NPRG036

XML Technologies

Lecture 5

XML Schema

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Lecture Outline

- XML schema languages
- **XML Schema**
  - Elements, attributes
  - Simple types, complex types
  - Advanced constructs

A Schema of an XML Document

- Well-formedness vs. validity
- A schema of an XML document
  - Description of allowed structure of XML data
  - Description of elements, attributes and their mutual relationship
- Tools for definition of the structure:
  - DTD (Document Type Definition)
  - XML Schema – W3C
  - Schematron, RELAX NG, … – ISO standards
- Tools for validity checking: XML validators

Terminology

- XML schema = allowed structure of XML data in any available language
  - DTD, XML Schema, RELAX NG, Schematron, …
- XML Schema = one of the languages
  - „XML schema in XML Schema"
  - XSD = XML Schema definition
    - Counterpart for DTD
- There are other options: XML-schema, XML-Schema, XML-schema, Xschema, …
  - In Czech: much more options

XML Schema – Advantages

- Does not require special syntax
  - XSDs = XML documents
- Strong support for data types
  - A set of built-in data types (e.g. Boolean, date, ...)
  - User-defined data types
- We can (easily) express number of occurrences of elements

```
<!ELEMENT person (name, e-mail, e-mail?, e-mail?, e-mail?,
e-mail?, relations?)>
```

XML Schema – Advantages

- We can define elements with the same name but different content
  - In DTD we can not – all elements are defined at the same level
- We can define empty elements and elements which can be specified without content
- We can specify the exact structure of mixed-content elements
- We can (easily) express unordered sequences

```
<!ELEMENT name ((first, surname)|(surname, first))>
```

XML Schema – Advantages

- We can re-use various parts of the schema
  - Data types, sets of elements, sets of attributes, …
  - Object-oriented features
- Keys and references
  - Specification of context
  - Combination of elements and/or attributes
- We can define the same thing in various ways
- Preserves DTD structures
  - Except for entities

XML Schema – Advantages = Disadvantages

- Does not require special syntax
  - XSDs are long and less lucid than DTDs
  - More complex schemas are difficult to understand
  - Complex description
    - Elements and attributes are defined using elements and attributes
- We can define the same thing in various ways
  - An advantage for the user
  - A disadvantage for processing

xhtml.xsd

XML Schema – Specification

- Version 1.0:
  - Part 0: Primer http://www.w3.org/TR/xmlschema-0/
    - Not a specification, a set of examples and explanations
  - Part 1: Structures http://www.w3.org/TR/xmlschema-1/
    - Structures of the language
  - Part 2: Datatypes http://www.w3.org/TR/xmlschema-2/
    - Built-in data types
- Version 1.1:
  - Part 1: Structures
    - http://www.w3.org/TR/xmlschema11-1/
  - Part 2: Datatypes
    - http://www.w3.org/TR/xmlschema11-2/

XML Schema – Basics

- XSD = a well-formed XML document
  - XML declaration, root element, …
  - Validity against XSD of XML Schema language

```
<?xml version="1.0" encoding="windows-1250"?>
<schema ...>
  ... <!-- XML schema definition --> ...
</schema>
```

- Components of the language = elements
  - Features – subelements/attributes
  - Defined in XML Schema namespace

XSD vs. XML Document

```
<?xml version="1.0" encoding="windows-1250"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  ... <!-- XML schema definition  --> ...
</xs:schema>
```

```
<?xml version="1.0" encoding="windows-1250"?>
<root_element_of_XML_document
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:noNamespaceSchemaLocation="schema2.xsd">
  ... <!-- XML document --> ...
</root_element_of_XML_document>
```

- XML Schema namespace
- Namespace of XML Schema instances = XML documents valid against an XSD
- URL of XSD file

Root element of XML document?

- Any globally defined element can be the root element of an XML document
  - Globally defined = direct subelement of element schema
- Globally defined components have in XML Schema special behaviour
  - Elements, attributes, data types, sets of elements, sets of attributes
    - Elements → root elements, ...
    - Other → can be used repeatedly, ... (see later)

Root Elements – Example (1)

```
<?xml version="1.0" encoding="windows-1250"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="employees">
    <!-- definition of content -->
  </xs:element>

  <xs:element name="person">
    <!-- definition of content -->
  </xs:element>

  <!-- definition of other elements -->
</xs:schema>
```

Root Elements – Example (2)

```
<?xml version="1.0" encoding="windows-1250"?>
<employees
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:noNamespaceSchemaLocation="emp.xsd">
  <!-- element content -->
</employees>
```

```
<?xml version="1.0" encoding="windows-1250"?>
<person
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:noNamespaceSchemaLocation="emp.xsd">
  <!-- element content -->
</person>
```

How to Work with XML Schema

- XML schema definition:
  - Definition of data types
  - Definition of elements and attributes
    - Name + data type
- Components of the language:
  - Basic – simple data type, complex data type, element, attribute, set of elements, set of attributes
  - Advanced – identity restriction, substitution groups, wildcards, external schemas, …
- „Kit" – we build complex components from simpler ones
  - We can extend, restrict, refer, …

