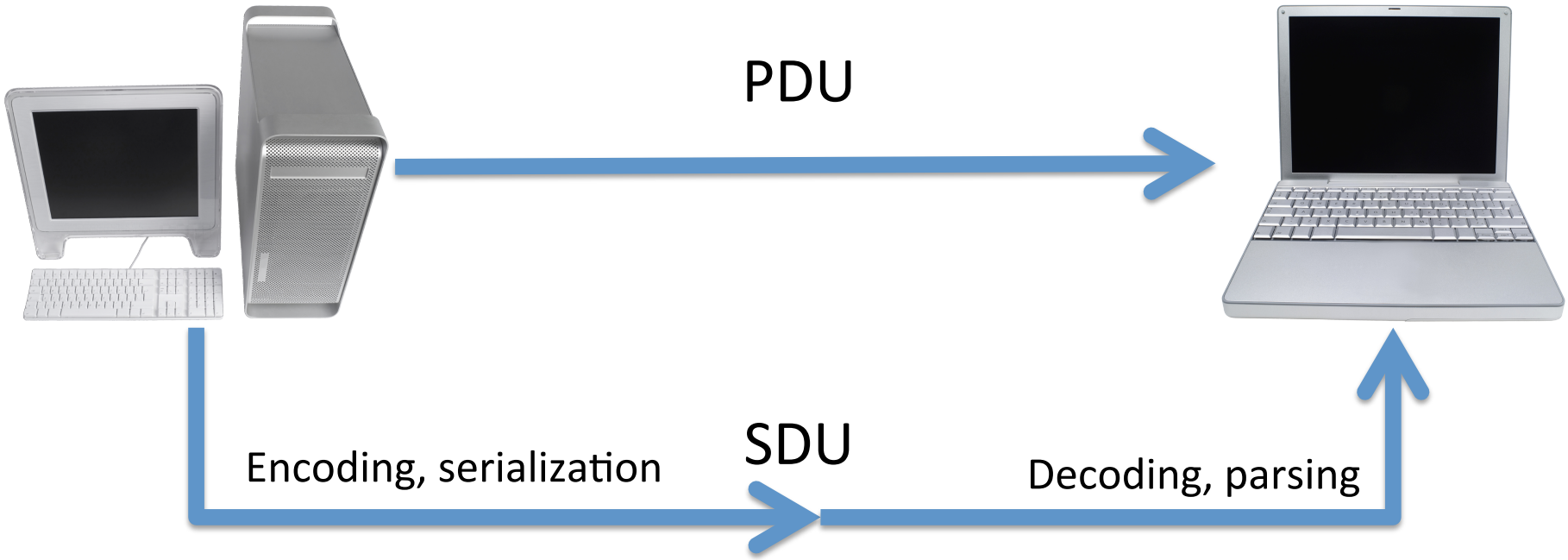
Data modeling, data encoding

What we want to do



- Get complex data structure from one node to another

Data transfer

- Data transfer can be
  - Binary
    - ASN.1
    - Mostly in telecommunications networks and lower layer protocols
  - Character based
    - XML, JSON, YAML, CSV
    - In the Internet infrastructure and higher layer protocols
- Data can be sent in
  - One large PDU
  - Several chunks

Data transfer

- Optimal data size
  - t: message overhead (flow control, address, checksum) size
  - d: useful data size
  - a: acknowledge message size
  - p_d, p_a: probabilities of bit errors in data and ack messages
- If p_d=p_a=0, d can be arbitrarily large
  - work over TCP

Data transfer

- If $p_d > 0$ and $p_a > 0$
  - The probalility of retransmission is:

    $p_r = 1 - (1 - p_d)(1 - p_a)$
  - The probalility that i retransmissions are needed is: $p_i = (1 - p_r)p_r^{i-1}$
  - Expected number of retransmissions is:

    $R = 1/(1 - p_r)$
  - Efficiency is: $E = d/R(d+t+a)$
  - The optimum data size can be found by solving:

    $\delta E/\delta d = 0$

Data transfer

- When to use chunks:
  - Unreliable medium
  - Lower layer protocols
- When to use one complex PDU:
  - Reliable medium
  - Applications operating over higher layer protocols (TCP, HTTP)

What we know about the data

- Mandatory fields
  - Fields without initial value in the function signature
- Optional fields
  - Fields with initial value in the function signature
- Extra fields
  - Fields present, but not specified in the requirements
  - Must be ignored, must not cause error
- Ordering of fields may or may not be defined

