Semistructured Data
Extensible Markup Language
Document Type Definitions

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Framework

1. *Information Integration* : Making databases from various places work as one.
2. *Semistructured Data* : A new data model designed to cope with problems of information integration.
3. *XML* : A standard language for describing semistructured data schemas and representing data.

The Information-Integration Problem

- Related data exists in many places and could, in principle, work together.
- But different databases differ in:
  1. Model (relational, object-oriented?).
  2. Schema (normalized/unnormalized?).
  3. Terminology: are consultants employees? Retirees? Subcontractors?
  4. Conventions (meters versus feet?).

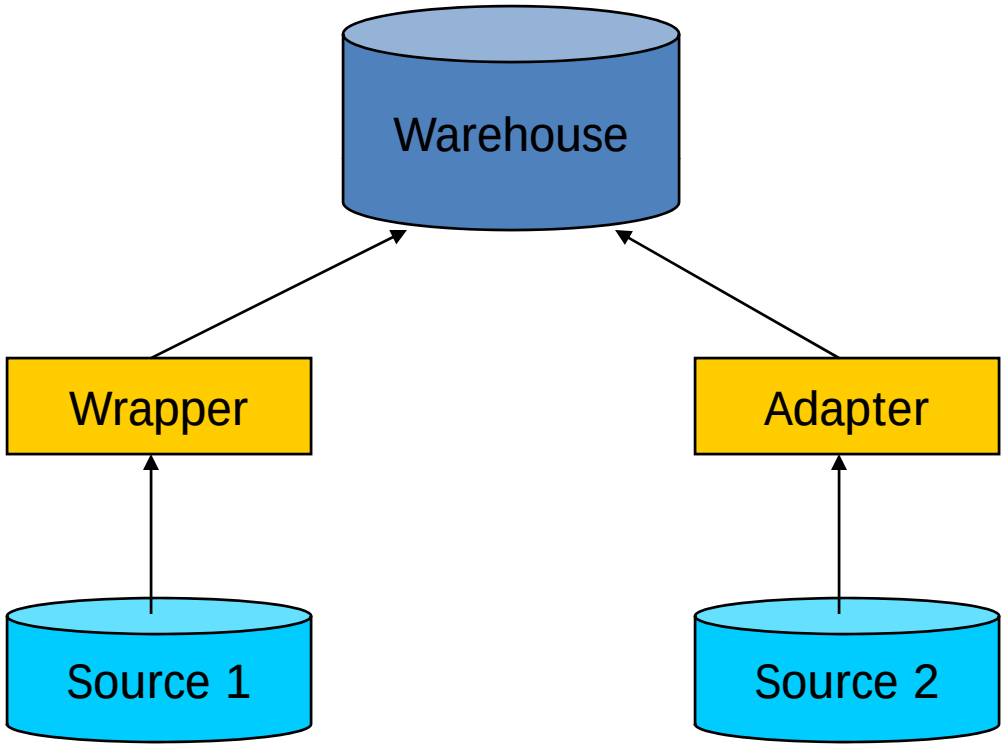
Example

- Every bar has a database.
  - One may use a relational DBMS; another keeps the menu in an MS-Word document.
  - One stores the phones of distributors, another does not.
  - One distinguishes ales from other beers, another doesn't.
  - One counts beer inventory by bottles, another by cases.