Basic Components

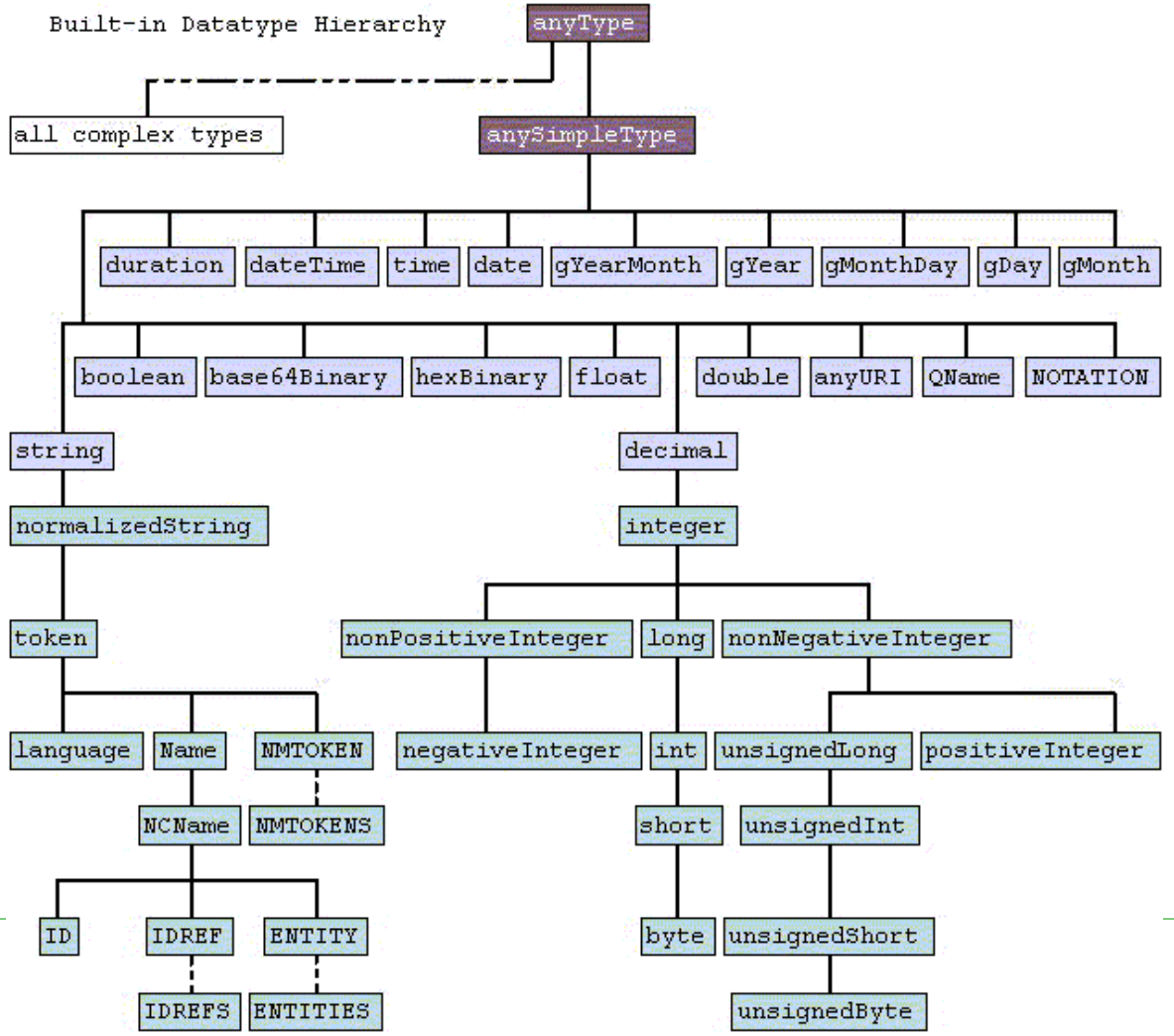
Simple Data Types

Note: In the following examples we omit XML declaration and element schema.

- Element content or attribute value is always textual
- Simple data type = restriction of textual values to a particular subset
- Types:
  - Built-in – pre-defined
    - see Specification Part 2: Datatypes
  - User-defined – specified by the user
    - Derived from other data types

Built-in Data Types

- Direct part of XML Schema
- Hierarchy:



Primitive Data Types (1)

- string – a sequence of characters
- boolean – true, false, 1, 0
- decimal – 0, positive or negative real value
  - e.g. -1.23, 1267.5433, 210
- float – 32-bit floating point data type
  - Values: m × 2^e, where |m| < 2^24, -149 <= e <= 104
  - e.g. -1E4, 1267.43233E12, 12
  - Special values: 0, -0, Inf, -Inf, +Inf, NaN
- double – 64-bit floating point data type
  - Values: m × 2^e, where |m| < 2^53, -1075 <= e <= 970

Primitive Data Types (2)

- duration – time interval of the form PnYnMnDTnHnMnS, where P and T are delimiters, nY means n years, nM means n months etc.
  - e.g. -P13Y7M, P2Y1MT2H
- dateTime – date and time of the form YYYY-MM-DDThh:mm:ss.ss, where T is a delimiter
- time – time of the form hh:mm:ss.ss
- date – date of the form YYYY-MM-DD
- gYearMonth – year and month of the form YYYY-MM
- gYear – year of the form YYYY
- gMonthDay – month and day of the form --MM-DD
- gMonth – month of the form --MM
- gDay – day of the form ---DD

Primitive Data Types (3)

- hexBinary – hexadecimal number
- base64Binary – binary data in Base64 encoding (idea „similar" to hexadecimal encoding)
- anyURI – absolute or relative URI
- QName – XML Qualified Name, i.e. string of the form prefix:local_name
  - see namespaces
- NOTATION – reference to notation
  - see notations

String Simple Data Types (1) – Derived from string

- normalizedString – string which does not contain characters CR, LF a tabulator
- token – normalizedString which does not contain leading or trailing spaces or internal sequences of two or more spaces
- language – language identifier
  - Allowed values are given by a standard
  - e.g. en, en-GB
- Name – XML Name, i.e. string which can contain letters, numbers and characters ‘-’, ‘_’, ‘:’ and ‘.’
- NCName – XML Name without character ‘:’

String Simple Data Types (2) – Derived from string

- NMTOKEN
- NMTOKENS
- ID
- IDREF
- IDREFS
- ENTITY
- ENTITIES
  - Note: Entities can be defined only in DTD