Data modeling

- Data modeling known in:
  - Database theory – Entity Relationship Diagrams
  - Object oriented modeling – UML Class Diagrams
  - These have about the same expressive power
- Data modeling has several abstraction levels:
  - Conceptual model – lots of informal elements
  - Logical model
  - Physical model – formal
- For encoding/decoding we need formal models

Problems

- Data modeling describes relational models
- Data serialization produces hierarchical models, hash trees
- What to do with many-to-many relationships?
  - This is the main cause of data structure refactorization

XML

- Describes a piece of data (a value) that can be exchanged between systems
- Primarily used in SOA and web based applications
- Provides structural relationship information, metadata
- Semantics can be assigned to its elements: XSD
- Appearance can be assigned to its elements: XSL

XML

- Components of an XML document
  - Declarations

    ```
    <?xml version="1.0" encoding="UTF-8"?>
    ```
  - Tags (start, end)

    ```
    <data>, </data>, <data />
    ```
  - Attributes

    ```
    id="42"
    ```
  - Data

    ```
    Some piece of text
    ```
  - Elements

    ```
    <data id="42">Some piece of text</data>
    ```
  - Comments

    ```
    <!- A comment -->
    ```

XML

- XML is hierarchical
  - An element may contain other elements or character data (text nodes)
- XML is good at representing
  - Lists
  - Trees
  - One-to-one and one-to-many relations
- XML is bad at representing
  - Many-to-many relations
  - Binary data

XML format, syntax

- Well-formed to be parsed successfully
  - XML declaration
  - Exactly one root element
  - Each element is properly nested
  - Attributes are in quotes
  - Special characters (' " & < > :) escaped
  - No spaces, special characters in element names
- XML is
  - Character based, any character encoding, default is UTF-8
  - Case sensitive

XML semantics

- Many XML documents can use the same element names
- To avoid semantic collisions: namespaces
  - An URN is assigned to a namespace URI
  - Elements tagged with the URN
  - Namespace can be introduced at any level of the XML hierarchy

XML Schema

- Defines the formal structure of an XML document (value), message format of an SDU
- Alternatives: DTD, SOX
- XSD
  - Written in XML
  - Automatic schema creation
  - Self-documentation
  - Provides semantics

XML Schema

- Defines:
  - Elements, attributes
  - Parent child relations of elements
  - Relation cardinality
  - Text nodes, empty nodes
  - Text node type
  - Default elements, attributes

XML Schema

- Root element

```
<?xml version="1.0”?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
targetNamespace="http://agile.tmit.bme.hu"
xmlsn="http://agile.tmit.bme.hu"
elementFormDefault="qualified">
…
</xs:schema>
```

  - xmlns:xs: XML Schema types
  - targetNamespace: element semantics
  - xmlns: default namespace
  - elementFormDefault: if tag must be qualified with the namespace

XML Schema

- A value of a type

```
<xs:element name="i" type="xs:integer"/>
```

- Built-in primitive types: xs:integer, xs:string, xs:date, xs:time, xs:datetime, xs:boolean, xs:float
- Default value: default attribute
- Constant: fixed attribute
- Cardinality: minOccurs, maxOccurs, optional if minOccurs is 0

XML Schema

- Attribute

```
<xs:attribute name="i" type="xs:integer"/>
```

- Must be enclosed in an element
- Similar to elements

XML Schema

- Complex type

```
<xs:complexType name="T”>
  <xs:sequence>
    <xs:element name="i" type="xs:integer"/>
    <xs:element name="d" type="xs:datetime"/>
    <xs:element name="s" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

- Structure: sequence, union: choice, set: all
- Type reference

```
<xs:element name="E" type="T”/>
```

XML Schema

- Type specialization, restrictions

```
<xs:simpleType name="T">
  <xs:restriction base="xs:integer”>
    <xs:minInclusive value="1"/>
    <xs:maxInclusive value="10"/>
  </xs:restriction>
</xs:simpleType>
```

- Enum

```
<xs:simpleType name="T">
  <xs:restriction base="xs:integer”>
    <xs:enumeration value="A"/>
    <xs:enumeration value="B"/>
  </xs:restriction>
</xs:simpleType>
```

- Pattern based restriction

XML Schema

- Type generalization

```
<xs:complexType name="T2">
  <xs:complexContent>
    <xs:extension base="T">
      <xs:sequence>
        ..
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