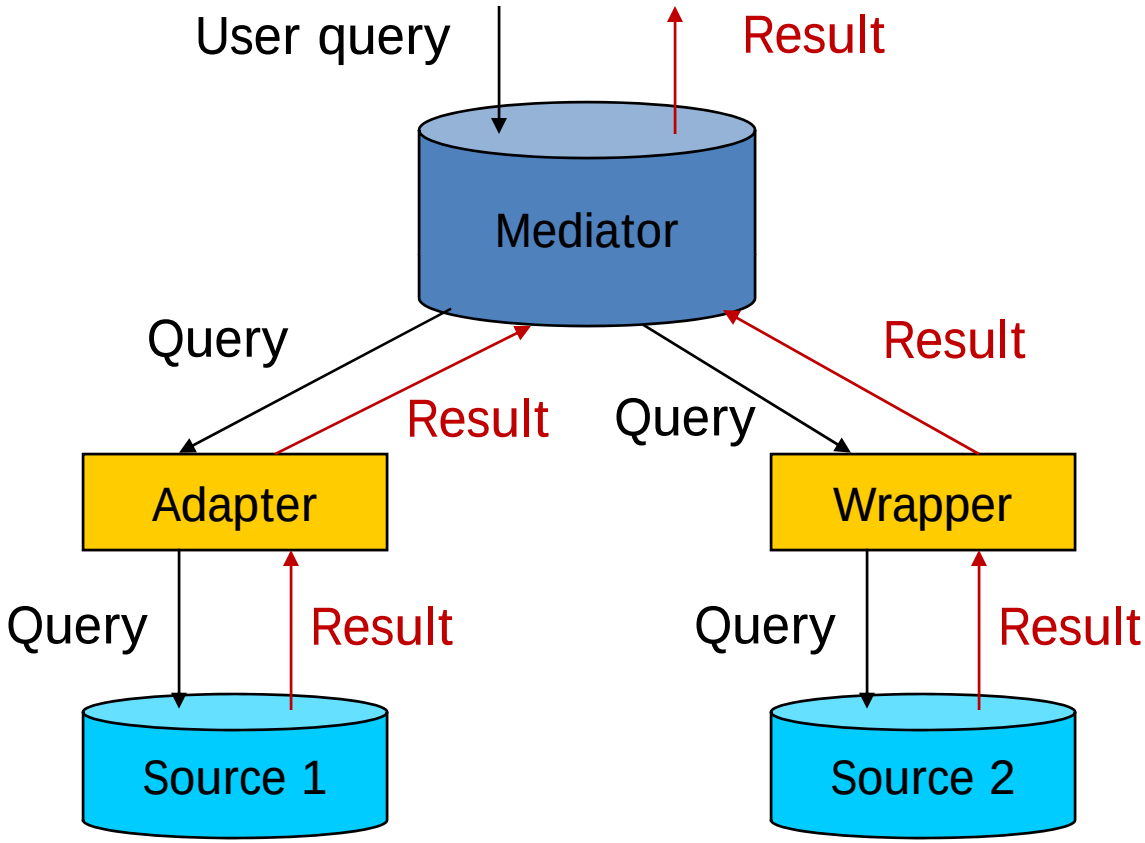
Two Approaches to Integration

1. *Warehousing* : Make copies of the data sources at a central site and transform it to a common schema.
   - Reconstruct data daily/weekly, but do not try to keep it more up-to-date than that.
2. *Mediation* : Create a view of all sources, as if they were integrated.
   - Answer a view query by translating it to terminology of the sources and querying them.

Warehouse Diagram



A Mediator


User query
Result
Mediator
Query
Result
Result
Query
Adapter
Wrapper
Query
Result
Query
Result
Source 1
Source 2