String Simple Data Types – Derived from decimal

- integer
- positiveInteger
- negativeInteger
- nonPositiveInteger
- nonNegativeInteger
- long – integer from < -2^63, 2^63-1 >
- int – integer from < -2^31, 2^31-1 >
- short – integer from < -2^15, 2^15-1 >
- byte – integer from < -2^7, 2^7-1 >
- unsignedLong – non negative integer less than 2^64
- unsignedInt – non negative integer less than 2^32
- unsignedShort – non negative integer less than 2^16
- unsignedByte – non negative integer less than 2^8

Simple Data Types – Notes

- Time data types can be defined in UTC (Coordinated Universal Time) possibly with offset
  - e.g. 15:30:25Z, 09:30:25+06:00
- Time data types can be negative
- Built-in data types with capital letters
  - Correspond to respective DTD data types
  - Can be assigned just with attributes

User-defined Simple Data Types (simpleType)

- Enables to define own data types
- Attributes:
  - name – (optional) name of the data type
  - final – forbids further derivation
    - restriction, union, list, #all
- Derived from another (built-in / user-defined) data type via
  - restriction
  - union
  - list

(annotation?, (restriction | list | union))

Derivation using restriction

- Restricts values of the original data type using a specified rule
- The restriction must make sense for the original data type, i.e. not everything is allowed
- Attributes:
  - base – restricted data type
    - Or specified using subelement simpleType

```
(annotation?, (simpleType?, (minExclusive |
minInclusive | maxExclusive | maxInclusive |
totalDigits | fractionDigits |
length | minLength | maxLength |
enumeration | whiteSpace | pattern)*))
```

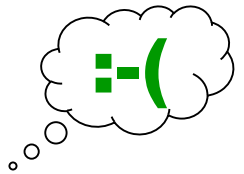
Derivation using restriction – Example

```
<xs:simpleType name="Ports">
  <xs:restriction base="xs:integer">
    <xs:enumeration value="111"/>
    <xs:enumeration value="21"/>
    <xs:enumeration value="80"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="NonEmptyString" final="#all">
  <xs:restriction base="xs:string">
    <xs:minLength value="1"/>
    <xs:maxLength value="10"/>
  </xs:restriction>
</xs:simpleType>
```

Derivation using restriction – Example

```
<xs:element name="PortNumber" type="Ports"/>

<xs:element name="ServerName" type="NonEmptyString"/>
```

```
<PortNumber>111</PortNumber>

<ServerName>kocour</ServerName>
```

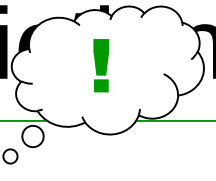



```
<PortNumber>112</PortNumber>
<PortNumber>hi</PortNumber>

<ServerName/>
<ServerName>kocour.ms.mff.cuni.cz</ServerName>
```

Allowed Types of Restrictions (1)

- length – the number of items of a particular data type
- minLength – the minimum number of items of a particular data type
- maxLength – the maximum number of items of a particular data type
- pattern – regular expression describing items of the data type
  - Operators: . (any character) \ (escape or meta character) ? * + | () (group) {} (repetition) [] (interval), \s (white space) \S (non white space) \d (number) \n \t
  - Example. *\d** … "*1234*", a{2,4} … "aaa", (\d|[A-Z])+ … "3", "U2"
- enumeration – a set of values
- maxInclusive – values <= specified value
- minInclusive – values >= specified value
- maxExclusive – values < specified value
- minExclusive – values > specified value
- totalDigits – maximum number of digits
- fractionDigits – maximum number of fraction digits

Allowed Types of Restrictions (2)



- whiteSpace – processing of whitespaces
  - preserve – no changes
  - replace – characters CR, LF and tabulator are replaced with a space
  - collapse – in addition, all leading and trailing whitespaces are removed and sequences of whitespaces are replaced with a single one

```
<xs:simpleType name="nameWithCapitalLetters">
  <xs:restriction base="xs:string">
    <xs:whiteSpace value="collapse"/>
    <xs:pattern    value="([A-Z]([a-z])* ?)+"/>
  </xs:restriction>
</xs:simpleType>
```

Derivation using list

- Creates a list of values of the original data type delimited using whitespaces
  - Problem: list of strings vs. white space delimiters
- Attributes:
  - itemType – original type
    - Or specified using subelement simpleType
- Multivalue data types
  - We cannot derive from other multivalue data types
    - i.e. create a list of lists
  - NMTOKENS, IDREFS, ENTITIES

(annotation?, simpleType?)

Derivation using list – Example

```
<xs:simpleType name="ListOfFloats">
  <xs:list itemType="xs:float"/>
</xs:simpleType>

<xs:element name="Temperatures"
            type="ListOfFloats"/>
```

```
<Temperatures>11 12.5 10.2</Temperatures>
<Temperatures>-3.14 0 -1.5</Temperatures>
```

Derivation using union

- Creates a union of values of original data types
- Attributes:
  - memberTypes – original data types
    - Or specified using subelements simpleType

```
<xs:simpleType name="NonZeroIntegers">
  <xs:union memberTypes="xs:positiveInteger
                         xs:negativeInteger"/>
</xs:simpleType>

<xs:element name="Temperature" type="NonZeroIntegers"/>
```

```
<Temperature>11</Temperature>
<Temperature>-3</Temperature>
<Temperature>10</Temperature>
```

(annotation?, simpleType*)

Globally vs. Locally Defined Simple Types

```
<xs:simpleType name="TypeZeroTo100">
  <xs:union>
    <xs:simpleType>
      <xs:restriction base="xs:positiveInteger">
        <xs:minInclusive value="1"/>
        <xs:maxInclusive value="100"/>
      </xs:restriction>
    </xs:simpleType>
    <xs:simpleType>
      <xs:restriction base="xs:string">
        <xs:enumeration value="zero"/>
      </xs:restriction>
    </xs:simpleType>
  </xs:union>
</xs:simpleType>
```

Attributes (attribute)

- Name + simple data type
  - Built-in – value of attribute type
  - Globally defined – value of attribute type
  - Locally defined – subelement simpleType

(annotation?, simpleType?)

