONS] CHOICE {
    one    BOOLEAN,
    ...,
    two    INTEGER,
    three  [GROUP] SEQUENCE {
        four [ATTRIBUTE] UTF8String,
        five  INTEGER
    },
    six    [GROUP] CHOICE {
        seven  BOOLEAN,
        eight  INTEGER
    }
}
```

The "two" component will always generate a single <two> element.

The "three" component will always generate a single <five> element. It will also generate a "four" attribute, but any number of attributes is allowed by the SINGULAR-INSERTIONS encoding instruction.

The "six" component will either generate a single <seven> element or a single <eight> element. Either case will satisfy the requirement that there will be a single element in any given encoding of the extension.

The third example shows extensions that satisfy the UNIFORM-INSERTIONS encoding instruction.

```
[UNIFORM-INSERTIONS] CHOICE {
    one    BOOLEAN,
    ...,
    two    INTEGER,
    three  [GROUP] SEQUENCE SIZE(1..MAX) OF four INTEGER,
    five   [GROUP] SEQUENCE {
        six    [ATTRIBUTE] UTF8String OPTIONAL,
        seven  INTEGER
    },
    eight  [GROUP] CHOICE {
        nine   BOOLEAN,
        ten    [GROUP] SEQUENCE SIZE(1..MAX) OF eleven INTEGER
    }
}
```

The "two" component will always generate a single <two> element.

The "three" component will always generate one or more <four> elements.

The "five" component will always generate a single <seven> element. It may also generate a "six" attribute, but any number of attributes is allowed by the UNIFORM-INSERTIONS encoding instruction.

The "eight" component will either generate a single <nine> element or one or more <eleven> elements. Either case will satisfy the requirement that there must be one or more elements with the same name in any given encoding of the extension.

## C.2. Versioning Example

Making extensions that are not forward compatible is permitted provided that the incompatibility is signalled with a version indicator attribute.

Suppose that version 1.0 of a specification contains the following type definition:

```
MyMessageType ::= SEQUENCE {
    version [ATTRIBUTE] [VERSION-INDICATOR]
        UTF8String ("1.0", ...) DEFAULT "1.0",
    one      [GROUP] [SINGULAR-INSERTIONS] CHOICE {
        two   BOOLEAN,
        ...
    },
    ...
}
```

An attribute is to be added to the CHOICE for version 1.1. This change is not forward compatible since it does not satisfy the SINGULAR-INSERTIONS encoding instruction. Therefore, the version indicator attribute must be updated at the same time (or added if it wasn't already present). This results in the following new type definition for version 1.1:

```
MyMessageType ::= SEQUENCE {
    version [ATTRIBUTE] [VERSION-INDICATOR]
        UTF8String ("1.0", ..., "1.1") DEFAULT "1.0",
    one      [GROUP] [SINGULAR-INSERTIONS] CHOICE {
        two   BOOLEAN,
        ...,
        three [ATTRIBUTE] INTEGER -- Added in Version 1.1
    },
    ...
}
```

If a version 1.1 conformant application hasn't used the version 1.1 extension in a value of MyMessageType, then it is allowed to set the value of the version attribute to "1.0".

A pair of elements is added to the CHOICE for version 1.2. Again the change does not satisfy the SINGULAR-INSERTIONS encoding instruction. The type definition for version 1.2 is:

```
MyMessageType ::= SEQUENCE {
    version [ATTRIBUTE] [VERSION-INDICATOR]
        UTF8String ("1.0", ..., "1.1" | "1.2")
        DEFAULT "1.0",
    one [GROUP] [SINGULAR-INSERTIONS] CHOICE {
        two BOOLEAN,
        ...,
        three [ATTRIBUTE] INTEGER, -- Added in Version 1.1
        four [GROUP] SEQUENCE {
            five UTF8String,
            six GeneralizedTime
        } -- Added in version 1.2
    },
    ...
}
```

If a version 1.2 conformant application hasn't used the version 1.2 extension in a value of `MyMessageType`, then it is allowed to set the value of the version attribute to "1.1". If it hasn't used either of the extensions, then it is allowed to set the value of the version attribute to "1.0".

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## Acknowledgement

Funding for the RFC Editor function is currently provided by the Internet Society.