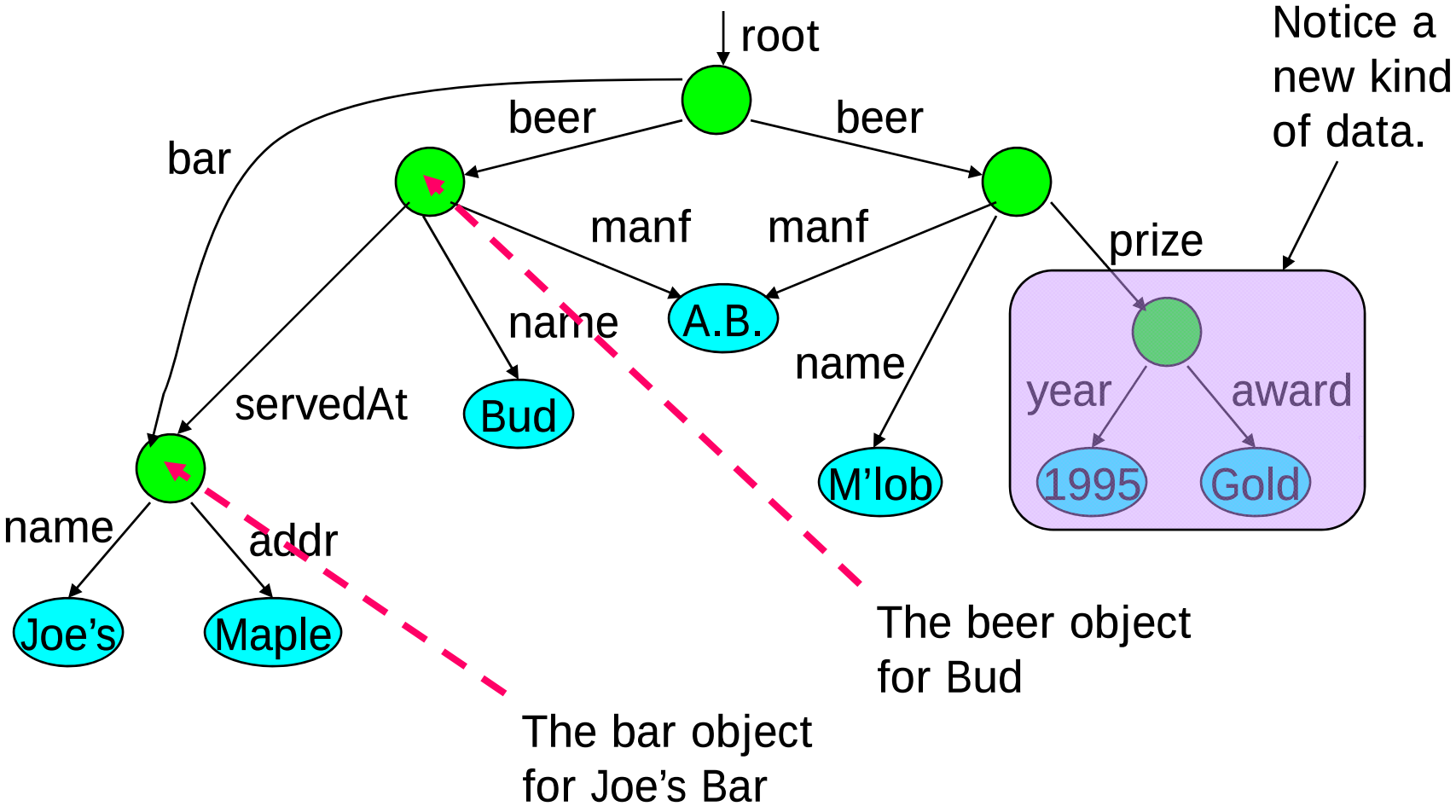
Semistructured Data

- Purpose: represent data from independent sources more flexibly than either relational or object-oriented models.
- Think of objects, but with the type of each object its own business, not that of its "class."
- Labels to indicate meaning of substructures.

Graphs of Semistructured Data

- Nodes = objects.
- Labels on arcs (attributes, relationships).
- Atomic values at leaf nodes (nodes with no arcs out).
- Flexibility: no restriction on:
  - Labels out of a node.
  - Number of successors with a given label.

Example: Data Graph



XML

- XML = E**X**tensible **M**arkup **L**anguage.

- While HTML uses tags for <u>formatting</u> (e.g., “italic”), XML uses tags for <u>semantics</u> (e.g., “this is an address”).

- Key idea: create tag sets for a domain (e.g., genomics), and translate all data into properly tagged XML documents.

Well-Formed and Valid XML

- *Well-Formed XML* allows you to invent your own tags.
  - Similar to labels in semistructured data.
- *Valid XML* involves a DTD (Document Type Definition), which limits the labels and gives a grammar for their use.

Is a Well-formed Document Valid?

- An XML document is said to be *well-formed* if it follows all of the "rules" of XML, such as proper nesting and attribute use, so by definition all XML documents are well-formed.

- A *valid* document, on the other hand, is one that is not only well-formed, but also follows the restrictions set out in a specific grammar, typically specified in a Document Type Definition (DTD) or some form of XML Schema.

Is a Wellformed Document Valid?