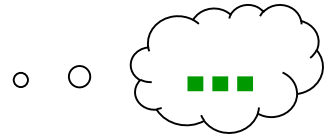
Attributes – Example

```
<xs:attribute name="Age" type="xs:positiveInteger"/>

<xs:attribute name="Name" type="NonEmptyString"/>

<xs:attribute name="PhoneNumber">
  <xs:simpleType>
    <xs:restriction base="xs:string">
      <xs:pattern value="\d{3}-\d{6}"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
```

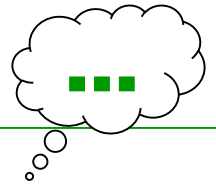
```
<person Age="30"
        Name="H. Simpson"
        PhoneNumber="123-445566"/>
```

Attributes

- Attributes:
  - default – implicit value
  - fixed – fixed value
  - use – occurrence
    - optional, required, prohibited (?)
- Attributes can be also defined globally / locally
  - In both the cases it has a name
  - Globally – element attribute is a subelement of element schema
    - We can refer to it using references
  - Locally – within a definition of a complex type or a set of attributes
    - Just local usage



Elements (element)



- Name + simple / complex data type
  - Simple type – element without attributes with a text content
    - Built-in – value of attribute type
    - Globally defined – value of attribute type
    - Locally defined – subelement simpleType
  - Complex type – other types of elements
    - Globally defined – value of attribute type
    - Locally defined – subelement complexType
- Enables to define keys/references
  - unique, key, keyref – see later

```
(annotation?, ((simpleType | complexType)?,
                (unique | key | keyref)*))
```

Elements – Example

```
<xs:element name="name" type="xs:string"/>

<xs:element name="surname">
  <xs:simpleType>
    <xs:restriction base="xs:string">
      <xs:minLength value="2"/>
    </xs:restriction>
  </xs:simpleType>
</xs:element>
```

```
<name>Marge</name>
<surname>Simpson</surname>
```

Elements

- Attributes:
  - nillable – possible empty content
  - default – implicit value
    - Only for elements with text content
  - fixed – fixed value
    - Only for elements with text content
- Elements can be also defined globally / locally
  - In both the cases it has a name
  - Globally – element element is a subelement of element schema
    - We can refer to it using references
    - Root elements of XML documents
  - Locally – within a definition of a complex type
    - Just local usage

Complex Data Types (complexType)

- For definition of more complex types of elements
  - Relations element-subelement and element-attribute
  - Numbers and order of subelements
  - Since version 1.1: Conditions for values of subelements/attributes
    - Using XPath
    - assert – see later
- Consists of:
  - Specification of content
    - empty = an empty element
  - Specification of attributes
    - empty = an elements without attributes

```
(annotation?, (simpleContent | complexContent |
                ((group | all | choice | sequence)?,
((attribute | attributeGroup)*, anyAttribute?),
                                        assert* )))
```

Complex Data Types – Example

```
<xs:complexType name="TypeAddress">
 <!-- specification of content -->
  <xs:sequence>
    <xs:element name="Street" type="xs:string"/>
    <xs:element name="Number" type="xs:integer"/>
    <xs:element name="City"   type="xs:string"/>
  </xs:sequence>

  <!-- specification of attributes -->
  <xs:attribute name="Country" type="xs:NMTOKEN"
                               default="CZ"/>
</xs:complexType>

<xs:element name="Address" type="TypeAddress"/>
```

Complex Data Types – Example

```
<Address>
  <Street>Blue Street</Street>
  <Number>25</Number>
  <City>Praha 1</City>
</Address>
```

```
<Address Country="SK">
  <Street>Red Street</Street>
  <Number>6</Number>
  <City>Bratislava 16</City>
</Address>
```

Complex Data Types

- Attributes:
  - mixed – an element with mixed content
- Can be also defined globally / locally
  - Usage same as in case of simple types
- Types of content:
  I. with a simple textual content (simpleContent)
  II. sequence of components (sequence)
  III. choice of components (choice)
  IV. unordered sequence of elements (all)
  V. model group (group)
  VI. with a complex content (complexContent)

I. Simple Content (simpleContent)

- The content of element is a simple type + attributes
- Derivation:
  - extension – adding attributes
  - restriction – adding attributes + type restriction

```
<xs:complexType name="Type">
  <xs:simpleContent>
    <xs:extension base="xs:string">
      <xs:attribute name="Subtype" type="xs:string"/>
    </xs:extension>
  </xs:simpleContent>
</xs:complexType>
```

```
(annotation?, (restriction | extension))
```

```
<xs:complexType name="CarType">
  <xs:simpleContent>
    <xs:restriction base="xs:string">
      <xs:enumeration value="Audi"/>
      <xs:enumeration value="VW"/>
      <xs:enumeration value="BMW"/>
      <xs:attribute name="Subtype" type="xs:string"/>
    </xs:restriction>
  </xs:simpleContent>
</xs:complexType>
```

```
<xs:element name="Vehicle" type="Type"/>
<xs:element name="Car"     type="CarType"/>
```

```
<Vehicle Subtype="mountain">bicycle</Vehicle>

<Car Subtype="TT">Audi</Car>
```