- simpleContent and complexContent

XML Schema

- Global vs. nested types

```
<xs:complexType name="T">
…
</xs:complexType>
<xs:element name="E" type="T”/>

<xs:element name="E”>
  <xs:complexType>
    …
  </xs:complexType>
</xs:element>
```

XML Schema

- Using types from other schemas

```
<import namespace="..." schemaLocation="..."/>
<include schemaLocation="…”/>
```

- Include uses the same namespace, import uses its own
  - Similar to Java packages

XSD, SOAP encoding

- Simple value → text node
- Compound value (structure, array) → element with child nodes
- Many-to-many relations
  - An index, id attribute must be intorduced
  - The association is a text node, its value is the index

XSD, SOAP encoding

- Arrays
  - XSD: array index attribute

```
<myList>
  <element id="1">…</element>
  <element id="1">…</element>
</myList>
```

  - SOAP: array dimensions and type in the array node

```
<myList soapenc:itemType="element"
soapenc:arraySize="2">
  <item>…</item>
  <item>…</item>
</myList>
```

XSD, SOAP encoding

- Multidimensional arrays
  - XSD: multiple parent child relations
  - SOAP:

```
<myList soapenc:itemType="element"
soapenc:arraySize="2 3">
```

XML, SOAP encoding

- Binary data is a problem as XML is character based
- Solutions
  - Base64 encoding, this results in big XML documents poor for parsing
  - MIME attachments and Content-ID

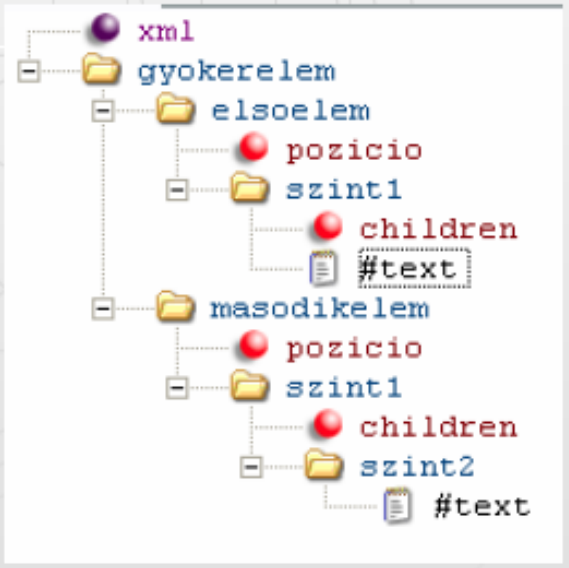
XML parsing

- Restore the complex data structure at the receiver and check the correctness of the received data
- Parser types:
  - DOM
  - SAX

XML parsing

- DOM parsers
  - Read the XML document fully
  - Build a Document Object Model tree

```
<?xml version="1.0" encoding="UTF-8"?>
<gyokerelem>
   <elsoelem pozicio="1">
      <szint1 children="0">Ez a …
       elemek</szint1>
   </elsoelem>
   <masodikelem pozicio="2">
      <szint1 children="1">
         <szint2>Ez a …
         elemek</szint2>
      </szint1>
   </masodikelem>
</gyokerelem>
```



XML parsing

- SAX parsers, only Java standard
  - Reads document as a stream
  - Event based: generates an event if a tag is detected
  - Events: start of an element, end of an element, start document, end document, text node

XML parsing

```
class MyHandler extends DefaultHandler {
    boolean elem;

    @Override
    public void startElement(String uri, String local, String qname,
Attributes attrs) {
        System.out.println("Starting "+qname);
        if (local.equals(”elem")) {
            elem= true;
        }
    }

    @Override
    public void endElement(String uri, String local, String qname) {
        System.out.println("End "+qname);
        if (local.equals(”elem")) {
            // ...
            elem= false;
        }
    }

    public void characters(char []c, int start, int len) {
        String s = new String(c, start, len);
        System.out.println(s);
    }
}
```

XML parsing

- Pros and cons
  - DOM is good choice for
    - modifying XML documents
  - DOM is bad choice for
    - reading large XML documents – memory needs
  - SAX is good choice for
    - reading XML documents
  - SAX is bad choice for
    - manipulating larger XML documents, though it can be used for smaller ones

Other data serialization languages

- JSON: JavaScript Object Notation
  - Very simple, less overhead
  - Hash tree: string key, string value
  - No semantics, no validation
- YAML: Yet Another Markup Language
  - Very simple, less overhead
  - Hash tree: string key, string/integer/real/bool value
  - Can handle lists
  - No semantics, no validation