- An example of a document that is well-formed but not valid based upon the XHTML grammar.

```
<body>
  <p>Example of Well-formed HTML</p>
  <head>
    <title>Example</title>
  </head>
  <zorko>What is this?</zorko>
</body>
```

HTML vs. XML

- In the case of HTML, browsers have been taught how to ignore invalid HTML such as the <zorko> element and generally do their best when dealing with badly placed HTML elements.

- The XML processor, on the other hand, can not tell us which elements and attributes are valid. As a result we need to define the XML markup we are using. To do this, we need to define the markup language's grammar.

Well-Formed XML

- Start the document with a *declaration*, surrounded by <? … ?> .
- Normal declaration is:

```
<? XML VERSION = “1.0”
  STANDALONE = “yes” ?>
```

  – “Standalone” = “no DTD provided.”
- Balance of document is a *root tag* surrounding nested tags.

Tags

- Tags, as in HTML, are normally matched pairs, as <FOO> … </FOO> .
- Tags may be nested arbitrarily.
- Tags requiring no matching ender, like <P> in HTML, are also permitted.

Example: Well-Formed XML

```
<? XML VERSION = “1.0” STANDALONE = “yes” ?>
<BARS>
    <BAR><NAME>Joe’s Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```

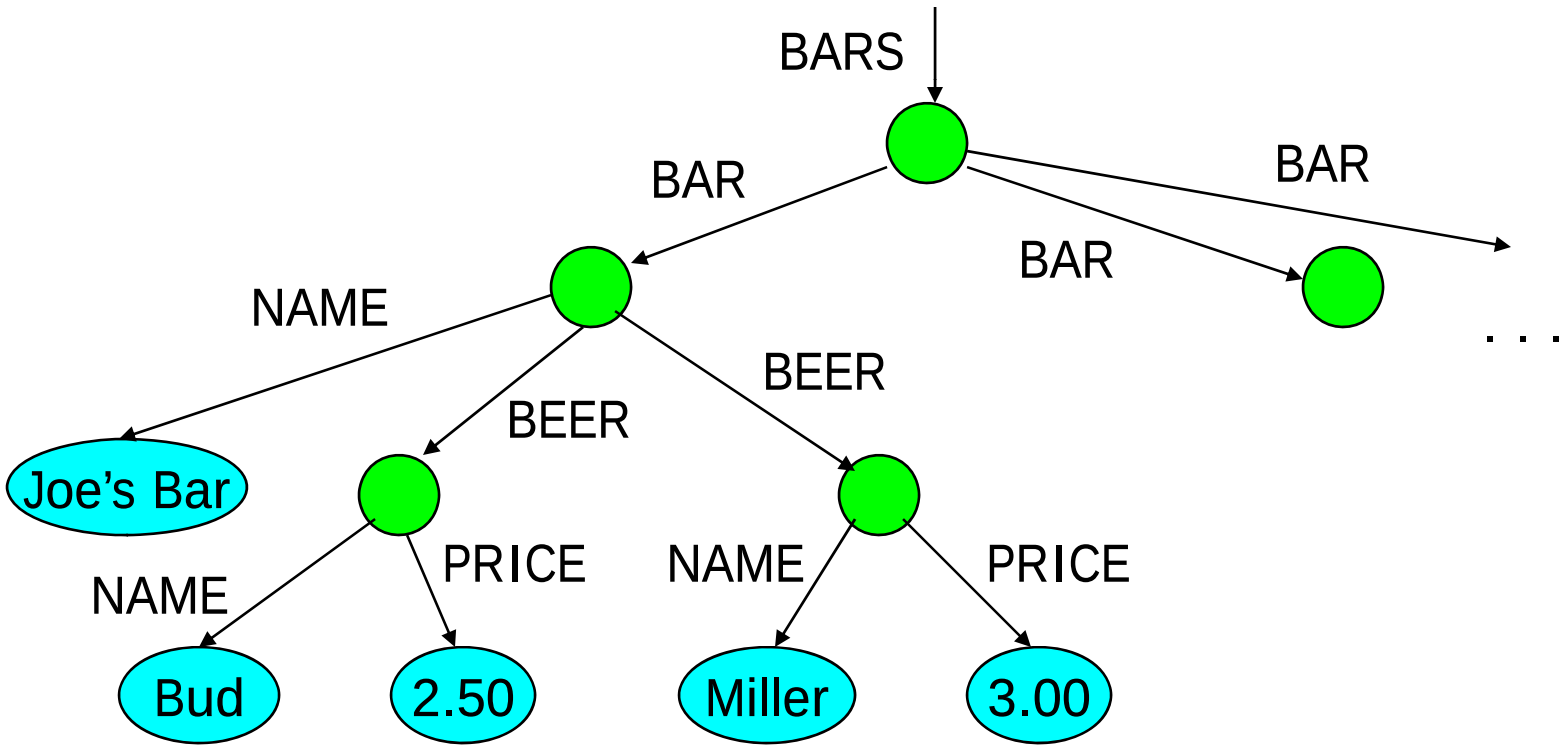
XML and Semistructured Data

- Well-Formed XML with nested tags is exactly the same idea as trees of semistructured data.

- We shall see that XML also enables nontree structures, as does the semistructured data model.

Example

- The <BARS> XML document is:



Document Type Definitions

- Essentially a context-free grammar for describing XML tags and their nesting.

- Each domain of interest (e.g., electronic components, bars-beers-drinkers) creates one DTD that describes all the documents this group will share.

DTD Structure