II. Sequence of Items (sequence)

- The content is formed by all the specified items in the given order

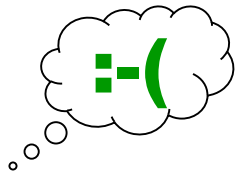
```
<xs:complexType name="person">
  <xs:sequence>
    <xs:element name="name"    type="xs:string"
                               maxOccurs="5"/>
    <xs:element name="surname" type="xs:string"/>
    <xs:element name="born"    type="xs:date"/>
    <xs:element name="note"    type="xs:string"
                               minOccurs="0"/>
  </xs:sequence>
  <xs:attribute name="Id" type="xs:ID"/>
</xs:complexType>
```

```
(annotation?, (element | group | choice | sequence | any)*)
```

Sequence of Items

```
<xs:element name="Attendee" type="person"/>
```

```
<Attendee Id="1234">
  <name>Charles</name>
  <surname>De Gaulle</surname>
  <born>1848-07-04</born>
  <note>leader</note>
</Attendee>
```




```
<Attendee Id="4567">
  <born>1850-12-12</born>
  <name>Jean</name>
  <surname>Moulin</surname>
</Attendee>
```

III. Choice of Items (choice)

- The content is formed by one of the specified items

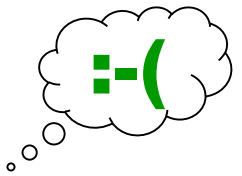
```
<xs:complexType name="TypePriceList">
  <xs:choice>
    <xs:sequence>
      <xs:element name="BasicPrice" type="xs:string"/>
      <xs:element name="FullPrice" type="xs:string"/>
    </xs:sequence>
    <xs:element name="BargainPrice" type="xs:string"/>
    <xs:element name="StudentPrice" type="xs:string"/>
  </xs:choice>
</xs:complexType>
```

```
(annotation?, (element | group | choice | sequence | any)*)
```

Choice of Items

```
<xs:element name="Price" type="TypePriceList"/>
```

```
<Price>
  <BasicPrice>1170EUR</BasicPrice>
  <FullPrice>1500EUR</FullPrice>
</Price>
<Price>
  <StudentPrice>1000EUR</StudentPrice>
</Price>
```




```
<Price>
  <FullPrice>1500EUR</FullPrice>
  <BasicPrice>1170EUR</BasicPrice>
</Price>
<Price>
  <FullPrice>1500EUR</FullPrice>
</Price>
```

IV. Unordered Sequence of Elements (all)

- The content is formed by the specified elements in an arbitrary order


```
<xs:complexType name="TypeBook">
  <xs:all>
    <xs:element name="Name"   type="xs:string"/>
    <xs:element name="Author" type="xs:string"/>
    <xs:element name="ISBN"   type="xs:string"
                              minOccurs="0"/>
  </xs:all>
</xs:complexType>
```

```
(annotation?, (element | any)*)
```

Unordered Sequence of Elements

```
<xs:element name="Book" type="TypeBook"/>
```

```
<Book>
  <Name>The King's Speech</Name>
  <Author>Mark Logue</Author>
  <ISBN>123-456-789</ISBN>
</Book>
<Book>
  <Author>Sally Bedell Smith</Author>
  <Name>Elizabeth the Queen</Name>
</Book>
```

Unordered Sequence of Elements

- Version 1.0: maxOccurs of elements and the whole set is <= 1
  - What if we want maxOccurs > 1?
    - Idea: Combination of choice and maxOccurs > 1
    - Can lead to a non-deterministic data model
      - Not allowed by specification, but there can exist a parser which supports it
- Version 1.1: maxOccurs of elements > 1
  - In general, not everything is allowed, but the rules are not so strict

V. Model Group (group)

- Contains a sequence / choice / set of items (elements)
- Always declared globally and has a name
  - Repeating usage of the content using references
- References in general:
  - We declare them using the same construct as the referenced item
    - Instead of attribute name we use attribute ref
  - The same principle can be used for model groups, elements, attributes and groups of attributes (see later)
    - In case of elements and attributes only the globally defined ones can be referenced

```
(annotation?, (all | choice | sequence)?)
```

Model Group + References

```
<xs:group name="CommonElements">
  <xs:sequence>
    <xs:element name="Name"   type="xs:string"/>
    <xs:element name="Author" type="xs:string"/>
    <xs:element name="Date"   type="xs:date"/>
  </xs:sequence>
</xs:group>

<xs:complexType name="TypeBook">
  <xs:sequence>
    <xs:group   ref="CommonElements" minOccurs="0"/>
    <xs:element name="ISBN"      type="xs:string"/>
    <xs:element name="Publisher" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

Model Group

```
<xs:element name="Book" type="TypeBook"/>
```

```
<Book>
  <Name>Elizabeth the Queen</Name>
  <Author>Sally Bedell Smith</Author>
  <Date>2006-02-30</Date>
  <ISBN>987-654-321</ISBN>
  <Publisher>Random House Trade Paperbacks</Publisher>
</Book>
```

Note: References and Elements

```
<xs:element name="Name">
  <xs:simpleType>
    <xs:restriction base="xs:string">
      <xs:minLength value="1"/>
    </xs:restriction>
  </xs:simpleType>
</xs:element>

<xs:complexType name="Book">
  <xs:sequence>
    <xs:element ref="Name"/>
    <xs:element name="Publisher" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

VI. Complex Content (complexContent)

- Inference of new types from already existing ones
- restriction – the new type is a subset of the original one
  - Restriction of occurrences of an element/attribute
    - Removing of elements: maxOccurs="0"
    - Removing of attributes: use="prohibited"
  - Restriction of allowed values of simple types (of attribute values, content of text elements)
- extension – the new type contains original and new data (in this order)
  - A kind of inheritance

(annotation?, (restriction | extension))

Complex Content – Example

```
<xs:complexType name="Publication">
  <xs:sequence>
    <xs:element name="Name"   type="xs:string"/>
    <xs:element name="Author" type="xs:string"
                              maxOccurs="unbounded"/>
    <xs:element name="Published" type="xs:gYear"/>
  </xs:sequence>
</xs:complexType>
```

Complex Content – Example of Restriction

```
<xs:complexType name="PublicationWithOneAuthor">
  <xs:complexContent>
    <xs:restriction base="Publication">
      <xs:sequence>
        <xs:element name="Name" type="xs:string"/>
        <xs:element name="Author" type="xs:string"/>
        <xs:element name="Published" type="xs:gYear"/>
      </xs:sequence>
    </xs:restriction>
  </xs:complexContent>
</xs:complexType>
```

Complex Content – Example of Restriction

```
<xs:element name="Book" type="Publication"/>
<xs:element name="Book1" type="PublicationWithOneAuthor"/>
```

```
<Book>
  <Name>XML technologie</Name>
  <Author>Irena Mlýnková</Author>
  <Author>Jaroslav Pokorný</Author>
  <Author>Karel Richta</Author>
  <Author>Kamil Toman</Author>
  <Author>Vojtěch Toman</Author>
  <Published>2006</Published>
</Book>
```

```
<Book1>
  <Name>Elizabeth the Queen</Name>
  <Author>Sally Bedell Smith</Author>
  <Published>2006</Published>
</Book1>
```

Complex Content – Example of Extension

```
<xs:complexType name="TypeBook">
  <xs:complexContent>
    <xs:extension base="Publication">
      <xs:sequence>
        <xs:element name="Publisher" type="xs:string"/>
        <xs:element name="ISBN"      type="xs:string"/>
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Complex Content – Example of Extension

```
<xs:element name="Book" type="TypeBook"/>
```

```
<Book>
  <Name>XML technologie</Name>
  <Author>Irena Mlýnková</Author>
  <Author>Jaroslav Pokorný</Author>
  <Author>Karel Richta</Author>
  <Author>Kamil Toman</Author>
  <Author>Vojtěch Toman</Author>
  <Published>2006</Published>
  <Publisher>Karolinum</Publisher>
  <ISBN>80-246-1272-0</ISBN>
</Book>
```

Complex Content

- Related attributes of complexType:
  - abstract – abstract data type
    - Cannot be assigned to any element
    - First we must derive a new type
  - final – forbids further derivation
    - Values: restriction, extension, #all
    - Like with simple types

Invariants (assert)

- Version 1.1: Possibility of specification of conditions for existence or values of subelements / attributes
  - Using XPath
- Similar to CHECK constraint in databases
- Attributes:
  - test – XPath expression which must hold true
- Meaning:
  - assert – error, when the expression does not return true

Invariants

```
<xs:complexType name="Interval">
  <xs:attribute name="min" type="xs:integer"/>
  <xs:attribute name="max" type="xs:integer"/>
  <xs:assert test="@min < @max"/>
</xs:complexType>
```

```
<xs:complexType name="Array">
  <xs:sequence>
    <xs:element name="Item" minOccurs="0"
                            maxOccurs="unbounded"
                            type="xs:string"/>
  </xs:sequence>
  <xs:attribute name="NumberOfItems" type="xs:integer"/>
  <xs:assert test="@NumberOfItems = fn:count(./Item)"/>
</xs:complexType>
```

Set of Attributes (attributeGroup)

- Contains a set / group of attributes
  - Similar to a model group of elements
- Always declared globally and always has a name
  - Repeating usage of a set of attributes
    - Using references
    - The same principle can be used for globally defined attributes

```
(annotation?, ((attribute | attributeGroup)*, anyAttribute?))
```

Set of Attributes – Example

```
<xs:attributeGroup name="CommonAttributes">
  <xs:attribute name="Borrowed" type="xs:boolean"/>
  <xs:attribute name="Id"       type="xs:ID"/>
</xs:attributeGroup>

<xs:complexType name="TypeBook">
  <xs:sequence>
    <xs:element name="Name"      type="xs:string"/>
    <xs:element name="Publisher" type="xs:string"/>
  </xs:sequence>
  <xs:attributeGroup ref="CommonAttributes"/>
</xs:complexType>
```

Set of Attributes – Example

```
<xs:element name="Book" type="TypeBook"/>
```

```
<Book Borrowed="true" Id="1234">
  <Name>XML technologie</Name>
  <Publisher>Karolinum</Publisher>
</Book>
```

Note: References and Attributes

```
<xs:attribute name="Borrowed">
  <xs:simpleType>
    <xs:restriction base="xs:string">
      <xs:enumeration value="yes"/>
      <xs:enumeration value="no"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>

<xs:complexType name="Book">
  <xs:sequence>
    <xs:element name="Name"      type="xs:string"/>
    <xs:element name="Publisher" type="xs:string"/>
  </xs:sequence>
  <xs:attribute ref="Borrowed"/>
</xs:complexType>
```

Advanced Components

XML Schema and Namespaces

- XML Schema enables to define a namespace
  - Target namespace
- Parts of a namespace vs. XML Schema constructs:
  - All element partition
    - Globally defined elements
  - Per element type partitions
    - Attributes of elements
  - Global attribute partition
    - Globally defined attributes
- Element schema has two special attributes:
  - elementFormDefault, attributeFormDefault
  - Values: qualified/unqualified
    - Default: unqualified
  - Denote the necessity of qualification of element/attribute names with namespace prefixes

XML Schema – Namespace Declaration

- Namespaces:
  - Namespace of XML Schema language
  - Target namespace
  - Implicit namespace
    - We do not have to use a prefix for defined items
      - If we do not define a target namespace, this holds implicitly