```
<!DOCTYPE <root tag> [
  <!ELEMENT  <name>  (  <components>  )>
  <more elements>
]>
```

Element Basics

- Defining elements within a DTD is done using an `<!ELEMENT>` declaration.
- `<!ELEMENT>` declarations along with all other declarations within a DTD have no content.
- `<!ELEMENT>` declarations are composed of several parts including the element name and the type of information it will contain.
- The resulting **element names** will be case sensitive.

```
<!ELEMENT   element_name     element_contents>
```

DTD Elements

- The description of an element consists of its name (tag), and a parenthesized description of any nested tags.
  - Includes order of subtags and their multiplicity.
- Leaves (text elements) have #PCDATA in place of nested tags.

What an <!ELEMENT> Can Contain

- An <!ELEMENT> declaration can contain several different types of content which include the following:
  - EMPTY.
  - PCDATA.
  - ANY.
  - Children Elements

EMPTY

- <!ELEMENT> declarations that include the EMPTY value allow us to create empty elements within our xml.
- The word EMPTY must be entered in uppercase as it is case-sensitive.

```
<!ELEMENT    element_name      EMPTY>
```

PCDATA

- <!ELEMENT> declarations that include the value PCDATA allow us to include text and other parsable content in our elements within our XML instance file.
- The word PCDATA must be enclosed in parenthesis with a preceding '#' and entered in uppercase as it is case-sensitive.
- PCDATA is text that will be parsed by a parser. Tags inside the text will treated as markup and entities will be expanded.

```
<!ELEMENT   element_name     (#PCDATA)>
```

ANY

- <!ELEMENT> declarations that include the value ANY allow us include any type of parsable content, including text and other elements, in our elements within our XML instance file.
- The word ANY must be entered in uppercase as it is case-sensitive.

```
<!ELEMENT   element_name     ANY>
```

Element Descriptions

- Subtags must appear in order shown.
- A tag may be followed by a symbol to indicate its multiplicity.
  - * = zero or more.
  - + = one or more.
  - ? = zero or one.
- Symbol | can connect alternative sequences of tags.

Example: DTD

```
<!DOCTYPE Bars [
   <!ELEMENT BARS (BAR*)>
   <!ELEMENT BAR (NAME, BEER+)>
   <!ELEMENT NAME (#PCDATA)>
   <!ELEMENT BEER (NAME, PRICE)>
   <!ELEMENT PRICE (#PCDATA)>
]>
```

A BARS object has zero or more BAR's nested within.

A BAR has one NAME and one or more BEER subobjects.

A BEER has a NAME and a PRICE.

NAME and PRICE are text.

Example: Element Description

- A name is an optional title (e.g., “Prof.”), a first name, and a last name, in that order, or it is an IP address:

```
<!ELEMENT NAME (
  (TITLE?, FIRST, LAST) | IPADDR
)>
```

Use of DTD's

1. Set STANDALONE = "no".
2. Either:
   a) Include the DTD as a preamble of the XML document, or
   b) Follow DOCTYPE and the <root tag> by SYSTEM and a path to the file where the DTD can be found.

Example (a)

```
<? XML VERSION = “1.0” STANDALONE = “no” ?>
<!DOCTYPE Bars [
    <!ELEMENT BARS (BAR*)>
    <!ELEMENT BAR (NAME, BEER+)>
    <!ELEMENT NAME (#PCDATA)>
    <!ELEMENT BEER (NAME, PRICE)>
    <!ELEMENT PRICE (#PCDATA)>
]>
```

The DTD

The document

```
<BARS>
    <BAR><NAME>Joe’s Bar</NAME>
        <BEER><NAME>Bud</NAME> <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME> <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```

Example (b)

- Assume the BARS DTD is in file bar.dtd.

```
<? XML VERSION = “1.0” STANDALONE = “no” ?>
<!DOCTYPE Bars SYSTEM “bar.dtd”>
<BARS>
    <BAR><NAME>Joe’s Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> …
</BARS>
```

Get the DTD from the file bar.dtd

Attributes

- Opening tags in XML can have *attributes*, like <A HREF = "…"> in HTML.

- In a DTD,

<!ATTLIST <element name>… >

gives a list of attributes and their datatypes for this element.

Example: Attributes

- Bars can have an attribute `kind`, which is either sushi, sports, or "other."

```
<!ELEMENT BAR (NAME BEER*)>
  <!ATTLIST BAR kind = "sushi" |
     "sports" | "other">
```

Example: Attribute Use

- In a document that allows BAR tags, we might see:

```
<BAR kind = “sushi”>
  <NAME>Akasaka</NAME>
  <BEER><NAME>Sapporo</NAME>
          <PRICE>5.00</PRICE></BEER>
  ...
</BAR>
```

ID’s and IDREF’s

- These are pointers from one object to another, in analogy to HTML’s NAME = “foo” and HREF = “#foo”.

- Allows the structure of an XML document to be a general graph, rather than just a tree.

Creating ID's

- Give an element *E* an attribute *A* of type ID.

- When using tag <*E* > in an XML document, give its attribute *A* a unique value.

- Example:

  <E A = "xyz">

Creating IDREF's

- To allow objects of type *F* to refer to another object with an ID attribute, give *F* an attribute of type IDREF.

- Or, let the attribute have type IDREFS, so the *F* –object can refer to any number of other objects.

Example: ID's and IDREF's

- Let's redesign our BARS DTD to include both BAR and BEER subelements.
- Both bars and beers will have ID attributes called `name`.
- Bars have PRICE subobjects, consisting of a number (the price of one beer) and an IDREF `theBeer` leading to that beer.
- Beers have attribute `soldBy`, which is an IDREFS leading to all the bars that sell it.

The DTD

```
<!DOCTYPE Bars [
    <!ELEMENT BARS (BAR*, BEER*)>
    <!ELEMENT BAR (PRICE+)>
        <!ATTLIST BAR name = ID>
    <!ELEMENT PRICE (#PCDATA)>
        <!ATTLIST PRICE theBeer = IDREF>
    <!ELEMENT BEER ()>
        <!ATTLIST BEER name = ID, soldBy = IDREFS>
]>
```

Bar objects have name as an ID attribute and have one or more PRICE subobjects.

PRICE objects have a number (the price) and one reference to a beer.

Beer objects have an ID attribute called name, and a soldBy attribute that is a set of Bar names.

Example Document

```
<BARS>
   <BAR name = “JoesBar”>
         <PRICE theBeer = “Bud”>2.50</PRICE>
         <PRICE theBeer = “Miller”>3.00</PRICE>
   </BAR> …
   <BEER name = “Bud”, soldBy = “JoesBar,
         SuesBar,…”>
   </BEER> …
</BARS>
```