```
<?xml version="1.0" encoding="windows-1250"?>
<xs:schema
      xmlns:xs="http://www.w3.org/2001/XMLSchema"
      targetNamespace="http://www.mff.cuni.cz/MySchema"
      xmlns="http://www.mff.cuni.cz/MySchema"
       elementFormDefault="qualified">
  ... <!-- definition of XML schema --> ...
</xs:schema>
```

XSD vs. XML Document – Usage of Namespaces

- XSD has a target namespace
  - Namespace of (all) instances of XML Schema (i.e. XML documents)
  - Namespace of XSD of the XML document + URL of the XSD file
  - Implicit namespace

```
<?xml version="1.0" encoding="windows-1250"?>
<root_element_of_XML_document
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation=
          "http://www.mff.cuni.cz/MySchema schema1.xsd"
    xmlns="http://www.mff.cuni.cz/MySchema">
  ... <!-- XML document --> ...
</root_element_of_XML_document>
```

Note: DTD and Namespaces

- DTD does not support namespaces
- We can add prefixes to element / attribute names
- In all the respective XML documents we must use the same prefixes!
  - Change of prefix means a change everywhere (DTD + all documents)
  - Namespaces do not define the prefix, it is defined locally

```
<!ELEMENT emp:employee (emp:name, emp:address, emp:phone,
emp:phone?, emp:phone?)>
<!ELEMENT emp:phone (#PCDATA)>
<!ATTLIST emp:employee
        emp:ID CDATA #REQUIRED
        emp:DID CDATA #REQUIRED
        >
```

External Schemas (include)

- Including of a schema with the same / none target namespace
  - The components of the included schema become parts of the current target name space
  - Like if we just copy the content of the schema

```
<xs:schema ...>
  <!-- including of components of an external schema -->
  <xs:include schemaLocation="MySchema1.xsd"/>

  <!-- definition of other schema components -->
</xs:schema>
```

External Schemas (import)

- Import of components with any namespace
  - Globally defined items can be then used for definition of the current schema
    - It is not a copy of the imported schema!
- Attributes:
  - schemaLocation – URI of imported schema
  - namespace – namespace of imported schema
    - If specified, we use qualified names

```
<xs:schema ...
    xmlns:types="http://www.priklady.cz/xml/MySchema2">
  <!-- import of components of an external schema -->
  <xs:import
      namespace="http://www.priklady.cz/xml/MySchema2"/>

  <element name="ElementWithExternalType"
           type="types:ExternalType"/>
</xs:schema>
```

External Schemas (redefine)

- Redefinition of an existing component
  - Simple type – restriction
  - Complex type – restriction / extension
  - Group of elements
    - Superset – includes the original set using attribute ref
    - Subset – minOccurs and maxOccurs
  - Group of attributes
    - Superset – includes the original set using attribute ref
    - Subset – modification of attribute use

```
(annotation | (simpleType | complexType | group |
                                        attributeGroup))*
```

External Schemas (redefine) – Example

```
<xs:redefine schemaLocation="MySchema2.xsd">
  <xs:complexType name="ExternalType">
    <xs:complexContent>
      <xs:extension base="ExternalType">
        <xs:sequence>
          <xs:element name="NewElement"
                      type="xs:string"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>
</xs:redefine>
```

Identity Restriction

- ID, IDREF, IDREFS – taken from DTD
  - Just for attributes
  - Must hold within the whole document
- XSD identity restrictions:
  - Key – compulsory, not-null, unique value (key)
  - Unique – not-null, unique value (unique)
  - Reference to key / unique value (keyref)
    - Similar to keys and foreign keys in relational databases
- Based on a (subset of) XPath

Subset of XPath

- Steps = elements / attributes (@)
- Can contain:
  - . – current element
  - / – child element / attribute
  - // – descendant in any depth
  - * – any name

```
Selector ::= PathS ( '|' PathS )*
Field    ::= PathF ( '|' PathF )*
PathS    ::= ('.//')? Step ( '/' Step )*
PathF    ::= ('.//')? ( Step '/' )* ( Step | '@' NameTest )
Step     ::= '.' | NameTest
NameTest ::= QName | '*' | NCName ':' '*'
```

Identity Restriction

- Attributes:
  - name – name of identity restriction
  - refer – reference to an existing identity restriction
    - Just for keyref
- Content:
  - selector – a set of elements within which the restriction must hold
    - Can be used only once
  - field – a set of subelements or attributes (relatively to the set from selector) bearing the restriction
    - At least one
    - Can be a combination of elements / attributes

`(annotation?, (selector, field+))`

unique – Example

```
<xs:element name="Library">
  ...
  <xs:element name="Book" maxOccurs="unbounded">
    ...
    <xs:element name="ISBN" type="xs:string"
                            minOccurs="0"/>
    ...
  </xs:element>

  <xs:unique name="UniqueISBN">
    <xs:selector xpath="./Book"/>
    <xs:field    xpath="./ISBN"/>
  </xs:unique>
</xs:element>
```

key – Example

```
<xs:element name="Library">
  ...
  <xs:element name="Book" maxOccurs="unbounded">
    ...
    <xs:element name="ISBN" type="xs:string"/>
    ...
  </xs:element>

  <xs:key name="PrimaryKey">
    <xs:selector xpath="./Book"/>
    <xs:field    xpath="./ISBN"/>
  </xs:key>
</xs:element>
```

keyref (1) – Example

```
<xs:element name="Library">
  <!-- The previously defined element and constraint -->
  <xs:element name="Author" maxOccurs="unbounded">
    ...
    <xs:element name="BestBook">
      ...
      <xs:element name="ISBN" type="xs:string"/>
      ...
    </xs:element>
    ...
  </xs:element>

  <xs:keyref name="ForeignKey" refer="PrimaryKey">
    <xs:selector xpath="./Author/BestBook"/>
    <xs:field    xpath="./ISBN"/>
  </xs:keyref>
</xs:element>
```

keyref (2) – Example

```
<Library>
  <!-- books in library -->
  <Book>
    <ISBN>111-222-333</ISBN>
    <Name>M. Logue - The King's Speech</Name>
  </Book>
  <Book>
    <ISBN>444-555-666</ISBN>
    <Name>D. Brown - The Lost Symbol</Name>
  </Book>
  <Book>
    <ISBN>123-456-789</ISBN>
    <Name>S. B. Smith - Elizabeth the Queen</Name>
  </Book>
…
```

keyref (3) – Example

```
…
  <!-- information on authors in library -->
  <Author>
    <name>Mark Logue</name>
    <BestBook>
      <ISBN>111-222-333</ISBN>
      <NumberOfEditions>123<NumberOfEditions>
    </BestBook>
  </Author>
  <Author>
    <name>Sally Bedell Smith</name>
    <BestBook>
      <ISBN>123-456-789</ISBN>
      <NumberOfEditions>0<NumberOfEditions>
    </BestBook>
  </Author>
</Library>
```

Implicit Substitutability

(Substitutability of Data Types)

- Implicit = we do not need to specify anything in the schema
- In the document we specify the data type
  - Derived from the original
- Using attribute xsi:type

```
<xs:element name="Publication" type="TypePublication"/>
```

- Attribute block of element complexType
  - Values: restriction, extension, #all

```
<Publication>
  <Name>The King's Speech</Name>
  <Author>M. Logue</Author>
</Publication>
<Publication xsi:type="TypeBook">
  <Name>Elizabeth the Queen</Name>
  <Author>S. B. Smith</Author>
  <ISBN>123-456-789</ISBN>
</Publication>
```

Substitution Groups

(Substitutability of Elements)

- Extension of substitutability
- Mechanism of explicit allowing / forbidding of substitution of whole elements (i.e., not only their data types)
- Idea: Elements are assigned to a substitution group of a leading element denoted using its name
  - The leading element can be then substituted with elements in its substitution group
- Conditions:
  - All elements must be defined globally
  - An element in a substitution group must have the same data type as the leading element or a type derived from its data type
  - Relation „to be in a substitution group" is transitive

Substitution Groups – Example

```
<xs:element name="Publication" type="TypePublication"/>
<xs:element name="Book"        type="TypeBook"
            substitutionGroup="Publication"/>
<xs:element name="Journal"     type="TypeJournal"
            substitutionGroup="Publication"/>

<xs:element name="Library">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="Publication" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
```

Substitution Groups – Example

```
<Library>
  <Publication>
    <Name>The King's Speech</Name>
    <Author>M. Logue</Author>
  </Publication>
  <Book>
    <Name>Elizabeth the Queen</Name>
    <Author>S. B. Smith</Author>
    <ISBN>123-456-789</ISBN>
  </Book>
  <!-- other elements Publication, Book or Journal -->
</Library>
```

Substitution Groups

- The features of the groups are given by attributes of element
  - substitutionGroup – name of the leading element, i.e. the group to which the element is assigned
  - abstract – abstract element
    - The element cannot be used in a document, it must be always substituted with an element from its substitution group
  - final – blocking of adding of elements to the substitution group of the element
    - Values: extension, restriction, #all
  - block – blocking of substitution of the element (there can be elements in its substitution group, but we cannot substitute for it at the particular position)
    - Values: extension, restriction, #all

Wildcards

- Enable to use at a particular position any item
- Element anyAttribute
  - Attributes:
    - namespace – namespace(s) of allowed items
      - A list of URIs of namespaces
      - ##any – any known namespace
      - ##targetNamespace – target namespace
      - ##other – other than target namespace
      - ##local – no specific namespace

(annotation?)

Wildcards

- processContents – the way of validation of the content
  - strict – strict validation
  - lax – validation in case the parser finds the component
  - skip – no validation
- notNamespace – list of namespaces from which we cannot use items
  - ##targetNamespace, ##local
  - Since version 1.1
- notQName – list of elements / attributes we cannot use
  - Since version 1.1

Wildcards

- Element any
  - Attributes:
    - nameSpace, processContents, notNamespace, notQName – the same meaning
    - minOccurs
    - maxOccurs

Wildcards

```
<xs:complexType name="AnyHtmlText">
  <xs:sequence>
    <xs:any namespace="http://www.w3.org/1999/xhtml"
            minOccurs="1"
            maxOccurs="unbounded"
            processContents="strict"/>
  </xs:sequence>
</xs:complexType>
```

notation

- Link to an external executable program
  - Like in DTD
  - Processing depends on another software
- Attributes:
  - name – name of notation
  - system – system identifier of the executable program
  - public – public identifier of the executable program
- References to notation – data type NOTATION
  - Can be used only via restriction enumeration
  - For each enumerated value there must exist a notation
    - Similar to DTD

notation – Example

```
<xs:notation name="EPS" system="C:\eps\eps.exe"/>

<xs:attribute name="Program">
  <xs:simpleType>
    <xs:restriction base="xs:NOTATION">
      <xs:enumeration value="EPS">
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
```

Annotation

```
<xs:annotation>
  <xs:documentation xml:lang="cs">
    Toto je příklad anotace pro člověka.
  </xs:documentation>
</xs:annotation>
```

- Denoted for documentation / comments of the schema
  - XML comments can be used as well
  - Part of any schema component
- Element appinfo – information for a program
  - Attributes:
    - source – URI of an external file, where the information is stored
- Element documentation – information for a human
  - Attributes:
    - source – URI of an external file, where the information is stored
    - xml:lang – language of the information, when provided directly in the schema

(appinfo | documentation)*